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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 IV: FEASIBILITY STUDY FOR TRANS-SULAWESI EAST 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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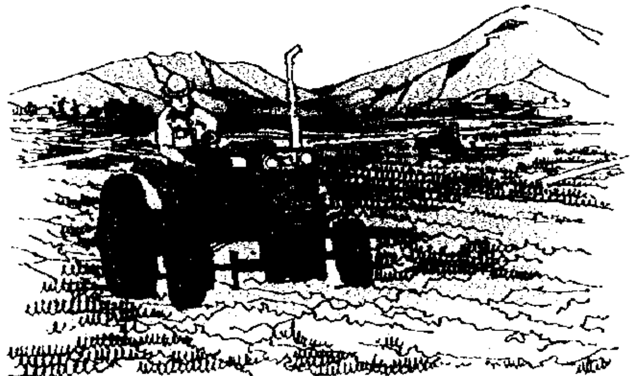
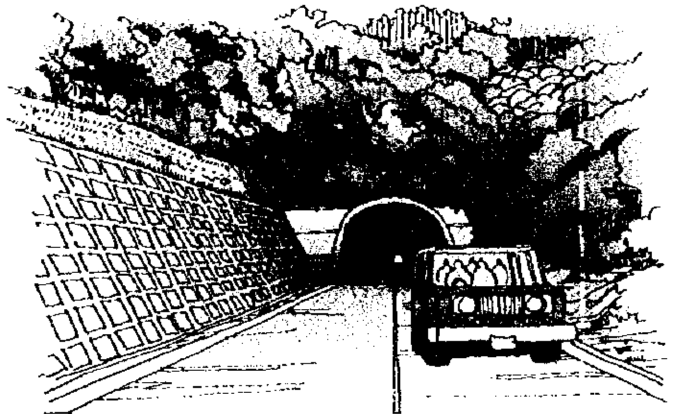


2 Expanded Agriculture Field with Modern Cultivation Equipment



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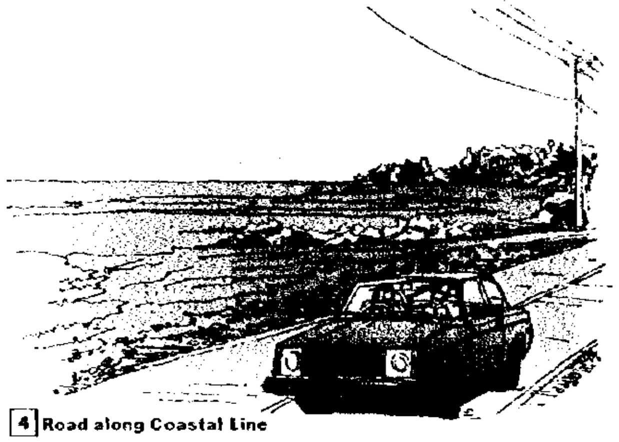

4 Road along Coastal Line

5 Proposed Bridge Development

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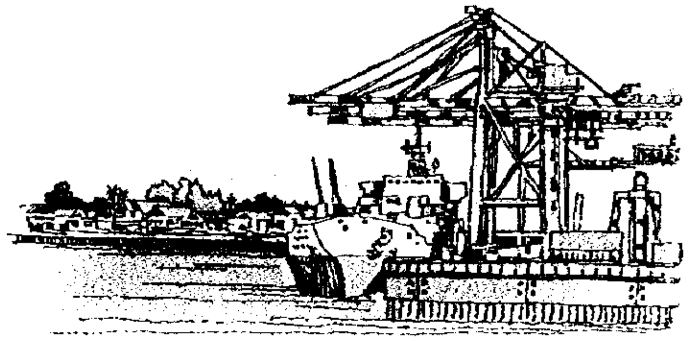

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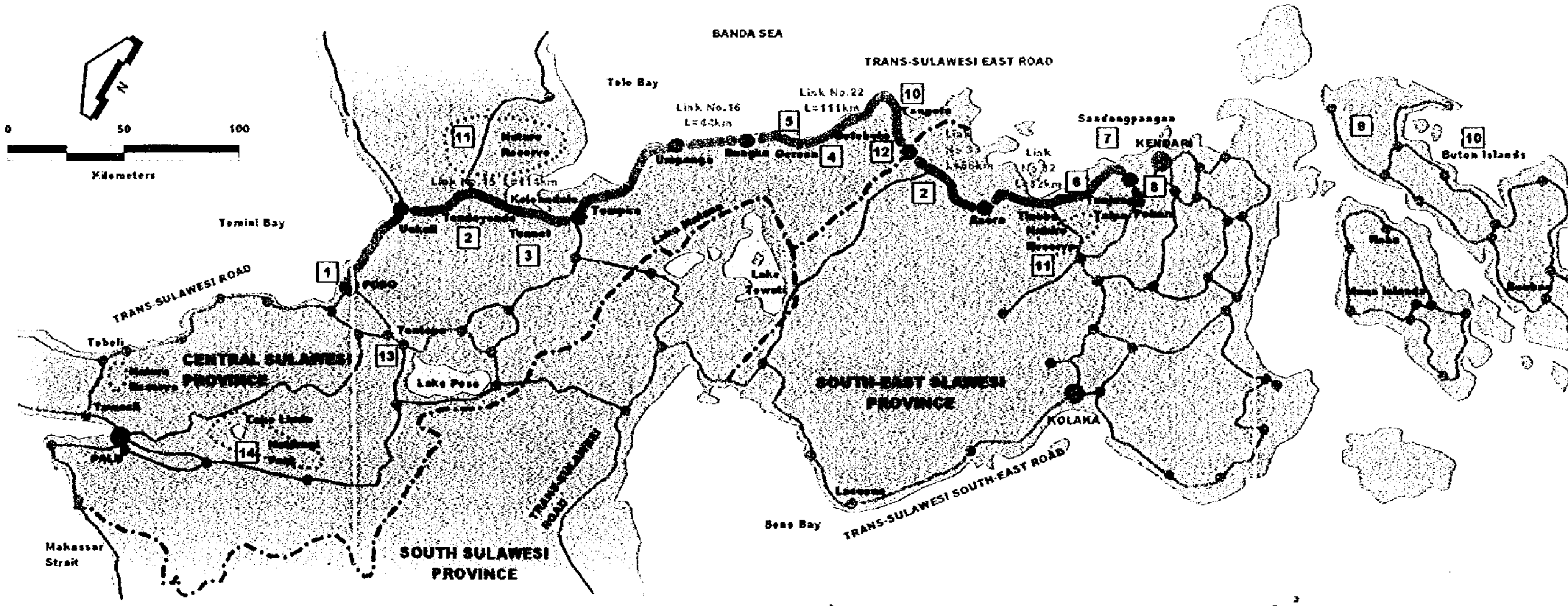

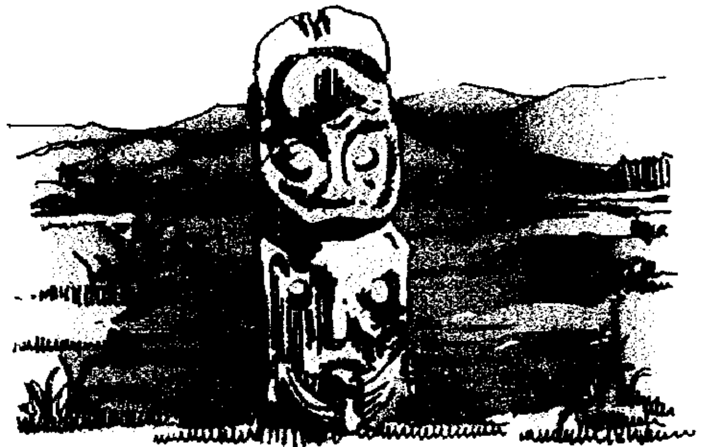

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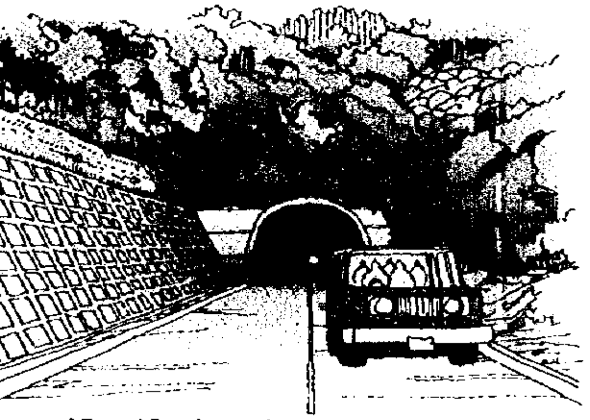
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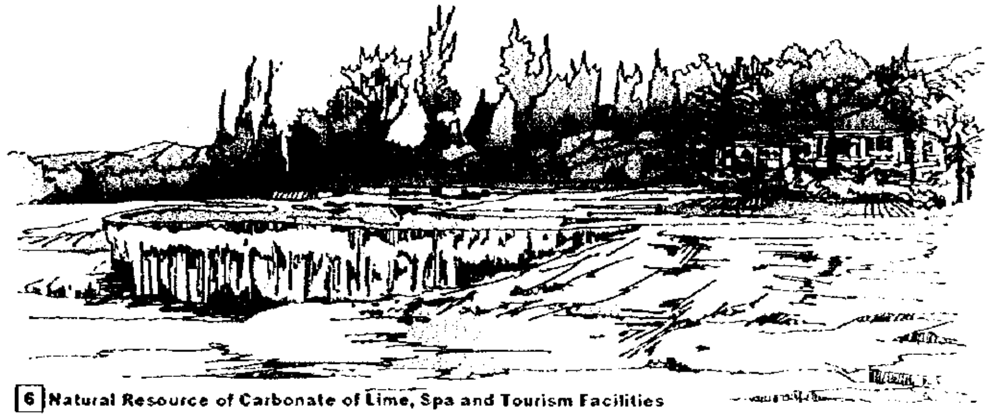
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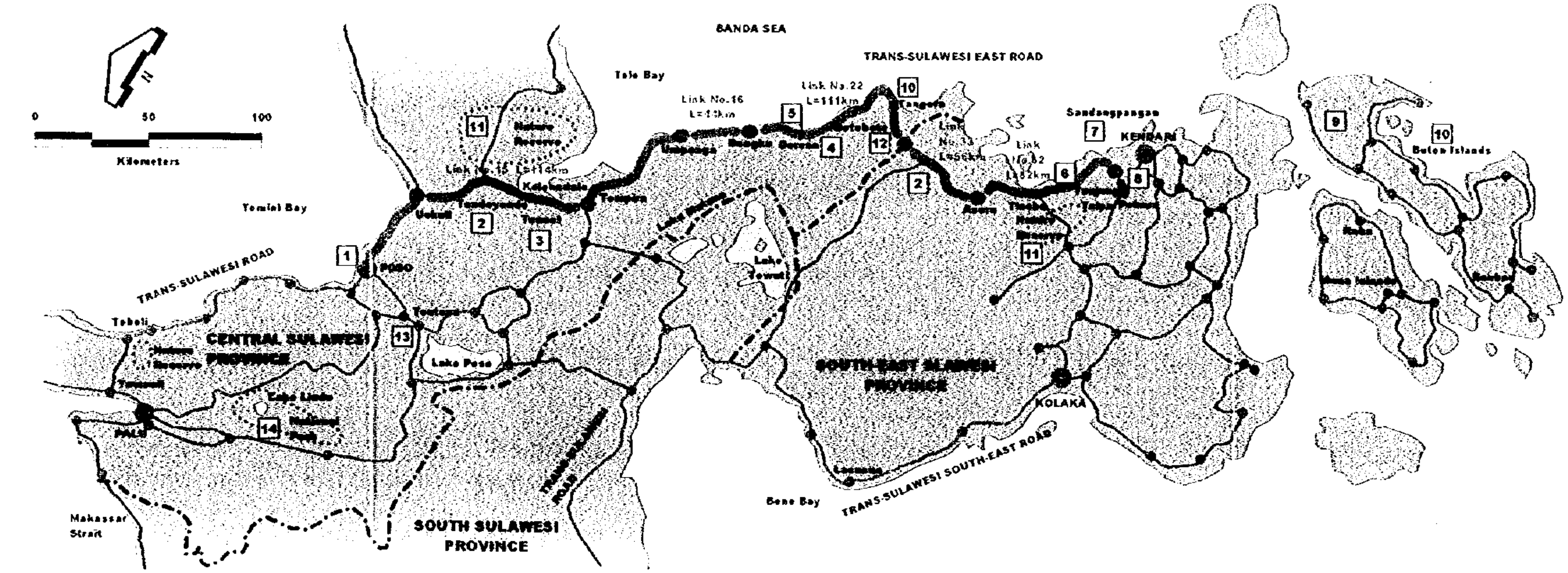


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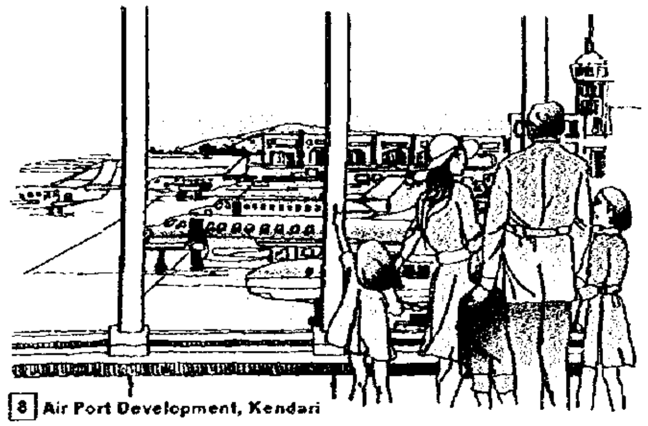
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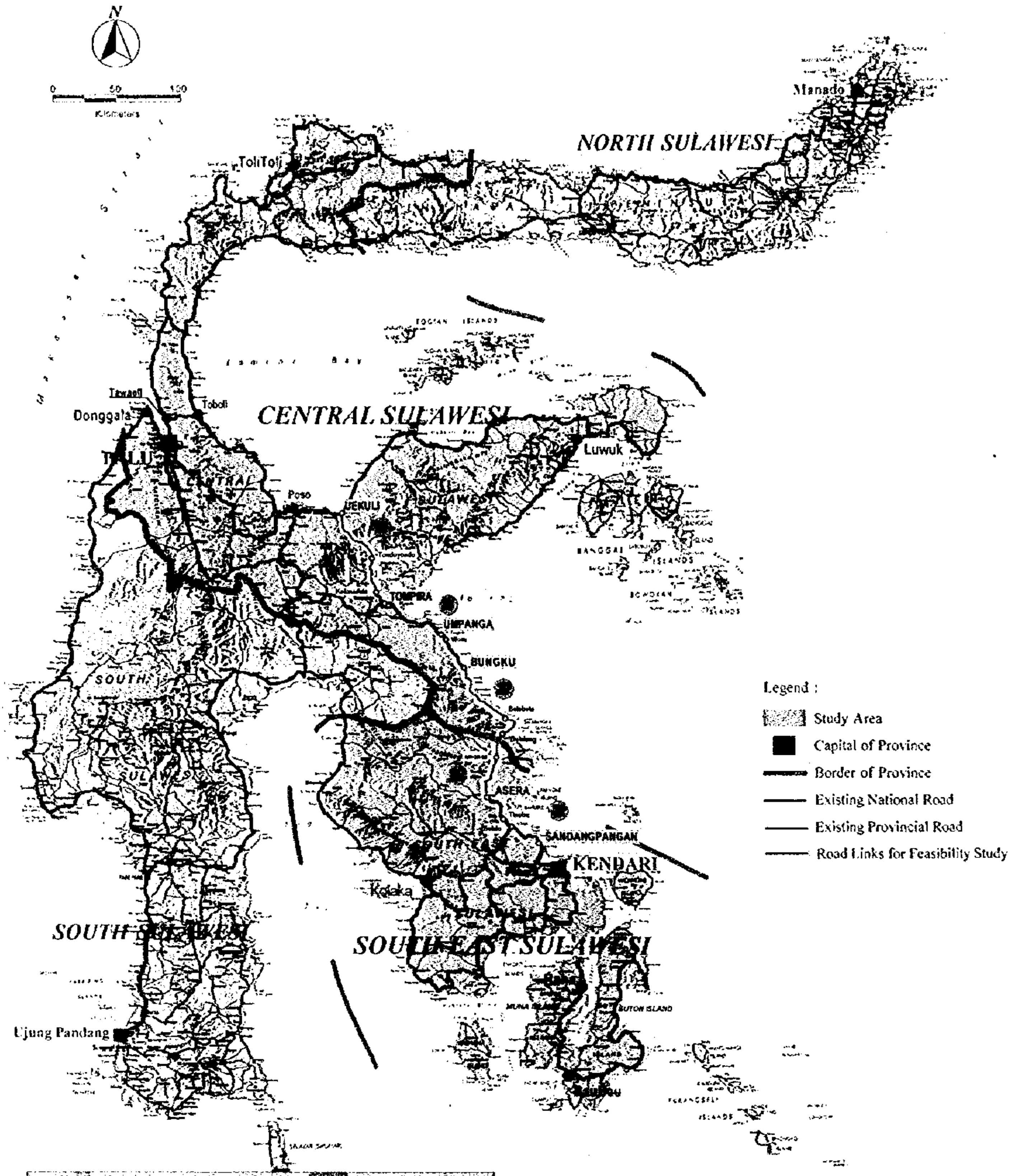
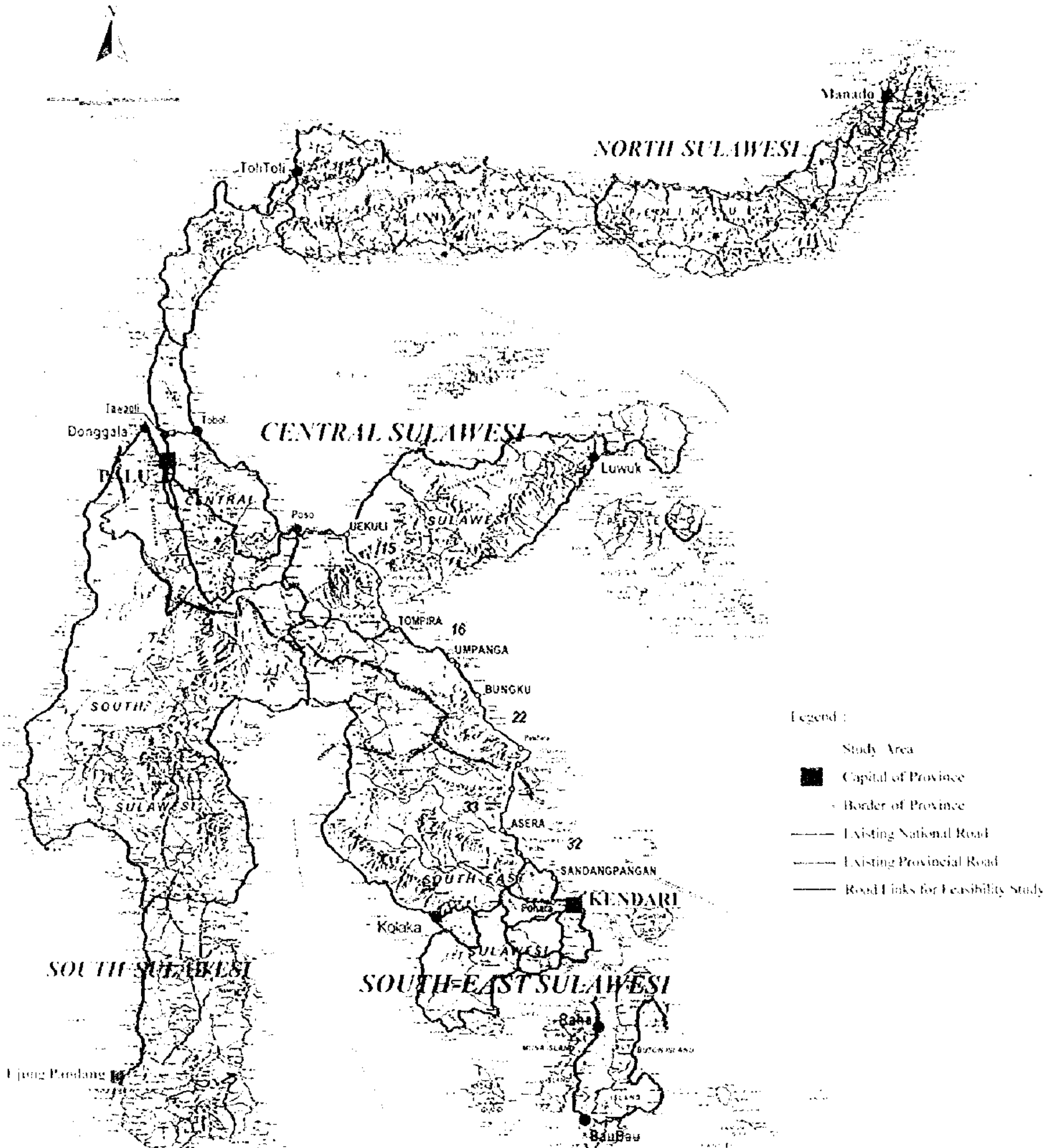
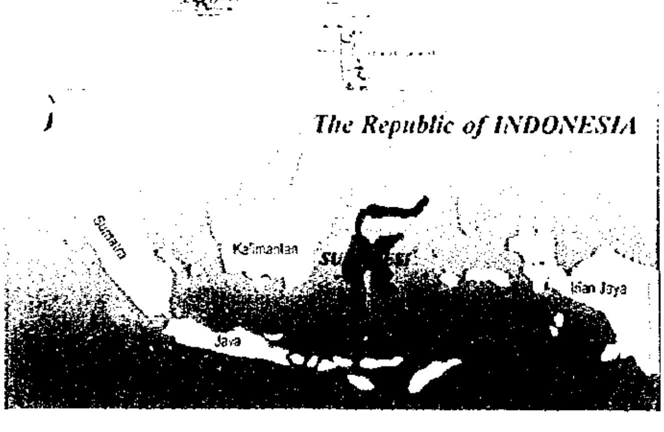


PROJECT LOCATION MAP





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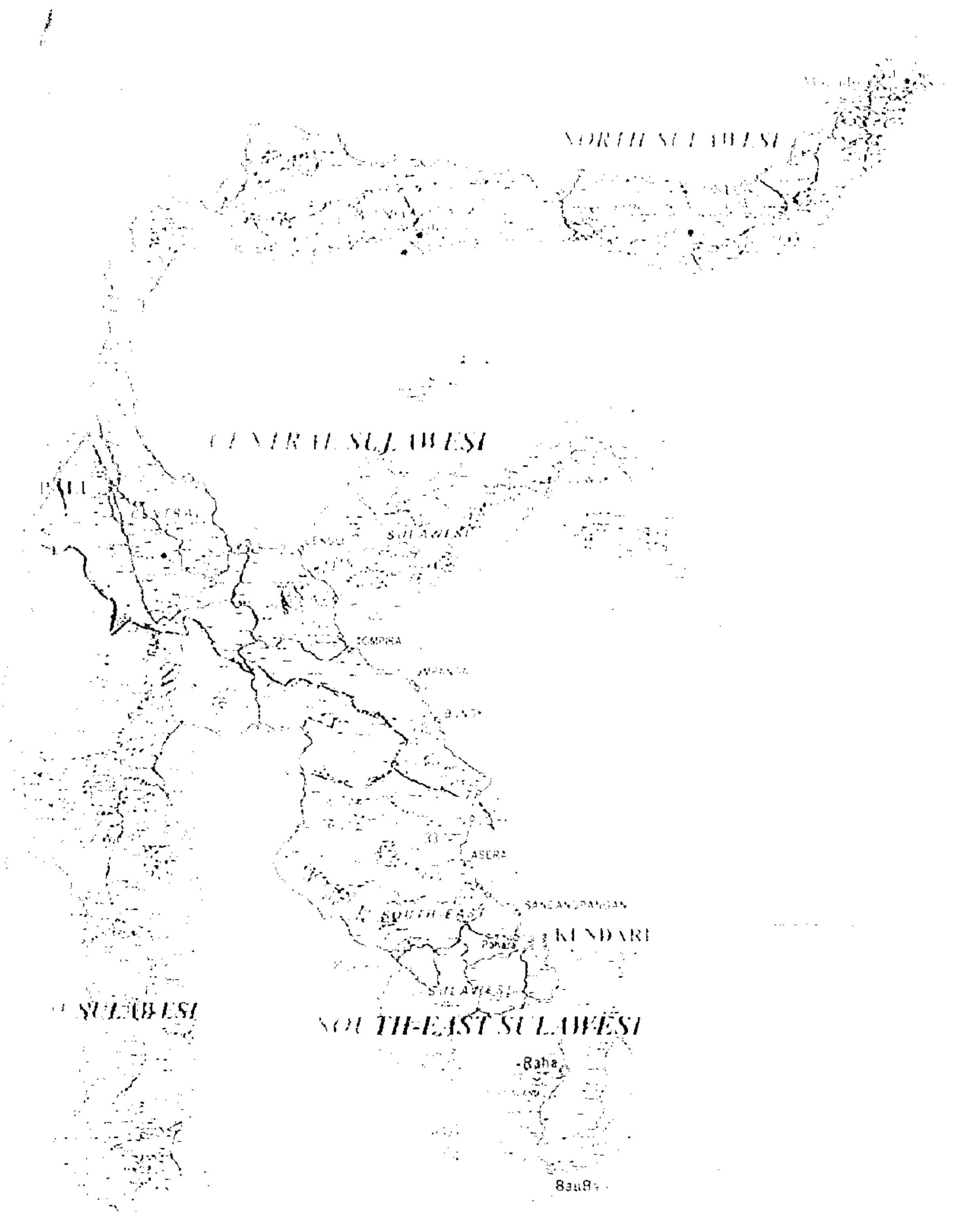

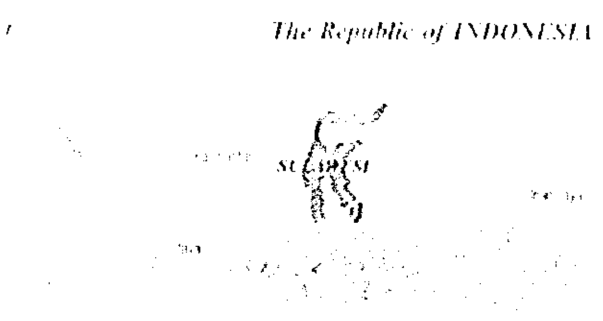

PROJECT LOCATION MAP

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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 IV: Feasibility Study for Trans-Sulawesi East Road

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Chapter 1

Introduction

CHAPTER 1 INTRODUCTION

The intent of this volume is to report on the feasibility study conducted for the route from Uekuli to Pohara (Trans-Sulawesi East Road) along the eastern coastal line of Sulawesi peninsula. The Trans-Sulawesi East Road starts at Poso in Central Sulawesi and ends at Pohara near Kendari. The feasibility study has been conducted for the following links;

- a part of Link No.15 (from Uekuli to Tompira, 114.1 km),
- a part of Link No.16 (from Umpanga to Bungku, 35.8 km),
- Link No.22 (from Bungku to Provincial Border, 110.7 km),
- Link No.33 (Provincial Border to Asera, 55.5 km) and
- a part of Link No.32 (Asera to Sandangpangan, 81.5 km).

The priority links of 300 km recommended from the result of the pre-feasibility study, Link No.15 of 114km from Uekuli to Tompira added to the feasibility study due to its high priority and importance to support regional development in the Eastern part of the region (strategic area of Luwuk). However, aerial photographic survey for topographic maps in scale of 1:5,000 and soil and material investigation were not conducted for Link No.15.

Chapter 2

Physical Geography

CHAPTER 2 PHYSICAL GEOGRAPHY

2.1 Topography

Feasibility study route (Link No.16, 22, 32 and 33) runs from the top of east Sulawesi peninsula to the east coast of lower east Sulawesi peninsula. These link routes are divided into mountainous or rolling terrain and coastal flat terrain.

A mountain range is located in the middle of the route from Uekli to Kolonadale. The highest point of this mountain range is more than 2,500 m above mean sea level. The route has to climb this mountain range, therefore, the characteristic of this route is rolling or mountainous terrain.

Kolonadale to Sandadangpangan via Tompira, Bungku, Tinobu, Pohara and Asera is located on the east coast of lower east Sulawesi peninsula. Most of the routes are located along the coastal area, but some parts have to climb the mountain range. The local government has carried out a road rehabilitation project for some parts of these routes. However the alignment of these roads, especially in the mountainous area, is not satisfactory due to low quality of workmanship and inadequate design criteria. Even after completion of the rehabilitation, it is difficult to climb the mountain because of the steep alignment.

2.2 River System

The number of rivers in the area is approximately thirty-eight. Table 2-2-1 shows major river names, width and river characteristic.

Table 2-2-1 River Characteristic in the Study Area

Road Section	Name of River	Width	River Characteristic
Malino – Tambayoli	S. Karosamora	12	Perennial, flood in rainy season
	S. Sangga	16	Perennial flow
Tambayori – Kolonadale	S. Tambayori	10	Perennial, flood in rainy season
Beteleme – Nuha	S. Karosakini	9	Perennial flow
	S. Karoolehaya	6	Perennial flow
	S. Koro Loa	< 6	Intermittent flow
Tompira – Latunjaya	S. Koro Loa	24	Perennial, flood in rainy season
	S. Koro Langkai	8	Perennial flow
	S. Tamnalaka	22	Perennial, flood in rainy season
	S. Solonsa	11	Perennial flow
	S. Lengkaya	19	Perennial, flood in rainy season
Latunjaya – Woso	S. Karupa	14	Perennial, flood in rainy season
	S. Bahu Ambuno	12	Perennial, flood in rainy season
	S. Babo Maburu	6	Perennial flow
	S. Baho Woso	12	Perennial, flood in rainy season
Woao – Bungku	S. Bahoerakoreko	13	Perennial, flood in rainy season
	S. Bahoelanona	15	Perennial, flood in rainy season
	S. Bahoeipi	12	Perennial, flood in rainy season
Bungku – Bahodopi	S. Bakolarangsangi	21	Perennial flow, over flow by high tide
	S. Bakomosi	9	Perennial flow
	S. Lasiumbatu	14	Perennial flow
	S. Bahokolanga	8	Perennial flow
	S. Bahodopi	16	Perennial flow, over flow by high tide
Bahodopi – Tongahu	S. Padabaho	8	Perennial flow
	S. Betebete	5	Perennial flow
Pohara – Matababu	S. Konawe Eho	28	Perennial, flood in rainy season
	S. Ambaku	7	Perennial flow
	S. Kambu Kambu	6	Perennial / intermittent flow
Matababu – Tinobu	S. Kakapi	8	Perennial flow
	S. Andolia	6	Perennial / intermittent flow
Tinobu – Asera	S. Aala Solo	16	Perennial flow
	S. Aala Amolami	7	Perennial flow
	S. Anggomate	9	Perennial flow
	S. Aala Monapa	5	Perennial / intermittent flow
	S. Aala Bowiyu	11	Perennial flow
Asera – Kuratao	S. Alala Lindu		Intermittent flow, flood in rainy season
Kuratao – Province bordar	S. Alala Lindu	10 - 14	Perennial flow
	S. Tanggu Napa		.

Source: Study Team

2.3 Climate

The climate along the route is commonly divided into two seasons, (rainy season and dry season) as is typical in Indonesia. Rainy season is between December and May and dry season is between June and November. Temperature is stable throughout the year regardless of the area. The difference of temperature throughout the year is at most within 10℃.
Table 2-3-1 shows monthly temperature data of Poso from 1992 to 1996.

Table 2-3-1 Monthly Temperature

(unit: ℃)

Month / Year	1	2	3	4	5	6	7	8	9	10	11	12
1992	26.0	25.6	25.6	26.2	26.7	26.0	25.8	26.2	26.4	26.4	26.4	26.7
1993	26.4	26.2	26.1	26.2	26.6	26.2	26.2	25.7	25.4	26.4	26.5	26.3
1994	25.9	26.3	26.3	26.8	27.0	26.7	26.0	26.3	26.5	26.4	25.8	26.3
1995	26.2	25.9	24.4	25.5	26.7	26.0	25.8	25.8	26.3	26.2	26.4	25.6
1996	25.7	26.6	27.0	27.0	27.0	26.6	26.2	23.3	26.4	25.6	26.6	26.0
Average	26.0	26.1	25.9	26.3	26.8	26.3	25.8	25.9	26.2	26.2	26.3	26.2

Source: Meteorological Station in Kasiguncu, Kabupaten Poso, 1997

Rainfall in the area is slightly heavier compared with the other three Sulawesi provinces because of its topographic characteristics. Table 2-3-2 and 2-3-3 shows monthly rainfall record of Kendari airport meteorological station from 1990 to 1994 and meteorological station in Kasiguncu from 1990 to 1996.

Table 2-3-2 Monthly Rainfall Data of Kendari

Year	Monthly Rainfall (mm)												Total (mm)
	1	2	3	4	5	6	7	8	9	10	11	12	
1990	194	128	170	185	218	32	42	27	0	10	0	376	1378
1991	218	143	113	141	331	132	35	0	93	78	16	291	1589
1992	509	212	441	392	392	192	89	2	2	0	130	238	2596
1993	447	157	413	458	252	83	15	28	0	6	15	90	1952
1994	394	253	290	94	217	276	241	52	43	38	122	149	1737
Average	352	178	283	254	282	143	84	22	27	26	57	229	1937

Source : Meteorological Station in Kendari Airport

Table 2-3-3 Monthly Rainfall data of Kasiguncu

Year	Monthly Rainfall (mm)												Total (mm)
	1	2	3	4	5	6	7	8	9	10	11	12	
1990	387	81	183	276	293	280	188	76	170	214	144	348	2640
1991	298	75	236	252	233	124	109	131	90	55	105	381	2089
1992	150	171	257	322	258	309	59	216	70	157	265	170	2304
1993	168	115	165	223	232	268	117	41	111	56	160	145	1801
1994	273	65	11	211	274	212	107	47	50	83	135	239	1707
1995	366	231	342	575	473	229	135	115	325	463	140	127	3521
1996	181	488	131	242	128	339	222	197	52	219	107	111	2417
Average	260	175	189	300	256	252	134	118	124	178	151	217	2354

Source: Meteorological Station in Kasiguncu, Kabupaten Poso, 1997

2.4 Seismology

The earthquake occurs frequently in Sulawesi. Table 2-4-1 shows the number of earthquakes occurring in Central Sulawesi between 1993 and 1995. The earthquake with the magnitude of more than four is less than 20 % in numbers, and more than 80% are small ones of which are not sensible to humans.

Table 2-4-1 Earthquake Data in Central Sulawesi

Month / Year	1	2	3	4	5	6	7	8	9	10	11	12
1993	359	158	170	150	180	204	147	116	155	80	610	397
1994	370	218	283	254	297	314	359	320	344	539	348	470
1995	322	574	403	633	1184	788	365	505	340	358	442	353
Average	350	317	285	346	554	435	290	314	280	326	467	407

Source: Mining Office in Palu

2.5 Geology

F/S area is located in Southeast Sulawesi and Central Sulawesi.
Metamorphic rock of Paleozoicera forms the geological basement over the F/S area, and subsequently sediments of Tokala formation and Meluhu formation deposited over the metamorphic rock. On the other hand, Ultra-basic rocks intrud the rocks on a large scale. Boundary between Ultra basic rocks and metamorphic/ sedimentary rocks usually forms large faults. Moreover, Matano formation of the late Mesozoic, Pandua formation and Tomata formation of the late Tertiary, and unconsolidated soil of Quaternary are deposited over the regional basement of metamorphic rock, Tokala formation, Meluhu formation and Ultra-basic rock. The basement rock forms mountains and hills, and the Tertiary sedimentary rock forms hills, and unconsolidated soil of Quaternary forms plain, fans, and talus.

Geological classification of the F/S area is shown in Table 2-5-1. Rock of the Study area is usually covered by vegetation, and location where outcropping rocks can be observed are very few. Outcropping rock can be observed only in the cutting slopes of the existing road.

Table 2-5-1 Stratigraphy of the F/S Area

Age		Formation	Faces
Quaternary	Pleistocene – Holocene	Alluvium - Diluvium	Clay, sand, gravel
Tertiary	Pliocene	Pandua formation, Tomata formation	Conglomerate, sandstone and mudstone
Mesozoic	Cretaceous	Matano formation	Limestone, shale, chart
		ultra basic rock	Peridotite, serpentine, diabase, gabbro
	Triassic	Meluhu formation	Sandstone, quartzite, shale, slate, limestone
		Tokala formation	Limestone, sandstone, shale, marl, slate

Source: Study Team

Chapter 3

Aerial Photographic Survey and Topographic Survey

CHAPTER 3 AERIAL PHOTOGRAPHIC SURVEY AND TOPOGRAPHIC SURVEY

3.1 General

3.1.1 Introduction

This chapter is concerned with the aerial photographic survey and topographic survey for the Road Network Study in Central and Southeast Sulawesi, which was executed by PT. EXSA International Co. Ltd. in accordance with the Contract Agreement between JICA Study Team as the Client and PT. EXSA International Co,.Ltd. as the Contractor.

The Project started on January 1998 and was completed in March 1998.

3.1.2 Project Location

The project area is located in Central and Southeast Sulawesi (See Figure 3-1-1).

3.1.3 Objective of the work

The main purpose of the work was to prepare a Photogrammetric Map (Digital Map) Scale 1 :5.000.

3.1.4 Scope of Works

Ground Control Survey for the project included the following activities:

- Monumentation (PVC)
- GPS Survey.
- Leveling Survey (including Tidal Observation).
- Field Identification.

3.1.5 Equipment

- GPS Trimble SSE 4000 : 3 (three) sets
- Automatic Level NAK-2 : 7 (seven) sets.

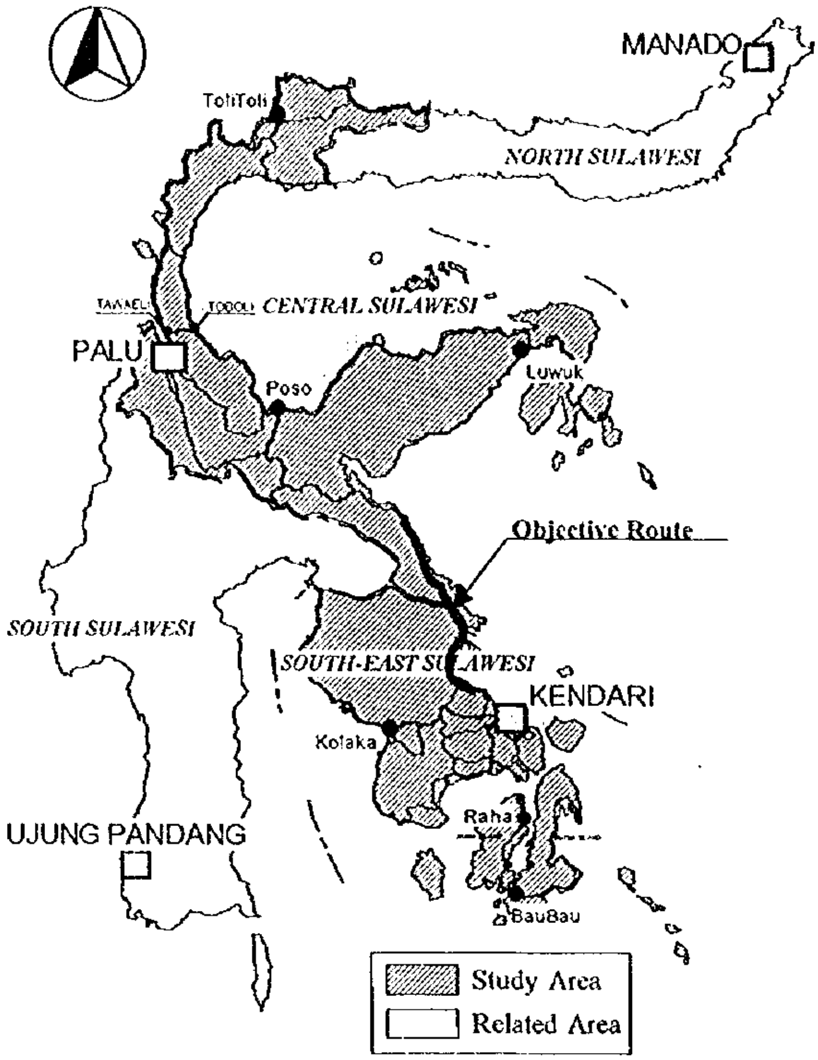


Figure 3-1-1 Objective Route

3.2 Methodology

3.2.1 Survey Controls

Point marks were installed along the project. A point mark was made from PVC 4-inch dia. pipe, set 50 cm into the ground and 20 cm above the ground surface.

The position of these control points was arranged in order to match the requirements of the aerial triangulation.

All bench marks and control points which were installed at both alternative dam sites were pre marked (air photo signal), so that they could be easily identified in the aerophoto map.

Dimension and shape of premark were shown in Figure 3-2-1.

(1) A four (4) wing type of premark was set up in principle.

(2) Size of a wing is 80 cm X 200 cm.
(3) Cloth sheet and/or 5-mm-thick plywood were used as material.
(4) Premark was painted in white color.
(5) Prior to setting up premark, permissions from landowners and/or proprietor's superintendent were obtained.
(6) Head clearance of more than 60 degrees was secured.
(7) Sketch of the site of a point was attached to the description of points.
(8) Terrestrial photograph(s) were taken at the site of a point.
(9) If it was found not appropriate to set up an aerial signal at the proposed location due to ground conditions, an eccentric setting up with its eccentricity measurement was acceptable.
(10) At all the premarked points, the eccentricity of at least one conspicuous ground feature in the neighborhood, identifiable on the aerial photograph, was measured so that the object could be used as an alternative photo control point in case the aerial signal is lost or can not be identified clearly on the aerial photograph.

3.2.2 Horizontal Photo Control Point Measurement

Determination of coordinates (x, y) of control points for photogrametrical mapping requirement and for other related works was carried out by using GPS Trimble 4000 SST.

Observation was made by static differential mode; that is 3 (three) units of GPS are sited at 3 (three) points each, which position will be determined. At least 5 (five) satellites should be simultaneously monitored for 1 (one) hour. Observation was made in a triangle network configuration so that each session of observation used link each other into a unity point. Observation was performed session by session until all control points were completely observed.

The newly established photo control points were coordinated to the Indonesian National Geodetic Network of the area.
Measurement was made to obtain relative values (coordinate difference) between two points. Consequently, measurement starts from and closes at the same reference point.

Expected accuracy of GPS observation is;

Horizontal ± 10 PPM in trigonometric closure

Vertical ± 10 PPM in trigonometric closure

To receive signals from the satellites, the following care should be taken.

(1) Antennas are set at each location higher than surrounding obstacles such as trees, steel towers, pylons, buildings and so on. Head clearance of more than 80 degrees is to be secured.
(2) Observation is made simultaneously at three (3) points.
(3) Satellite with an elevation angle of more than 15 degrees is to be observed.
(4) Observation hours in static mode is more than 1.5 hours when observing 4 satellites or 1 hour when observing 5 or more satellites.
(5) Computation of the base line vector between observed points are executed from the observed data.

(6) Computation of coordinates of the observed points in reference to the given point is to be carried out. Checking shall be made by computing coordinate closures using simultaneously observed points. The closure shall not be more than ± 10 PPM.

A computer attached to the GPS instrument is used for computation.

3.2.3 Vertical Control Point Measurement

It is specified that vertical control measurement shall be performed by differential leveling method.

Vertical control points necessary for execution of aerial triangulation and preparation of the 1:5,000 scale topographic map have been increased by spirit leveling of 350 km using Sokkia B2 Auto-Level and Wild NAK-2.

In the Terms of Reference, measurement shall start from the existing National Geodetic benchmark (TTG) and close to another TTG. However, there was no TTG in the project location, so the reference point for vertical measurement used Tidal Observation at five locations.

Expected accuracy is ± 5 cm $\sqrt{S}$ for difference of double running or closure of loop, where S is the length in kilometers of a single run of the leveling route.

(1) Value of reference point from which the leveling started and closed was to have been checked prior to the work execution.

(2) Scales of staff from ground surface up to 10 cm were not read.

(3) Sight distance of fore- and back-sight were not exceed 80 m and the distance was equalized at each instrument set-up in order to avoid residual instrument collimating error.

(4) Level was set up on a straight line between two staffs.

(5) Approximately at 500 m intervals, spot elevation by minor order leveling have been marked in the field on two (2) times enlarged aerial photographs.

Marked points were selected at such suitable positions for mapping as crossing points of roads and railways, near ground objects or bottoms and tops of ground undulation.

3.2.4 Field Identification.

Using two (2) times enlarged aerial photographs, the keys for photo interpretation required for plotting and cartography have been collected by verifying them in the field. The work quantity was 450 km^2 for the mapping of 1:5,000 scale.

In compliance with the map style and its application rule, the following have been investigated and/or confirmed in the field.

(1) Items difficult to interpret on the photographs.

(2) Items to be represented on the map such as roads and their width, bridges and their length and width, buildings, rivers, irrigation canals, vegetation cover, specified areas, topography, control points, etc.

(3) Geographical and administrative names necessary for annotation and administrative boundaries.

(4) Other data which can be collected at local offices.

Results of field verification have been adjusted on two (2) times enlarged aerial photographs.

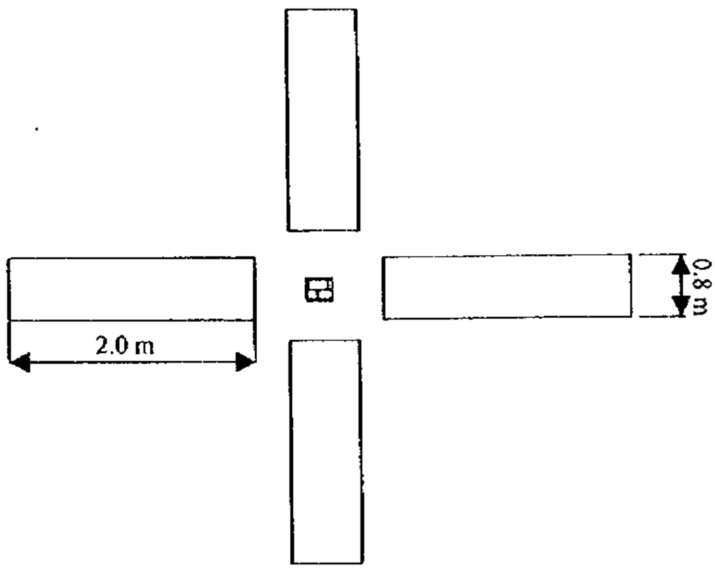


Figure 3-2-1 Shape and Dimension of Premark

3.3 Work Activity

3.3.1 Preparation

The preparation phase consisted of the following:

(1) Administrative Matters

- Preparation of assignment letter for personnel
- Preparation of other required permit letters for performance of the work
- Preparation of Contract Agreement

(2) Technical Matters

- Preparation of time schedule for execution of the work
- Preparation of all the instruments to be used on the project, checking, testing and calibration
- Preparation of existing topographic maps
- Preparation of personnel who will be involved

3.3.2 Setting Premark and PVC

Based on the distribution of the premark positions which have been plotted on a topographic map scale 1: 50.000, the team orientated the fixed position of each point, using Ensign GPS.

There are 60 (sixty) point marks / premarks which were installed along the project.
The point mark / premark numbers were KD-01, KD-02, up to KD-60.

The positions of the point mark / premark points were arranged in order to match the requirements of aerial triangulation.

3.3.3 Horizontal Photo Control Point Measurement

Determination of coordinates (x, y) of control points for photogrametrical mapping requirement and for other related works was carried out by using GPS Trimble 4000 SST.

Observation was made by static differential mode; that is 3 (three) units of GPS were sited at 3 (three) points each, which position was determined. At least 5 (five) satellites were simultaneously monitored for 1 (one) hour. Observation was made in a triangle network configuration so that each session of observation linked each other into a unity point. Observation was performed session by session until all control points were completely observed.
The network configuration is shown in Figure A3-1-1, Appendix A-3.1.

The newly established photo control points have been referenced to the Indonesian National Geodetic Network of the area.
The reference points of GPS observation are :

(1) N.4006

Located near Wolter Monginsidi Airport, Kendari, South East Sulawesi

Geographic Coordinates :

S : 04° 05' 15.6781"
E : 122° 24' 27.1189"

UTM Coordinates (Datum : WGS 84) :

S : 434,238.683 m
E : 9,584,155.690 m

(2) N1.4008

Located at Danau Poso, Poso, and Central Sulawesi.

Geographic Coordinates :

S : 02° 04' 18.0611"
E : 120° 41' 03.3953"

UTM Coordinates (Datum : WGS 84) :

S : 242,414.822 m
E : 9,770,827.456 m

The Coordinates results are shown in Tables A3-2-1 to A3-2-3, Appendix A-3.2.

3.3.4 Vertical Control Point Measurement

Vertical control measurement was performed by the differential leveling method, using automatic leveling Sokkia B2 Auto-Level and Wild NAK-2.

In the Terms of Reference, measurement started from the existing National Geodetic benchmark (TTG) and closed to another TTG. However, there was no TTG in the project location, so the reference point for vertical measurement used Tidal Observation at six locations. The locations of these observances are:

- Bete-bete I
- Bete-bete II
- Bete-bete III
- Bungku Harbour
- Kendari Harbour
- Motui Harbour

Reference points for leveling observations and calculations are :

(1) **BM-25** Height : 1.230 m
Based on Bete-bete I Palm Observation (-0.650 m)

(2) **BM-24** Height : 10.756 m
Based on Bete-bete II Palm Observation (-1.300 m)

(3) **B-1** Height : 7.852 m
Based on Bete-bete III Palm Observation (-1.287 m)

(4) **BM-II** Height : 1.887 m
Based on Bungku Harbour Palm Observation (-1.850 m)

(5) **PLB** Height : 1.748 m
Based on Kendari Harbour Palm Observation (-1.000 m)

(6) **PAL-1** Height : 1.813 m
Based on Motui Palm Observation (-1.650 m)

Accuracy was ± 5 cm $\sqrt{S}$ for difference of double running or closure of loop, where S is the length in kilometers of a single run of the leveling route.

3.3.5 Accuracy Analysis

Loop I : BM.II - KD.10 - KD.12 - KD.14 - KD.18 - KD.19
KD.20 - KD.21 - KD.22 - KD.23 - B.1

Total Distance : 63,894.700 m
Accuracy : 0.001 m
Accuracy Allowable : 0.390 m
Status : Acceptable

Loop II : B.1 - KD.27 - KD.28 - KD.29 - KD.30 - KD.31-
KD.32 - KD.33 - KD.34 - KD.35 - KD.36 - KD.37 -
KD.38 - KD.39 - KD.40 - KD.41 - KD.42 - 43C/I-
KD.44 - KD.45 - KD.47 - KD.48 - 49C/I - KD.50 -
KD.51 - KD.52 - KD.53 - TP - 55W/I - KD.56 -
KD.57 - PAL.1

Total Distance : 205,897.900 m
Accuracy : 0.028 m
Accuracy Allowable : 0.710 m
Status : Acceptable

Independent Loops

1.	KD.I - BM.II	Total Distance		38,653.300 m
2.	KD.57 - KD.60	Total Distance	:	23,047.600 m
3.	KD.10 - KD.11	Total Distance	:	1,925.200 m
4.	1241 - KD.13	Total Distance	:	1,167.400 m
5.	4L - KD.15	Total Distance	:	3,419.500 m
6.	TB - KD.16	Total Distance	:	439.900 m
7.	7W/4 - KD.17	Total Distance	:	2,195.500 m
8.	28A/1 - KD.26	Total Distance	:	4,563.700 m
9.	39W/2 - KD.16	Total Distance	:	780.800 m
10.	49C/4 - KD.49	Total Distance	:	793.500 m
11.	TP - KD.54	Total Distance	:	448.200 m
12.	5W/3 - KD.55	Total Distance	:	2,890.400 m

Total distance for leveling : 354,800.000 m.

The Leveling results are shown in Figure A3-3-1 and A3-3-2, Appendix A-3.3.

3.4 Result of Survey

Results of the survey are as follows:

(1) Description of photo mark / premark

(2) Leveling survey and photo point:
- Field data observation
- Data processing and leveling result.

(3) GPS survey:
- Field data observation
- Data processing and coordinates result.

(4) Field identification:
- Photo point pricking on 2 (two) times enlarged aerial photographs.
- Field identification on 2 (two) times enlarged aerial photographs.

Chapter 4

Soil and Material Investigation

CHAPTER 4 SOIL AND MATERIAL INVESTIGATION

4.1 General

4.1.1 Topography of the Study Area

The route of the Feasibility Study (F/S) extends from north to south along the coastal area of Central and Southeast Sulawesi. Topography of the area around F/S route is classified as follows;

- Narrow coastal plain and coral reef fringing the coastal plain
- Inland plain extending along rivers
- Upland and hill with gentle slope
- Mountain area with gentle slope
- Small Alluvial plain in lowland along rivers in uplands, hills and mountains

As listed above, topography along the F/S route has a rich variety, and the route passes through various kinds of topographical units such as uplands, hills, mountains, etc. In Southeast Sulawesi the route usually passes through inland areas, but usually passes along the coastal area in Central Sulawesi.
An outline of the classification of landform for each link is as follows:

(1) Link No.15

The F/S route passes through gentle slopes of Dilvium between Sta.1km and 3km, then mountain slopes in Sta.3km - 27km, valley floor in Sta.27km - 31km, mountain slopes in Sta.31km - 42km, and valley floor in Sta.42km - 63km. The route passes through slope of mountains near the coast line without a coastal plain and beach between Sta.63km and 100km. The foot of the mountain faces the sea with steep slopes making a drowned valley. The route passes through the Alluvial plane between Sta.100km and 118km, a narrow valley floor between Sta.118km and 120km, hills with undulating surfaces between Sta.120km and 155km, hillside slope between Sta.155km and 163km, and a valley floor in hills between Sta.163km and 174km (Nuha). Valley between Sta.0km (Uekuli) and 23km is considered to be formed by fault movements on a large scale. Fracture zones are expected to be developed between Sta.69km and 82km caused by intrusion of Ultra basic rock into limestone, where Karst landscapes are well developed originating from the fracture zones of the limestone.

(2) Link No.16

Topography of link No.16 consists of coastal plains and hills with gentle slopes. The route lies on the coastal plain. The plain extends the length of link No.16, and rivers flowing in the plain meander and split up into several smaller channels. The route passes near the coastal line, and the distance between the route and the sea is sometimes only 50m. The boundary between the coastal plain and the hills creates gentle slopes, and it is sometimes difficult to trace its complicated boundary. The boundary is usually located at a distance of 200 m - 2,000m from the coastal line. A wave-cut platform has developed along the beach under the hill extending to the sea. The route passes the foot of a mountain between Bungku and Sta. 33.5km.

(3) Link No.22

Sta.146.480 km (Provincial Border) – 127.5km
The route is along mountain slopes. Though these mountains have gentle slopes, the gradient of the existing road becomes severe in some places where the ground surface is rugged. This area is the most rugged ground and at the highest elevation of all the F/S area. The highest point is located near Sta.143.5km where the route changes direction. Geological formation between Sta.146.48km and 141km comprises calcareous rocks such as limestone, and many sinkholes have developed in the rock and are seen in the aerial photographs.

Sta.127.5km - 116km
There is a small plain about 1 km wide at Sta.127.5km (Buleleng), which the route crosses. Between Tangofa and Buleleng the hills and mountains extend to near the coastal line, and the route passes at the foot of the hills along the narrow coastal plain. The route passes along a wide coastal plain around Tangofa.

Sta.116km - 100km
The route changes direction to the west near Sta.116km and climbs the mountain, passing along the mountain slopes and valley side. At the top of the mountain the ground is gently undulating, and the route passes along a valley floor. The mountain slope is steep and the road gradient is steep between Sta.104.5km and 101km, where the route descends to the coastal plain of Betebete. In particular the mountain slope is also steep between Sta.102km and 101km.

Sta.100km - 94km
A large coastal plain extends to the west of Betebete, and the route is almost in the center of the plain. Boring sites 27 and 28 are located at the boundary between the narrow coastal plain and the hills.

Sta.94km - 84km
The route passes along a narrow coastal plain along the foot of the hills.

Sta.84km - 53km
The route passes through four (4) large coastal plains. The ground surface of these coastal plains is slightly rugged. The coastal plains originate from Diluvial upland, and the plain was eroded by rivers, when Alluvium was deposited in the lowlands, which resulted in an irregular ground surface. A long spit extends along the coastal line from the mouth of the river. Rivers on the plain about meander and divide into several small channels. Former river channels are distributed about the plain. Boring sites 29,30 and 31 are located where the route intersects the main river. A hill with gentle slope is located at the back of the coastal plain, and is far from the coastal line due to denudation.
The route passes through a narrow beach at the foot of the slope between Sta.70km and 72km, where the mountain extends to near the coastal line.

Sta.53km - 37km
The topography between Sta.53km and 49.5km comprises a narrow beach and hill. A mountain faces the coastal line with steep cliffs between Sta.49.5 and 37km, where a coastal plain has not developed. The route passes along the cliff slope facing the sea with many

curves. Narrow coastal plains are distributed along the foot of the slope in some places, where there are some fishing villages.

Sta.37km – 35.775km(Bungku)
A large coastal plain extends between Sta.37km and Bungku, and the route passes near the coastal line.

(4) Link No.32

Sta.283.391(Tondowatu) – 227.5km
In this area, the existing road usually passes along the boundary between the coastal plain and the hills. Hills are dissected, and the slopes are usually very gentle. Road cutting is not common. Base of the existing road consists of Alluvial or Colluvial deposits, and the ground condition is usually stable. Most of the route is on the hill side. The coastal plain of this section is usually wide, and the boundary between the Alluvial plain and hills is far from the coastal line. Therefore it is rare that the route is near the coastal line except three areas listed below:

1) North of Tg.Taipa between Sta.258km and 259km, where hills extend to near the coastal line. The route passes near the sea on a narrow coastal plain or on the slope of the hills.
2) The route passes on a narrow coastal plain between Sta.247.5km and 246.5km.
3) North of Tinobu between Sta.229km and 233km, where hills extend towards the coastal line and the route passes on a narrow coastal plain.

Boring sites Nos.1 to 4 are located where rivers cross the boundary between the coastal plain and the hills.

Sta.227.5km - 223km
The route is into a hilly area at Sta.227.5km and along a ridge with gentle slope.

Sta.223km – 218.5km
The route is on the slope of a mountain near the topographical boundary with a hill at Sta.223km. Boring sites 5 and 7 are located in this area. The boundary between the mountain and hill forms a turning point of slope gradient, and the route passes along this point. The highest point of the routes is at Sta.217km and the route then descends to the valley floor. Gradients are steep between Sta. 216.5km and 218.5km.

Sta.218.5km - 217km
The route passes through a narrow valley floor in hilly areas.

Sta.217km - 212km
The route passes through a wide valley floor. The valley floor extends to an Alluvial plain of the Asera River where is suitable for crops. Boring site No. 6 is located in this plain.

Sta.212km – 203.5km
The route passes through hills and mountains with gentle slopes. Boring sites 8 and 9 are located at the valley floor of this area.

Sta.203.5km – 201.94km(Asera)
The route passes at the foot of a hill along the Alluvial plain. The Alluvial plain is wide around a confluence of rivers near Asera.

(5) Link No.33

Sta.201.94(Asera) - 192km
The route is along the boundary between the floodplain of the Asera River and the hill/mountain area. Boring sites No.10 and 11 are located in this area.

Sta.192km - 205km(existing route)
Floodplain of the Asera River becomes wider around Sta.192km. The route is through this wide floodplain in which the Alluvium is thicker. Boring sites 12,13 and 14 are located in the floodplain. The route passes near the foot of a hill around boring site 13, and subsequently passes through the center of the floodplain to Sta.185km, then turns in the east ward direction and crosses the Asera River again at Sta.205km (existing route).

Sta.205km(existing route) – 193km(existing route)
The route crosses the boundary between the floodplain and terraces, and the boundary between terraces and mountains. Boring sites 15,16 and 17 are located where the route crosses rivers in this area. The mountain consists of serpentine, and the rocks exposed on cutting faces of the existing road are highly weathered.

Sta.193km(existing route)-170.5km
The route passes through a large terrace area. This terrace is characterized by a flat surface with steep cliffs. The terrace surface has not yet fully dissected and still remains flat. As a whole this area is a gently undulating plain. The valley floor of the terrace forms small Alluvial plain. The terrace area is used for cultivation by immigrants, and few trees are seen due to cutting. The route crosses the Ramonai River at Sta.178.5km, then passes straight in an east and west from Sta.177.5km to 172.5km. Boring site Nos. 18, 19, 20, 21, 22, 23 and 24 are located in the valley floor of the terrace.

Sta.170.5km – 148.5km
The route is along the boundary between terrace and mountain. The terrace surface is almost flat or gently undulating, and dipping slightly towards the rivers. The mountain area is rich in vegetation but the terrace area is not. Boring site No.25 is located in the valley floor in this area.

Sta.148.5km - 146.48 (Border)
The route is through a mountain area, and the slope becomes steeper. The route passes along a slope with a steep gradient between Sta.148.5km and 146.48km.

4.1.2 Geology of the Study Area

Metamorphic rock of Paleozoic Era forms the geological basement all over the F/S area, with sediments of Tokala formation and Meluhu formation subsequently deposited over the metamorphic rock. Also, Ultra-basic rocks have intruded on a large scale. The boundary between the Ultra basic rocks and metamorphic or sedimentary rocks usually forms large faults. Moreover, Matano formation of the late Mesozoic, Pandua formation and Tomata formation of the late Tertiary, and unconsolidated soil of Quaternary one deposited over the regional basement which consists of metamorphic rock, Tokala formation, Meluhu formation and Ultra-basic rock. The basement rock forms mountains and hills, the sedimentary rock of Tertiary forms hills, and unconsolidated soil of Quaternary forms plains, fans, and talus.

Geological classification of the F/S area is shown in Table 4-1-1. Rock of the study area is usually covered by vegetation, and outcropping rock can be observed only in the cuttings of the existing road.

Table 4-1-1 Stratigraphy of the F/S Area

Age		Formation	Faces
Quaternary	Pleistocene – Holocene	Alluvium - Diluvium	Clay, sand, gravel
Tertiary	Pliocene	Pandua formation、Tomata formation	Conglomerate, sandstone and mudstone
Mesozoic	Cretaceous	Matano formation	Limestone, shale, chart
		Ultra basic rock	Peridotite, serpentine, diabase, gabbro
	Triassic	Meluhu formation	Sandstone, quartzite, shale, slate, limestone
		Tokala formation	Limestone, sandstone, shale, marl, slate

Source: Study Team

Geology for each link is as follows:

(1) Link No.15

Geology of link No.15 is summarized as shown in Table 4-1-2.

Ultra basic rock is distributed in many places where are between Sta.0km (Uekuli1) and 25km、34km and 42km、81km and 98km、114km and 120km. Many cracks and fracture zone are expected to be developed in the Ultra basic rocks including serpentine. Especially between Sta.0km (Uekuli1) and 25km, the route possibly passes through steep slopes accompanied with large scale faults. Ultra basic rocks of the east side thrust over metamorphic rocks of west side along the faults. It is difficult to construct new road in route of Sta.81km - 98km in terms of both geology and topography, because the route is along the mountain side which faces the sea and has steep slopes. Tertiary rocks forms a hilly area with flat surface and gentle slope between Sta.126km and 174km(Nuha), therefore, there are few problems of road construction with no fracture zones and the road construction work of this section is easier than the other sections of link No.15.

Table 4-1-2 Geological Classification in Link No.15

	Age	Formation	Face
Quaternary	Pleistocene - Holocene	Alluvium, Diluvium	Clay, sand, gravel
Tertiary	Pliocene	Tomata formation	Sandstone, mudstone, tuff
	Miocene	Bungka formation	Sandstone, conglomerte, marl, shale
Mesozoic	Cretaceous	Matano fotmation	Limestone, marl
		Pompangeo complex	Schist, phyrite, slate, gneiss, surpentine, quartzite
		Ultra basic rock	Peridotite, serpentine, diabase, gabbro
	Jurassic	Tetambahu formation	Limestone, marl, sandstone

Source: Study Team

Table 4-1-3 Geology along the Route of Link No.15

Location (Sta.km)	Geology	Location (Sta.km)	Geology	Location (Sta.km)	Geology
0 (Uekuli) - 25	Ultra basic rock / Pompangeo complex	63 – 81	Tetambahu formation	114 – 120	Ultra basic rock / Matano formation
25 – 34	Bungka formation	81 - 98	Ultra basic rock	120 – 126	Matano formation
34 – 42	Ultra basic rock	98 - 106	Matano formation	126 – 174	Tomato formation
42 – 63	Alluvium	106 - 114	Alluvium		

Source: Study Team

(2) Link No.16

Geological classification of link No.16 is shown in Table 4-1-4.

Table 4-1-4 Geological Classification in Link No.16

Age		Formation	Face
Quaternary	Pleistocene - Holocene	Alluvium, Diluvium	Clay, sand, gravel
Tertiary	Pliocene	Tomata formation	Sandstone, mudstone, tuff
Mesozoic	Triassic – Jurassic	Tokala formation	Limestone, sandstone, shale, marl, slate

Source: Study Team

Alluvium/Diluvium and Tomata formation of Tertiary constitute the geology of this route. The route is mainly on the Alluvial plain. Alluvium is underlain by Tomata formation, where formerly Alluvium was deposited over an offshore terrace which was developed on the surface of the Tomata formation. The boundary between Alluvium and Tomata formation

which forms low hills becomes a gentle slope. Diluvium is also partially distributed around the boundary, which makes it difficult to trace the exact boundary of each formation.
Tokala formation forms mountains between Bungku and Sta.33.5km, and the route passes at the foot of the mountains. Geology along the route of link No.16 is shown in Table 4-1-5.

Table 4-1-5 Geology along the route of Link No.16

Location	Geology
Umpanga-Bungku	Alluvium

Source: Study Team

(3) Link No.22

Geological classification of link No.22 is shown in Table 4-1-6.
Alluvium and Diluvium are distributed in the plain along the coast, Tomata formation of Tertiary is distributed in the hilly area, and Tokala formation and Ultra-basic rock of Mesozoic are distributed in the mountainous area.
The route is on the Alluvium, which consists of clay and sand, and is distributed between Sta.98km and 99.5km (Betebete). Tokala formation is distributed between Sta.99.5km and 116km(Tangofa), where the route is on the mountain slope. From Sta.116km(Tangofa) to 127km(Buleleng) the route passes along the boundary between the Alluvial plain and mountains which consist of Tokala formation .

Table 4-1-6 Geological Classification in Link No.22

Age		Formation	Face
Quaternary	Pleistocene - Holocene	Alluvium, Diluvium	Clay, sand, gravel
Tertiary	Pliocene	Tomata formation	Sandstone, mudstone, tuff
Mesozoic	Cretaceous	Matano formation	Limestone, shale, chart
		Ultra basic rock	Peridotite, serpentine, diabase, gabbro
	Triassic – Jurassic	Tokala formation	Limestone, sandstone, shale, marl, slate

Source: Study Team

Sta.141km – 146.48km
The route passes through mountains between Sta.141km and 146.48km, which are of the Matano formation. Calcareous rock, which constitutes Matano formation, forms a rugged ground surface with many sinkholes, which makes the mountain slope steep in parts.

Sta.127.5km(Buleleng) - 141km
Ultara-basic rock is distributed between Sta.127.5km (Buleleng) and 141km where the route passes through a mountainous area. There are many photo-lineaments recognized in this area, where there are expected to be fracture zones caused by faults.

Sta.127.5km - 116km
Tokala formation forms a mountainous area and Alluvium covers the plain along the route.

Sta.99.5km - 116km

Tokala formation forms a mountainous area along the route.

Sta.99.5km - 53km
Geology along the route between 99.5km and 53km consists of Alluvium / Diluvium and Tomata formation of Tertiary. Tomata formation forms hills behind the plain which have been pushed back far from the coastal line by denudation. The plains are widespread and consist of Alluvium / Diluvium, where ground surfaces are slightly rugged. Diluvium forms the higher parts and Alluvium forms the lower parts. Alluvium is deposited only in lower parts of the ground surface, of which the thickness reduces over the width of the plain.
Ultra-basic rock forms mountainous area between Sta.70km and 72km along the route.
Boring sites 27 and 28 are located at the boundary between the narrow plain in Betebete and hills, and boring Sites 29,30 and 31 are located at the center of the plain.

Sta.53km - 37km
Tokala formation forms hills, and Alluvium forms a narrow coastal plain and valley floor between 53km and 49.5km along the route.
Tokala formation forms mountains which extend to the coastal line between Sta.49.5 and 37km. The mountain area is bordered by the sea with steep cliffs and no coastal plain.

Sta.37km – 35.775km(Bungku)
The coastal plain is widespread in this area, and Alluvium is widely distributed.
Geology along the route of link No.22 is shown in Table 4-1-7.

Table 4-1-7 Geology along the Route of Link No.22

Location (Sta.km)	Geology	Location (Sta.km)	Geology	Location (Sta.km)	Geology
35.8 – 37.0	Alluvium	79.0 – 84.0	Alluvium	122.0 – 123.5	Diluvium
37.0 – 53.0	Tokala formation	84.0 – 86.0	Tomata formation	123.5 – 124.0	Tokala formation
53.0 – 62.0	Alluvium	86.0 – 100.0	Alluvium	124.0 – 128.0	Alluvium
62.0 – 69.0	Diluvium	100.0 – 116.0	Tokala formation	128.0 – 133.0	Ultra-basic rock
69.0 – 71.5	Ultra-basic rock	116.0 – 120.5	Alluvium	133.0 – 146.48	Matano formation
71.5 – 75.0	Alluvium	120.5 – 121.5	Tokala formation		
75.0 – 79.0	Diluvium	121.5 – 122.0	Alluvium		

Source: Study Team

(4) Link No.32

Geological classification of link No.32 is shown in Table 4-1-8.

Geology of link No.32 is:

Sta.283.391km (Tondowatu) – 227.5km

Alluvium is distributed in the plain along the coast, and sediment of talus and Diluvium are distributed in the gentle upland slopes. Meluhu formation of Mesozoic, which consists of sandstone and shale, is distributed in hills and mountains with gentle slopes.

Table 4-1-8 Geological Classification in Link No.32

Age		Formation	Face
Quaternary	Pleistocene - Holocene		Clay, sand, gravel
Tertiary	Pliocene	Pandua	Conglomerate, sandstone and mudstone
Mesozoic	Cretaceous	Ultra basic rock	Peridotite, serpentine, diabase, gabbro
	Triassic	Meluhu formation	Sandstone, quartzite, shale, slate, limestone
		Tokala formation	Limestone, sandstone, shale, marl, slate

Source: Study Team

Sta.227.5km – 201.94km(Asera)

Ultra-basic rock which consists of peridotite and serpentine, and Tokala formation which consists of sandstone and shale, form hills and mountains with gentle slopes. Lowland of the hills and mountains consists of Alluvial, Colluvial and Diluvial deposits.

Geology along the route is:

Table 4-1-9 Geology along the Route of Link No.32

Location (Sta.km)	Geology	Location (Sta.km)	Geology	Location (Sta.km)	Geology
283.391- 268.0	Alluvium	244.0 – 232.0	Tokala formation	214.0 – 212.0	Alluvium
268.0 – 247.0	Tokala formation	232.0 - 227.5	Alluvium	212.0 – 213.0	Tokala formation
247.0 – 446.0	Alluvium	227.5 – 228.5	Tokala formation	213.0 – 212.0	Alluvium
246.0 – 245.0	Tokala formation	228.5 – 218.5	Ultra basic rock	212.0 – 210.0	Tokala formation
245.0 – 244.0	Alluvium	218.5 – 214.0	Tokala formation	210.0 – 201.94	Ultra-basic rock

Source: Study Team

(5) Link No.33

Geological classification of link No.33 is shown in Table 4-1-10.
Geology along the route is:

Sta.201.94km(Ascra) - 205km(existing)

Alluvium of the Lindu River covers the plain. The route passes along the boundary between plain and hill or mountain. Alluvium in the plain consist of clay, sand, gravel. Hills and mountains consist of Pandua formation of Tertiary and Ultra-basic rocks of Cretaceous.

Table 4-1-10 Geological Classification in Link No.33

Age		Formation	Face
Quaternary	Pleistocene - Holocene	Alluvium, Diluvium	Clay, sand, gravel
Tertiary	Pliocene	Pandua	Conglomerate, sandstone and mudstone
Mesozoic	Cretaceous	Matano formation	Limestone, shale, chart
		Ultra basic rock	Peridotite, serpentine, diabase, gabbro

Source: Study Team

Sta.205km(existing) - 170.5km

The route passes along the boundary between Pandua formation of Tertiary and Ultra-basic rock of Cretaceous between Sta.205km and 182km (existing route), therefore, both are distributed along the route. Pandua formation forms uplands with a flat ground surface, and Ultra-basic rock forms mountains. Pandua formation is widely distributed between Sta.205km and 146.48km, and forms uplands with extremely flat ground surface. This upland is deeply cut by erosion of existing rivers between Sta.177.5km and 172.5km.

Sta.170.5km - 146.48km (Border of Province)

Pandua formation of Tertiary and Matano formation of Cretaceous are distributed between Sta.170.5km and 146.48km, and Pandua formation forms uplands and Matano formation forms hills/mountains. The route is on the gentle slope of the upland which comprises the Pandua formation between Sta.170.5km and 148.5km, then ascends the steep mountain slope of the Matamo formation between Sta.148.5km and 146.48km.

Geology along the route of link No.33 is shown in Table 4-1-11.

Table 4-1-11 Geology along the route of Link No.33

Location (Sta.km)	Geology	Location (Sta.km)	Geology	Location (Sta.km)	Geology
201.94 – 200.0	Alluvium	192.0 – 191.0	Ultra-basic rock	(190.0)-(184.0)	Pandua formation
200.0 – 197.0	Ultra-basic rock	191.0 – 185.0	Diluvium	(184.0)-(182.0)	Ultra-basic rock
197.0 – 196.0	Alluvium	185.0 – (207.0)	Alluvium	(182.0)-(179.0)	Pandua formation
196.0 – 195.0	Ultra-basic rock	(207.0)-(205.5)	Pandua formation	(179.0)-(177.5)	Alluvium
195.0 – 194.0	Alluvium	(205.5)-(205.0)	Alluvium	(177.5)-148.0	Pandua formation
194.0 – 193.0	Diluvium	(205.0)-(204.0)	Pandua formation	148.0 – 146.48	Matano formation
193.0 – 192.0	Alluvium	(204.0)-(190.0)	Ultra-basic rock		

Note: (   ) of station number shows along existing route *Source: Study Team*

4.1.3 Natural Disasters Related to Topography and Geology

(1) Topography of the route

The route usually passes along the knick point of the ground surface which is usually seen at the foot of hills/mountains, where gradient of the ground surface changes. Basement for the route may be weathered rock or talus which consists of colluvial deposit. This is favorable for a road in terms of ground strength. Large cutting is not necessary because of the gentle slope formed of talus at the foot of upland/hill/mountain. But some colluvial deposit which forms talus is loosely deposited, and may cause collapse of the slope.

(2) Soft Ground

1) Link Nos. 22 and 16

In link Nos. 22 and 16, the routes pass mainly in the coastal region where the coastal plain is widespread. In particular the route meets soft ground of the coastal plain from Sta.84km to 53km in link No. 22, and from Bungku to Umpanga in link No. 16.

2) Link Nos. 33 and 32

Alluvial plain is widespread along the coastal line in link No. 33. The route usually passes on the gentle slope at the foot of hill/mountain where Alluvium is not thick.
The route of link No.32 passes through upland, hill and mountain of the inland area where thick Alluvium such as marine deposit is not distributed. Alluvium is distributed in the lowland where the route crosses the current river flow. This Alluvium resulted from erosion and sedimentation by the current river flow which cut down the upland/ hill/ mountain. Thickness of the Alluvium is usually small.

(3) Weathering of Rock

Weathered zones have developed up to less than 1m below ground on the cutting of the existing road, but extremely deep weathering is not seen. Generally speaking, large cuttings on a steep slope with a deep weathered zone are apt to collapse. However, such an unstable slope is not seen in the F/S area.
However, precautions about following points are necessary.

1) Pandua formation of Tertiary consists of soft rock which is of young geological age, and is easily broken up by weathering. Pandua formation is widespread between Sta.191km (existing route) and the border of province, in which an migration area extends.

2) Matano formation which is distributed around the border of province consists of calcareous rock and pelitic rock which are heavily weathered. The mountains are rugged with many sinkholes, which makes the gradient of the existing road steep in parts. In addition, clayey soil on the road surface produced from weathered rock easily becomes muddy in the rain. As a result, it is difficult for vehicles to pass through this area.

3) Mudstone, shale and tuff are distributed in the F/S area. These are subject to weathering and are easily dissolved into clay. Protection work for cuttings are necessary where mudstone, shale and tuff are distributed , and the soil derived from these cuttings should not be used as material for the new road construction.

(4) Ultra-basic Rock

Ultra-basic rock is widespread in the area from Tinobu in Southeast Sulawesi, 223km of Link No.32, to Buleleng in the Central Sulawesi. Ultra-basic rock is distributed in the areas listed in Table 4-1-12.

Table 4-1-12 Distribution Area of Ultra-basic Rock

Link No.	Location (Sta.km)
Link-32	218.5 - 228.5km, 210 - 201.94km(Asera)
Link-33	200 - 197km, 196 - 195km, 192 - 191km, 204 - (190)km, 184 - 182km
Link-22	69 - 71.5km, 128 - 133km
Link-15	0km(Uekuli) - 25km, 34 - 42km, 81 - 98km, 114 - 120km

Source: Study Team

Problems of new road construction caused by Ultra-basic rock are:

1) Slope cutting of Ultra-basic rock are subject to weathering due to its physical characteristics. Even a rock which looks hard easily breaks down because of many fractures with slickensides.
2) Rock exposed on a cutting slope rapidly weathers and is easily dissolved to clay. Most of the ultra-basic rock in the F/S area forms large fracture zones.
3) Protection of slope cuttings and careful management of excavated soil from a cutting work are necessary in areas where the ultra-basic rock is distributed. Ultra-basic rock is not

suitable for road construction material. There are many places where Ultra-basic rock is distributed in the F/S area, and traffic disruptions are caused by using Ultra-basic rock as a road material which quickly dissolves to clay with swelling.

(5) Fault

The most dominant faults in the F/S area form a boundary between Ultra-basic rock and other formations such as Meluhu formation, Tokala formation and Matano formation. Ultra-basic rock contacts with other formations through faults, along which fracture zones are expected to be developed. Fracture zones are assumed to exist in the areas listed below;

1) Link No.32: from Sta.222.0km to 218.5km
2) Link No.22: from Sta.128.0km to 133.0km
3) Link No.15: from Sta.0.0km to 25.0km

However, the existence of large faults as listed above are not so obvious in the field along the route. On the other hand it is more common that all the Ultra-basic rock in the F/S area shows lithofaceis looking like a fracture zone. For example, many photo-lineaments are seen on Ultra-basic rock distributed between Sta.133km and 128km of link No.22. Other than faults which have developed in the Ultra-basic rock, there are many faults in most of the formations except Alluvium and Diluvium, however these faults are of small scale and not severe.

(6) Landslides

The route runs along the foot of a slope in many places, where a landslide is apt to occur. However, a landslide on a large scale is not seen in the F/S area. This results from the fact that the slopes have already been denuded in many places, and the slopes are too gentle for a landslide to occur.

(7) Slope Failures

Slope failures on a large scale are not seen along the route. Slope failure is dominated by slope gradient, geological structure and vegetation. The route mainly passes along the foot of gentle slopes, and the slopes are too gentle for slope failure to occur. Dense flourishing vegetation on the slopes also prevents the slope from collapse. In the case where the route passes the foot of a steep mountain slope near the coastal line, slope failures are possible to occur. Such places are as listed below:

1) Link No.32: from Sta.222.0km to 218.5km
2) Link No.33: from Sta.205.0km to 181.0km
3) Link No.22: from Sta.100.0 km to 116.0km, from 49km to 53km

the route crosses steep mountain slope which extends to the sea, especially between 49km and 53km of link No.22, and slope failure in this area would cause a disaster. Superficial failures on a small scale frequently take place on cut slopes without vegetation. There are some slopes without vegetation in several places in the F/S area especially around the border of province. However, few existing superficial failures have been seen along the route, but it does not mean that slope failure takes place frequently in the F/S area.

(8) Talus

The route at the foot of uplands, hills and mountains, where Colluvial deposits usually form talus. A cutting of slopes which consists of loose Colluvial deposit sometimes causes the slope to become unstable and to slide. Stability of Colluvial deposit is difficult to predict, and careful inspection is necessary.

(9) Debris Flow

There is no slope along the route in the F/S area where debris flow has taken place on a large scale. Debris flow usually takes place on the steep slopes of a mountain, however, such slopes are not common along the route in the F/S area. The areas to which attention should be paid are as listed below:

1) Link No.32: from Sta.222.0km to 218.5km
2) Link No.33: from Sta.205.0km to 181.0km
3) Link No.22: from Sta.100.0km to 110.0km, from 49.0km to 53km

4.2 Boring Survey

4.2.1 Outline of Boring Survey

(1) Purpose

Propose of the survey was to determine the geological condition and strength of the ground where new bridges were proposed.

(2) Location of Boring Site

Boring sites were selected from the places where the route crosses the existing rivers. Finally 40 sites were selected as representative sites for the boring survey. The boring sites are shown in Figures A6-1-1 to A6-1-11.

(3) Detailsof Boring Survey

The total number of boring sites is 40 and the total number of boreholes is 62. Where the length of the proposed bridge is less than 25m, the boring with one bore-hole was carried out while for a proposed bridge of a length of more than 25m, 2 boreholes per site were executed. Depth of each boring is shown in Table 4-2-1.

4.2.2 Result of Boring Survey

(1) Ground Condition of Boring Sites

Boring sites are scattered over the 300km F/S area. The sites are located in various types of major topographic units such as coastal plain, uplands, hills and mountains. All boring points are located at the Alluvial lowland which was formed by the current river flow, because all points were selected to be at the river side. Unconsolidated soil such as clay, sand and gravel are deposited near the ground surface at all the boring points.

(2) Result of Boring Survey

The result of the boring is shown in Figures A4-1-1 to A4-1-6, which shows N values of the standard penetration test.

Table 4-2-1 Boring Depth at Each Site

Site	Location	Br.No	Depth	Site	Location	Br.No	Depth	Site	Location	Br.No	Depth
Link-16											
Site	Location	Br.No	Depth	Site	Location	Br.No	Depth	Site	Location	Br.No	Depth
32	29.2km	Br-46	16m	34	22.3km	Br-51	14m	37	11.0km	Br-56	32m
		Br-47	16m	35	17.6km	Br-52	31m			Br-57	31m
33	27.8km	Br-48	15m			Br-53	31m	38	7.0km	Br-58	34m
		Br-49	16m	36	16.0km	Br-54	31m			Br-59	33m
34	22.3km	Br-50	15m			Br-55	30m				
Link-22											
Site	Location	Br.No	Depth	Site	Location	Br.No	Depth	Site	Location	Br.No	Depth
26	127.0km	Br-34	17m	28	96.7km	Br-38	18m	30	65.5km	Br-42	19m
		Br-35	18m			Br-39	20m			Br-43	20m
27	98.2km	Br-36	15m	29	75.5km	Br-40	20m	31	56.5km	Br-44	28m
		Br-37	16m			Br-41	19m			Br-45	29m
Link 32											
Site	Location	Br.No	Depth	Site	Location	Br.No	Depth	Site	Location	Br.No	Depth
1	255.4km	Br-1	20m	4	227.5km	Br-6	10m	7	213.7km	Br-11	22m
		Br-2	20m			Br-7	10m	8	206.0km	Br-12	19m
2	243.5km	Br-3	16m	5	223.0km	Br-8	17m	9	203.6km	Br-13	12m
		Br-4	16m	6	221.3km	Br-9	11m				
3	239.9km	Br-5	16m	7	213.7km	Br-10	15m				
Link 33											
Site	Location	Br.No	Depth	Site	Location	Br.No	Depth	Site	Location	Br.No	Depth
10	194.2km	Br-14	10m	15	202.0km	Br-21A	15m	21	166.6km	Br-27	10m
11	192.6km	Br-15	18m			Br-21B	15m	22	165.0km	Br-28	9m
12	181.5km	Br-16	25m	16	195.0km	Br-22	10m	23	158.7km	Br-29	7m
		Br-17	25m	17	183.0km	Br-23	15m	24	151.5km	Br-30	10m
13	189.0km	Br-18	16m	18	176.6km	Br-24	17m			Br-31	10m
14	187.5km	Br-19	25m	19	176.6km	Br-25	25m	25	147.0km	Br-32	10m
		Br-20	16m	20	173.3km	Br-26	21m			Br-33	10m

Source: Study Team

(3) Bearing Layer for Bridge Foundation

Bearing layer for a bridge foundation should be a stratum which is older than Diluvium. Depth below ground surface to the bearing layer depends on the topographic unit of each site, because the thickness of the Alluvium is closely related to the topographic unit. Criteria for bearing layer are assumed as listed below;

a) N value more than 50, and thickness of a layer more than 3m or
b) N value more than 30, and thickness of a layer more than 5m.

The depth of the bearing layers and the soil classification are shown in Table 4-2-2.

Table 4-2-2 Depth of Bearing Layer for Bridge Foundation

Link 16											
Site	Br.No	Depth	Soil	Site	Br.No	Depth	Soil	Site	Br.No	Depth	Soil
32	Br-46	14m	Sand/Gravel	34	Br-51	12m	Gravel	37	Br-56	27m	Fine Sand
	Br-47	14m	Sand/Gravel	35	Br-52	27m	Fine Sand		Br-57	26m	Fine Sand
33	Br-48	12m	Gravel		Br-53	27m	Fine Sand	38	Br-58	30m	Fine Sand
	Br-49	12m	Gravel	36	Br-54	27m	Fine Sand		Br-59	29m	Fine Snd
34	Br-50	13m	Gravel		Br-55	26m	Fine Sand				
Link 22											
Site	Br.No	Depth	Soil	Site	Br.No	Depth	Soil	Site	Br.No	Depth	Soil
26	Br-34	14m	Gravel	28	Br-38	15m	Sand/Gravel	30	Br-42	15m	Fine Sand
	Br-35	14m	Sand/Gravel	29	Br-39	15m	Sand/Gravel		Br-43	16m	Fine Sand
27	Br-36	12m	Fibe Sand		Br-40	16m	Fine Sand	31	Br-44	22m	Fine Sand
	Br-37	13m	Fine Sand	30	Br-41	15m	Fine sand		Br-45	27m	Fine Sand
Link 32											
Site	Br.No	Depth	Soil	Site	Br.No	Depth	Soil	Site	Br.No	Depth	Soil
1	Br-1	18m	Gravel	4	Br-6	7m	Silt/Gravel	7	Br-11	18m	Sand/Gravel
	Br-2	17m			Br-7	7m	Sand/Gravel	8	Br-12	15m	Soft Rock
2	Br-3	13m	Sand/Gravel	5	Br-8	15m	Gravel	9	Br-13	10m	Soft Rock
	Br-4	14m	Sand/Gravel	6	Br-9	10m	Soft Rock				
3	Br-5	12m	Sand/Gravel	7	Br-10	13m	Rock				
Link 33											
Site	Br.No	Depth	Soil	Site	Br.No	Depth	Soil	Site	Br.No	Depth	Soil
10	Br-14	8m	Gravel	15	Br-21A	5m	Hard Silt	20	Br-27	6m	Gravel
11	Br-15	15m	Silt/Gravel		Br-21B	13m	Hard silt	21	Br-28	7m	Rock
12	Br-16	25m	Hard Silt	16	Br-22	7m	Rock	22	Br-29	1m	Rock
	Br-17	24m	Hard Silt	17	Br-23	8m	Hard Silt	23	Br-30	2m	Rock
13	Br-18	13m	Hard Clay	18	Br-24	15m	Gravel	24	Br-31	2m	rock
14	Br-19	>25m	Rock		Br-25	22m	Sand	25	Br-32	7m	Rock
	Br-20	14m		19	Br-26	19m	Hard Silt		Br-33	7m	Rock

Source: Study Team

4.3 Laboratory Test

4.3.1 Outline of Laboratory Test

(1)Purpose

Purpose of the laboratory test was to determine the physical / mechanical characteristics of the soils of the sites where new bridges are proposed.

(2) Samples for Laboratory Test

Undisturbed samples for laboratory test were taken from each borehole. One undisturbed sample was taken from one borehole, and total number of samples is 62.

(3) Items for Laboratory Test

Items and the number of samples are as follows:

Table 4-3-1 Items and the Number of Laboratory Test

	Item	Number
1	Unit gravity	62 nos.
2	Specific Gravity	62 nos.
3	Water content	62 nos.
4	Liquid limit	62 nos.
5	Plastic limit	62 nos.
6	Grain size analysis	62 nos.
7	Confined compression test	52 nos.
8	Triaxial CU compression test	62 nos.
9	Consolidation test	62 nos.
10	CBR test including water content specific gravity, liquid limit,plastic limit, compaction test,CBR test	5 nos.

Source: Study Team

4.3.2 Result of Laboratory Test

The result of laboratory test is shown in Table A4-2-1.

(1) Sampling depth

Sampling depth is usually shallower than GL-5m, but sometimes GL-10m.

(2) Sampled soil

Soft clay or clayey silt and loose sand distributed below the near ground surface were sampled by thin wall sampler. Most of sampled soils are Alluvial clay and clayey silt. Results of laboratory test are shown in detail in "Soil Investigation Report". The result of the test is shown in Table A4-2-1.

(1) Grain size analysis

Most soils sampled in this survey were classified into fine soil containing more than 90% fine grains. These fine soil samples contain silt and clay with the same ratio, and show physical characteristics between high plastic clay (CH) and high compressive silt (MH). On the other hand some soil samples are sandy.

(2) Water content

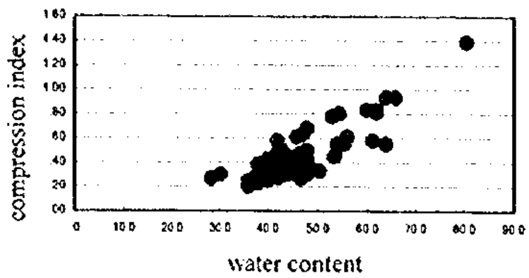
Water content of soil samples are ranging between 28.2% and 80.5%, majority is between 30% and 60% with most frequent values between 40% and 50 %.

(3) Unit weight

Wet unit weight of soil samples are usually 1.5－1.8. On the other hand, dry unit weight of samples are usually in a range from1.0 tf/m^3 to1.3 tf/m^3.

(4) Void ratio

Void ratio of samples are usually from1.0 to 1.5. Void ratio has close relation to water content.



Source: Study Team

(5) Consolidation Characteristics

Most soil samples show compression index of around 0.3 in normally consolidated area. Consolidation yield stress of the samples is between 30 kg/cm^2 and 50 kg/cm^2 , but most of these are 40 kg/cm^2. It is concluded that most of sampled soils are in the condition of overconsolidation at site because the soils were sampled at depth of less than 5m. Compression index of the soils have a close relation to the water content. Values of coefficient of consolidation are around 3×10^{-3} cm/sec in normally consolidated area, and are between 5×10^{-3} cm/sec and 20×10^{-3} cm/sec in the area where consolidation load is less than consolidation yield stress. The values of parameters obtained from consolidation test stand in the normal range.

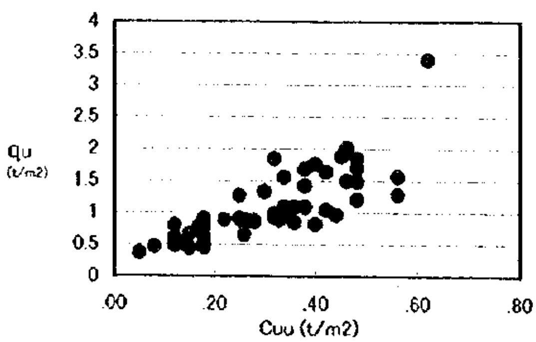
(6) Unconfined Compression Strength

Unconfined compression strength of soil samples are around 10t/m^2 with differences between places. Sampled clay is not soft clay but normal clay, because the values of unconfined compression strength are greater than that expected from sampling depth of less than 5m.

(7) Tri-Axial Compression Test

Unconsolidated and undrained compression test (UU test) were carried out as tri-axial compression test. Average value of ϕ_{uu} is 20 degree.

Usually ϕ_{uu} of clay is near zero (0), however, ϕ_{uu} sometimes has value of ϕ_{uu} more than zero depending on degree of saturation and content of sand, or in case of hard clay or fractured



Source: Study Team

clay. Actually soil samples with high sand content show high value of ϕ_{uu}, on the other hand soil samples with high clay content show low value of ϕ_{uu}. Both Cuu and ϕ_{uu} should be examined in design. Cohesion of soil sample are usually in a range from 1 tf/m^2 to 3 tf/m^2 with great difference by places. Cohesion and unconfined strength has close relation, however the relation is not general relation which qu is the same as the half of Cuu.

(8) CBR Test

The result of CBR is shown in Table 4-3-3. The result of CBR test shows difference between samples from Alluvium and samples from Diluvium because of difference in soil. CBR shows small values around 4% in clayey soils and large values of 24% and 49% of sandy or gravely soils.

Table 4-3-2 Result of CBR Test

Sample No.	Location	Geology	Soil	CBR(2.5)	CBR(5)
TP-1	Link-32, 80.5km	Alluvium	Clay	4.4	5.0
TP-2	Link-33, 128km	Alluvium	Clay	3.6	4.1
TP-3	Link-33, 210km	Diluvium	Sand with gravel	49.1	56.0
TP-4	Link-22, 135km	Alluvium	Clay	4.8	5.4
TP-5	Link-16, 85km	Diluvium	Sand	24.1	28.6

Source: Study Team