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No. 52

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
DIRECTORATE GENERAL OF HIGHWAYS
MINISTRY OF PUBLIC WORKS
THE REPUBLIC OF INDONESIA

ROAD NETWORK STUDY IN CENTRAL AND SOUTHEAST SULAWESI IN THE REPUBLIC OF INDONESIA

FINAL REPORT

VOLUME III : FEASIBILITY STUDY FOR TAWAELI-TOBOLI ROAD

DECEMBER 1998

PACIFIC CONSULTANTS INTERNATIONAL
YACHIYO ENGINEERING CO.,LTD.

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NOTE

The following exchange rate is applied.

US$ 1.00 = Rp 10,600 (as of July 1998)

The exchange rate between the US $ and Indonesian Rp is based upon the exchange rate used officially for the government budget, July 1998.

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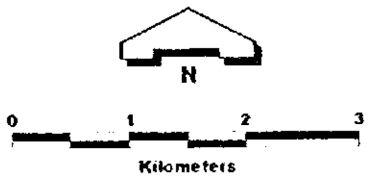

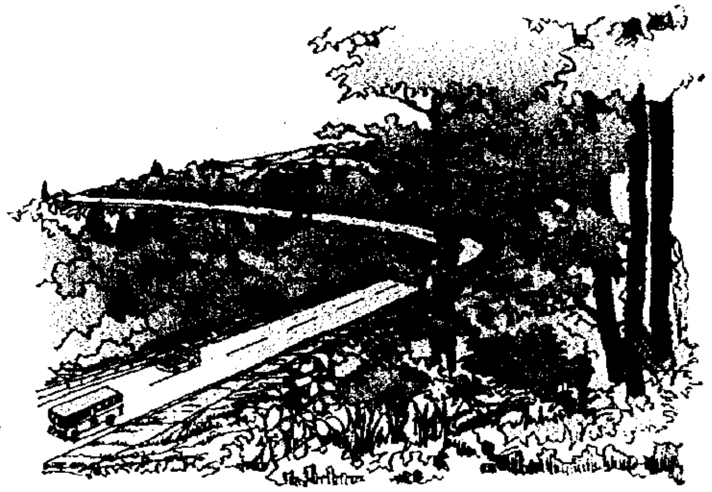

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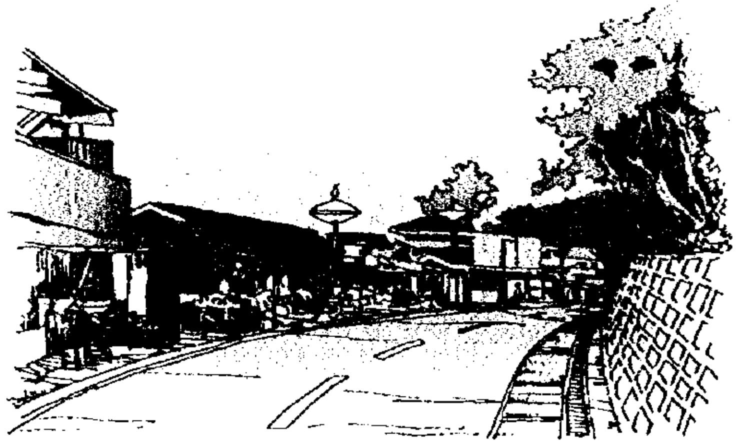

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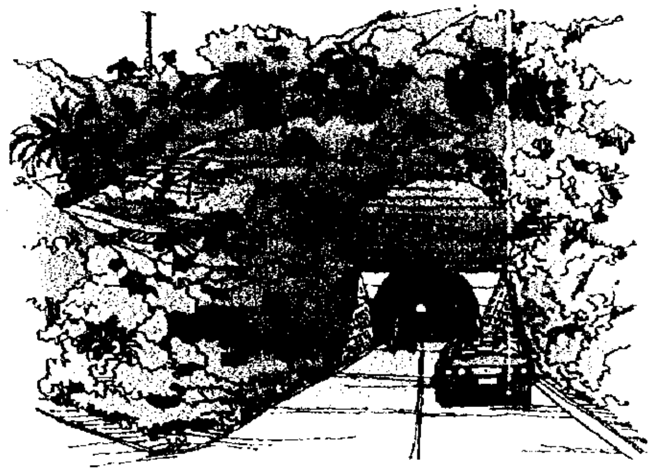

5 Proposed Tunnel of 620m in Length

6 Road Improvement wit
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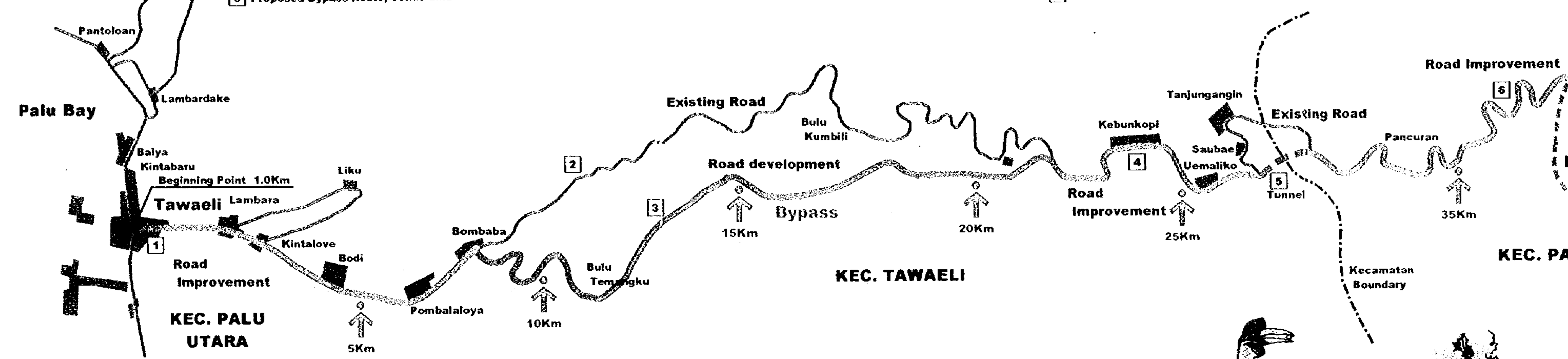

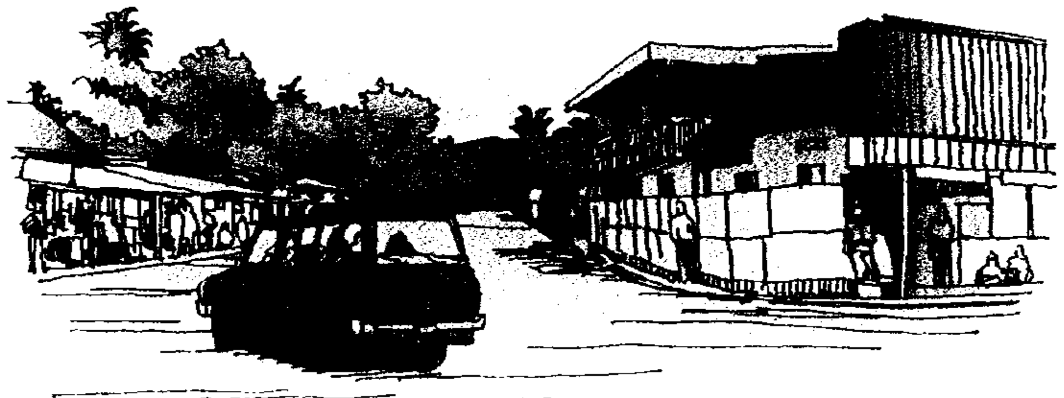

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2 Existing Road condition through maintenance

7 Valuable Wild Animals are inhabited
in the Nature Reserve, Pangi-Binangga

8 Existing Townscape at

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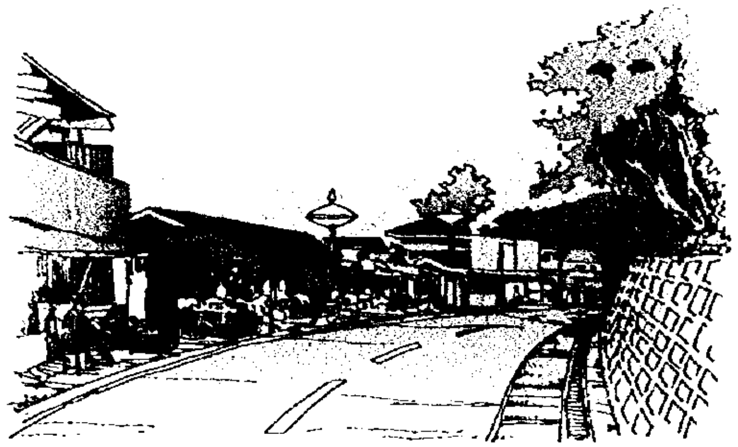

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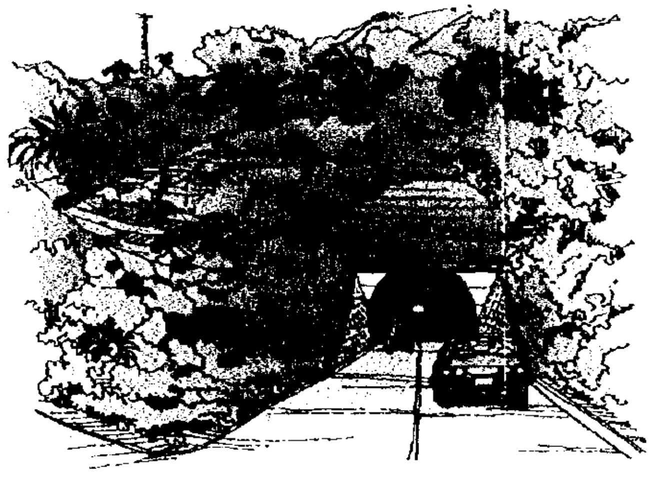

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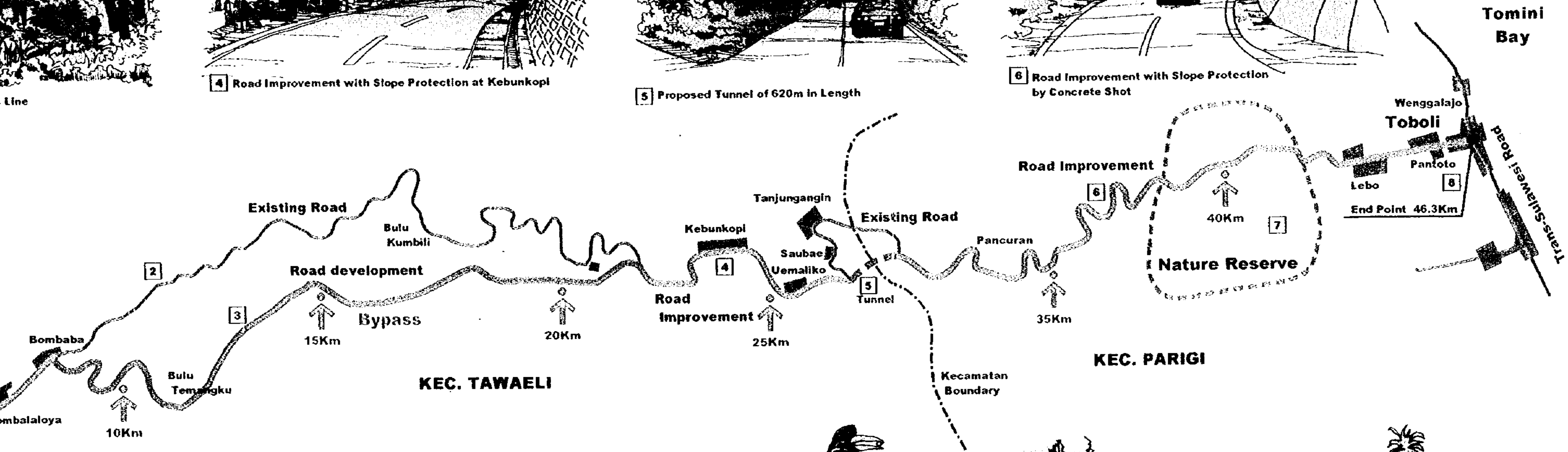

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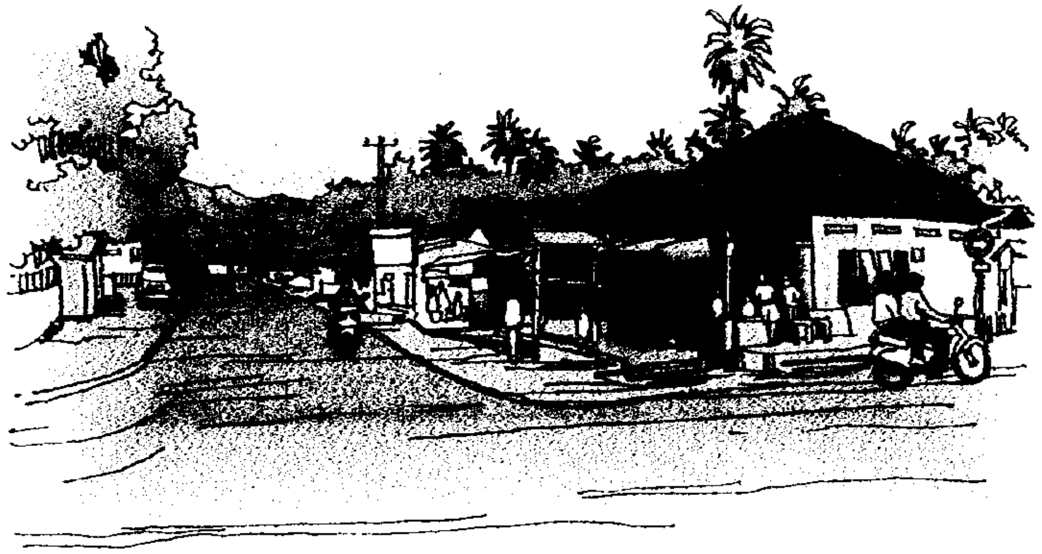

8 Existing Townscape at End Point, Toboli

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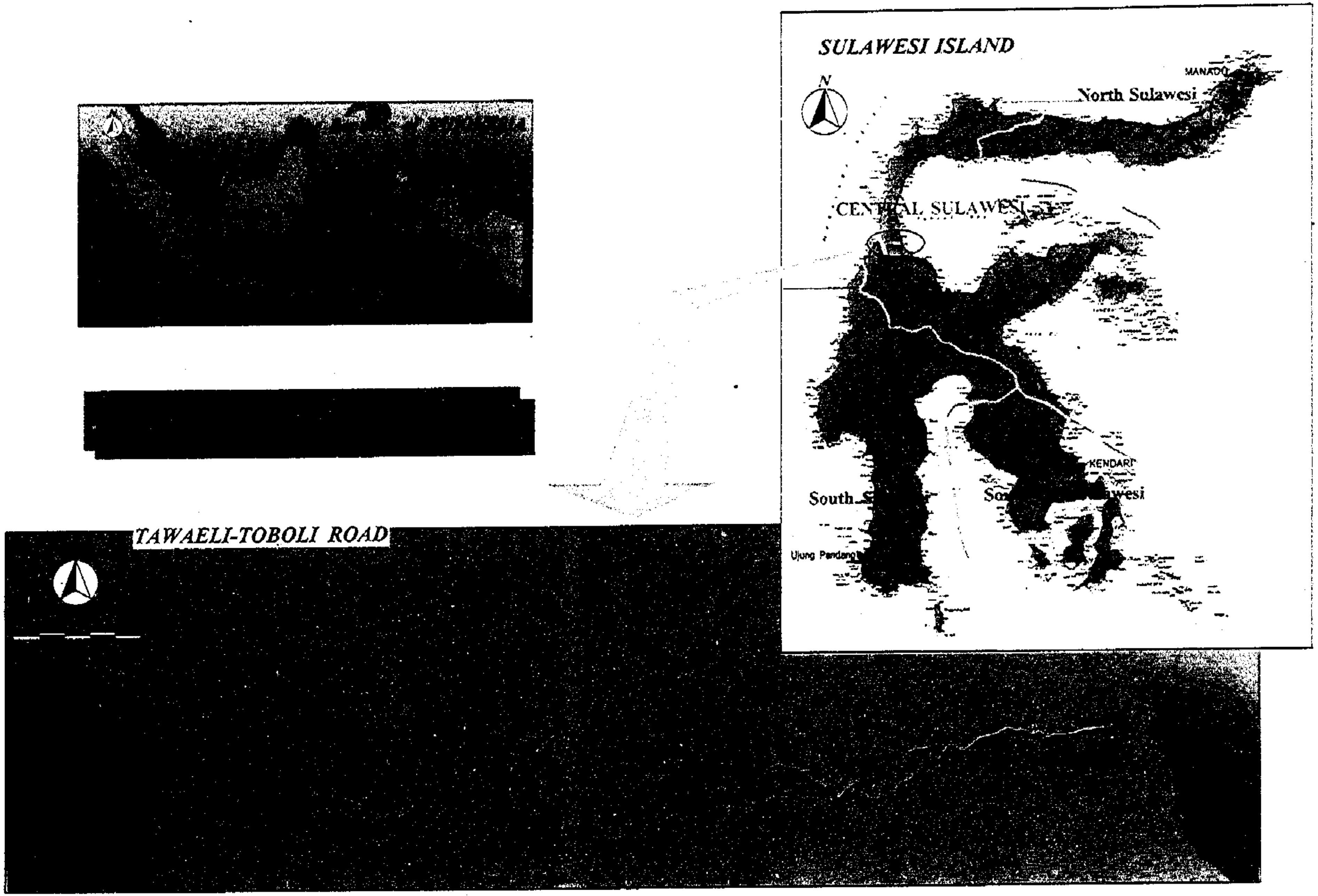
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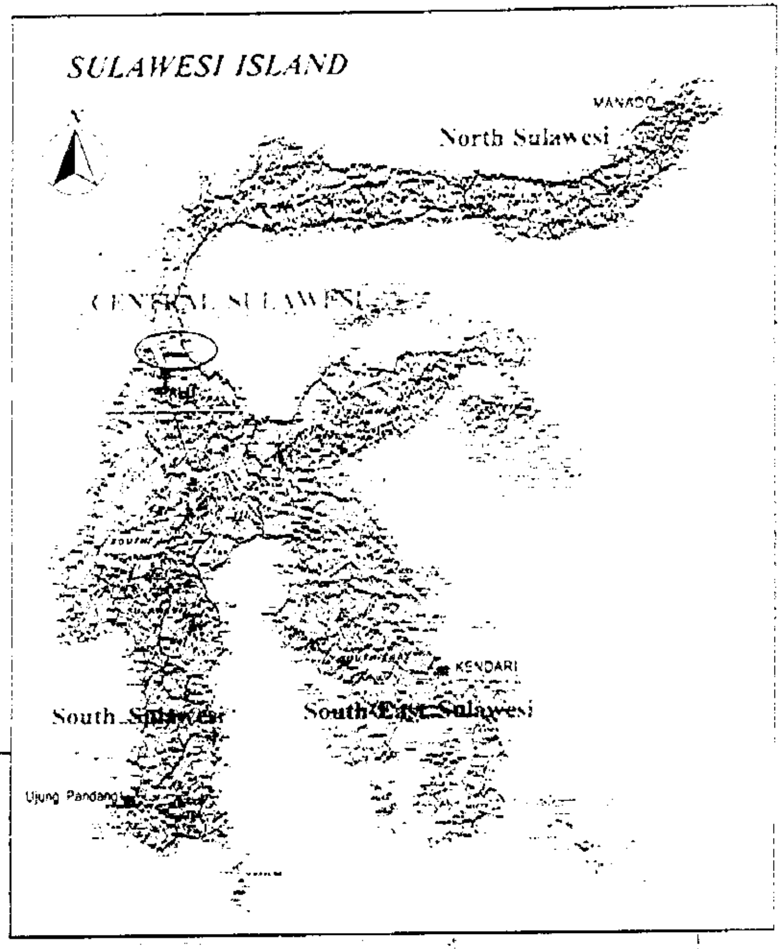
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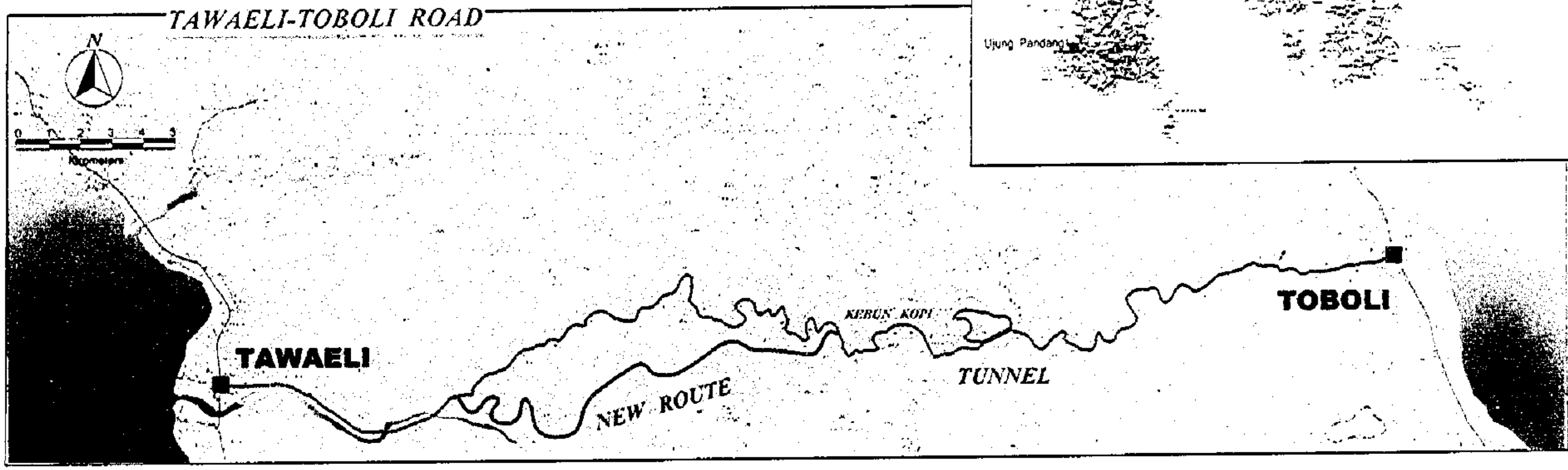
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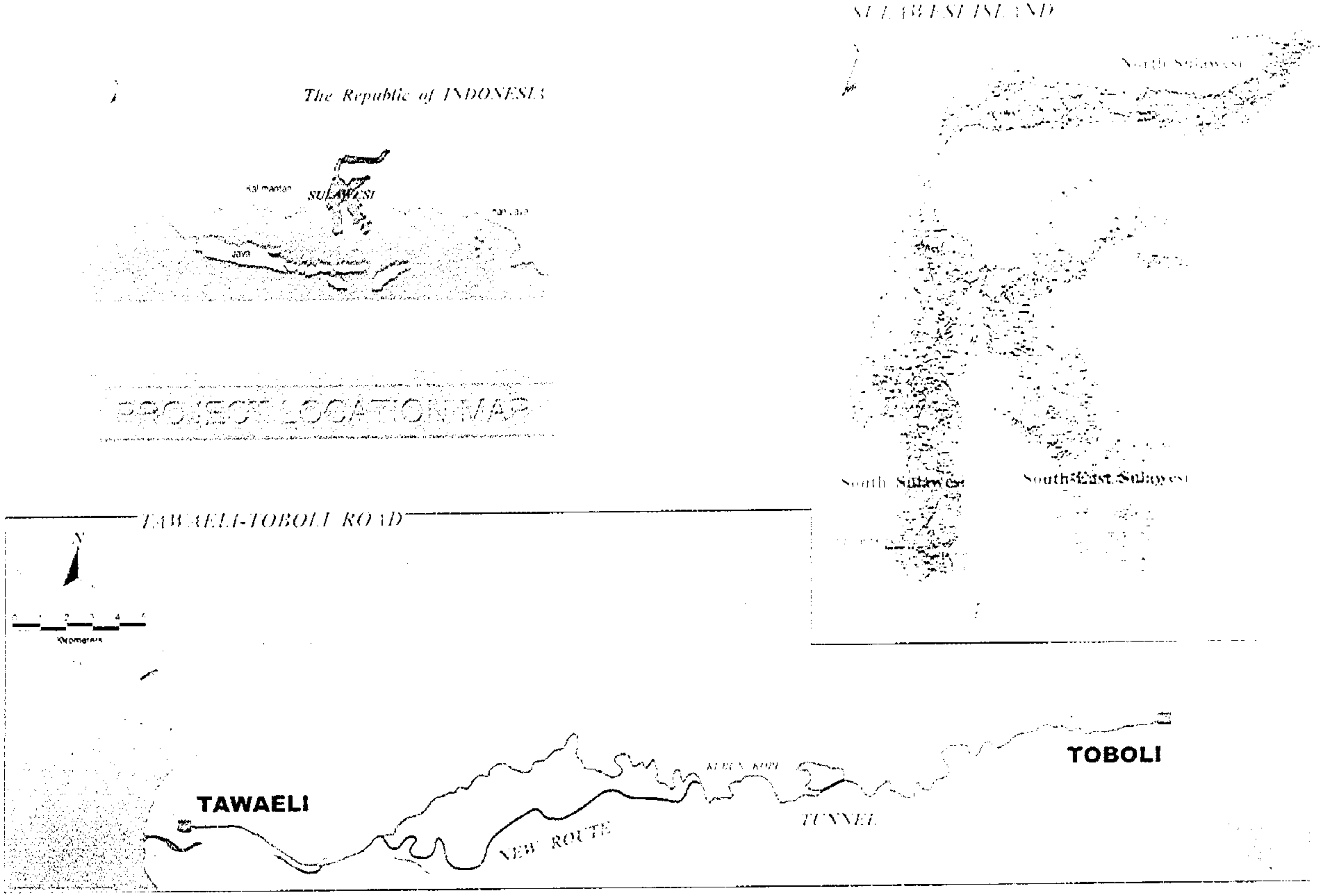
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ABBREVIATION AND GLOSSARY

AADT	Annual Average Daily Traffic
AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ADB	Asian Development Bank
ADT	Average Daily Traffic
AMDAL	Environmental Impact Assessment
ANDAL	Environmental Impact Statement
APBD	Anggaran Pendapatan dan Belanja Daerah, (Provincial or District Budget)
APBN	Anggaran Pendapatan dan Belanja Negara (National Budget)
APPKD	Anggaran Penerimaan dan Pengeluaran Kas desa (Village Budget)
ASTM	American Society for Testing and Materials
B/C	Benefit Cost ratio
BPR	Bureau of Public Road, USA
BPS	Biro Pusat Statistik (Central Bureau of Statistics, Indonesia)
Bappeda	Badan Perencanaan Pembangunan Daerah (Regional Development Planning Agency)
Bappenas	Badan Perencanaan Pembangunan Nasional (National Development Planning Agency, Indonesia)
Bina Marga	Directorate General of Highways
Binkot	Directorate of Urban Roads
Bintec	Directorate of Technical Support
Bipran	Directorate of Planning
CBR	California Bearing Ratio
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
DPUK	Road Department of Regency or Prefecture
DPUP	Road Department of Province
Desa	Administrative village
Dinas PU	Department of Public Works, Office of Provincial Government
EIA	Environmental Impact Analysis
EIRR and FIRR	Economic and Financial Internal Rate of Return
F/S	Feasibility Study
F/C	Foreign Currency
FG	Finished Grade
G/A	Generation/Attraction
GDP	Gross Domestic Product
GNP	Gross National Product
GRDP	Gross Regional Domestic Product
IEE	Initial Environmental Examination
JICA	Japan International Co-operation Agency
KA-ANDAL	Terms of Reference of Environmental Impact Assessment
KEL	Knife-Edge Load
Kabupaten	Regency or Prefecture Administrative Unit below the Province
Kanwil	Kantor Wilayah (Regional Office, Ministry of Public Works)

Kecamatan	Sub-regency, Administrative Unit below the Regency (Kabupaten)
Kotamadya	Municipality
L/C	Local Currency
LIPI	National Institute of Sciences
NPV	Net Present Value
OD	Origin and Destination
PC	Prestressed Concrete
PCC	Portland Cement Concrete
PCU	Passenger Car Unit
PJP II	Pembangunan Jangka Panjang II (Second Long-Term Development, 1994-2018)
Pre-F/S	Pre-feasibility Study
PU	Pekerjaan Umum (Public Works)
RC	Reinforced Concrete
RKL	Environmental Management Plan
ROW	Right-Of-Way
RPL	Environmental Monitoring Plan
Rp.	Rupiah
Sta.	Station
Sulawesi Tengah	Central Sulawesi
Sulawesi Tenggara	Southeast Sulawesi
UDL	Uniformly Distributed Load
UKL	Environmental Management
UPL	Environmental Monitoring
VOC	Vehicle Operating Cost

Dia. or ϕ	Diameter
Hr	Hour
Km	Kilometer
Km/h or KPH	Kilometer per Hour
cm, cm^2, cm^3	Centimeter, Square Centimeter, Cubic Centimeter
veh./h	Vehicle per Hour

ROAD NETWORK STUDY
IN CENTRAL AND SOUTH-EAST SULAWESI
IN THE REPUBLIC OF INDONESIA

Final Report - Volume III: Feasibility Study for Tawaeli-Toboli Road

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Chapter 1

General

Chapter 1 GENERAL

The intent of this volume is to report on the feasibility study conducted for the Tawaeli-Toboli road.

The Tawaeli - Toboli road is located to the north of Palu, the capital city of Central Sulawesi. This route is an important arterial road together with the Trans-Sulawesi Road, connecting with road networks of North, Central and South Sulawesi. Total length of the route is approximately 45 km with an altitude of 3 m to 865 m above sea level. In spite of this being an important arterial road, landslide disasters, slope failure and other problems frequently occur. Such disasters adversely affect traffic and economic activities. Improvement of this road will contribute to the economic and social activities of all people in Sulawesi.

An improvement plan for the Tawaeli-Toboli road has been made in the past, but, unfortunately was not implemented due to lack of funding. The Central Sulawesi provincial government gives top priority to the improvement of this route.

Chapter 2

Physical Condition and Engineering Survey

Chapter 2 PHYSICAL CONDITION AND ENGINEERING SURVEY

2.1 Topography and River System

The Tawaeli-Toboli road traverses a complicated terrain formed by mountain ranges which run through the narrowest section of the peninsula of Central and North Sulawesi. The Tawaeli-Toboli road runs from west to east across this peninsula along a gorge of the mountain range. This mountain range was formed by volcanic activity and plate movement. Earthquakes therefore occur frequently due to active earth movement.

There are three major rivers along a gorge of the mountain range, namely, the Bunangga Tawaeli, Kuala Toboli and Kuala Satubai rivers. Tributaries of these rivers flow from those mountain ranges. In the dry season, the river bed itself dries up while infiltrated water continues to flow underground, but in the rainy season, river flow becomes rapid due to steep terrain.

2.2 Climate

The Tawaeli-Toboli road is located 0.4 to 0.5 degrees south of the equator and consequently has a tropical climate.

The seasons are influenced by monsoons which blow from a general southeast direction from June to October, and from the northwest or west from November to May.

The seasons are clearly divided, one being the dry season from June to October, the other being the rainy season from November to May.

Table 2-2-1 shows average temperature, humidity and rainfall in Palu and Bau-Bau. Rainfall varies according to altitude, with a total yearly rainfall from 1000 mm to 2000 mm in the lowland.

Table 2-2-1 Average Temperature, Humidity and Rainfall

	Maximum (℃)	Minimum (℃)	Humidity (%)	Rainfall (mm)
Palu	33.5	23.5	76	276
Bau-Bau	31.5	20.1	83	1310

Source: Meteorological Station

Table 2-2-2 shows the rainfall at Palu airport from 1993 to 1995. There is no rainfall recording station along the Tawaeli-Toboli road. According to meteorological station staff, rainfall in the mountains is commonly more than 2000 mm per year.

Table 2-2-2 Rainfall Data at Palu Airport

(mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1993	116	126	57	95	68	48	125	20	0	51	32	35	773
1994	61	53	76	60	108	95	136	33	1	21	25	56	725
1995	72	131	123	77	171	80	104	183	103	119	124	155	1442
Ave	83	103	85	77	116	74	122	79	35	64	60	82	980

Source: Palu airport Meteorology station

2.3 Seismology

Earthquakes occur frequently on Sulawesi Island. The following data shows the number of earthquakes felt in Central Sulawesi. Earthquakes with a magnitude of more than four amount to less than 20% of the total and most of the total number are undetectable to the human body. The effect of earthquakes is usually not so critical.

Table 2-3-1 Earthquake Data in Central Sulawesi

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	322	574	403	633	1184	788	365	505	340	358	442	353
1994	370	218	283	254	297	314	359	320	344	539	348	470
1993	359	158	170	150	180	204	147	116	155	80	610	397
Ave	350	317	285	346	554	435	290	314	280	326	467	407

Source: Mining Office in Palu

2.4 Geology

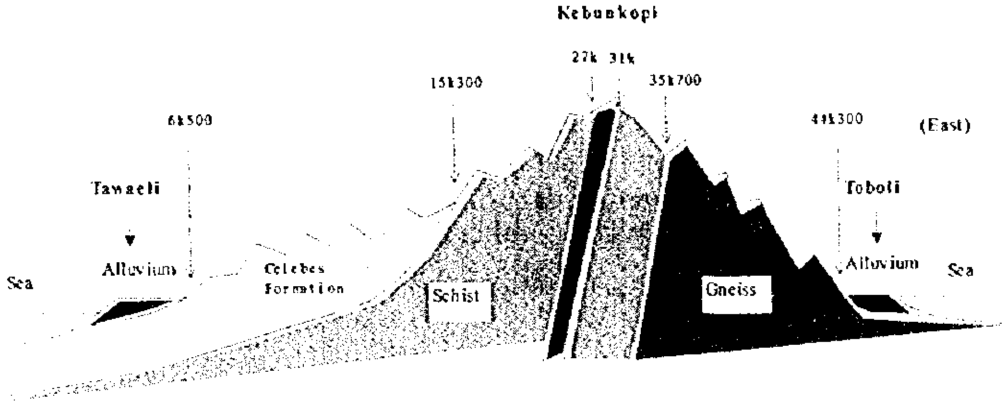
Geological condition between Tawaeli - Toboli is as follows:

Table 2-4-1 Geological Condition of Tawaeli - Toboli

Geological Age	Formation	Geology	Distribution	Note
Holocene	Alluvium	Unconsolidated sand, clay, gravel	1k 100 - 6k 500 44k 300 - 45k 418	Alluvium is distributed in the low plains near Tawaeli and Toboli.
Miocene	Celebes Formation	Sandstone Conglomerate Mudstone	6k 500 - 15k 300	This formation is weakly consolidated and classified in property as material between soil and soft rock.
Palaeogene Period	Metamor-phic Rock	Schist Gneiss	Schist: 16k - 27k, 31k - 35k700, Gneiss: 15k300-16km, 27km-31km 35km700-44k300	Schist is distributed in Tawaeli side, gneiss is distributed in Toboli side.

Source: Study Team

Geological boundary between formations described in Table 2-4-1 extends in a north - south direction. This means that the existing road extending east to west crosses the geological structure at a right angle. Generally speaking, gneiss is harder than schist and schist is harder than weakly consolidated sandstone such as the Celebes Formation in the study area, which is reflected in its topography. The watershed divide between Tawaeli and Toboli is located near Toboli, the gneiss distributed on the Toboli side is harder and more resistant against weathering than the schist and sandstone distributed on the Tawaeli side.



Source: Study Team

Figure 2-4-1 Geological Concept between Tawaeli and Toboli (East-West profile)

(1) Alluvium

Alluvial deposit is distributed on the alluvial plain between 1km 100m and 6km 500m near Tawaeli along rivers, and between 44km 300m and 45km 418m near Toboli. This formation consists of unconsolidated soft clay, sand and gravel which were deposited in the floodplain by sedimentation of the existing rivers. Thickness of the formation may be less than 20m and is not a strong formation.

(2) Celebes Formation

The Celebes Formation is distributed between 6km 500 and 15km 300m overlying the basement of metamorphic rock. This formation consists of alternating sandstone, conglomerate, mudstone layers with each layer having thickness of 0.1m - 4m. Geological age of this formation is relatively young dating from Miocene or Neogene period, and it is better to call the formation weakly consolidated sand / gavel / clay than to call it rock. Sandstone and conglomerate is less consolidated and easily dissolved into soil particles though mudstone is more consolidated. Material of the Celebes Formation is coarser such as gravel on the boundary with underlying metamorphic rock, but becomes finer toward the west, and it is more clayey and silty in Tawaeli.

The formation is strikes range from S - N to E - W dipping at less than 30 degrees with slight folding. There are many small faults cutting the formation. Characteristics of the formation are as follows;

a) This formation is not strongly consolidated and resistance against erosion caused by rainfall is small. Sandstone and conglomerate are easily dissolved into sand and gravel and easy to collapse from the slope.
b) The formation is outcropping on excavation slopes without any protection work, causing stone-fall from slopes and shallow slope failure during heavy rainfall.

c) Gravel remains in unstable condition on the excavation slope after sand and clay supporting gravel were washed out by rain.

d) There are many small faults cutting the formation. However, fracture zone of the faults is not so serious because the formation is originally soft.

(3) Metamorphic Rock

Metamorphic rock comprises of schist and gneiss is distributed between No.34 and No.65 of the existing road. Distribution of the rock is as follows;

a) Schist is distributed mainly in Tawaeli side, between 16km and 35km 700m though gneiss is distributed between 27km and 31km in the small scale.

b) Gneiss is distributed mainly in Toboli side, between 35km 700m and 44km 300m in large scale and 15km 300m to 16km in small scale.

The schist is mica-schist of green color, developing many cleavages. Fresh part of both of schist and gneiss is hard or medium-hard. However, a large number of cracks develop in schist, and a thick weathered zone is developed in the gneiss especially on the surface of excavation slopes, where rock looks like sand or soft rock. Properties of these rocks is as follows;

Schist

Schist has many cracks and rock fragments easily as fall or collapse due to cracks, especially where small valleys cross the existing road, as flowing water during heavy rain accelerates collapsing of rock and erodes pavement, causing the current dangerous conditions for traffic. Rock on dip slope slides easily over cracks and rock on cuesta scarp also falls often due to cracks.

Gneiss

Gneiss tends to be weathered into sand as well as granite, and sometimes deep weathering takes place in such rock. Gneiss is distributed in the east part of the study area, between 35km 700m and 44km 300m, where gneiss has weathered to sand in many excavation slopes at a depth of 1m - 4m causing shallow slope failure.

(4) Problem Caused by Geological Condition During Road Construction

Problems caused by geological conditions during road construction are as follows;

Fracture Zone

There is a fracture zone about 16.5 km from Tawaeli of relatively large scale, where schist is fractured and weathered to rock fragments, clay and soil, probably due to fault movement. Groundwater is flowing out from the slope. Such a place is likely to bring about slope failure. Road of this area is now (June, 1997) under improvement. Except for this site, no other serious fracture zone has been recognized so far in the study area.

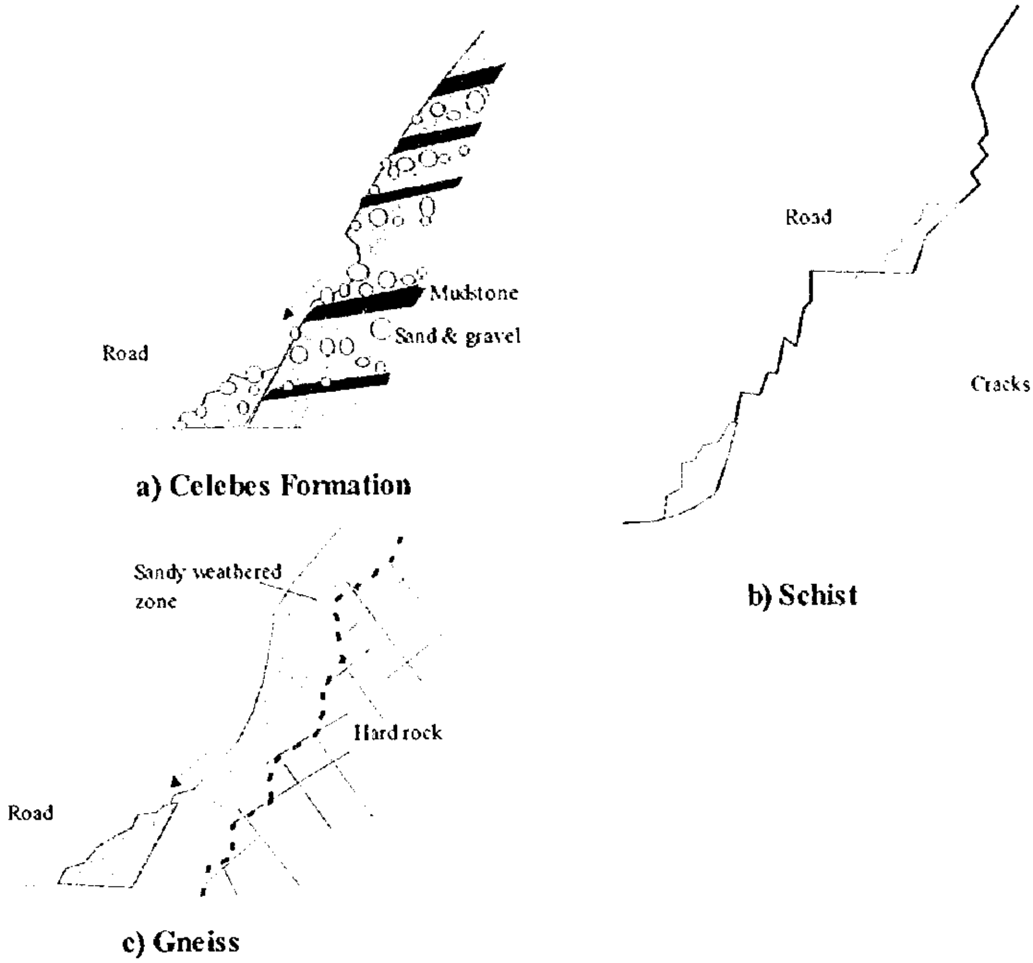
Slope Failure

Slope failures have taken place in the Celebes Formation, Schist and Gneiss in the study area.

a) Slope failures occurring in shallow part of excavation slope are frequent in gneiss area, as gneiss is easily weathered into sandy material.

b) Many fractures are concentrated in schist, causing rock under the existing road to collapse down to the valley. Therefore, erosion of road is still advancing, causing the current dangerous traffic conditions.

c) Sandstone, conglomerate and mudstone of the Celebes Formation are not so consolidated and hard; therefore excavated slopes in the rock are easily eroded by rainfall.

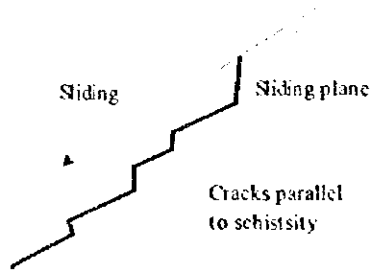


Source: Study Team

Figure 2-4-2 Types of Slope Failure by Rock Types

Landslide

Landslide is taking place more frequently where schist is distributed. Because many cracks are developed parallel to each other in schist, slopes of mountain tend to start sliding over these cracks during heavy rain. According to local engineers, landslides which took place in the past around 18km 200m, 20km 100m and 22km 450m, made road surface settle down , undulate and move toward valley more than 1m.



Source: Study Team

Figure 2-4-3 Cause of Landslide of Schist

Chapter 3

Aerial Photographic Survey and Topographic Survey

Chapter 3 AERIAL PHOTOGRAPHIC SURVEY AND TOPOGRAPHIC SURVEY

3.1 General

Aerial photogrammetry and ground survey were carried out in order to prepare the 1:5000 topographic map and longitudinal profile data necessary for the implementation of the Feasibility Study for Tawaeli - Toboli Road.

The survey accuracy was in accordance with the overseas survey standard (class B) by JICA.

3.2 Aerial Photogrammetry

(1) Minor Order Leveling

Leveling instruments used were three units of Wild NA2/NAK2 units and Total Station over a distance of 74.2 km. The reference elevations of TTG and the surveyed elevations of control points are shown in Tables 3-2-1 to 3-2-3 The leveling secured the specified allowable error value of ± 5 cm$\sqrt{s}$ (s : in kilometers).

(2) Measurement of Photo Control Point

Horizontal control points of 13 newly established locations and three existing bench marks for a mapping area of 90 km^2 as shown in Figure 3-2-1 were surveyed by GPS observation applying differential carrier phase static method. Based on the satellite constellation, the observation was carried out using three units of Trimble 4000 SSE / SST Receivers. The observation log is shown in Table 3-2-4.

As shown in Figure 3-2-2, GPS observation corridor network was closed with two reference points N.4005A, at Palu and N.4005, at Toboli. The data were processed by Trimvec Plus Software Program. Final coordinates on geodetic datum DGN-95 and GPS traverse closure analysis are shown in Table 3-2-5 and 3-2-6, respectively. The control point survey secured the specified allowable errors on both horizontal and vertical closure at a value of ± 10 ppm in 3 dimensional vector.

Table 3-2-1 Accuracy of Leveling

Main Route

WP1/3

Point Name	Distance (km)	Elevation Difference (m)				Error (mm)	Tolerance (mm)	Judgment	Elevation (m)	Note
		Forward	Reverse	Average	TTG					
TTG 707									**18.260**	)N TAWAE:
	4.344	77.186	-77.163	77.1745	77.186	11.5	104.2	OK		
TTG 708									**95.446**	
	4.337	114.050	-114.048	114.0490	114.043	-6.0	104.1	OK		
TTG 709									**209.489**	
	4.648	243.538	-243.531	243.5345	243.500	-34.5	107.8	OK		
TTG 710									**452.989**	
	4.700	181.344	-181.353	181.3485	181.332	-16.5	108.4	OK		
TTG 711									**634.321**	
	5.322	153.303	-153.321	153.3120	153.294	-18.0	115.3	OK		
TTG 712									**787.615**	
	4.932	85.913	-85.939	85.9260	85.924	-2.0	111.0	OK		
TTG 713									**873.539**	
	9.322	-340.285	340.265	-340.2750	-340.219	56.0	152.7	OK		
TTG 715									**533.320**	
	4.080	-261.796	261.795	-261.7955	-261.769	26.5	101.0	OK		
TTG 716									**271.551**	
	5.629	-259.710	259.730	-259.7200	-259.751	-31.0	118.6	OK		
TTG 717									**11.800**	;MP TOBOL
Sub tota!	47.314									

Source: Study Team

Xa10/Exc/D.D.(B)/Per/970606

Table 3-2-2 Accuracy of Leveling

WP2/3

Point Name	Distance (km)	Elevation Difference (m) Forward	Reverse	Average	Error (mm)	Tolerance (mm)	Judgment	Elevation (m)	Note
TTG 707								18.260	
	1.100	-3.681	3.685	-3.683	4.0	52.4	OK		
GPS 01								14.577	
TTG 707								18.260	
	1.899	-16.904	16.920	-16.912	16.0	68.9	OK		
GPS 02								1.348	
TTG 708								95.446	
	0.797	-18.649	18.651	-18.650	2.0	44.6	OK		
GPS 03								76.796	
HP-1								199.998	
	0.170	63.898	-63.898	63.898	0.0	20.6	OK		by Total Statio
GPS 04								263.896	
HP-2								353.550	
	0.094	22.130	-22.144	22.137	-14.0	15.3	OK		by Total Statio
GPS 05								375.687	
TTG 711								634.321	
	0.557	22.092	-22.098	22.095	-6.0	37.3	OK		
GPS 06								656.416	
TTG 713								873.539	
	1.780	13.007	-12.999	13.003	8.0	66.7	OK		
GPS 07								886.542	
TTG 713								873.539	
	3.376	16.985	-16.983	16.984	2.0	91.9	OK		
GPS 08								890.523	
TTG 715								533.320	
	2.856	201.731	-201.725	201.728	6.0	84.5	OK		
GPS 09								735.048	
Sub total	12.628								

Source: Study Team

Table 3-2-3 Accuracy of Leveling

Photo Control Points and Photo Points

WP3/3

Point Name	Distance (km)	Elevation Difference (m)			Error (mm)	Tolerance (mm)	Judgment	Elevation (m)	Note
		Forward	Reverse	Average					
TTG 715								533.320	
	1.743	-128.021	128.013	-128.0170	-8.0	66.0	OK		
GPS 10								405.303	
TTG 717								11.800	
	1.316	1.788	-1.796	1.7920	-8.0	57.4	OK		
GPS 11								13.592	
TTG 717								11.800	
	1.574	-11.705	11.709	-11.7070	4.0	62.7	OK		
GPS 12								0.093	
TTG 710								452.989	
	1.641	60.878	-60.880	60.8790	-2.0	64.0	OK		
GPS 13								513.868	
TTG 717								11.800	
	1.125	29.434	-29.438	29.4360	-4.0	53.0	OK		
BM- 1								41.236	
P.92								51.580	
	3.900	-2.043	2.039	-2.0410	-4.0	98.7	OK		
BM-90								49.533	
P.96								18.652	
	0.878	-16.020	16.016	-16.0180	-4.0	46.8	OK		
P. 101								2.634	
P.97								20.664	
	1.061	-18.733	18.730	-18.7320	-3.0	51.5	OK		
P. 102								1.932	
TTG 717								11.800	
	1.023	-12.150	12.156	-12.1530	6.0	50.6	OK		
P. 107								-0.353	**'asut TOBOL**
Sub total	14.260								
Grand total	74.202								

Source: Study Team

Table 3-2-4 GPS Observation Log

GPS 3

No.	Session Number	Date	Operating Time			Station Name			Remarks
			Begin	End	Sp. Time	1	2	3	
1	102-1	April 12,1997	10:30:30	11:59:30	1:29:00	GPS.10	GPS.11	GPS.12	
2	102-2	April 12,1997	14:40:30	15:39:45	0:59:15	GPS.12	GPS.11	GB.831	
3	102-3	April 12,1997	17:00:45	17:59:45	0:59:00	GPS.09	GPS.10	GPS.08	
4	103-1	April 13,1997	08:15:30	09:44:30	1:29:00	GPS.06	GPS.04	GPS.05	
5	103-2	April 13,1997	10:35:30	12:04:45	1:29:15	GPS.06	GPS.13	GPS.05	
6	103-3	April 13,1997	14:40:30	16:09:45	1:29:15	GPS.07	GPS.06	GPS.08	
7	104-1	April 14,1997	08:10:15	10:09:45	1:59:30	**N.4005A**	GPS.02	GPS.01	
8	104-2	April 14,1997	13:12:00	13:59:30	0:47:30	GPS.03	GPS.01	BM.90	
9	104-3	April 14,1997	14:44:00	16:09:30	1:25:30	GPS.03	GPS.02	GPS.04	
10	105-1	April 15,1997	11:30:30	12:59:45	1:29:15	BM.1	**N.4005**	GPS.10	
11	106-1	April 16,1997	10:39:45	11:13:30	0:33:45	-	**N.4005**	GB.831	

Instr.1 : Trimble 4000 SST s/n 3038A01142 Operated by : Baroto
Instr.2 : Trimble 4000 SSE s/n 3447A08882 Operated by : Sembodo
Instr.3 : Trimble 4000 SSE s/n 3447A08881 Operated by : Yahman

Source: Study Team

Table 3-2-5 Final Coordinates of Control Points

GPS 1

No.	Station Name	Geographical Coordinate		Trans SUL-TENG TM-3°System		Elevation (meter)	Remarks
		Latitude	Longitude	N. (meter)	E. (meter)		
1	N.4005A	0°54′ 56. 6981″ S	119°54′ 20. 2696″ E	-101,248.434	9,497.208	N/A	Reference Point (PALU GBU.20)
2	N.4005	0°42′ 32. 8343″ S	120°05′ 41. 4248″ E	-78,402.808	30,555.711	11.962	Reference Point (T0BOLI D.448)
3	GPS.01	0°44′ 37. 5581″ S	119°51′ 49. 1667″ E	-82,233.460	4,825.186	14.577	
4	GPS.02	0°42′ 59. 2058″ S	119°51′ 44. 1502″ E	-79,212.854	4,670.001	1.348	
5	GPS.03	0°44′ 33. 0344″ S	119°53′ 32. 0975″ E	-82,094.438	8,007.440	76.796	
6	GPS.04	0°43′ 39. 8835″ S	119°55′ 29. 0223″ E	-80,461.989	11,622.312	263.896	
7	GPS.05	0°43′ 07. 8283″ S	119°56′ 21. 3896″ E	-79,477.483	13,241.315	375.687	
8	GPS.06	0°43′ 07. 3171″ S	119°58′ 25. 2037″ E	-79,461.746	17,069.223	656.416	
9	GPS.07	0°43′ 44. 5965″ S	120°00′ 15. 8273″ E	-80,606.665	20,489.325	886.542	
10	GPS.08	0°43′ 06. 9488″ S	120°01′ 08. 2344″ E	-79,450.431	22,109.574	890.523	
11	GPS.09	0°43′ 37. 4488″ S	120°02′ 06. 0745″ E	-80,387.159	23,897.785	735.048	
12	GPS.10	0°42′ 49. 8225″ S	120°03′ 14. 8022″ E	-78,924.478	26,022.624	405.303	
13	GPS.11	0°43′ 08. 7323″ S	120°05′ 59. 7173″ E	-79,505.323	31,121.231	13.592	
14	GPS.12	0°41′ 47. 4214″ S	120°05′ 28. 5902″ E	-77,008.075	30,158.935	0.093	
15	GPS.13	0°42′ 51. 4654″ S	119°57′ 28. 7006″ E	-78,974.921	15,322.336	513.868	
16	BM.1	0°42′ 39. 6671″ S	120°05′ 08. 0484″ E	-78,612.638	29,523.820	41.228	Control Point by SEECON
17	BM.90	0°44′ 01. 4400″ S	119°52′ 41. 3967″ E	-81,124.148	6,439.924	49.533	Control Point by SEECON
18	GB.831	0°42′ 32. 5208″ S	120°05′ 41. 5001″ E	-78,393.180	30,558.039	12.049	Monument of TTG 0717 (SMP TOBOLI)

Source: Study Team

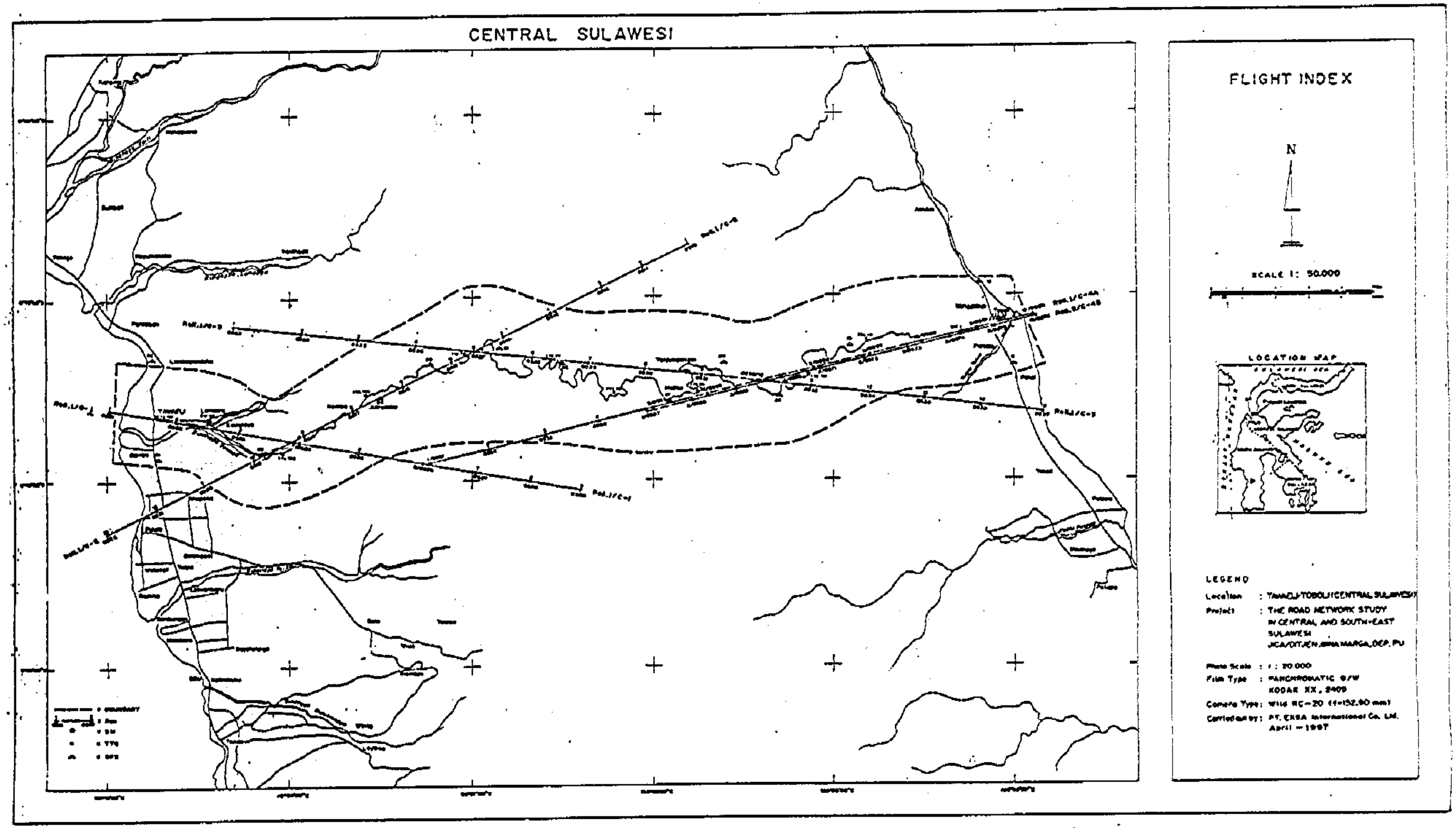
Xa10/Exc/Per/970607

Table 3-2-6 GPS Traverse Close Analysis

GPS 2

Traverse Number	Section	Closure (meter)				Total Dist. (meter)	Accuracy (ppm)
		dx	dy	dz	dh		
Baseline	**N.4005A** - GPS.01 - GPS.04 - GPS.06 - GPS.08 - GPS.10 - **N.4005**	0.183	0.085	0.093	-0.020	45,899.656	4.83
1	**N.4005A** - GPS.02 - GPS.01 - **N.4005A**	0.006	-0.010	0.014	-0.012	45,168.519	0.40
2	GPS.01 - GPS.03 - BM.90 - GPS.01	0.004	-0.005	0.001	-0.006	6,989.793	0.93
3	GPS.02 - GPS.03 - GPS.04 - GPS.02	-0.004	-0.010	-0.001	-0.007	15,451.220	0.70
4	GPS.04 - GPS.06 - GPS.05 - GPS.04	0.001	0.015	0.003	0.012	11,290.293	1.36
5	GPS.06 - GPS.05 - GPS.13 - GPS.06	-0.004	-0.002	0.004	0.000	7,804.081	0.77
6	GPS.06 - GPS.07 - GPS.08 - GPS.06	0.010	0.009	0.007	0.013	10,652.760	1.42
7	GPS.08 - GPS.09 - GPS.10 - GPS.08	0.003	-0.009	0.001	-0.009	8,605.077	1.11
8	GPS.10 - BM.1 - **N.4005** - GB.831 - GPS.12 - GPS.10	-0.033	0.014	0.001	0.029	10,616.868	3.38
9	GPS.10 - BM.1 - **N.4005** - GB.831 - GPS.11 - GPS.10	-0.050	0.063	0.016	0.079	10,991.878	7.46
10	GB.831 - GPS.11 - GPS.12 - GB.831	-0.001	0.001	-0.001	0.001	5,364.956	0.32

Source: Study Team



Source: Study Team

Figure 3-2-1 Horizontal Control Points Map

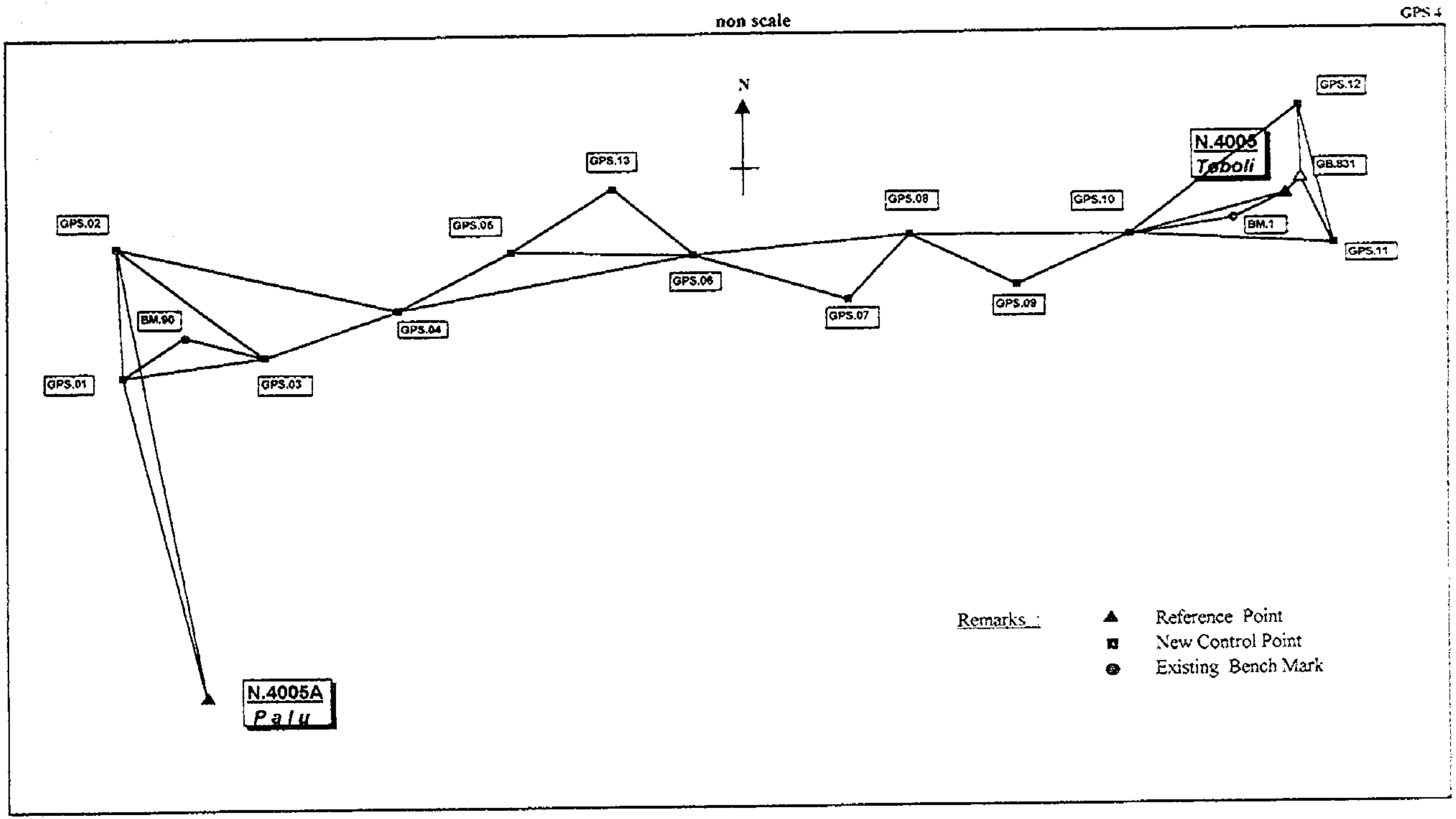


Figure 3-2-2 GPS Observation Network

Source: Study Team

(5) Aerial Photographing

The aircraft required was twin propeller Taurus King Air mounted with an aerial survey camera (Wild RC-20 / PTW 30 FMC) with 152.90 mm lens.

Aerial photography at a nominal scale of 1:20,000 has been performed to cover 78 line km in total over the area.

The aerial film negatives were annotated. Data usage security clearance by military authorities was provided before printing of photos.

Tolerable shifting error, flight altitude, overlapping, crab, tip and tilt, haze, clouds etc. of 59 photo frames were checked for further processing.

A 1:50,000 scale flight index map including number of flight line and photograph, control points, bench marks, etc, is shown in Figure. 3-2-1.

(6) Field Verification.

Field verification was conducted over an area of 90 km^2 using twice-enlarged aerial photographs.

All objects in the photographs were verified according to map symbols. Names of villages, rivers, offices, political boundaries, etc, were annotated and spot elevations pricked out on the two-times photo enlargements.

(7) Aerial Triangulation

After photo control points were selected carefully by Mirror Stereoscopes, the points were transferred to the duplicated film positives using Wild PUG-4. Photo coordinates were measured by Zeis Stecometer C.

Aerial Triangulation for 45 stereo models was computed using PAT M-43 program.

Residuals of photo control points and discrepancies met with JICA Regulations, as shown in Table 3-2-5.

(8) Mapping

The work quantity is 90 km^2 on a scale of 1:5,000 with 5 meters contour interval.

Map compilation by applying the digital mapping method was carried out, using three units of converted Wild A-8 Stereoplotter with Mcmap Digital Mapping System developed in Canada.

AUTOCAD 13 with HP 650 C Design Jet Plotter was used for final map sheet process.

(9) Projection System

The mapped area is spread over the two UTM zones 50 and 51 which are divided by the central meridian 120° E. The scale factor is, therefore, much too large; as exactly at Tawaeli in zone 50, the scale factor is 1.000900 and rapidly increasing eastward. The effective projection area was, therefore, restricted to a narrow zone embracing the central meridian.

In this study " 3° Modified TM System " was applied, using central scale factor 0.999900 in projection zones 3° wide in longitude. Named " Trans SUL-TENG TM - 3° System " with parameters :

- geodetic datum : DGN-95
- central meridian : 120° E
- false easting : 20,000.000m
- latitude origin : 0° N (Equator)
- false northing : 0.000m
- central scale factor : 0.999900

3.3 Longitudinal Profiling

Longitudinal profiling was carried out in order to obtain topographical data over a stretch of 50 kms at about 200 m along the center line of existing road and proposed tunnels using three units of automatic level Wild NA2/NAK2 and a Total Station. All bridges, box culverts and concrete pipes were surveyed.
Final profile charts were completed at scale horizontal 1:5,000 and vertical 1:500 by AUTOCAD.

Chapter 4

Soil and Material Investigation

Chapter 4 SOIL AND MATERIAL INVESTIGATION

4.1 Aerial Photograph Analysis

Lineaments were identified based on aerial photographs. Lineament is defined as a large-scale linear feature which expresses itself in topographical terms which is in itself an expression of underlying structural features such as fault, joint, schistity and cracks etc.. Lineament is usually identified by aerial photograph analysis. Moreover, scars from landslides, slope failures and debris flow which took place in the past are also identified by aerial photograph analysis.

(1) Lineament

There is no large scale lineament crossing the existing Tawaeli-Tobili road or newly proposed route; however small scale lineaments are scattered along both of them. These lineaments extend in north-south direction which corresponds to the general geological structure of the study area. Location of the lineaments are as follows;

a) Lineament crossing proposed route at 16km 250m and the existing road at 13km 250m.
b) Lineament crossing proposed route at 16km 700m.
c) Lineament crossing proposed route at 17km 800m and the existing road at 16km 500m.
d) Lineament crossing proposed route at 18km 200m.
e) Lineament crossing proposed route at 19km 000m and the existing road at 18km 100m.
f) Lineament crossing proposed route at 20km 300m and the existing road at 21km 200m.
g) Lineament crossing the existing road at 26km 50m.
h) Lineament crossing proposed route at 28km 300m and the existing road at 30km 900m.

The above lineaments were considered to be expression of zones where schistity and joint were developed. Along the lineaments rocks were in the process of weathering and rock blocks are likely to slide down due to low strength of weathered rocks. Rocks in the study area were covered by vegetation and it was difficult to investigate actual condition of weathered rock along the lineaments.

(2) Previous Landslides and Slope Failures

Previous landslides and slope failures are not clear in the aerial photographs. It was reported by field investigation that road settlements took place in the past at 18k 200m, 20k 100m, 22k 450m of the existing road; however aerial topographics do not show landslide features in these three places. Landslide of creep type which moves slowly down the slope is considered to have occurred in these 3 areas by cutting of the existing road, however there is no evidence so far.
Fault crush zone at 16.5km appears to be a sliding block along the fault that was crushed and strongly weathered in the process of sliding.

(3) Physical Features of Proposed Tunnel Area

Previous landslides and slope failures were not seen on the slope of hill where tunnel is proposed. Fissilized surfaces caused by schistity and joint dipping in the west have developed on the hill. The large scale fissilized surface may be identified as lineament.

4.2 Boring Survey

(1) Purpose of Boring Survey

Boring survey was carried out between Tawaeli - Toboli Road. The total number of boreholes drilled was twenty-three (23). Purpose of boring survey is to obtain information on items below;

a) Geological condition of entrance and the center of proposed tunnel.
b) Geological condition of proposed bridges

(2) Location of Boring Survey

Location of boring survey is shown in Figures 4-2-1 and 4-2-2, and outline of the survey is shown in Table 4-2-1.

Table 4-2-1 Outline of Boring

No	Depth (m)	Purpose	No	Depth (m)	Purpose	No	Depth (m)	purpose
T-1	30	Entrance of tunnel	T-9	50	Entrance of tunnel	B-2	10	Bridge Foundation
T-2	30	Entrance of tunnel	T-10	50	Entrance of tunnel	B-3	12	Bridge Foundation
T-3	30	Entrance of tunnel	T-11	30	Center of tunnel	B-4	10	Bridge Foundation
T-4	30	Entrance of tunnel	T-12	30	Center of tunnel	B-5	11	Bridge Foundation
T-5	30	Entrance of tunnel	T-13	30	Entrance of tunnel	B-6	10	Bridge Foundation
T-6	30	Entrance of tunnel	T-14	30	Entrance of tunnel	B-7	10	Bridge Foundation
T-7	30	Entrance of tunnel	T-15	30	Entrance of tunnel	B-8	10	Bridge Foundation
T-8	50	Center of tunnel	B-1	7	Bridge Foundation			

Source: Study Team

(3) Result of Boring Survey

1) Tunnel

Geological condition of proposed tunnel is classified as Table 4-2-2.

Table 4-2-2 Geological Condition of Planned Tunnel

Soil	N value	Note
Colluvial Deposit	Less than 50	Colluvial deposit is composed of silt, clay, sand and gravel.
Strongly weathered rock	More than 50	Rock is weathered to clayey sand and gravel in the boundary with colluvial deposit and the boundary is unclear. Core was taken as silt, sand and gravel, rock fragment.
Weathered rock	Impossible to penetrate	Core was taken as sand and gravel, rock fragment, and short / long cylindrical core.

Source: Study Team

Geological condition of proposed tunnel is as follows:

20k 200m - 22k 400m

Rock of this section is composed of mica-schist. Tow boreholes, T-5 and T-13, were drilled on the slope along the existing Tawaeli - Toboli road. The drilling points of the boreholes correspond to location of tunnel entrance. Based on the result of boring survey, geology above GL-10m~-20m is composed of colluvial deposit and strongly weathered rock, and geology under GL-10m - 20m is composed of hard weathered gneiss. The result of the boring survey is shown in Tables 4-2-3 and 4-2-4.

Table 4-2-3 Result of T-5

Depth	Classification of rock	N value
GL0m ~ GL-3m	Colluvial deposit - Strongly weathered schist	more than 50
GL-8m~GL-10m	Weathered schist	Impossible to penetrate

Source: Study Team

Table 4-2-4 Result of T-13

Depth	Classification of rock	N value	Note
GL0m ~ GL-8m	Colluvial deposit – strongly weathered schist	15 - more than 50	N value increases downward.
GL-8m~GL-20m	Strongly weathered schist	more than 50 - impossible to penetrate	-
GL-20m~GL-30m	Weathered schist	impossible to penetrate	-

Source: Study Team

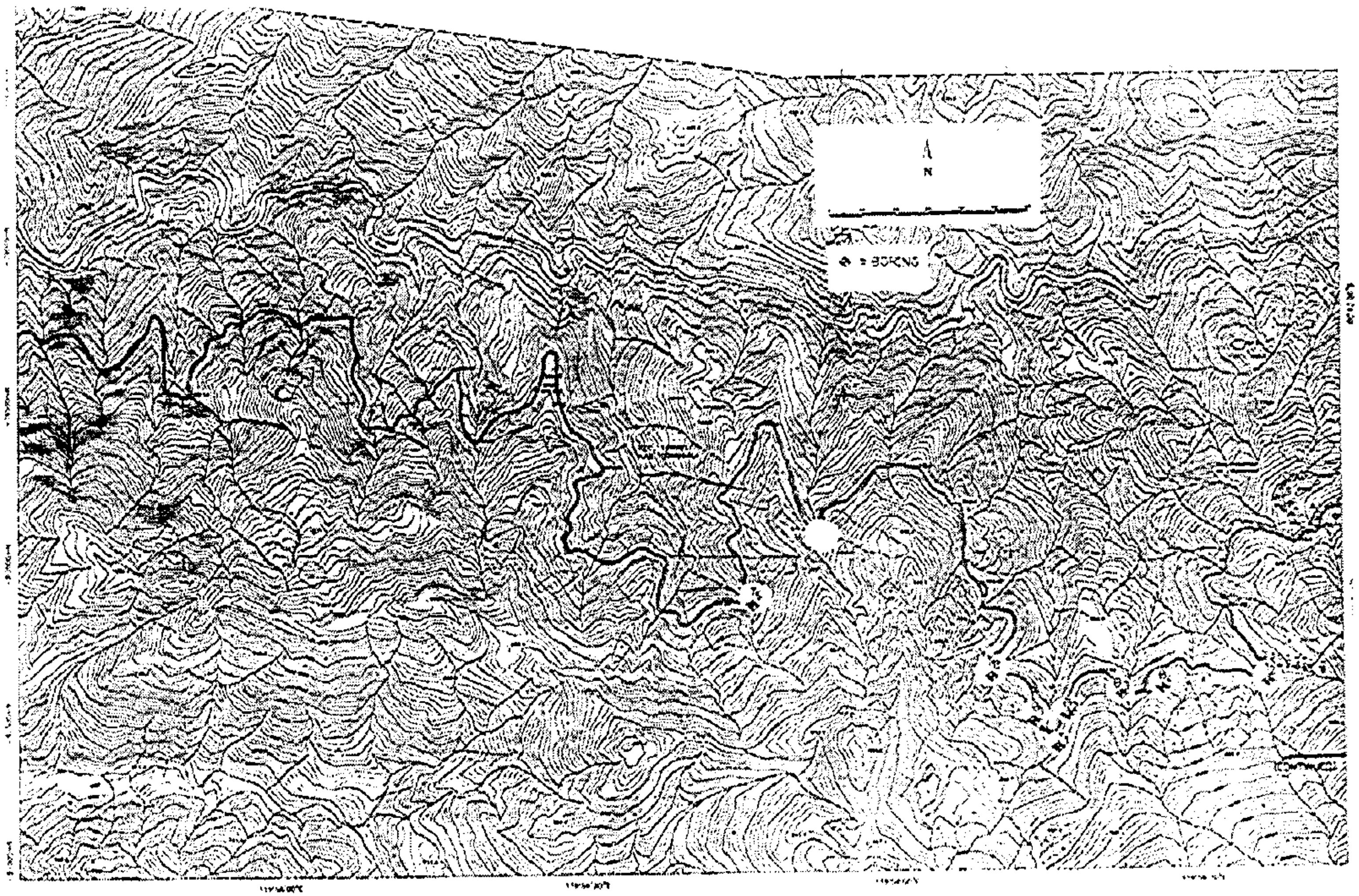
23k 600m - 26k 000m section

Rock of this section is composed of mica-schist. Tow borehole, T-2 and T-3, were drilled on the slope of mountain along the existing Tawaeli - Toboli road. The drilling points of the boreholes correspond to location of tunnel entrance. According to boring survey, geology above GL-15m is composed of colluvial deposit and strongly weathered rock, and geology under GL-15m is composed of hard weathered gneiss. The result of the boring survey is shown in Tables 4-2-5 and 4-2-6.

Table 4-2-5 Result of T-2

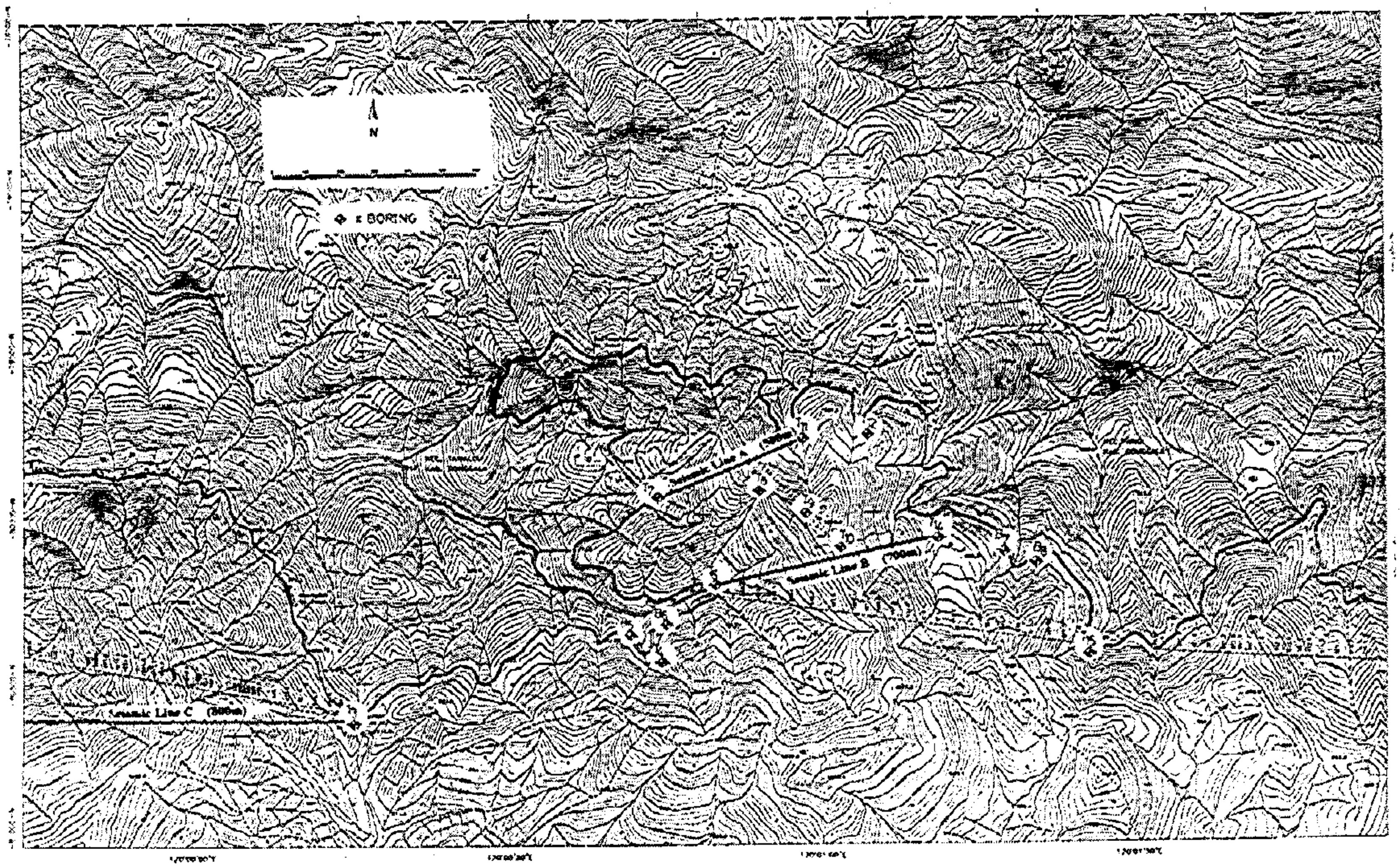
Depth	Classification of rock	N value
GL0m ~ GL-6m	Colluvial deposit - strongly weathered schist	28 - 41
GL-8m~GL-13m	Strongly weathered schist	more than 50
GL-13m~GL-30m	Weathered schist	impossible to penetrate

Source: Study Team



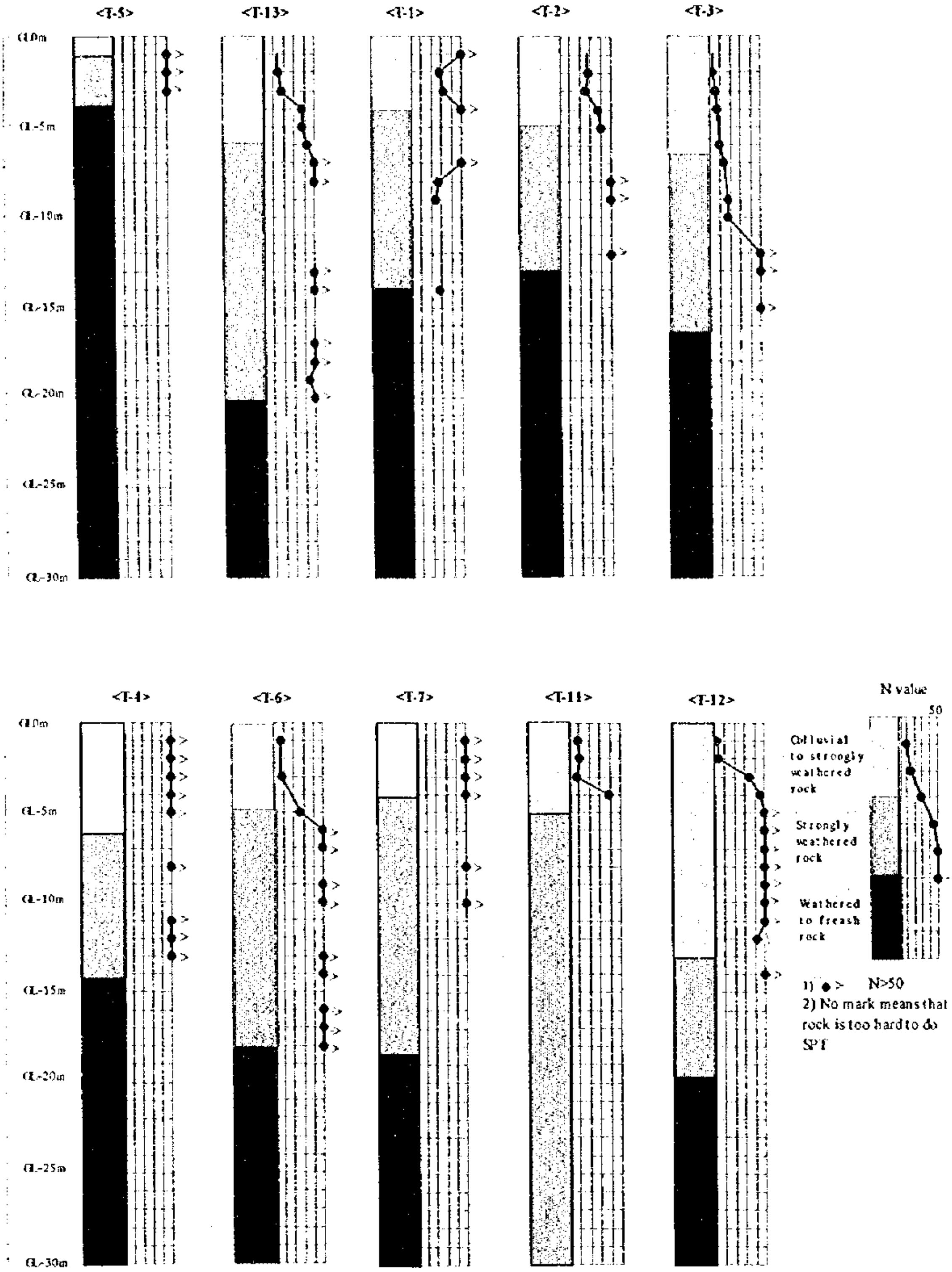
Source: Study Team

Figure 4-2-1 Location of Boring Survey (1)



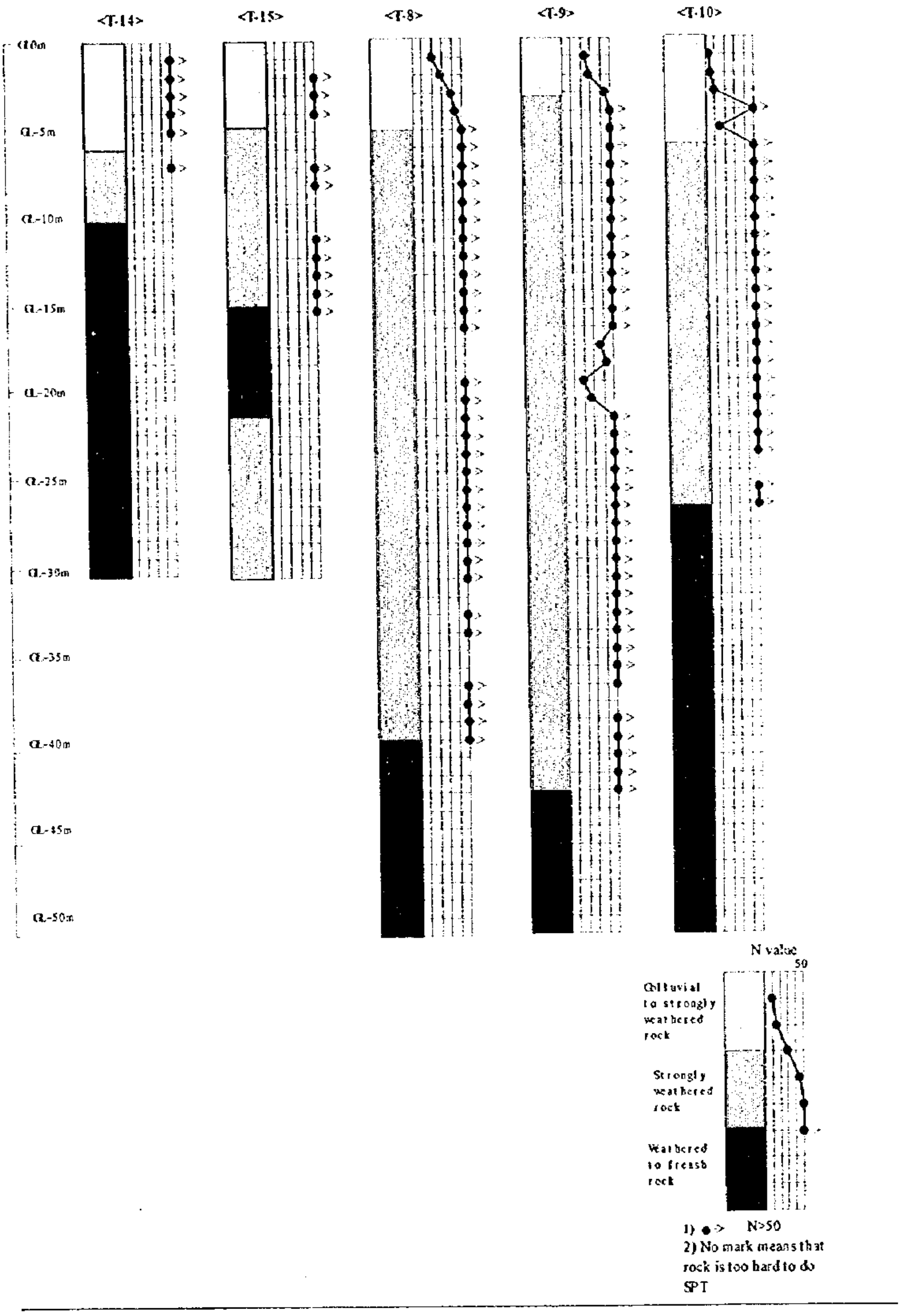
Source: Study Team

Figure 4-2-2 Location of Boring Survey (2)



Source: Study Team

Figure 4-2-3 Result of Boring for Tunnel (1)



Source: Study Team

Figure 4-2-4 Result of Boring for Tunnel (2)

Table 4-2-6 Result of T-3

Depth	Classification of rock	N value	Note
GL0m ~ GL-6m	Colluvial deposit	3 - 6	N value increases downward.
GL-6m ~ GL-15m	Deeply weathered schist	14 - more than 50	N value increases downward.
GL-15m~GL-30m	Weathered schist	impossible to penetrate	

Source: Study Team

<u>**27k 300m - 32k 300m**</u>

Geology of this section is divided into two rocks types. Gneiss is distributed between 27k 300m and 31km 500m and mica-schist is distributed between 31km 500m and 32km 300m. Six (6) boreholes were drilled on the slope along the existing road, and three (3) boreholes were drilled on the top of the mountain. Location of the six boreholes on the slope, T-6, T-7, T-11, T-12, T-14, T-15, correspond to proposed tunnel entrance, and location of the three boreholes, T-8, T-9, T-10, correspond to the middle of proposed tunnel. In this section, geological condition is changing from colluvial deposit near the ground surface → deeply weathered rock → weathered rock in the deeper part. Colluvial deposits are unstable sediments which were provided from upper part of the slope, and of which thickness and strength must be examined as it may cause some problems in construction of the tunnel entrance. The thickness and strength of weathered zone also must be examined in regards to construction. The results of boring survey is as follows:

a) Results of the boring at proposed tunnel entrance location

According to the boring survey, geology above GL-15m is composed of colluvial deposit and strongly weathered rock, and geology under GL-15m is composed of relatively hard weathered gneiss. The result of the boring survey is shown in Tables 4-2-7 to 4-2-12.

Table 4-2-7 Result of T-6

Depth	Classification of rock	N value
GL0m ~ GL-5m	Colluvial deposit	7~26
GL-5m ~GL-18m	Deeply weathered gneiss	more than 50
GL-18m~GL-30m	Weathered gneiss	impossible to penetrate

Source: Study Team

Table 4-2-8 Result of T-7

Depth	Classification of rock	N value
GL0m ~ GL-4m	Colluvial deposit	more than 50
GL-4m ~GL-11m	Deeply weathered gneiss	36~more than 50
GL-11m~GL-30m	Weathered gneiss	impossible to penetrate

Source: Study Team

Table 4-2-9 Result of T-11

Depth	Classification of rock	N value
GL0m ～ GL-5m	Colluvial deposit	8～39
GL-5m ～ GL-m	Weathered gneiss	impossible to penetrate

Source: Study Team

Table 4-2-10 Result of T-12

Depth	Classification of rock	N value
GL0m ～ GL-5m	Colluvial deposit	3～35
GL-5m ～GL-14m	Deeply weathered gneiss	more than 50
GL-14m～GL-30m	Weathered gneiss	impossible to penetrate

Source: Study Team

Table 4-2-11 Result of T-14

Depth	Classification of rock	N value
GL0m ～ GL-5m	Colluvial deposit and Deeply weathered gneiss	more than 50
GL-5m ～ GL-10m	Deeply weathered gneiss	more than 50 - impossible to penetrate
GL-10m ～GL-30m	Weathered gneiss	impossible to penetrate

Source: Study Team

Table 4-2-12 Result of T-15

Depth	Classification of rock	N value
GL0m ～ GL-5m	Colluvial deposit	more than 50
GL-5m ～GL-16m	Deeply weathered schist	more than 50 - impossible to penetrate
GL-16m～GL-30m	Weathered schist	impossible to penetrate

Source: Study Team

b) Result of boring at the middle of proposed tunnel

Based on the result of boring survey, thickness of deeply weathered zone is 30m～40m. It is concluded that thickness of weathered zone at the top of a mountain is greater than that on the slope. The result of boring survey is shown in Tables 4-2-13 to 4-2-15.

Table 4-2-13 Result of T-8

Depth	Classification of rock	N value	Note
GL0m ～ GL-3m	Colluvial deposit	20 - 39	-
GL-3m ～GL-40m	Deeply weathered gneiss	43 - more than 50	-
GL-40m～GL-50m	Weathered gneiss	impossible to penetrate	-

Source: Study Team

Table 4-2-14 Result of T-9

Depth	Classification of rock	N value	Note
GL0m ～ GL-3m	Colluvial deposit	24 - 45	-
GL-3m ～GL-43m	Deeply weathered gneiss	19 - more than 50	Weathering is deep in GL-17m - 21m. N value of the section is 19 to 36.
GL-43m～GL-50m	Weathered gneiss	impossible to penetrate	-

Source: Study Team

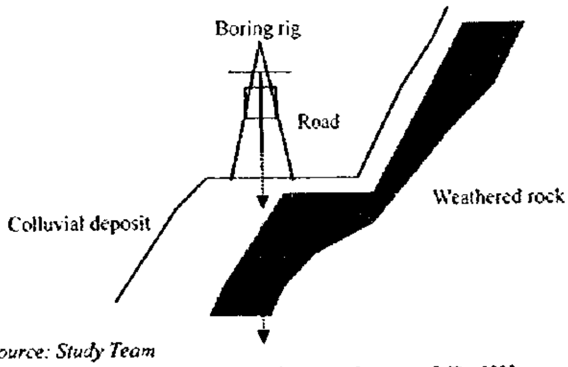
Table 4-2-15 Result of T-10

Depth	Classification of rock	N value	Note
GL0m ～ GL-3m	Colluvial deposit	4 - 9	-
GL-3m ～GL-27m	Deeply weathered gneiss	more than 50	-
GL-27m～GL-50m	Weathered gneiss	impossible to penetrate	-

Source: Study Team

(2) Proposed Bridges

Purpose of boring survey is to confirm the depth and strength of bearing stratum for proposed bridge foundations. The situation of boring survey site is illustrated in Figure 4-2-5. Boring survey in the site finished after confirming the stratum with N value more than 50 and thickness of 5m. Based on the boring survey, topographical and geological conditions in the site are as follows:



Source: Study Team

Figure 4-2-5 Situation of Drilling

a) Proposed bridges are located in the mountain slope. Soil and rock in the site is classified as Table 4-2-16.

Table 4-2-16 Classification of soil and rock in bridge site

Soil and rock	N value
Colluvial deposit	Less than 50
Deeply weathered rock	More than 50
Weathered rock	impossible to penetrate

Source: Study Team

b) Boring survey was carried out on the existing road shown in Figure 4-2-6. There is a slope near the boring point. Depth of valley under the boring point is 15m - 20m and gradient of the slope to bottom is about 40 degrees. The slope is covered with dense vegetation and colluvial deposit on the slope and is difficult to see.

c) Colluvial deposits which were provided from the upper part of the slope are distributed at the depth of GL-0 to GL-4m. The colluvial deposit is composed of silt, clay, sand and gravel, and N value of it is less than 50.

d) Deeply weathered rock and weathered rock with N value more than 50 are distributed below the ground in depth of more than 5 m, and these rock has an enough as bearing stratum for bridge foundations.

e) N values become more than 50 at deeper than GL-3m and stratum under GL-3m is considered as bearing stratum for bridge foundations. However, colluvial deposit and deeply weathered rock are thick at boring point B-5, and N value become more than 50 at deeper than GL-8m.

Result of boring at each point is as follows:

B-1 and B-2

Table 4-2-17 Result of B-1

Depth	Classification of rock	N value
GL0m ~ GL-5m	Colluvial deposit - strongly weathered schist	more than 50
GL-5m~GL-10m	Weathered schist	impossible to penetrate

Source: Study Team

Table 4-2-18 Result of B-2

Depth	Classification of rock	N value
GL0m ~ GL-8m	Colluvial deposit - strongly weathered schist	more than 50
GL-8m~GL-10m	Weathered schist	impossible to penetrate

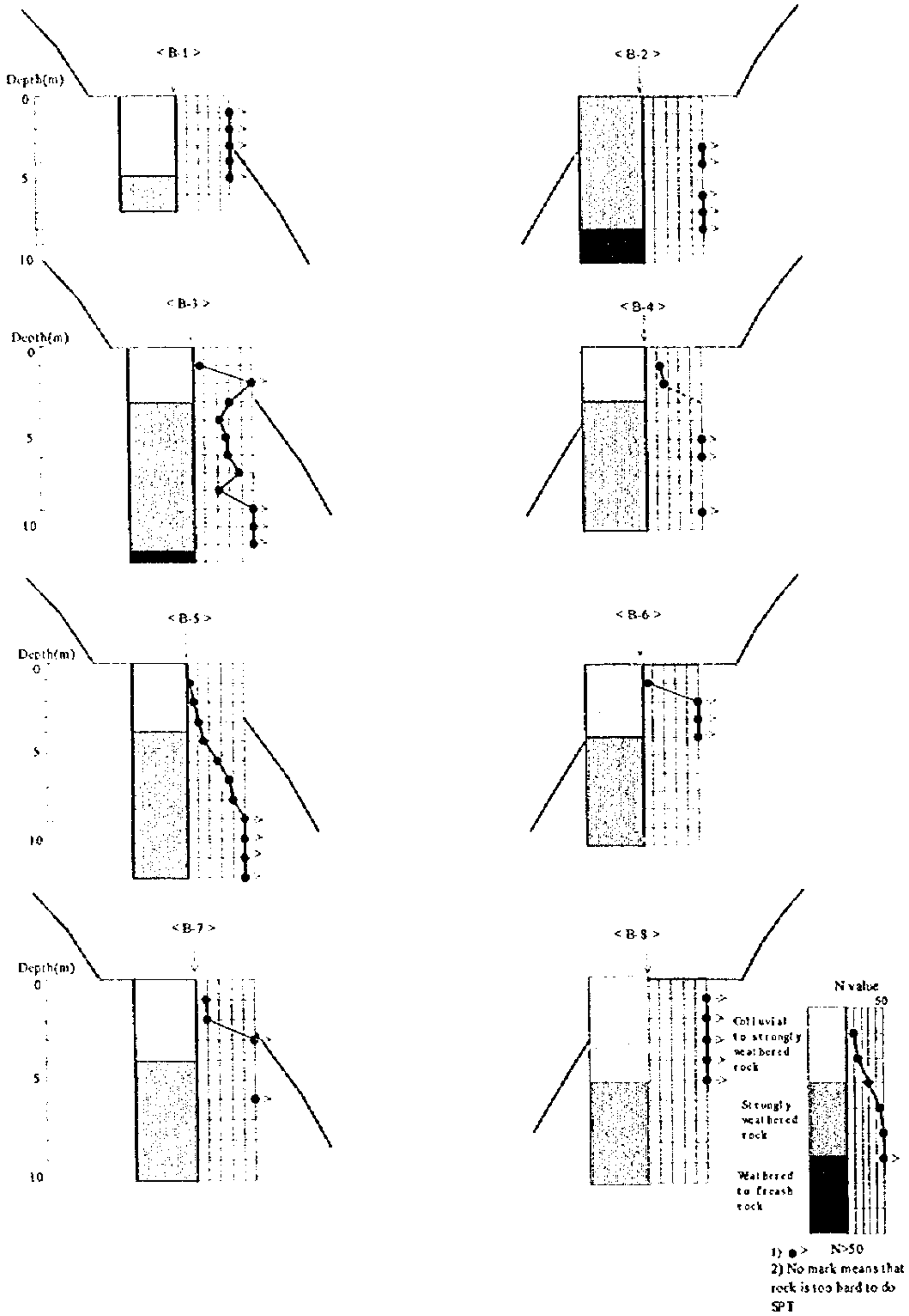
Source: Study Team

B-3 and B-4

Table 4-2-19 Result of B-3

Depth	Classification of rock	N value
GL-0~GL-2m	Colluvial deposit	more than 6
GL-2m~GL-11.51m	Deeply weathered schist	21 - more than 50
GL-11.5m~GL-12m	Weathered schist	impossible to penetrate

Source: Study Team



Source: Study Team

Figure 4-2-6 Result of Boring for Bridge

Table 4-2-20 Result of B-4

Depth	Classification of rock	N value
GL-0～GL-3m	Colluvial deposit	14 - 17
GL-3m～GL-10m	Deeply weathered schist	more than 50 - impossible to penetrate

Source: Study Team

B-5 and B-6

Table 4-2-21 Result of B-5

Depth	Classification of rock	N value
GL-0～GL-8m	Colluvial deposit - deeply weathered gneiss	3 - more than 50
GL-8～GL-11m	Deeply weathered gneiss	more than 50

Source: Study Team

Table 4-2-22 Result of B-6

Depth	Classification of rock	N value
GL-0～GL-4m	Colluvial deposit - deeply weathered gneiss	7 - more than 50
GL-4m～GL-10m	Weathered gneiss	impossible to penetrate

Source: Study Team

B-7 and B-8

Table 4-2-23 Result of B-7

Depth	Classification of rock	N value
GL-0～GL-4m	Colluvial deposit - deeply weathered schist	9 - more than 50.
GL-4m～GL-10m	Deeply weathered schist - weathered schist	More than 50 - impossible to penetrate

Source: Study Team

Table 4-2-24 Result of B-8

Depth	Classification of rock	N value
GL-0～GL-5.5m	Colluvial deposit - deeply weathered schist	More than 50.
GL-5.5m～GL-10m	Weathered schist	Impossible to penetrate

Source: Study Team

(4) Groundwater

Groundwater level was not found by drilling survey. There was no leakage of muddy water for drilling and groundwater flowing into boreholes during the drilling. The area of groundwater basin where groundwater infiltrates into the proposed tunnel is small. It is considered that both sudden groundwater flowing out from crush zone during construction and permanent groundwater flowing out after construction may not be observed.

4.3 Seismic Survey

Seismic exploration was carried out to obtain geological information of proposed tunnel route. Seismic profile lines are shown in Figure 4-3-1. An outline of the survey is as follow:

a) The number of seismic profile lines is three (3).

b) Length of the lines

Line A........... 800m
Line B........... 700m
Line C........... 500m
Total........... 2,000m

c) Purpose of the Seismic Exploration

Purpose of seismic prospecting is to understand geological condition of proposed tunnel routes. Items to be surveyed are hardness of rock, density of cracks, thickness of weathered zone, existence of faults and fracture zone, which are analyzed based on the velocity profile resulting from seismic prospecting.

d) Result of Seismic Prospecting

Velocity layer profiles are shown in Figure 4-3-1 to Figure 4-3-3 for A - C lines.

Line A

The geology along line A was analyzed into 3 velocity layer as shown in Figure 4-3-1.

Table 4-3-1 Velocity layer of Line A

Velocity layer	Depth	Velocity(km/sec)	Geological Condition
1 st	Thickness less than 10m.	0.10～0.25	Colluvial deposit to deeply weathered gneiss
2 nd	Thickness less than 45m.	1.00～1.50	Deeply weathered
3 rd	Velocity basement	2.60-3.30	Weathered gneiss

Source: Study Team

Weathering zone is relatively thick at a thickness of 40-50m from the ground surface. A low velocity layer with the width of 30 m that is considered to be fault crush zone was detected as shown in Figure 4-3-1. This low velocity layer is assumed to continue up to a low velocity layer which was detected in line B. Gradient of the low velocity layer is unknown. This low velocity layer was not detected by aerial photograph analysis.

Line B

The geology along line B was analyzed into 3 velocity layers as shown in Figure 4-3-2.

Table 4-3-2 Velocity layer of Line B

Velocity layer	Depth	Velocity(km/sec)	Geological Condition
1 st	Thickness 5m - 10m.	0.15～0.50	Colluvial deposit to deeply weathered gneiss
2 nd	Thickness less than 60m.	0.60～1.80	Deeply weathered
3 rd	Velocity basement	2.5-3.30	Weathered gneiss

Source: Study Team

Thickness of weathering zone is obviously different between the east slope and the west slope. The thickness of weathering zone is less than 30m in the east side slope, on the other hand 40 - 50m distribution and maximum 60m in the west side slope. A low velocity layer with the width of 20 m that is considered to be fault crush zone was detected between 27k 900m - 27k 950m as shown in Figure 4-3-2. This low velocity layer is assumed to continue up to a low velocity layer which was detected in line A as shown in Figure 4-2-4. Gradient of the low velocity layer is unknown. This low velocity layer was not detected from the aerial photographic analysis.

<u>Line C</u>

The geology along line A was analyzed into 3 velocity layers as shown in Figure 4-3-3.

Table 4-3-3 Velocity layer of Line C

Velocity layer	Depth	Velocity(km/sec)	Geological Condition
1 st	Thickness 5m - 10m	0.10～0.25	Colluvial deposit to deeply weathered gneiss
2 nd	Thickness less than 30m	0.90～2.00	Deeply weathered
3 rd	Velocity basement	3.30-5.00	Weathered gneiss

Source: Study Team

Thickness of weathering zone is about 40m under the ground, which is thinner than in line A and line B. A low velocity layer with the width of 30 m is considered to be fault crush zone is shown in Figure 4-3-3. Gradient of the low velocity layer is unknown. This low velocity layer was not detected by aerial photographic analysis.

LINE A (500m)

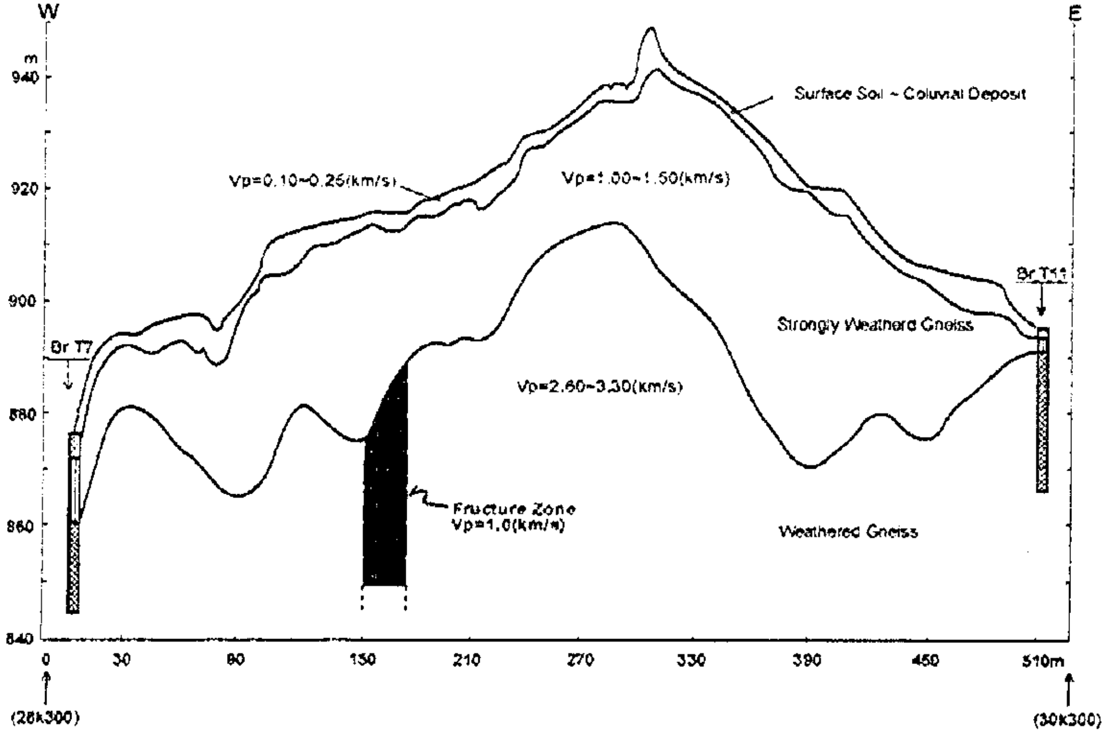
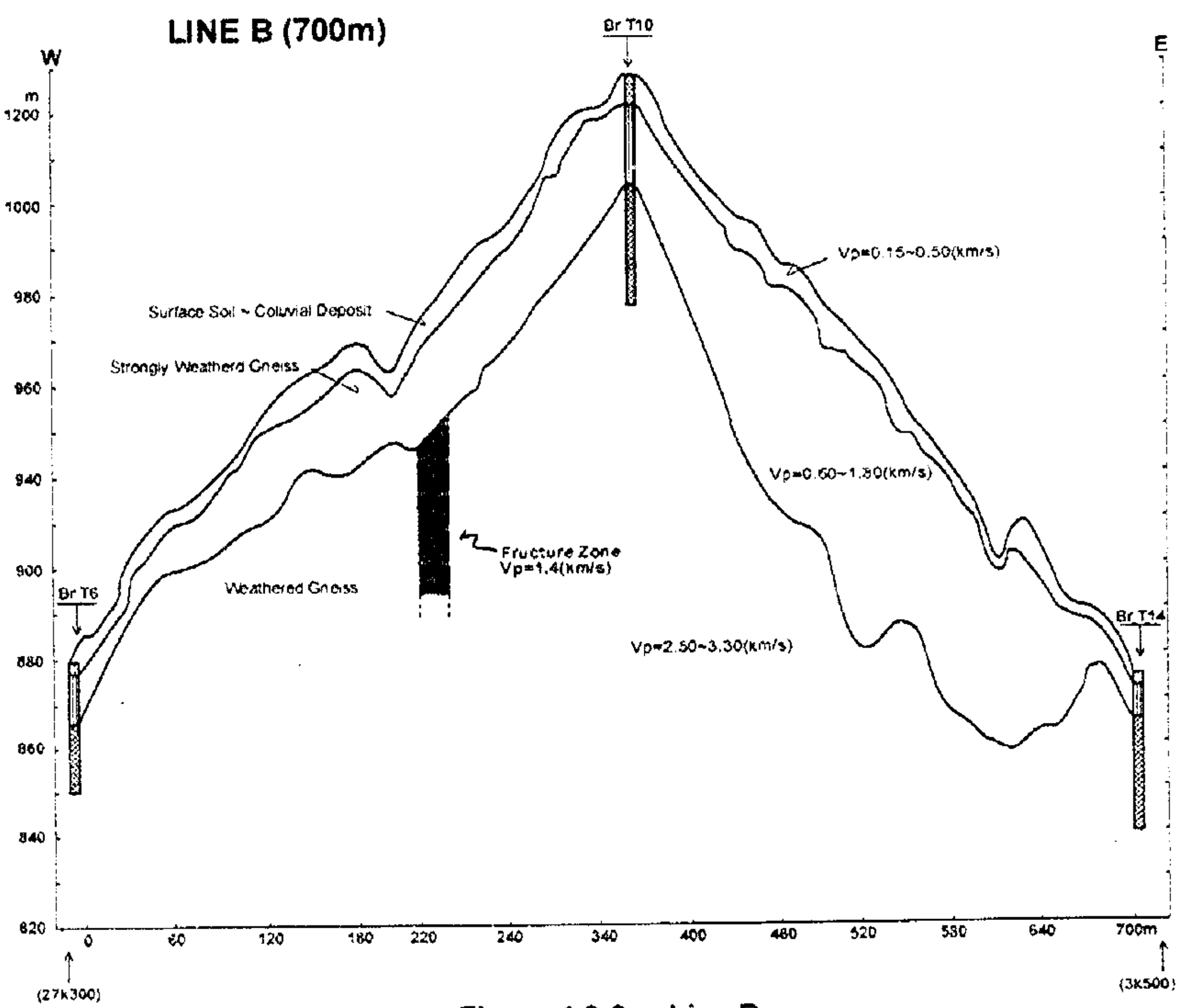


Figure 4-3-1 Line A

Source: Study Team



Source: Study Team

Figure 4-3-2 Line B

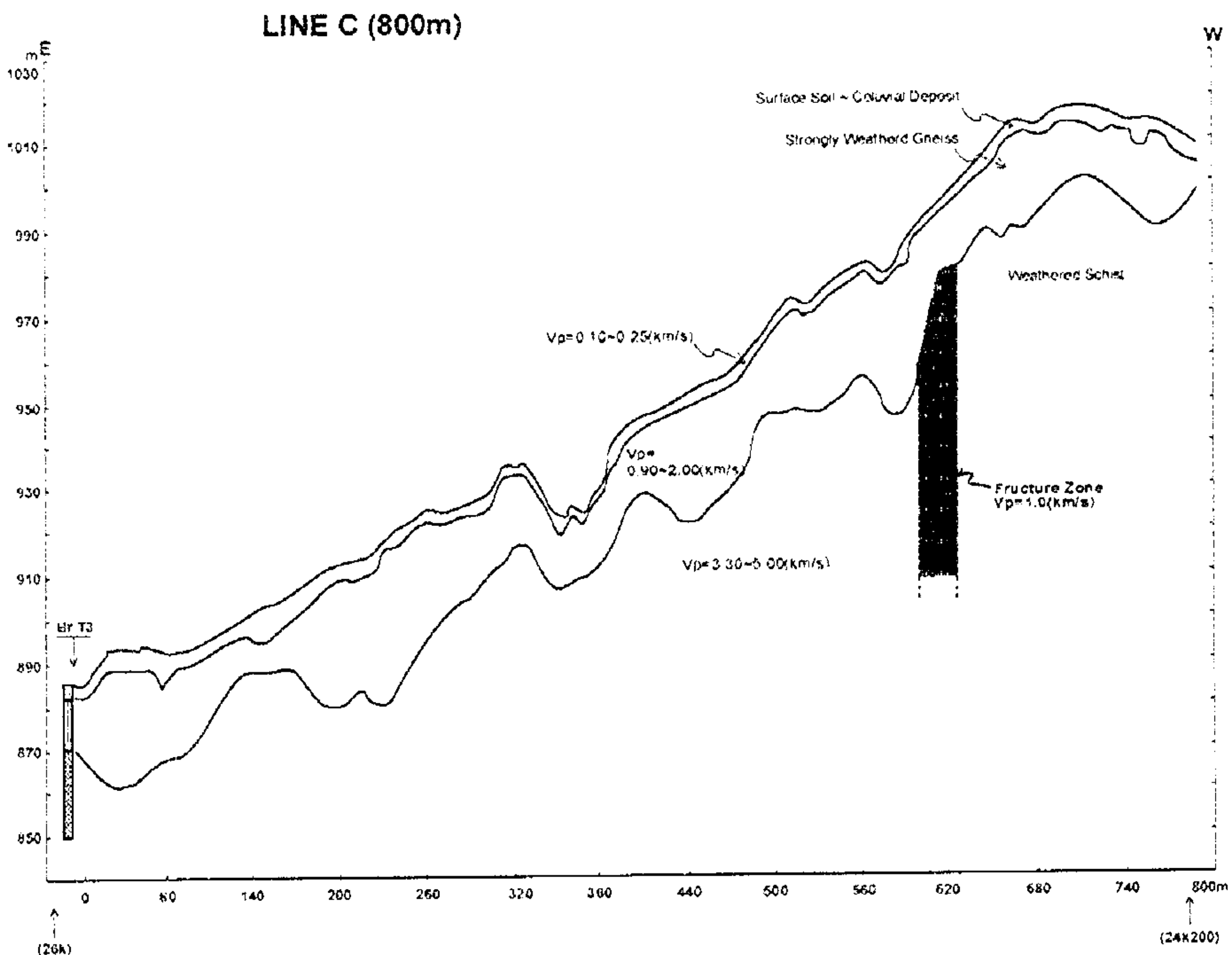
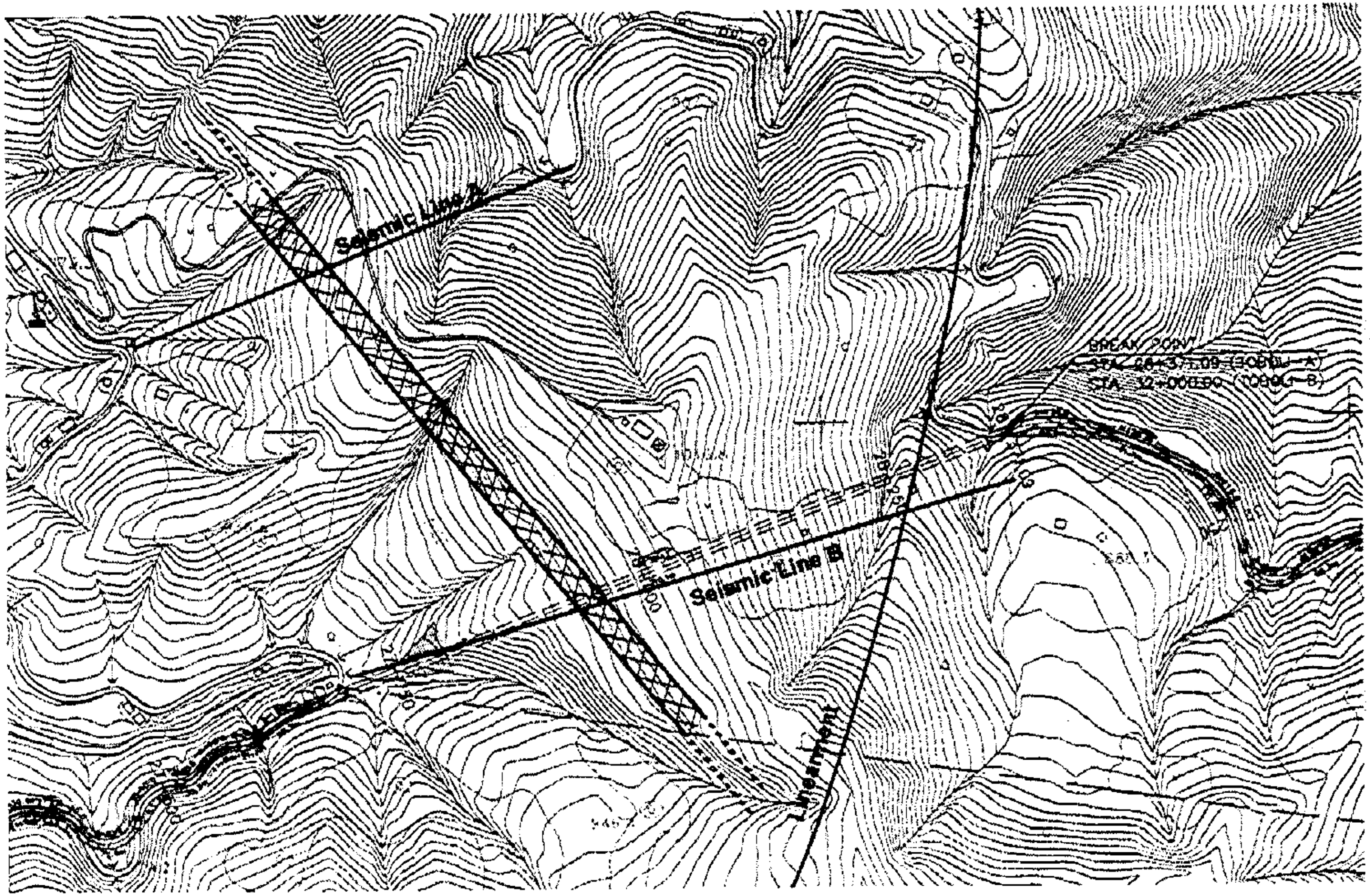


Figure4-3-3 Line C

Source: Study Team



Source: Study Team

Figure 4-3-4 Low Velocity Layer and Lineament

4.4 Laboratory Test

Content of laboratory soil test is as follows:

Table 4-4-1 Outline of Laboratory Soil Test

Item	Purpose
Physical properties	To know physical properties of soils covering rock.
Unconfined compression test	To know strength of rock related to tunneling method.
Laboratory CBR test	To judge suitability of banking materials.

Source: Study Team

(1) Result of Physical Property Test

Results of Physical Property Test are shown in Table 4-4-2.

Table 4-4-2 Result of Physical Property Test

Br No	Depth (m)	Water content (%)	Specific gravity	Void ratio	Saturation ratio (%)	Plastic limit (%)	Liquid limit (%)	Plasticity index (%)
B-5	GL-1.50	62.1	2.60	1.55	104.2	38.2	82.5	44.3
B-6	GL-0.50	43.5	2.62	1.26	90.5	40.2	86.5	46.3
B-7	GL-0.50	30.2	2.66	1.06	75.8	48.1	73.2	25.1
T-3	GL-1.50	54.5	2.70	1.55	94.9	n.p.	n.p.	n.p.
	GL-7.00	28.4	2.64	1.06	70.7	34.7	69.5	34.8
T-6	GL-0.5	62.5	2.67	1.62	103.0	44.5	49.2	4.70
	GL-4.50	34.2	2.64	1.18	76.5	n.p.	n.p.	n.p.
T-8	GL-0.50	45.7	2.64	1.40	86.2	38.5	62.5	24.0
	GL-1.50	37.5	2.66	1.23	81.1	39.4	65.2	25.8
T-9	GL-18.50	27.3	2.68	1.02	71.7	37.2	58.4	21.2
T-10	GL-31.00	57.2	2.68	1.55	98.9	40.2	46.5	6.3
	GL-2.50	44.7	2.67	1.32	90.4	39.4	44.7	5.3
T-11	GL-0.50	57.3	2.60	1.60	93.1	41.5	77.1	35.6
	GL-1.50	55.4	2.62	1.54	94.3	42.7	79.3	36.6
	Average	45.75	2.65	1.35	88.0	40.4	66.2	25.8

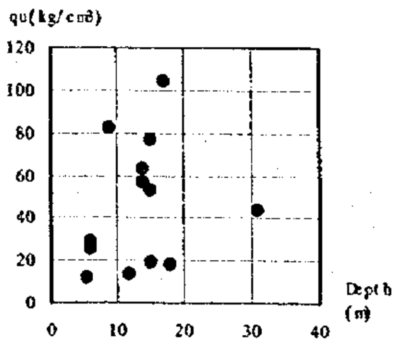
Source: Study Team

(2) Result of Unconfined Compression Test

Results of unconfined compression test are shown in Table 4-4-3 and Figure 4-4-1.

Table 4-4-3 Result of Unconfined Compression Test

Br. No	Depth (m)	qu (kg/cm²)	Dry density (t/m³)
B-1	GL-6.00	28.88	2.33
B-6	GL-5.50	11.71	2.40
B-7	GL-6.00	25.77	2.38
T-4	GL-14.00	56.4	2.29
T-5	GL-9.00	82.9	2.50



	GL-15.00	76.6	2.70
T-7	GL-18.00	18.71	1.94
T-10	GL-31.00	44.40	2.54
T-11	GL-12.00	13.35	2.45
	GL-15.00	52.8	2.67
T-12	GL-15.00	19.46	1.98
T-13	GL-17.00	104.0	2.64
T-14	GL-14.00	62.9	2.55
	Average	46.00	2.41

Source: Study Team

Source: Study Team

Figure 4-4-1 Relationship between depth (m) and unconfined compression strength (kg/cm²)

Boring cores with length of more than 10 cm were used for unconfined compression test.

Average of unconfined compression strength is 46 (kg/cm²). Unconfined compression strength of cores sampled along seismic prospecting line is as follows;

Line A (T7、T11) ····· ··28 (kg/cm²)
Line B (T6、T10、T14) ··53 (kg/cm²)

(3) CBR Test

Results of CBR Test are shown in Table 4-4-4.

Samples used for the CBR test were taken from sand and gravel layer of Celebes Formation.

Table 4-4-4 Result of CBR Test

Sample No.	Sampling point	CBR
1	12k 750	28.3
2	10k 100	30.5
3	7k 400	32.5

Source: Study Team

Sand and gravel of Celebes Formation used for CBR test consists of silt, sand and round gravel with diameter of less than 5 cm, which has good graining texture.