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Japan International
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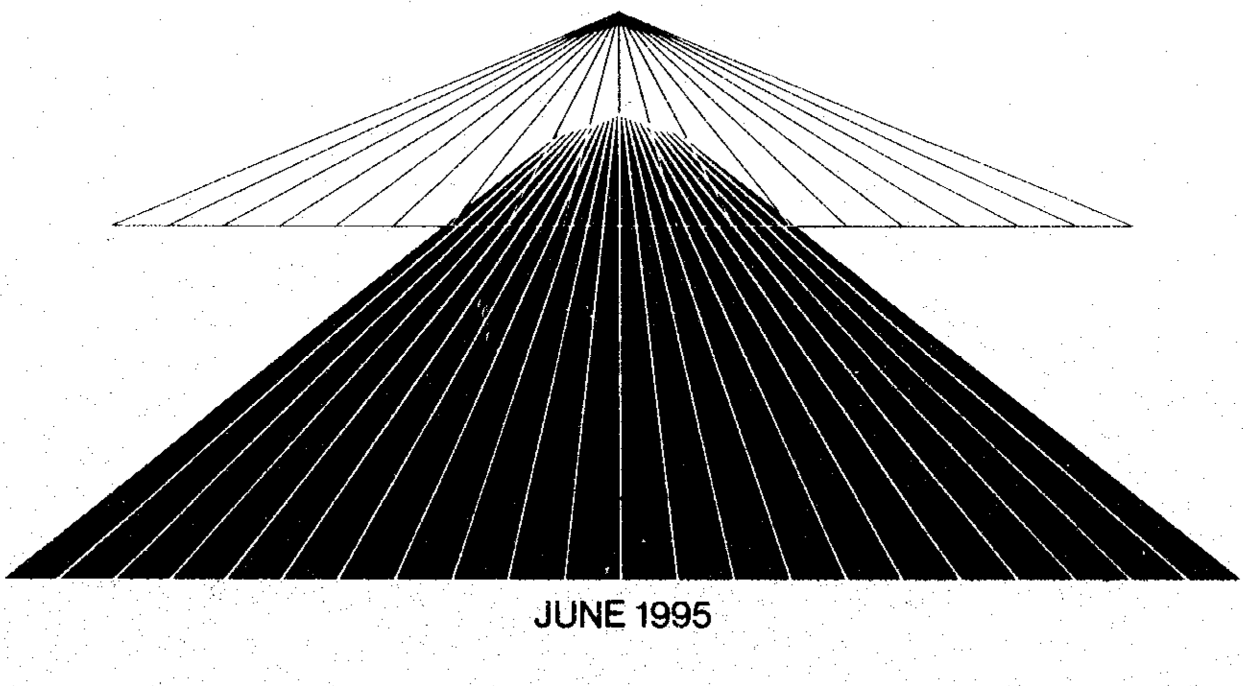
Kingdom of Thailand
Ministry of Transport and
Communications
Department of Highways

The Study on Road Disaster Prevention Plan in The Kingdom of Thailand

FINAL REPORT
SUMMARY

VOLUME 1



JUNE 1995

ORIENTAL CONSULTANTS
KATAHIRA & ENGINEERS INTERNATIONAL

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The following foreign exchange rate is applied in the study:

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(as of November 1994)

PREFACE

In response to a request from the Government of The Kingdom of Thailand, the Government of Japan decided to conduct a feasibility study on The Study on Road Disaster Prevention Plan in The Kingdom of Thailand and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a study team headed by Mr. Masashi Oshitari, Oriental Consultants Co., Ltd., from December 1993 to February 1995.

The team held discussions with the officials concerned of the Government of Thailand, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of The Kingdom of Thailand for their close cooperation extended to the team.

June 1995

Kimio Fujita
President
Japan International Cooperation Agency

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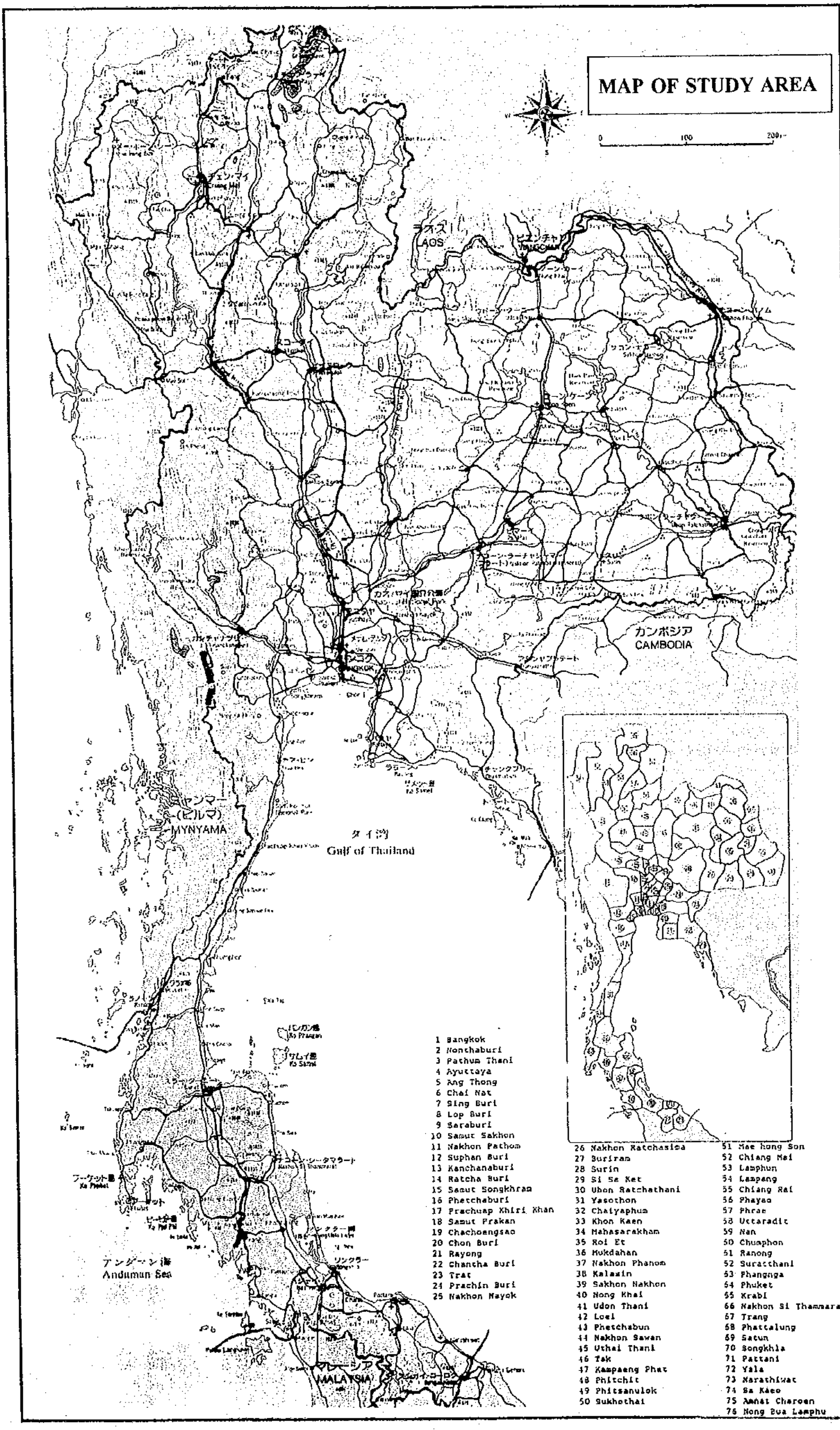
MAP OF STUDY AREA
0
100
ラオス
LAOS
カンボジア
CAMBODIA
ミャンマー
(ビルマ)
MYNYAMA
タイ湾
Gulf of Thailand
アンダマン海
Andaman Sea
MALAYSIA
1 Bangkok
2 Nonthaburi
3 Pathum Thani
4 Ayuttaya
5 Ang Thong
6 Chai Nat
7 Sing Buri
8 Lop Buri
9 Saraburi
10 Samut Sakhon
11 Nakhon Pathom
12 Suphan Buri
13 Kanchanaburi
14 Ratcha Buri
15 Samut Songkhram
16 Phetchaburi
17 Prachuap Khiri Khan
18 Samut Prakan
19 Chachoengsao
20 Chon Buri
21 Rayong
22 Chantha Buri
23 Trat
24 Prachin Buri
25 Nakhon Nayok
26 Nakhon Ratchasima
27 Buriram
28 Surin
29 Si Sa Ket
30 Ubon Ratchathani
31 Yasothon
32 Chaiyaphum
33 Khon Kaen
34 Mahasarakham
35 Roi Et
36 Mukdahan
37 Nakhon Phanom
38 Kalasin
39 Sakhon Nakhon
40 Nong Khai
41 Udon Thani
42 Loei
43 Phetchabun
44 Nakhon Sawan
45 Uthai Thani
46 Tak
47 Kampaeng Phet
48 Phitchit
49 Phitsanulok
50 Sukhothai
51 Mae hong Son
52 Chiang Mai
53 Lamphun
54 Lampang
55 Chiang Rai
56 Phayao
57 Phrae
58 Uttaradit
59 Nan
60 Chumphon
61 Ranong
62 Suratthani
63 Phangnga
64 Phuket
65 Krabi
66 Nakhon Si Thammarat
67 Trang
68 Phattalung
69 Satun
70 Songkhla
71 Pattani
72 Yala
73 Narathiwat
74 Sa Kaeo
75 Amnat Charoen
76 Nong Bua Lamphu

OUTLINE OF THE STUDY

1. BACKGROUND

Recently, flood-related damages and slopes damaged by erosion, landslides and rockfalls have been increasing as highways are built in order to achieve a denser highway network. However, measures for road damage prevention and road restoration have been insufficient so far. In this context, the creation of a road damage prevention system and road restoration system are urgent issues for the highway sector.

2. OBJECTIVES

The main objectives of the Study are:

(1) To carry out a study on the feasibility of repairing and/or restoring damaged roads selected from the DOH highway network.
(2) To recommend a management and operations system to cope with future road disasters and damage.
(3) To prepare road damage prevention and restoration manuals.
(4) To transfer technology to Thai counterpart personnel in the course of the Study.

3. SUMMARY OF THE STUDY

1) Types of road damage

Road damage is divided into four major categories, and these are broken down into a further 12 categories as shown in the following table.

Categories for Roadway Damage		Breakdown of Roadway Damage Categories
I	Slope Damage	1.Slope Erosion 2.Rockfalls 3.Landslide
II	Collapsing of Bridge	4.Girder Displacement 5.Pier Collapsing 6.Abutment Collapsing 7.Scouring of Approach Road 8.Overflow 9.Scouring of River Bank
III	Collapsing of Embankment Roads	10.Scouring of Embankment Slope 11.Washout of Shoulder
IV	Road Flooding	12.Inundation

2) Feasibility study

Eight project roads are selected for feasibility studies, with four of the project roads from the North and four from he South. Then, a total of 38 spots from the eight project roads are chosen for a preliminary design.

Project Road	No. of Spots For Pre-Design	Types of Damage for Preliminary Design
Rt.109	3	Slope erosion, Rockfalls, Landslide
Rt.1095	4	Rockfalls, Landslide
Rt.1149	2	Slope erosion, Landslide
Rt.1256	12	Slope erosion, Rockfalls, Landslide, Abutment collapsing, Scouring of river bank, Inundation
Rt.4	3	Landslide, Abutment collapsing, Scouring of river bank
Rt.410	6	Slope erosion, Landslide, Rockfalls, Overflow
Rt.4015	5	Abutment collapsing, Scouring of approach road, Scouring of embankment slope, Washout of shoulder
Rt.4107/4058	3	Abutment collapsing, Overflow of bridge

Various types of restoration measures were listed up for various types of damages. Then, the most suitable measures for each type damage were determined based on the concepts below:

- Be effective in eliminating the cause of damage
- Be effective in resisting the forces that produces damage
- Be easy to implement
- Be cost effective
- Be environmentally friendly

Repair work for road damage is divided into the three categories of urgent repair work, temporary repair work and permanent repair work, after taking into consideration the issues of time and quality.

3) Road damage prevention and restoration manual

A road damage prevention and restoration manual is drawn up. The main scope of the manual consists of:

- An evaluation method for road damage potential.
- Methodologies for field inspection and surveys.
- Basic damage prevention and restoration measures and

procedures for selecting suitable measures.
- How to plan and design a road least susceptible to damage.
- A procurement and allocation system for the materials and equipment for urgent repair work.
- Recommendations for a road damage detection system and communications system.

4. PROJECT COST

The following table shows the costs for the eight project roads and an implementation schedule.

Project Road	Project Cost (x 1,000 Baht)	Implementation Year
Rt.109	643,330	2004
Rt.1095	79,071	2003
Rt.1149	8,422	2002
Rt.1256	69,561	2004
Rt.4	17,844	1996
Rt.410	61,771	2002
Rt.4015	5,444	1997
Rt.4017/4058	11,419	1999

5. PROJECT EVALUATION

The economic analysis in the table below revealed that six out of the eight project roads are economically feasible (Route 109, Route 1256 were found infeasible).

Project Road	B/C	IRR (%)	NPV (x 1,000 Baht)
Rt.109	0.933	10.90	- 16,970
Rt.1095	2.541	24.48	69,325
Rt.1149	1.329	15.23	2,057
Rt.1256	0.963	11.51	- 1,334
Rt.4	2.886	29.07	26,608
Rt.410	2.893	25.97	67,717
Rt.4015	6.081	43.36	20,566
Rt.4107/4058	1.729	20.43	4,256

6. RECOMMENDATIONS

The recommendations of the Study are as follows:

(1) to revise the present management and operations system to cope with road damage based on the Study.
(2) to establish a new road damage prevention and restoration system based on the proposed manual.
(3) to repair and/or restore the damaged project roads that were found feasible.

THE STUDY ON ROAD DISASTER PREVENTION PLAN
IN THE KINGDOM OF THAILAND
FINAL REPORT - VOLUME 1

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List of Abbreviation

AASHTO	American Association of State Highway and Transportation Officials
AC	Asphalt Concrete
ADT	Average Daily Traffic
AL	Atterberg Limits
AS	Asphalt Concrete
BC	Bridge Collapsing
B/C	Benefit/Cost Ratio
Bkk	Bangkok
BMR	Bangkok Metropolitan Region
C.	Central
CBR	California Bearing Ratio
DBST	Double Bituminous Surface Treatment
DOH	Department of Highways
GDP	Gross Domestic Product
GEO.	Geology
GPP	Gross Provincial Product
GRP	Gross Regional Product
HB	Heavy Bus
HT	Heavy Truck
IRR	Internal Rate of Return
JICA	Japan International Cooperation Agency
LB	Light Bus
LT	Light Truck
MC	Motorcycle
N.	North
N.A.(NA)	Not Available
NE.	Northeast
NESDB	National Economic and Social Development Board
NMC	Natural Moisture Content
Nos.	Numbers
NPV	Net Present Value
PC	Passenger Car
PM	Penetration Macadam
PSA	Particle Size Analysis
RC	Road Collapsing
RF	Road Flooding
Rt.	Route
S.	South
SA	Soil Aggregate
SBST	Single Bituminous Surface Treatment
SD	Slope Damage
SE.	Southeast
SPT	Standard Penetration Test
ST	Surface Treatment
SW.	Southwest
TOPO.	Topography
UPM	Penetration Macadam
VOC	Vehicle Operating Cost

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The development of the highway network in Thailand is one of the key programs being implemented by the government in order to achieve national socioeconomic goals. The total length of highway under the jurisdiction of DOH reached 52,500 km as of 1991.

In November 1988, the South Region of Thailand was hit by heavy rains that caused large-scale flooding with debris flows in 14 changwat (provinces). The worst hit changwats were Nakon Si Thammarat and Surat Thani, which are located about 1,000 km south of Bangkok. Altogether 1,560 bridges and 5,694 km of road were damaged.

In addition, some areas in the north and the northeast of Thailand were hit by Typhoon "Fred", which brought heavy rains from August 17th to 19th in 1991. Other than Petchabun, which was the most seriously damaged changwat, Phitsanulok, Phichit, Sakhon Nakhon, Mukdahan and Khon Kaen were also seriously affected by the typhoon.

Besides flood-related damages, slopes damaged by erosion, landslides and rockfalls have been increasing as highways are developed in mountainous areas in order to achieve a denser highway network.

The socioeconomic activities of some of these areas have been badly affected by damage to roads. Thus, road damage prevention has become one of the major topics in the field of road maintenance amongst DOH and other concerned road agencies.

However, measures for road damage prevention and damaged road restoration have been insufficient so far. In this context, the creation of a road restoration system and damage prevention measures are urgent issues for the highway sector in order to ensure essential transportation service.

1.2 OBJECTIVES OF THE STUDY

The main objectives of the Study are as follows:

(1) To carry out a study on the feasibility of repairing and/or restoring damaged roads selected from the DOH highway network.

(2) To recommend a management and operations system to cope with future road disasters and damage.

(3) To prepare road damage prevention and restoration manuals.

(4) To transfer technology to Thai counterpart personnel in the course of the Study.

1.3 IMPLEMENTATION OF THE STUDY

The Study is divided into three stages as shown in Fig.1.3.1.

(1) The First Stage (December 1993 - February 1994)

In this stage, past disaster records are analyzed and project roads are identified and selected. In addition, the following reports are submitted:

Inception Report : December 1993
Interim Report 1 : February 1994

(2) The Second Stage (March 1994 - October 1994)

In second stage, technical surveys and a feasibility study are executed. In addition, the following reports are submitted:

Progress Report : June 1994
Interim Report 2 : October 1994

(3) The Third Stage (November 1994 - February 1995)

In third stage, a management and operations system to restore damaged roads is recommended and road damage prevention and restoration manuals are prepared. In addition, a report is submitted and a workshop is held, as shown below.

Draft Final Report : January 1995
Organization of Workshop : February 1995

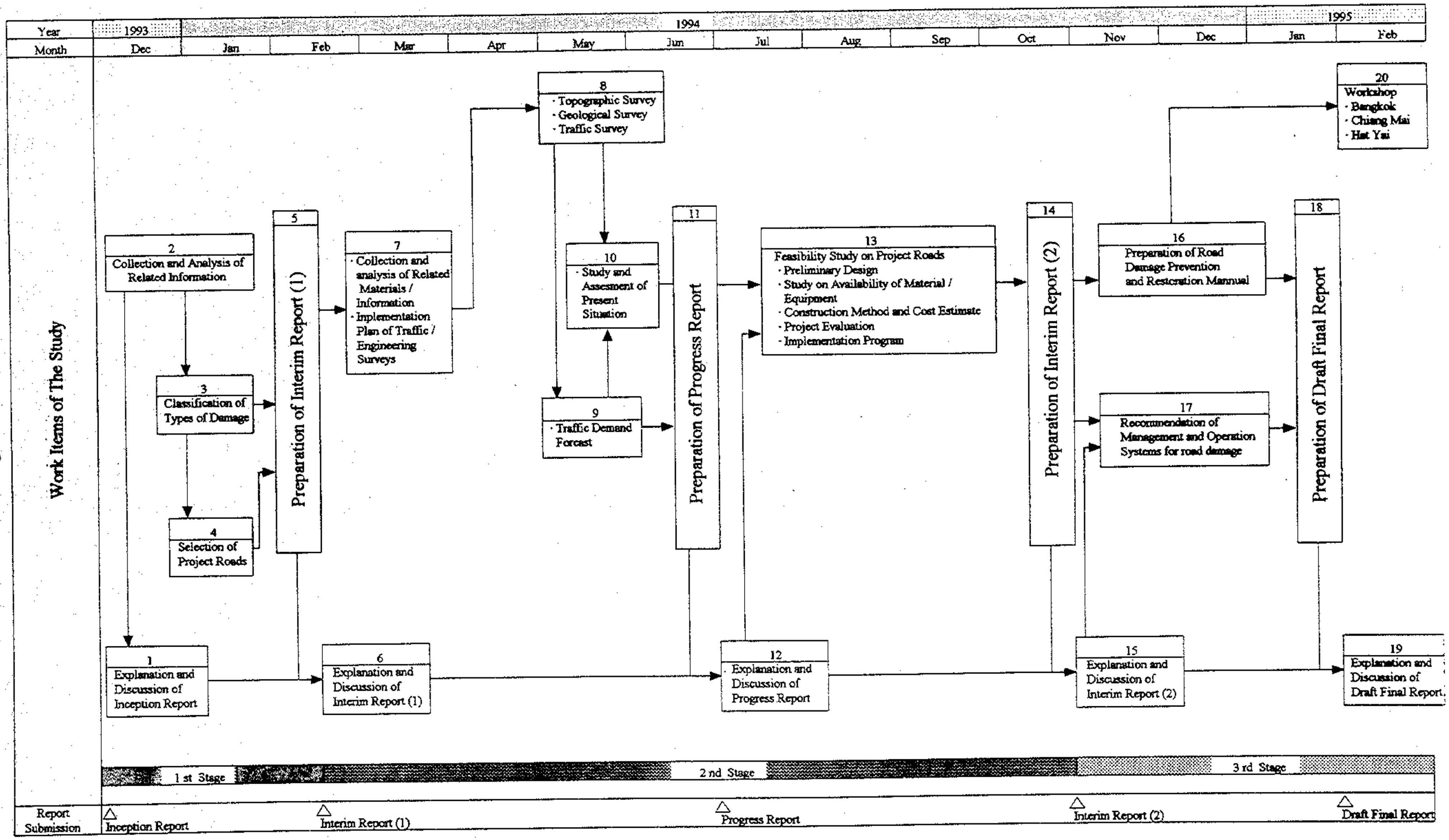


Fig. 1.3.1 General Work Flow Chart

(4) The Fourth Stage (May 1995)

The Final Report is submitted.

1.4 STRUCTURE OF THE FINAL REPORT

The present document constitutes the Final Report, which is divided into five volumes, namely:

(1) VOLUME 1 : SUMMARY

Volume 1 briefly summarizes the Study.

(2) VOLUME 2 : MAIN TEXT

Volume 2 is comprised in three parts. Part 1 concentrates on the identification and selection of project roads. Part 2 describes a feasibility study for the eight selected project roads. Part 3 describes the management and operations systems for restoring damaged roads.

(3) VOLUME 3 : DRAWINGS

The alignments of project roads, locations of damaged spots, and the drawings for temporary and permanent repair work are included in Volume 3.

(4) VOLUME 4 : APPENDICES

Volume 4 mainly contains collected and processed statistical data and the results of technical surveys.

(5) VOLUME 5 : ROAD DAMAGE PREVENTION AND RESTORATION MANUAL

A road damage prevention and restoration manual is prepared.

1.5 PARTICIPANTS OF THE STUDY

Participants of the Study are (1) Thai Committee Members, (2) Japanese Advisory Committee Members, (3) JICA Study Team, and (4) Thai Counterparts to the JICA Study Team.

(1) Thai Committee Members

Chairmen:

Mr. Sukree Dheeragool	Deputy Director General
Mr. Anan Nanthapisudhi	Deputy Director General

Members:

Mr. Likhit Khaodhiar	Director, 4th Construction Div.
Dr. Prapansak Buranaprapa	Director, Location and Design Div.
Mr. Chinchai Mahasan	Director, Maintenance Div.
Dr. Teeracharti Ruenkrairergsa	Director, Road Research and Development Center
Mr. Kanchit Tongmark	Director, Planning Div.
Mr. Somwang Changsuwan	Director, Material and Research Div.
Mr. Solos Temiyabutra	Chairman of Thai Counterparts
Mr. Isamu Bito	JICA Expert
Mr. Shunichi Hamada	JICA Expert

(2) Japanese Advisory Committee Members

Chairman:	Mr. Osamu Matsuo
Member:	Mr. Tomiyuki Adachi
Member:	Mr. Hidetoshi Kohashi

(3) JICA Study Team

Mr. Masashi Oshitari	Team Leader/Road Management Expert
Mr. Yoshiharu Yanagisawa	Hydrologist/Road Disaster Analyst
Mr. Hani Abdel Halim	Traffic Planner/Transport Economist
Mr. Richard James Purser	Soil Engineer
Mr. Keigo Konno	Structural Engineer
Mr. Takao Inami	Highway Engineer
Mr. Atsushi Nishimura	Construction Expert

(4) Thai Counterparts to the JICA Study Team

Mr. Solos Temiyabutra	Chairman
Mr. Likhit Khaodhiar	Vice Chairman
Mr. Ekawit Veerapunth	Member
Mr. Kampol Uruyos	Member
Mr. Yongyuth Taesiri	Member

Mr. Pawit Wacharamanee	Member
Mr. Suchatr Leerakomson	Member
Mr. Narong Achariyakul	Member
Ms. Phimchai Yuthabandol	Member
Mr. Chitapant Prakobporn	Secretary
Mr. Atisak Sengkampan	Assistant Secretary

CHAPTER 2 PRESENT SITUATION

2.1 PHYSICAL CONDITIONS

Thailand's weather is generally tropical, but there are distinct climatic regional differences, since the country covers between 5 and 20 degrees of latitude and there are significant local microclimatic variations due to topographical effects.

Annual rainfall

The average annual rainfall in Thailand by climatic region varies from 1,200 mm to 2,700 mm (see Fig.2.1.1).

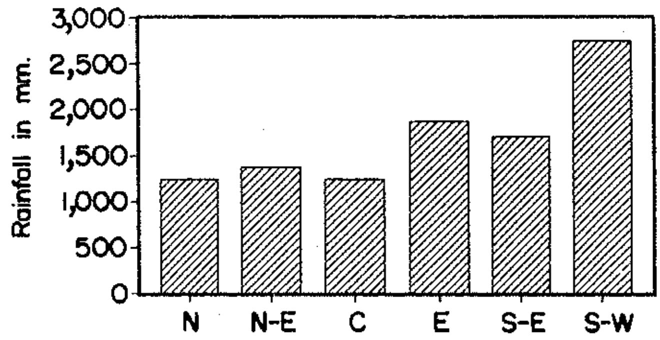


Fig.2.1.1 Average Annual Rainfall by Region

The areas with the greatest amount of annual rainfall exceed 4,000 mm and are in Ranong and Trat, while the areas with the lowest amount of annual rainfall receive around 1,000 mm, and are in the vicinity of Chiang Mai and Phetchabuti as shown in Fig.2.1.2.

Monthly rainfall

The pattern of monthly rainfall in the Southeast Region is slightly different from that of the other regions. This region has a distinct peak in November. The other five regions have their peaks in either September or August (see Fig.2.1.3).

2.2 SOCIOECONOMIC CONDITIONS

Thailand is administratively divided into six regions; namely, the Bangkok Metropolitan Region (BMR) and the Central, East, West, North and South regions. The six regions

AVERAGE 30 YEARS (1961-1990)

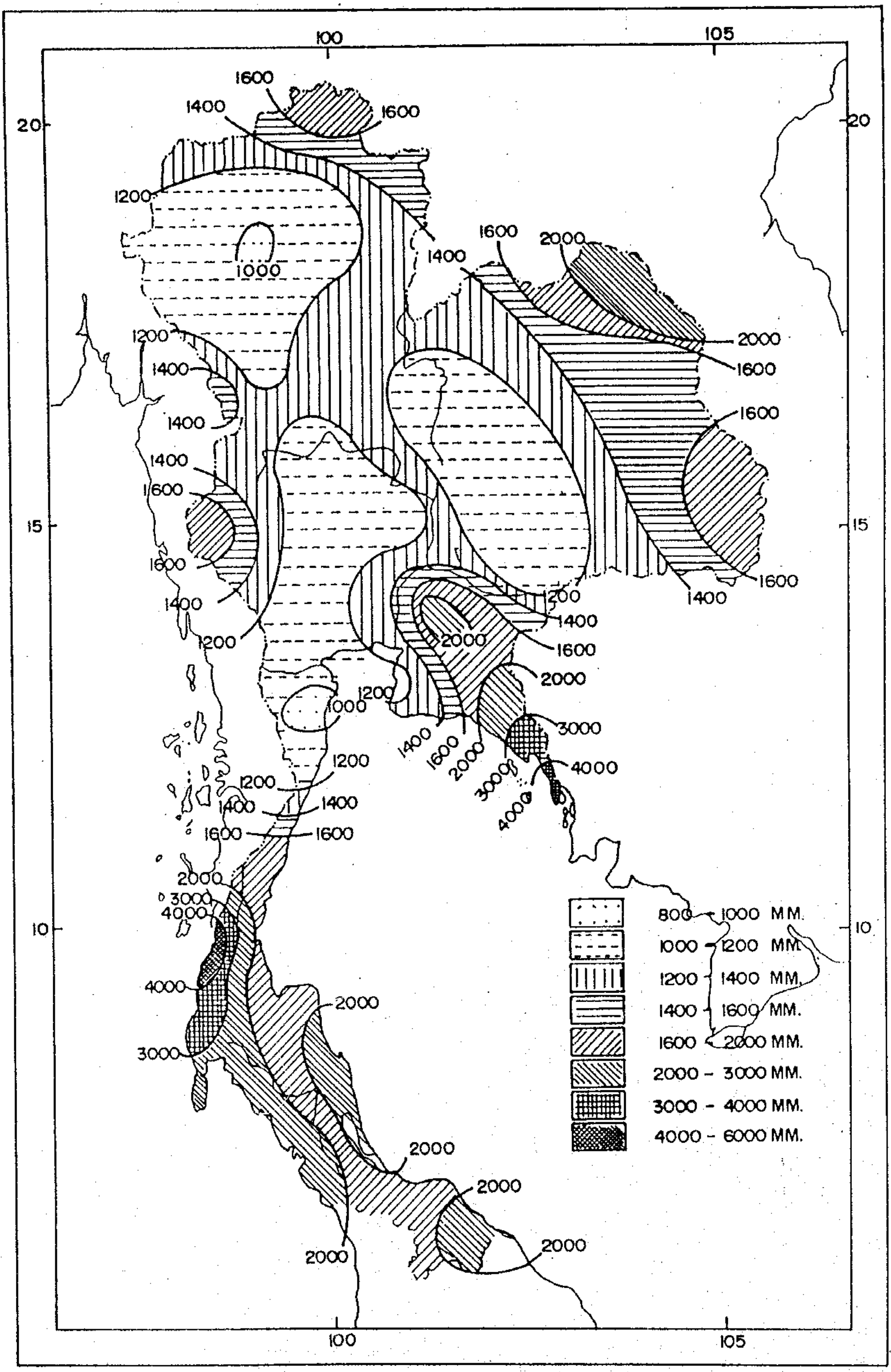


Fig. 2.1.2 Annual Rainfall in Thailand

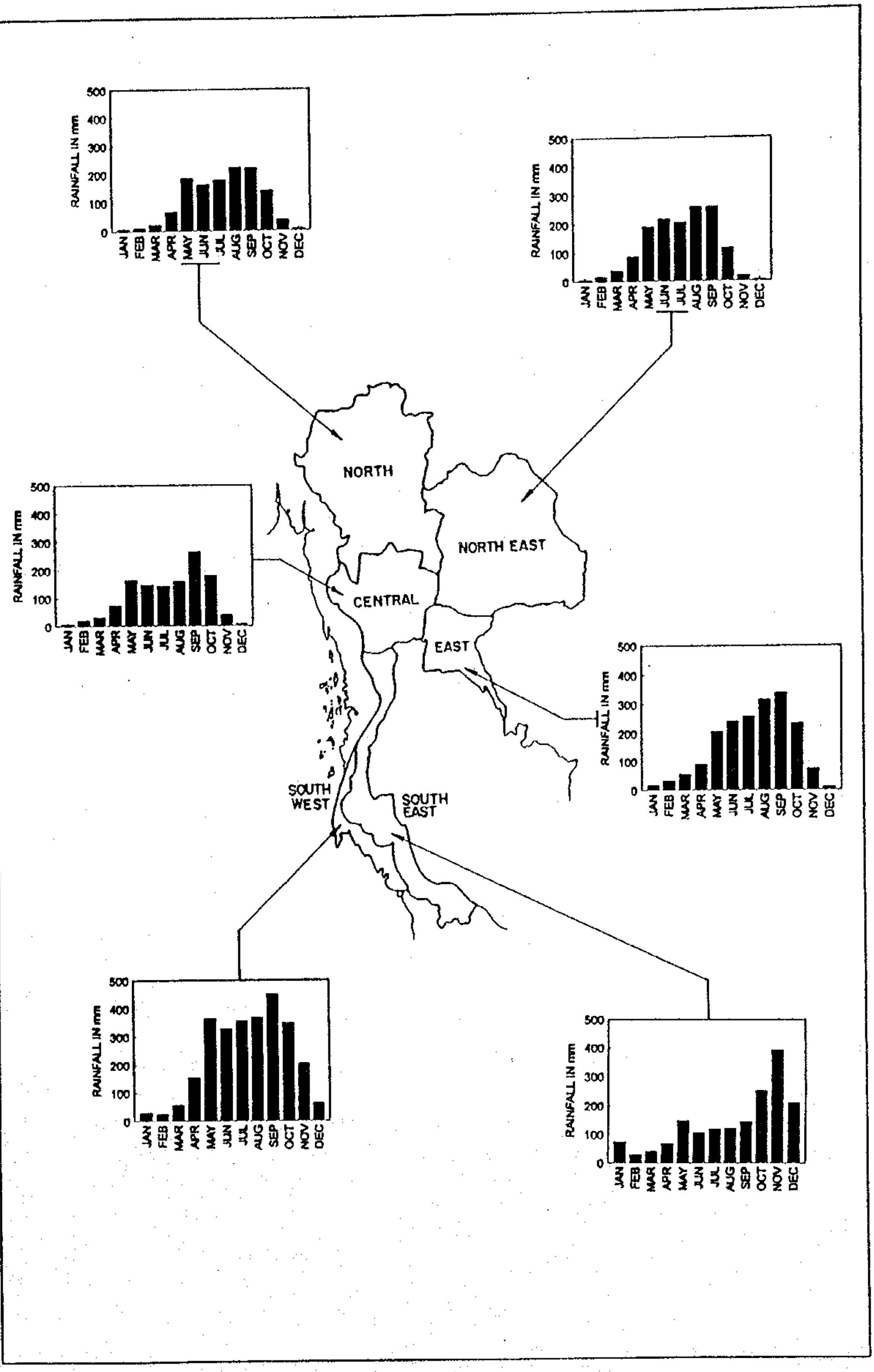


Fig. 2.1.3 Monthly Rainfall Distribution

are divided into 76 changwats. The forests in Thailand are still extensive and cover about 28% of the country's land area, while farm land accounts for about 46% of Thailand's land area.

As of 1992, total population was 57,789,000 inhabitants. Population growth in Thailand slowed down from an annual average of about 2.0% during 1981-1986 to 1.4% during 1986-1991. The population target growth rate in the 7th National Economic and Social Development Plan for 1992-1996 has been set at 1.2% per year.

The economic performance of Thailand has shown remarkable growth over the last few years. The GDP of Thailand in 1991 amounted to 2,509 billion baht at current market prices, which is about 3.3 times the 1981 GDP of 760 billion baht (see Fig.2.2.1). The average annual growth rate increased from 5.4% during the 5th Plan to 10.9% during the 6th Plan. In the same period, per capita GDP increased from about 16,000 baht in 1981 to 44,000 baht in 1991, and the average annual growth rate increased from 3.4% to 9.1%.

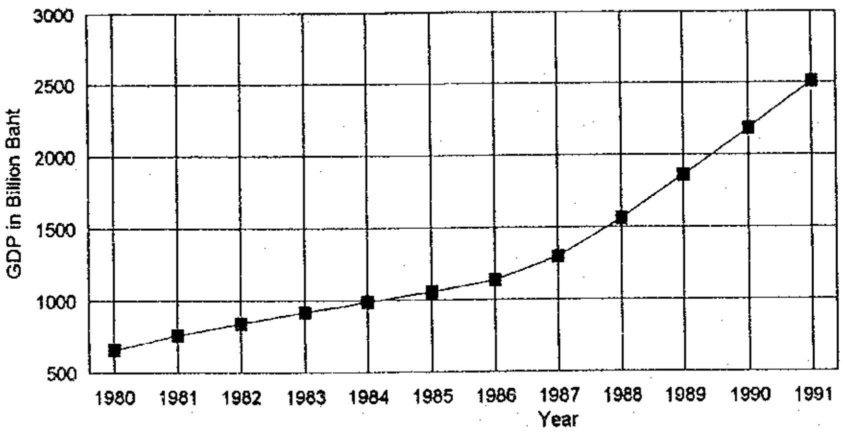


Fig.2.2.1 GDP at Current Market Prices

Growth in the number of registered vehicles continued to increase rapidly. By the year 1990, more than 7.5 million vehicles were registered in Thailand, with more than 2.0 million in Bangkok alone.

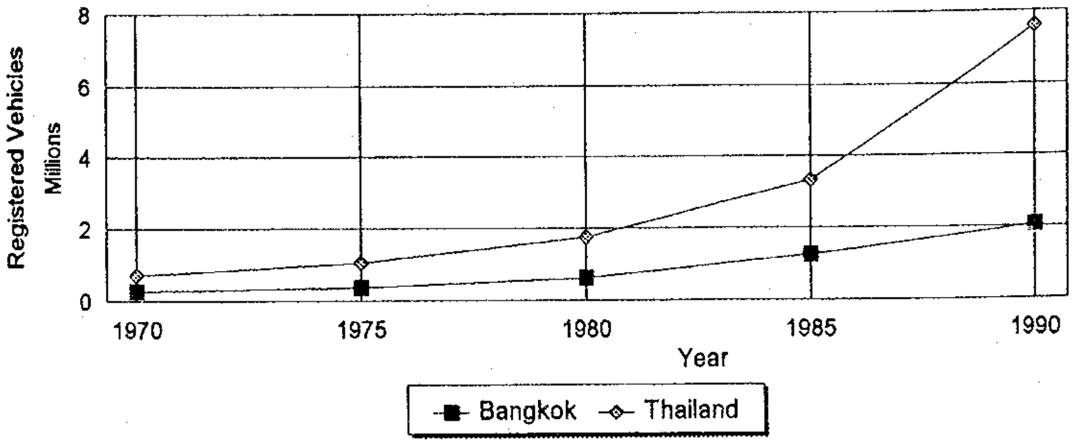


Fig.2.2.2 Growth in Vehicle Registration

2.3 ROAD NETWORK

The public road network system in Thailand consists of the following:

- Special highways or motorways
- National highways
- Rural roads
- Municipal roads
- Roads in small municipal areas
- Concession highways

Of the above roads, DOH is responsible for the special, national, and concession highways. Road in Thailand are broken down into four regions: the North, Northeast, Central, and South regions. The total length of DOH highways and a regional breakdown are shown in Table 2.3.1.

Table 2.3.1 Regional Breakdown of DOH Highways in 1988

	North	Northeast	Central	South	Total
Paved (km)	9,483	10,135	9,647	6,609	35,874
Ratio paved (%)	(86.8)	(82.9)	(87.2)	(87.1)	(85.9)
Unpaved (km)	1,440	2,090	1,410	980	5,920
Under construction (km)	3,952	1,638	1,706	778	8,074
Total (km)	14,875	13,863	12,763	8,367	49,868
Density					
Existing (km / km2)	0.064	0.072	0.106	0.107	0.081
Total (km / km2)	0.088	0.082	0.123	0.118	0.097

The total length of national highway, for which DOH is responsible increased from 12,276 km. in 1965 to 45,600 km. in 1991, or an annual increase of 2.6%.

Regarding highway density by region, the Central Region has the highest value of 0.123, which is road length per square kilometer of land area (including highways under construction), and is followed by the South region with 0.118. On the other hand, highway density in the North and Northeast regions are a low 0.088 and 0.082.

2.4 ROAD DAMAGE

In Thailand, the types of natural disasters that cause most of the damage to roads are lingering depressions and monsoons or typhoons with heavy rains. Annual losses due to road damage from 1976 to 1992 are shown in Table 2.4.1.

Table 2.4.1 Annual Losses Due to Road Damage

Year	Northern Region		North-eastern Region		Central Region		Southern Region		Total	
	No. of Routes	Cost (1000 Baht)	No. of Routes	Cost (1000 Baht)	No. of Routes	Cost (1000 Baht)	No. of Routes	Cost (1000 Baht)	No. of Routes	Cost (1000 Baht)
1976	46	2,197	46	1,297	78	14,487	60	7,080	230	25,061
1977	57	2,869	77	5,563	29	1,203	66	8,960	229	18,595
1978	81	12,435	128	21,714	50	6,588	47	5,383	306	46,120
1979	39	4,164	99	26,963	84	6,404	48	8,157	270	45,688
1980	133	27,085	83	11,173	30	3,235	43	1,994	289	43,487
1981	106	21,781	94	7,600	127	30,486	36	1,076	363	60,943
1982	45	6,955	91	17,006	74	15,950	75	39,647	285	79,558
1983	21	4,432	44	3,797	63	40,007	30	1,958	158	50,194
1984	43	4,905	68	9,333	159	61,287	53	9,154	323	84,679
1985	30	11,781	32	5,322	36	16,903	60	25,309	158	59,315
1986	42	4,880	16	1,159	64	10,347	41	5,260	163	21,646
1987	71	9,654	35	3,467	62	3,675	50	9,943	218	26,739
1988	36	5,372	19	1,333	67	8,750	72	12,588	194	28,043
1989	31	10,282	20	1,786	87	15,590	132	157,331	270	184,989
1990	13	1,141	24	4,828	8	1,350	18	13,122	63	20,441
1991	87	63,583	67	26,762	51	38,889	12	17,582	217	146,816
1992	19	5,405	7	742	24	1,598	19	643	69	8,388
Total	900	198,921	950	149,845	1,093	276,749	862	325,187	3,805	950,702
Annual Average	53	11,701	56	8,814	64	16,279	51	19,129	224	55,923

As mentioned in Section 1.1, the North and South regions of Thailand were seriously damaged by heavy rains in 1991 and 1988, respectively. Maps indicating damaged road spots in the North and South are shown in Fig.2.4.1 and Fig.2.4.2.

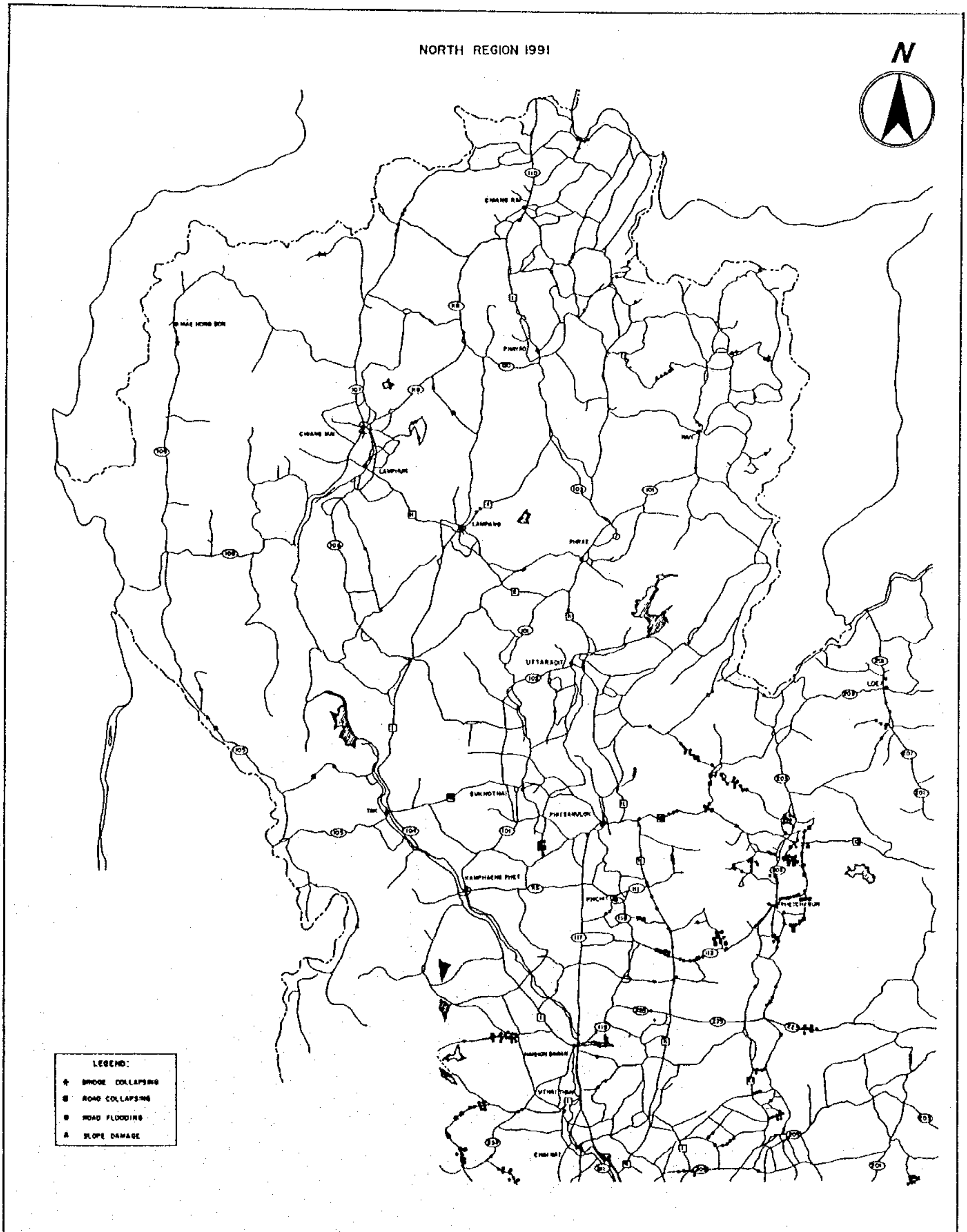


Fig. 2.4.1 Road Damage in the North - 1991

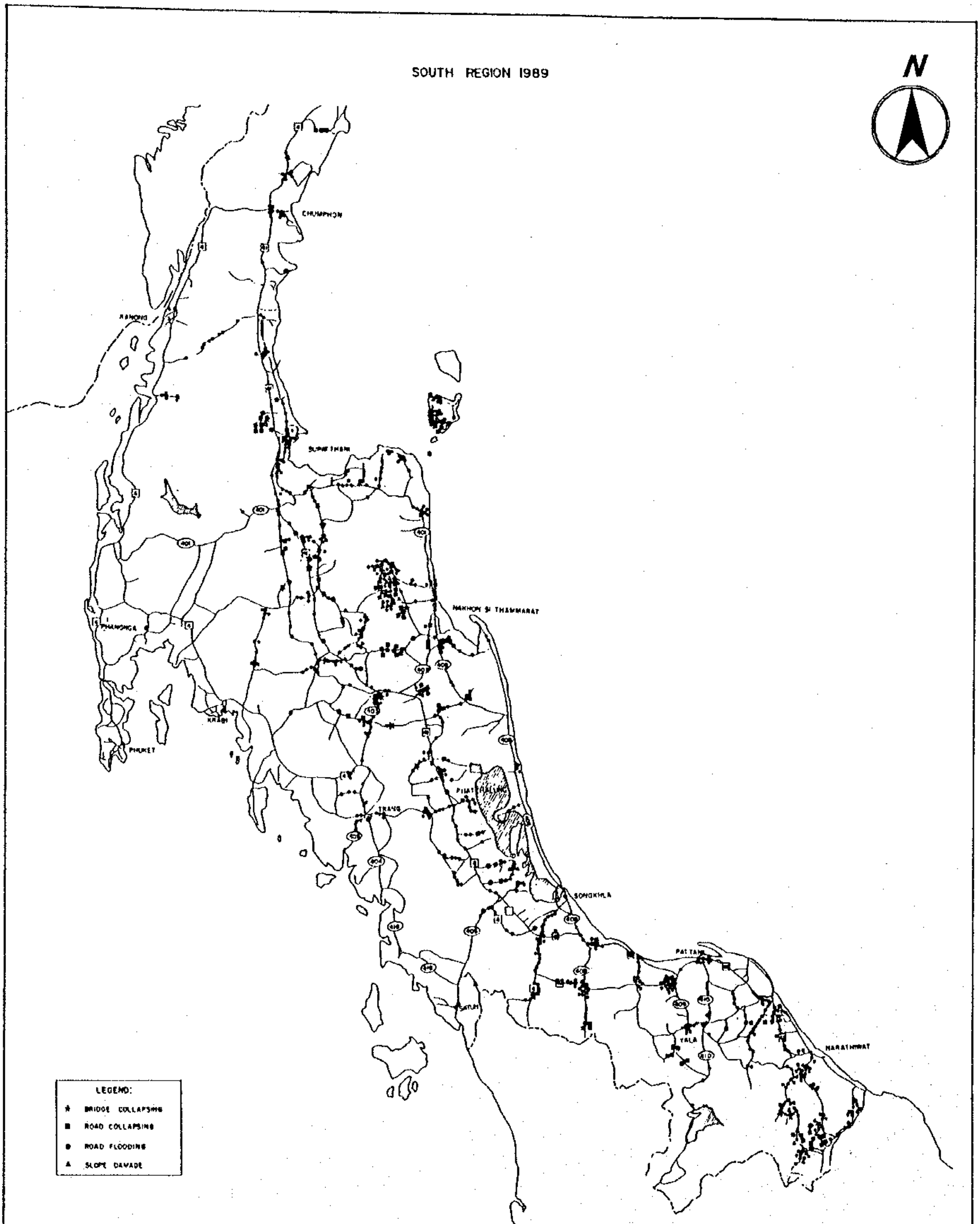


Fig. 2.4.2 Road Damage in the South - 1988

CHAPTER 3 IDENTIFICATION OF PROJECT ROADS

3.1 ASSESSMENT OF ROAD DAMAGE POTENTIAL

As for the relationship between road damage and natural conditions, it is not exactly clear. The potential for road damage, however, is higher when design standards are not followed or when proper prevention work is not executed.

From the standpoint of potential road damage, it can be said that there are two geologically distinct areas in Thailand where this potential is higher than normal.

The first is an area with a high potential for slope failure (see Fig.3.1.1). Rock deposits in such an area consist mainly of limestone, shale and granite. As long as these deposits are covered by top soil, the potential for slope failure is not high. However, they become prone to failure after exposure to the air, for example, by construction work that did not take proper precautions or that was not carried out in accordance with design standards. The other area with a high potential for road damage is an alluvium flood plain (see Fig.3.1.2).

3.2 CLASSIFICATION OF ROAD DAMAGE

Road damage, as shown below, is divided into four major categories based on the portion of roadway damaged or the type of disaster that has occurred.

(1) Slope damage
(2) Collapsing of bridges
(3) Collapsing of embankment roads
(4) Road flooding

The above-mentioned categories, as shown in Table 3.2.1, are broken down into a further 12 categories based on the type of damage sustained or failure that has occurred.

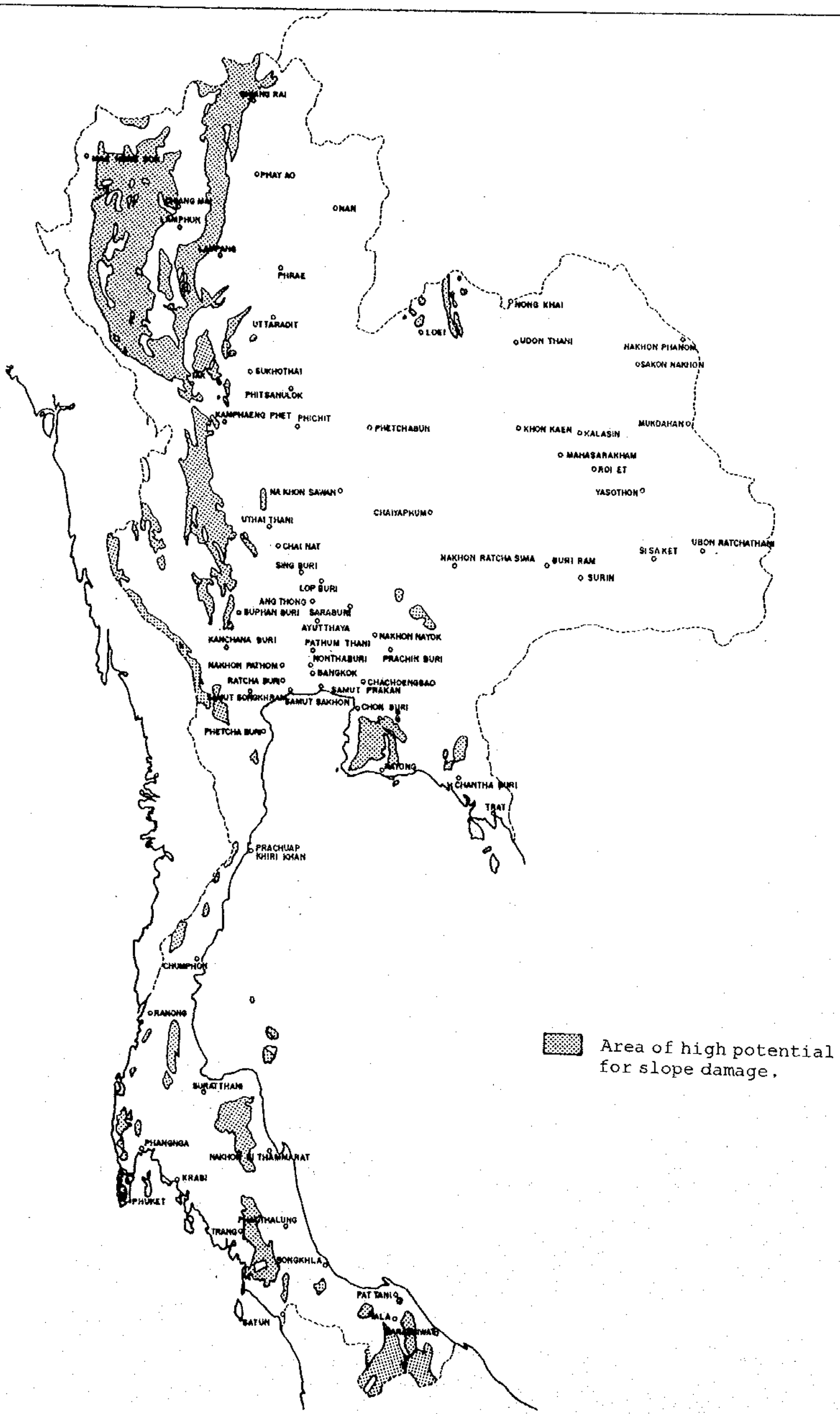


Fig. 3.1.1 Area of High Potential for Slope Damage

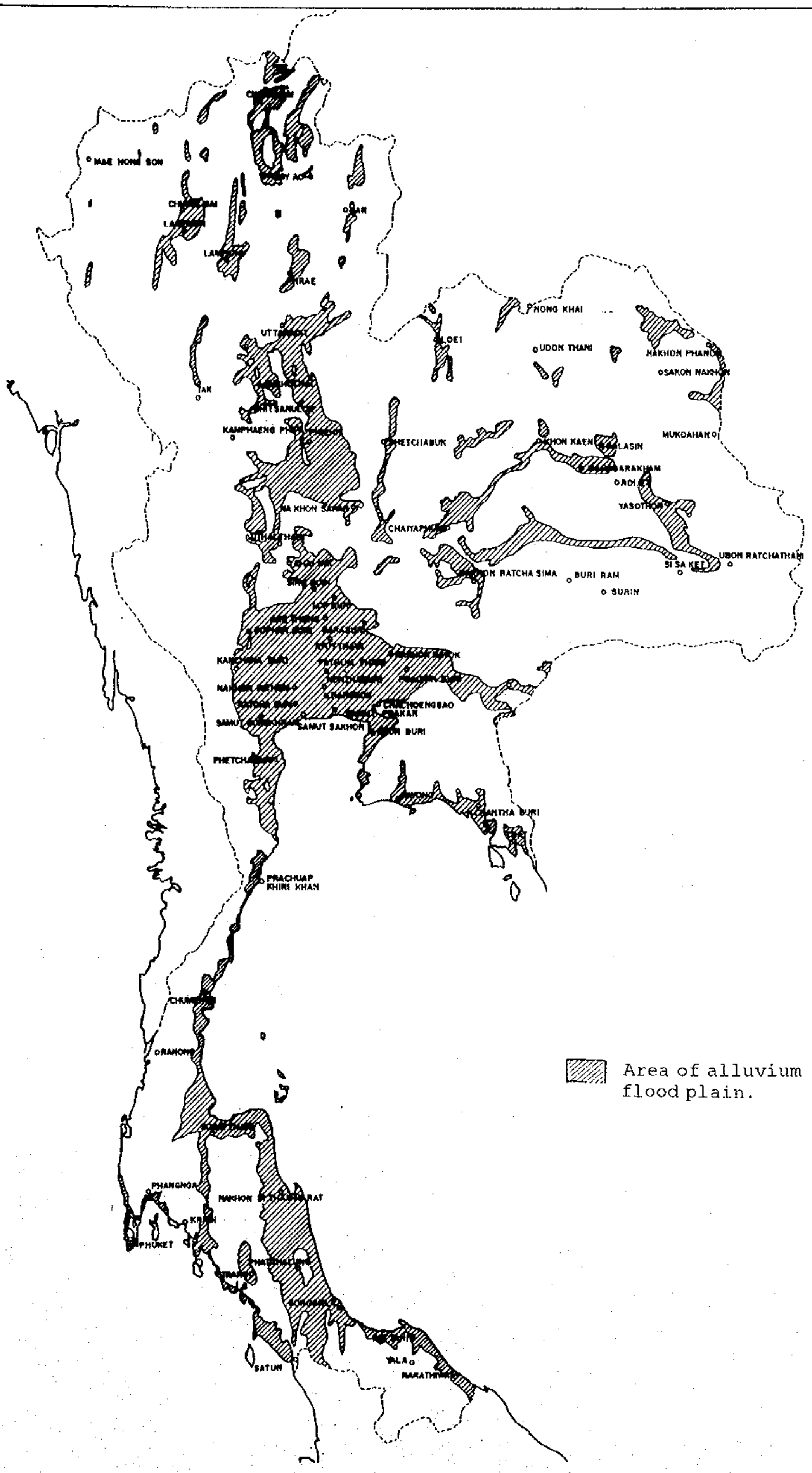


Fig. 3.1.2 Flood Plain

Table 3.2.1 Breakdown of Road Damage

Categories of Roadway Damage	Breakdown of Roadway Damage Categories
I Slope Damage	1. Slope erosion 2. Rockfalls 3. Landslide
II Collapsing of Bridges	4. Girder displacement 5. Pier collapsing 6. Abutment collapsing 7. Scouring of approach road 8. Overflow 9. Scouring of river bank
III Collapsing of Embankment Roads	10. Scouring of embankment slope 11. Washing out of shoulder
IV Road Flooding	12. Inundation

The definitions for these 12 categories of roadway damage are explained in Table 3.2.2 to 3.2.5.

3.3 SELECTION OF PROJECT ROADS

In Thailand, it can be said that there is no clear relationship between road damage and a region's geographical and meteorological characteristics, based on an analysis of past road damage. The local conditions around a damaged spot, however, such as the type of slope, slope gradient, the geological formation of the slope, and surface protection, are closely related to road damage. In other words, the occurrence of damage is dominated by man-made conditions and not by natural conditions.

In selecting a project road, priority was placed on past damage records. The outline of the selection procedure is shown in Fig.3.3.1.

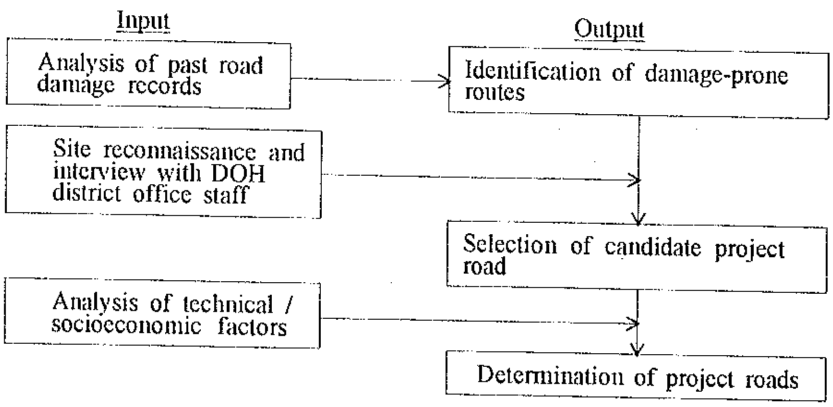


Fig.3.3.1 Selection of Project Roads

Table 3.2.2 Definition of Slope Damage (1)

Type of Damage	Definition	Cause
Slope Erosion	- Scouring by runoff water in a vertical direction on a slopes surface. - Slope erosion consists mainly of the three following phenomena : * Uniform erosion of a slope's entire surface (sheet erosion). * Numerous parallel shallow channelways narrowly spaced (rill erosion). * Deep channels widely spaced (gully erosion).	- Slope erosion occurs due to scouring by runoff water or seepage of weak areas on a slop's surface.

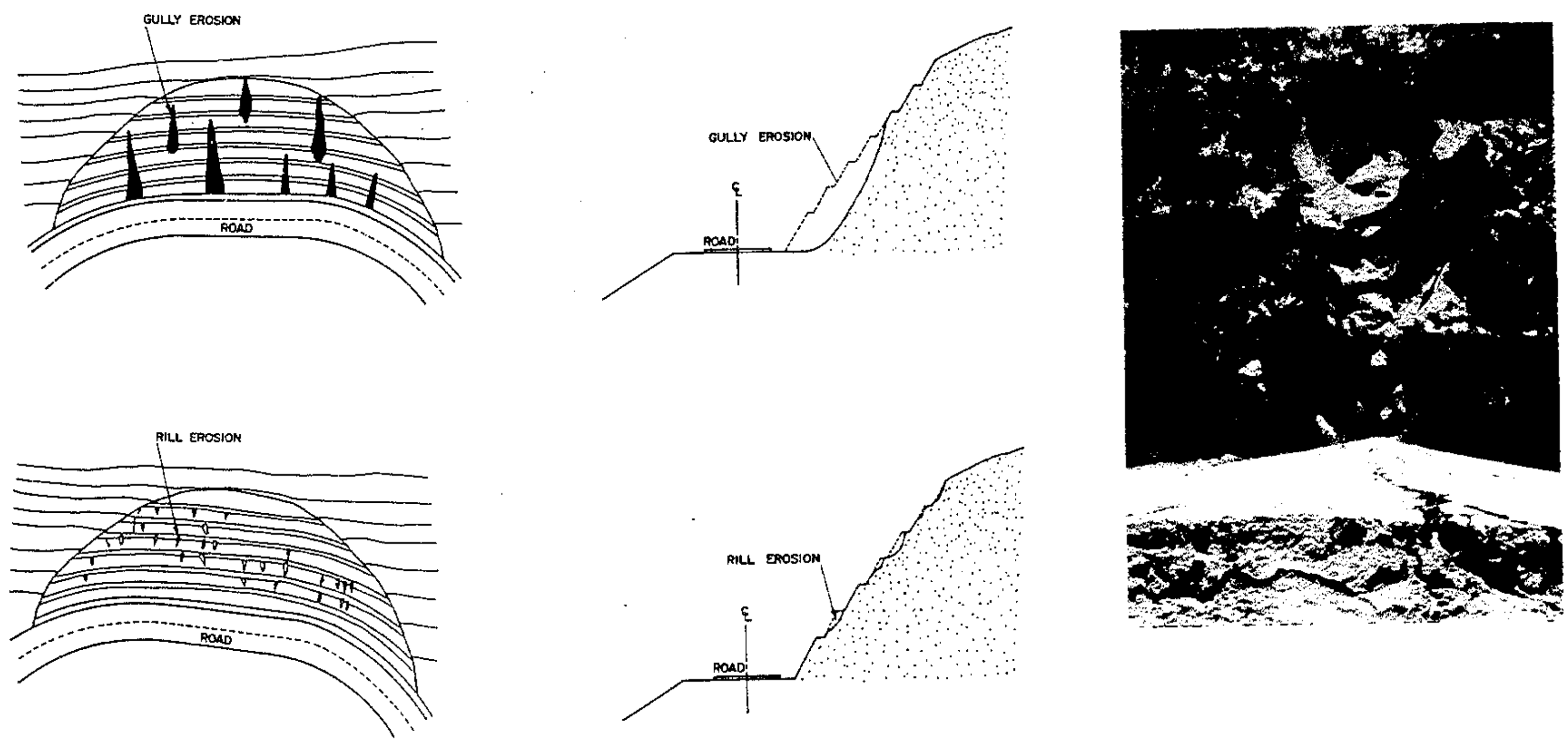
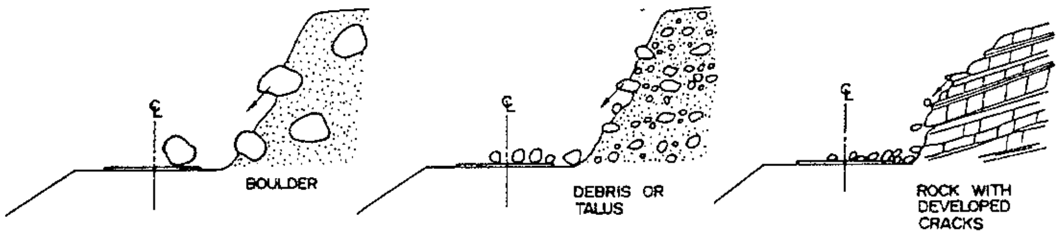
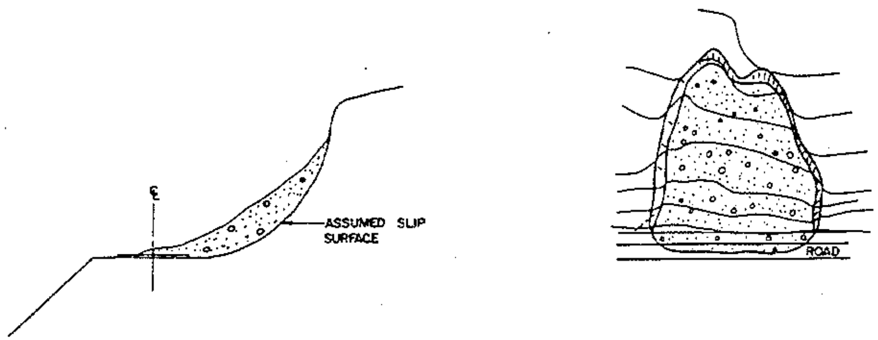


Table 3.2.2 Definition of Slope Damage (2)

Type of Damage	Definition	Cause
Rockfalls	- A rockfall consists of any downslope movement of intact blocks of rock. - The falling of detached rock from the surface of a slope made up of bedrock having cracks, joints, and beddings. - The falling of unsupported pebbles, boulders from the surface of a slope made up of debris or talus.	- Stable boulders lose their balance and fall due to the scouring of matrix soil under the boulders by runoff water or seepage. - Rock blocks lose their balance and fall due to the development of cracks in rock by runoff water or seepage.



Type of Damage	Definition	Cause
Landslide	- Any movement of soil and rock downslope in response to gravitational forces.	- Landslide result from the Gravitational driving forces exceed the frictional restraining force. - A decrease in the cohesion of soil due to an increase in pore water pressure from a rise in ground water, which results in a decrease in frictional restraining force.



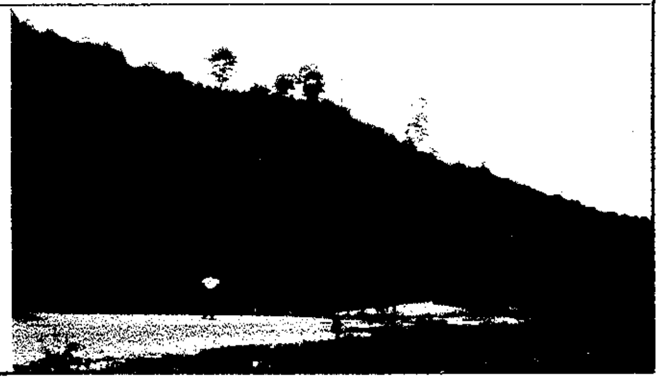
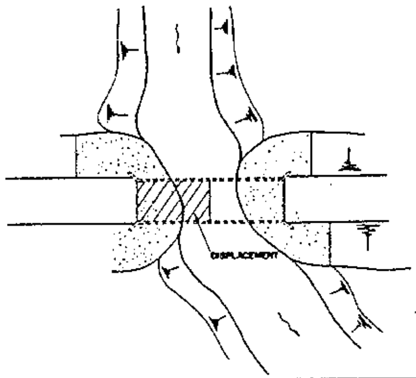
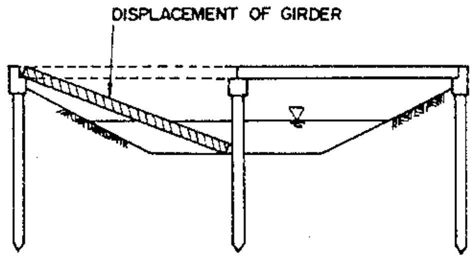


Table 3.2.3 Definition of Collapsing of Bridges (1)

Type of Damage	Definition	Cause
Girder Displacement	- The falling of a girder from the top of a substructure due to a loss of support. - Lateral movement of a girder on the top of a substructure. - Fracturing of girder.	- Girder displacement occurs due to the collapsing, tilting, settlement and / or sliding of a pier and / or abutment. - Lateral movement of a girder is caused by lateral forces on the girder exerted by water, debris or mud flows, or floating timber. - Fracturing of girder due to girder displacement.





Type of Damage	Definition	Cause
Pier Collapsing	- Tilting, and settlement of pier. - Fracturing of column.	- Tilting of piers and fracturing of columns are caused by lateral forces on piers exerted by water flows, debris or mud flows, or floating timber. - The scouring of a foundation may result in the vertical settlement of a pier due to a loss of the side friction of piles.

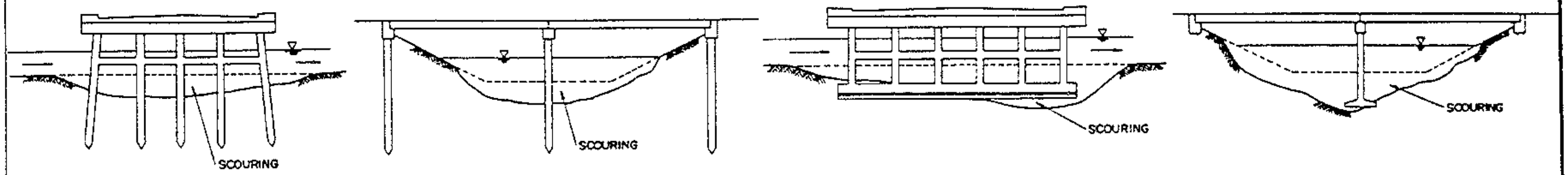
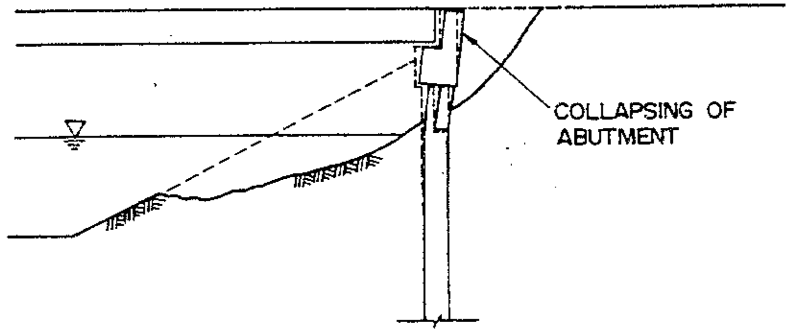
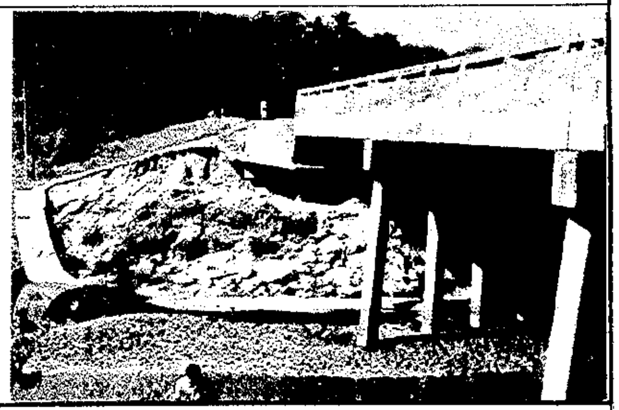


Table 3.2.3 Definition of Collapsing of Bridges (2)

Type of Damage	Definition	Cause
Abutment Collapsing	- The collapsing, tilting, settlement and sliding of an abutment. - The collapsing of an abutment fill slope is included.	- The collapsing, tilting and sliding of an abutment occurs due to the loss of lateral resistance caused by the scouring of an abutment fill slope, etc. - The settlement of an abutment is caused by the loss of bearing capacity of a foundation due to scouring.





Type of Damage	Definition	Cause
Scouring of Approach Road	- From partial scouring to the total collapse of an approach road.	- The river flow collides with the approach road due to the diversion of the river channel.

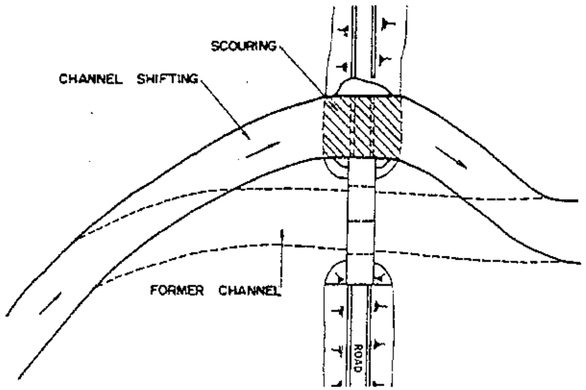


Table 3.2.3 Definition of Collapsing of Bridges (3)

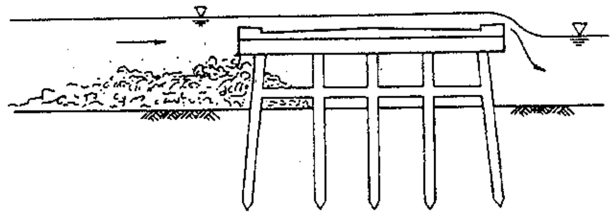
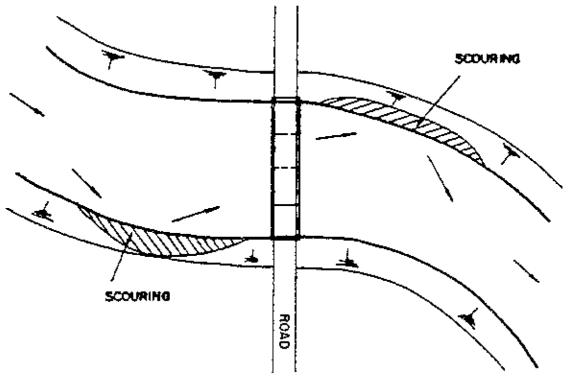
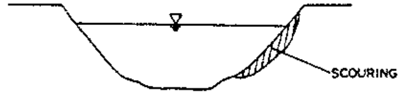
Type of Damage	Definition	Cause
Overflow of Bridge	- The water level of a river rises above a bridge's deck level with no damage to the bridge.	- The elevation of bridge girders is not high enough. - Obstacles downing up a river near or at a bridge crossing.
		
Scouring of River Bank	- From partial scouring to the total collapsing of a river bank.	- Scouring by high velocity river flows; in particular, the outside bank at bends is likely to be scoured due to higher velocity flows caused by the power of inertia.
	 	

Table 3.2.4 Definition of Collapsing of Embankment Roads

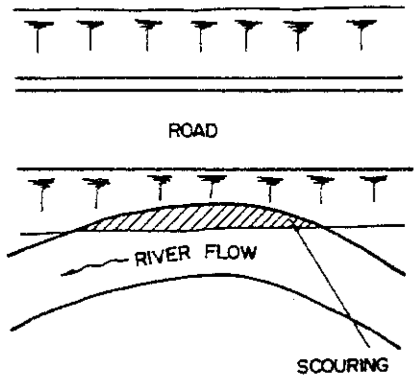
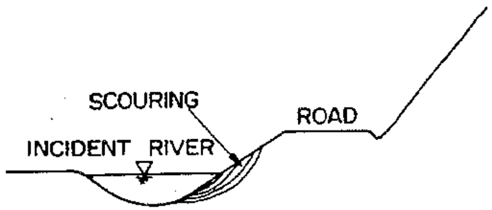
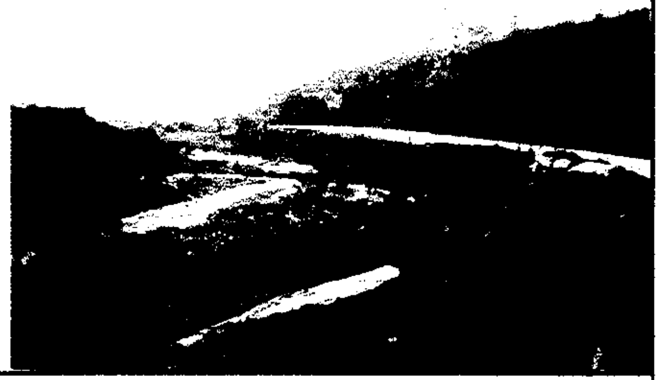
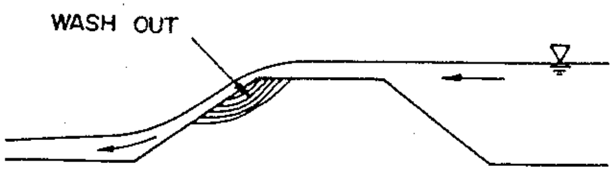
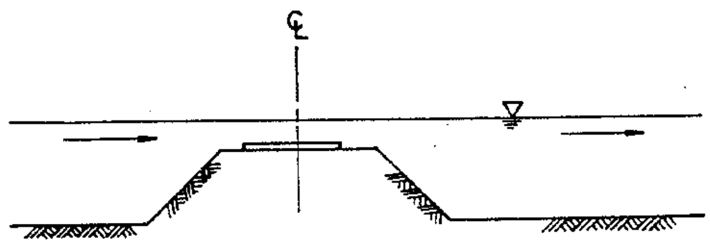
Type of Damage	Definition	Cause
Scouring of Embankment Slope	- From the partial scouring of an embankment slope to the total collapse of an embankment.	- Rapid water flows in parallel with the side of an embankment. - At the time of flooding, the portion of an embankment adjacent to a drainage opening is likely to be damaged by the above-mentioned water flows.
	 	
Washing Out of Shoulder	- Washing out of embankment shlulder on downstream side.	- When flood waters overflow an embankment, the downstream side of an road embankment is where the water flow is at its maximum velocity and is therefore the most vulnerable spot.
		

Table 3.2.5 Definition of Road Flooding

Type of Damage	Definition	Cause
Inundation	- Submergence of road surface with no damage to the road's embankments.	- Elevation of the road surface is insufficient.
		

In addition, a set of criteria shown below was established. In selecting project roads at the final screening stage, conformity to the criteria was checked for each project road.

(1) Criteria with respect to the development of a road damage prevention and restoration plan (technical)
- Exhibits a past history of frequent and long traffic interruptions due to road damage
- Exhibits a wide variety of road damages
- Possesses a high potential for future damage
- Has a wide variety of physical conditions

(2) Criteria with respect to the importance of a road as part of the highway network (socioeconomic)

- Ensures uninterrupted traffic flow along a trunk road with high traffic volume
- Improves communications between urban centers
- Ensures access in emergencies
- Provides access to areas of tourist interest
- Serves the interests of minorities
- Conforms to the priorities of the 7th National Highway Development Plan

As a result of screening, a total of eight project roads were chosen: four project roads from the North and four from the South, as illustrated in Fig.3.3.2 and Fig.3.3.3. All the project roads are for repair work and not preventive work.

3.4 DAMAGED ROAD SPOTS FOR THE STUDY

The eight project roads contain 192 damaged spots that were taken up by the Study. Preliminary designs and cost estimates were carried out for 38 of the spots, while the cost for restoration work was estimated for the remaining 154 spots.

A summary of the damaged spots for the Study is tabulated in Table 3.4.1.

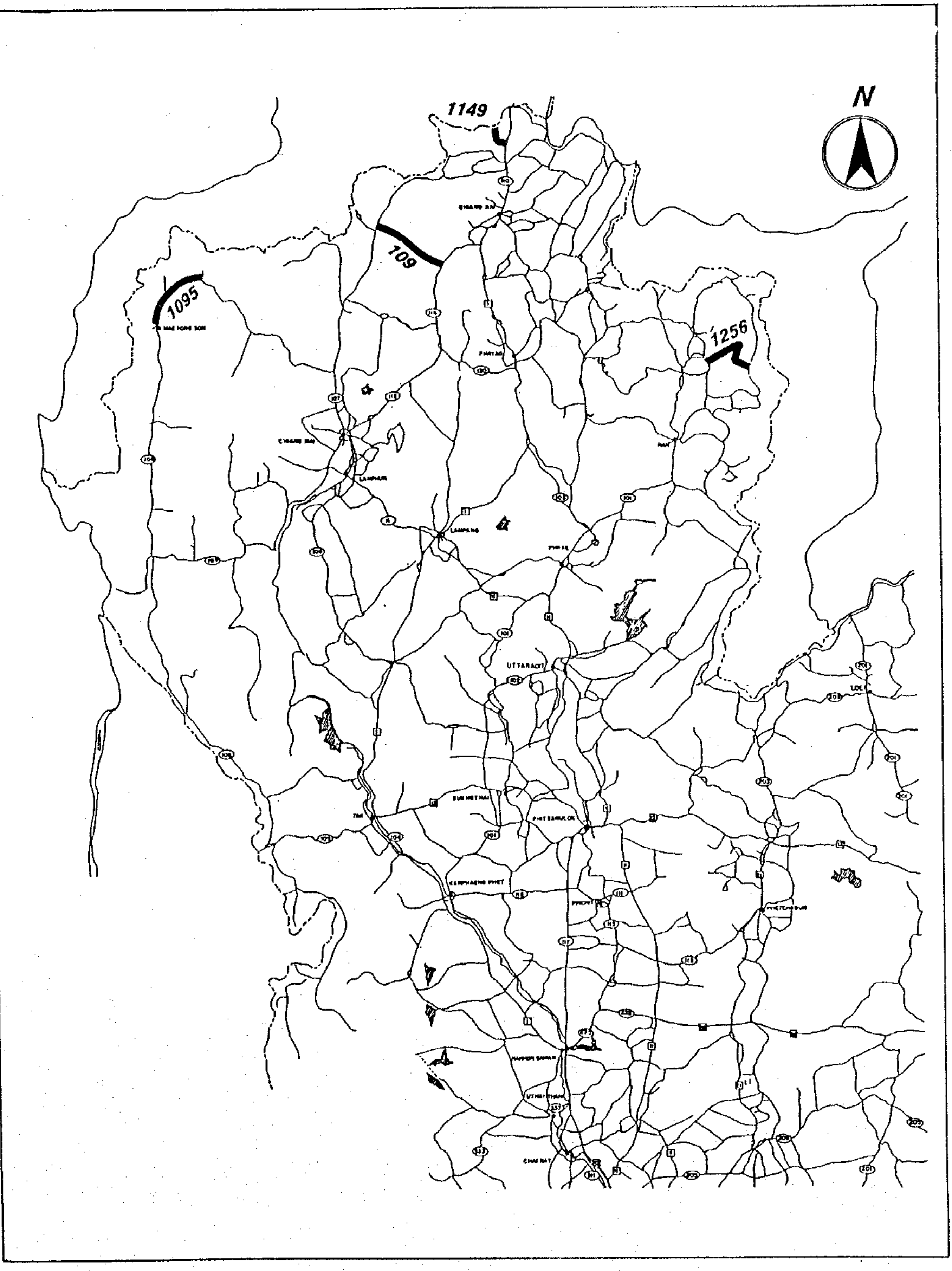


Fig. 3.3.2 Project Roads in the North

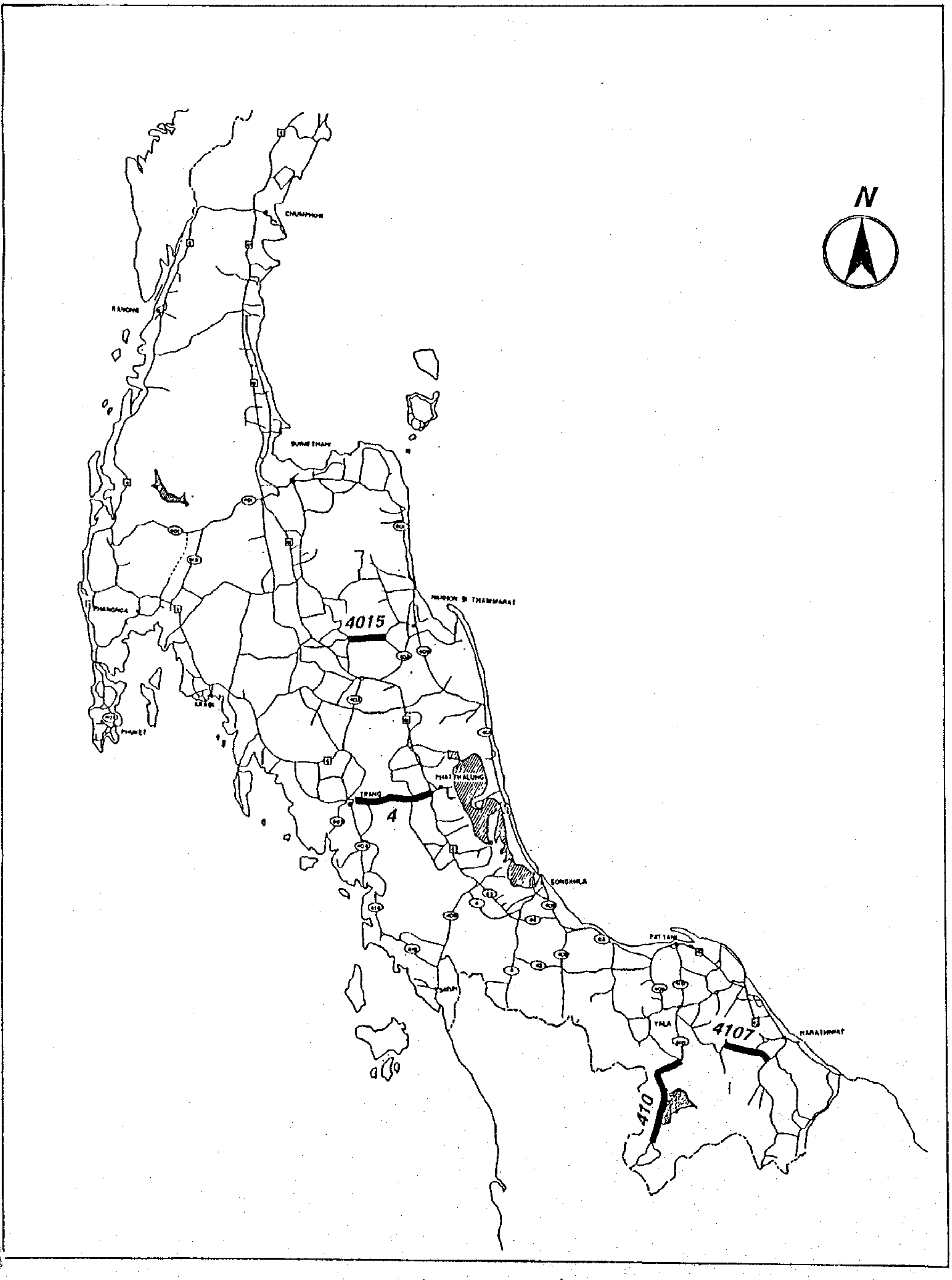


Fig. 3.3.3 Project Roads in the South

Table 3.4.1 Summary on Damaged Spots for the Study

Route No.	Project Road Length (km)	Number of Spots for Cost Estimation			Number of Spots by Type of Damage			
		No. of spots for prelimi-nary design	No. of spots estimated cost only	Total	Slope Damage	Collapsing of Bridges	Collapsing of Embankment Roads	Road Flooding
109	72.86	3	10	13	12			1
1095	55.30	4	41	45	45			
1149	14.80	2	10	12	12			
1256	46.89	12	35	47	44	2		1
4	52.95	3	5	8	6	2		
410	79.91	6	51	57	56			1
4015	23.88	5	2	7		5	2	
4107/ 4158	32.05	3	0	3		3		
Total	378.64	38	154	192	175	12	2	3

CHAPTER 4 FEASIBILITY STUDY

4.1 TECHNICAL SURVEY

Three technical surveys on traffic, geotechnical conditions and topographical characteristics were carried out on the project routes as described below.

1)Traffic survey and traffic demand forecast

A traffic count survey was carried out at five locations to determine the present average daily traffic volume and the distribution of vehicle categories in the traffic flow on the project routes.

Future traffic volumes on project routes are a main output of the economic evaluation process for the project. To forecast these volumes, a future socioeconomic framework was established, as described in the previous section,in which predictions of the future population and economic indicators were carried out. In this traffic forecasting procedure, the methodology applied utilizes the expected growth in population and economic indicators to estimate the traffic growth rates for each of the project routes. The applied methodology can be simplified as in the flow chart presented in Fig.4.1.1.

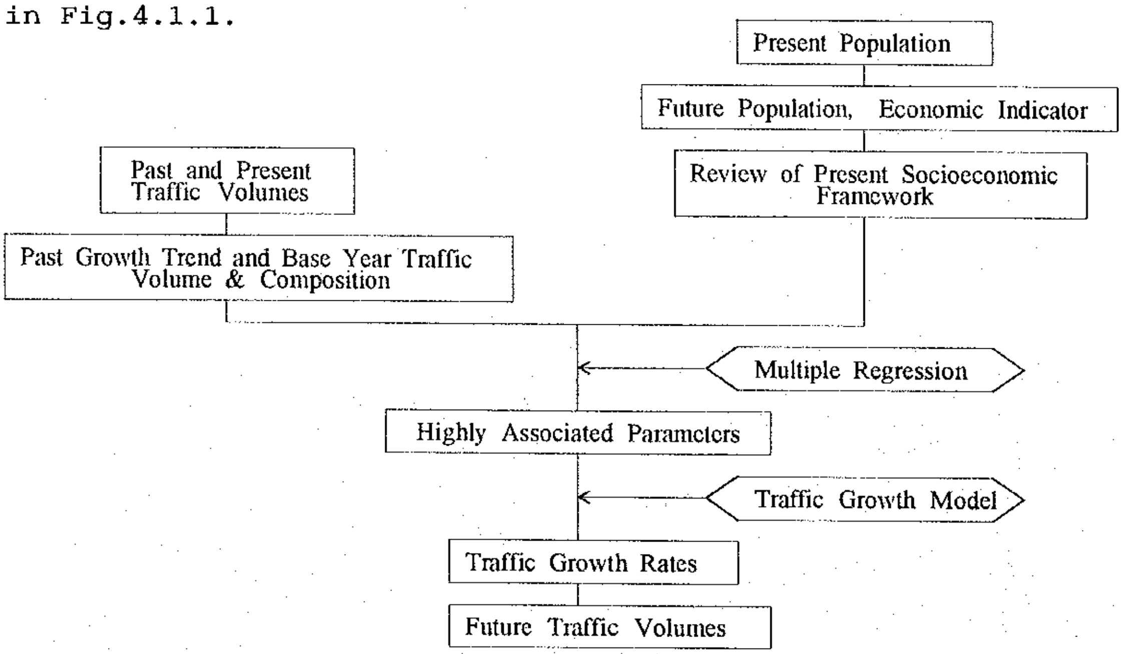


Fig.4.1.1 Forecasting of Future Traffic Demand

2)Geological survey

Geological surveys, which consisted of drilling and laboratory testing, were carried out for nine selected landslide spots to be used for the analysis and detailed study of landslides.

3)Topographic surveys

Plane table surveys were carried out to obtain geographical information on damaged spots for slopes (8), for roads (1), and bridges (4).

Cross-section surveys were carried out to obtain river profile information to aid in the study of remedial measures against bridges collapsing at four bridge sites.

4.2 PRELIMINARY DESIGN

Preliminary designs were carried out for 38 of the spots on the eight project roads. The 38 spots were broken down by type of damage and are shown in Table 4.2.1.

Table 4.2.1 Types of Damage for Preliminary Design

Categories of Roadway Damage	Type of Damage	No. of Spot for Preliminary Design	Route No.
Slope Damage	Sheet erosion on slope	1	1256
	Gully erosion on slope	4	109, 1149, 1256, 410
	Rockfalls due to undercutting	4	109, 1095, 1256, 410
	Landslide on cut slope	12	109, 1095, 1095, 1095, 1149, 1256, 1256, 1256, 4, 410, 410, 410,
	Landslide on fill slope	3	1256, 1256, 1256
	Sub-total	24	
Collapsing of Bridge	Abutment scouring	5	1256, 4, 4015, 4015 4015
	Erosion of approach road	2	4015, 4107
	Overflow	1	4058
	Scouring of river bank	2	1256, 4
	Sub-total	10	
Collapsing of Embankment Road	Scouring of embankment slop	1	4015
	Washing out of shoulder and embankment slope	1	4015
	Sub-total	2	
Road Flooding	Overflow on at-grade road	1	1256
	Road burial by debris flow	1	410
	Sub-total	2	
	Total	38	

Typical examples of damage, such as slope damage, the collapsing of a bridge and the collapsing of an embankment road, are shown in Fig.4.2.1-Fig.4.2.6 with a few sketches and a photo for each.

In the Study, repair work for road damage is divided into three categories: urgent repair work, temporary repair work, and permanent repair work. Since all the selected spots have already received urgent repair work, the preliminary design handled temporary repair work and permanent repair work. All types of repair works are defined as below.

Urgent Repair Work

The main objective of urgent repair work is to reopen as soon as possible a road section closed to traffic after the detection of the damage using a makeshift measure.

Temporary Repair Work

If permanent repair work is considered to be an over investment at present, temporary repair work with a lifetime of more than 5 years shall be carried out as a makeshift measure.

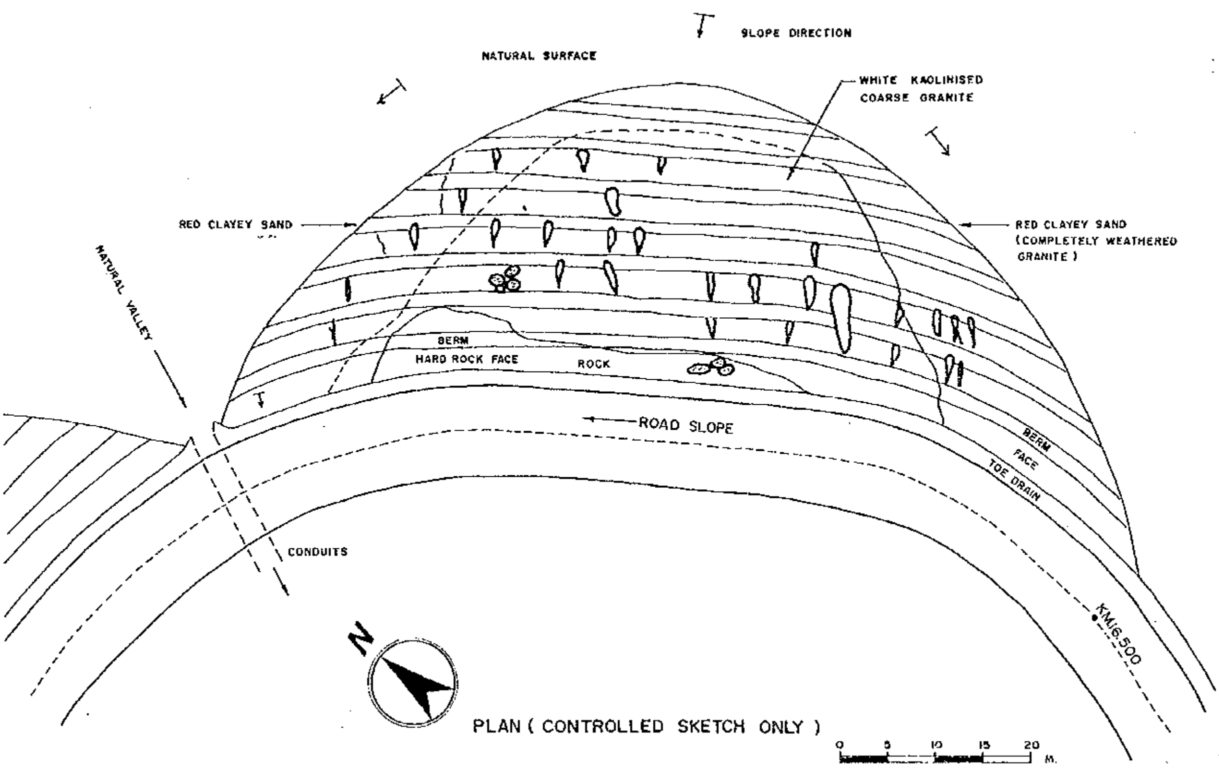
Temporary repair work shall be applied in the following cases:

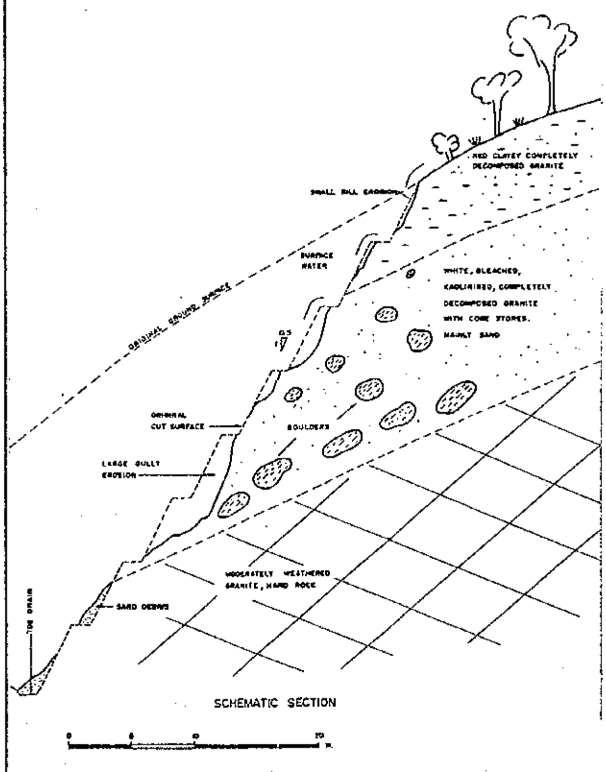
- When a detour route, which does not result in a large increase in traveling time, is available;
- For road sections with a low traffic volume that does not justify the higher repair costs of permanent repair work; and
- When further damage is not anticipated in the near future.

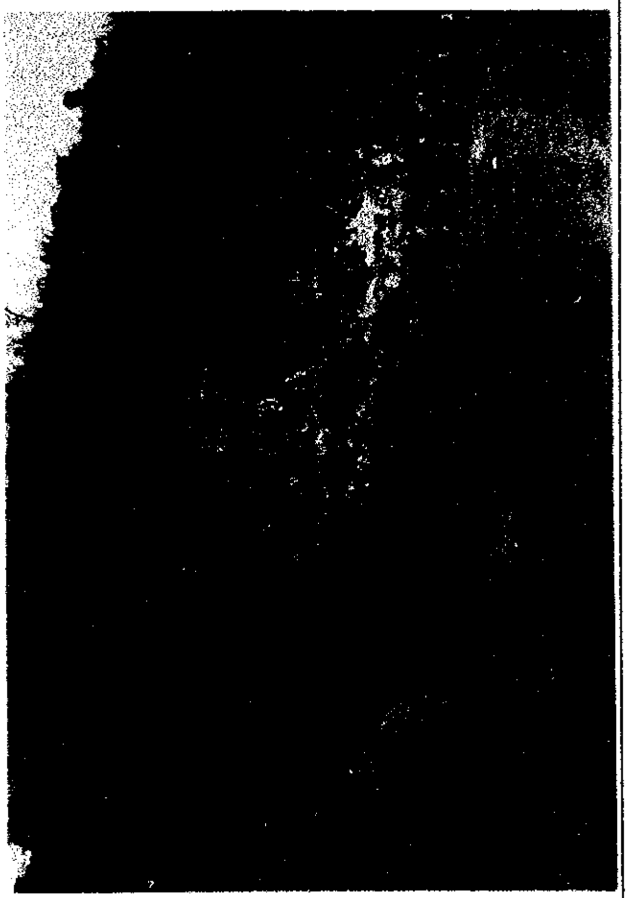
Permanent Repair Work

Permanent repair work shall be applied in the following two cases:

- When the lifetime of a temporary repair job is about to expire; and
- When the damaged spot is located in an important part of the road network that will produce adverse socioeconomic consequences if not permanently repaired.

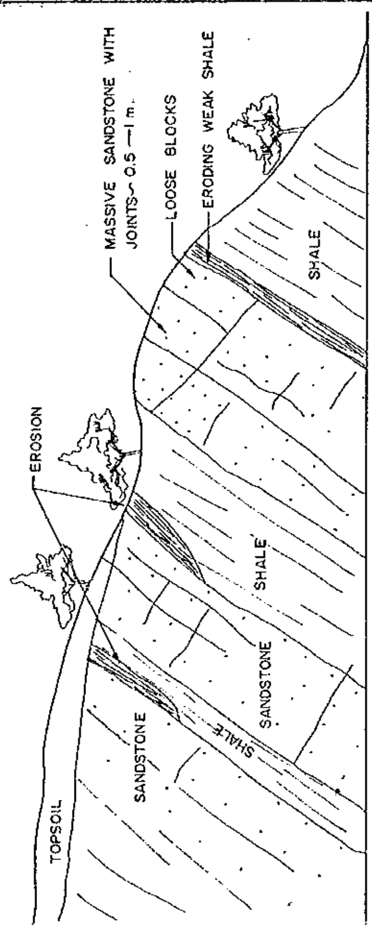




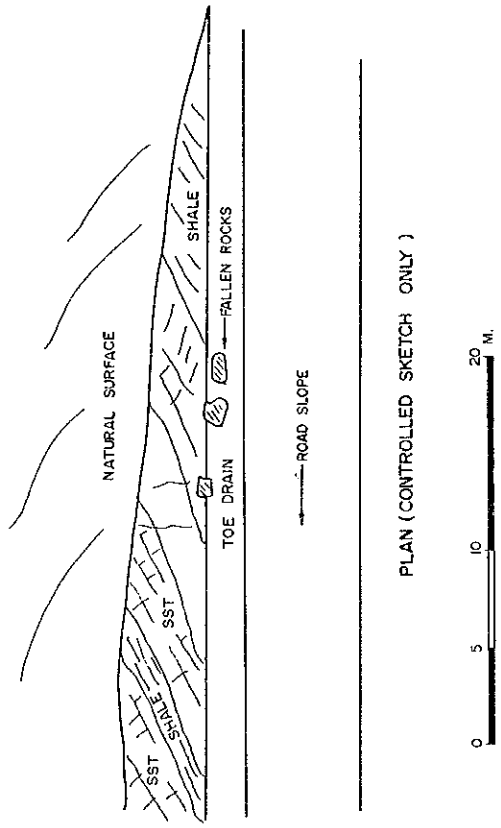


SPOT 109/2 KM. 16.500
EXISTING CONDITIONS

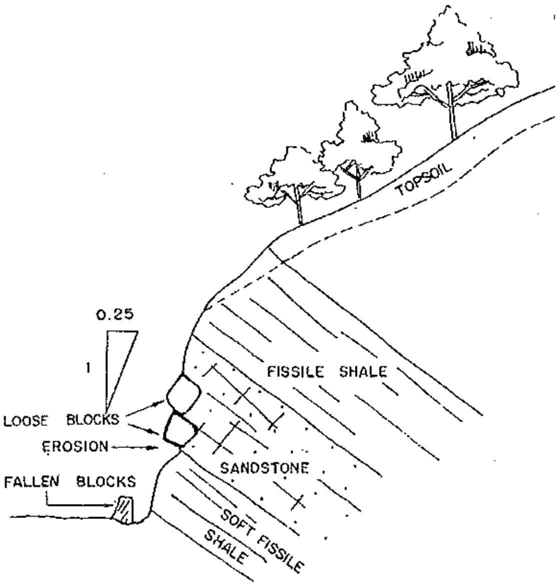
Fig. 4.2.1 Details of Damage Spot



ELEVATION

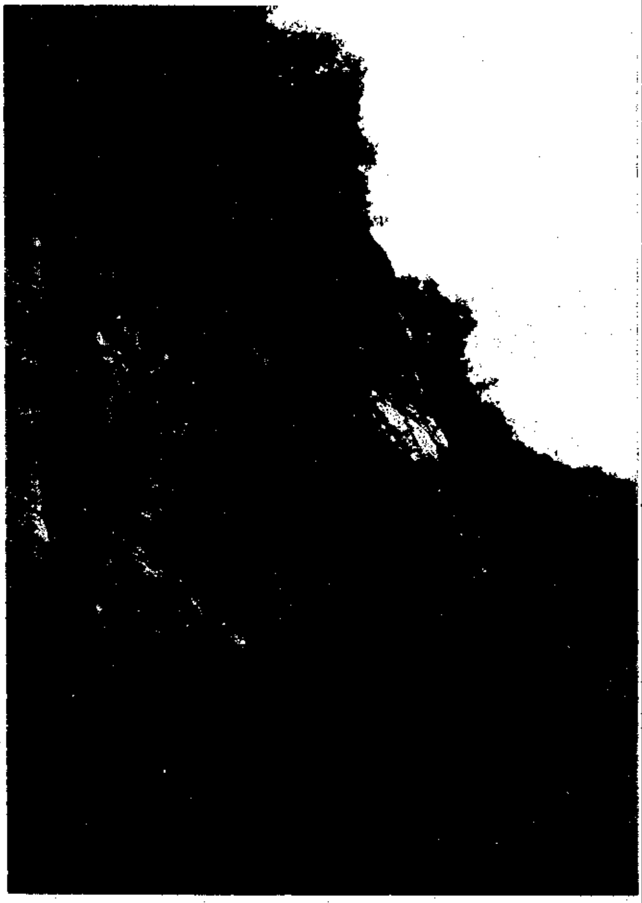


PLAN (CONTROLLED SKETCH ONLY)



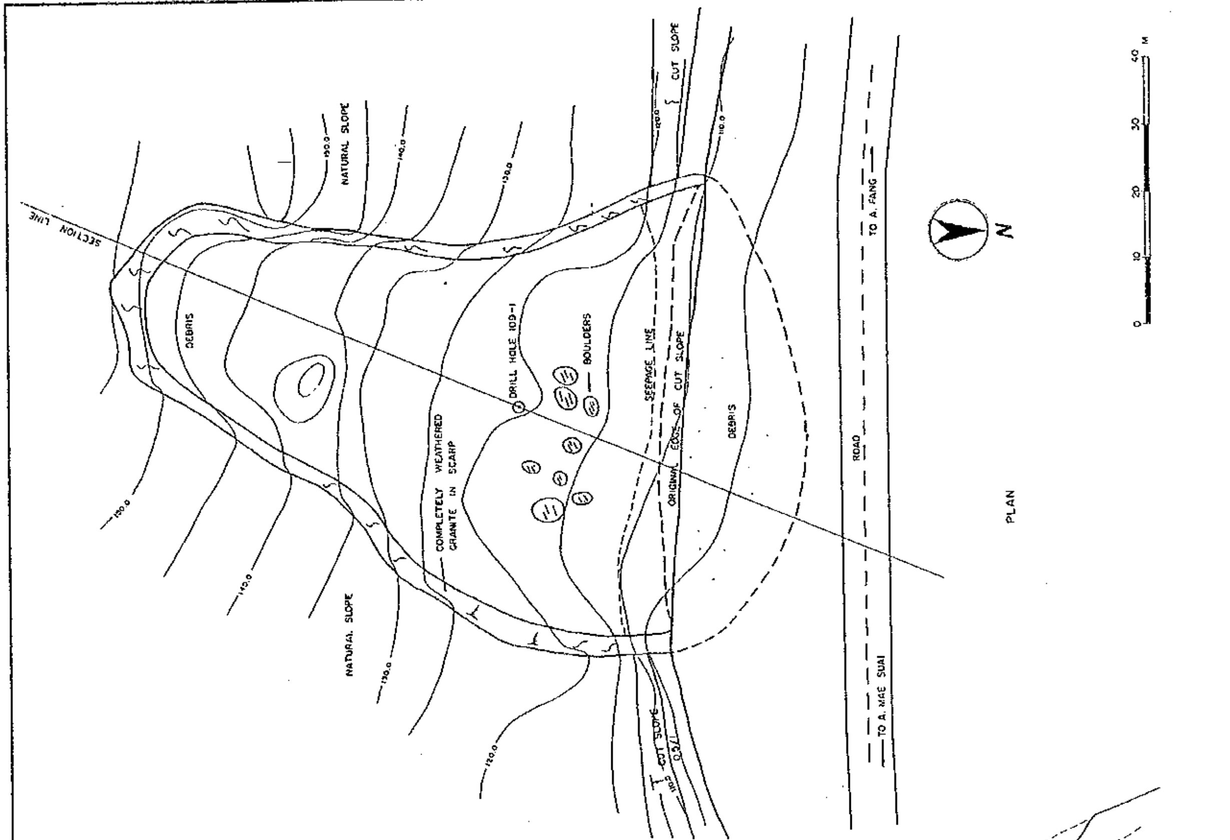
SCHEMATIC SECTION

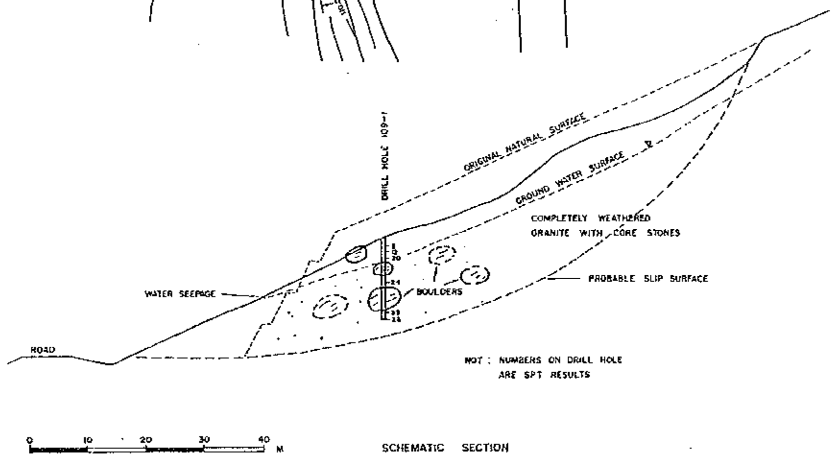
0 5 10 20 M.



SPOT 1256/10 KM. 44.600
EXISTING CONDITIONS

Fig. 4.2.2 Details of Damage Spot





SPOT 109/3 KM. 24.65
EXISTING CONDITIONS

Fig. 4.2.3 Details of Damage Spot

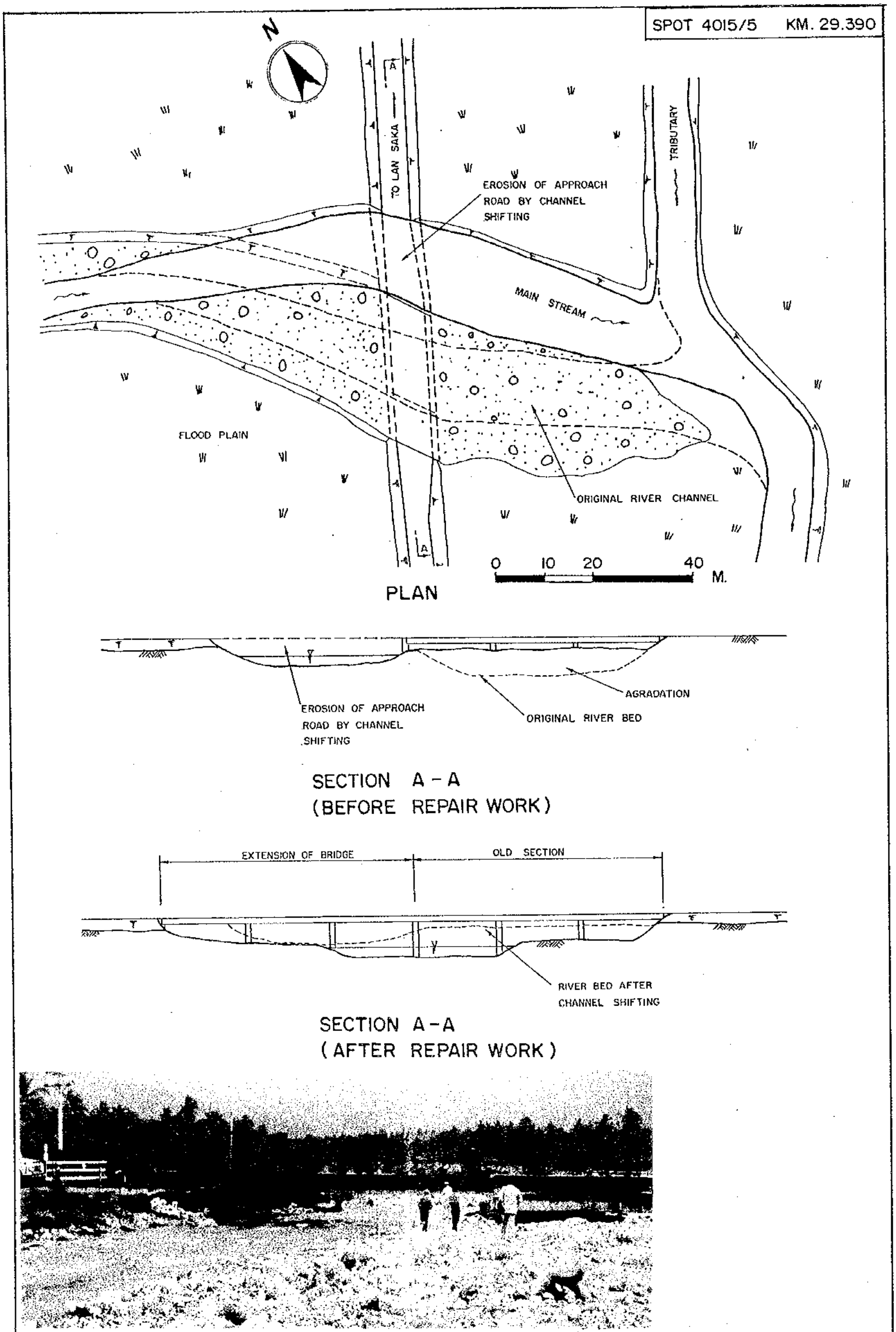


Fig. 4.2.4 Details of Damage Spot

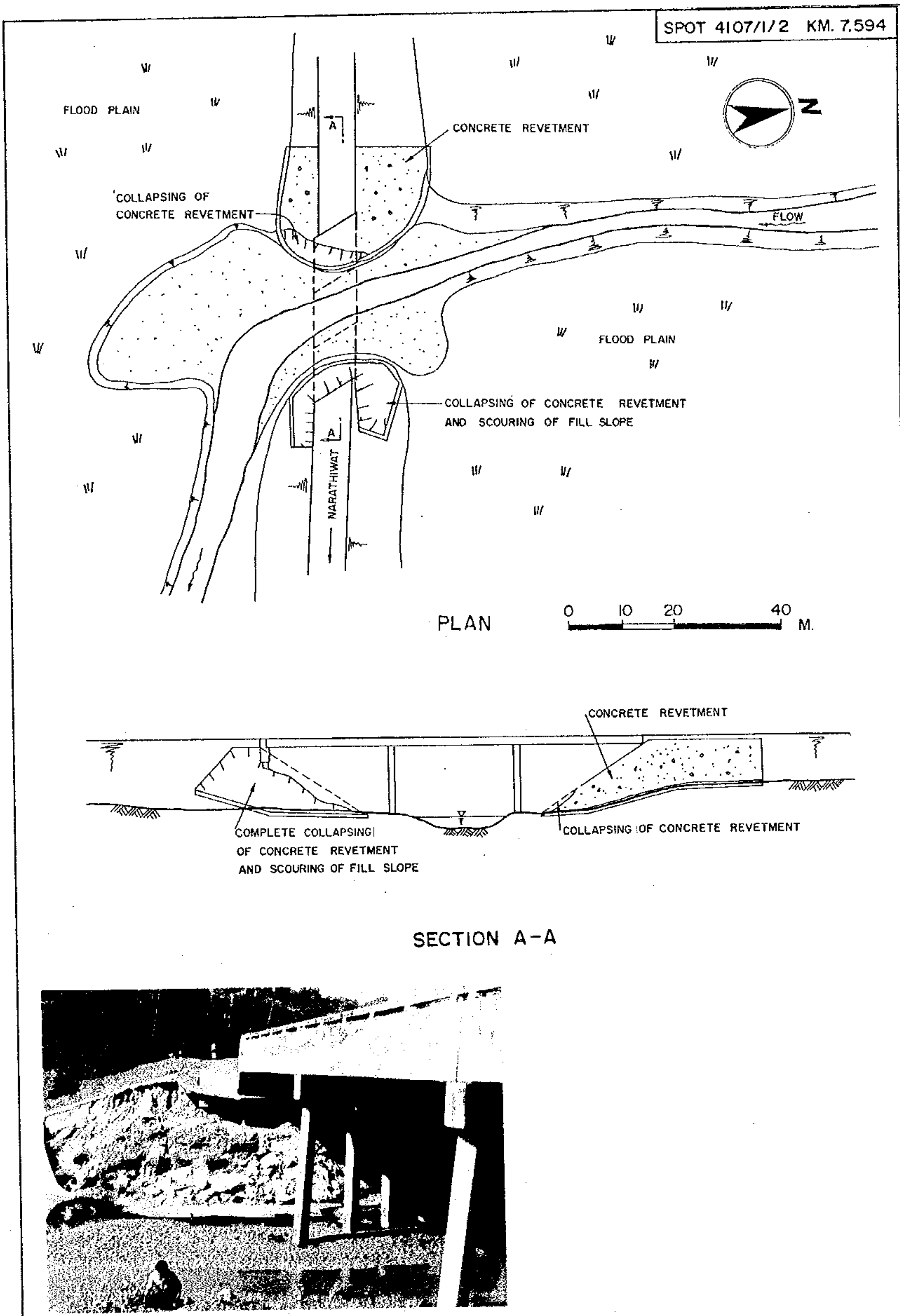


Fig. 4.2.5 Details of Damage Spot

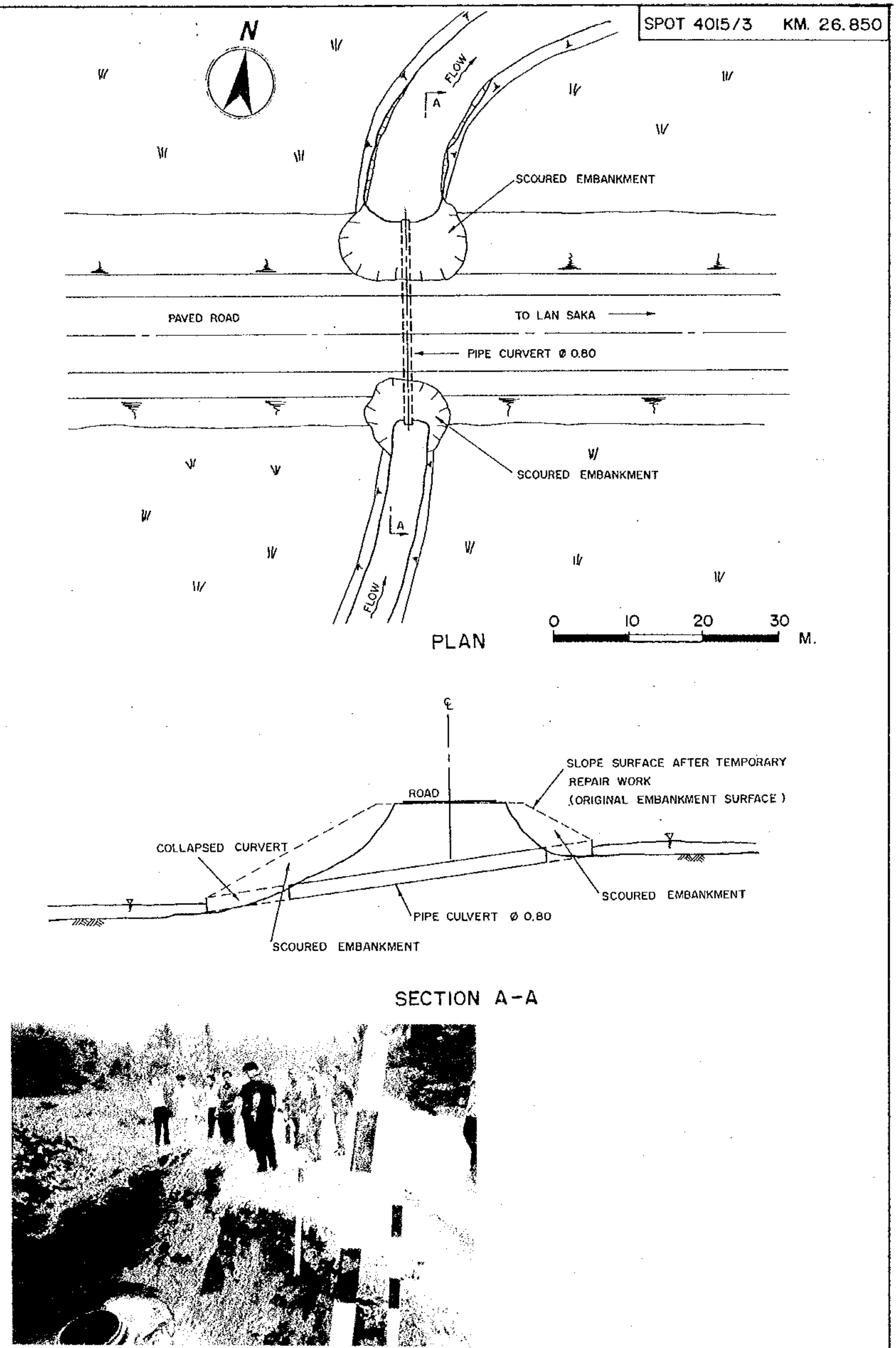


Fig. 4.2.6 Details of Damage Spot

Regarding restoration measures, various types of measures were listed up for various types of damage. Then, the most suitable measures were decided for each damaged spot via a preliminary design based on the concepts below.

- Be effective in eliminating the cause of damage.
- Be effective in resisting the forces that produce damage.
- Be easy to implement.
- Be cost effective.
- Be environmentally friendly.

The selected restoration measures are summarized in Table 4.2.2.

It is suggested that the materials and equipment used in restoration work should basically be procured from suppliers or contractors when the restoration work is carried out.

4.3 PROJECT COST

Project cost consists of construction cost, engineering cost and compensation cost. Construction cost is composed of real construction cost (90 %) and physical contingency costs (10%). The engineering cost was estimated as 10% of construction cost.

As for land acquisition cost, it is calculated based on the following conditions: 1) the right-of-way boundary is defined using DOH road inventory data, and 2) The area damaged by a landslide belongs to DOH.

The total project costs for the eight project roads is tabulated in Table 4.5.1.

4.4 PROJECT EVALUATION

Economic Evaluation

In the economic evaluation for each project road, a microeconomic approach was applied. The basic procedure is based on the analysis of both the costs, which are required to implement and maintain the project, and the benefits, which are gained after completing the project.

Table 4.2.2 (1) Applied Restoration Measures

Spot No.	Type of Damage	Temporary Measure	Permanent Measure
109 - 1	Rockfalls due to Undercutting	- Removal of Boulder - Crest ditch	- Refilling with Compaction - Surface Drainage - Vegetation
109 - 2	Gully Erosion	- Vegetation	- Recutting - Cribwork with Vegetation
109 - 3	Landslide on Cut Slope	——	- Horizontal Drain Hole - Removal of Unstable Scarp - Vegetation - Surface Drainage
1095 - 1	Landslide on Cut Slope	——	- Removal of Slide Debris and Unstable Scarp - Surface Drainage - Vegetation
1095 - 2	Rockfalls due to Toppling	——	- Removal of Unstable Rocks - Rockfall Prevention Net - Crest Ditch
1095 - 3	Landslide on Cut Slope	——	- Horizontal Drain Hole - Removal of Unstable Scarp - Surface Drainage
1095 - 4	Landslide on Cut Slope	——	- Removal of slide debris and Unstable Debris - Crest Ditch - Vegetation
1149 - 1	Landslide on Cut Slope	——	- Horizontal Drain Hole - Removal of Unstable Scarp - Surface Drainage - Vegetation
1149 - 2	Gully Erosion	- Crest Ditch	- Refilling with Compaction - Vegetation
1256 - 1	Inundation	——	- Raising of Roadway Elevation - Enlargement Cross-sectional Area of Culvert
1256 - 2/3	Abutment Collapsing Scouring of River Bank	- River Bed Revetment - Dumped Rock	- Concrete Revetment - Stone Riprap with Mortar
1256 - 4	Gully Erosion	- Crest Ditch	- Refilling with Compaction - Vegetation
1256 - 5	Landslide on Fill Slope	- Gabion Mat	- Shifting of Alignment
1256 - 6	Landslide on Cut Slope	- Removal of Unstable Scarp and Slide Debris - Vegetation - Crest Ditch	- Horizontal Drain Hole - Surface Drainage
1256 - 7	Landslide on Cut Slope	——	- Removal of Unstable Scarp and Slide Debris - Crest Ditch - Vegetation
1256 - 8	Landslide on Fill Slope	——	- Shifting of Alignment

Table 4.2.2 (2) Applied Restoration Measures

Spot No.	Type of Damage	Temporary Measure	Permanent Measure
1256 - 9	Sheet Erosion	——	- Crest Ditch - Shotcrete Work - Removal of Unstable Materials
1256 - 10	Rockfalls due to Undercutting	- Removal of Unstable Rocks - Shotcrete Work	- Recutting - Concrete Barrier - Rockfall Prevention Net
1256 - 11/12	Landslide on Cut Slope	- Removal of slide Debris	- Shift of Alignment
4 - 1	Landslide on Cut Slope	——	- Removal of Unstable Scarp - Horizontal Drain Hole - Surface Drainage
4 - 2/3	Abutment Collapsing Scouring of River	——	- Concrete Revetment - River Bed Protection - Stone Riprap Revetment
410 - 1	Road Burial by Debris Flow	——	- Enlarge net Cross-sectional Area of Culvert - Removal of Debris
410 - 2	Landslide on Cut Slope	- Gabion Mat - Crest Ditch - Vegetation	- Horizontal Drain Hole
410 - 3		——	- Removal of Unstable Scarp - Gabion Mat - Crest Ditch - Vegetation
410 - 4	Rockfalls due to Toppling	- Removal of Unstable Rocks	- Concrete Barrier
410 - 5	Gully Erosion	——	- Crest Ditch - Toe Ditch
410 - 6	Landslide on Cut Slope	——	- Removal of Slide Debris - Concrete Barrier - Vegetation - Surface Drainage
4015 - 1	Abutment Collapsing	——	- Guide Dike - Concrete Revetment - River Bed Revetment
4015 - 2	Wash Out of Embankment	——	- Enlargement Cross-sectional Area of Culvert - Improvement of Inlet and Outlet
4015 - 3	Scouring of Embankment Slope	——	- Enlargement Cross-sectional Area of Culvert - Improvement of Inlet and Outlet
4015 - 4	Abutment Collapsing	——	- Concrete Revetment - Extension of Protection - River Bed Revetment
4015 - 5	Scouring of Approach Road	——	- Channel Dredging - Concrete Revetment - Stabilize the Stream Bank
4107 - 1/2	Abutment Collapsing Scouring of Approach	——	- Concrete Revetment - River Bed Revetment - Extension of Protection
4058/1	Overflow	——	- Raising of Roadway Elevation

The benefits in the case of the "with project" are defined as the savings in extra costs that are needed in the "without project" case if the project is not implemented. Costs and benefits are divided into direct costs/benefits, which are evaluated on a monetary basis, and indirect costs/benefits, which are assessed in terms of project impact. The cost and benefit streams are generalized as follows:

Cost Stream	Benefit Stream
* Direct Costs	* Direct Benefits
- Construction	- Detour-Cost Savings
- Maintenance	- Travel-Time Savings
- Compensation	- Annual Restoration Work Savings
* Indirect Cost	* Indirect Benefits
- Taxes	- Socioeconomic Activities
	- Transport Facilities
	- Safety

Project construction cost was estimated for all spots on the project roads at the current market prices of 1994. Maintenance cost in this analysis was set as an average percentage of the total economic construction cost based on similar DOH projects.

The direct economic benefits of roads are calculated as savings in vehicle operating costs (VOC) and in travel time. Without implementing the project, urgent repair work would have to be carried out every time there was a natural disaster. These savings were estimated and added to the benefit stream of each project road depending on the road length subject to damage.

To estimate the benefits of each project road, a traffic interruption pattern was established based on the road damage data and past records. The average annual number of days that traffic was interrupted for each project road was established for the two cases of full and partial closure (one lane is secured for traffic).

The cost/benefit cash flow was established to calculate the economic indicators of the benefit/cost ratio (B/C), internal rate of return (IRR) and net present value (NPV).

Technical Evaluation

In addition to recommending methods for road damage repair and/or restoration, some new technologies for Thailand are introduced by the Study and they are as shown below.

Damage Type	Countermeasure
Slope Erosion	Cribwork Cribwork with vegetation
Rockfalls	Prevention net Prevention fence Rockfall barrier Rock bolt Structural support
Landslide	Horizontal drain hole
Road Collapsing	Trestle work

These countermeasures are expected to improve DOH's performance in preventing damage to roads.

In addition, the Study examined environmental problem caused by repair work, and it chose environmentalally friendly measures in particular for repairing slope damage. That is to say, most shotcrete work is replaced by hydroseeding work or by cribwork with vegetation to eliminate slopes that are unsightly and environmentally damaging.

For bridge-related damage, the securing of reasonable waterway openings is the most important concept in improving the existing conditions.

Overall Evaluation

The main results of the economic evaluation are shown in Fig.4.4.1. Rt.109 and Rt.1256 in the North have IRR values lower than 12%, which is the official discount rate of the NESDB (National Economic and Social Development Board) in Thailand, while all the southern project roads have high IRR values.

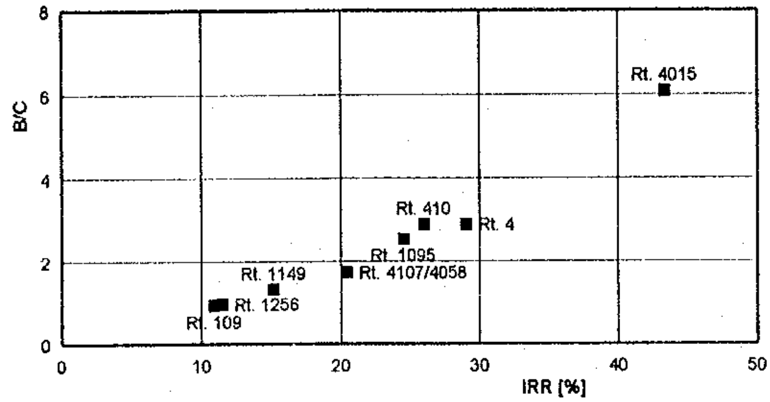


Fig.4.4.1(1) Economic Evaluation of Project Roads

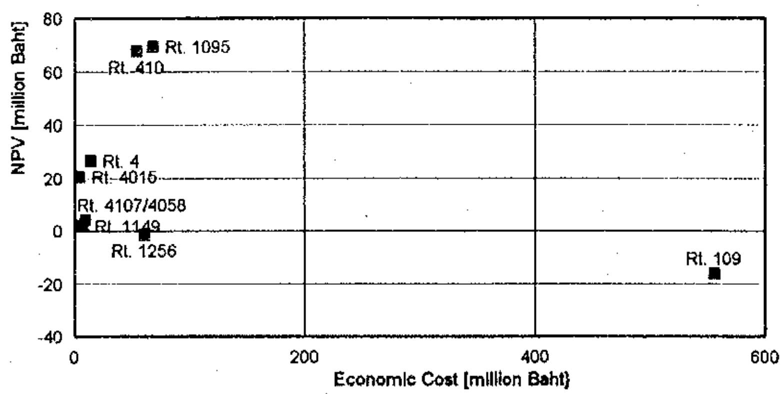


Fig.4.4.1(2) Economic Evaluation of Project Roads

A summary of the results of the economic analysis are presented in Table 4.4.1. Six of the eight projects are economically feasible in monetary terms, even after accounting for a 10% increase in cost and a 10% decrease in benefits via sensitivity analysis.

The required repair works are also expected to produce benefits that are non-monetary (i.e., indirect benefits).

Table 4.4.1 Summary of Economic Indicators

Rt. No.	Economic Const. Cost [1,000 B]	B/C	Economic Indicators IRR %	NPV [1,000 B]
109	555,444	0.933	10.90	- 16,970
1095	68,980	2.541	24.48	69,325
1149	7,309	1.329	15.23	2,057
1256	60,549	0.963	11.51	- 1,334
4	15,485	2.886	29.07	26,608
410	53,480	2.893	25.97	67,717
4015	4,702	6.081	43.36	20,566
4107/4058	9,868	1.729	20.43	4,256

The implementation of repair work will produce the following results:

- Promotion of social and economic activities.
- Elimination of the risks and costs associated with damages.
- Improvement of the environment.

4.5 PROJECT IMPLEMENTATION PROGRAM

The implementation program for the proposed project roads was prepared based on following assumptions:

- All temporary repair work will be implemented in the first five years;
- Temporary repair work precedes permanent repair work by five or more years;
- Permanent repair work for high priority project roads will be implemented at an early stage; and
- Repair work for bridges and landslide will be implemented at an early stage.

Yearly disbursement for each project road is presented in Table 4.5.1. In this table, T stands for temporary repair work and P stands for permanent repair work.

Table 4.5.1 Proposal for Project Implementation Program (1)

(X 1000 Baht)

Year / Spot No.	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Project Cost
109/1		T 330					P 527				857
109/2		T 490					P 5,653				6,143
109/3	P 2,602										2,602
Others	15,100	13,682	9,800	11,526	10,663	119,504	114,273	113,060	113,060	113,060	633,728
Total	17,702	14,502	9,800	11,526	10,663	119,504	120,453	113,060	113,060	113,060	643,330
1095/1	P 3,269										3,269
1095/2	P 346										346
1095/3		P 3,186									3,186
1095/4		P 186									186
Others	5,466	13,618	7,953	6,702	18,597		5,653	13,568	527		72,084
Total	9,081	16,990	7,953	6,702	18,597	0	5,653	13,568	527	0	79,071
1149/1	P 3,133										3,133
1149/2	T 51					P 152					203
Others	3,903	210	113			204	321	335			5,086
Total	7,087	210	113	0	0	356	321	335	0	0	8,422
1256/1		P 2,849									2,849
1256/2/3	T 74					P 229					303
1256/4			T 56					P 190			246
1256/5	T 732					P 994					1,726
1256/6		T 764					P 1,775				2,539
1256/7						P 227					227
1256/8		P 1,092									1,092
1256/9						P 4,605					4,605
1256/10		T 1,150					P 959				2,109
1256/11/12	T 634					P 668					1,302
Others	1,611	5,309	6,472	5,640	9,817	4,605	9,056	3,930		6,123	52,563
Total	3,051	11,164	6,528	5,640	9,817	11,328	11,790	4,120	0	6,123	69,561

Table 4.5.1 Proposal for Project Implementation Program (2)

(X 1000 Baht)

Year / Spot No.	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Project Cost
4/1	P 3,177										3,177
4/2/3	P 4,119										4,119
Others	10,230	318									10,548
Total	17,526	318	0	0	0	0	0	0	0	0	17,844
410/1	P 723										723
410/2	T 658					P 1,058					1,716
410/3	P 530										530
410/4		T 53					P 981				1,034
410/5						P 135					135
410/6	P 3,033										3,033
Others	12,574	6,523	6,286	424	4,860	11,025	8,763	4,145			54,600
Total	17,518	6,576	6,286	424	4,860	12,218	9,744	4,145	0	0	61,771
4015/1	P 861										861
4015/2		P 594									594
4015/3			P 568								568
4015/4	P 998										998
4015/5	P 1,561										1,561
Others		431	431								862
Total	3,420	1,025	999	0	0	0	0	0	0	0	5,444
4107/1/2		P 530									530
4058/1					P 10,889						10,889
Total	0	530	0	0	10,889	0	0	0	0	0	11,419
Grand Total	75,385	51,315	31,679	24,292	54,826	143,406	147,961	135,228	113,587	119,183	896,862

CHAPTER 5 RECOMMENDATIONS

5.1 MANAGEMENT AND OPERATIONS SYSTEM TO COPE WITH ROAD DAMAGE

First, the following aspects of DOH's present management and operations system are described:

- Management and operations organization,
- Data collection system,
- Data processing system,
- Presentation of information to road users and other agencies,
- Urgent repair work system,
- Permanent repair work system

Second, DOH's demands on the present management and operations system were ascertained via a series of interviews with DOH officers.

Third, a comparative analysis was made with the Japanese system and other systems, in order to identify problems with the present management and operations system.

Last, improvements to the management and operations system were recommended. The main recommendations are described below.

1) Improvement of information collection system

To decide promptly on countermeasures for a disaster, real-time information shall be concentrated at the responsible organization (cf. Fig.5.1.1). Information shall come from other agencies and consist of such essential data as meteorological data and data on river conditions.

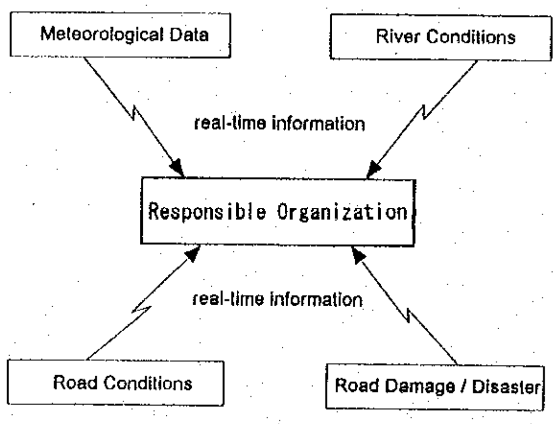


Fig. 5.1.1 Real-Time Information

2) Improvement of damage detection system

The numbers of patrol staff and cars are not sufficient for disasters. Therefore, it is essential to develop other systems to detect road damage and inform the responsible sections of DOH instead of the patrolling staff. For this reason, a road information monitoring system is recommended to collect information on damage more promptly.

The monitoring system shall be organized by designating truck drivers with regular runs or roadside residents as monitors on a contractual basis. When a monitor witnesses damage or hears of damage, he would report this to the depot or district office concerned.

3) Improvement of internal communications in DOH

In a serious disaster, it is essential to ensure certain and prompt internal DOH communications between depots and district offices, and between district offices and the head office. The following improvements are recommended to this end:

- Install a fax machine or telephone exclusively for use in disasters,
- Increase the capacity of the telephone network,
- Develop a private telecommunications network via microwave technology, satellite communications, etc.

4) Improvement of traffic control at damage sites

The numbers of depot staff and cars are not sufficient for disasters. The following improvements in traffic control at a damage site are recommended to compensate for the deficiency:

- Entrust a monitor with setting up and removing traffic signs,
- Entrust a local contractor with traffic management at a damage site, such as setting up and removing traffic signs, controlling passage, etc.

5.2 ROAD DAMAGE PREVENTION AND RESTORATION MANUAL

The Manual has eleven chapters and two appendices.

Chapter 1 explains the background, scope and organization of the Manual.

Chapter 2 provides basic information on road damage from disasters in Thailand and it includes references to geology and meteorology.

Chapter 3 classifies and defines the types of road damage.

The Prevention Manual consists of Chapters 4,5,6 and 7.

Chapter 4 describes the evaluation method for the road damage potential of existing roads by type of damage.

Chapter 5 describes the methodology of field inspections and surveys at damage prevention work sites and describes inspection and survey items and the work procedures for the different types of damage.

Chapter 6 describes the types of basic damage prevention measures for existing roads and procedures for the different types of damage.

Chapter 7 describes how to plan and design roads least susceptible to damage.

The practical use of the Prevention Manual is as shown in Fig. 5.2.1.

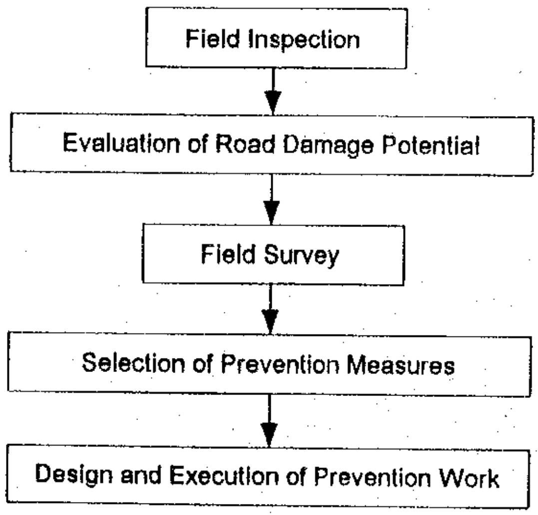


Fig.5.2.1 Usage of Prevention Manual

The Restoration Manual consists of Chapters 8,9,10 and 11.

Chapter 8 describes the methodology of field inspection work for urgent and temporary/permanent repairs and it contains inspection sheets. Survey items for such work are also presented.

Chapter 9 explains the types of urgent and temporary/permanent restoration measures, including selection procedures.

Chapter 10 describes the material and equipment for urgent repair work, and it proposes a system of procurement and arrangement.

Chapter 11 recommends a road damage detection system and communications system under the heading of "Management and Operation for Damaged Road Restoration".

The practical use of the Restoration Manual is as shown in Fig. 5.2.2.

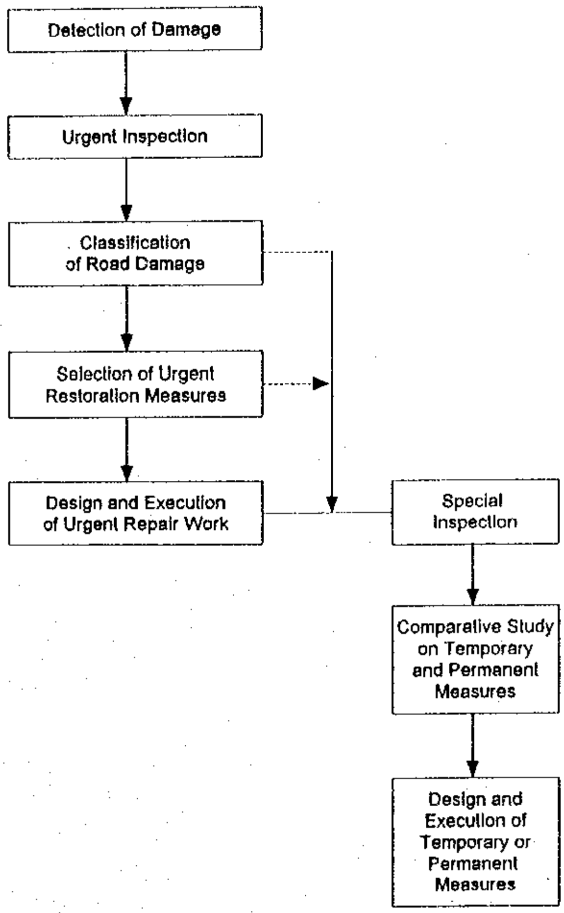


Fig.5.2.2 Usage of Restoration Manual

Appendix 1 describes the detailed methods for analysis of slope stability with respect to landslides, the stability analysis for concrete retaining walls, the hydrological analysis for drainage, etc., with sample calculations where necessary.

Appendix 2 contains the standard drawings.

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