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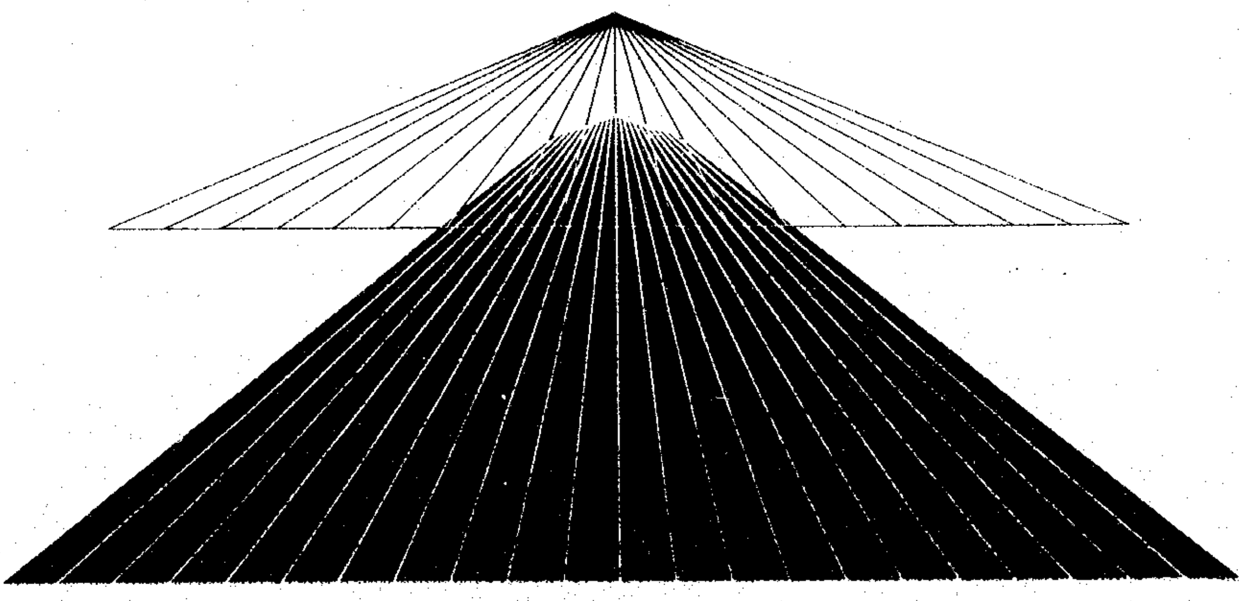
The Study on Road Disaster Prevention Plan in The Kingdom of Thailand

FINAL REPORT
MAIN TEXT

VOLUME 2



JUNE 1995

ORIENTAL CONSULTANTS
KATAHIRA & ENGINEERS INTERNATIONAL

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THE STUDY ON ROAD DISASTER PREVENTION PLAN

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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

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 kilometers as of 1991.

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

In addition, some areas in the north and the northeast of Thailand were hit by typhoon "Fred" with heavy rains from August 17th to 19th in 1991. Other than Phetchabun, 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 disasters, slopes damaged by erosion, landslides and rockfalls have also been increasing as highways are developed in mountainous regions in order to achieve a denser highway network.

Thus, the socioeconomic activities of some damaged areas were badly affected by the above-mentioned disasters, and road disaster 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 disaster prevention and road restoration have been insufficient so far. In this context, the creation of a road restoration system and disaster prevention measures are urgent issues for the highway sector in order to ensure essential transportation facilities.

1.2 Objectives of the Study

The main objectives of the first stage Study and the second stage Study are as follows:

1) to identify disaster spots for the Study;

2) to select appropriate restoration measures for said disaster spots;

3) to carry out a feasibility study on project roads that are selected from the entire DOH highway network; and

4) to facilitate technical transfer to Thai Counterparts throughout the duration of the Study.

1.3 Implementation of the Study

The Study is comprised in three stages: (1) the identification and selection of project roads; (2) the execution of a feasibility study on project roads; and (3) the drawing up of recommendations for management and for an operations system for road disasters and the preparation of a disaster prevention and restoration manual.

A general flow chart of the Study is shown in Fig. 1.3.1. The first stage of the Study commenced in December 1993 and completed in February 1994. The second stage of the Study commenced in March 1994 and then, the third stage of the Study continue for five months from November 1994 to March 1995, including preparation of the final report of the Study.

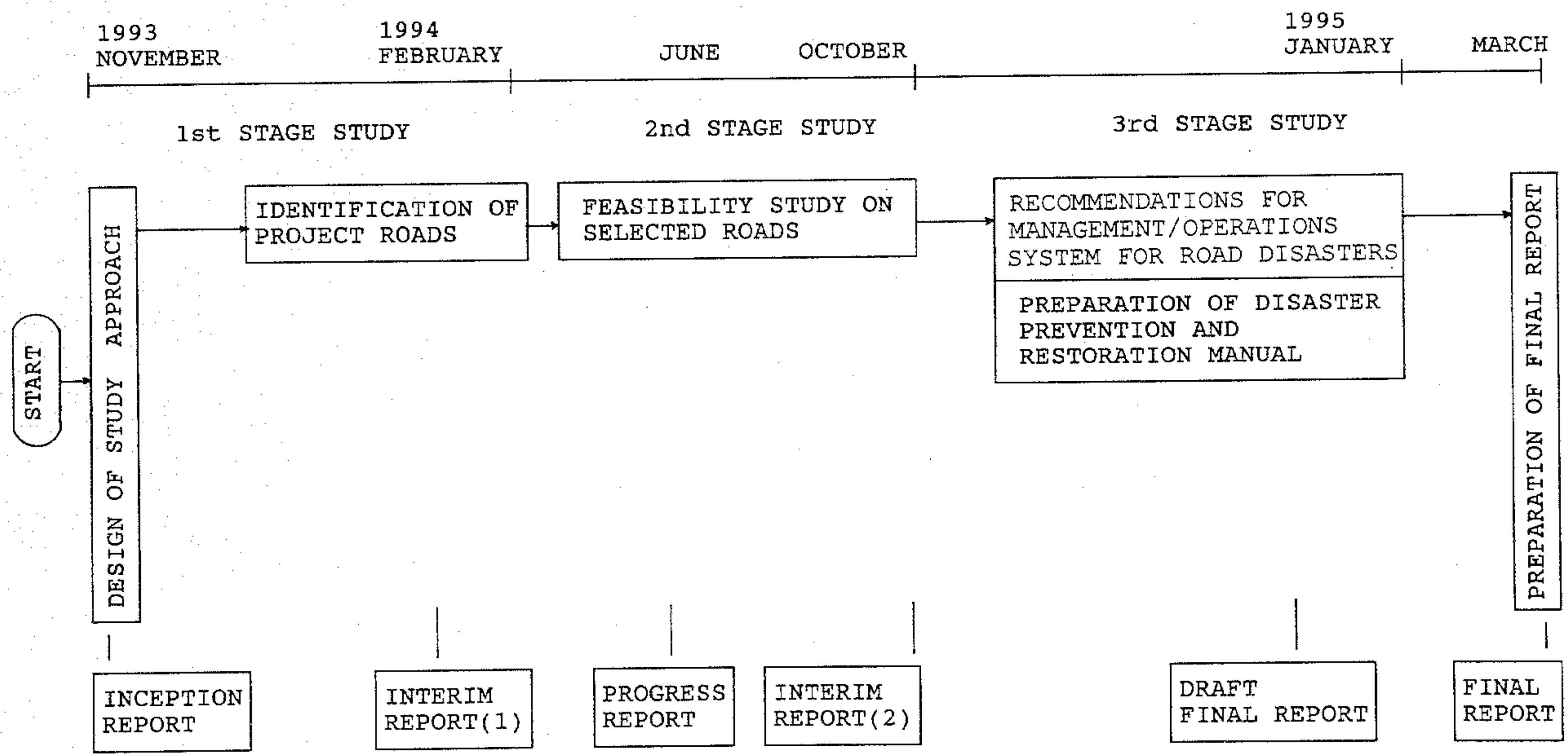


Fig. 1.3.1 General Flow Chart of the Study

PART 1

SELECTION OF PROJECT ROADS

Chapter 2

Present Situation

Chapter 2 Present Situation

2.1 Natural Conditions

2.1.1 Geology

1. Sedimentary and Metamorphic Rocks

General knowledge concerning the stratigraphic nomenclature of Thailand is as shown in Table 2.1.1 and Fig 2.1.1.

1) Precambrian

The oldest rocks in Thailand are stratigraphically dated amphibolic Precambrian gneiss, schist, and calcsilicate. They are located in the Lan Sang National Park, and in outcroppings along a western belt from Chiang Mai to Kanchanaburi, in north Prachuap Kiri Khan, and at Chonburi on the eastern coast of the Gulf of Thailand.

The Precambrian rocks are mainly metamorphosed marine sediments from continental margins. They were deeply buried and subsequently uplifted prior to the Middle Cambrian Period.

The Precambrian rocks cover a wide range of compositions from foliated granites and granitic gneiss to pegamatites. They are characterised by intense fold structures and also form the cratonic core of the Shan-Thai terrane.

2) Lower Paleozoic

Lower Paleozoic (Cambrian-Ordivician) rocks are more widespread than Precambrian rocks, but are restricted to a western belt on the Shan-Thai terrane. Cambro-Ordivician outcroppings are closely associated with the Precambrian rocks of this western belt. The total thickness of Cambrian-Ordivician sandstones and limestones reach 1,600 meters at Ko Tarutao.

The Lower Paleozoic rocks have been sudivided into two types: a lower siliciclastic (the Tarutao Group) and an upper carbonate (the Tung Song Group). Most of the lower dynamic metamorphism produced quartzite, phyllite, schist, and recrystalline limestone.

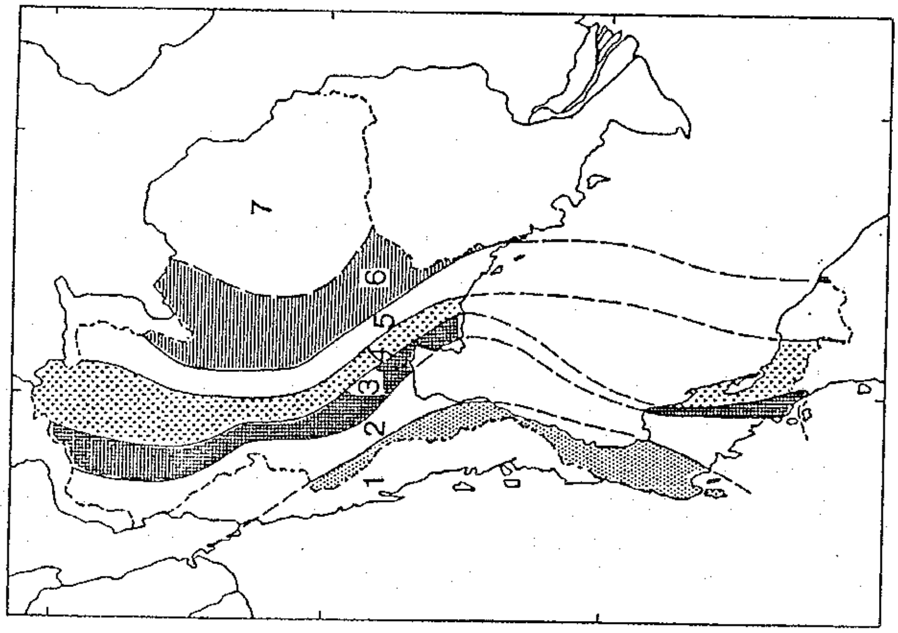


Fig. 2.1.1 Seven Stratigraphic Belts of Thailand

Table 2.1.1 Stratigraphic Nomenclature

Geo. Time		Belt 1 Upp. Peninsula	2 West, w.North, Low-Peninsula	3 Main Western Ranges	4 central North e. Low Peninsula	5 eastern North Eastern Gulf		6 Western Plateau Margin	7 Khorat Plateau
		SHAN-THAI TERRANE						INDOCHINA TERRANE	
MESOZOIC	Cret.	Chumpon Redbeds		U.Khorat G. *			NAN SUTURE	Khorat Group *	
	Jura.	Mae Moei Group *		Cratonic Area	L.Khorat Group *				
	Tria.				Lampang Group *			Lomsak, Nam Pha F.; Nam Pat F. *	
PALEOZOIC (Upper)	Perm.	Ratburi Group *			Ngao Group	Phrae & Chanthaburi Groups *		Saraburi G. * (Drilled holes)	
	Carb.	Kaeng Krachan (Phuket) G. *	Mae Hong Son F. *		Dan Lan Hoi (Mae Tha) Group *			Wang Saphung F. *	
LOWER PALEOZOIC	Devo.		Thong Pha Phum Group *		Sukhothai Group *			Pak Chom F. *	
	Silu.							Na Mo F.	
	Ordo.		Thung Song Group *						
	Camb.		Tarutao Group *						
Precambrian				Lan Sang Gneiss *					

3) Middle Paleozoic

Middle Paleozoic (Silurian-Devonian) rocks need to be considered in terms of their terrane.

The Shan-Thai terrane can be differentiated into several belts from west to east. The Thong Pha Group is a fossiliferous carbonate shelf sequence that occurs throughout the lower part of Peninsular Thailand and the southern end of the Western Mountains at Kanchanaburi. In the mountains north of Kanchanaburi, scattered remnants of metasediments can be found that could belong to this group. They were originally clastic sediments of sandstone and shale.

The Sukhothai Group can be found in the east of the Western Mountains, where the sediments are strongly deformed. This group has been further sudivided into three sedimentary facies. These are 1) the back-arc basin, 2) the volcanic-arc, and 3) the fore-arc shales, cherts, and limestones and can be found at Fang and Chiang Mai in the north and near Rayong and Yala in the south. The volcanic-arc sediments can be seen in the central north near Chiang Rai as amphibolites and mica schists and as green schist metamorphosed agglomerates and tuffs near Nakon Sawan. They can also be seen at South Narathiwat on the peninsula and they form a north-south trending zone in the Sukothai Fold Belt. To the east, the arch trench deposits are marbles and bedded cherts.

The Middle Paleozoic of the Indochina terrane block in the Loei Fold Belt contains marine sedimentary rocks of about the same age as the Sukhothai Fold Belt. The sediments appear to have formed as a simple clastic wedge from the accumulation of erosion products shed by the Indochina continent to the east. The Na Mo Formation is a sequence of low-grade metamorphic rocks in an area between Udon Thani and Loei. It consists of phyllite, chlorite and pelitic schists, metatuff, and quartzite. The Pak Chon Formation is a late Silurian to Devonian sequence outcropping mainly to the east of Loei and west of Udon Thani. The lower unit consists of shales, limestone, tuff, and chert. The upper unit can be found in the Pak Chon district and has abundant chert beds with intercalations of tuff, shale, and limestone.

4) Upper Paleozoic

Upper Paleozoic rocks can be found in the Sukhothai Fold Belt of the Shan-Thai block. The Kraeng Krachan Formation consists of pebbly mudstones in the peninsula near Phuket and in the west. To the north, the Mae Hong Son Formation is composed of chert, sandstone, and shale. The shallow marine deposits of the Dan Lan Hoi Group are comprised of sandstone, shale, greywacke,argillite, and limestone. The Phrae Formation is composed of agglomerate, conglomerate, greywacke, argillite, and limestone which are deposited as arc-trench gap facies. The Wang Saphung Formation of the Loei Fold Belt was deposited in a near shore marine environment and is comprised of sandstone and shale with limestone lenses.

The Permian karstic limestone in the peninsula and in the west are referred to as the Ratburi Group. The Saraburi Group of limestone with siliclastic interbeds occurs on the western edge of the Khorat Plateau.

5) Mesozoic

The Mesozoic sequences in Thailand have been lithologically subdivided into two main facies: the marine facies and the younger continental facies. The former contains the Triassic Lampang Group, the Upper Triassic to Jurassic Mae Moei Group and the Triassic Nam Pat Formation. The latter is recognized as the Khorat Formation ranging in age from the Upper Triassic to Cretaceous.

The marine Triassic sequences in Thailand are exposed in four main areas: in the north (Lamppang-Phrae-Nan), west (Kanchanaburi-Mae Sariang), east (Chanthaburi-Trat), and south (Phangnga-Songkhla). The Lampang Group is composed of alternating sequences of carbonates, sub-marine fan deposists and fan-delta redbeds. Deep marine Middle Triassic sediments occur in the Nan Suture zone and the Trat, Mae Sariang, and Mae Sot areas.

The continental facies (the Khorat Group) covers a large proportion of eastern Thailand and was formed in successor basins as a result of a collision between the Shan-Thai and Indochina terranes. It has a lower contact that lies unconformably on Permian and Lower Triassic strata. It has been subdivided into seven formations. In general, the group consists of beds of sandstone, siltstone, and mudstone. Some substantial evaporite deposits can be found at the Maha Sarakham Formation of this group. Dinosaur remains are found in many of its formations.

6) Cenozoic

The Tertiary basins in Thailand are mainly graben and half grabens which were developed by conjugate strike slip faults. The collision between India and the Eurasian landmass created a rotation and displacement that created these features. The Cenozoic rocks are mainly fresh-water shales and sandstones and contain lignite and oil shales. The Upper Cenozoic deposits contain mainly coarse grained deposits. Offshore Tertiary basins in the Andaman Sea and the Gulf of Thailand have potential for petroleum.

Geophysical evidence suggests that the southern section of the central basin contains about 4000 meters of sediment, where as the northern basin has up to 7000 meters of sediment.

The Quarternary deposits consist of unconsolidated fluvial sand and gravels in the terrestrial basins and the coastal marine deposits on the emergent east coast of the Malay Peninsula.

2. Igneous Rocks

Most igneous rocks in Thailand have an acidic magmatic composition in which granite and granodiorite are the most abundant intrusive and rhyolite as the most common extrusive. Basic rocks such as diorite, gabbro, and basalt are relatively uncommon.

1) Granitoids

Granite is the most common intrusive rock found in Thailand and is frequently associated with mineralisation. They have been subdivided into three north trending belts, namely, the Western, Central and Eastern Belts as illustrated in Fig 2.1.2.

The Western Belt is characterised by numerous small isolated plutons with multiple injections of porphyritic biotite-

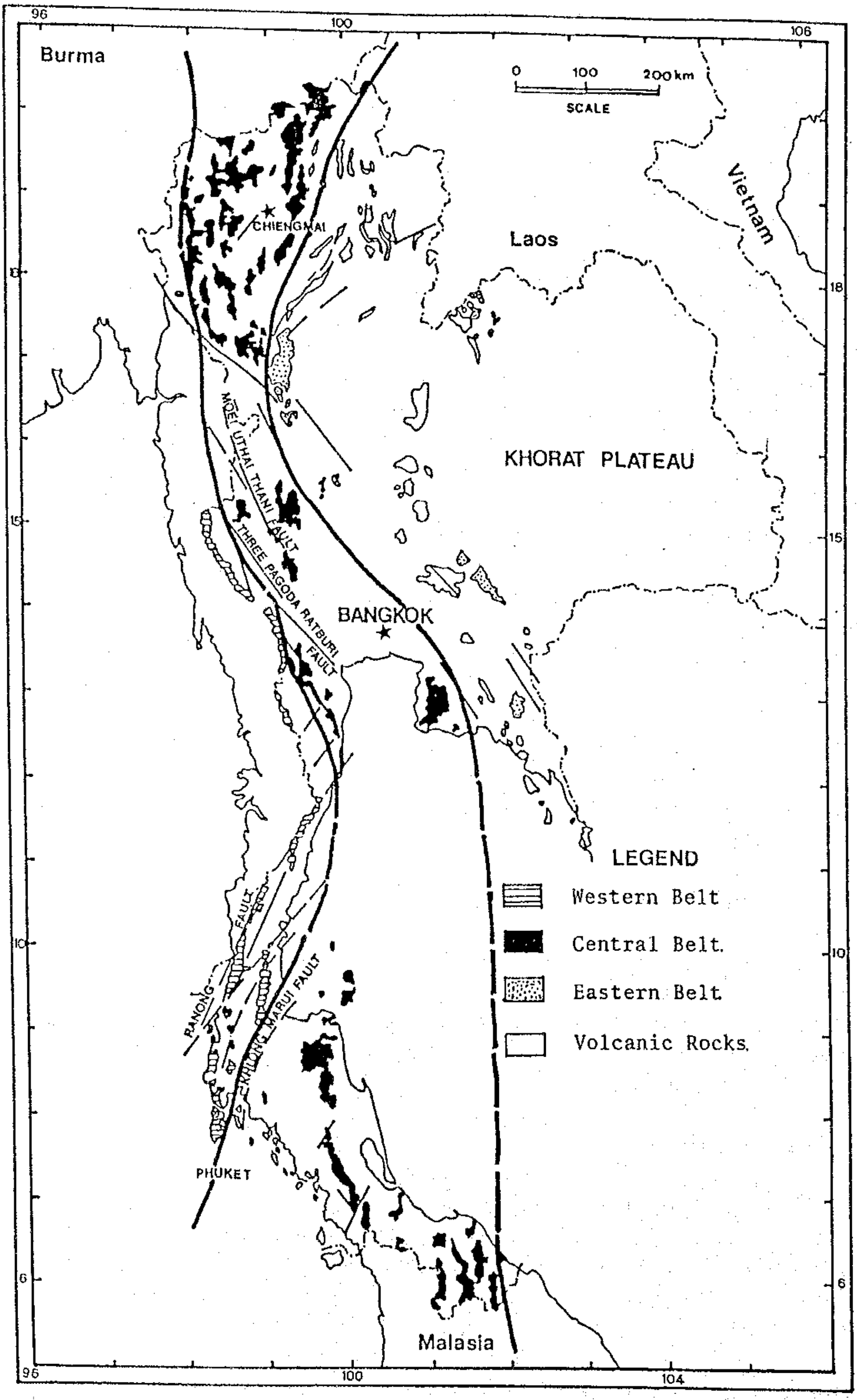


Fig. 2.1.2 Distribution of Granitoid and Volcanic Rocks

muscovite granite. They occur predominantly along the Thai-Burma border and along the western part of the Malay Peninsula, including Phukt Island. Tin and tungsten mineralization is common. The Western Belt is possibly associated with Mesozoic subduction from the west between the Indian and Shan-Thai terranes.

The Central Belt consists prediminantly of Permo-Triassic large granitoid batholiths and a variety of smaller plutons. It contains biotite-muscovite granites with characteristic K-feldspar megacrystals. It is commonly associated with foliated granites. Tin and tungsten mineralization is also common.

The Eastern Belt is well defined in the Chanthaburi area but includes only scattered plutons in the north. The granites in this belt are mostly equi-granular hornblende-biotite granites and occur as isolated complexes of multiple plutons ranging in age from the Upper Carboniferous to Triassic. They are associated with diorite, andesite, and basaltic dykes. Copper, iron, and gold mineralization is associated with these rocks.

2) Volcanics

The earliest volcanic activity in Thailand was during the Silurian and Devonian Periods and resulted in the deposition of agglomerates and tuffs in the north. Widespread andesites, rhyolites, agglomerates, and tuffs in many Permo-Carboniferous and Permo Triassic sequences suggest that volcanic activity occurred at these times. The upper volcanic rocks consist of rhyolitic flows and associated pyroclastic rocks interbedded with clastic red beds of the lower part of the Khorat Group.

The youngest volcanic rocks are Quaternary basalts, mostly lava flows, but with minor plugs and pyroclastics. These are scattered throughout Thailand except for the southern region. It has been suggested that there is an association between the Quaternary volcanics and the impact of a large comet near the Thai-Laos-Cambodian border as indicated by abundant tektites and impact structures.

2.1.2 Meteorology

1. Introduction

Thailand generally has a tropical climate, but there are distinctive regional differences, since the country covers over 16 degrees of latitude and has significant local micro-climatic variations due to topographical effects. The Thai Meteorological Department has divided the country into six regions as illustrated in Fig 2.1.3. The main influence on the weather of the country is the annual migration of the intertropical convergence zone and associated weather phenomena, such as the direction and magnitude of tropical depressions, storms, and typhoons. Collisions between the cold continental northern air with the wet warm tropical air masses produce significant rainfall.

In general, the country is under the influence of the Northeast and Southwest monsoons (See Fig 2.1.4). The Northeast Monsoon is dry and cool, prevailing from November to February. The Southwest Monsoon is moist and warm, lasting from May to October. The Southwest Monsoon brings widespread rainfall. Atmospheric disturbances in the form of tropical depressions, storms, and typhoons also affect Thailand in the July-November period. The rainfall associated with these events is superimposed on the monsoon season, producing a bimodal rainfall pattern.

The recording of rainfall and other weather patterns is primarily the responsibility of the Meteorological Department of the Ministry of Communications. Other agencies also contribute information and the Royal Irrigation Department has stream gauging facilities distributed throughout Thailand. Numerous publications from these departments are available concerning specific weather events, flooding incidents, and weather records for specific years or periods.

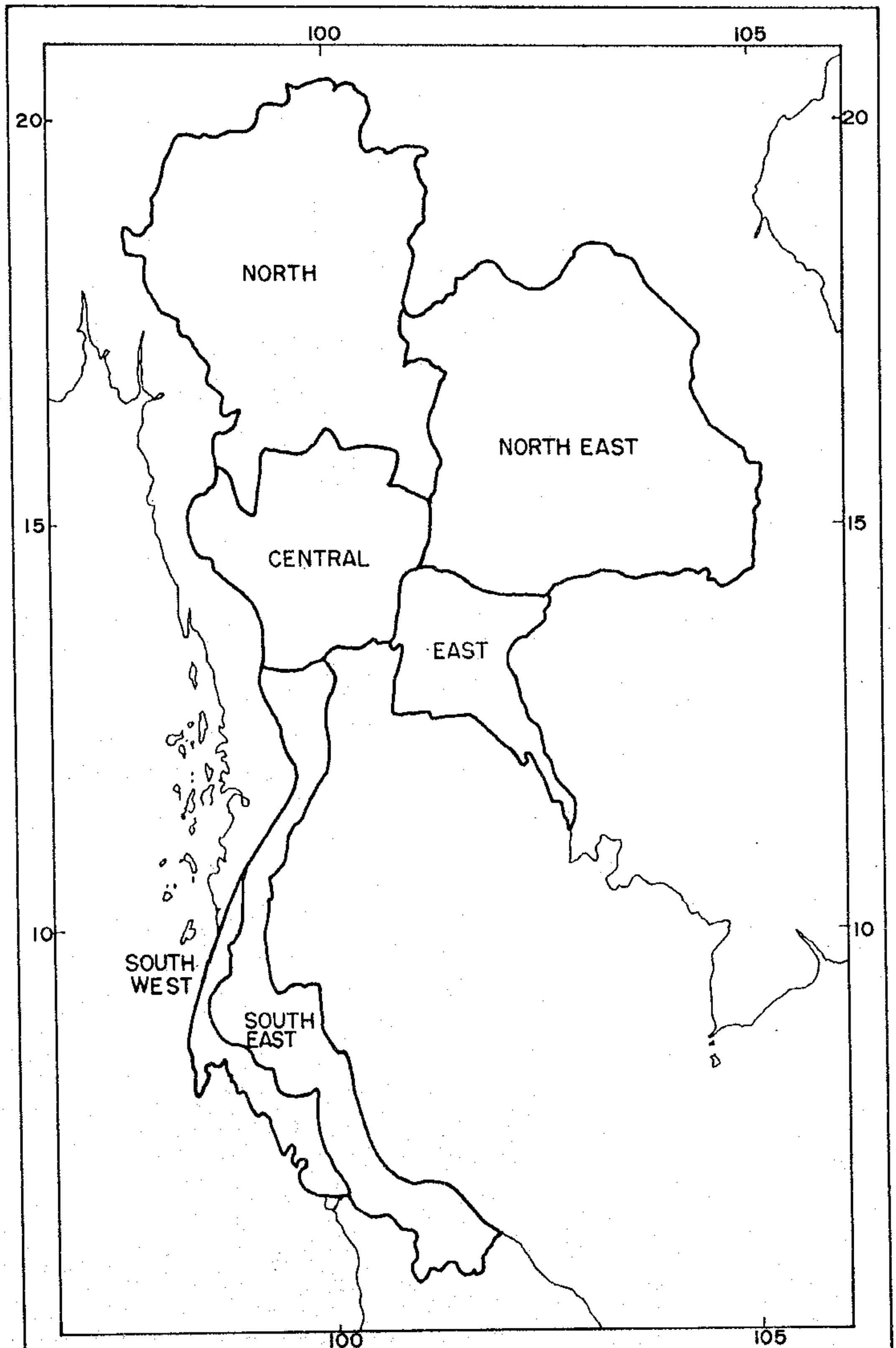


Fig. 2.1.3 Climatic Regions of Thailand

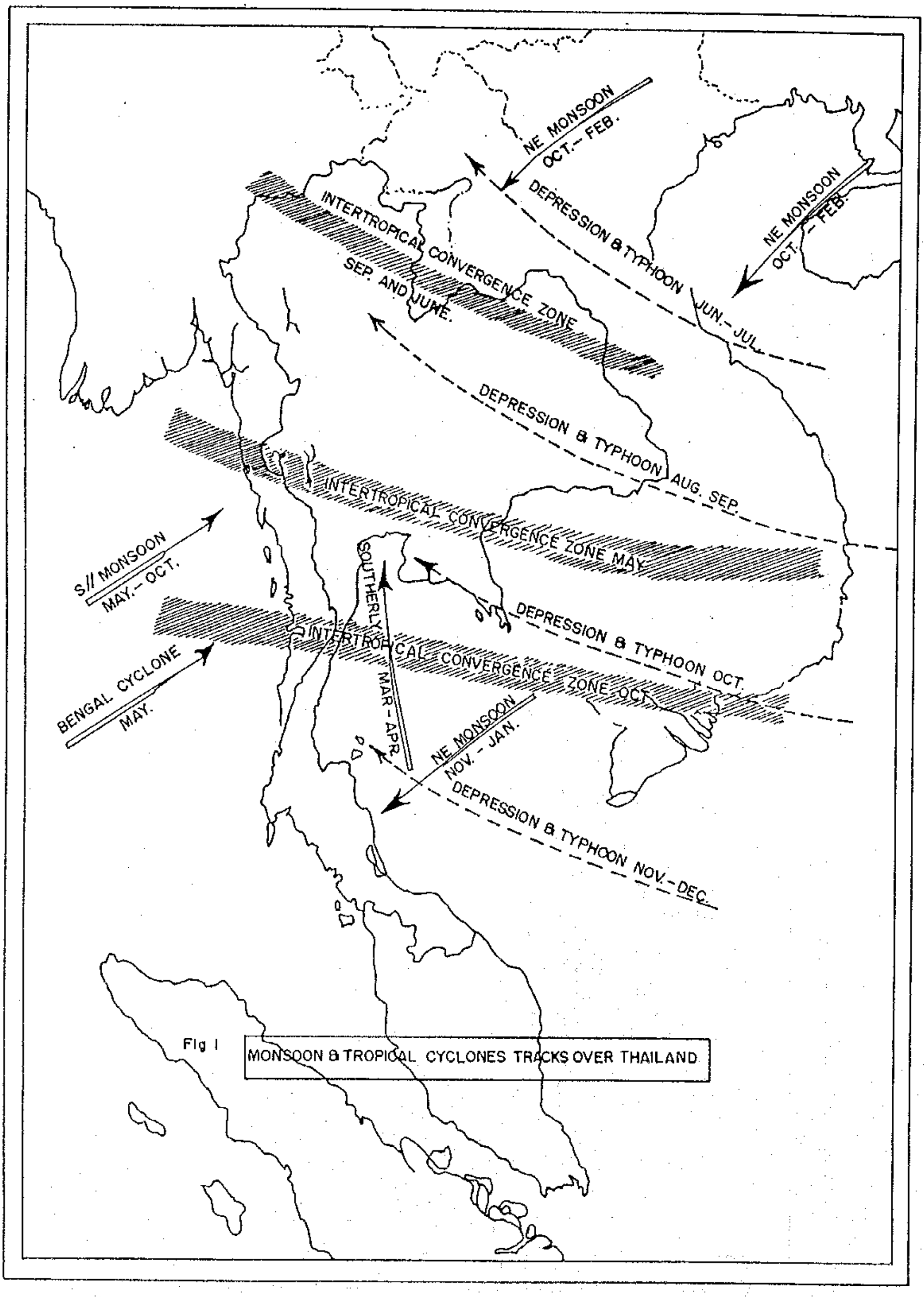


Fig. 2.1.4 Areas Experiencing Monsoons and Cyclones in Thailand

AVERAGE FOR 30 YEARS (1961-1990)

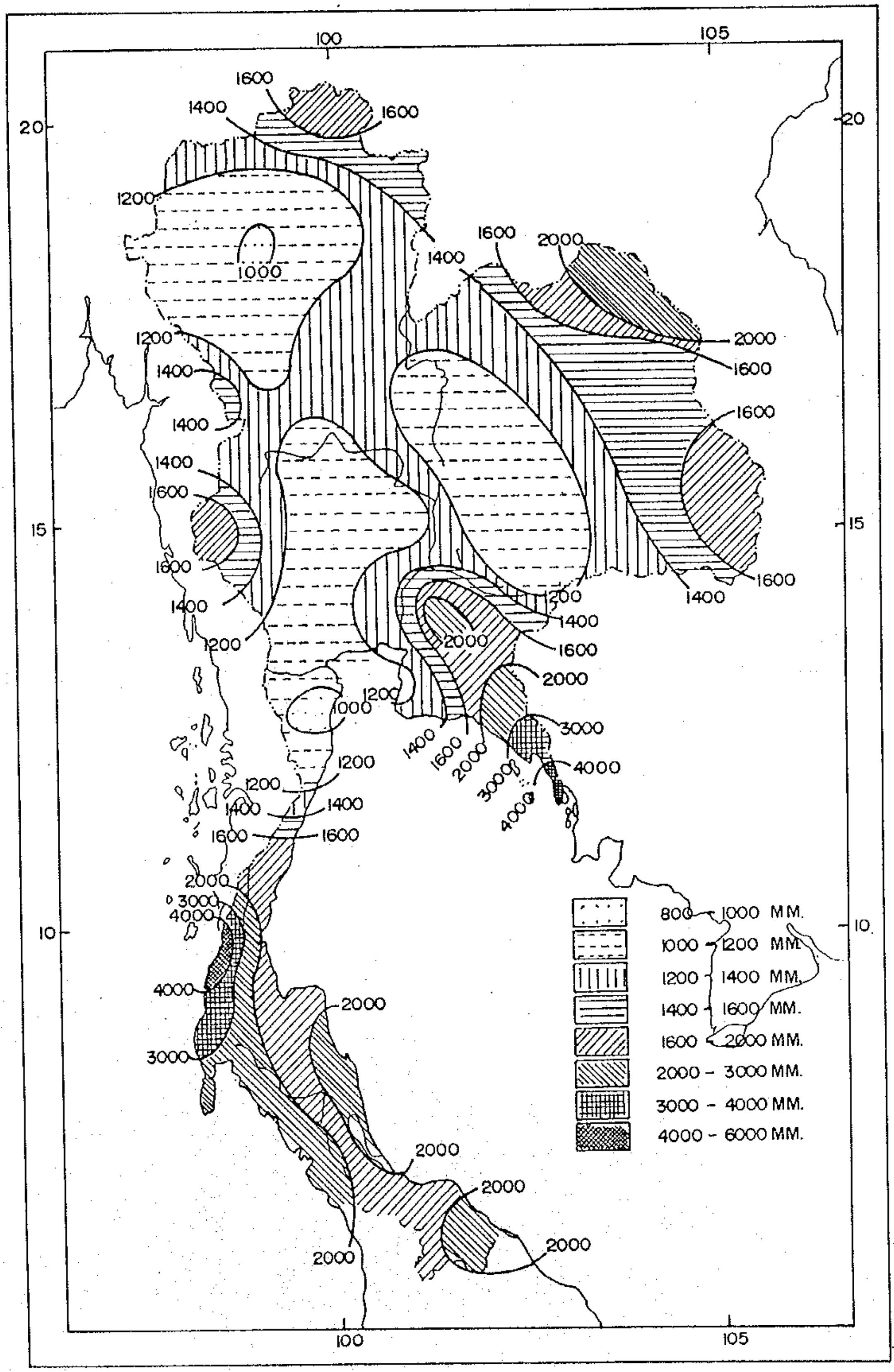


Fig. 2.1.5 Yearly Rainfall for Thailand

In this section average annual rainfall is examined (Fig. 2.1.5 and Fig. 2.1.6), with specific flooding events discussed in Section 2.1.4.

In Thailand, the following three seasons are generally recognized:

a) Rainy Season - middle May to middle October

b) Cool Season - middle October to middle February

c) Hot Season - middle February to middle May

The rainy season commences when the Southwest Monsoon affects Thailand. The actual onset may vary a week or two depending on the weather patterns for a particular year. The cool season occurs when the Northeast Monsoon prevails, and temperatures can go as low as 0 degrees in the high northern regions. The hot season occurs when the sun is at its maximum azimuth and before the onset of the rains. If the cold northern continental air meets the southern moist air streams, local thunderstorms are experienced in the north. Inland areas can experience temperatures of up to 40 degrees with a high evaporation rate.

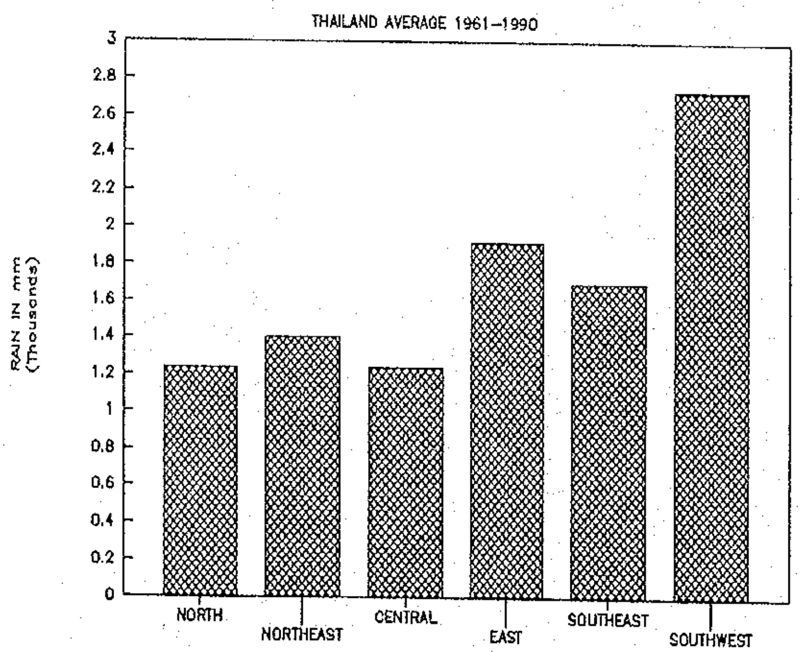


Fig. 2.1.6 Annual Rainfall by Region

2. Southeast Region

This region's rainfall distinctly peaks in November, when tropical depressions tend to cross the Malay Peninsula (see Fig. 2.1.7). The prevailing winds during the wet season here are from the north. The switch to easterly winds in January results in a marked reduction in rainfall, with minimum rainfall occurring in February. The Southwest Monsoon usually begins in May, and there is an average monthly rainfall of over 150mm until September.

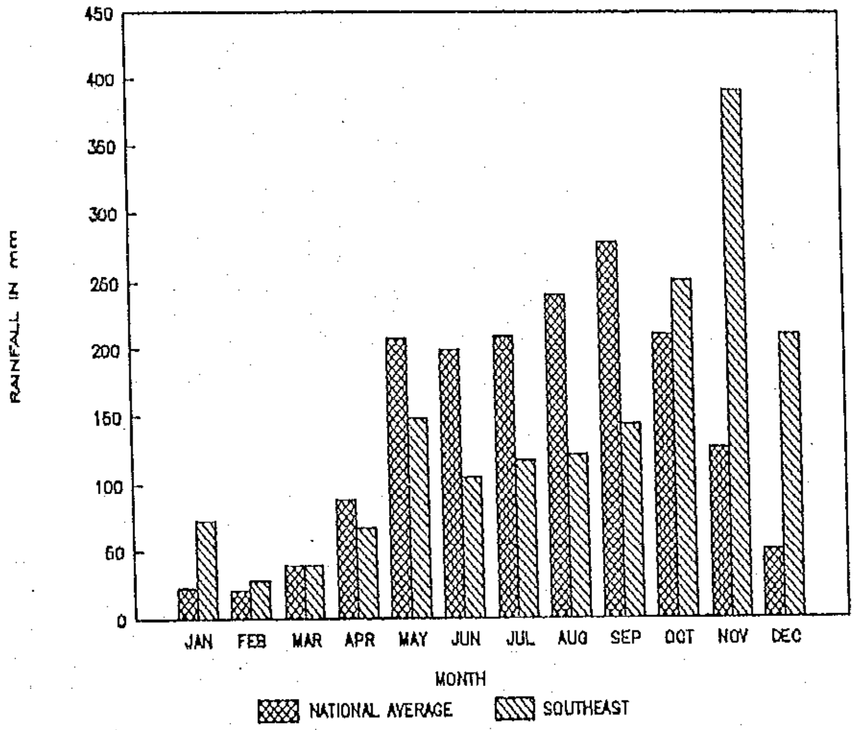


Fig. 2.1.7 Annual Rainfall for the Southeast Region

Monsoon rains, combined with occasional typhoons coming from the southern sector of the South China Sea, produce maximum rainfall during the October-November period. The region has an annual rainfall of about 1700mm.

3. Southwest Region

On the western side of the mountains of the Malay Peninsula, the weather pattern is distinctly different due to topographical effects and the influence of Indian Ocean cyclones. This region has the largest rainfall in the country, with Ranong having an annual average of 4184mm.

The regional average is 2738mm. Rainfall occurs mainly in the May to October period, with August in Ranong having an average of over 800mm (see Fig. 2.1.8).

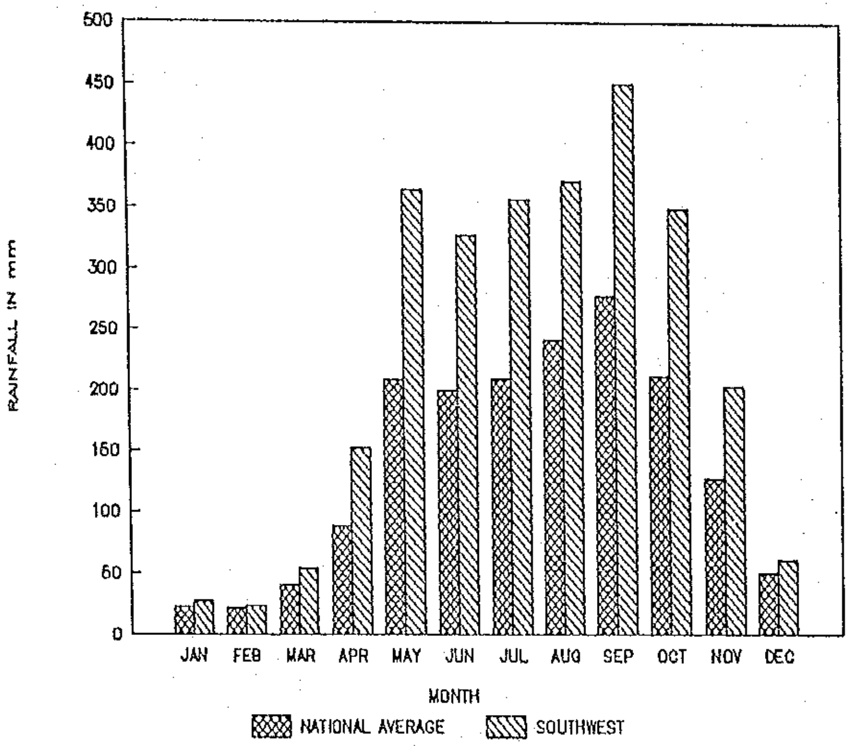


Fig. 2.1.8 Annual Rainfall for the Southwest Region

Mountains shield the region from rain induced by late tropical depressions; thus, the peak of the rainy season is not from October - November as on the eastern side. The largest 24hr rainfall recorded in the 1961-1990 period was 460.9mm at Changwat Ranong on the 22nd of June 1970.

4. East Region

The area to the east of Bangkok around Chonburi, Rayoung, Chantaburi, and Trad has significantly greater rainfall than the adjacent Central Region. The annual average is 1913 mm.

The coastal areas have moderate temperatures, while the mountain areas are generally subject to heavier rains and contribute to the higher average for the region. The month with the greatest rainfall is September, with an average of 336mm (see Fig. 2.1.9).

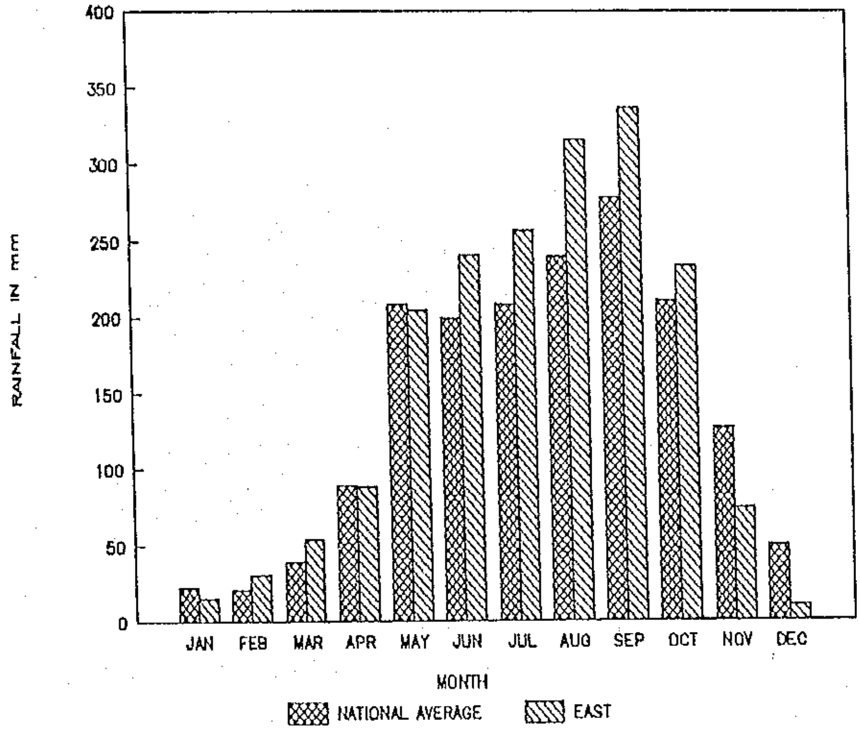


Fig. 2.1.9 Annual Rainfall for the East Region

The maximum 24hr rainfall in the 1961-1990 period was 553.7mm at Changwat Trad on the 16th of August 1970.

5. Central Region

The central plains of Thailand have one of the lowest average annual rainfalls of all the regions (1233mm). The mountainous areas of this region lie to the west and thus the plains are less affected by tropical depression systems, since much of the rainfall has dissipated by the time they reach the area.

Two peaks in rainfall can be seen, with the first and smaller peak of 163 mm occurring in May and the second and larger peak occurring from August-September. The maximum amount of monthly rainfall in the August-September period is 263mm (see Fig. 2.1.10). The largest 24hr rainfall recorded for the 1961-1990 period was 248.6mm on the 8th of May 1986 at Bangkok.

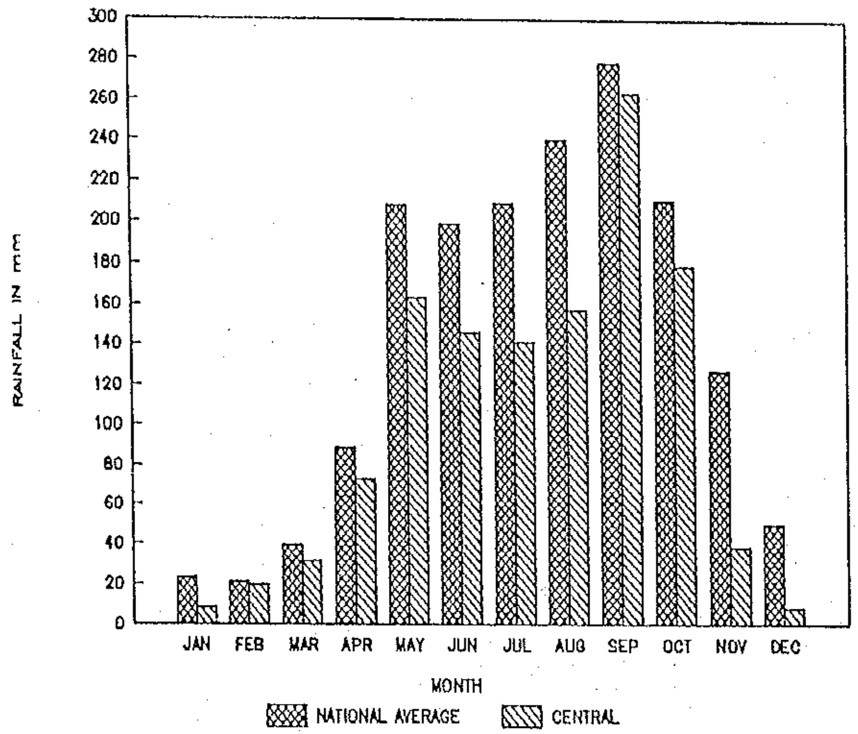


Fig. 2.1.10 Annual Rainfall for the Central Region

6. Northeast Region

The large Khorat Plateau area of Thailand has few major mountain systems and consists of undulating terrain. The rainfall is fairly uniform over the area with an annual average of 1401mm (1961-1990 period). Maximum rainfall occurs in the August-September period, with an average monthly value of about 260mm (see Fig. 2.1.11).

The largest recorded 24hr rainfall in the 1961-1990 period was 459.2mm at Changwat Nakhon Parom on the 17th of June 1962.

7. North Region

The North Region of Thailand has a rainfall pattern similar to the Central Region. It has an average annual rainfall of 1232mm (1961-1990 period), with the months of May and August having the maximum amount of rainfall with values of 181mm and 221mm, respectively (see Fig. 2.1.12). During the winter months, the region is often affected by cold dry air moving down from China and the lowest temperatures in the country are experienced here. The relatively high altitudes also contribute to its being cold.

The maximum recorded 24hr rainfall (1961-1990) occurred at Changwat Phitsanulok with a value of 265.7mm.

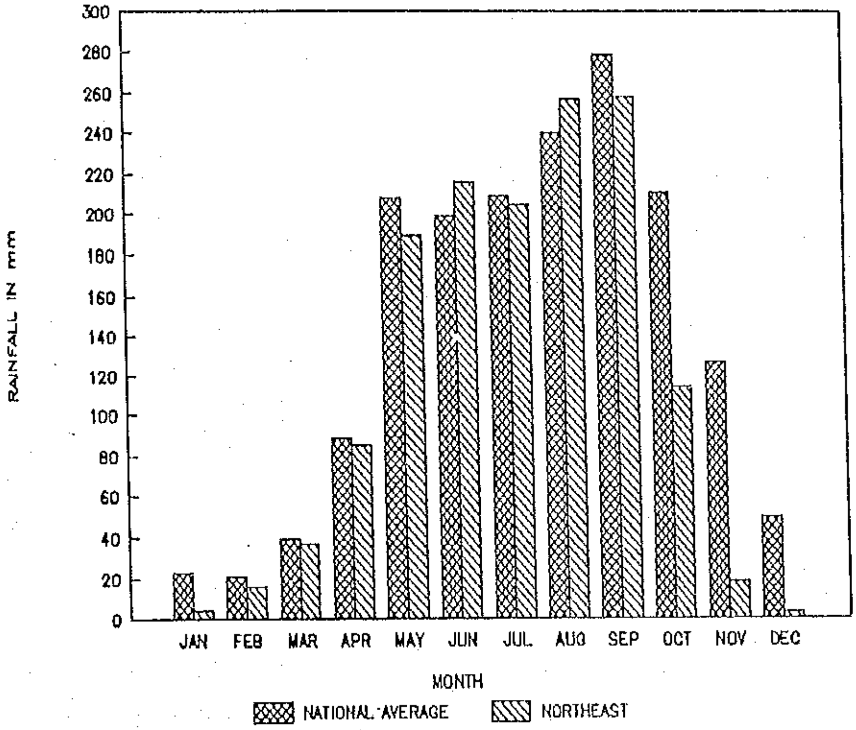


Fig. 2.1.11 Annual Rainfall for the Northeast Region

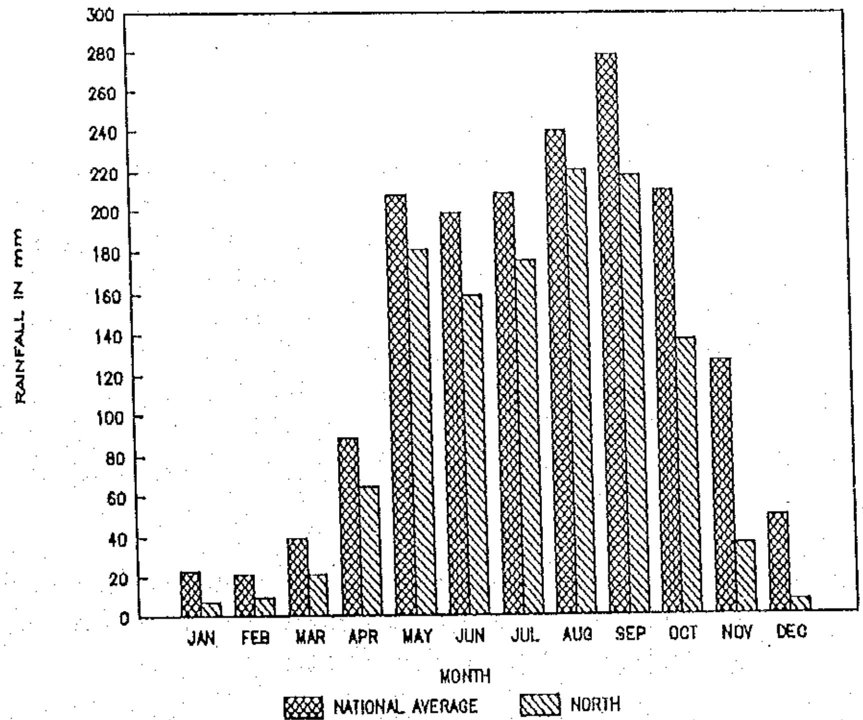


Fig. 2.1.12 Annual Rainfall for the North Region

8. Rainfall Intensity Distribution

To predict the hydraulic capacity requirements of road structures, short-term rainfall intensity is more significant than absolute annual rainfall volume. In order to appreciate this, a plot has been prepared for 24hr rainfall volume, as predicted for a one in fifty-year return period, from data supplied by the Meteorology Department (see Fig. 2.1.13).

As Fig. 2.1.13 indicates, the peninsular part of Thailand has the highest 24hr rainfall intensity (up to 500mm/day), together with the coastal sections to the east of Bangkok (400mm/day). The far northeast also has a fairly high intensity of around 300mm per day. The central and western areas have a maximum probable rainfall of around 150-200mm/day. To design hydraulic structures, maximum probable intensity should be considered along with catchment size and runoff characteristics. For example, culverts in the area around Pattani should be twice the cross-sectional area of culverts in the area around Phitsanulok, despite their similar catchment conditions.

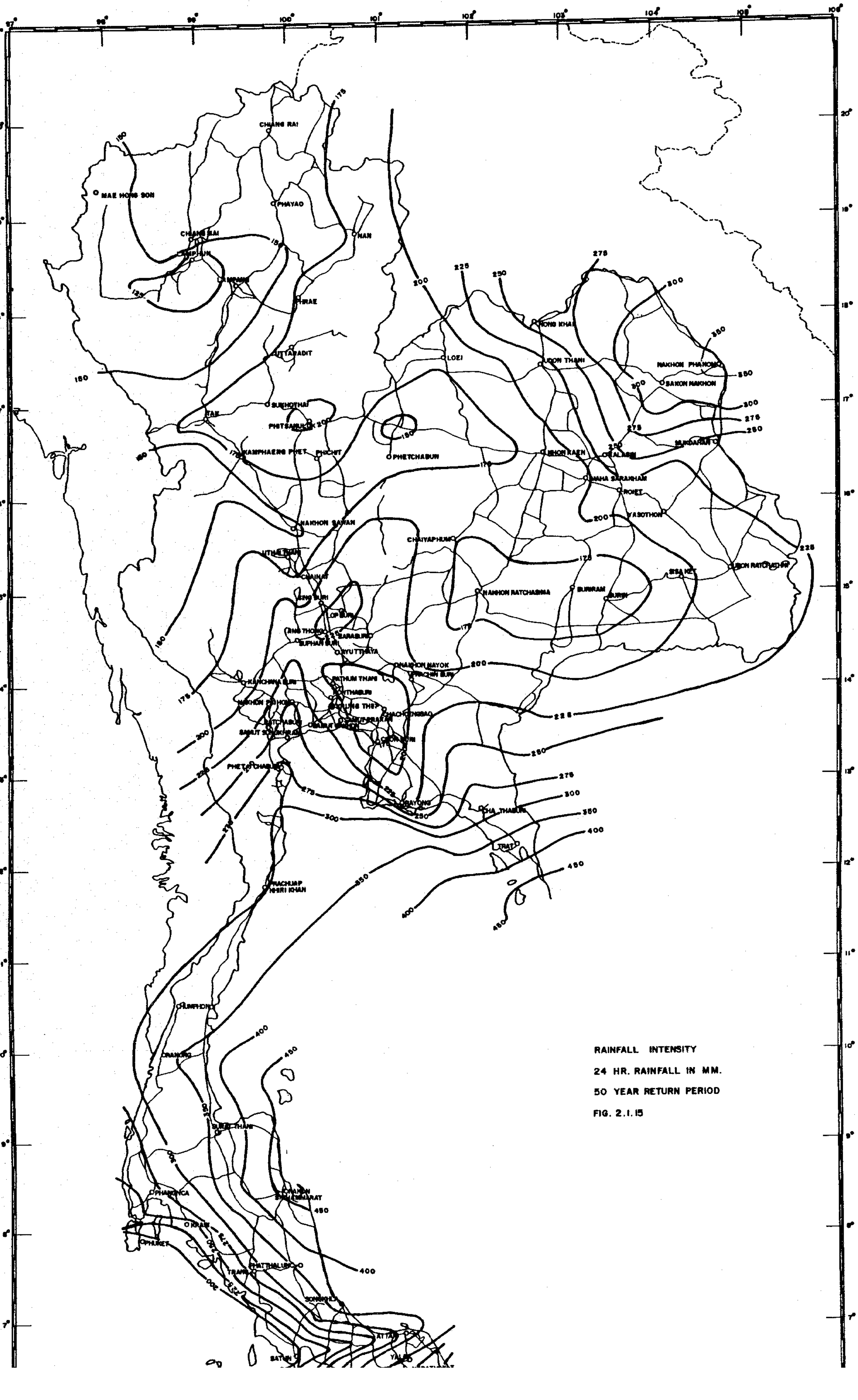
The data presented in Fig. 2.1.13 can be used as a preliminary design guide, but reference should be made to the detailed information available from the Climatology Division of the Department of Meteorology.

9. Meteorologically Induced Disasters

The main natural cause of physical damage to the national infrastructure is heavy rain leading to flash floods and landslides. The frequency of these events has probably not changed significantly since the beginning of the Holocene Period (end of the last ice age). However, the social impact has become greater, due to changes in vegetation and the placement of man-made structures in the path of natural floods, which is a consequence of the dramatic increase in population and the severe competition for scarce land resources.

It needs to be accepted that disasters such as floods are inevitable and natural processes need to be accommodated in the engineering design of man-made structures.

On average, Thailand experiences 3.3 major floods per year.



RAINFALL INTENSITY

24 HR. RAINFALL IN MM.

50 YEAR RETURN PERIOD

FIG. 2.1.15

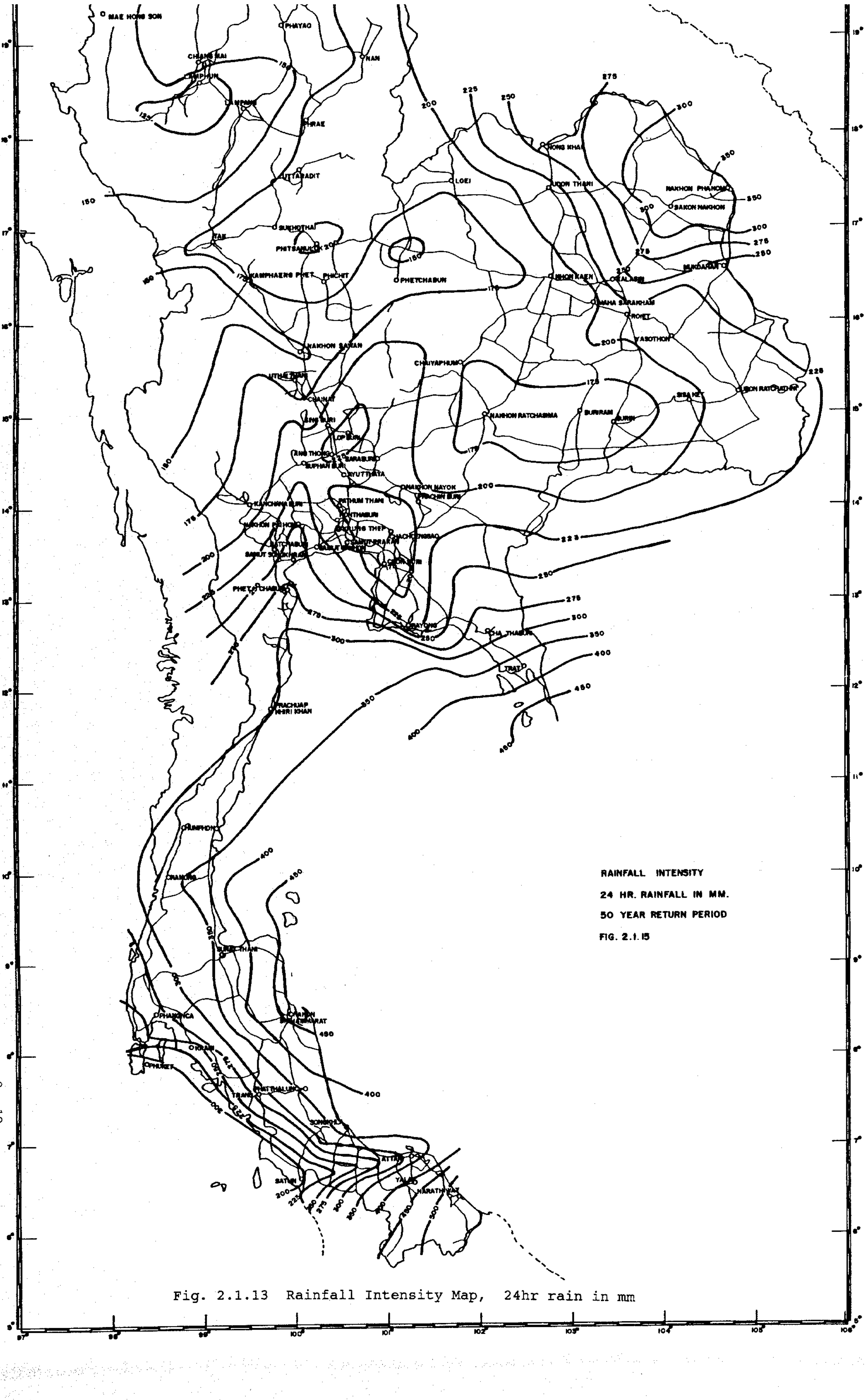


Fig. 2.1.13 Rainfall Intensity Map, 24hr rain in mm

However, there has been a downward trend in their number during the ten-year period from 1983 to 1992 (see Fig. 2.1.14). On the other hand, the severity and effects of floods appear to have become worse. In the period from 1983 to 1992, 33 major floods occurred and caused the deaths of 734 individuals. The single worst flood was in November 1988 when 373 people lost their lives and over one million domestic animals were killed. Damage was estimated at nearly US$260 million.

The social and environmental impacts of floods vary with the topographical nature of an area, the density of development and population, and the amount and duration of rainfall. It should be noted that the information for this section was supplied by the Local Administration Department of the Civil Defence Division of the Ministry of the Interior. The references to annual events in this section are for calendar years. The data analyzed in Section 3.1 is derived from DOH records and thus refer to Fiscal Years.

A summary of the main floods that occurred in the 1983-1992 period is given in Table 2.1.2 and graphically summarized in figs. 2.1.14 to 2.1.17. The two main meteorological causes for these floods are explained below.

Table 2.1.2 Floods from 1983 to 1992

YEAR	DATES	TYPE	DEAD	AREA FLOODED	COSTS(US$mil.)
1983	26-27 JUNE	TYPHOON	1	NE. 2,317 ha.	?
1983	10-19 OCT.	2 TYPHOONS	56	C. 871,754 ha.	1.11
1983	3-15 DEC.	NE MONSOON	1	SE. 55,727 ha.	1.67
1984	10-12 JUNE	TYPHOON		N.&NE.	
1984	13-18 AUG.	SW MONSOON	8	N.&NE. 64,083 ha.	0.95
1984	1-15 SEPT.	SW MONSOON		N.&NE.	
1984	13 OCT.	TYPHOON		N.&NE.	
1984	8-9 NOV.	TYPHOON	0	NE.&C. 176 ha.	?
1984	28 NOV.-3 DEC.	NE MONSOON	27	SE. 136,063 ha.	0.46
1985	10-28 AUG.	SW MONSOON	9	N.&NE. 16,158 ha.	3.31
1985	16-17 SEPT.	DEPRESSION		N.&NE.	
1985	12-13 OCT.	DEPRESSION		N.,NE.&C.	
1985	16-17 OCT.	TYPHOON	18	N,NE&C. 22,607 ha.	3.38
1985	1-3 NOV.	NE MONSOON	0	SE. 32 ha.	0.02
1986	8-9 MAY	DEPRESSION	41	N.&C. 23,321 ha.	2.41
1986	1-6 SEPT.	TYPHOON	2	ALL 11,046 ha.	0.44
1986	1-13 OCT.	MONSOON	0	ALL 6,826 ha.	?
1986	25 NOV.-9 DEC.	MONSOON	3	SE. 56,152 ha.	0.07
1987	15-24 AUG.	2 TYPHOONS	19	N,NE&S. 91,013 ha.	6.35
1987	4 NOV.-7 DEC.	NE MONSOON	41	C.&S. 311,290 ha.	14.41
1988	15-25 SEPT.	DEPRESSION		N.,C.&SW.	
1988	16-18 OCT.	DEPRESSION	44	N,NE&C. 479,865 ha.	10.63
1988	19-22 NOV.	DEPRESSION	373	S. 364,011 ha.	259.38
1989	25-27 MAY	TYPHOON	11	N.&NE. 172,311 ha.	3.02
1989	13-14 OCT.	TYPHOON		N.&NE.	
1990	28-31 AUG.	TYPHOON	2	N.&NE. 312,413 ha.	2.21
1990	3-21 OCT.	2 TYPHOONS	39	NE&C. 3,497,284 ha.	202.01
1991	17-19 AUG.	TYPHOON	38	N.&NE. 533,303 ha.	84.17
1991	26-27 OCT.	DEPRESSION	1	C.&SE. 7,000 ha.	1.49
1992	17-19 OCT.	TYPHOON	0	NE. 0 ha.	2.51

The first type of flooding is due to heavy prolonged rains from monsoon troughs (refer to Fig. 2.1.4). These floods are generally widespread and of a sustained duration (heavy rain for up to two weeks). The build up of flood waters is relatively slow but the accumulated volume can be substantial. Large areas of the country can be affected simultaneously. Peak 24hr rainfall rates are relatively low.

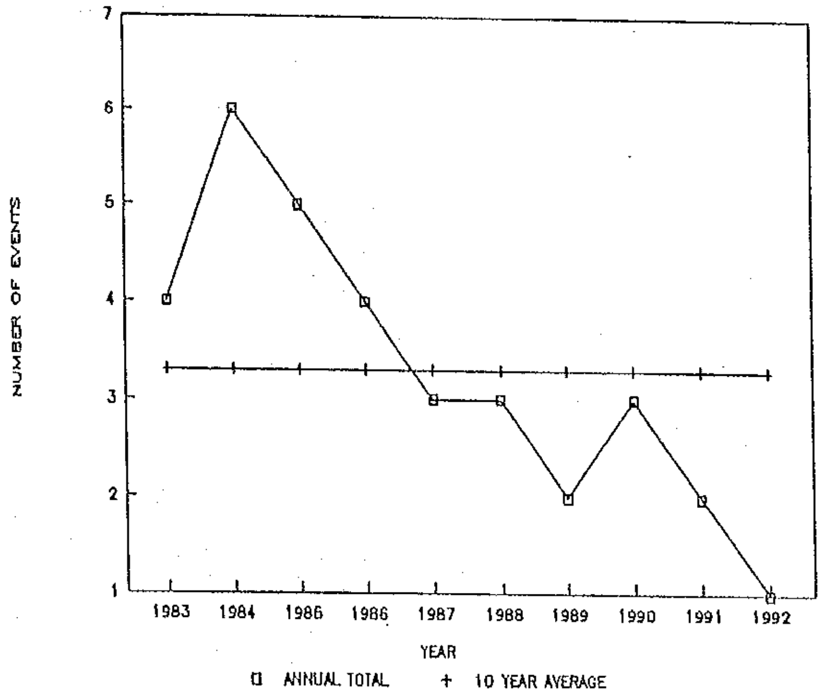


Fig. 2.1.14 Floods in Thailand (1983 - 1992)

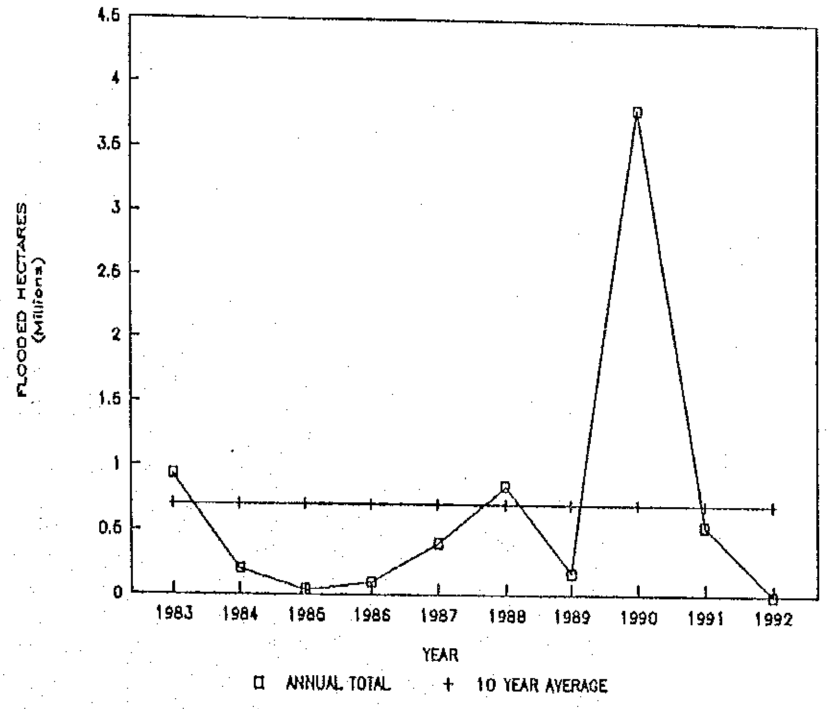


Fig. 2.1.15 Flooded Hectares in Thailand (1983 - 1992)

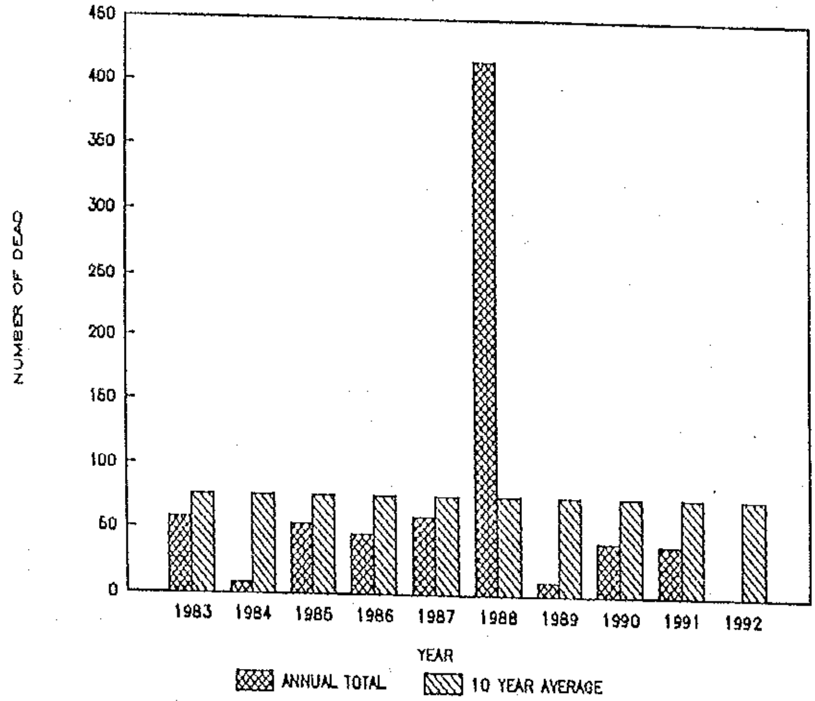


Fig. 2.1.16 Deaths due to Floods in Thailand (1983 - 1992)

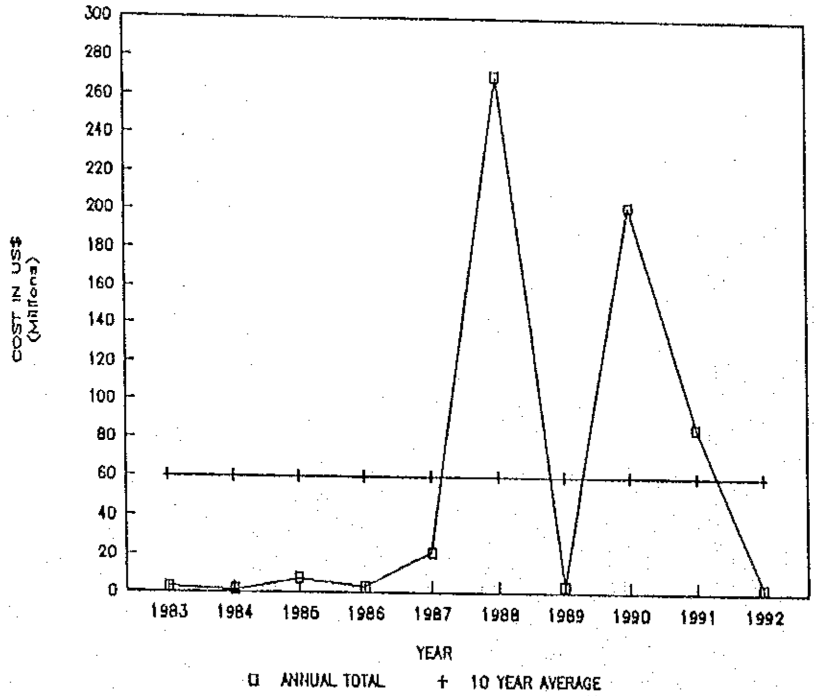


Fig. 2.1.17 Costs of Floods in Thailand (1983 - 1992)

The second type of flood is associated with the movement of tropical depressions and storms across the country. These usually come from the Pacific Ocean from the east of the Philippines. If they cross the South China Sea and hit the Vietnam coast, they rapidly degenerate into a depression. That is, tropical storm systems need to be over warm water to develop and strengthen. The energy for the system is derived from the differential between the sea's surface temperature and the air drawn in to the circulating mass. When a storm crosses land, no significant new energy enters the system and the storm or depression has to consume its existing kinetic and thermal energy. The result is a progressive drop in wind velocities and an increase in rainfall. As precipitation occurs, latent heat is surrendered. If a storm system continues across land (or moves across to higher sea latitudes with a low surface water temperature) the entire depression will run out of energy and dissipate.

In northern and central Thailand, the most common flooding is due to partially depleted tropical storm systems after they have crossed Vietnam, Laos, or Cambodia. Although wind velocities usually are low enough not to cause damage, they can still produce significant rates of precipitation. The areas affected at any one moment are not as extensive as those of the monsoon rains, but the path of these storms ensures that a significant swathe from east to west is affected. In general, the intensity of rainfall decreases from east to west as the systems deteriorate, and a general reduction in both annual rainfall quantity and 24hr rainfall intensity probability can also be seen.

Intense 24hr rainfall can be experienced for about 1-2 days in any location in the path of a tropical storm. However, topographic features can affect a local area's total. In 1991, a weakened Typhoon "Fred" crossed the Northeast and Central regions in only three days, but left in its path US$84 million in damage and 38 dead. There was a maximum 24hr rainfall of nearly 200mm at Khon Ken and about 150 mm at Phetchabun.

In Peninsular Thailand, especially late in the year, tropical storm systems can hit land almost directly from the water. Therefore, strong and destructive winds can be experienced along with intense rainfall over a short period of time. The rainfall intensity map in Fig. 2.1.13 illustrates this. The

South Region is thus the most susceptible to damage. For example, the South was affected by a tropical depression for only 4 days in November 1988 but the damage was nearly US$260 million. Peak 24hr rainfall at Nakhon Si Thammarat was nearly 450mm while that at Surat Thani was about 280 mm. Topographical features also adversely affect the South, as there is a slow progressive tilting of the peninsula with the east coast emerging. This results in a tendency for flooding to deposit extensive sheets of alluvial soil.

2.2 Socioeconomic Conditions

Thailand is administratively divided into seven regions, namely; the Bangkok Metropolitan Region (BMR) and the Central, East, West, Northeast, North and South regions. The seven regions are divided into 76 changwats (provinces). However, socioeconomic data are available only for 73 changwats, as there are no databases yet established for the three new changwats created in 1993. A boundary map for the administrative system of Thailand is shown in Appendix 1.1.

2.2.1 Land Use

The forests in Thailand are still extensive and account for about 28% of the total land area. Thailand has four main forest types: dry dipterocarpeae, evergreen, mixed deciduous and pine. Among these, evergreen forests are the most productive in terms of tree volume per unit area and annual growth capacity.

Land utilization is generally classified into three major categories: (1) forest land, (2) farm land, and (3) unclassified land. Unclassified land includes swamps, municipal areas, railways, roads and public areas. With the promotion of development in the agricultural sector as one of the main targets in national development plans, the share of farm land expanded from about 37% in 1980 to 46% in 1988 at the expense of forest and unclassified land. Fig. 2.2.1 illustrates the land-use distribution in Thailand for the 1980-1988 period.

Land-use distribution in 1988 is shown in Table 2.2.1 for all the regions in Thailand. The North Region has the highest percentage of forests followed by the West Region. Farm land covers 81.9% of the Central Region and 67.4% of the Bangkok Metropolitan Region (BMR).

2.2.2 Population

Population data from the Ministry of Interior for 1992 showed a total population of 57,789,300 inhabitants. This represents an annual growth rate of 1.5% when compared to the population in 1991. 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

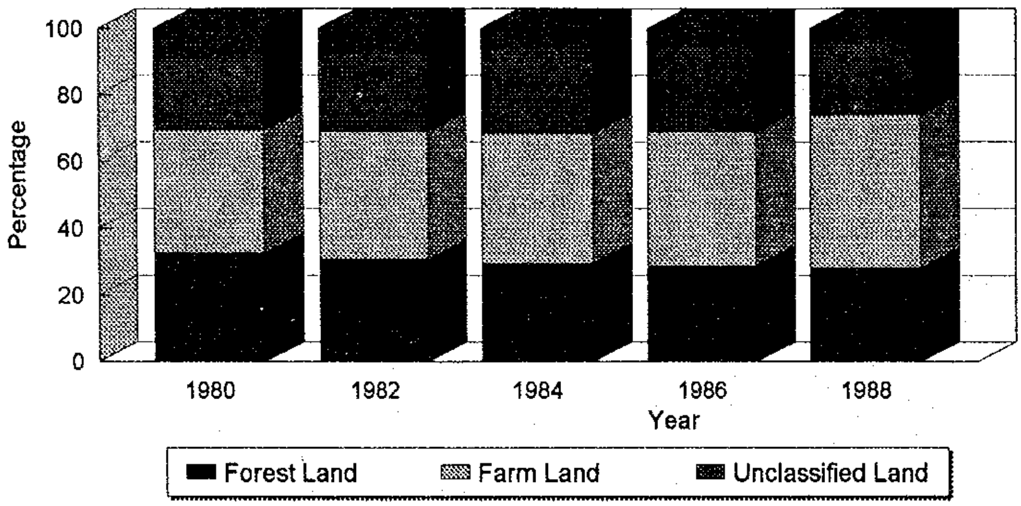


Fig. 2.2.1 Trend of Land-Use Distribution in Thailand

Table 2.2.1 Regional Land-Use Distribution - 1988 (sq km)

Region		Forest Land	Farm Land	Unclassified Land	Total Area
BMR		-	5,228	2,530	7,758
	%	-	67.4	32.6	100.0
Central		367	13,596	2,630	16,593
	%	2.2	81.9	15.8	100.0
East		7,834	19,445	9,224	36,503
	%	21.5	53.3	25.3	100.0
West		16,877	16,071	10,098	43,047
	%	39.2	37.3	23.5	100.0
Northeast		23,693	97,324	47,837	168,854
	%	14.0	57.6	28.3	100.0
North		80,402	54,433	34,809	169,644
	%	47.4	32.1	20.5	100.0
South		14,630	30,383	25,702	70,715
	%	20.7	43.0	36.3	100.0
Thailand		143,928	236,811	132,977	513,715
	%	28.0	46.1	25.9	100.0

Source: Agricultural Statistics of Thailand, 1988/89.

National Economic and Social Development Plan (1992-1996) is set up at 1.2% per year. With an area of 513,715 square kilometers, the average population density in the country was 112.5 inhabitants per square kilometer in 1992. The highest population density of 3,554 inhabitants per square kilometer was that of the Bangkok Metropolitan Area, with a population of 5,562,100 inhabitants and an area of 1,565 square kilometers. Fig. 2.2.2 presents the regional population distribution for the seven regions in 1992. The Northeast Region is the most populated region in the country, accounting for 34.4% of the country's total population, followed by the North Region with 20.2% of Thailand's total population.

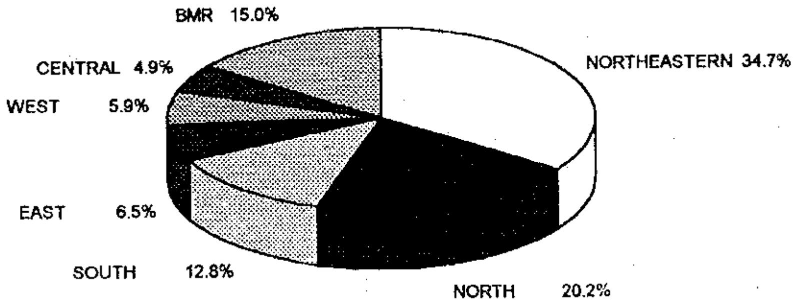


Fig. 2.2.2 Regional Population in Thailand - 1992

Changwat population and growth rates between 1975 and 1992 are presented in Appendix 1.2. In 1992, Bangkok had the highest changwat population of about 5.56 million, accounting for 9.6% of the national total. Nakhon Ratchasima was in second place with a population of about 2.47 million and there are another 14 changwats with populations of more than 1.0 million. These are mostly in the Northeast Region. Ranong in the South Region, with a population of 130,800, is the least populous changwat followed by Phuket (188,500), Trat (201,600) and Mae Hong Son (206,900). Fig. 2.2.3 shows the trend of regional population growth in the period 1975-1992. The population of 1992 is 1.36 times that of 1975, which indicates that the population will double in about 50 years.

Population distribution by age and sex, as illustrated in Fig. 2.2.4, is pyramidal with the younger the age group the higher the population share. In this distribution, the productive population, which can be considered to be between 16 and 65 years of age, is about 57.6% of the total population.

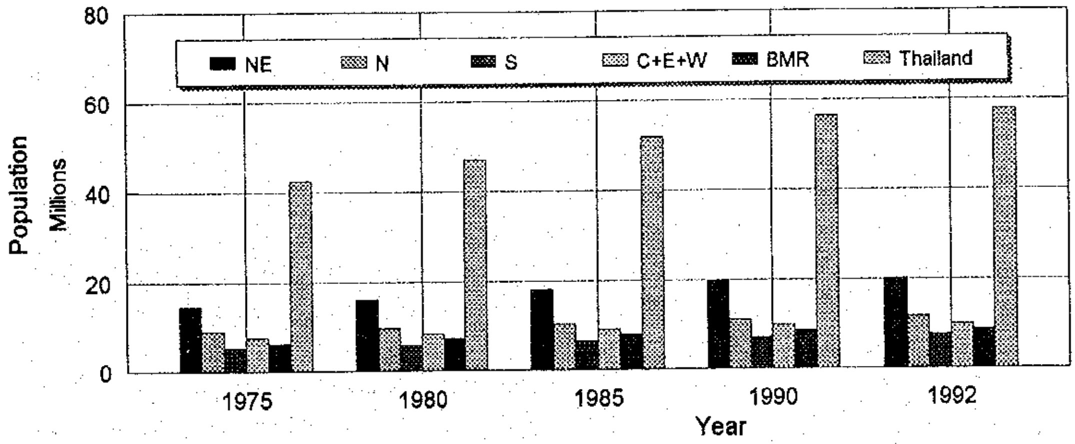


Fig. 2.2.3 Growth in Regional Population

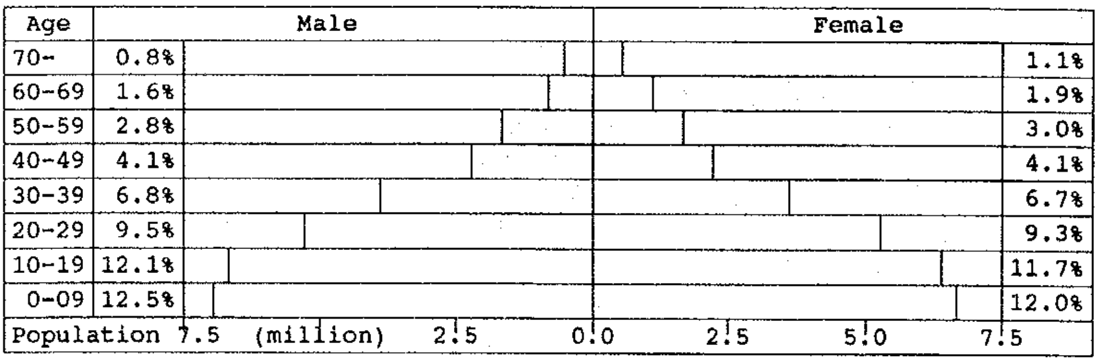


Fig. 2.2.4 Age Distribution in Thailand - 1991

2.2.3 Economy

The economy of Thailand has shown remarkable growth over the last few years. To sustain such growth, the 7th National Economic and Social Development Plan (1992-1996) was set up with the main objectives of 1) maintaining economic growth at appropriate levels to ensure sustainability and stability, 2) redistributing income and decentralizing development to regions and rural areas, and 3) accelerating the development of human resources and upgrading the quality of life, environment and natural resources management. To achieve these objectives, quantitative and qualitative targets were established in which the overall economic target growth rate was set at 8.2% per year. The breakdown of this target is a minimum of 3.4% for the agricultural sector and 8.6% for the non-agricultural sector. In the non-agricultural sector, industry has the highest target growth rate of 9.5% per year followed by 8.9% for construction and 8.1% for services and others.

1. Gross Domestic Product (GDP)

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 as shown in Table 2.2.2. 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%. As shown in Figure 2.2.5, the beginning of the 6th Plan was a turning point in the economic growth of the country due to an increase in exports, investment, tourism and industrial production.

Table 2.2.2 Gross Domestic Product (million baht)

	1981	1986	1991
GDP at current market prices (billion baht)	760	1,133	2,509
GDP at 1988 constant prices (billion baht)	968	1,257	2,108
Average Annual Growth Rate of GDP	5.4%	10.9%	
Per Capita GDP at current market prices (baht)	15,934	21,584	44,085
Per Capita GDP at 1988 constant prices (baht)	20,280	23,942	37,037
Average Annual Growth Rate of Per Capita GDP	3.4%	9.1%	

Source: National Income of Thailand, Rebase Series, 1980-1991, NESDB.

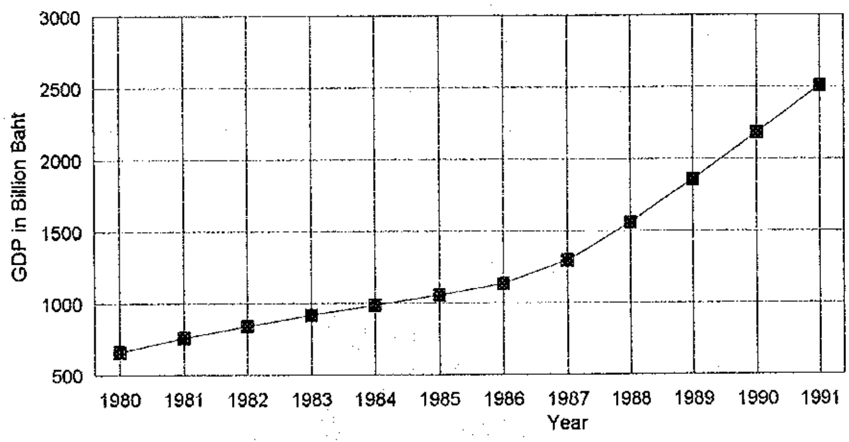


Fig. 2.2.5 GDP at Current Market Prices in Thailand

The sectoral breakdown of the GDP is presented in Table 2.2.3, in which the manufacturing sector had the highest share of 22.6% in 1981 and 28.2% in 1991. The share of the agricultural sector decreased from 21.4% in 1981 to 12.8% in 1991.

Table 2.2.3 Sectoral GDP at Current Market Prices

Sector	1981		1991	
	million baht	%	million baht	%
Agriculture	162,390	21.4	321,356	12.8
Mining and Quarrying	11,208	1.5	39,331	1.6
Manufacture	172,143	22.6	706,561	28.2
Construction	34,696	4.6	170,893	6.8
Electricity and Water Supply	10,814	1.4	52,941	2.1
Transportation and Communication	41,648	5.5	175,686	7.0
Wholesale and Retail Trade	138,594	18.2	426,233	17.0
Banking, Insurance and Real Estate	21,833	2.9	134,342	5.4
Ownership of Dwellings	26,344	3.5	71,589	2.9
Public Administration and Defense	33,361	4.4	86,483	3.4
Services	107,325	14.1	324,012	12.9
GDP	760,356	100.0	2,509,427	100.0

Source: Gross Regional and Provincial Products, Preliminary Series, NESDB.

2. Gross Regional Product (GRP)

The GDP share for each region (GRP) is illustrated in Fig. 2.2.6. The BMR has the highest share and accounts for nearly half of the country's GDP. This indicates the existing high disparity between regions. GRP at current market prices between 1981 and 1989 is shown in Fig. 2.2.7, while the GRP growth rates for the same period, with 1981 as the base year, are shown in Fig. 2.2.8. Only the BMR and the East Region have growth rates higher than the national average, while all the other regions have lower rates.

Regional disparities in Thailand are noticeable from the per capita GRP shown in Fig. 2.2.9 for the 1981-1989 period.

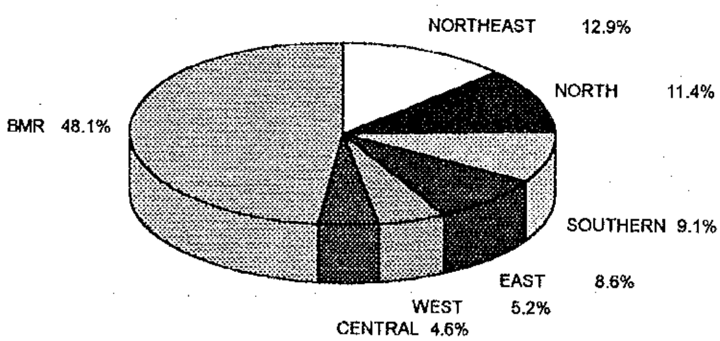


Fig. 2.2.6 GDP Distribution by Region - 1989

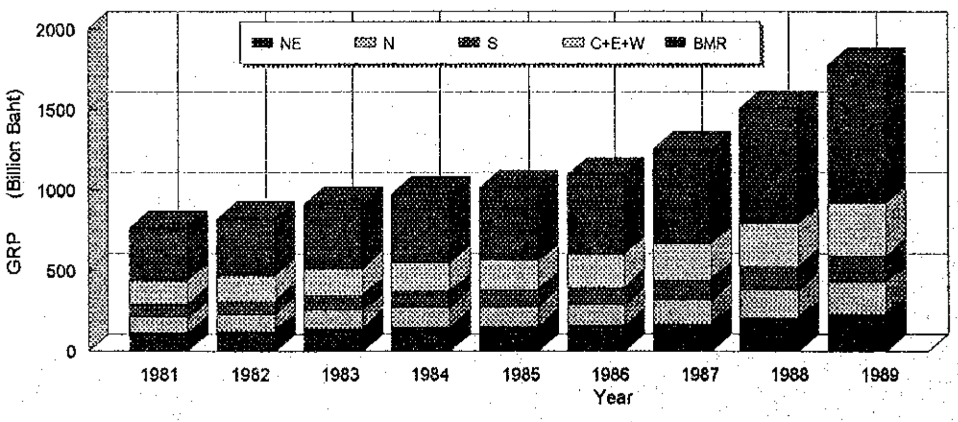


Fig. 2.2.7 GRP at Current Market Prices

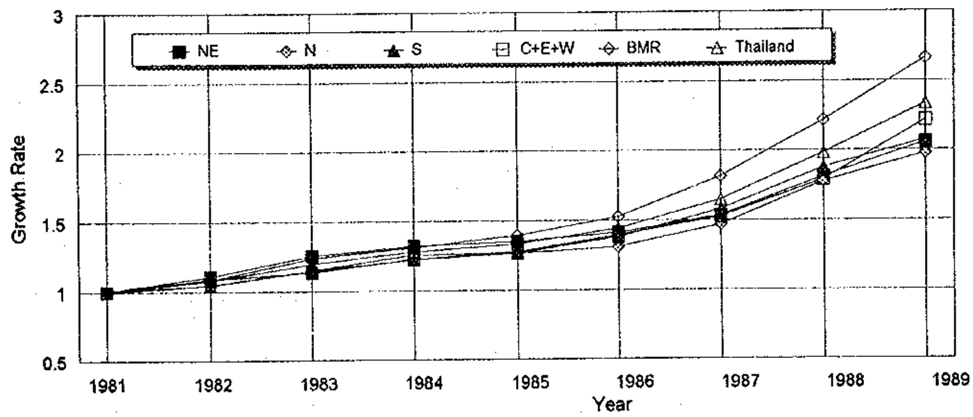


Fig. 2.2.8 GRP Growth Rates

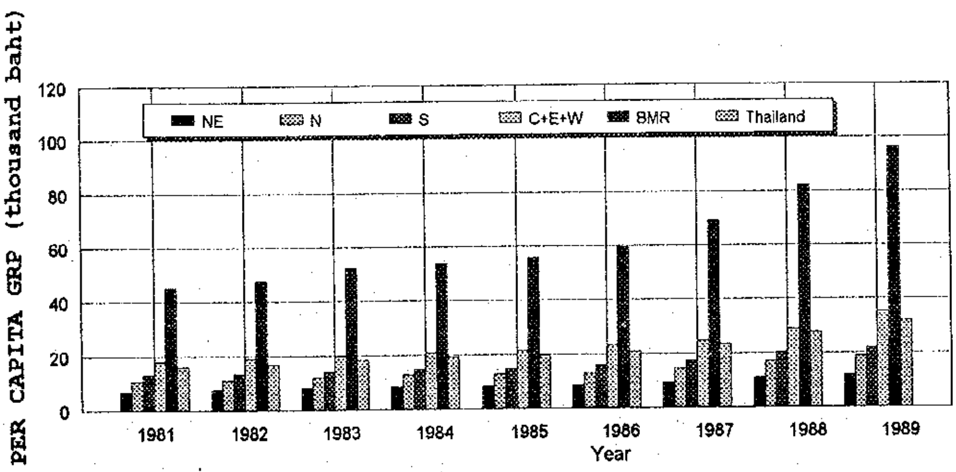


Fig. 2.2.9 Per Capita GRP

Table 2.2.4 presents the 1989 sectoral GRP for each region and each sector's share. The highest shares for the agricultural sector are in the South and North regions, while the manufacturing sector has its highest shares in BMR and the East and Central regions, respectively.

Table 2.2.4 Sectoral GRP - 1989 [at Current Market prices in billion baht]

Sector	NE	%	N	%	S	%	E	%	W	%	C	%	BMR	%	Total	%
Agriculture	63.2	27	62.8	31	53.0	33	22.4	15	24.1	26	15.4	19	25.4	3	266.4	15
Mining and Quarrying	5.1	2	11.3	6	8.4	5	11.9	8	6.6	7	12.4	15	5.0	1	60.7	4
Manufacture	17.2	8	15.2	7	8.8	6	41.1	27	14.0	15	16.0	20	341.0	40	453.3	26
Construction	14.8	6	11.7	6	9.4	6	10.6	7	5.1	6	2.7	3	57.9	7	112.3	6
Elec. and Water Supply	3.6	2	3.5	2	3.2	2	3.5	2	2.1	2	3.0	4	22.7	2	41.5	2
Transport and Commun.	10.4	5	10.1	5	9.9	6	8.8	6	5.2	6	3.8	5	74.9	9	123.1	7
Wholesale and R. Trade	50.9	22	35.4	17	30.1	19	20.3	13	16.8	18	12.7	15	106.5	12	272.9	15
Banking, I. & R-Estate	6.5	3	7.2	4	5.5	3	4.7	3	3.1	3	2.2	3	58.6	7	87.9	5
Ownership of Dwellings	15.1	7	9.6	5	5.5	3	3.8	2	3.3	4	2.8	3	18.3	2	58.5	3
Public Adm. & Defense	14.8	6	10.5	5	7.7	5	4.3	3	3.7	4	4.1	5	19.2	2	64.4	4
Services	28.3	12	25.6	12	19.8	12	21.2	14	8.0	9	6.9	8	125.6	15	235.6	13
GRP	229.9	100	202.9	100	161.3	100	152.6	100	92.2	100	82.0	100	855.1	100	1,776.4	100

Source: Gross Regional and Provincial Products, Preliminary Series, NESDB.

3. Gross Provincial Product (GPP)

GPP at current market prices and at 1972 constant prices are presented in Appendices 1.3 and 1.4. Changwats in the BMR and some in the East Region have in general the highest values of GPP and annual growth rates. Bangkok had the highest GPP per capita in 1989 at 34,669 baht. It is followed by most of the changwats in the BMR. In the Central Region Saraburi was the highest at 19,010 baht, and in the West Region it was Kanchanaburi at 11,971 baht. Phuket in the South (20,621), Uthai Thani in the North (11,232) and Khon Kaen and Nakhon-Ratchasima in the Northeast (5,293) had the highest GPP per capita in their respective regions.

2.2.4 Vehicle Registration

In July 1988, the registration of motor vehicles under the Motor Vehicle Act was transferred to the Department of Land Transport, Ministry of Transport and Communications, with some changes made in the registration procedure and vehicle classification. Growth in the total number of vehicle registrations, however, continued to increase rapidly as shown in Fig. 2.2.10. By the year 1990, more than 7.5 million vehicles were registered in Thailand, with more than 2.0 million in Bangkok. The average annual growth rate was higher in Bangkok between 1980-85 than between 1985-90, but the national average reached a higher annual growth of 18.0% as shown in Table 2.2.5. The composition of vehicle registrations for 1990 is presented in Fig. 2.2.11.

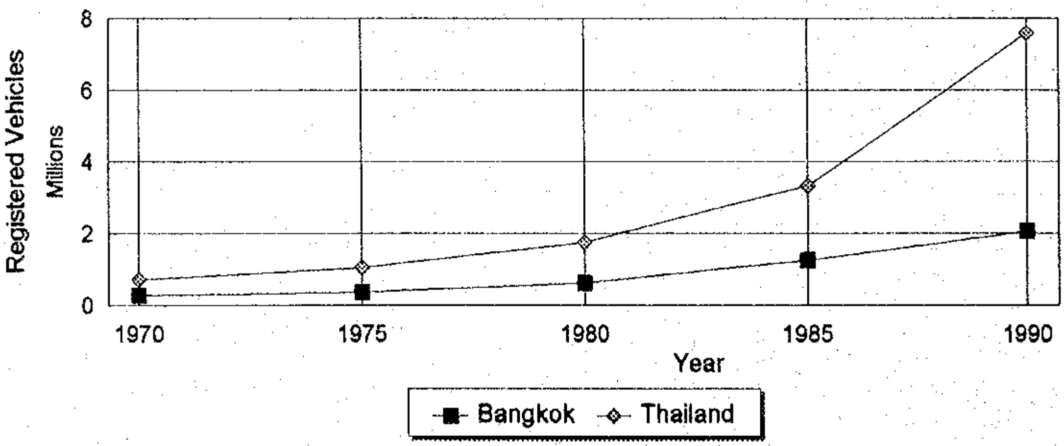


Fig. 2.2.10 Growth of Vehicle Registration

Table 2.2.5 Number of Vehicle Registrations

	Number of Vehicles					Av. Annual Growth %			
	1970	1975	1980	1985	1990	-75	-80	-85	-90
Bkk	275,425	392,972	610,136	1,245,252	2,045,814	5.7	10.9	15.3	10.4
Thai	717,123	1,034,328	1,737,320	3,312,906	7,592,085	7.6	10.9	13.8	18.0

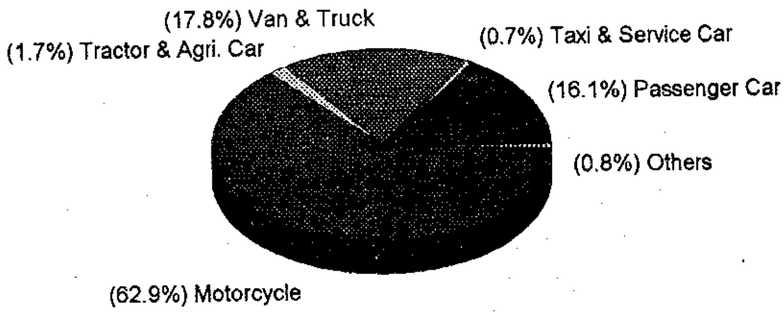


Fig. 2.2.11 Composition of Vehicle Registration - 1990

Taking 1970 as the base year, Fig. 2.2.12 compares the growth in population, GDP and number of vehicles. In the twenty-year period between 1970 and 1990, GDP grew by a factor of about 14 followed by vehicles at a factor of 10.6. On the other hand, population growth increased only by a factor of 1.6 during the same period.

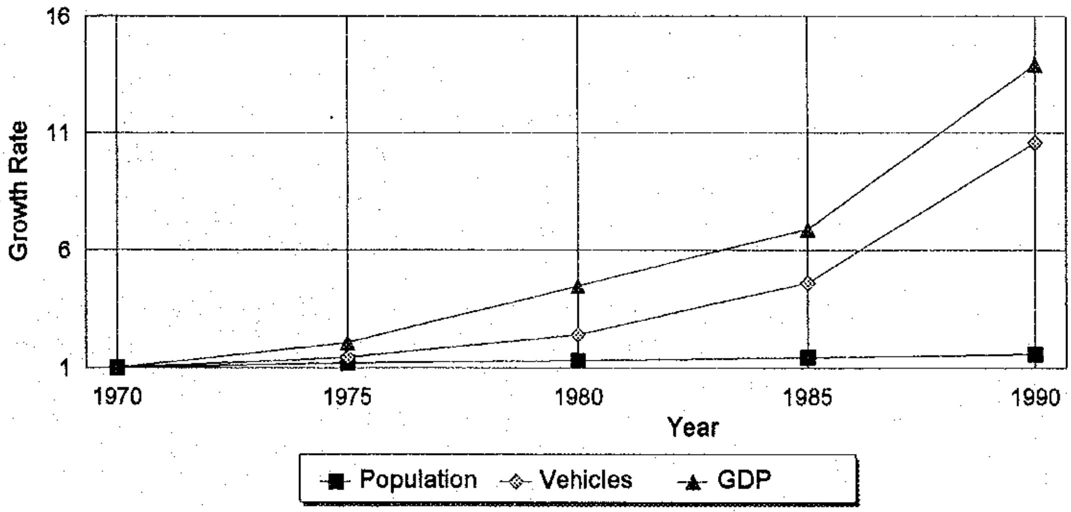


Fig. 2.2.12 Population, GDP and Vehicle Registration Growth

2.3 Highway Network

2.3.1 Current DOH Highway Statistics

Roads in Thailand are registered applying the six (6) categories below.

1. Special Highways or Motorways
2. National Highways
3. Rural Roads
4. Municipal Roads
5. Roads in Small Municipal Areas
6. Concession Highways

Among the above roads, DOH is responsible for only special, national, and concession highways. Table 2.3.1 shows the length of DOH highways.

Since 1975, the ratio of paved national highways has been over 90 percent. As for provincial highways, the ratio of paved surface rose from 14.5 percent in 1965 to 78.1 percent in 1991.

The total length of national and provincial highways, 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 percent. The increase in provincial highways was an especially high 9.1 percent between 1965 and 1991.

Table 2.3.2 shows a regional comparison of DOH highways in 1988. The Central Region has the highest road density of 0.123, which is road length per square kilometer (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.

The ratio of paved national highways for each region is more than 99 percent, while the ratio of paved provincial highways is more than 70 percent.

Table 2.3.1 Length of DOH Highways

Year	1965	1970	1975	1980	1985	1991
National Highway						
Paved (km)	5,046	8,260	11,840	13,733	15,132	18,365
(% Paved)	(53.2)	(82.3)	(93.5)	(98.8)	(99.4)	(99.6)
Unpaved (km)	4,436	1,781	818	160	86	72
Subtotal (km)	9,482	10,041	12,658	13,893	15,218	18,437
Annual growth rate (%)		1.2	4.7	1.9	1.8	3.2
Under construction(km)	4,600	4,284	2,776	980	483	1,468
Total (km)	14,082	14,325	15,434	14,873	15,701	19,905
Provincial Highway						
Paved (km)	405	1,479	3,396	8,670	17,124	21,216
(% Paved)	(14.5)	(25.1)	(45.7)	(60.8)	(77.8)	(78.1)
Unpaved (km)	2,389	4,413	4,043	5,587	4,893	5,947
Subtotal (km)	2,794	5,892	7,439	14,257	22,017	27,163
Annual growth rate (%)		16.1	4.8	13.9	9.1	3.6
Under construction(km)	5,475	5,892	15,447	14,709	8,440	5,333
Total (km)	8,269	11,784	22,886	28,966	30,457	32,496
Grand Total	22,351	26,109	38,320	43,839	46,158	52,401
Paved (km)	5,451	9,739	15,236	22,403	32,256	39,581
Unpaved (km)	6,825	6,194	4,861	5,747	4,979	6,019
Subtotal (km)	12,276	15,933	20,097	28,150	37,235	45,600
Under construction(km)	10,075	10,176	18,223	15,689	8,923	6,801

Source: Highway in Thailand, 1992 by DOH

Table 2.3.2 Regional Comparison of DOH Highways in 1988

	North	Northeast	Central	South	Total
Area (km2)	169,644	168,854	103,902	70,715	513,115
National Highway (km)					
Paved	3,366	4,597	4,754	3,105	15,822
(% Paved)	(99.5)	(99.3)	(99.6)	(99.8)	(99.5)
Unpaved	16	34	20	7	77
Under construction	360	90	310	39	799
Subtotal	3,742	4,721	5,084	3,151	16,698
Provincial Highway (km)					
Paved	6,117	5,538	4,893	3,504	20,052
(% Paved)	(81.1)	(72.9)	(77.9)	(78.3)	(77.4)
Unpaved	1,424	2,056	1,390	973	5,843
Under Con.	3,592	1,548	1,396	739	7,275
Subtotal	11,133	9,142	7,679	5,216	33,170
Total (km)					
Paved	9,483	10,135	9,647	6,609	35,874
(% Paved)	(86.8)	(82.9)	(87.2)	(87.1)	(85.9)
Unpaved	1,440	2,090	1,410	980	5,920
Under construction	3,952	1,638	1,706	778	8,074
Grand total	14,875	13,863	12,763	8,367	49,868
Density (km/km^2)					
Existing	0.064	0.072	0.106	0.107	0.081
Total	0.088	0.082	0.123	0.118	0.097

Source: DOH

2.3.2 Road Maintenance

1. Organizations Dealing with Road Disaster Prevention and Service Restoration in DOH

There are several organizations dealing with road disaster prevention and service restoration, such as the Maintenance Division, Construction 4, the Location and Design Division, and the Material Research Division. Details on these organizations will be discussed later in this report.

2. Highway Maintenance Organization and Works

Highway divisions and districts, which are under the direction of the offices of the director general, deputy director general, and senior expert for maintenance, are responsible for the maintenance of national and provincial highways. The organizational flow chart for highway maintenance for all of Thailand is as shown in Fig. 2.3.1.

Highway maintenance work in DOH, as shown in Table 2.3.3, is classified into five types of maintenance consisting of numerous maintenance items and measures.

Table 2.3.3 Classification of Road Maintenance

Type of Maintenance	Maintenance Items and Measures	
Routine Maintenance	Asphalt Surface	Filling Cracks Surface Sealing Surface Leveling Skin Patching Deep Patching Surface Grinding Surface Cleaning
	Concrete Pavement	Repairing Joint Seals Concrete Patching Repairing Seal Cracks Leveling with Cold Mix or Hot Mix Surface Cleaning
	Soil Aggregate Surface	Surface Patching Light Grading Heavy Grading
	Road Shoulders & Medians	Shoulder Grass Cutting Shoulder Patching Shoulder Light Grading Shoulder Filling Repairing Cracking

Table 2.3.3 Classification of Road Maintenance (Continued)

Routine Maintenance	Road Shoulders & Medians	Shoulder Crack Filling Surface Shoulder Asphalt Sealing Surface Leveling Skin Patching Deep Patching Asphalt Shoulders Median Maintenance and Repairs
	Drainage	Restoration of Drainage Culvert Repairs
	Traffic Aids and Highway Roadside Shelters	Maintenance of Traffic Signs and Markings Maintenance of Guide-Posts, Guardrails, etc Maintenance of Traffic Signals and Road Lighting
	Traffic Aids and Highway Roadside Shelters	Maintenance of Highway Roadside Shelters
	Maintenance and Repair of Highway Structures	Bridge Maintenance/ Repair Repairing Bridge Slopes Repairing Retaining Walls Repairing Pedestrian Bridges
	Roadside Maintenance	Repairing Slopes Clearing the Roadside Maintenance of Road-side Development

Table 2.3.3 Classification of Road Maintenance (Continued)

Maintenance Equipment	Repairing and Servicing Maintenance Equipment
Periodic Maintenance	Asphalt Seal-Coating Asphalt Overlaying Soil Aggregate Resurfacing
Special Maintenance and Rehabilitation	Rehabilitation of Asphalt Pavement Asphalt Surface Leveling Major Repairs of Asphalt Pavement Major Repairs of Concrete Pavement Repairing Joint Seals Major Repairs of Shoulders Shoulder Improvements Major Slope Repairs Pavement Widening Surface Improvements Pavement Widening Improving Geometry Improving Drainage Structures Constructing Permanent Ditches Preventing Erosion Elimination and Prevention of Flooding Major Bridge Repairs Constructing Minor Retaining Walls Applying Thermoplastic Painting Installation of Road Signs and Delineators Provision of Raised Pavement Markers Major Repairs of Traffic Signals and Road Lighting Provision of Traffic Signs and Road Lighting Provision of Guardrails Roadway Improvements Provision of Bicycle Lanes Provision of Pedestrian Bridges Provision of Bus Stops and Shelters Planting and Sodding Provision of Rest Areas and Improvement of Ways

Table 2.3.3 Classification of Road Maintenance (Continued)

Special Maintenance and Rehabilitation	Repairing of Bus Shelters Provision of Sub-drains
Emergency Maintenance Work	Repairs after Flooding Repairs after a Major Landslide Repairing Damage Caused by a Major Accident

Source: Maintenance Division, DOH

3. Budget for Maintenance

DOH's maintenance budget has been increasing in recent years and will continue to do so in the near future, as shown in Table 2.3.4.

Highway maintenance work, including improvements, are expected to increase in the future. For example, the proposed budget for 1995 is 11,358.8 million baht as compared to 7104.2 million baht for 1994. This is due to the expansion of the highway network, the necessity for a higher level of service, and the increase in traffic volume and axle weight.

2.3.3 Traffic Volume

According to 1990 DOH records, the Central Region had the largest traffic volume of Thailand's four (4) regions. Especially, the traffic volume on national highway Route 31 in the Central Region was recorded carrying 121,524 vehicles per day.

The percentage of national highway routes with a traffic volume of more than 8,000 vehicles per day by region is as follows:

Percentage of National Highway Routes with More Than 8,000 vehicles/day by Region

	North	Northeast	Central	South
Ratio	15 %	7 %	43 %	20 %

Table 2.3.4 Comparison of Budget Allocations

Year	National Budget (A) (Mill. Bht.)	DOH Budget (B) (Mill. Bht.)	A/B (%)	Subdivision of DOH Budget						
				Administration (C) (Mill. Bht.)	C/B (%)	Construction (D) (Mill. Bht.)	D/B (%)	Maintenance (E) (Mill. Bht.)	E/B (%)	Annual Growth Rate of Maintenace
1980	114,556.5	7,263.7	6.3	1,475.4	20.3	4,759.2	65.5	1,029.1	14.2	
1985	213,000.0	8,968.5	4.2	1,710.9	19.1	4,858.3	54.2	2,399.3	26.8	18.4
1986	218,000.0	8,928.2	4.1	1,757.3	19.7	4,867.8	54.5	2,303.1	25.8	- 4.2
1987	226,000.0	8,562.3	3.8	1,804.0	21.1	4,231.5	49.4	2,521.8	29.5	9.5
1988	243,500.0	10,007.3	4.1	1,983.3	19.8	5,208.2	52.0	2,815.8	28.1	11.7
1989	285,500.0	11,794.5	4.1	2,057.2	17.4	6,940.1	58.8	2,797.1	23.7	- 0.7
1990	335,000.0	15,675.9	4.7	2,384.9	15.2	9,790.2	62.5	3,500.9	22.3	25.2
1991	387,500.0	17,920.6	4.6	2,840.8	15.9	10,990.1	61.3	4,089.7	22.8	16.8
1992	460,400.0	22,136.7	4.8	3,068.3	13.9	13,816.2	62.4	5,252.2	23.7	28.4
1993								6,207.9		18.2
1994								7,104.2		14.4
1995								11,358.8		59.9

Table 2.3.5 shows the number of vehicle kilometers for DOH highways for the whole of Thailand during the last five (5) years.

Table 2.3.5 Annual Vehicle Kilometers for DOH Highways by Highway Type

Type of Highway	Annual Vehicle Kilometers					
	1987	1988	1989	1990	1991	1992
National Highways						
Primary	13,000.3	14,828.5	18.717.4	18,556.1	20,890.5	23,463.8
Secondary	8,268.4	9,410.8	11,166.4	13,220.2	16,281.8	19,571.5
Provincial Highways	10,448.1	10,940.3	11,710.1	13,993.5	14,926.2	20,806.9
Total	31,716.8	35,179.6	41,593.9	45,769.8	52,098.5	63,842.2
Annual Growth Rate (%)		10.9	18.2	10.0	13.8	22.5

Source: DOH

Annual vehicle kilometers for DOH highways grew steadily at a rate of 10% or more for the period 1987-1992. That is, the number of vehicle kilometers during 1987 to 1992 increased more than two times.

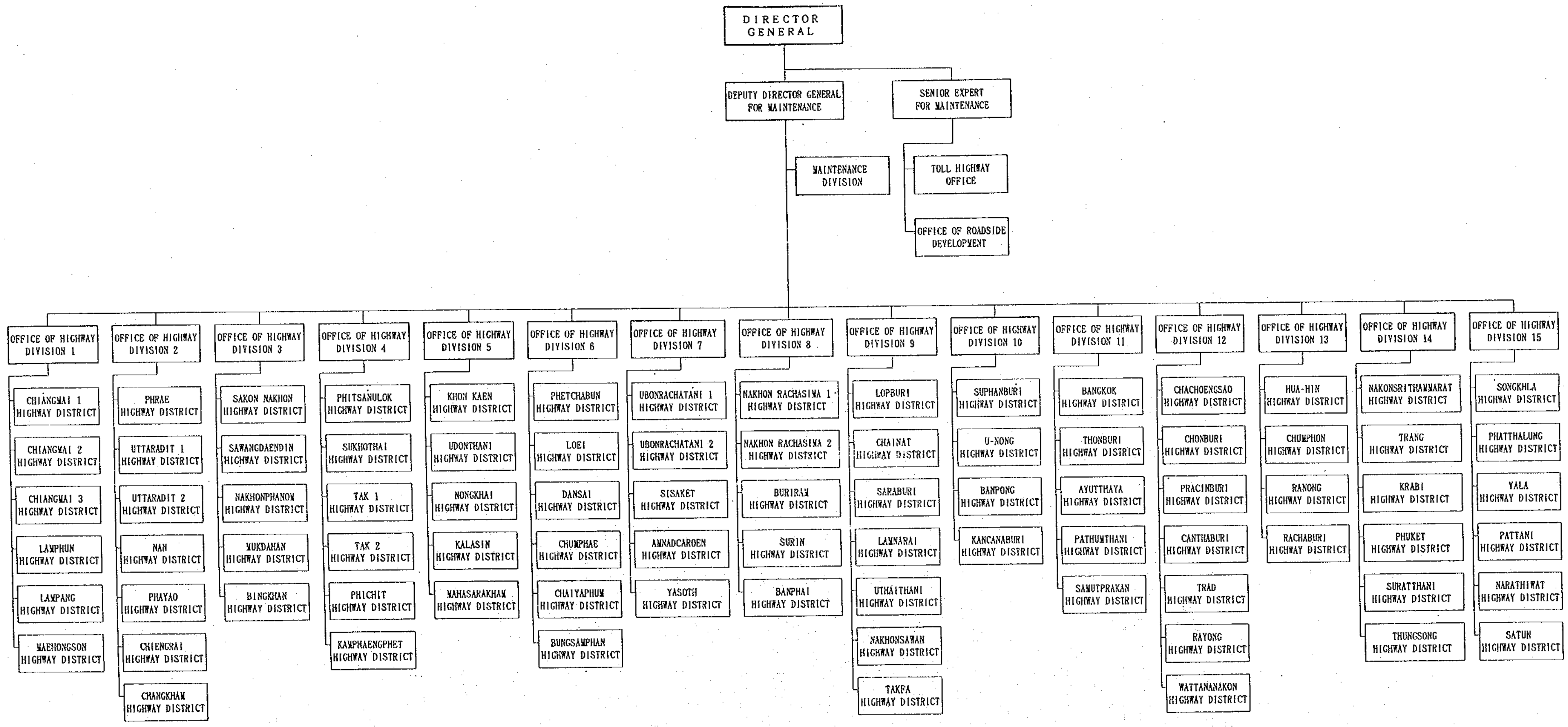


Fig. 2.3.1 Organization for Highway Maintenance (1992)

2.4 Road Disaster

2.4.1 Past Disaster Records

The Central Office of the Department of Highways (DOH) has records on past road disasters for the fiscal years 1976 to 1993. The quality and detail of these records vary depending on the policy at the time of the event.

Summaries of disaster-related highway repair costs for 1991 and 1992 are presented in Table 2.4.1 and 2.4.2. These tables show the number of routes, temporary repair costs and permanent repair costs by region. The separate recording of temporary repair and permanent repair costs commenced in 1991. As expected, the cost of the latter is considerably higher than that of the former.

Table 2.4.1 Summary of Disaster-Related Highway Repair Costs for 1991

Region	No. of Routes	Distance (km.)	Repairs (baht)		Total
			Temporary Repair	Permanent Repair	
N	87	464.600	17,340,000 (27)	46,243,000 (73)	63,583,000 (100)
NE	67	99.880	5,389,000 (20)	21,373,000 (80)	26,762,000 (100)
C	51	73.330	10,129,000 (26)	28,760,000 (74)	38,889,000 (100)
S	12	22.010	3,035,000 (17)	14,547,000 (83)	17,582,000 (100)
Total	217	659.820	35,893,000 (24)	110,923,000 (76)	146,816,000 (100)

Remarks : ( ) is %.

Table 2.4.2 Summary of Disaster-Related Highway Repair Costs for 1992

Region	No. of Routes	Distance (km.)	Repairs (baht) Temporary Repair	Permanent Repair	Total
N	19	10.820	2,305,170 (43)	3,099,430 (57)	5,404,600 (100)
NE	7	2.630	110,000 (15)	631,600 (85)	741,600 (100)
C	24	47.990	925,500 (58)	672,500 (42)	1,598,000 (100)
S	19	10.240	400,000 (62)	242,560 (38)	642,560 (100)
Total	69	71.680	3,740,670 (45)	4,646,090 (55)	8,386,760 (100)

Remarks : ( ) is %.

The changes in the annual repair costs for disaster-related highway damage for the four DOH regions are illustrated in Table 2.4.3 and Fig. 2.4.1. A summary for all of Thailand is illustrated in Fig. 2.4.2, and regional annual averages are shown in Table 2.4.4.

Table 2.4.3 Annual Road Repair Costs for Disaster-Related Damage

Year	North Region			Northeast Region			Central Region			South Region			Total		
	No. of Routes	km.	Cost (1000 Baht)	No. of Routes	km.	Cost (1000 Baht)	No. of Routes	km.	Cost (1000 Baht)	No. of Routes	km.	Cost (1000 Baht)	No. of Routes	km.	Cost (1000 Baht)
1976	46	37	2,197	46	44	1,297	78	130	14,487	60	210	7,080	230	421	25,061
1977	57	87	2,869	77	123	5,563	29	36	1,203	66	229	8,960	229	475	18,595
1978	81	220	12,435	128	326	21,714	50	185	6,588	47	225	5,383	306	956	46,120
1979	39	99	4,164	99	375	26,963	84	210	6,404	48	96	8,157	270	780	45,688
1980	133	224	27,085	83	84	11,173	30	38	3,235	43	70	1,994	289	416	43,487
1981	106	172	21,781	94	102	7,600	127	299	30,486	36	35	1,076	363	608	60,943
1982	45	78	6,955	91	229	17,006	74	211	15,950	75	315	39,647	285	833	79,558
1983	21	17	4,432	44	30	3,797	63	208	40,007	30	34	1,958	158	289	50,194
1984	43	91	4,905	68	89	9,333	159	358	61,287	53	115	9,154	323	653	84,679
1985	30	21	11,781	32	26	5,322	36	51	16,903	60	199	25,309	158	297	59,315
1986	42	33	4,880	16	5	1,159	64	81	10,347	41	61	5,260	163	180	21,646
1987	71	43	9,654	35	19	3,467	62	58	3,675	50	76	9,943	218	196	26,739
1988	36	39	5,372	19	5	1,333	67	109	8,750	72	171	12,588	194	324	28,043
1989	31	89	10,282	20	12	1,786	87	198	15,590	132	705	157,331	270	1,004	184,989
1990	13	2	1,141	24	9	4,828	8	5	1,350	18	82	13,122	63	98	20,441
1991	87	464	63,583	67	100	26,762	51	73	38,889	12	22	17,582	217	659	146,816
1992	19	11	5,405	7	3	742	24	48	1,598	19	10	643	69	72	8,388
Total	900	1,727	198,921	950	1,581	149,845	1,093	2,298	276,749	862	2,655	325,187	3,805	8,261	950,702
Annual Average	53	102	11,701	56	93	8,814	64	135	16,279	51	156	19,129	224	486	55,923

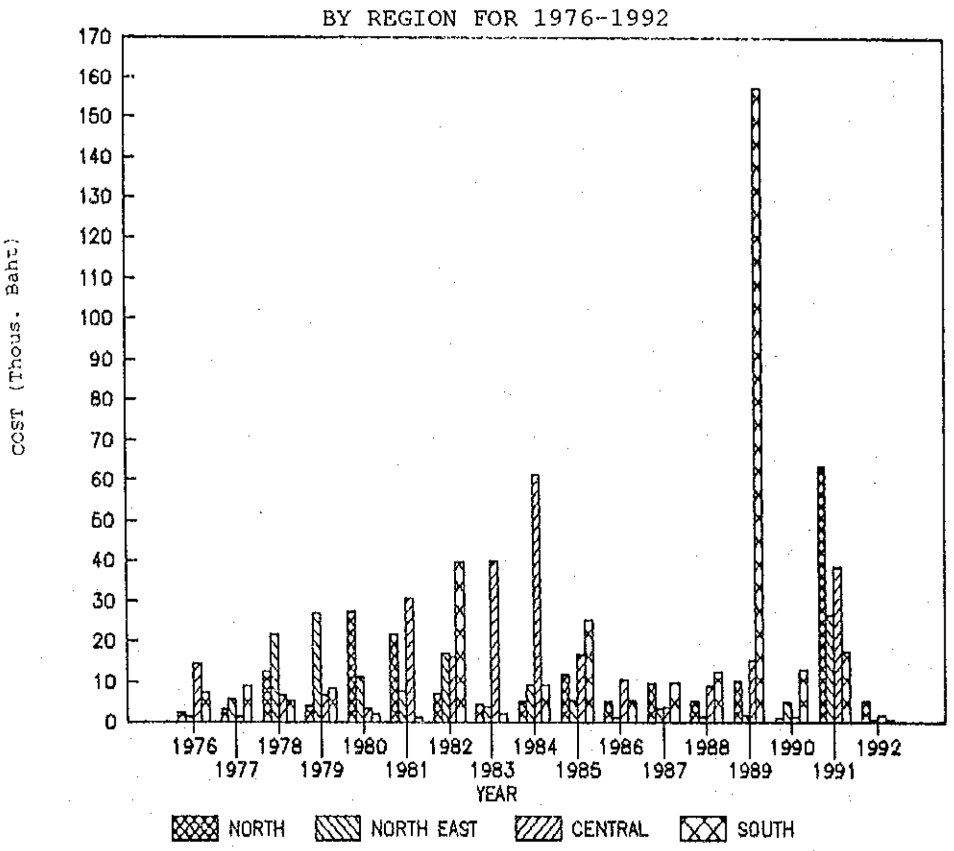


Fig. 2.4.1 Annual Road Repair Costs for Disaster-Related Damage by Region

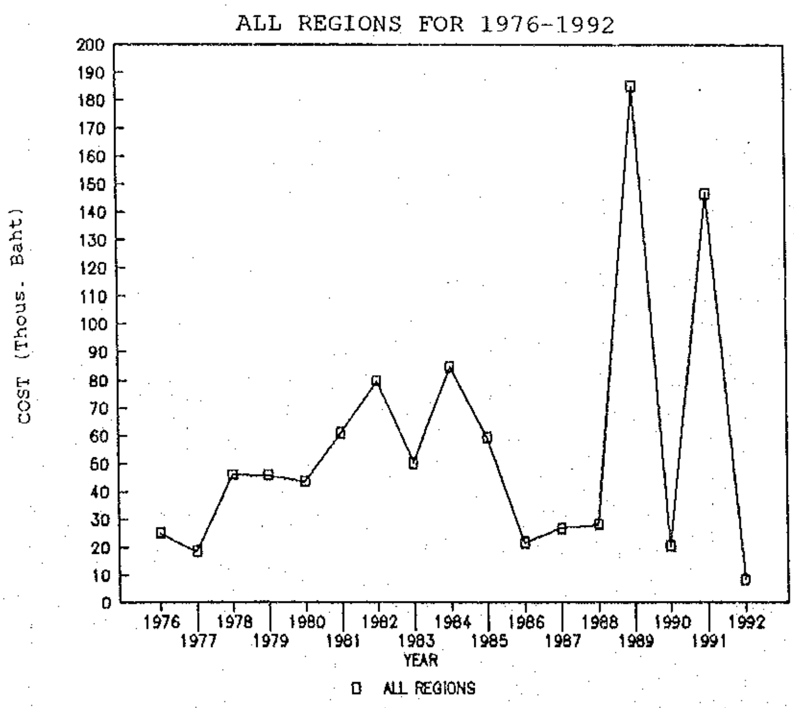


Fig. 2.4.2 Annual Road Repair Costs for Disaster-Related Damage in Thailand

Table 2.4.4 Annual Average of Road Repair Costs for Disaster-Related Damage

Region	No. of Routes	km.	Cost (M. Baht)	Existing Road (km)	Cost/km (Baht)
N	53	102	11.7	14,875	787
NE	56	93	8.8	13,863	635
C	64	135	16.3	12,763	1,277
S	51	156	19.1	8,367	2,283
TOTAL	224	486	55.9	49,868	1,121

Remarks: Fiscal years 1976 - 1992

The average repair cost per route for disaster-related damage and the annual average repair cost are also illustrated in Fig. 2.4.3 and 2.4.4. As shown in these records, the cost for fiscal 1989 and 1991 are unusually high, with the South Region being most affected in 1989 and the North Region in 1991.

Based on the DOH records from 1983 to 1993, the distribution of road repair costs for disaster-related damage is presented in Table 2.4.5.

Table 2.4.5 Distribution of Road Repair Costs for Disaster-Related Damage

1000 Baht	N		NE		C		S		TOTAL	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
0	35	8	50	12	128	17	86	12	299	13
less than 50	150	32	155	38	195	25	207	28	707	29
50-less 100	52	11	55	14	100	13	90	12	297	12
100 - 500	176	37	124	31	274	35	280	37	854	36
500 - 1000	35	7	14	4	43	6	36	5	128	5
1000 - 5000	24	5	6	1	33	4	39	5	102	4
5000 - 10000	0	0	0	0	2	-	7	1	9	}
10000 -	1	-	0	0	0	0	3	-	4	} 1
TOTAL	473	100	404	100	775	100	748	100	2400	100

Remarks : Data of 1983 - 1993 for each report.

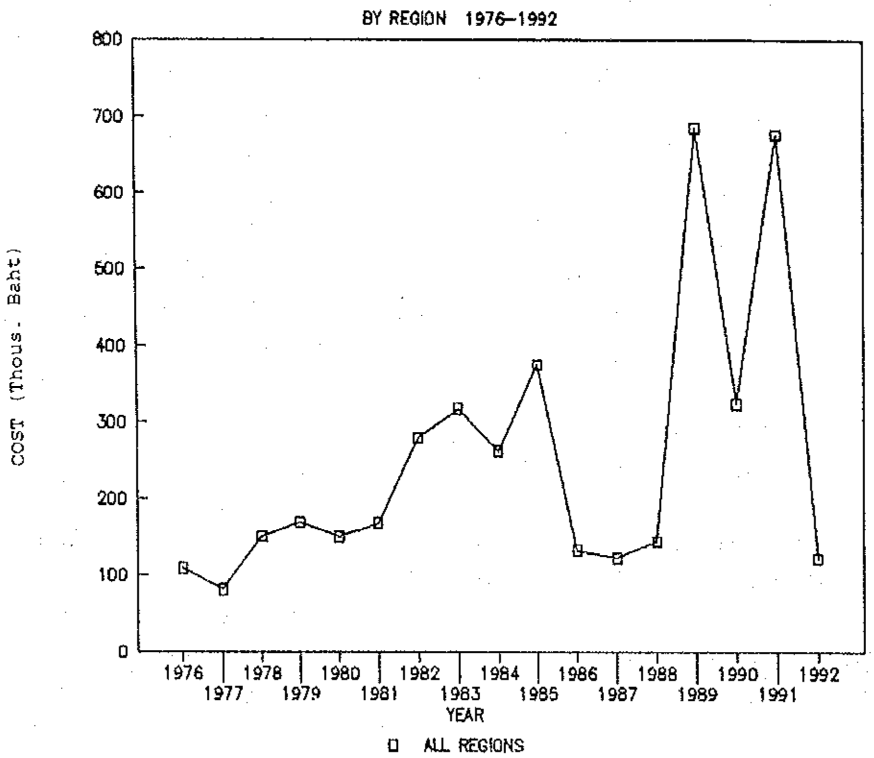


Fig. 2.4.3 Average Cost / Route for Road Repairs for Disaster-Related Damage

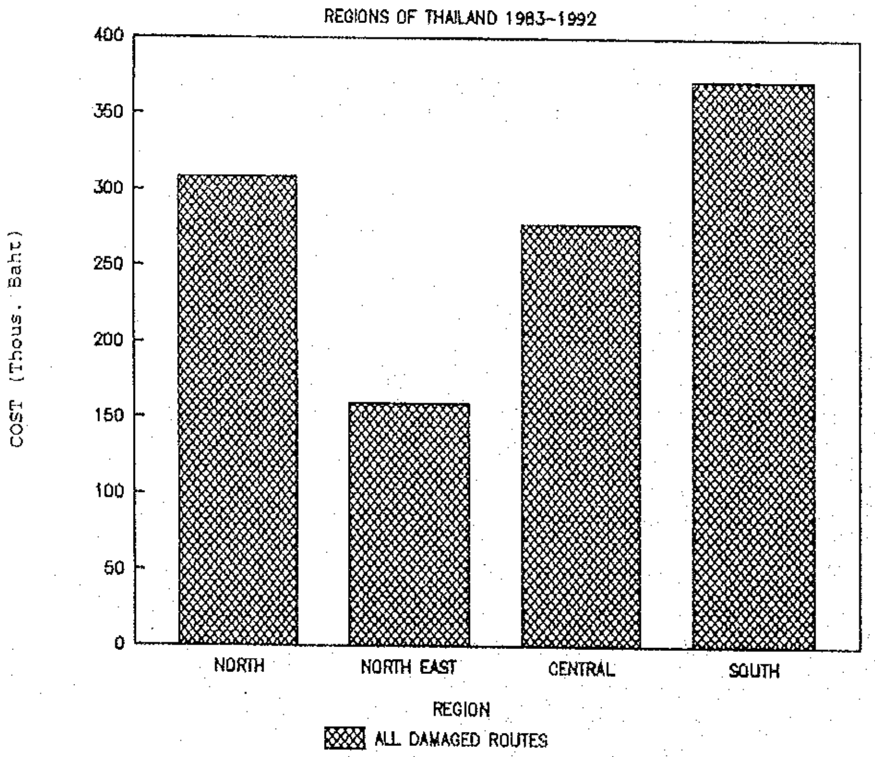


Fig. 2.4.4 Annual Average Road Repair Costs for Disaster-Related Damage

The number of routes with repair costs in excess of one million baht during the 11-year period is summarized as below:

- North Region 25 routes
- Northeast Region 6 routes
- Central Region 35 routes
- South Region 49 routes

It can be seen that the South Region has had the most serious road disasters for the last 11 years, which vary in number depending on the frequency of typhoons and tropical depressions for a particular year.

The five most frequently damaged routes for each region are shown in Table 2.4.6, and the regional and annual averages for road repair costs are presented in Table 2.4.7. It can be seen from these tables that the South Region has the highest average cost (129% of the national average) and the Northeast Region has the lowest (55% of the national average).

Table 2.4.6 Road Damage Reports for Five Most Frequently Damaged Routes by Region

No.	N Region			NE Region			C Region			S Region		
	Rt. No.	No. of Reports	No of Locations	Rt. No.	No. of Reports	No. of Locations	Rt. No.	No. of Reports	No. of Locations	Rt. No.	No. of Reports	No. of Locations
1	113	19	27	2	11	18	3	55	175	4	70	240
2	1	16	31	2134	10	25	1	25	47	42	34	154
3	11	12	25	212	8	11	344	13	19	401	24	58
4	2275	11	37	202	7	7	3113	13	31	41	20	50
5	101	10	14	2291	7	41	323	12	40	410	17	49

Remarks: Data for 1983 - 1993

Table 2.4.7 Annual Average Road Repair Costs for Disaster-Related Damage

Region	1,000 Baht	%
North	308	107
Northeast	159	55
Central	278	97
South	372	129
National Average	288	100

Remarks: Data for 1983 - 1992.

The annual number of road sections damaged is presented in Table 2.4.8. These data illustrate the significant differences for each year and region. The frequency of road damage is generally higher in the Central and South regions compared to the rest of the country. The relative annual averages for the regions are presented in Table 2.4.9. It can be seen that an average of 73 routes were damaged each year, with 218 reports consisting of 734 locations.

Table 2.4.8 Annual Number of Road Sections Damaged

Year	Region				Total
	N	NE	C	S	
1983	52	152	394	43	641
1984	159	257	817	324	1557
1985	76	93	121	390	680
1986	125	37	174	132	468
1987	229	108	156	201	694
1988	110	45	270	455	880
1989	83	47	387	820	1337
1990	24	83	21	54	182
1991	286	225	158	31	700
1992	43	13	108	41	205
Total	1187	1060	2606	2491	7344
Annual Average	119	106	260	249	734
Existing Road (km)	14,875	13,863	12,763	8,367	49,868
Annual Av. Locations/100km	0.80	0.76	2.04	2.98	1.47

Table 2.4.9 Frequency of Road Damage by Region

Region	No. of Routes Damaged	Frequency of Damage Reported	No. of Locations Damaged
Northern	193 (17)	473 (43)	[119]
North-eastern	182 (16)	404 (37)	[106]
Central	251 (23)	775 (70)	[260]
Southern	190 (17)	748 (68)	[249]
Total	806 (73)	2400 (218)	[734]

Remarks : ( ) Annual averages derived from 1983 - 1993 data
[ ] Annual averages derived from 1983 - 1992 data

2.4.2 Distribution of Road Damage by Disaster Type

Due to differences in data classification adopted by DOH and that adopted in this study, two sets of tables are presented here to reflect the distribution of the different types of disaster-related damage in the different regions. Table 2.4.10 and 2.4.11 present distributions based on the DOH system.

Table 2.4.10 Annual Record of Special Disasters on Highways

REGION	YEAR	No. of Special Disaster Locations									
		DESTROYED ROADS	LAND SLIDES	PIPE DAMAGE	BROKEN PIPE	BRIDGE ABUTMENT DAMAGED	BRIDGE ABUTMENT DESTROYED	BRIDGE DAMAGED	BRIDGE CUT	BRIDGE TOTALLY DESTROYED	Total
	1981	5	1	2	5	14	21	7	22	28	105
	1982	4	1	3	3	4	6	1	4	5	31
	1983				3	1	3	11	1	11	30
	1984	5	2	24	1	5	6	6	8	1	58
N	1985	1	5	4		2	5	5	2		24
	1988	11		1	2	3	7	1	1		26
	1989	4	5		2	2	2		1		16
	1990						1		2		3
	1991	3	4	4		11	7	19	6		54
	1992		3	1				1			5
	SUB-TOTAL	33	21	39	16	42	58	51	47	45	352
	1981	9		2	9	11	22	4	5	4	66
	1982	36		11	8	14	43	2	3		117
	1983	14		8	4	11	7	2	2		48
	1984	2		12	1	7	4	8	3		37
	1985	5		1			2	4			12
NE	1988	2			6		1	2			11
	1989	6		2	3	1	1	1			14
	1990	2		2	3	4	7	3			21
	1991	1		2	1	3	17	1			25
	1992					1					1
	SUB-TOTAL	77		40	35	52	104	27	13	4	352
	1981	1		4	1	8	1	4	1		20
	1982	2		4	1	7	2	1	3		20
	1983	1		7		5	1	4			18
	1984	8		33		7	4	12	4		68
	1985			2				1			3
C	1988			3			2	3			8
	1989	7	1	2	2		3				15
	1990			2							2
	1991	1				2	1		1		5
	1992	1					2				3
	SUB-TOTAL	21	1	57	4	29	16	25	9	0	162
	1981	1				2		3	1		7
	1982	51	17	2	6	9	17	16	18	1	137
	1983	3			5	1	1	6	2		18
	1984	6		12		5	3	5	2	1	34
	1985	29	25	7	33	11	4	22	3		134
S	1988	2	4	3	3	10	7	4	1		34
	1989	35	9	4	18	15	48	5	10	1	145
	1990		1	2			3	1			7
	1991			1			1	1			3
	1992	3				1			1		5
	SUB-TOTAL	130	56	31	65	54	84	63	38	3	524
TOTAL		261	78	167	120	177	262	166	107	52	1390

Remark : Data for 1986 and 1987 are N.A.

Table 2.4.11 Annual Averages for Road Damages

Region	No. of Routes	No. of Locations	No. of Special Disaster Locations (Details): Road Destroyed	Land Slide	Pipe Damaged	Pipe Destroyed	Bridge Abutment Damaged	Bridge Abutment Destroyed	Bridge Damaged	Bridge Cut	Bridge Totally Destroyed	Other Road Damage (minor)
N	43	119	3	2	4	2	4	6	5	5	5	83
NE	47	106	8	0	4	4	5	10	3	1	0	71
C	69	260	2	0	6	0	3	2	3	1	0	243
S	51	249	13	6	3	7	5	8	6	4	0	197
TOTAL	210	734	26	8	17	12	18	26	17	11	5	594
Approximate Estimation of Cause			Road Collapsing	Slope Damage	Road Flooding	Road Collapsing	Bridge Collapsing					10% Slope Damage 90% Road Flooding

Remarks : Data from 1981 to 1992 (except 1986 and 1987)
No. of locations (734) - No. of special disaster locations (140) = No. of other road damage (minor)

The approximate corresponding causes of the two alternative systems are given below:

Road Destroyed - Road Collapsing
Landslide - Slope Damage
Pipe Damage - Road Flooding
Pipe Destroyed - Road Collapsing
Bridge Abutment Damaged to Bridge Totally Destroyed
 - Bridge Collapsing
Other Road Damage - Road Flooding 90 %
 - Slope Damage 10 %

Table 2.4.12 shows the alternative system used in the Study. It can be seen that the average number of damaged locations is 734 and 81% of these were considered to be minor. About 11% of the damage was in connection with bridges. Table 2.4.12 shows that the rate of bridges collapsing was unusually high in the North and Northeast regions (21% and 18%). Road flooding in the Central Region accounted for 87% of the events there. The national flooding average for this approximate 10-year period was about 75% of all events. Reported slope damage was only 9 %, but this could be due to many slope damage events not being reported by the district offices as they did not close the roadway.

Table 2.4.12 Frequency of Road Damage Types

No.	Type	Annual Average Number of Locations									
		N	(%)	NE	(%)	C	(%)	S	(%)	TOTAL	(%)
1	Bridge Collapsing	25	(21)	19	(18)	9	(3)	23	(9)	76	(11)
2	Road Collapsing	5	(4)	12	(11)	2	(1)	20	(8)	39	(5)
3	Road Flooding	79	(66)	68	(64)	225	(87)	180	(72)	552	(75)
4	Slope Damage	10	(9)	7	(7)	24	(9)	26	(11)	67	(9)
	Total	119	(100)	106	(100)	260	(100)	249	(100)	734	(100)

Remarks : Averages between Oct. 1983 and Sep. 1992
Estimated approximate distribution of causes of minor road damage: Road flooding 90 % - Slope damage 10 %

The comparative ratios between the regions and damage types per year for the 1991-1993 period is shown in Table 2.4.13.

Table 2.4.13 Ratio of Road Damage Types by Region (%)

Regions	Bridge Collapsing	Road Collapsing	Road Flooding	Slope Damage	Total
N.	4	12	74	10	100
NE.	2	18	77	3	100
C.	1	4	92	3	100
S.	2	6	83	9	100
Total	2	8	85	5	100

Remarks : 1991 - 1993 data

2.4.3 Frequency of Traffic Interruptions

Table 2.4.14 illustrates the distribution of the duration of traffic interruptions in days on a regional basis as derived from DOH data for the 1983-1992 period (except 1991). It can be seen that 60% of the road damage reported did not cause any significant interruption to traffic. Only 2% of traffic interruptions lasted 20 days or longer. The regions had distinctly different distributions of traffic interruptions per road damage report. For example, 75% of reported damage in the Central Region resulted in no interruptions to traffic, whereas in the South Region only 42% of reported damage were without an interruption to traffic.

Table 2.4.14 Number of Days Traffic Interrupted

N. Region				NE. Region				C. Region				S. Region				Total	
Days	Frequency		(%)	Days	Frequency		(%)	Days	Frequency		(%)	Days	Frequency		(%)	Frequency	(%)
0	185		(61)	0	155		(58)	0	428		(75)	0	199		(42)	967	(60)
1	24 }	50	(16)	1	35 }	52	(20)	1	26 }	48	(9)	1	68 }	106	(22)	256	(16)
2	26 }			2	17 }			2	22 }			2	38 }				
3	14 }			3	11 }			3	12 }			3	44 }				
4	12 }			4	8 }			4	8 }			4	32 }				
5	12 }	52	(17)	5	7 }		(15)	5	4 }			5	22 }				
6	5 }			6	4 }	39		6	7 }	41	(7)	6	17 }	135	(29)	267	(17)
7	1 }			7	5 }			7	1 }			7	7 }				
8	8 }			8	3 }			8	7 }			8	9 }				
				9	1 }			9	2 }			9	4 }				
10	2 }			10	3 }			10	6 }			10	13 }				
11	1 }			12	1 }			11	3 }			11	4 }				
12	3 }	12	(4)	13	1 }	9	(3)	12	6 }			12	2 }				
14	3 }			14	3 }			13	5 }			13	2 }				
15	2 }			19	1 }			14	3 }	34	(6)	14	3 }	29	(6)	84	(5)
16	1 }							15	5 }			15	2 }				
								16	3 }			16	2 }				
								17	1 }			18	1 }				
								18	1 }								
								19	1 }								
20	2 }			22	2 }			21	5 }			20	1 }				
26	1 }			23	1 }			22	3 }			21	2 }				
27	1 }	7	(2)	24	1 }		(4)	23	3 }			22	1 }	6	(1)	42	(2)
29	1 }			28	2 }	10		24	1 }			23	1 }				
31	1 }			32	1 }			25	1 }			26	1 }				
32	1 }			42	1 }			26	1 }	19	(3)						
				46	1 }			35	1 }								
				48	1 }			37	1 }								
								45	1 }								
								58	1 }								
								72	1 }								
Total	306		(100)		265		(100)		570		(100)		475		(100)	1616	(100)

Remarks : 1983 – 1992 (except 1991)

The distribution of traffic interruptions that lasted 20 days or longer during the past nine years is presented below:

North Region - 7 occasions

Northeast Region - 10 occasions

Central Region - 19 occasions

South Region - 6 occasions

Total (all regions) - 42 occasions

The frequency of long traffic interruptions with respect to road class is presented in Table 2.4.15. Single-digit roadways only experienced a long interruption once on Route 3 in 1984. There was also only one similar occurrence for double-digit roadways on Route 33 in 1984. On two occasions (on Route 206 in 1984 and Route 410 in 1988) triple-digit roadways suffered interruptions for 20 days or longer. The remaining 38 long interruptions occurred on four-digit roadways. The number of interruptions lasting 20 days or longer has shown a marked reduction in recent years (see Fig.2.4.5).

Table 2.4.15 Traffic Interruptions 20 Days or Longer by Road Class and Region from Disaster-Related Damage

Region	Frequency	No. of Routes by Road Class				Notes
		Single Digit	Double Digit	Three Digit	Four Digit	
N	7				7	Same route two times-Rt. 1265
NE	10			1	9	Same route two times-Rt. 2086, 2285
C	19	1	1		17	Three times-Rt. 2244 Four times-Rt. 2212
S	6			1	5	
Total	42	1	1	2	38	

Remarks : 1983 - 1992 (except 1991)

In all cases of long interruptions there was heavy rain and 76% of the time flooding resulted. The analysis of the actual events (see Fig. 2.4.6) reveals that nearly all of the problems can be ascribed to "road destroyed", "bridge destroyed" and "bridge approach destroyed".

Traffic interruptions of all durations are summarized in Fig. 2.4.7. It can be seen that the Central Region experienced the largest number of total traffic days lost (approx. 1500 days for 9 years or 170 days per year). If the data is normalized for the total route distances in each region, it can be seen that the number of days lost/1000km/year is nearly equal in the Central and South regions at 17 days/1000km/year. The North and Northeast regions have values only one-third of this. Here, total route distance is the length of existing roads.

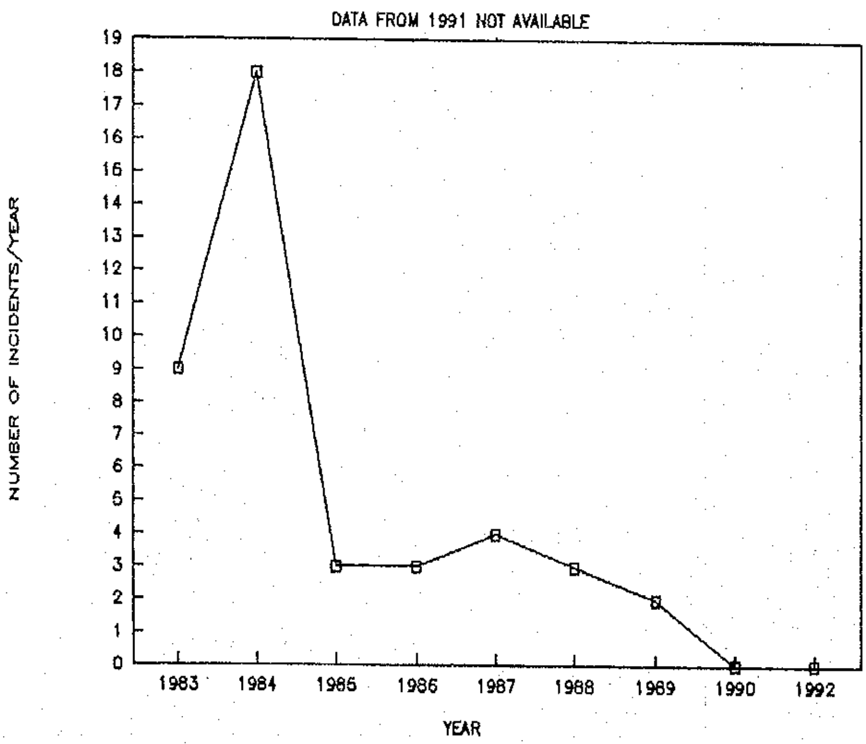


Fig. 2.4.5 Traffic Interruptions ≥ 20 Days

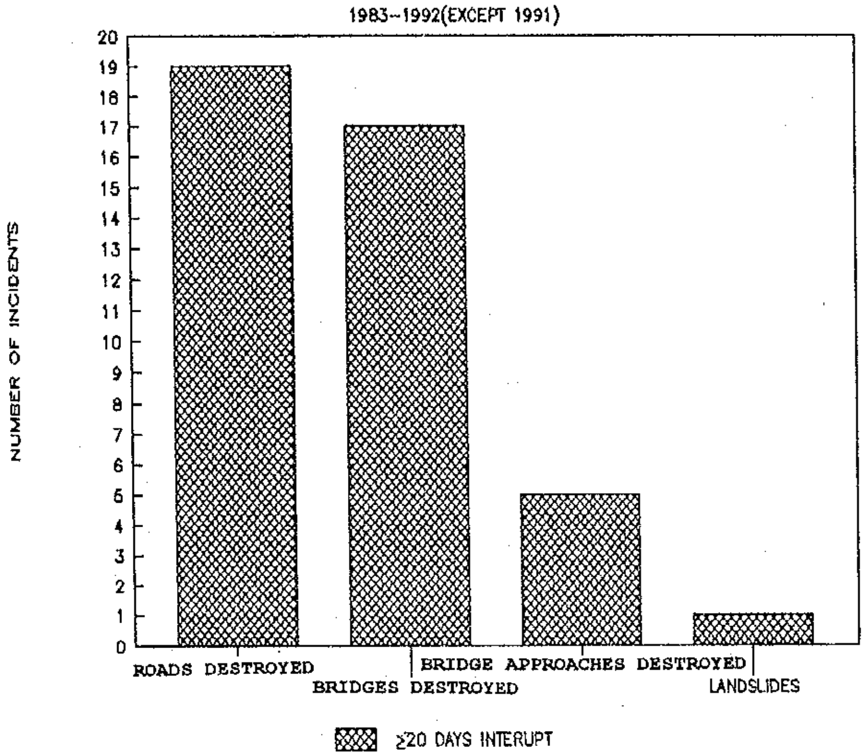


Fig. 2.4.6 Causes of Traffic Interruptions ≥ 20 Days by Disaster Type

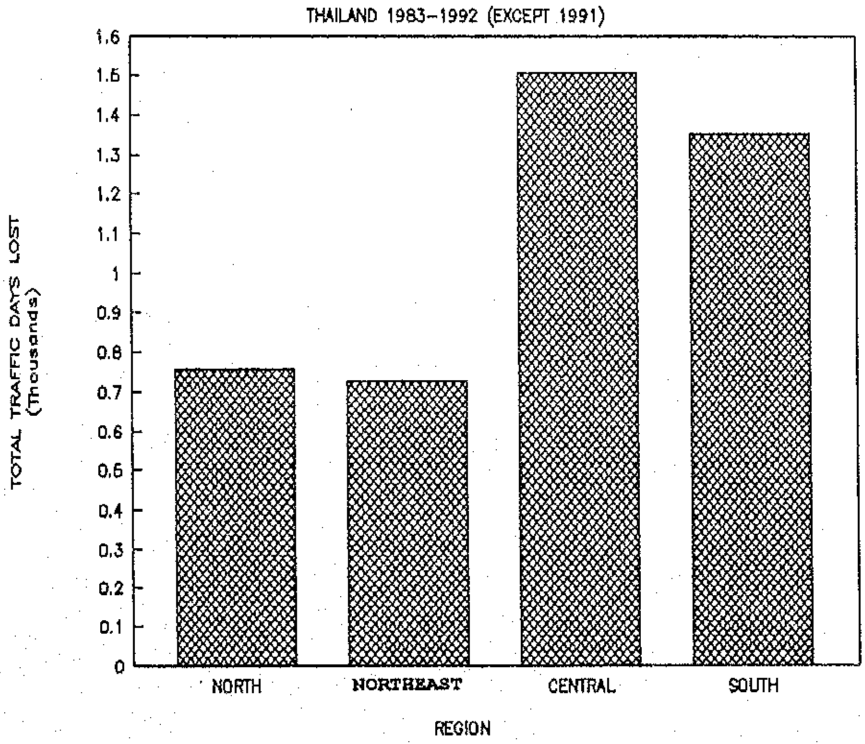


Fig. 2.4.7 Traffic Interruptions (Total Traffic Days Lost) by Region

Chapter 3

Identification of Project Roads

Chapter 3 Identification of Project Roads

3.1 Assessment of Road Damage Potential

The causes of road damage are numerous and sometimes complicated. Accordingly, there are many factors that influence road damage potential, with the main factors being as follows:

(1) geological conditions,
(2) geographical conditions,
(3) rainfall,
(4) planted vegetation,
(5) applied engineering methods,
(6) construction quality.

The first three factors are natural conditions and the second three factors are man-made conditions. Below, the relationship between road damage and these factors for Thailand is examined.

3.1.1 Natural Conditions

1. Geological Conditions

Geological conditions have a great influence on slope damage such as erosion, landslides, rockfalls, etc. Soil and/or rock which is slide-prone and/or erodible are lime-stone, shale, granite and weathered rock. The distribution of these rocks are roughly illustrated in Fig. 3.1.1.

2. Geographical Conditions

In Thailand, it can be said that natural slopes covered by vegetation hardly sustain any damage. This indicates that most road damage is not influenced by geographical conditions. Geographical conditions are only related to incidents of flooding that mainly occur in flood plains shown in Fig. 3.1.2.

3. Rainfall

Most road damage, such as slope damage, the collapsing of a bridge, and the collapsing and flooding of roads, is induced

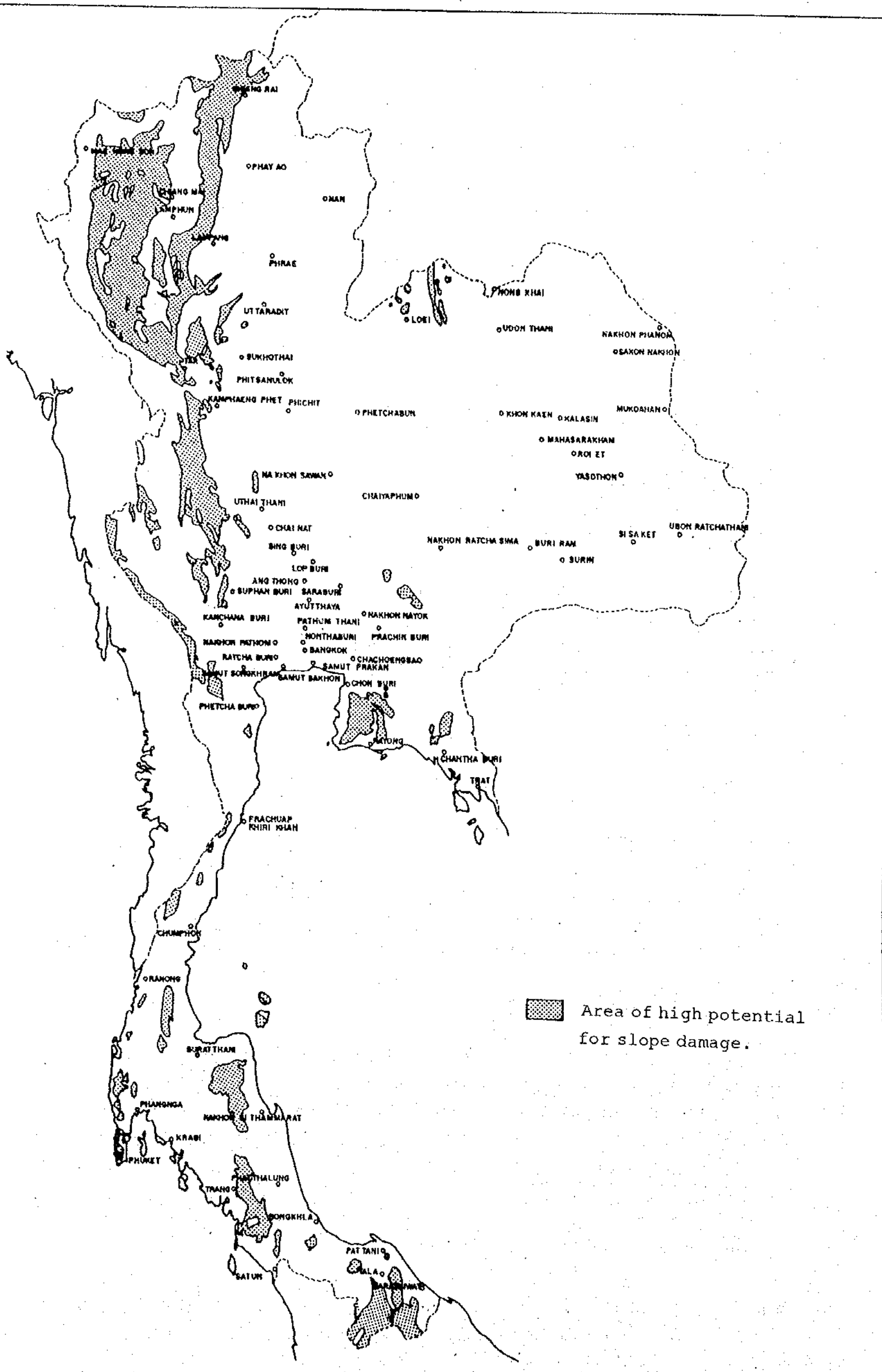


Fig. 3.1.1 Area of High Potential for Slope Damage

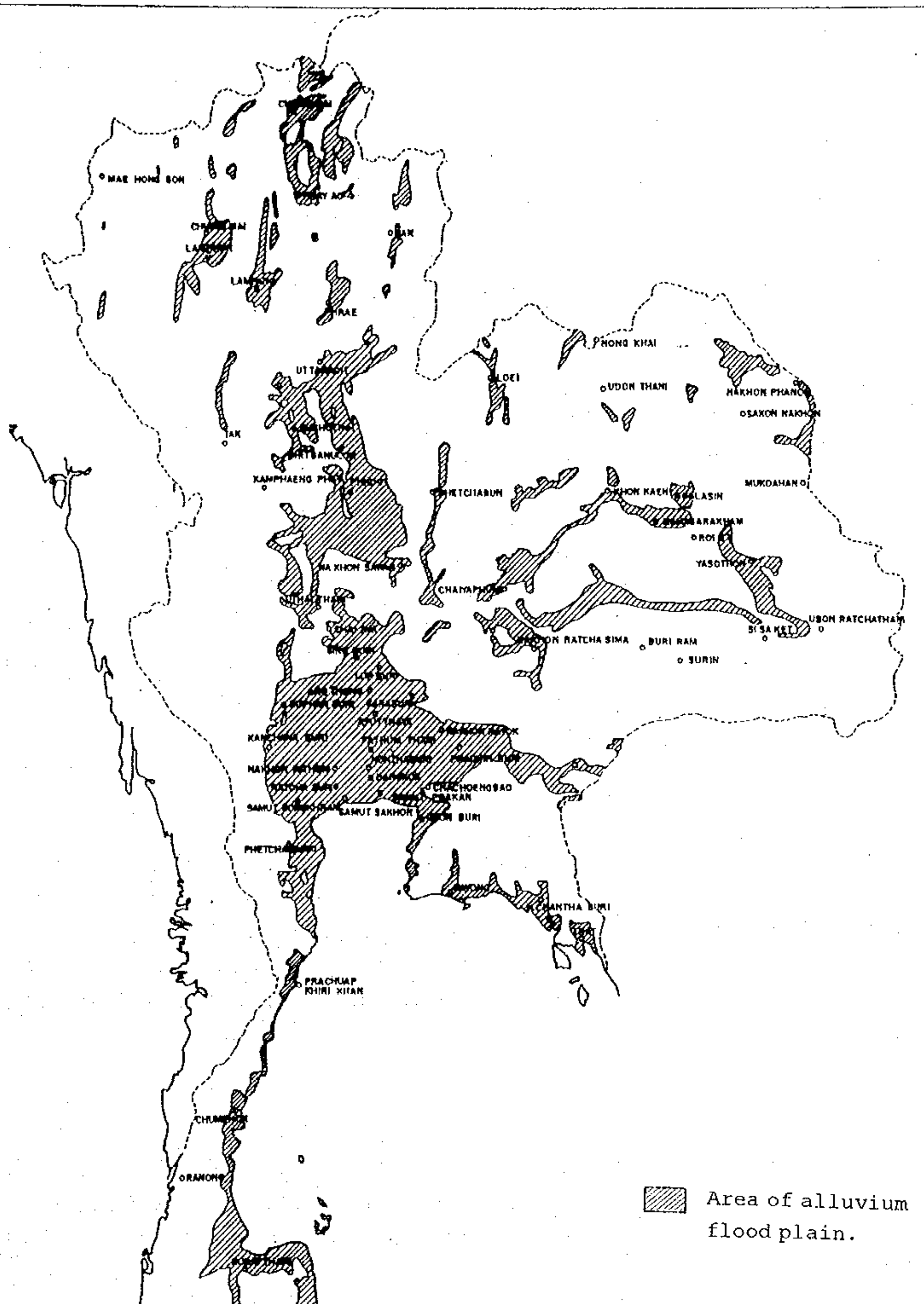


Fig. 3.1.2 Flood Plain

by rainfall. The influence of rain is usually expressed by two indices. i.e., rainfall intensity and precipitation. Rainfall intensity and precipitation in Thailand varies considerably by region. Damage from rain is also classified into two types. The first type of damage is caused by heavy rainfall and consists of the collapsing and/or flooding of bridges and roads and some types of slope damage. The second type of damage can be caused by either ordinary or heavy rainfall and consists of many types of slope erosion. In conclusion, there is always the risk in Thailand that road damage caused by rainfall will occur.

3.1.2 Man-Made Conditions

In the Study, road damage potential is assessed from the viewpoint of regional characteristics in order to efficiently chose project roads. That is, regional characteristics are applied to analyze on a macroscopic scale road damage potential in order to select quickly those roads needing the most attention.

Man-made condition on the other hand, such as the planting of vegetation, applied engineering methods, and construction work quality, are microscopic and random in nature and are independent of regional characteristics. Therefore, man-made condition can not be applied in assessing road damage potential.

3.1.3 Road Damage Potential

In the Study, road damage potential at a spot shall be assessed referring to Fig. 3.1.1 (Areas with High Potential for Slope Damage), Fig. 3.1.2 (Flood Plain) and past damage seconds.

3.2 Classification of Road Damage

The initial classification of disaster-induced traffic interruptions, as used in this study, is based on the four basic types below:

- Bridge Collapsing (BC)
- Road Collapsing (RC)
- Road Flooding (RF)
- Slope Damage (SD)

The next level of classification involves subdividing bridge, road, and slope structures into more specific structural types. A coding system has been developed as a shorthand method for referring to specific features to aid in analysis.

The final component of the road damage classification system is to identify damage in more detail. This is also expressed by a numeric code.

The full classification system is summarized below in Table 3.2.1.

Table 3.2.1 Classification of Damage

Cause of Traffic Interruption	Features	Damage
Bridge Collapsing (BC)	1. Bridge 2. Box culvert 3. Pipe culvert	1. Girder displacement 2. Pier collapsing 3. Abutment collapsing 4. Pier scouring 5. Abutment scouring 6. Collapsing of abutment protection 7. Erosion of approach road 8. Overflow 9. Scouring of river bank 10. River choking with sediment

Road Collapsing (RC)	1. At grade 2. Embankment on flat ground 3. Embankment on sloping ground	1. Scouring of embankment slope 2. Washing out of shoulder
Road Flooding (RF)	1. At grade 2. Embankment on flat ground 3. Embankment on sloping ground	1. Inundation 2. Overflow 3. Road burial by debris flow
Slope Damage (SD)	1. Natural slope 2. Cut slope 3. Fill slope 4. Raised embankment	1. Sheet erosion 2. Rill erosion 3. Gully erosion 4. Tunnel erosion 5. Scouring by incident stream 6. Rotational landslide 7. Two-dimensional landslide 8. Three-dimensional landslide 9. Rockfalls by toppling 10. Rockfalls by undercutting

The above system can be codified by using the letters and numbers of each subgroup. For example, a two-dimensional landslide on a fill slope would be represented by SD-3-7.

3.2.1 Bridge Collapsing

1. Classification of Features

In this category, all hydraulic road structures are considered. These are bridges, box culverts and pipe culverts as shown in Fig. 3.2.1.

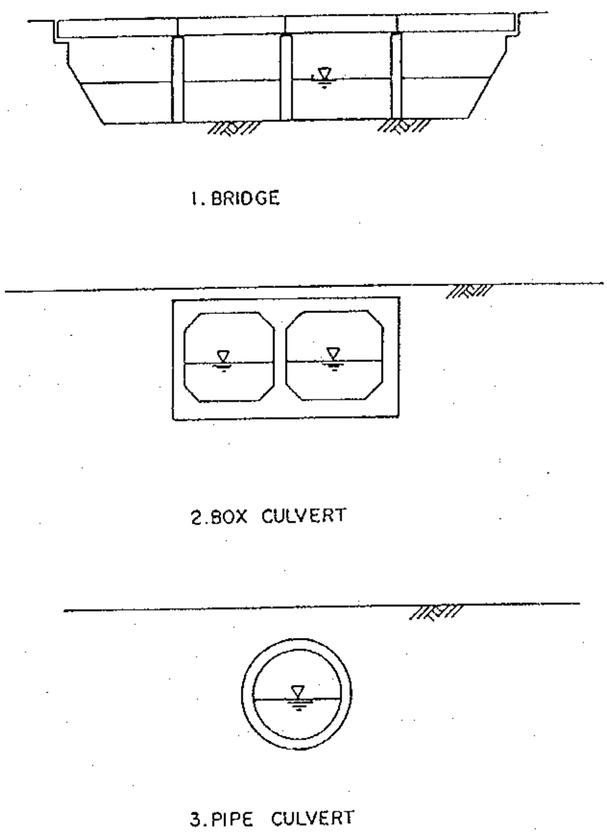


Fig. 3.2.1 Classification of Bridge Features

2. Damage Classification

The collapsing of bridges can be divided into ten major categories depending on the bridge part affected and the type of damage incurred. These are collapses associated with the substructure, superstructure and associated structures as illustrated in Fig. 3.2.2.

1) Girder Displacement

A girder can be displaced by the lateral pressure of water,floating debris or debris flow itself. It results in the horizontal displacement on the top of the substructure or the down stream translation of the main deck elements.

2) Pier Collapsing

There are two major causes for a pier collapsing: the lateral pressure of water, floating debris or debris flow and scouring. If scouring around a pier is deep, its lateral resistance would be reduced and result in the complete collapse of the pier and the supported superstructure. The scouring of a foundation may also result in the vertical settlement of a pier due to the loss of side friction at piles.

3) Abutment Collapsing

The collapse of an abutment occurs usually in the same manner as that of a pier, i.e., by lateral pressure and scouring. In addition, the erosion of abutment back-fill can result in an abutment collapsing.

4) Pier Scouring

Pier scouring that affects a substructure occurs when the supporting system, such as piles and pile caps, is undercut by scouring that produces a reduction in the resistance to horizontal and vertical forces.

5) Abutment Scouring

Abutment scouring can take place if water velocity is fast relative to the soil characteristics. The abutments of bridges are vulnerable, as they form the boundaries of a constriction in flow during periods of flooding with high water velocities.

6) Collapsing of Abutment Protection

The loss of toe support for an abutment protection by scouring and the impact of debris can result in the breakup of the protection. Another mechanism for an abutment protection to collapse is from tunnel erosion caused by water flowing beneath the protection.

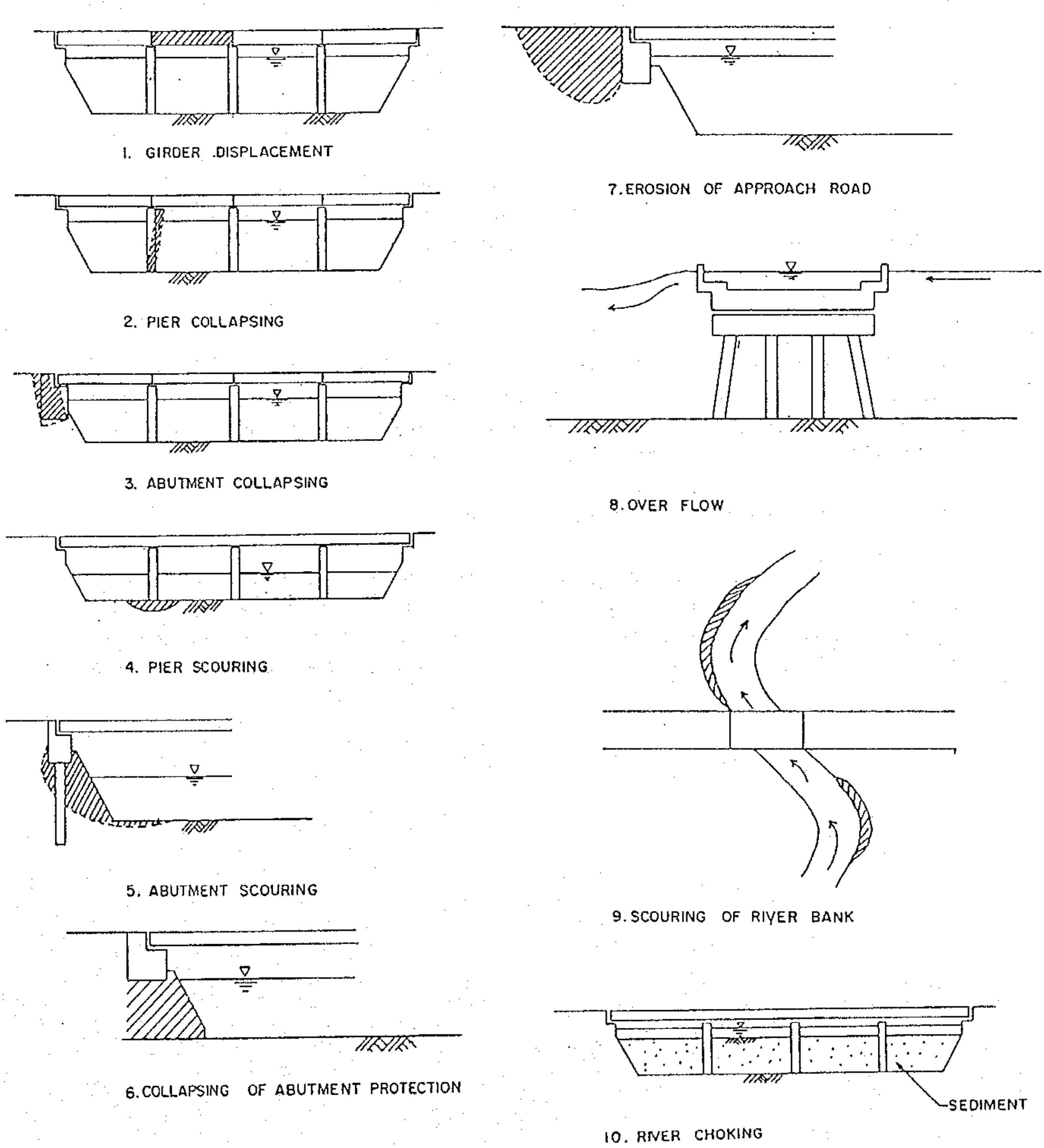


Fig. 3.2.2 Classification of Bridge Damage

7) Erosion of Approach Road

If a river meanders close to a bridge, the approach road can be scoured by the river flow. The sides of the abutment approaches may be scoured prior to the bridge being submerged if they are at a level lower than the deck.

8) Overflow

Overflow occurs if the water level rises above the deck level and traffic can not pass. This classification is used when there is no damage to the bridge and the interruption to traffic is entirely due to the submergence of the bridge.

9) Scouring of River Bank

Scouring may be confined to the banks of a river upstream or downstream from a bridge. A change in the river's path may be a precursor for other damage, such as the scouring of abutments and the erosion of approach roads.

10) River Choking with Sediment

River choking is caused by the over supply of river sediment such as sand, boulders and other debris. It results in the reduction of the clearance from water level to the bottom of girder and shallowing of the water channel section which can induce a flooding.