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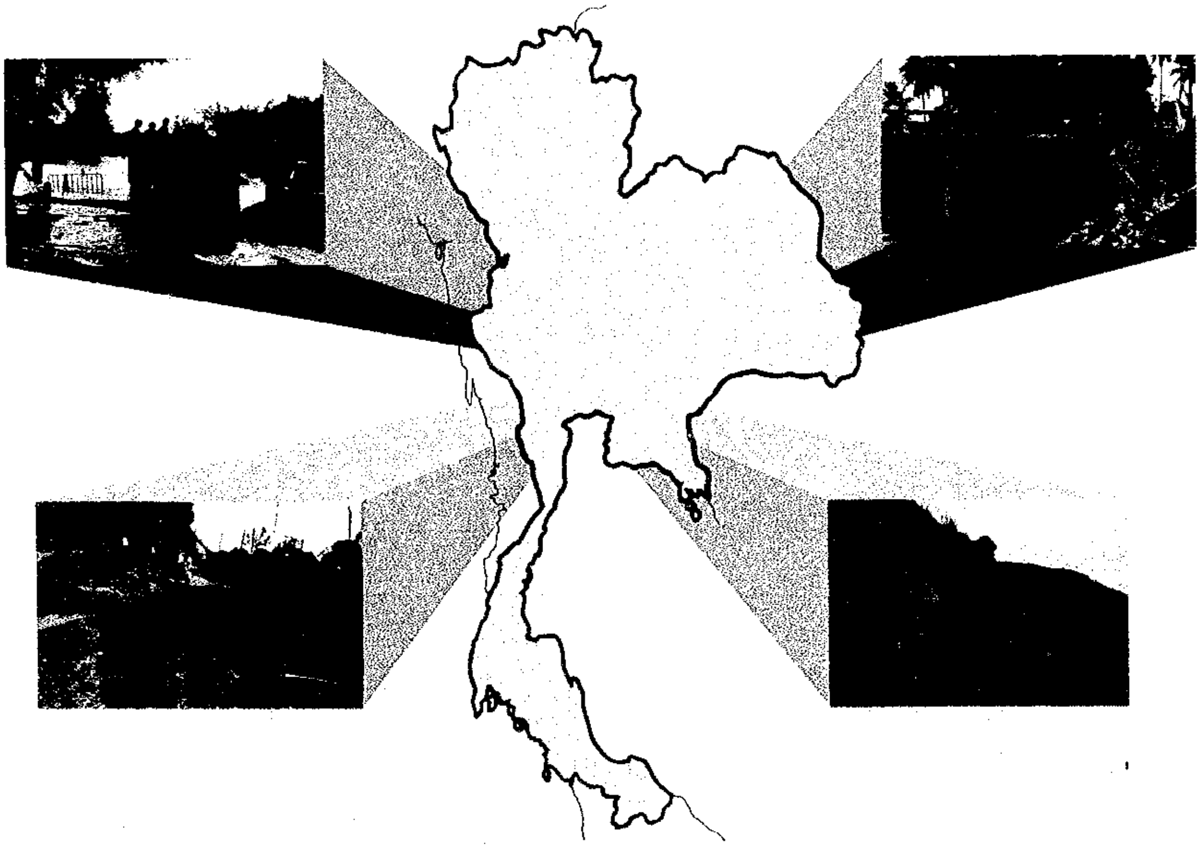
The Study on Road Disaster Prevention Plan in The Kingdom of Thailand

ROAD DAMAGE PREVENTION AND RESTORATION MANUAL

VOLUME 5



JUNE 1995

ORIENTAL CONSULTANTS
KATAHIRA & ENGINEERS INTERNATIONAL

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ROAD DAMAGE PREVENTION AND RESTORATION MANUAL

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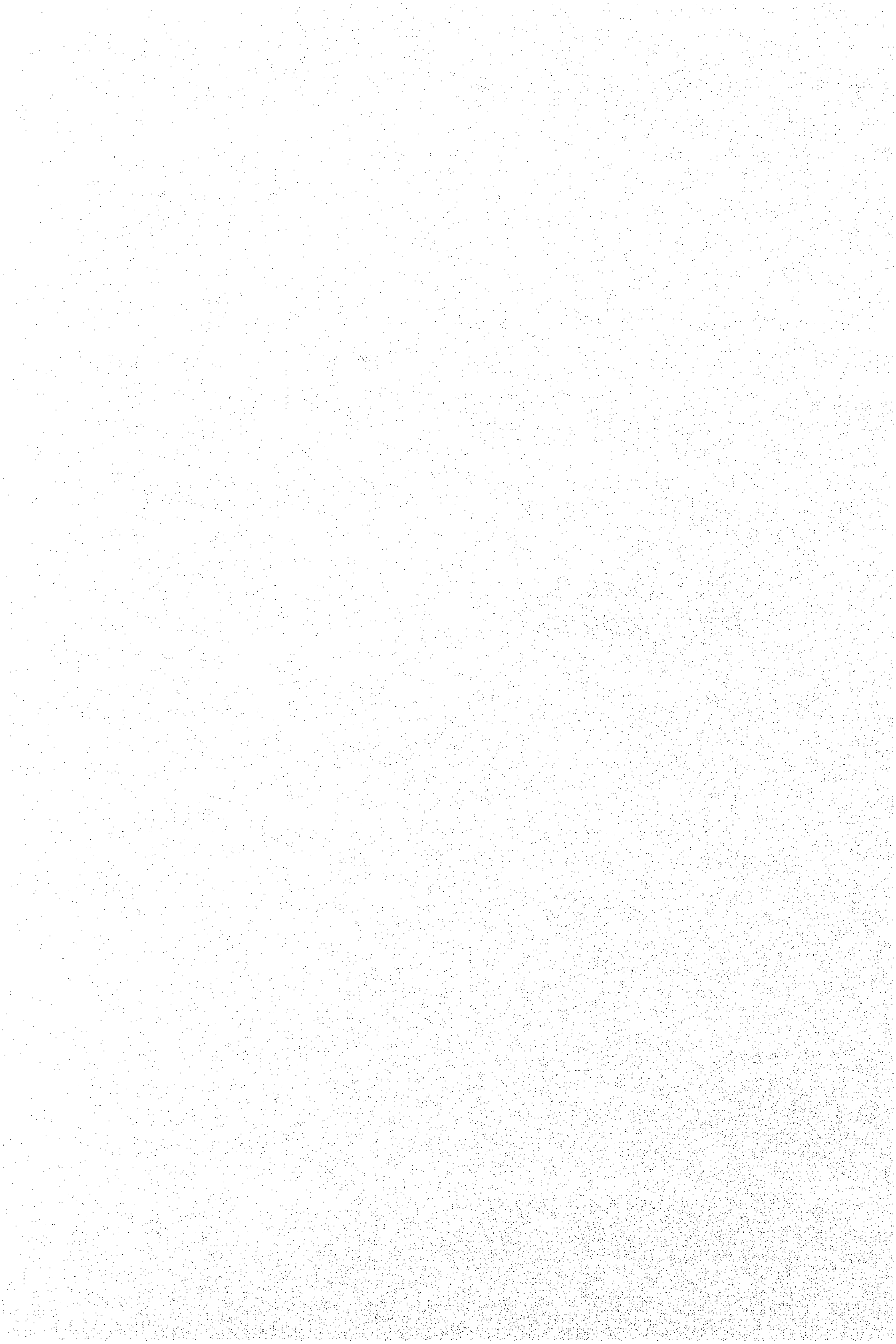
List of Abbreviation

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

A study on a road disaster prevention plan (hereinafter referred to as the Study) was carried out with the main objective of developing technologies for repairing special and national highways damaged by disasters.

The outline of the Study is as follows:

- The sections of eight (8) routes were selected as project roads for a feasibility study. Four (4) of the sections are located in the northern region and four (4) in the southern region.

- A total of 192 spots were identified for study. Then, preliminary designs and cost estimates were carried out for 38 of the spots. As for the remaining 154 spots, cost estimates were made to draw up measures for preventing road damage.

- Finally, an implementation program for the project roads was prepared.

Below, the spots receiving preliminary design are categorized by the types of damage they have sustained.

Type of Damage	Number of Spots for Preliminary Design
Bridge Collapsing	10
Road Collapsing	2
Road Flooding	2
Slope Erosion	5
Landslide	15
Rockfalls	4
Total	38

This Manual was prepared based mainly on the findings from the Study, with the aim of becoming a reference for designing and constructing roads less prone to damage and for repairing already damaged roads.

1.2 Coverage of the Manual

The Manual is comprised of the Road Damage Prevention Manual (hereinafter referred to as the Prevention Manual) and the Damaged Road Restoration Manual (hereinafter referred to as the Restoration Manual).

The coverage of the Manual is defined as follows:

1) Road Class

The Manual covers all highways under the control of DOH.

2) Type of Damage

The Manual covers only the following types of road damage:

- Cut and fill slopes on roads damaged by erosion, landslides and rockfalls.

- The collapsing of bridges, culverts, access roads to bridge and river banks.

- The collapsing of road embankments

- Road flooding

Damages other than that above, for example, defects in bridge members like beam/upper deck/substructure cracking and deterioration of pavement, are not covered by the Manual.

3) Range of Prevention and Restoration Measures

The measures in the Manual deal only with road projects. Therefore, such work as river control, sabo and seashore control work are not covered by the Manual.

As for damage prevention measures, they cover the following two time frames:

- Damage prevention measures for future roads

- Damage prevention measures for existing roads

Restoration measures are divided into two types: urgent repair work to open roads to traffic immediately, and temporary/permanent repair work to repair roads for long-term use.

1.3 Organization of the Manual

The Manual, as shown below, has eleven (11) chapters and two (2) appendices.

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

Chapter 2 provides basic information on road damage by disaster in the Kingdom of Thailand, and includes references to geology and meteorology.

Chapter 3 classifies and defines the types of road damage.

The Prevention Manual is comprised of Chapter 4,5,6 and 7.

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

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

Chapter 6 presents the types of basic damage prevention measures for existing roads, and the procedure to select suitable measures.

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

The practical use of the Prevention Manual is as shown in Fig.1.3.1.

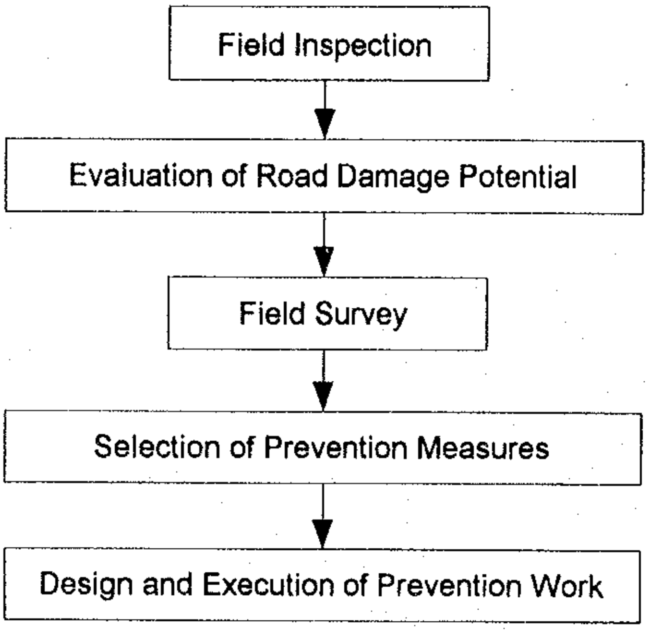


Fig. 1.3.1 Usage of Prevention Manual

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

Chapter 8 presents the methodology on field inspection work for urgent and temporary/permanent repairs, and contains an inspection sheet. Survey items for these works 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 proposes a procurement and arrangement system.

Chapter 11 recommends a road damage detection system and communications system under the heading of management and operation for road damage restoration.

The practical use of the Restoration Manual is as shown in Fig.1.3.2.

Appendix-1 contains detailed analytical methods on slope stability in regard to landslides, stability analysis for concrete retaining walls, hydrological analysis for drainage,etc., with sample calculations when necessary.

Appendix-2 contains the standard drawings.

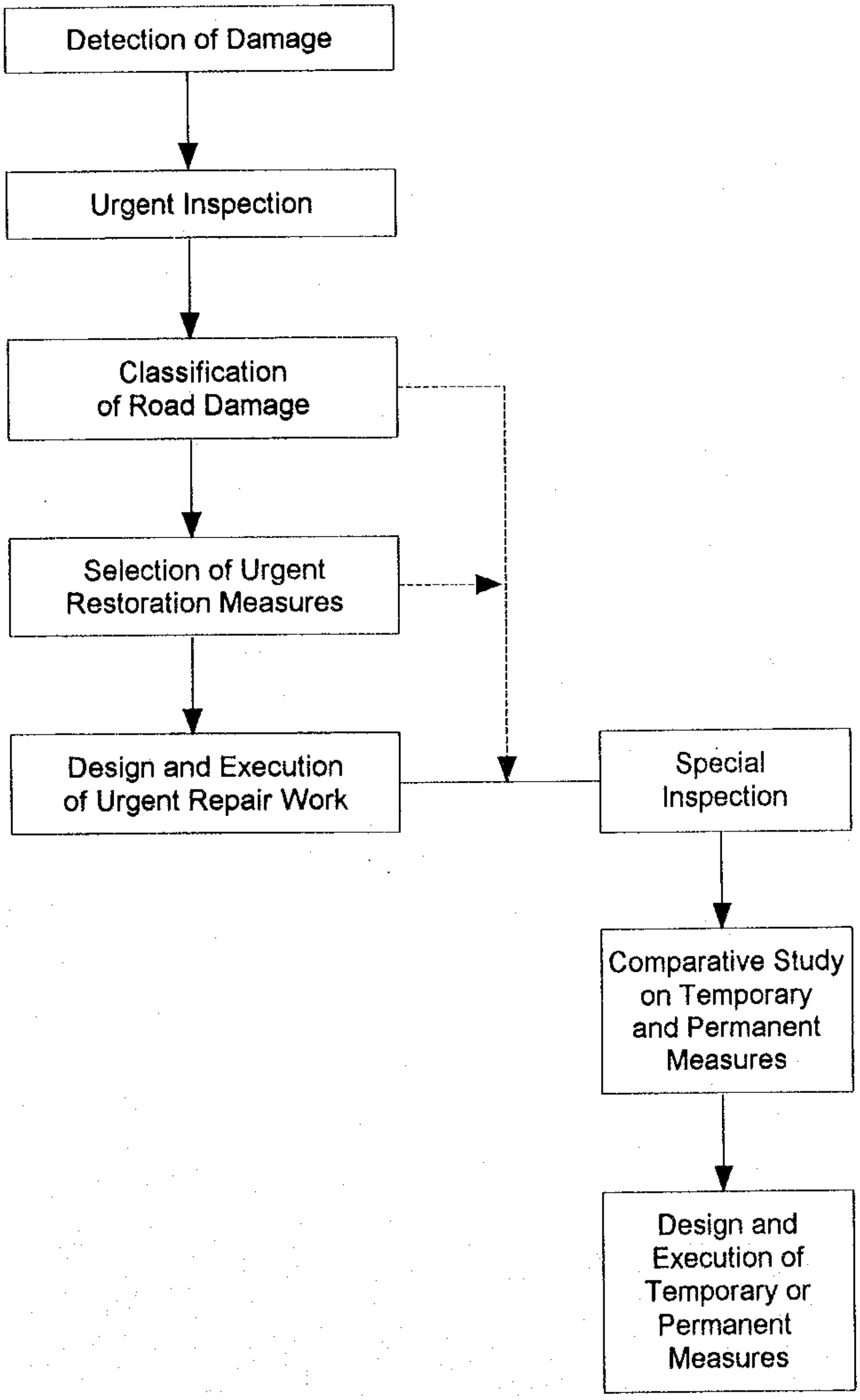


Fig. 1.3.2 Usage of Restoration Manual

Chapter 2

Road Damage by Disaster in the Country

Chapter 2 Road Damage by Disaster in the Country

2.1 Physical Conditions

2.1.1 Geology

Thailand is located on the southeastern edge of the Eurasian continental land mass. It has complex geological characteristics and contains a wide variety of rocks.

From the standpoint of the potential for road disasters, it can be said that there are two distinct geological characteristics in Thailand.

The first is an area with high potential for slope failure (refer to Fig.2.1.1). The deposition of the rocks in the area are mainly limestone, shale and granite. As long as these deposits are covered by top soil, the potential for slope failure is not remarkable. However, they become prone to failure after exposure to the air, for example, by construction work that did not take proper precautions.

The other is a flood plain shown in Fig.2.1.2. Such an area contains deposits of alluvium sand, silt, back swamp deposits and beach sand.

Here, the existence of faults can be one of the indices in detecting an unstable layer. For this reason, a distribution map of faults is given in Fig.2.1.3.

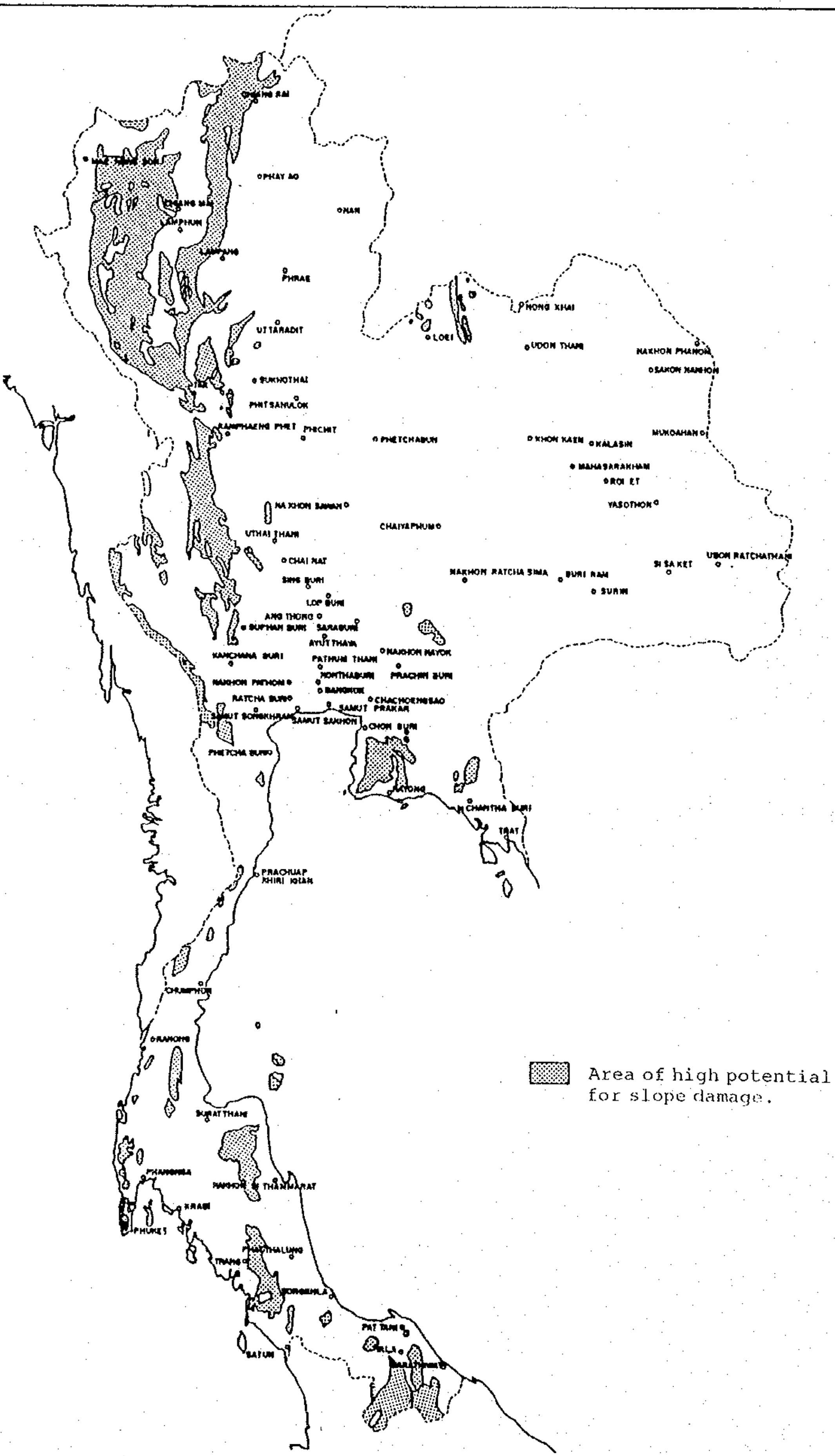


Fig. 2.1.1 Area of High Potential for Slope Failure

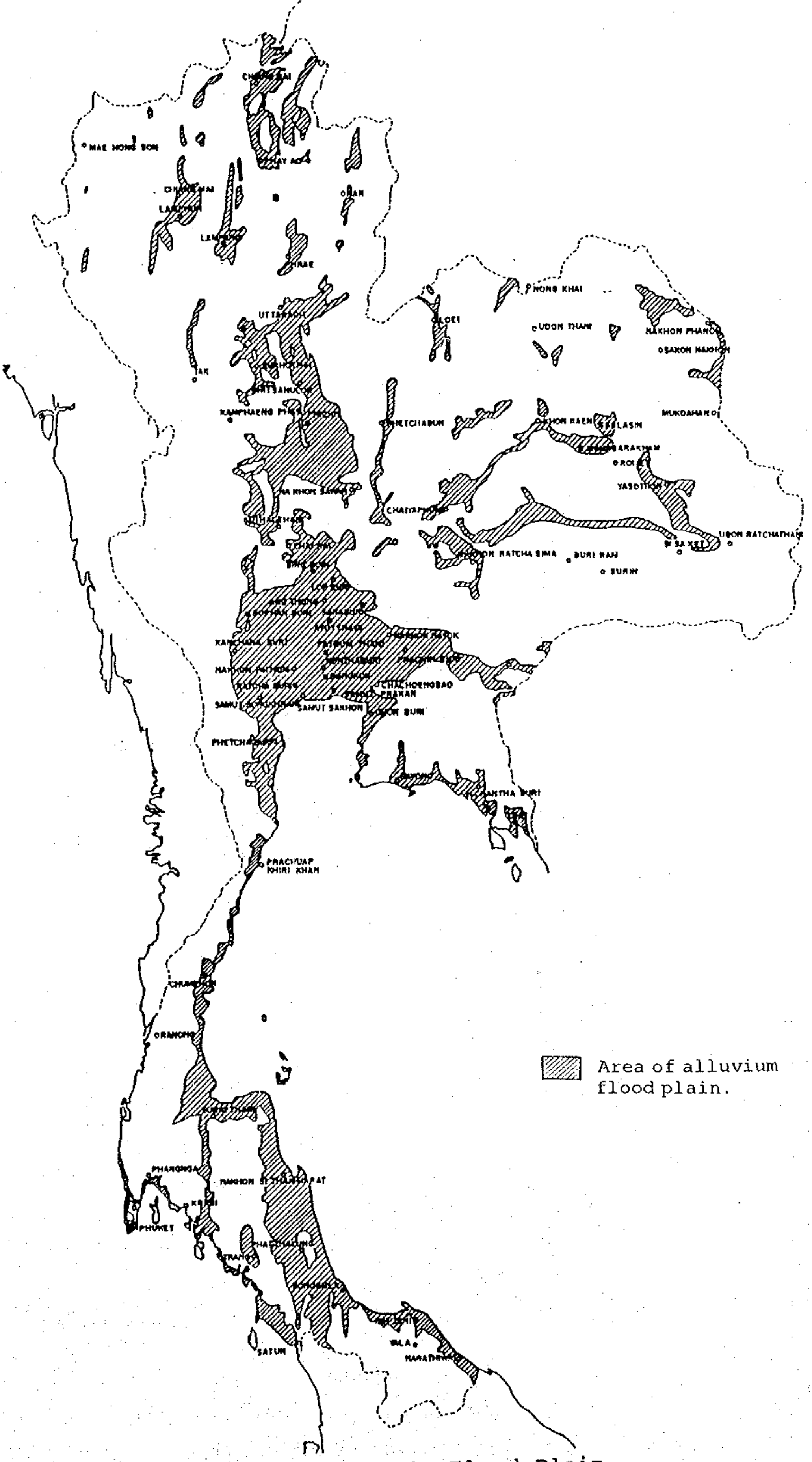


Fig. 2.1.2 Flood Plain

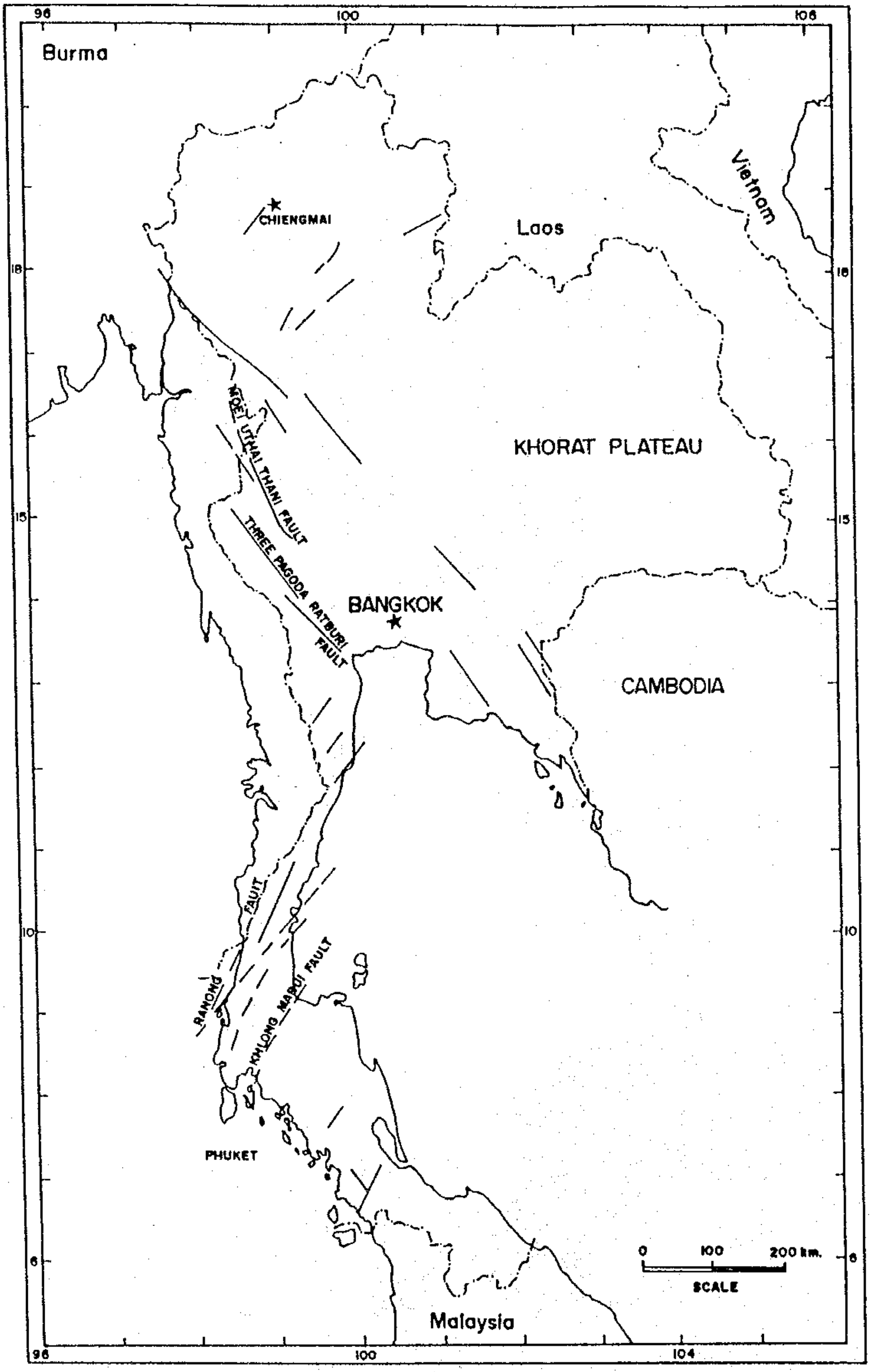


Fig. 2.1.3 Distribution of Faults

2.1.2 Meteorology

1) Climate Type

The climate of Thailand is classified into six types by region by the Thai Meteorological Department (see Fig.2.1.4).

Southeast Region: The region has a distinct rainfall peak in November when the track of tropical depressions tend to cross the Peninsula.

Southwest Region: On the western side of the Peninsula mountains, the weather pattern is distinctly different due to topographical effects and the influence of Indian Ocean cyclones.

Eastern Region: The region has a significantly greater rainfall compared to the adjacent Central Region. The coastal areas have moderate temperature ranges. The mountain areas are generally subject to heavier rains.

Central Region: The central plains receive one of the lowest amounts of rainfalls of all the regions. The mountainous areas of the region lie to the west and thus are less affected by the transition of depleted tropical depression systems.

Northeast Region: Peak rainfall occurs in the August-September period. The rainfall is fairly uniform over the region.

Northern Region: During the winter months the region is often affected by cold dry air moving down from China. The lowest temperatures in the country are experienced here.

2) Rainfall

Annual rainfall for Thailand and the average annual rainfall by region over the past 30 years from 1961 to 1990 are shown in Fig.2.1.5 and 2.1.6, respectively. Monthly rainfall distribution is illustrated in Fig.2.1.4.

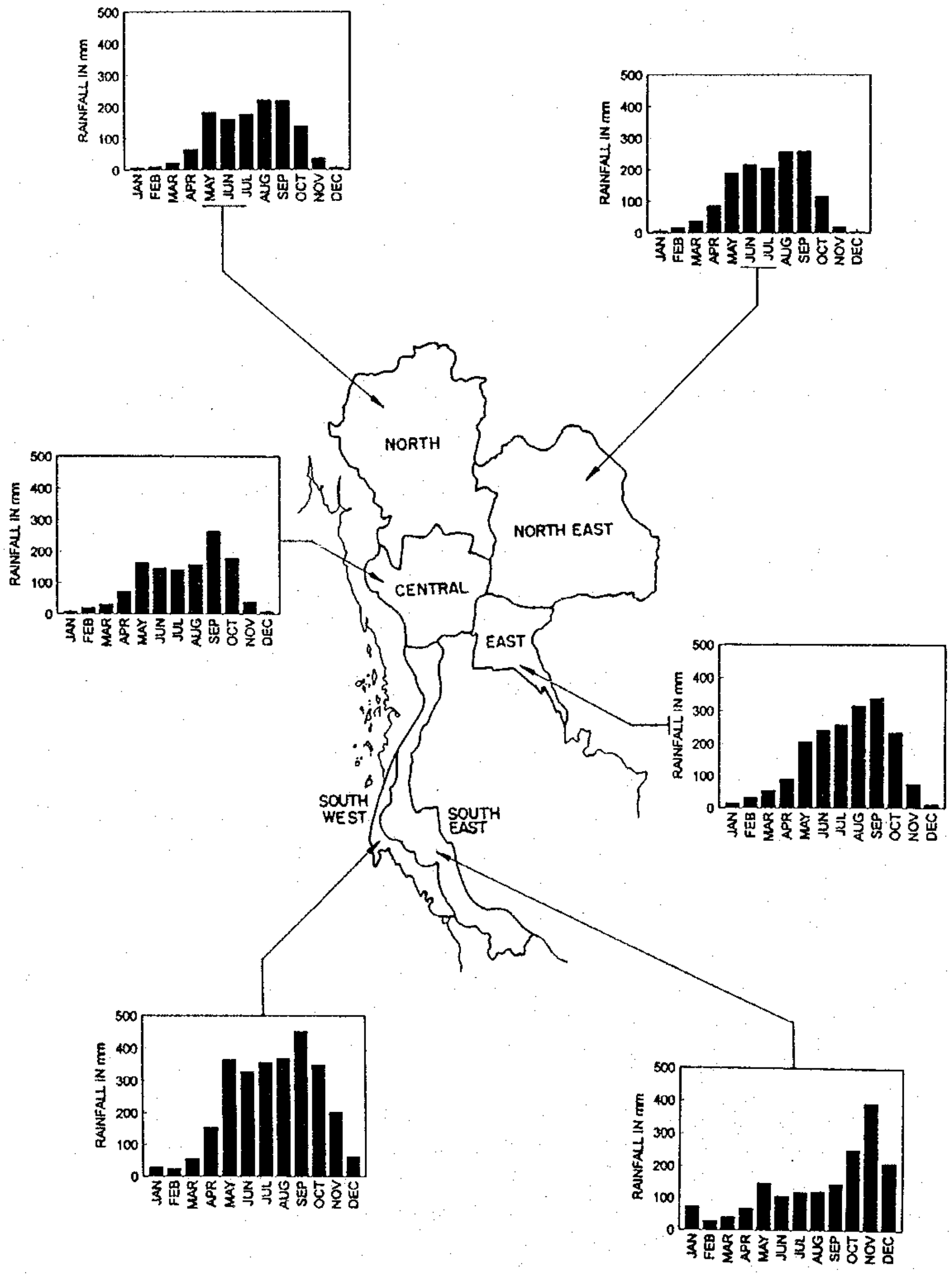


Fig. 2.1.4 Monthly Rainfall Distribution

YEARLY RAINFALL FOR THAILAND

AVERAGE 30 YEARS (1961-1990)

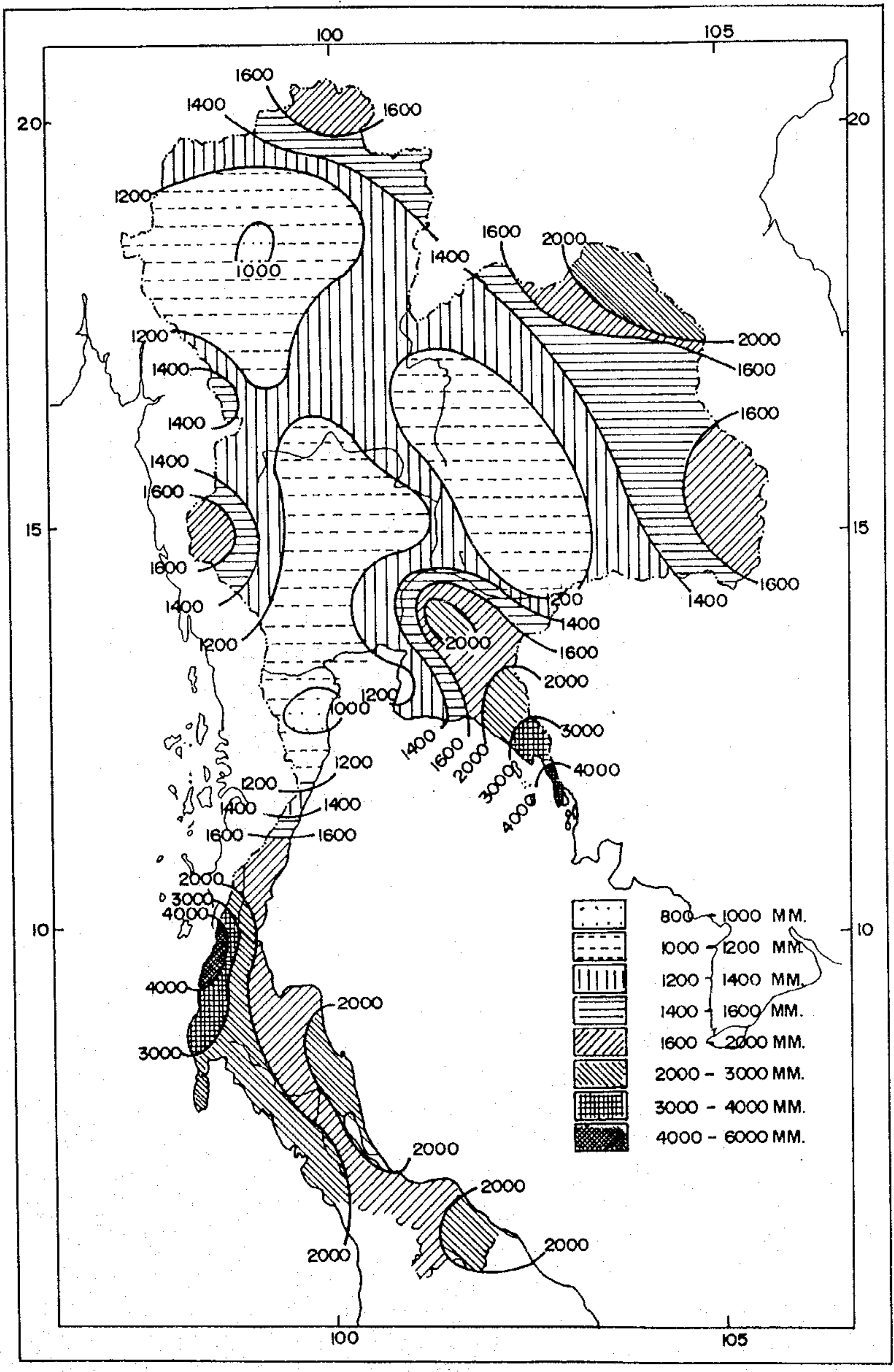


Fig. 2.1.5 Yearly Rainfall for Thailand

Annual rainfall

The average annual rainfall in Thailand by region varies from 1,200 mm to 2,700 mm. The areas with the greatest amount of rainfall exceed 4,000 mm and are in Ranong and Trat, while the areas with the lowest amount of rainfall have around 1,000 mm, and are in the vicinity of Chiang Mai and Phetchaburi.

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.

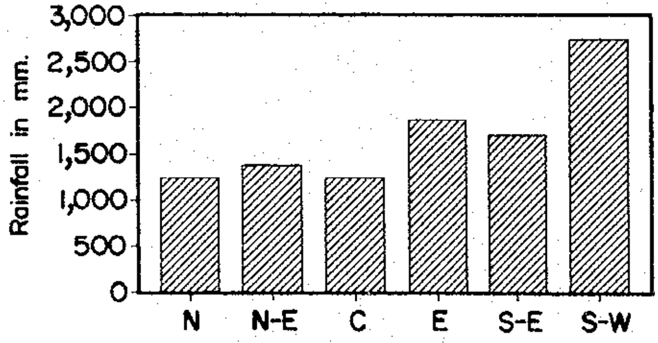


Fig. 2.1.6 Average Annual Rainfall by Region

2.2 Natural Disasters

Thailand does not suffer from disasters related to earthquake and volcanic activity to any great extent. This is due to the country being outside the currently active plate boundaries. Seismic activity in Burma sometimes can be felt inside the country but not usually at a magnitude that can cause any significant damage.

The main natural cause of physical damage to the national infrastructure is heavy rains leading to flash floods and inundation.

A summary of the major flooding events for the 1983-1992 period is given in Table 2.2.1. The causes of flooding are summarized below.

- Heavy prolonged rain from monsoon troughs.
- Tropical depressions and storms that cross the country from the Pacific Ocean.
- Tropical storm systems in the Peninsula.

The monsoon and cyclone tracks over Thailand are shown in Fig. 2.2.1.

Table 2.2.1 Flood Disasters 1983-1992

YEAR	DATES	TYPE	DEAD	AREA FLOODED		COST (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.	91,031 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

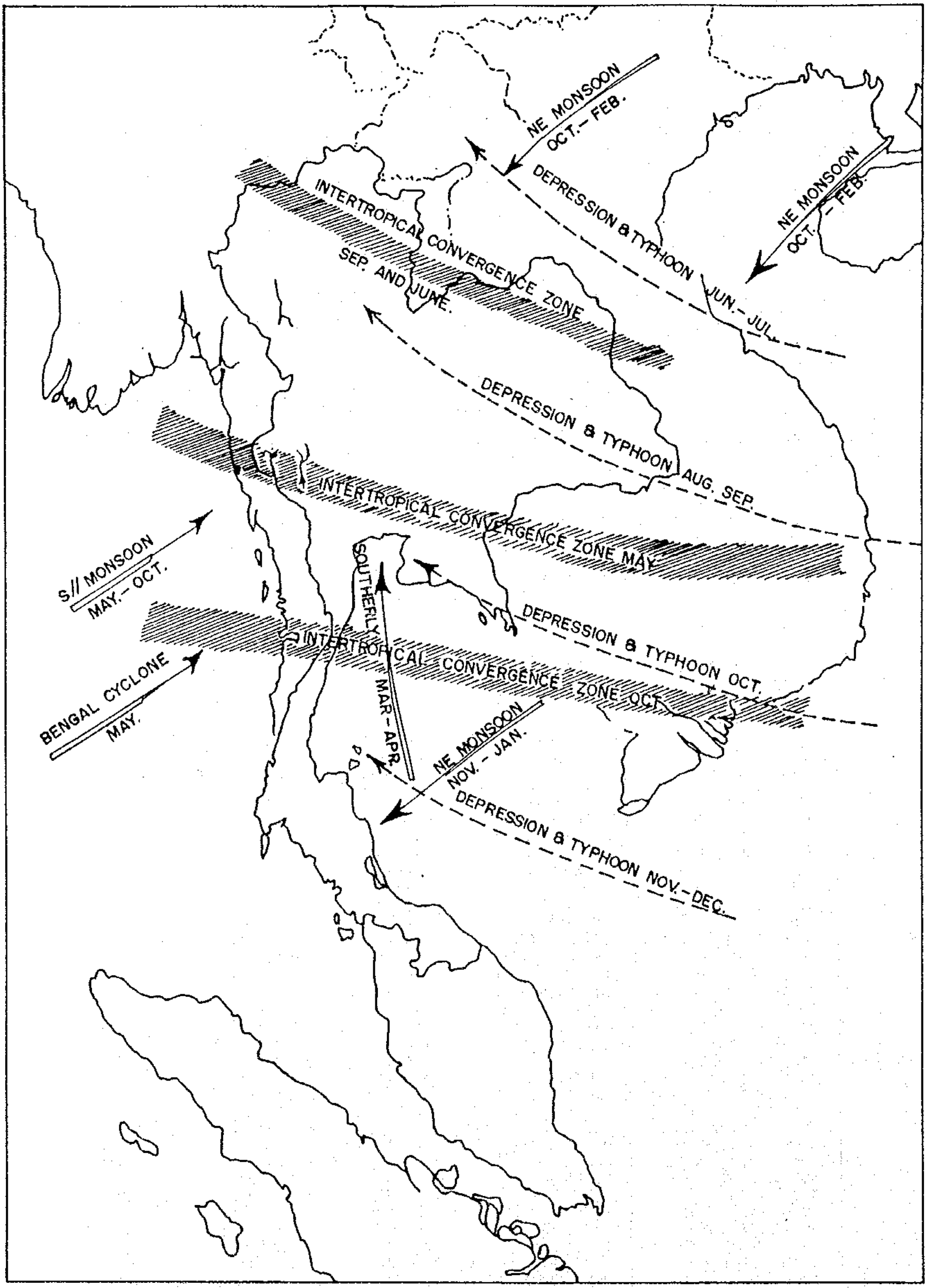


Fig. 2.2.1 Monsoon and Cyclone Tracks over Thailand

2.3 Road Network

The public road network system in Thailand consists of:

- 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 special, national, and concession highways. The total length of DOH highways and a regional breakdown are shown in Table 2.3.1.

The total length of national 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.

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

Table 2.3.1 Regional Breakdown of DOH Highways in 1988

	North	Northeast	Central	South	Total
Area (km2)	169,644	168,854	103,902	70,715	513,115
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

2.4 Road Damage

In Thailand, the type of natural disaster causing most of the damage to roads is depressions, monsoons or typhoons with their heavy rains. Annual road damage from 1976 to 1992 is shown in Table 2.4.1.

In order to evaluate the magnitude of damage, the duration of a traffic interruption can be a key index. The frequency and the number of days traffic was interrupted by region are tabulated in Table 2.4.2.

Table 2.4.1 Annual Loss Caused by Road Damage

Year	Northern Region			North-eastern Region			Central Region			Southern Region			Total		
	No. of Routes	Length km.	Cost (1000 Baht)	No. of Routes	Length km.	Cost (1000 Baht)	No. of Routes	Length km.	Cost (1000 Baht)	No. of Routes	Length km.	Cost (1000 Baht)	No. of Routes	Length 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

Table 2.4.2 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	(16)	1	35	(20)	1	26	(9)	1	68	(22)	256	(16)
2	26		2	17		2	22		2	38			
3	14	(17)	3	11	(15)	3	12	(7)	3	44	(29)	267	(17)
4	12		4	8		4	8		4	32			
5	12		5	7		5	4		5	22			
6	5		6	4		6	7		6	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	(4)	10	3	(3)	10	6	(6)	10	13	(6)	84	(5)
11	1		12	1		11	3		11	4			
12	3		13	1		12	6		12	2			
14	3		14	3		13	5		13	2			
15	2		19	1		14	3		14	3			
16	1					15	5		15	2			
						16	3		16	2			
						17	1		18	1			
						18	1						
						19	1						
20	2	(2)	22	2	(4)	21	5	(3)	20	1	(1)	42	(2)
26	1		23	1		22	3		21	2			
27	1		24	1		23	3		22	1			
29	1		28	2		24	1		23	1			
31	1		32	1		25	1		26	1			
32	1		42	1		26	1						
			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)

Chapter 3

Classification of Road Damages

Chapter 3 Classification of Road Damage

Road damage, as shown below, is divided into four (4) major categories based on the portion of roadway damaged or the type of disaster that has occurred.

I Slope Damage
II Collapsing of Bridges
III Collapsing of Embankment Roads
IV Road Flooding

The above-mentioned categories, as shown in Table 3.1, are broken down into a further 12 categories based on the type of damage sustained or failure that has occurred.

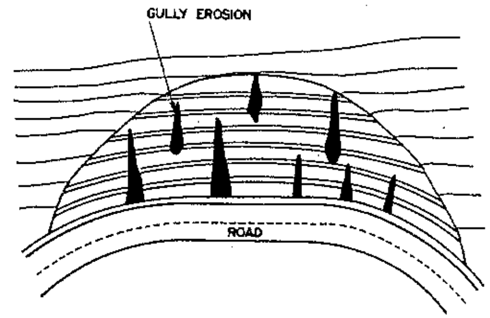
In Table 3.2 to 3.5, the definitions for these 12 categories of roadway damage are explained.

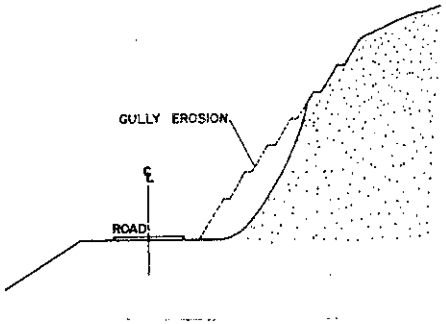
Table 3.1 Breakdown of Road Damage

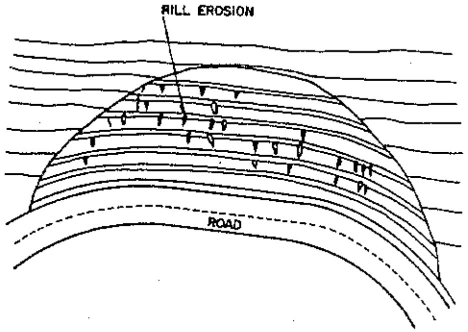
Categories of Roadway Damage	Breakdown of Roadway Damage Categories
I Slope Damage	1. Slope erosion 2. Rockfalls 3. Landslide
II Collapsing of Bridges	4. Girder displacement 5. Pier collapsing 6. Abutment collapsing 7. Scouring of approach road 8. Overflow 9. Scouring of river bank
III Collapsing of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

Table 3.2 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.







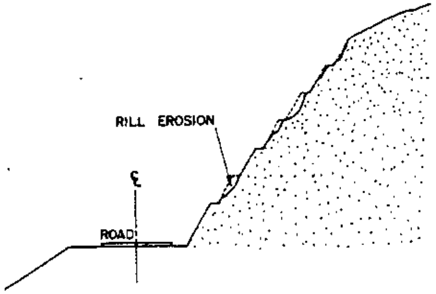


Table 3.2 Definition of Slope Damage (2)

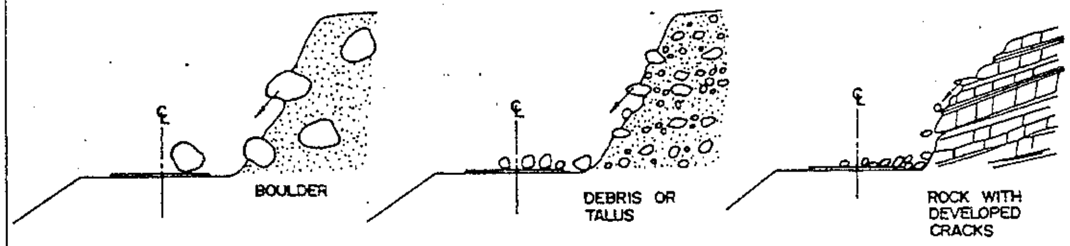
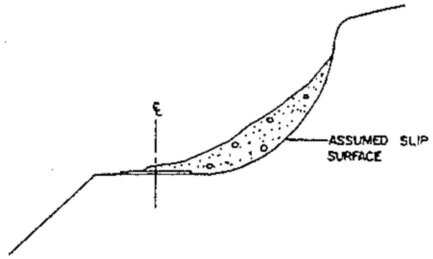
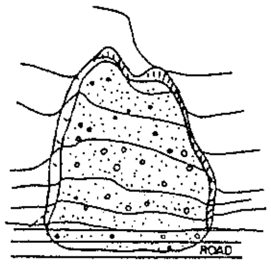
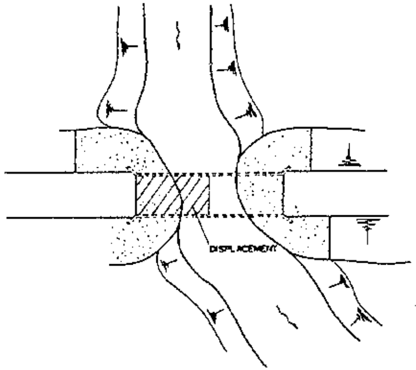
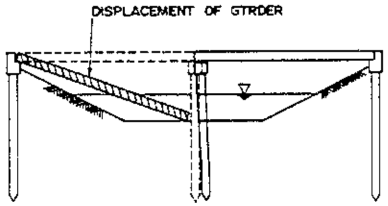
Type of Damage	Definition	Cause
Rockfalls	- A rockfall consists of any downslope movement of intact blocks of rock. - The falling of detached rock from the surface of a slope made up of bedrock having cracks, joints, and beddings. - The falling of unsupported pebbles, boulders from the surface of a slope 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 3.3 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.
		

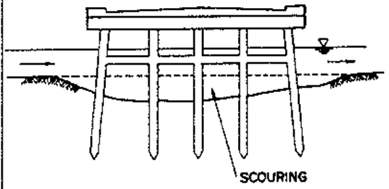
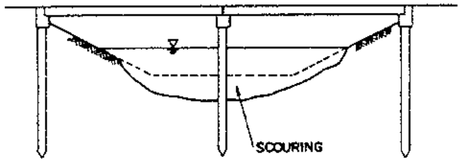
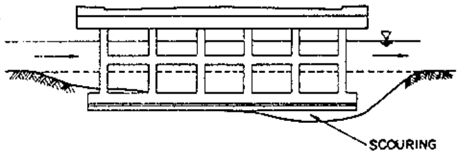
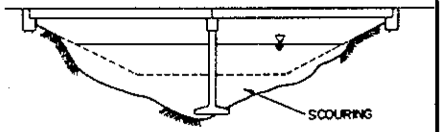
Type of Damage	Definition	Cause
Pier Collapsing	- Tilting, and settlement of pier. - Fracturing of column.	- Tilting of piers and fracturing of columns are caused by lateral forces on piers exerted by water flows, debris or mud flows, or floating timber. - The scouring of a foundation may result in the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

Table 3.3 Definition of Collapsing of Bridges (2)

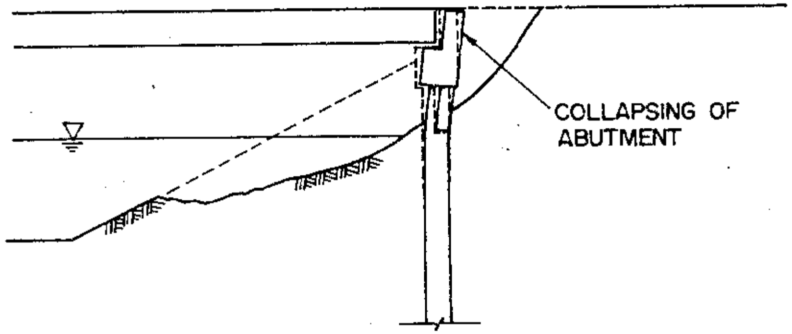
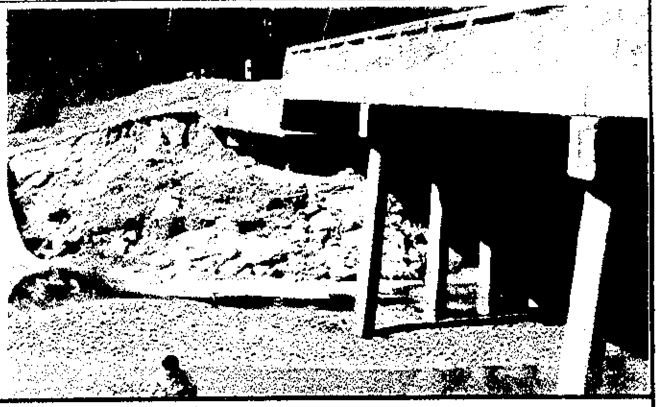
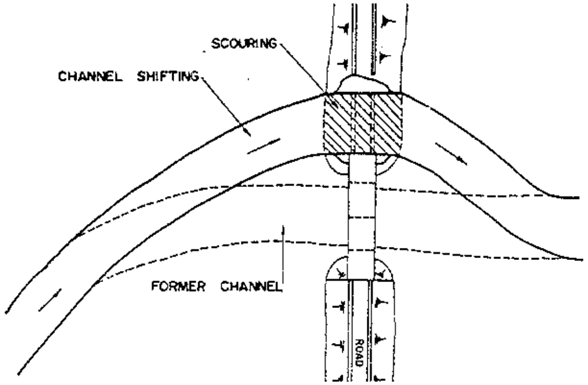
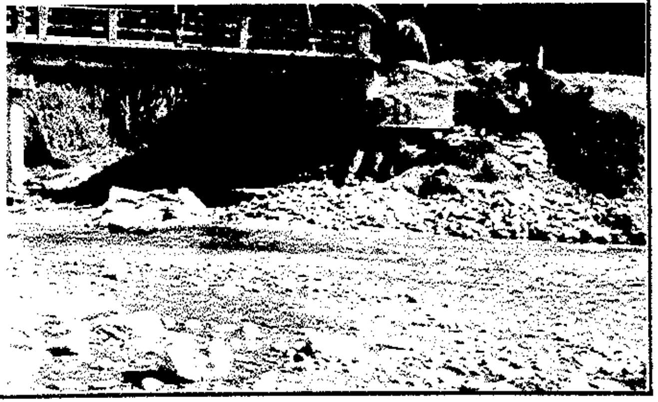
Type of Damage	Definition	Cause
Abutment Collapsing	- The collapsing, tilting, settlement and sliding of an abutment. - The collapsing of an abutment fill slope is included.	- The collapsing, tilting and sliding of an abutment occurs due to the loss of lateral resistance caused by the scouring of an 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 3.3 Definition of Collapsing of Bridges (3)

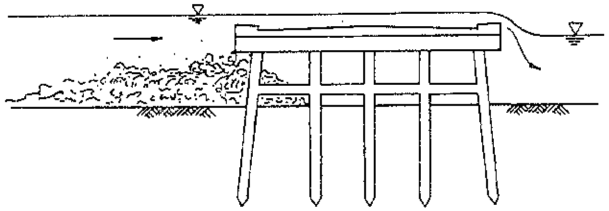
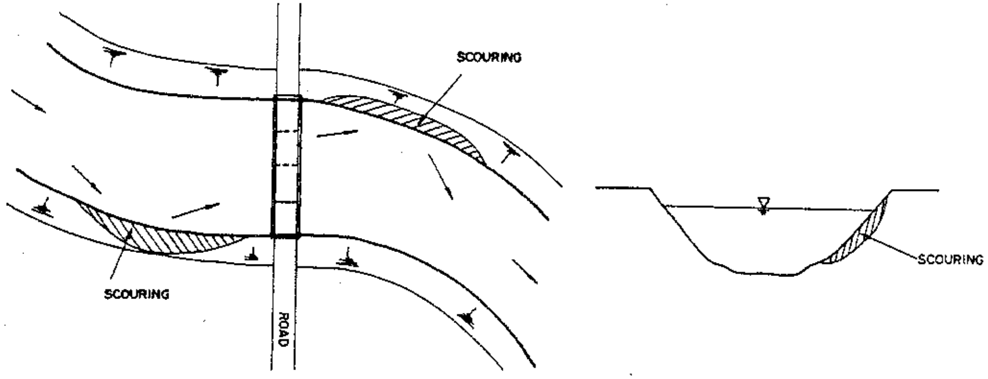
Type of Damage	Definition	Cause
Overflow of Bridge	- The water level of a river rises above a bridge's deck level with no damage to the bridge.	- The elevation of bridge girders is not high enough. - Obstacles downing up a river near or at a bridge crossing.
		
Scouring of River Bank	- From partial scouring 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 3.4 Definition of Collapsing of Embankment Roads

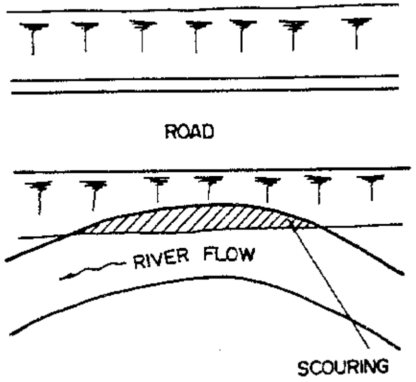
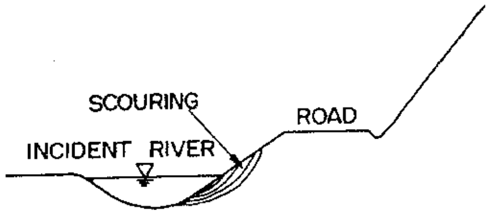
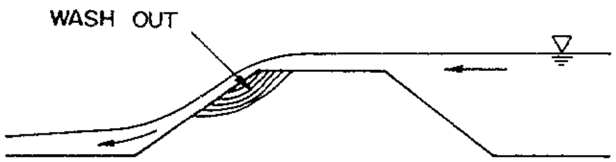
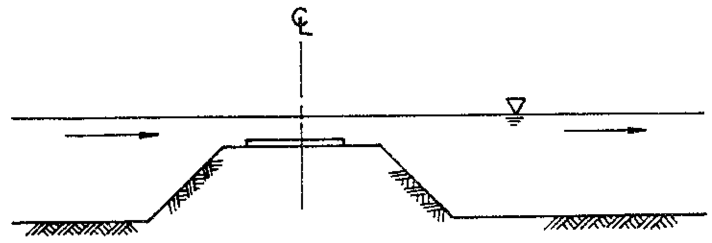
Type of Damage	Definition	Cause
Scouring of Embankment Slope	- From the partial scouring of an embankment slope to the total collapse of an embankment.	- Rapid water flows in parallel with the side of an embankment. - At the time of flooding, the portion of an embankment adjacent to a drainage opening 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 3.5 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.**
		

PART 1

ROAD DAMAGE PREVENTION MANUAL

PART 1 ROAD DAMAGE PREVENTION MANUAL

This manual describes how to carry out a route inspection, how to evaluate road damage potential, and how to execute damage preventive measures for existing roads.

Road damage prevention shall be executed in line with the two flows as shown in Fig.P1. The first flow is based on the findings of route inspection, while the other flow is based on the results of a damage potential evaluation.

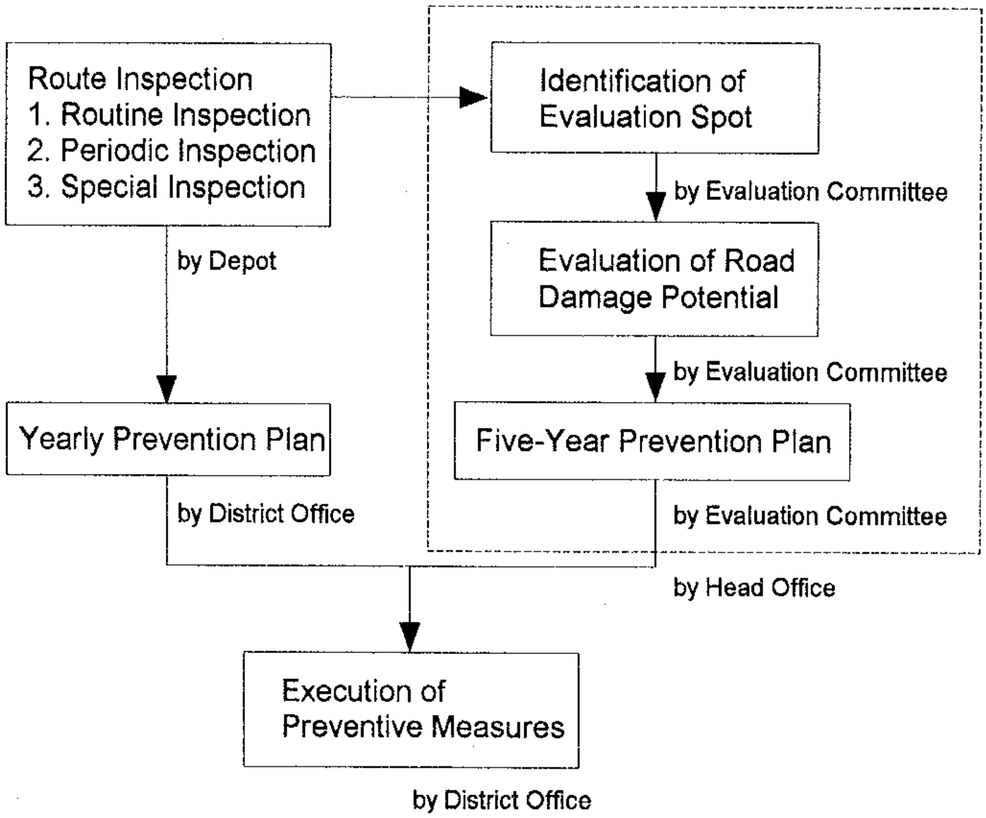


Fig. P1 Flow for Road Damage Prevention

In addition, some recommendations for road planning/designing from the standpoint of damage prevention are presented in Chapter 7.

Chapter 4

Evaluation of Road Damage Potential

Chapter 4 Evaluation of Road Damage Potential

In Thailand, it can be said that there is no distinct relationship between road damage and a region's geographical and meteorological characteristics. The local conditions of a damaged spot, such as the type of slope, slope gradient, the geological formation of the slope, and surface protection, however, are closely related to the damage.

In this context, it is quite important to identify the spots likely to be damaged, and evaluate their potential for damage even in the case where annual rainfall is not heavy or geological conditions are stable.

The spots to be evaluated shall be identified based on the following criteria:

- A spot judged hazardous by DOH based on routine inspections.
- Serious human injury and physical damage ensue if a spot is damaged.
- Large adverse social and economic impacts occur if a spot is damaged.
- There are no alternative routes if a spot is damaged.
- Restoration work is difficult if a spot is damaged.

The evaluation shall be executed once every five years by the members of an evaluation committee. The committee members shall be comprised in DOH staff and in specialists mainly from the local universities.

Damage to DOH highways are classified into a total of six types. The method of evaluation for each type of road damage is recommended in this Prevention Manual.

Damage potential is evaluated through three steps: an initial evaluation based on primary factors and historical records, a secondary evaluation that arranges the results of the initial evaluation, and a final evaluation that totals the results of the initial and secondary evaluations with some adjustments. The total evaluation system is shown in Fig.4.1.

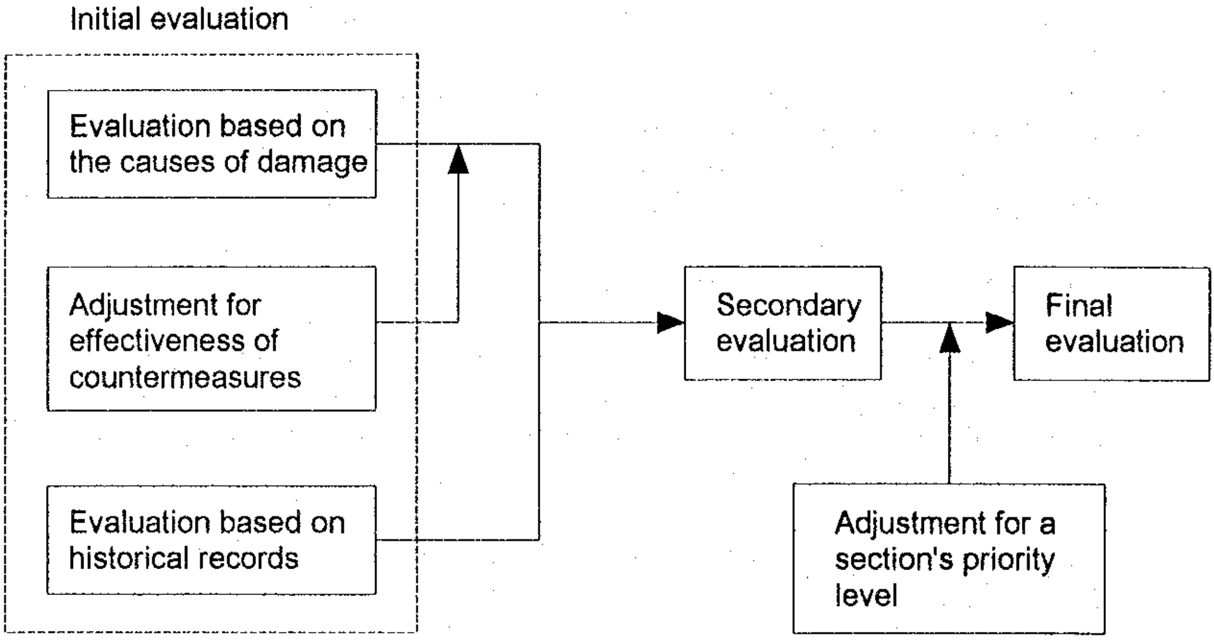


Fig. 4.1 General Flow for Damage Potential Evaluation

The items taken into consideration in damage potential evaluation can be summarized as follows:

1. Initial evaluation

The initial evaluation is comprised in an evaluation based on the cause of damage, an evaluation based on historical records, an evaluation based on calculation (if necessary) and an adjustment for effectiveness of countermeasures.

The evaluation based on the cause of damage evaluates the following factors:

- the geological conditions of a spot
- the topographical conditions of a spot
- existing situation of the object (signs of damage or failure, unconformity to the design standard, etc.)

The evaluation based on historical records evaluates the following:

- the frequency of damage
- the magnitude of damage

The adjustment for effectiveness of countermeasures considers the following factors:

- the existence of countermeasures
- the effectiveness of countermeasures

2. Secondary evaluation

The role of the secondary evaluation is to arrange the initial evaluation and includes several items.

3. Final evaluation

The final evaluation for damage potential is made by adjusting the secondary evaluation from the standpoint of the priority level of the route concerned. The priority level of the route depends on traffic conditions; in concrete terms, traffic volume and the existence of adequate detours.

Evaluation sheets for road damage potential are prepared for the following six types of damage:

Cut Slope Erosion	Table 4.1
Rockfalls	Table 4.2
Landslide	Table 4.3
Abutments,Piers & Approach Roads	Table 4.4
Embankments	Table 4.5
Road Flooding	Table 4.6

Table 4.1 EVALUATION OF POTENTIAL FOR ROAD DAMAGE

- CUT SLOPE EROSION -

1 of 2 pages

GENERAL ITEM	FACTOR		EVALUATION ITEM	EVALUATION ITEM WEIGHT	SCORE
Soil & Geology	Soil prone to collapse	- Soil prone to erosion - Soil easily weakened after absorbing water - Others	- Definitely - To some extent - Not applicable	(20) 20 10 0	
	Rock prone to collapse	- Rock with large number of cracks & weak strata - Soft rock easily eroded - Fast-weathering rock, etc.	- Definitely - To some extent - Not applicable	(10) 10 5 0	
Slope Condition	Surface drainage		- No surface drainage - Crest ditch only - Berm & crest ditch	(15) 15 5 0	
	Vegetation		- Bare Surface - Vegetation & bare surface - Vegetation	(15) 15 8 0	
Shape of Slope	Slope height	Earth	- H ≥ 30 m - 30 > H ≥ 15 - 15 > H	(15) 15 8 0	
		Rock	- H ≥ 50 m - 50 > H ≥ 30 - 30 > H	(5) 5 3 0	
Signs of Erosion	Small amount of erosion Berm collapsing Water runoff on slope surface		- Exists: Clear & plural - Exists: But not clear - None	(20) 20 10 0	
Total Points				(100)	(A)

Remarks : The higher the number the greater the chance of a road being damaged

- CUT SLOPE EROSION -

(A)

Adjustment for Effectiveness of Countermeasures

Effectiveness of Countermeasures for Existing Facilities	Adjustment (α)	Score
High effect	0	
Little effect	- 20	
Effective for limited area	- 10	
No countermeasures	0	
	[A + α] (B)	

Adjustment for a Section's Priority Level

Priority Level (Traffic Volume: ADT)	Weight (β)	Score
- ADT ≥ 2000 - ADT ≥ 1000: sections with no detours	+ 10	
- ADT ≥ 1000 - ADT ≥ 500: sections with no detours	+ 5	
- Others	0	

Final Evaluation

TOTAL SCORE	RANK		
(B + β)	1	80 ≤	
	2	60 - 79	
	3	60 >	
	4	Countermeasure unnecessary	

Table 4.2 EVALUATION OF POTENTIAL FOR ROAD DAMAGE

- ROCKFALLS -

1 of 2 pages

GENERAL ITEM	FACTOR		EVALUATION ITEM	EVALUATION ITEM WEIGHT		SCORE
Soil & Geology	Soil prone to collapse	- Soil prone to erosion - Soil easily weakened after absorbing a large amount of water - Others	- Definitely - To some extent - Not applicable	(14)	14 7 0	
	Rock prone to collapse	- Rock with large number of cracks & weak strata - Soft rock easily eroded - Fast-weathering rock, etc.	- Definitely - To some extent - Not applicable	(23)	23 12 0	
Surface Condition	Top soil, loose rock & boulders		- Unstable - Somewhat unstable - Stable	(13)	13 6 0	
	Spring water		- Exists - Seepage - None	(8)	8 4 0	
	Vegetation		- Bare surface - Vegetation & bare surface - Vegetation & man-made structure - Man-made structure	(5)	5 4 2 0	
Shape	Inclination (I) & Height (H)	Earth	- H > 30 m - H ≤ 30, I > Standard - I ≤ Standard, 15 ≤ H < 30 - I ≤ Standard, H < 15	(20)	20 15 10 5	
		Rock	- H ≥ 50 m - 50 > H ≥ 30 - 30 > H ≥ 15 - 15 > H		20 18 15 10	
Signs of Deformation	Spalling, small rockfalls, gullying, scouring, depressions, slope bulging, etc.		- Exist: Causes clear & plural - Exist: Causes not clear - None	(17)	17 8 0	
Total Points				(100)		(A)

Remarks : The higher the number the greater the chance of a road being damaged.

- ROCKFALLS -

2 of 2 pages

(A)

Adjustment for Effectiveness of Countermeasures

Effectiveness of Countermeasures for Existing Facilities	Adjustment (α)	Score
Sufficiently effective for predicted rockfalls	0	
Effective for predicted rockfalls but not a total solution	- 20	
Effective for some of the predicted rockfalls	- 10	
No countermeasures	0	
	[A + α] (B)	

Evaluation Based on Historical Records

Frequency and Scale of Damage	Item Weight	Score
Obstacles to road traffic soon after repairs were made.	100	
No obstacles to road traffic but there is a history of large rockfalls reaching the road	70	
There is a history of small-scale rockfalls	50	
* If there are no rockfalls soon after repair work, then this evaluation is not carried out.		
	(C)	

Select The Maximum Value from B & C
(D)

Adjustment for a Section's Priority Level

Priority Level (Traffic Volume: ADT)	Weight (β)	Score
- ADT ≥ 2000 - ADT ≥ 1000: sections with no detours	+ 10	
- ADT ≥ 1000 - ADT ≥ 500: sections with no detours	+ 5	
- Others	0	

Final Evaluation

TOTAL SCORE	RANK		
(D + β)	1	80 ≤	
	2	60 - 79	
	3	40 - 59	
	4	40 >	

Table 4.3 EVALUATION OF POTENTIAL FOR ROAD DAMAGE

- LANDSLIDES -

Evaluation Based on Primary Factors

1 of 2 pages

GENERAL ITEM	EVALUATION ITEM		EVALUATION ITEM WEIGHT		SCORE
Geology of Cut Slope	Fault, fracture zone	< * Select Plural Items >	(55)	18	
	Zones affected by volcanic activity, solfataric soil			18	
	Dipping slope			14	
	Dipping backward slope with fissures			7	
	Massive rock (intrusive rock structure, capped rock structure)			5	
	Others			0	
Rock System	Mesozoic/paleozoic (crystal dacite, sedimentary rock)		(10)	10	
	Tertiary (Sedimentary rock)			10	
	Quaternary (sedimentary rock)			5	
	Others (volcanic rock, igneous rock, etc.)			0	
Spring Water	Existing		(10)	10	
	None			0	
Cut Slope	Inclination (I) Height (H)	H≥20m & I≥30°, 20>H≥10m & I≥45°	(25)	25	
		20>H≥10m & 45>I≥20°, H≥20° & 30>I≥20°		10	
		Others		0	
Embankment	Inclination (I) Height (H)	H≥15m & I≥35°		25	
		15>H≥5 & I≥25°, H≥15 & 35>I≥25		10	
		Others		0	
	Total Points		(100)		(A)

Evaluation Based on Stability Calculations

SAFETY FACTOR BASED ON CALCULATIONS	EVALUATION ITEM WEIGHT		SCORE
Extremely Unstable : F < 1.0	(90)	90	(B)
Relatively Unstable: 1.0 ≤ F < 1.05		60	
Stable : 1.05 ≤ F		0	

Evaluation Based on Landslide History

GENERAL ITEM	EVALUATION ITEM		EVALUATION ITEM WEIGHT		SCORE
Landslide History	Past disaster records (If there has been no landslides after repair work, select "None".)	Exist	(50)	50	
		None		0	
Oncoming Signs of Landslide	Cracking, depressions on slope & road surface Deformation of structures for slope protection (If repair work has been executed, select "None".)	Definite signs	(50)	50	
		Slight signs		30	
		None		0	
	Total Points		(100)		(C)

Remarks : The higher the number the greater the chance of a road being damaged.

Stability Evaluation Based on Secondary Factors

Evaluation Based on Primary Factors	(A)
Evaluation Based on Stability Calculation	(B)
Evaluation Based on Historical Records	(C)
Select The Maximum Value from A, B & C	(D)

(D) = Max (A,B,C)

Adjustment for a Section's Priority Level

Priority Level (Traffic Volume: ADT)	Weight (β)	Score
- ADT ≥ 2000 - ADT ≥ 1000: sections with no detours	+ 10	
- ADT ≥ 1000 - ADT ≥ 500: sections with no detours	+ 5	
- Others	0	

Final Evaluation

TOTAL SCORE	RANK		
(D + β)	1	80 ≤	
	2	60 - 79	
	3	60 >	
	4	Countermeasure unnecessary	

Table 4.4 EVALUATION OF POTENTIAL FOR ROAD DAMAGE

– ABUTMENTS, PIERS & APPROACH ROADS –

Evaluation Based on Primary Factors

1 of 3 pages

GENERAL ITEM	FACTOR	EVALUATION ITEM	EVALUATION ITEM WEIGHT	SCORE
Features & Shape of River	Gradient of riverbed: More than 1 / 250 (rapid river)	Yes No	(60) 10 0	
	Bridge situated at bend in river	Yes No	10 0	
	Piers situated where water flow is turbulent, resulting in deep hollows.	Yes No	15 0	
	Width of river at bridge site is narrower than that of other locations, and piers are situated at low-flow channel.	Yes No	15 0	
	Bridge located on a flood plain.	Yes No	10 0	
Bridge Structure	Piers go against pile bent or water flow.	Yes No	(30) 20 0	
	River flow blockade ratio	More than 7 % 5 – 7 % Less than 5 %	4 2 0	
	Span length		3 0	
	Clearance		3 0	
Effective-ness of Counter-measures	Depth of embedment	> 4 m 2 – 4 m 0 – 2 m Shallow	(-30) – 20 – 10 0 10	
	Effectiveness of scouring countermeasures	Foundation enforced Continuous foot protection Discontinuous or random blocking Nothing	(-30) – 30 – 20 – 10 0	
	Total Points		(100)	(A)

Remarks : The higher the number the greater the chance of a road being damaged.

- ABUTMENTS, PIERS & APPROACH ROADS -

2 of 3 pages

Evaluation Based on Existing Signs of Deformation

GENERAL ITEM	SIGNS OF DEFORMATION	SUB-ITEM		EVALUATION ITEM WEIGHT	SCORE
Scouring	Scouring or exposure of foundation structure (pier)	Shallow spread foundation	Existing: Lack of bedrock to support foundation, exposure of footing	(100) 100	
			Existing: Lack of bedrock to support foundation, footing not exposed	60	
			Existing: Scoured depth < 1 m as compared to surrounding riverbed	30	
			Existing: Foundation supported by bedrock or lack of progress in scouring	10	
			None	0	
		Pile foundation	Existing: Corrosion under footing in case of pile foundation	(70) 70	
			Existing: Smaller corrosion than above	40	
			Existing: Corrosion depth < 1 m as compared to surrounding riverbed	20	
			None	0	
Joint between Bridge and River Bank	Deformation of bank and dike (abutment, etc.)	Existing: Settlement, cracking, deformation or scouring (Evidence)		(80) 80	
		Existing: But not serious		50	
		Existing: Minor		30	
		None		0	
		Total Points			(C)

Remarks : The higher the number the greater the chance of a road being damaged.

(A)

Adjustment Based on Frequency of Occurrence

Frequency of Occurrence	Adjustment (α)	Score
Less than 60 cm of clearance at bottom of girder once a year	+ 10	
Less than 60 cm of clearance at bottom of girder once every 10 years	+ 5	
Clearance is more than that mentioned above.	0	

(B) [A + α]

(C)

Select The Maximum Value from B & C

(D)

Adjustment for a Section's Priority Level

Priority Level (Traffic Volume: ADT)	Weight (β)	Score
- ADT ≥ 2000 - ADT ≥ 1000: sections with no detours	+ 10	
- ADT ≥ 1000 - ADT ≥ 500: sections with no detours	+ 5	
- Others	0	

Final Evaluation

TOTAL SCORE	RANK		
(D + β)	1	80 ≤	
	2	60 - 79	
	3	45 - 59	
	4	45 >	

Table 4.5 EVALUATION OF POTENTIAL FOR ROAD DAMAGE

– EMBANKMENTS –

1 of 2 pages

GENERAL ITEM		EVALUATION ITEM	EVALUATION ITEM WEIGHT					SCORE
			Cut & Fill	< Embankment >			Max.Points for Each Category	
				Along Stream	On Slo-ping Ground	On Flat Ground		
Signs of Deformation		Existence of structural cracks & mouth cracks	15	15	15	15	(15)	
		Scouring of lower slope	15	15	15	15		
		Numerous repair spots	10	10	10	10		
		Slope worn down	5	5	5	5		
		Not applicable	0	0	0	0		
Foundation Layer		Landslide, creep	10	10	10	10	(10)	
		Soft layer	5	5	5	5		
		Talus	5	5	5	5		
		Stable layer	0	0	0	0		
Embankment Materials		Sandy soil	5	5	5	5	(5)	
		Cohesive soil	0	0	0	0		
		Gravelly soil	0	0	0	0		
		Unknown	5	5	5	5		
Impact of Groundwater & Surface Water		Dump slope toe	30	30	30	30	(30)	
		Traces of water flow on embankment slope	30	30	30	30		
		Spring water from slope	10	10	20	10		
		Adjacent area wet	–	10	10	10		
		No ditch at toe of cut slope	–	–	10	–		
		Not applicable	0	0	0	0		
Stream Condi-tion	Existing Situation	Debris in river	15	15	–	–	(15)	
		Slope failure upstream	10	10	–	–		
		Gully erosion without regular stream	10	10	–	–		
		Poor water catchment for drainage	10	10	–	–		
		Not applicable	0	0	–	–		
	Crossing Drainage Facilities	Diameter of drainage facility < 100 cm	15	15	–	–	(15)	
		Insufficient outlet control	15	15	–	–		
		Reduction of cross-sectional area by bending of pipe, no crossing drain works	15	15	–	–		
		150cm > Diameter ≥ 100cm	10	10	–	–		
		Not applicable	0	0	–	–		
River Condition		Toe of embankment submerged by flooding	10	10	10	10	(10)	
		Drain outlet submerged by flooding	10	10	10	–		
		Toe of embankment constantly submerged	5	5	5	10		
		Not applicable	0	0	0	0		
Total Points							(100)	

Remarks : The higher the number the greater the chance of a road being damaged.

- EMBANKMENTS -

(A)

Adjustment for Effectiveness of Countermeasures

Type of Counter-measure	Type of Work	Adju-stment (α)	Score
Deformation Counter-measure	Structural work	- 20	
	Prevention work	- 10	
	Others, no countermeasures	0	
Under-ground & Surface Water Counter-measure	Dewatering work	- 20	
	Crib & slope covering work	- 15	
	Slope drainage, vegetation work	- 10	
	side-gutter work	- 5	
	Others, no countermeasures	0	
River Flow Counter-measure	Retaining wall, revetment work	- 5	
	Others, no countermeasures	0	
		[A + α] (B)	

Evaluation Based on Historical Records

Item	Evaluation Item	Adju-stment	Score
Damage	Occurred	+ 30	
	Didn't occur	0	
Scale	Wash-out of entire embankment (road impassable)	+ 70	
	Part of embankment wash out (road impassable)	+ 60	
	Erosion of road surface (only one side of road passable for a few days)	+ 45	
	Slight damage (no interruption to traffic)	+ 20	
Count-ermea-sures	Complete repair of embankment, sufficient countermeasures	- 70	
	Emergency repairs	- 30	
	Countermeasures same as before damage	- 20	
	No counter-measures	0	
		(C)	

Select The Maximum Value from B & C

(D)

Adjustment for a Section's Priority Level

Priority Level of (Traffic Volume: ADT)	Weight (β)	Score
- ADT ≥ 2000 - ADT ≥ 1000: sections with no detours	+ 10	
- ADT ≥ 1000 - ADT ≥ 500: sections with no detours	+ 5	
- Others	0	

Adjustment for Repair Difficulty (τ)

Embankment Height	Weight(τ)	Score
H ≥ 10 m	+ 15	
3 m ≤ H < 10	+ 5	
H < 3 m	0	

Final Evaluation

TOTAL SCORE	RANK		
(D + β + τ)	1	80 ≤	
	2	60 - 79	
	3	40 - 59	
	4	40 >	

Table 4.6 EVALUATION OF POTENTIAL FOR ROAD DAMAGE

– ROAD FLOODING –

1 of 2 pages

Evaluation Based on Primary Factors

GENERAL ITEM	EVALUATION ITEM		EVALUATION ITEM WEIGHT	SCORE
Feature & Shape of River/ Basin	Gradient of riverbed : Less than 1 / XXX	Yes No	(55) 15 0	
	Shape of river stream	Meandering Not meandering	15 0	
	Width of river near the road is narrower than that of other locations.	Yes No	10 0	
	Road located on flood plain.	Yes No	25 0	
River Control	High-velocity river Controlled in vicinity of bridge crossing Well controlled		(35) 20 10 0	
	Discharge control in basin	No good Average Very good	15 8 0	
Total Points			(100)	(A)

Evaluation Based on Historical Record

GENERAL ITEM	EVALUATION ITEM		EVALUATION ITEM WEIGHT		SCORE
History of Flooding	Past disaster records, flooding documents, reliable word-of-mouth, etc.	Many exist Few exist None	(50)	50 25 0	
	Traffic interruption by flooding in past 5 years	More than 10 days 3 - 9 days 1 - 2 day None	(50)	50 35 20 0	
Total Points			(100)		(B)

Remarks : The higher the number the greater the chance of a road being damaged.

(A)

(B)

Select The Maximum Value from A & B

(C)

Adjustment for a Section's Priority Level

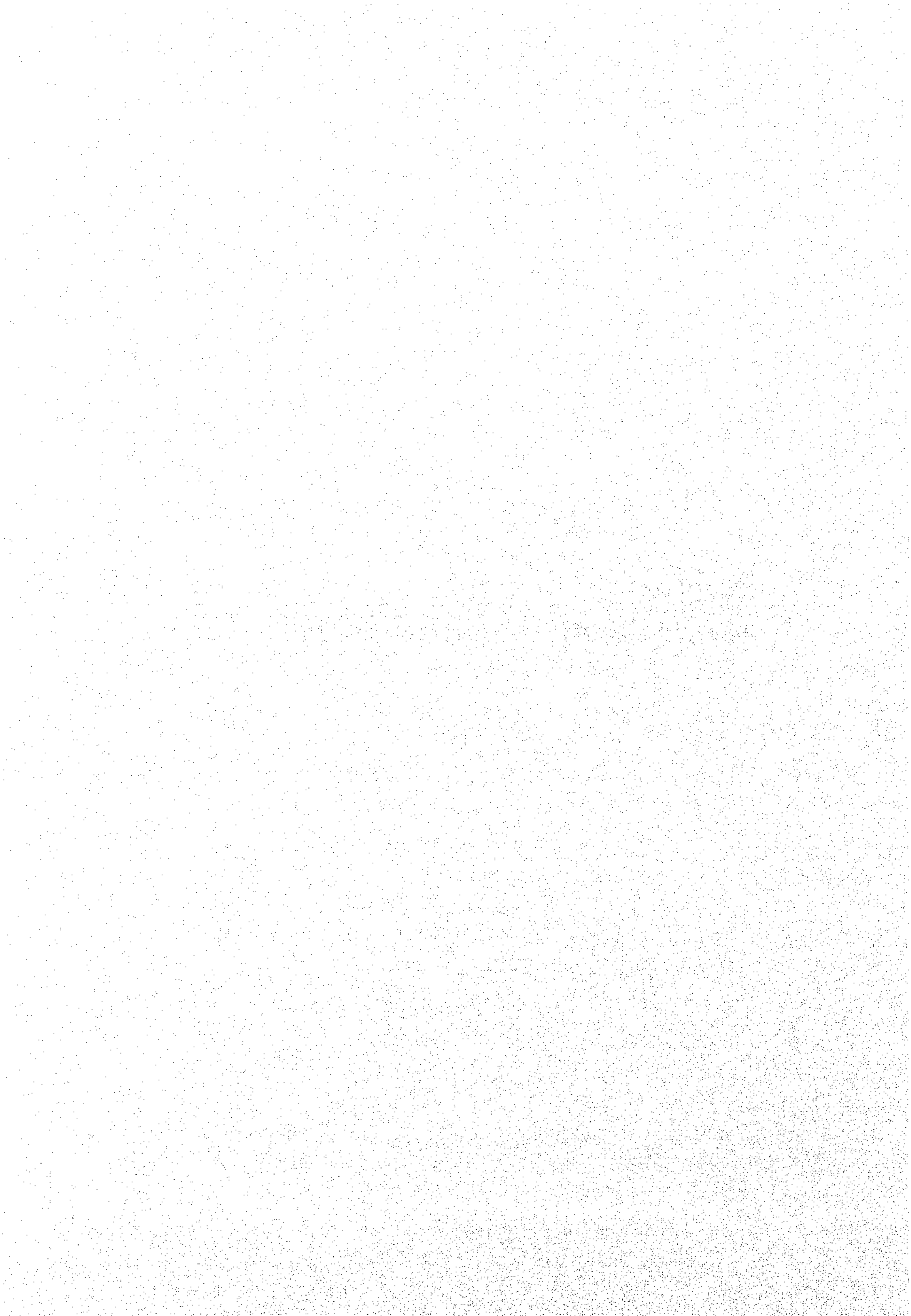
Priority Level (Traffic Volume: ADT)	Weight (β)	Score
- ADT ≥ 2000 - ADT ≥ 1000: sections with no detours	+ 10	
- ADT ≥ 1000 - ADT ≥ 500: sections with no detours	+ 5	
- Others	0	

Final Evaluation

TOTAL SCORE	RANK	
(C + β)	1	80 ≤
	2	60 - 79
	3	40 - 59
	4	Countermeasure unnecessary

Chapter 5

Route Inspection and Survey



Chapter 5 Route Inspection and Survey

5.1 Route Inspection

5.1.1 Categorization of Inspection

Inspection work for road damage prevention is categorized into the following three types in terms of purpose and method as follows:

- Routine inspection

  Visual inspection on a weekly basis of road structures, facilities and slopes related to road, within the limits of visually observable damage.

- Periodic inspection

  Inspection by foot of road structures, facilities and slopes related to road after urgent repair work has been finished, in order to ascertain the progress in existing damage prior to temporary/permanent repair work and to forecast future damage.

- Special inspection

  Unscheduled inspection of road structures, facilities and slopes related to road due to the unexpected occurrence of a heavy rain, lingering tropical depression, monsoon, typhoon, etc.

A flow chart of these above-mentioned inspections is shown in Fig. 5.1.1.

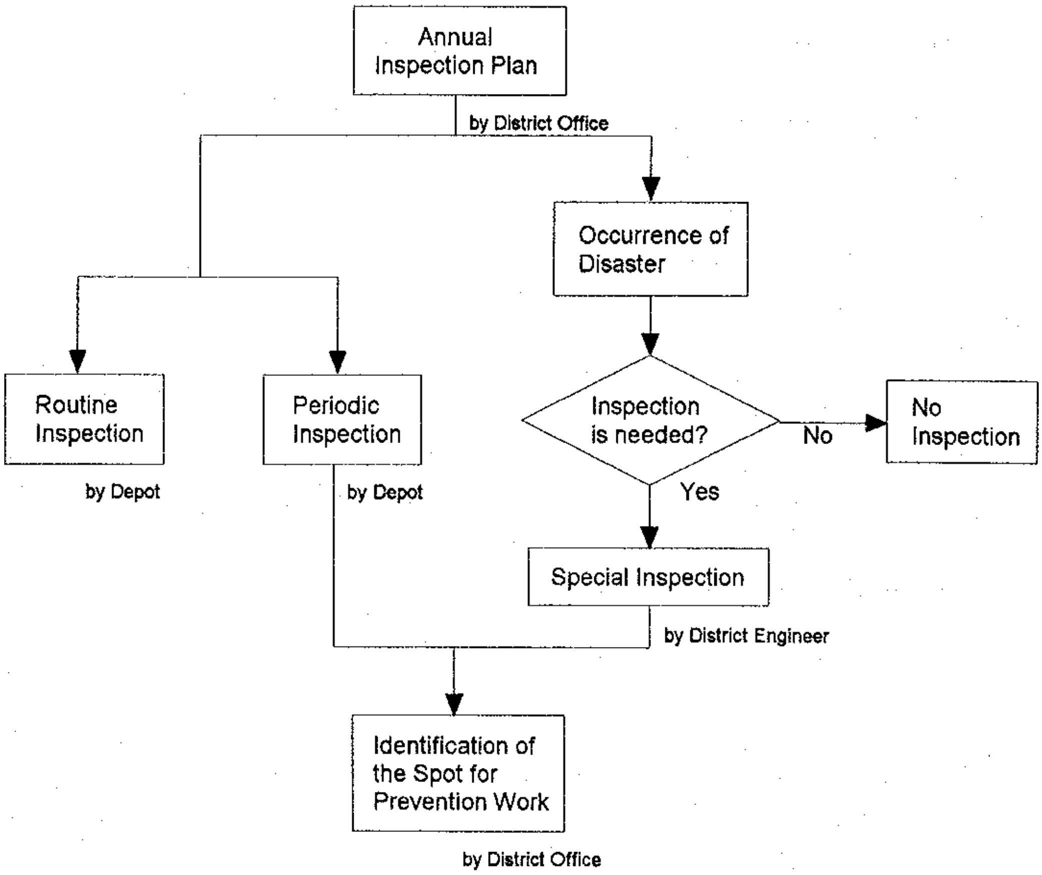


Fig. 5.1.1 Route Inspection Flow Chart for Road Damage Prevention

5.1.2 Frequency of Inspection

The frequencies of the above categorized inspection work depend on the purpose and methods of the inspections and are as follows:

- Routine inspection

  Performed daily by depots over the whole length of the highway under their control in the course of a week.

- Periodic inspection

  Performed twice a year at the end of the dry and wet seasons, respectively.

- Special inspection

  Performed when necessity requires it.

5.1.3 Objects or Phenomena to be Inspected

1. Routine inspection

The objects and items in Table 5.1.1 shall be examined via routine inspection, and entries made on a routine inspection sheet (see Table 5.1.2) about undesirable signs or changes.

Table 5.1.1 Inspection Items for Routine Inspection

Object	Inspection Item
Slope Surface	Erosion, Rockfalls, Cracking of Slope, Movement / Bulge of Slope
Road Surface	Cracks, Surface Water
Structure	Cracks, Deformation
Rockfall Prevention Device	Failure, Deformation
Bridge	Deformation, Displacement, Scouring of Pier / Abutment
Culvert	Existence of Debris / Deposits / Sediment, Scouring
Drainage	Existence of Debris / Deposits / Sediment

Table 5.1.2 ROUTINE INSPECTION SHEET

ROUTE NUMBER ________INSPECTED BY ______________ DATE___/___/___

CONTROL SECTION __________ TRAVEL : FROM( ) TO( )

Inspection Item	Chain-age	Name of Place	Undesirable Signs, Changes, etc.	Follow-up Measures

<Selection of inspection items>
A: Condition of slope (erosion, rockfalls, crack, movement, bulge, etc.)
B: Condition of road surface (crack, surface water,etc.)
C: Condition of structure (crack, deformation, etc.)
D: Condition of prevention fence/net, etc. (failure, deformation, etc.)
E: Condition of bridge (deformation, scouring, etc.)
F: Condition of box/pipe culvert (scouring, existence of debris, deposits)
G: Condition of drainage (existence of debris, deposits, etc.)
H: Other ( )

* Inspection items are chosen from the selection above. Make sure you choose a letter between "A" and "H" for the Inspection Item column.

2. Periodic inspection

Periodic inspection performed at the end of the dry season aims to collect information on damage-prone objects. The necessity of prevention measures prior to the rainy season is determined by the findings of this inspection.

As for the periodic inspection performed at the end of the rainy season, statistical data on the influence of rain on deteriorating road and road structures are collected. In addition, an inspection examining the influence of road flooding shall be carried out once a year at the end of the rainy season.

The phenomena to be examined by periodic inspection are described below and the inspection items for these phenomena shown in the inspection sheets.

- Slope erosion	Table 5.1.3
- Rockfalls	Table 5.1.4
- Landslide	Table 5.1.5
- Collapsing of bridge	Table 5.1.6
- Collapsing of embankment and flooding	Table 5.1.7

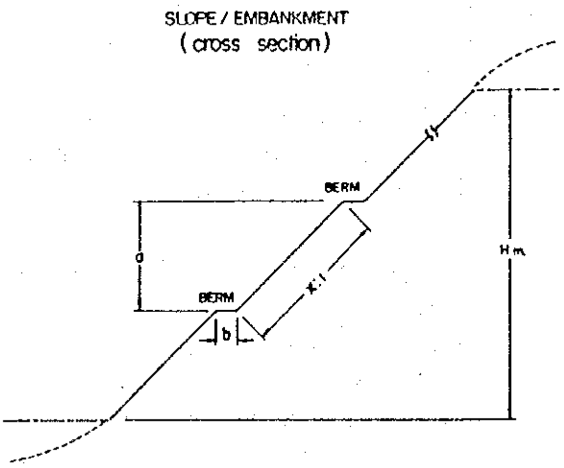
Table 5.1.3

Periodic Inspection Sheet

(Slope Erosion)

1 of 2 pages

Date of Inspection: / / 25

Road:	Chainage:	Inspector:	
Road Type	(1) Class: (2) Roadway Width: m (3) Pavement Type: (4) Pavement Width: m		
Type of Slope	(1) Natural Slope (2) Cut Slope (3) Fill Slope · (4) Embankment		
Height of Slope: H = ... m Slope Gradient: X : 1 Refer to Figure →			...... : 1 
Berms	(1) None	(2) Present Height: a = m Width: b = m No. of Steps:	
Surface Protection	(1) None	(2) Type:	
Slope Support	(1) None	(2) Type:	
Surface Drainage	(1) None	(2) Type:	
Probability of Erosion by Type	(1) Sheet: High probability Some probability Uncertain (2) Rill : High probability Some probability Uncertain (3) Gully: High probability Some probability Uncertain (4)		
	Distinctive Feature:		
Geomorphology	General Area	(1) Flat (2) Undulating (3) Hilly (4) Mountainous	
	Road Site	(1) Crest (2) Side of Slope (3) Foot of Slope (4) Valley Floor	
Weathering	(1) Much (2) Little (3) No		
Soil Description	Dominant Grain Size	(1) Boulder (2) Gravel (3) Sand (4) Silt (5) Clay	
	Moisture Content	(1) Wet (2) Moist (3) Dry	
	Relative Density	(1) Dense (2) Loose	
	Stratification	(1) Yes (2) No	Thickness: m
Water Condition	Surface Water	(1) Sheet Flow (2) Channel Flow	
	Groundwater Seepage	(1) None (2) Present: m above foot of slope	
Meteorology	Annual Average Rainfall for Area	mm/year	

Periodic Inspection Sheet
(Slope Erosion)

2 of 2 pages

Engineering Appraisal	Detour Road	(1) Available (Rt. No.: ....) (2) None
	Probability of Erosion	(1) Uncertain (2) Low (3) Medium (4) High
	Anticipated Scale of Erosion	(1) Uncertain (2) ≤ 0.05 ha (3) 0.06 - 0.30 ha (4) 0.31 - 1.00 ha (4) 1.00 < (ha)
	Anticipated Road Length in Danger	( ) Uncertain (2) .... m, Extent: ....
	Reasons	
	Short-term Proposals:	
	Long-term Proposals:	

Photographs	Sketch

Table 5.1.4

Periodic Inspection Sheet

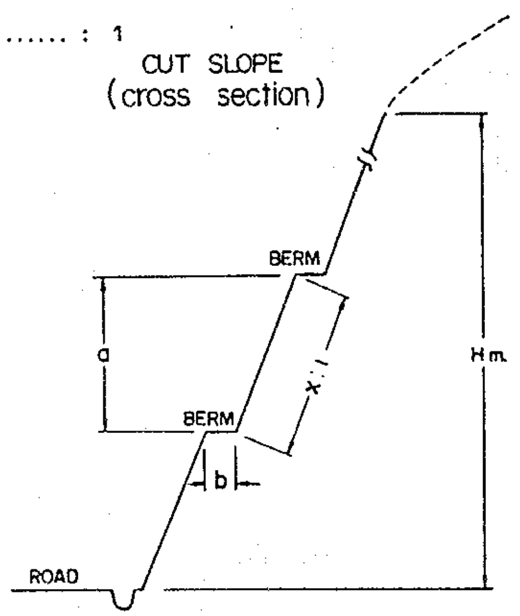
(Rockfalls)

1 of 2 pages

Date of Inspection: / / 25

Road:	Chainage:	Inspector:

Road Type	(1) Class: (2) Roadway Width: m (3) Pavement Type: (4) Pavement Width: m
Type of Slope	(1) Natural Slope (2) Cut Slope (3) Fill Slope (4) Embankment

Height of Slope: H = ... m Slope Gradient: X : 1 Refer to Figure →			
Berm	(1) None	(2) Present Height: m Width: m No. of Steps:	
Prevention Net	(1) None	(2) Area:	
Prevention Fence	(1) None	(2) Length:	
Prevention Barrier	(1) None	(2) Length: Height:	
Surface Drainage	(1) None	(2) Type:	
Probability of Rockfall	(1) High probability (2) Some probability (3) Uncertain		
	Size of Rock Estimated: (1) < 30cm (2) 30 ~ 100cm (3) > 100cm		
	Distinctive Feature:		

Geomorphology	General Area	(1) Flat (2) Undulating (3) Hilly (4) Mountainous	
	Road Site	(1) Crest (2) Side of Slope (3) Foot of Slope (4) Valley Floor	
Geological Condition of Slope	Rock Type	(1) Hard Rock (2) Soft Rock	
	Weathering	(1) Much (2) Little (3) No	
	(1) Boulder in Soil Matrix (2) Debris or Talus (3) Rock with Cracks: ( ) Sparse ( ) Regular ( ) Developed		
Soil Description	Dominant Grain Size	(1) Boulder (2) Gravel (3) Sand (4) Silt (5) Clay	
	Moisture Content	(1) Wet (2) Moist (3) Dry	
	Relative Density	(1) Dense (2) Loose	
	Stratification	(1) Yes (2) No	Thickness: m
Water Condition	Surface Water	(1) Sheet Flow (2) Channel Flow	
	Groundwater Seepage	(1) None (2) Present: m above foot of slope	
Meteorology	Annual Average Rainfall for Area	mm/year	

Periodic Inspection Sheet
(Rockfalls)

2 of 2 pages

Engineering Appraisal	Detour Road	(1) Available (Rt. No.: ....) (2) None
	Anticipated Scale of Rockfall	(1) Uncertain (2) ≤ 0.05 ha (3) 0.06 - 0.30 ha (4) 0.31 - 1.00 ha (4) > 1.00 ha (ha)
	Anticipated Road Length in Danger	(1) Uncertain (2) .... m, Extent: ....
	Anticipated Impact on Traffic	(1) Low (2) Medium (3) High (4) ......
	Reasons	
	Short-term Proposals:	
	Long-term Proposals:	

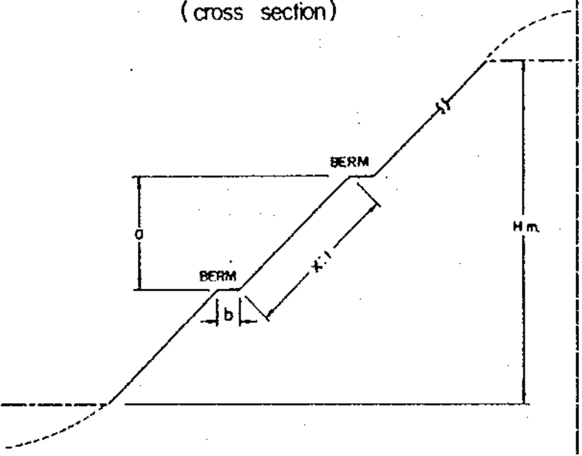
Photographs	Sketch

Table 5.1.5

Periodic Inspection Sheet
(Landslide)

1 of 2 pages

Date of Inspection: / / 25

Road:	Chainage:		Inspector:			
Road Type	(1) Class:	(2) Roadway Width: m	(3) Pavement Type:	(4) Pavement Width: m		
Type of Slope	(1) Natural Slope	(2) Cut Slope	(3) Fill Slope	(4) Embankment		
Height of Slope: H = ... m Slope Gradient: X : 1 Refer to Figure →			...... : 1 SLOPE / EMBANKMENT (cross section) 			
Berm	(1) None	(2) Present	Height: m Width: m No. of Steps:			
Surface Protection	(1) None	(2) Type:				
Slope Support	(1) None	(2) Type:				
Surface Drainage	(1) None	(2) Type:				
Sub-surface Drainage	(1) None	(2) Type:				
Probability of Landslide	(1) High probability (2) Some probability (3) Uncertain					
	Material of Slide Debris: (1) Soil (2) Soil + Boulder (3) Rock					
	Distinctive Feature (Fault, Fracture Zone, Cracks, Subsidence, Deformation, etc.):					
Geomorphology	General Area	(1) Undulating	(2) Hilly	(3) Mountainous		
	Road Site	(1) Crest	(2) Side of Slope	(3) Foot of Slope	(4) Valley Floor	
Geological Condition of Slope	Rock Type	(1) Hard Rock	(2) Soft Rock			
	Weathering	(1) Much	(2) Little	(3) No		
	Condition of Crack	(1) Sparse	(2) Regular	(3) Developed		
Soil Description	Dominant Grain Size	(1) Boulder	(2) Gravel	(3) Sand	(4) Silt	(5) Clay
	Moisture Content	(1) Wet	(2) Moist	(3) Dry		
	Relative Density	(1) Dense	(2) Loose			
	Stratification	(1) Yes	(2) No	Thickness: m		
Water Condition	Surface Water	(1) Sheet Flow	(2) Channel Flow			
	Groundwater Seepage	(1) None	(2) Present:	m above foot of slope		
Meteorology	Annual Average Rainfall for Area	mm/year				

Periodic Inspection Sheet
(Landslide)

2 of 2 pages

Engineering Appraisal	Detour Road	(1) Available (Rt. No.: ....) (2) None
	Anticipated Scale of Landslide	(1) Uncertain (2) ≤ 0.05 ha (3) 0.06 - 0.30 ha (4) 0.31 - 1.00 ha (4) > 1.00 ha (ha)
	Anticipated Road Length in Danger	(1) Uncertain (2) .... m, Extent: ....
	Anticipated Impact on Traffic	(1) Low (2) Medium (3) High (4) ......
	Reasons	
	Short-term Proposals:	
	Long-term Proposals:	

Photographs	Sketch

Table 5.1.6

Periodic Inspection Sheet

(Bridge Collapsing)

Date of Inspection: / / 25

Road:	Chainage:	Inspector:	
Name of Bridge		Type of Bridge	(1) Permanent (2) Temporary
General Bridge Structure	(1) Class: (2) Total Width : m (3) No. of Lanes: Lanes		
Bridge Information	Surface Type	(1) Concrete (2) AC (3) PM (4) Gravel (5) Earth	
	Bridge Length(Span Length)	m (m)	Clearance of Bridge: ....
	Type of Superstructure		
	Type of Abutment		
	Type of Pier		
	Type of Foundation		
Prediction of Damage	Type of Damage: Scale : Reasons :		
	Anticipated Impact on Traffic	(1) Low (2) Medium (3) High (4)	
Existing Conditions	General Area	(1) Flat (2) Undulating (3) Hilly (4) Mountainous	
	Approach Road		
	Riverbed	(1) Boulder (2) Gravel (3) Sand (4) Mud	Gradient of River: ....
	Rainfall Intensity (mm/day) 50-year Return Period	(1) < 150 (2) 150-250 (3) 250-350 (4) 350-450 (5) > 450	
	Detour Road	(1) Available(Rt. No.: ....) (2) None	
Engineering Appraisal	Countermeasure(s):		

Photographs	Sketch

Table 5.1.7

Periodic Inspection Sheet

(Road Collapsing & Flooding)

Date of Inspection: / / 25

Road:	Chainage:	Inspector:
Road Type		(1) Class: (2) Roadway Width: m (3) Pavement Width: m
Road Information	Surface Type	(1) Concrete (2) AC (3) PM (4) Gravel (5) Earth
	Terrain	(1) Flat (2) Rolling (3) Mountainous
	Cross Section	(1) Embankment (2) Fill (3) Cut (4) Cut/Fill (5) Flat
Prediction of Damage	Type of Damage	(1) Culvert (Type: .... Drainability: ....) (2) Washout/Scouring of Roadbed (3) Scouring of Shoulder (4) flooding/Muddy Surface (5) ....
	Anticipated Road Length in Danger	(1) Uncertain (2) .... m, Extent: ....
	Anticipated Impact on Traffic	(1) Low (2) Medium (3) High (4) ....
Existing Conditions	Road Surface Condition	(1) Fair (2) ....
	Drainage Facilities	(1) Existing ( ) (2) None
	Surface Protection of Slope	
	Rainfall Intensity (mm/day) 50-year Return Period	(1) < 150 (2) 150-250 (3) 250-350 (4) 350-450 (5) > 450
	Detour Road	(1) Available (Rt. No.: ....) (2) None
Engineering Appraisal	Countermeasure(s):	

Photographs	Sketch

3. Special inspection

The special inspection shall be performed focusing on the following spots:

- Spots with a history of being damaged.
- Spots adjacent to the spots mentioned above.
- Spots slightly damaged but not yet repaired.

The execution of a special inspection shall be ordered by a district engineer, based on the effects of the on-going disaster.

The survey sheet for special inspections is shown in Table 5.1.8.

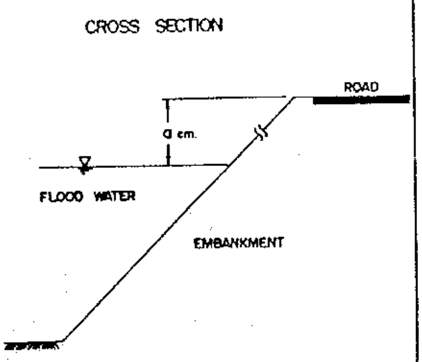
Table 5.1.8

Special Inspection Sheet
(PREVENTION)

Date of Inspection: / /25 , Name of Inspector:

District Office	Depot	Route No.	Control Section	Chainage	Name of Place

Typhoon, Monsoon or Depression: (1) Date of heavy rain; (2) Continuous heavy rain; .... days (3) Intermittent shower; .... days	Fear of traffic interruption: ( ) high, ( ) some extent, ( ) low, ( ) ....

Fear of Damage Type	State of affairs	
Cut Slope Erosion	Water flow on slope: ( ) channel flow ( ) sheet flow ( ) from slope to toe ditch ( ) from slope to .... Erosion debris: ( ) in toe ditch ( ) on shoulder ( ) .... Hazardous road length: .... m	
Rockfall	Rockfall: ( ) in toe ditch, ( ) on shoulder, ( ) on ...., ( ) .... Condition of rocks on slope: ( ) stable ( ) uncertain ( ) unstable Size of unstable rock: D = ... m (max.) Hazardous road length: .... m	
Landslide	Movement of slope: ( ) clear, ( ) uncertain, ( ) none Crack: ( ) crack on road surface ( ) crack on slope surface Sign of landslide: ( ) exist, ( ) uncertain, ( ) none Hazardous road length: .... m	
Bridge (abutment, pier and approach road)	Clearance: .... m Fear of damage: ( ) scouring of abutment back fill ( ) scouring of approach road ( ) damming up of floating timber ( ) .... Hazardous bridge length: .... m	
Embankment	Condition of waterflow: ( ) fear of inundation ( ) fear of scouring on slope ( ) fear of scouring at toe ( ) .... Hazardous road length: .... m	
Road Flooding	Hazardous road length: .... m Height between road surface and level of flood water: a = ... cm (min.) .... cm (average)	

* Use only one sheet for one spot.
* Make a check in the relevant parentheses and fill in the required information on the dotted lines.
* Condition of the spot shall be sketched on another sheet.

5.2 Survey

A survey shall be carried out at the spot where is identified as damage prevention work is necessary. The necessity of the prevention work shall be decided based on the findings from periodic inspection and special inspection, or the result of the evaluation for road damage potential (refer to Chapter 4).

The survey basically consists of four types of survey, namely a soil and geotechnical survey, a topographical survey, a hydrological survey and an environmental survey.

In principle, the survey shall be executed by private companies based on contract under the control of the district office concerned.

5.2.1 Soil and Geotechnical Survey

Survey items vary with the types of anticipated damage. The following items shown in Table 5.2.1 are recommended to be surveyed for each type of damage. As a guide to the selection of survey method, the relationship between the survey items and the survey methods are tabulated in Table 5.2.2.

Table 5.2.1 Soil Survey Items

Type of Damage	Survey Method	Findings
Cut slope erosion	Boring	- Properties of surface soil - Weathering of surface rock
	Soil test	- Strength of soil - Strength of weathered rock - Hardness of surface soil - Fertility of surface soil
Rockfalls	Boring	- Properties of rock - Stratification structure - Cracks, joints of rock
	Rock test	- Properties of rock - Cracks, joints of rock - Strength of rock
Landslide	Boring	- Properties of soil - Stratification structure - Groundwater level - Location of sliding plane - Strength of soil
	Soil test	- Strength of soil
	Movement survey	- Location of sliding plane - Direction of movement - Amount of movement
Collapsing of bridge	Boring	- Properties of soil - Depth of bearing layer - Bearing capacity
	Soil test	- Strength of soil
Collapsing of embankment	Boring	- Properties of embankment material
	Soil test	- Strength of embankment material

Table 5.2.2 Application of Geotechnical Survey

Survey Method Survey Item		Boring	Auger Boring	Test Pit	Sounding	Soil Test	Rock Test	Movement Survey
Soil/Rock Properties		O	□	□	+	O	O	
Geological Structure	Stratification Structure, Fault, Fracture Zone, etc.	□						
	Crack, Joint	O		□			□	
	Weathering	O	+	□			+	
	Thickness of Top Soil	O	O	O	□			
	Unconformity, Discontinuity	O		□	□			
Strength of Ground		□		□	□	O	O	
Strength of Embankment Material						O		
Properties of Embankment Material		□	□	□		O		
Condition of Groundwater Level		□	+	□				
Landslide	Location of Sliding Plane	□		□	□			O
	Direction and Amount of Movement							O
	Prediction of Movement							O
Vegetation	Soil Hardness					□		
	Soil Material					O		
	Fertility of Soil					□		
	Composition of Soil Grading					O		

Note: O Most Applicable
□ Applicable
\+ Supplemental

The outline of each soil and geotechnical survey methods described below.

1) Boring: The purpose of boring is to collect information on the underground soil and/or rock of a site by boring a hole into the ground. Then, through observing and laboratory testing of the samples obtained by boring, physical properties of soil and/or rock, strata formation, etc. are determined. Information on groundwater level and sliding surfaces in the case of landslide can also obtained by boring.

2) Auger Boring: The main purpose of auger boring is to examine only the properties and conditions of top soil using simple boring methods.

3) Test Pit: A test pit aims to observe soil directly by excavating a pit that can accommodate an investigator.

4) Sounding: Sounding is generally applied to standard penetration test (SPT).

5) Soil Test: The purpose of soil test is to obtain information on a soil's engineering properties via laboratory testing. Samples for the test are usually collected by boring. Information on the applicability of vegetation work can also

be determined by soil testing.

6) Rock Test: The engineering properties of rock are examined by laboratory tests using samples collected by boring.

7) Movement Survey: This survey aims to detect the movement of a slope, and provides their information on the location of sliding planes, direction of their movement, etc. A tiltmeter and extensometer are commonly used for these purposes.

5.2.2 Topographic Survey

Survey items in accordance with the types of anticipated damage are shown in Table 5.2.3.

Table 5.2.3 Topographic Survey Items

Type of Damage	Survey Method	Survey Items
Cut slope erosion	Plane table survey Cross-section survey Measurement of size	- Entire affected area - Entire affected area - Cavity
Rockfalls	Plane table survey Cross-section survey Measurement of size	- Entire affected area - Entire affected area - Remaining boulders / rock
Landslide	Plane table survey Cross-section survey	- Entire affected area - Entire affected area & the gap between scarp and slide debris
Collapsing of bridge	Plane table survey Cross-section survey Level survey Measurement of size	- Bridge and river concerned - Bridge and river concerned - Along river - Damaged portion
Collapsing of embankment	Plane table survey Cross-section survey Measurement of size	- Entire affected area - Entire affected area - Damaged portion
Road flooding	Cross-section survey Level survey	- Entire affected area - Along road

5.2.3 Hydrological Survey

Applicable survey methods to collect the hydrological information on anticipated damage spot are shown for each type of damage in Table 5.2.4.

Table 5.2.4 Hydrological Survey Items

Type of Damage	Survey Method	Survey Items
Cut slope erosion	Precipitation survey	- Catch basin concerned
	Surface water survey	- Water runoff, seepage
Rockfalls	Precipitation survey	- Catch basin concerned
	Surface water survey	- Water runoff, seepage
Landslide	Precipitation survey	- Catch basin concerned
	Boring	- Pore water pressure - Groundwater level - Groundwater distribution
	Surface water survey	- Water runoff, spring / seepage water
Collapsing of bridge	Precipitation survey	- Catch basin concerned
	Riverflow survey	- River concerned
	Survey related to bridge clearance	- Around bridge
Collapsing of embankment	Precipitation survey	- Catch basin concerned
	Survey related to drainag capacity	- Affected area
	Riverflow survey	- River concerned

The outline of each hydrological survey method is described follows.

1) Precipitation Survey: Consists of a site survey and data collection. A site survey collects information on past rainfall and flooding from witnesses living nearby a damaged spot. Regarding data collection, statistical data on precipitation in the area shall be collected at the Meteorological Department or Hydrology Division of the Royal Irrigation Department.

2) Surface Water Survey: Collects information on surface water flow and the track of surface water flow on site.

3) Stream Flow Survey: Collect data on river flows at the Hydrodrogy Division of the Royal Irrigation Department and ana-

lyzes the data (see list below).

- High water level at the time of flooding.
- Velocity of river flow.
- River discharge.
- Condition of riverbed.

5.2.4 Environmental Survey

In the course of selecting preventive measures, the following shall be taken in consideration to eliminate adverse environmental impacts directly or indirectly brought about by preventive work.

- Alleviation of adverse impacts on residents who earn a living from natural resources.

- Minimization of adverse impacts on human health.

- Minimization of adverse impacts on flora and fauna.

- Alleviation of adverse impacts on residents living adjacent to a preventive work spot.

The general procedure for an environmental survey is illustrated in Fig.5.2.1, and begins with the collection of information on the state of the environment and ends with a decision on a final prevention plan.

1. Collection of information on state of environment

First, the draft of road prevention plan shall be checked to see if it compromises the environmental restraints peculiar to a preventive work spot. To grasp these restraints, information on the state of the environment shall be collected considering the following the three fields:

- Socioeconomic environment
- Natural environment
- Environmental pollution

Survey items for each field are shown in the survey sheet (see Table 5.2.5).

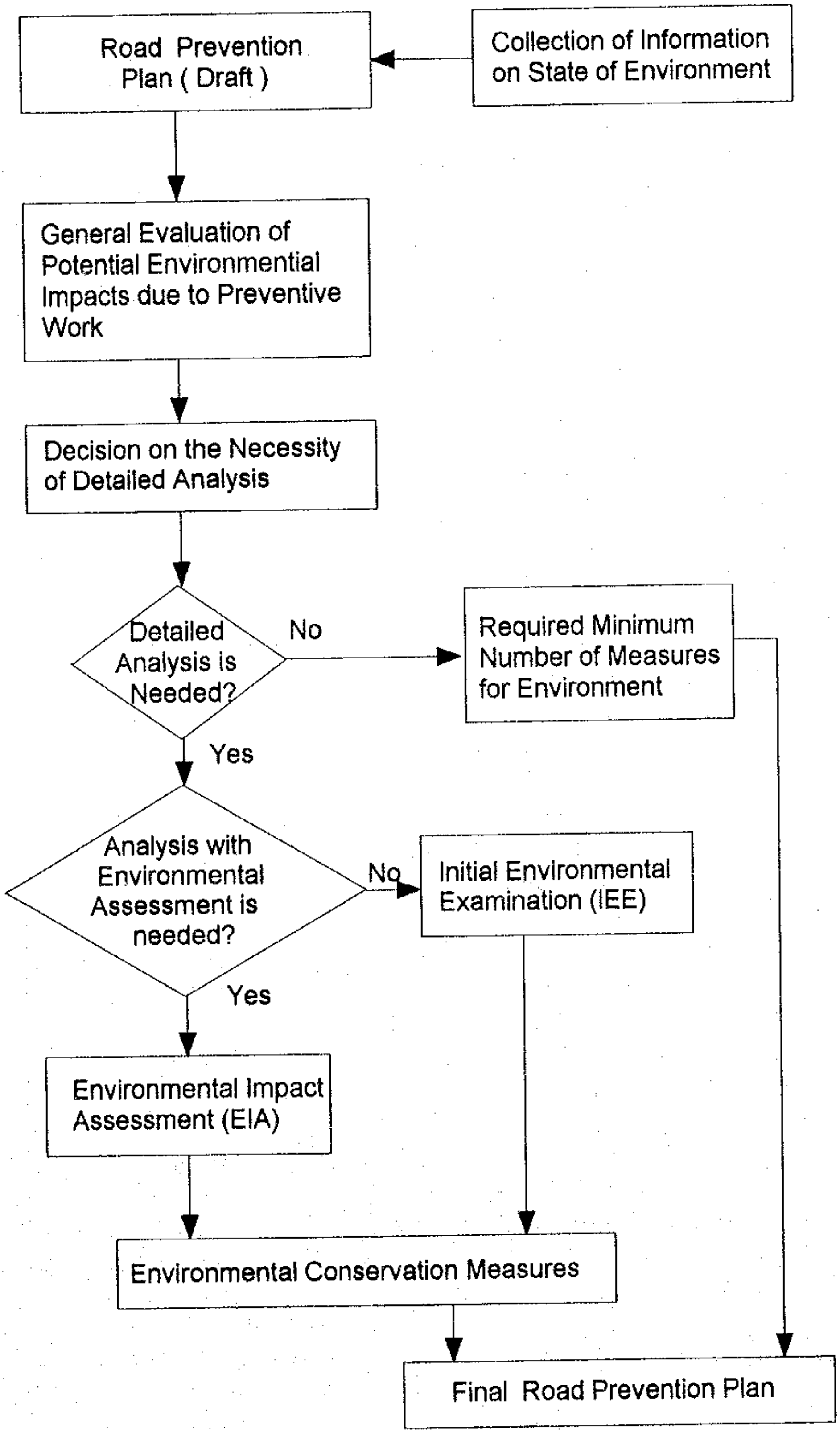


Fig. 5.2.1 Procedure for Environmental Survey

Table 5.2.5 Survey Sheet for Environmental Situation

Route No.:
Section Concerned: from ...... km to ...... km

Item		Present Situation
Socio-economic Environment	Area Residents (Inhabitants/Aborigines /Understanding of Project, etc.)	
	Land Use (City/Farm Village/Historic Site /Scenic Area/ Hospital, etc.)	
	Economic/Transportation Function (Commercial Area, Farm or Fishery Area/Bus Terminal, etc.)	
Natural Environment	Topography, Geology (Steep Slope, Soft Ground, Swamp/Fault, etc.)	
	Valuable Flora & Fauna, Territory (Sanctuary, Preservation of Species , etc.)	
Environ-mental Pollution	Frequency of Grievances (Highly-concentrated Pollution, etc.)	
	On-going Treatment (Institutional Measures , Compensation, etc.)	
Miscellane-ous		

2. Evaluation of environmental impacts caused by preventive work

In the case of a new road project, the execution of an initial evaluation to assess potential of negative environmental impacts is generally recommended. For example, a total of 23 evaluation items for this initial evaluation are recommended in the case of the road development study by JICA as shown in Table 5.2.6.

In the case of preventive work for existing road, the evaluation items are more limited in the case of a new road project, since only the environmental changes caused by preventive work are taken up. Therefore of the above-mentioned 23 items, only 8 items are recommended and are listed in Table 5.2.7.

Table 5.2.7 Evaluation Items in the Case of Preventive Work

	During Preventive Work	After Completion of Preventive Work
Socioeconomic Environment	- Waste material	- Water rights
Natural Environment	- Soil erosion - Groundwater - Hydrological situation	- Hydrological situation - Landscape
Environmental Pollution	- Water pollution - Noise & Vibration	

3. Formulation of road restoration plan

It is necessary to decide whether detailed analysis of environmental impacts is required at the time of an engineering study.

The necessity of a detailed analysis mainly depends on the scale of the preventive work or the construction methods of it. However, most preventive work will not be subjected to a detailed analysis. If the analysis is needed, an initial environmental examination(IEE) or an environmental impact

Table 5.2.6 Initial Evaluation Sheet for Environmental Impacts from a New Road Project

Evaluation Item	Evaluation during construction		Evaluation after traffic is opened.			Total evaluation
	Changes in Topography, Land Use	Operation of Construction Machines and Vehicles	Changes in Land Use	Movement of Vehicles	Movement of People and Commodities	
<Socio-economic Environment> 1. Resettlement						
2. Economic Activities						
3. Traffic & Public Facilities						
4. Split of Communities						
5. Cultural Property						
6. Water Right, Right of Common						
7. Health, Sanitary						
8. Waste Materials						
9. Hazard (Risk)						
<Natural Environment> 10. Topography, Geology						
11. Soil Erosion						
12. Ground Water						
13. Hydrological Situation						
14. Coastal Zone						
15. Flora & Fauna						
16. Weather						
17. Landscape						
<Environmental Pollution> 18. Air Pollution						
19. Water Pollution						
20. Soil Contamination						
21. Noise & Vibration						
22. Ground Subsidence						
23. Offensive Odor						

assessment (EIA) shall be carried out. Then, environmental conservation measures based on the results of the detailed analysis shall be established.

In general, a final prevention plan for damage anticipated road shall be formulated considering the evaluation items shown in Table 5.2.7.

Chapter 6

Prevention of Damage on Existing Road

Chapter 6 Prevention of Damage to Existing Roads

6.1 Damage Prevention Measures

In order to eliminate the adverse social impacts of damage brought about by various kinds of disasters, such as traffic interruption, damage to public and private properties, etc., possible damage shall be prevented prior to its occurrence.

The preventive measures will differ depending on the type of damage. A desirable preventive measure shall satisfy the various conditions peculiar to a particular kind damage and the surrounding environment. The main requirements of a preventive measure are as follows:

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

Damage prevention measures are classified into six categories by type of damage. They are tabulated in Table 6.1.1 - 6.1.6, with a description on their functional characteristics and applicable location.

The relation between the types of damage and the number of tables are shown below.

Slope erosion	Table 6.1.1(1) - (5)
Rockfalls	Table 6.1.2(1) - (3)
Landslide	Table 6.1.3(1) - (4)
Collapsing of bridges	Table 6.1.4(1) - (6)
Collapsing of embankment road	Table 6.1.5(1) - (3)
Road flooding	Table 6.1.6

Table 6.1.1 (1) Types of Preventive Measures for Slope Erosion

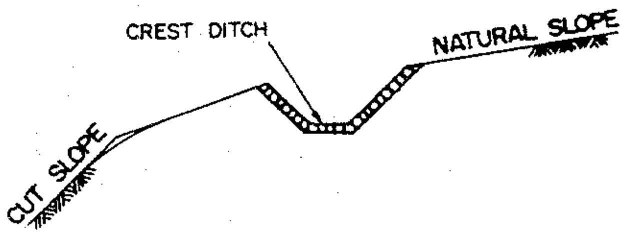
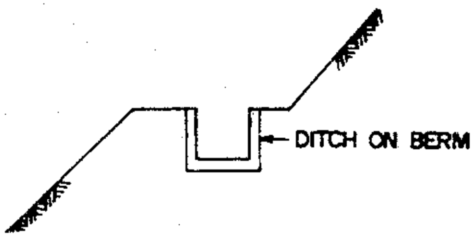
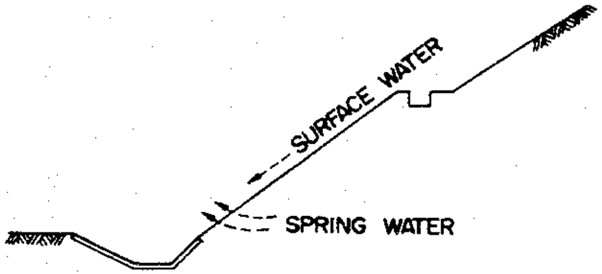
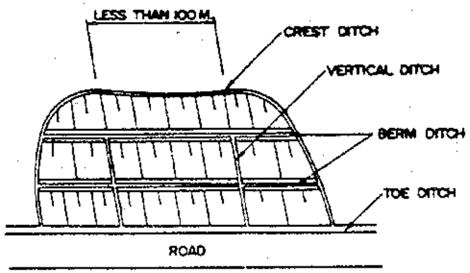
Classification	Type of Work	Functional Characteristics	Application	Illustration
(1) Surface drainage	Crest ditch	- To prevent the erosion and scouring of a slope surface by collecting runoff water along the top of a cut slope.	- Cut slope. - Weathered rock, soil.	
	Berm ditch	- To prevent the erosion and scouring of a slope surface by collecting surface water in berm.	- Cut slope, fill slope. - Weathered rock, soil.	
	Toe ditch	- To prevent runoff water from reaching a road's surface.	- Cut slope.	
	Vertical ditch	- To collect and drain surface water on a slope with a vertical ditch to prevent the erosion and scouring of the slope's surface.	- Generally applied on a slope surface. - Cut slope, fill slope.	

Table 6.1.1 (2) Types of Preventive Measures for Slope Erosion

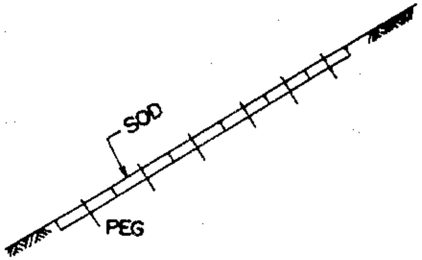
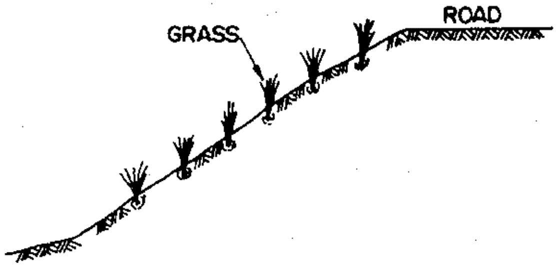
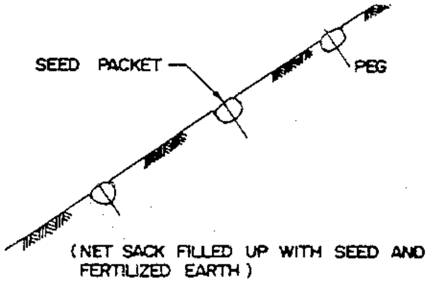
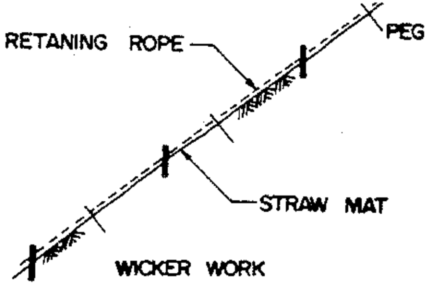
Classification	Type of Work	Functional Characteristics	Application	Illustration
(2) Vegetation	Block sodding	- To prevent the erosion, scouring and weathering of a slope by covering it with vegetation. - To place sod directly on a slope.	- Cut slope, fill slope. - Soil.	
	Spot sodding	- To prevent the erosion, scouring and weathering of a slope by covering it with vegetation. - To place sod directly on a slope.	- Cut slope, fill slope. - Weathered rock, soil.	
	Seed packet work	- To prevent the erosion, scouring and weathering of a slope by covering it with vegetation. - To place bags filled with seeds and fertilized soil on a slope.	- Applied to a slope relatively unsuitable for growing grass. - Cut slope. - Weathered rock, soil.	
	Erosion control with local material	- To prevent the erosion, scouring and weathering of a slope by covering it with vegetation. - To cover seed with a straw mat.	- Cut slope, fill slope. - Soil surface.	

Table 6.1.1 (3) Types of Preventive Measures for Slope Erosion

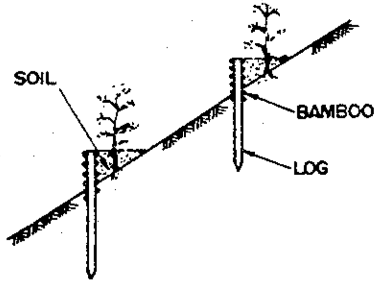
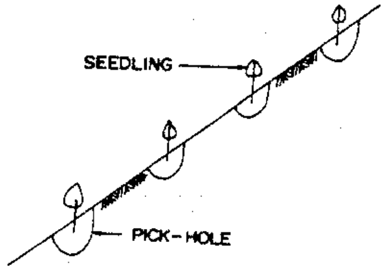
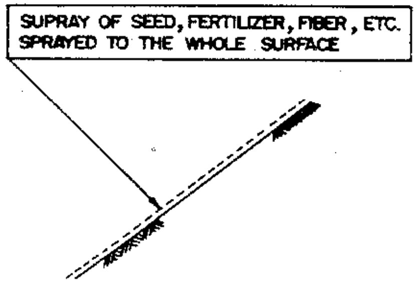
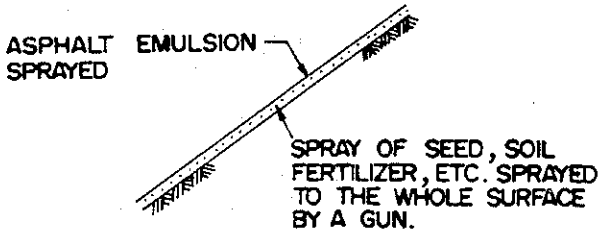
Classification	Type of Work	Functional Characteristics	Application	Illustration
(2) Vegetation	Wicker work	- To prevent the erosion, scouring and weathering of a slope by covering it with vegetation.	- Cut slope, fill slope. - Weathered rock, soil.	
	Pick-hole seedling work	- To prevent the erosion, scouring and weathering of a slope by covering it with vegetation. - To fill holes on a slope with seeds and fertilized soil.	- Applied to a slope relatively unsuitable for growing grass. - Generally applied to a cut slope. - Weathered rock, soft rock.	
	Seed spraying with pump (seed spraying)	- To prevent the erosion, scouring and weathering of a slope by covering it with vegetation. - To spray seed with a pump.	- Generally applied to the soil surface of a cut or fill slope.	
	Seed-mix spraying with a gun (hydroseeding)	- To prevent the erosion, scouring and weathering of a slope by covering it with vegetation. - To spray mixed slurry or mud composed of seed, water, fertilizer, soil, etc., with a spray gun.	- Mainly applied to the weathered rock, soft rock and soil surface of a cut or fill slope.	

Table 6.1.1 (4) Types of Preventive Measures for Slope Erosion

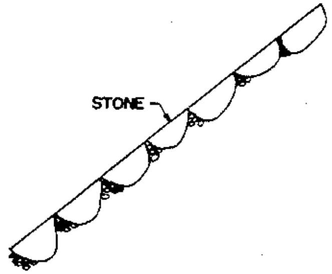
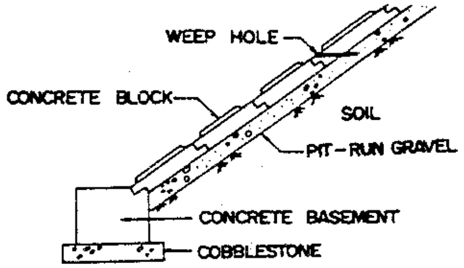
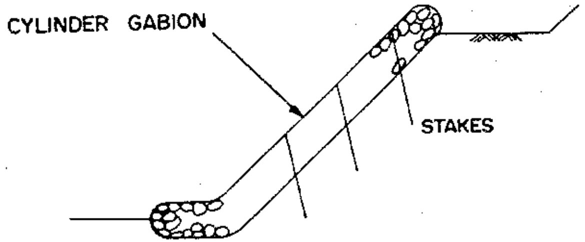
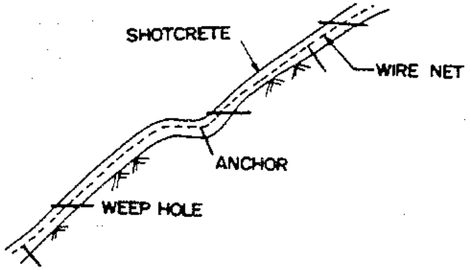
Classification	Type of Work	Functional Characteristics	Application	Illustration
(3) Structure	Stone pitching	- To protect a slope by covering it with stone pitching.	- Usually applied to a slope surface gentler than 1.5 : 1.	
	Concrete block pitching	- To protect a slope by covering it with cast-in-place concrete.	- Usually applied to a slope surface gentler than 1.5 : 1.	
	Cylinder gabion work	- To protect a slope by covering it with gabion.	- Usually applied to a slope surface gentler than 0.5 : 1 with seepage water.	
	Shotcrete	- To protect a slope by covering it with sprayed concrete.	- Not applicable to a slope surface with much seepage water.	

Table 6.1.1 (5) Types of Preventive Measures for Slope Erosion

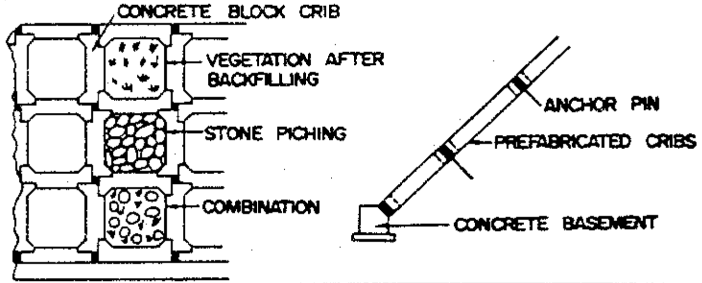
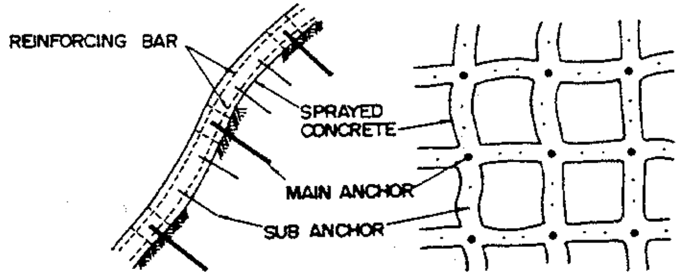
Classification	Type of Work	Functional Characteristics	Application	Illustration
(3) Structure	Concrete block crib	- To protect a slope by covering it with a precast concrete block crib.	- Usually applied to a slope surface gentler than 1.0 : 1.	
	Sprayed concrete crib	- To protect a slope by covering it with a crib made by spraying concrete with a gun.	- Applicable to a slope surface steeper than 1.0 : 1. - Applicable to an undulated surface.	

Table 6.1.2 (1) Types of Preventive Measures for Rockfalls

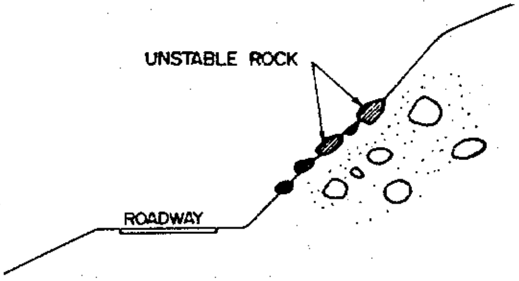
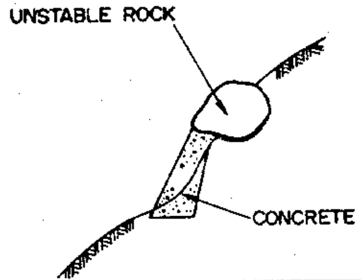
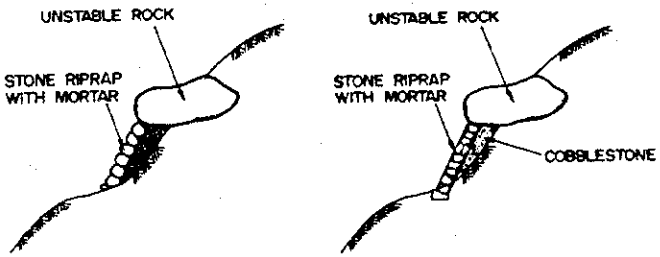
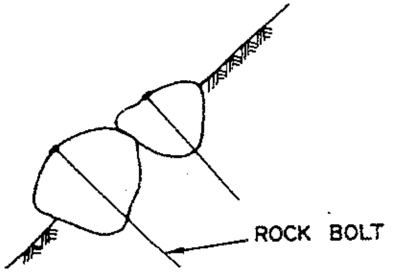
Classification	Type of Work	Functional Characteristics	Application	Illustration
(1) Removal work	Removal of unstable rock	- To remove unstable rocks before they fall down.	- Generally applied to huge and medium-size rocks.	
(2) Structural support	Foot protection with concrete	- To prevent unstable rock from falling down by supporting it with a concrete structure.	- Applied to huge rocks that are accessable.	
	Foot protection with stone riprap	- To prevent unstable rock from falling down by supporting it with stone riprap.	- Applied to huge rocks that are accessable.	
(3) Anchoring	Rock bolt	- To prevent unstable rocks from falling down by anchoring them to bedrock with rock bolts.	- Applicable to huge rocks.	

Table 6.1.2 (2) Types of Preventive Measures for Rockfalls

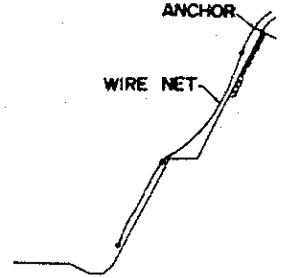
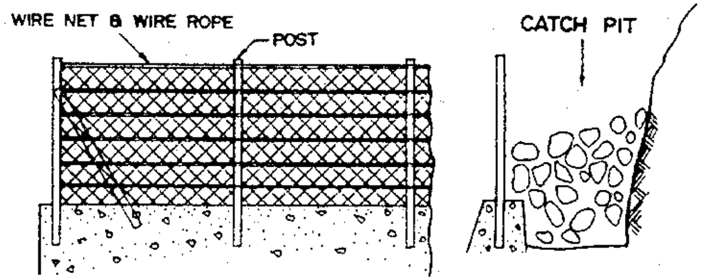
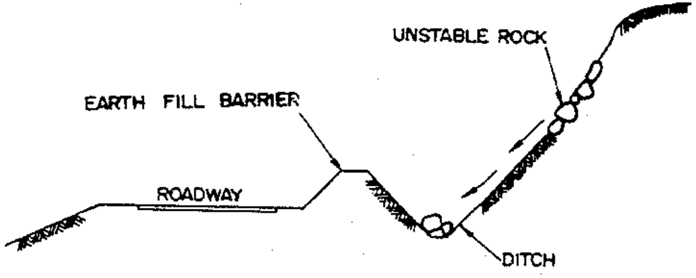
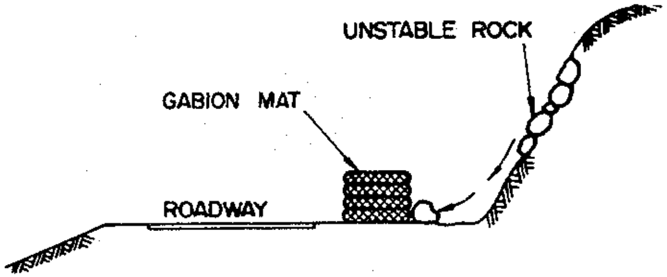
Classification	Type of Work	Functional Characteristics	Application	Illustration
(4) Rockfall prevention device	**Prevention net**	**- To prevent falling rock from reaching a road by providing a catch wire net.**	**- Applied where there is no roadside space.** **- Unsuitable for a slope with rock that easily weathers.**	
	Prevention fence	**- To prevent falling rock from reaching a road by providing a catch fence.**	**- Applied where there is sufficient roadside space to contain fallen rock.**	
	Barrier with earth fill	**- To prevent falling rock from reaching a road by providing an earth fill and ditch.**	**- A wide space is required between a road edge and the toe of a slope to contain fallen rock.**	
	Barrier with mat gabion	**- To prevent falling rock from reaching a road by providing a gabion barrier.**	**- Applied where there is sufficient roadside space to contain fallen rock.**	

Table 6.1.2 (3) Types of Preventive Measures for Rockfalls

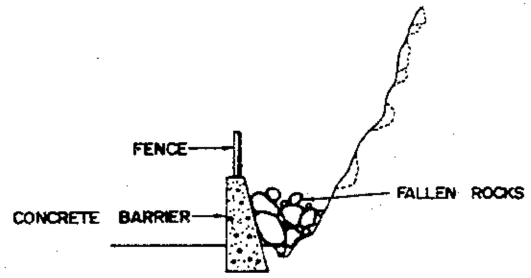
Classification	Type of Work	Functional Characteristics	Application	Illustration
(4) Rockfall prevention device	Barrier with concrete wall	- To prevent falling rock from reaching a road by providing a concrete wall.	- Applied where there is sufficient roadside space to contain fallen rock.	

Table 6.1.3 (1) Types of Preventive Measures for Landslides

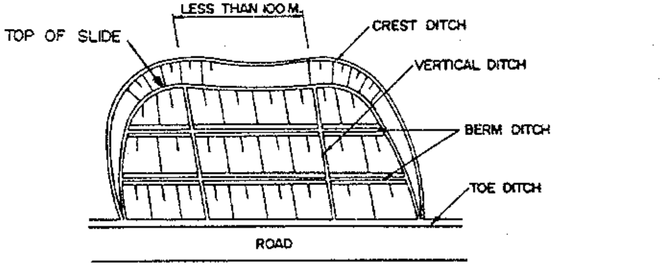
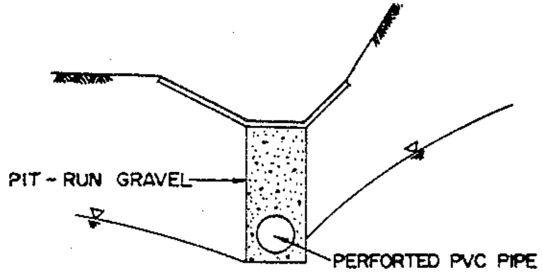
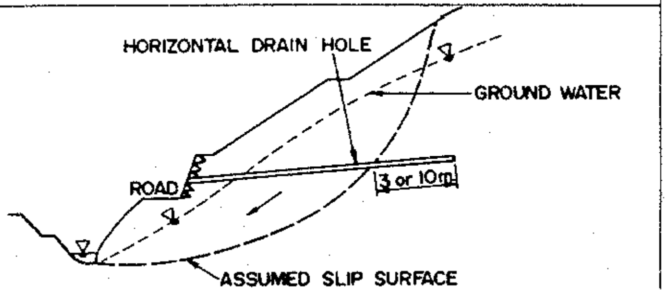
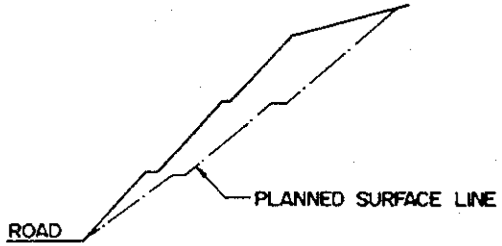
Classification	Type of Work	Functional Characteristics	Application	Illustration
(1) Surface drainage	Surface drainage - Crest ditch - Berm ditch - Vertical ditch - Toe ditch	- To collect and drain surface water by providing a ditch to prevent the erosion and scouring of a slope's surface, and to prevent runoff water from permeating into slide debris.	- Mainly applied to the surface of slide debris composed of colluvium or clayey soil.	
(2) Subsurface drainage	Underground drainage with pits and pipes	- To drain shallow groundwater and thus stabilize a slope.	- Usually used in combination with surface drainage. - Generally applied to a slope with much seepage water.	
	Horizontal drain hole	- To stabilize a landslide-prone slope by draining groundwater.	- Generally applied to a cut or fill slope with high groundwater pressure.	
(3) Recutting	Recutting	- To stabilize a slope by cutting it to its optimum gradient.	- Usually applied with drainage work and slope protection work.	

Table 6.1.3 (2) Types of Preventive Measures for Landslides

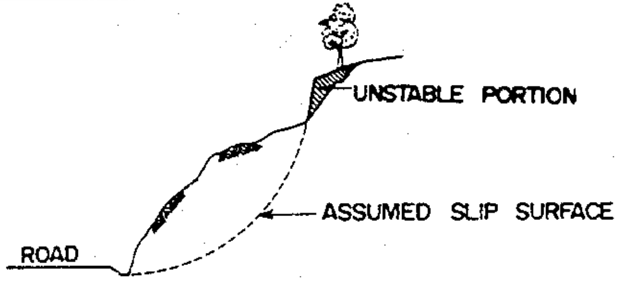
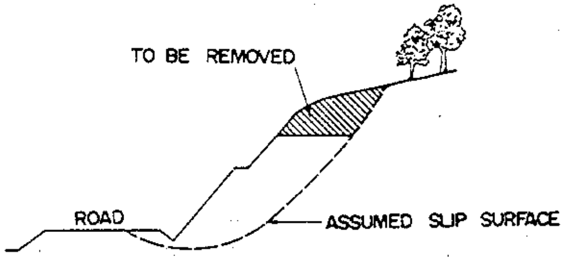
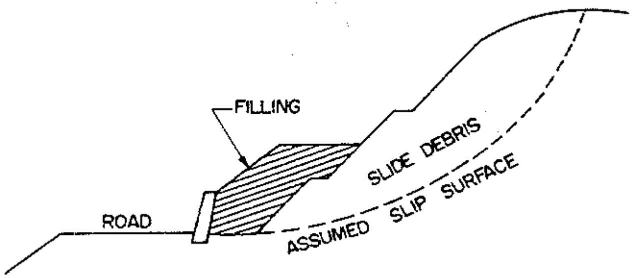
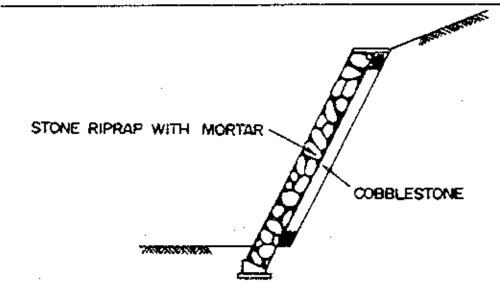
Classification	Type of Work	Functional Characteristics	Application	Illustration
(3) Recutting	Removal of unstable portion	- To stabilize a slope by removing unstable portions.	- Usually applied to remove a scarp with some drainage work.	
(4) Weight shifting	Removal of head of slide debris	- To reduce the sliding force of slide debris by removing the head portion.	- Generally applied to a cut slope.	
	Counterweight fill	- To resist a landslide's force with a counterweight fill at the foot of a slope.	- Cut slope, fill slope.	
(5) Structural support	Stone riprap wall	- To protect a slope from landslides by resisting earth pressure.	- Applicable to a riprap wall less than 5 m high. - Generally applied to a cut or fill slope.	

Table 6.1.3 (3) Types of Preventive Measures for Landslides

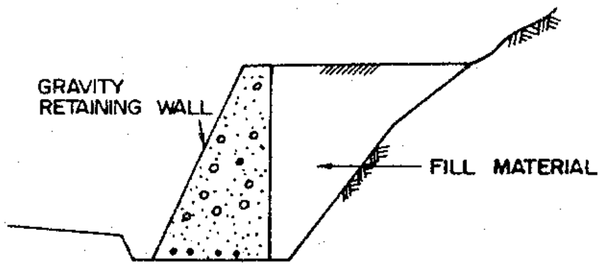
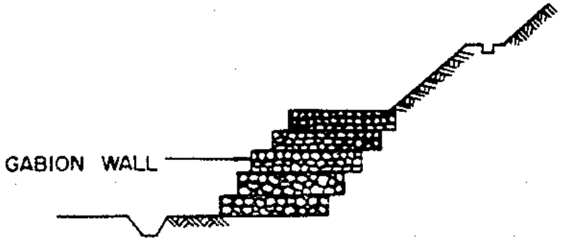
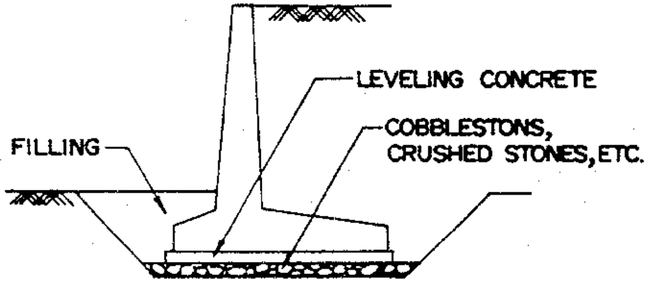
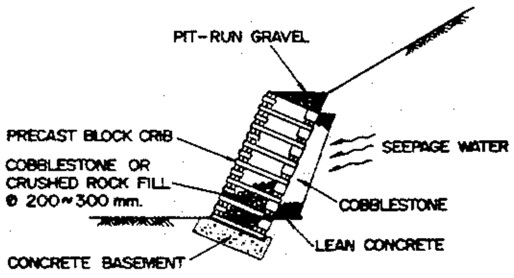
Classification	Type of Work	Functional Characteristics	Application	Illustration
(5) Structural support	Gravity-type retaining wall	- To protect a slope from landslides by resisting earth pressure.	- Applicable to a wall less than 3 m high. - Generally applied to a cut or fill slope.	
	Gabion wall	- To protect a slope from landslides by resisting earth pressure.	- Mainly applied to the toe of a fill slope with seepage water.	
	T-shaped retaining wall	- To protect a slope from landslides by resisting earth pressure.	- Usually applied to a wall 3 to 10 m high. - Generally applied to a cut or fill slope.	
	Crib retaining wall	- To protect a slope from landslides by resisting earth pressure with a precast concrete block crib.	- Mainly applied to a cut slope with spring water.	

Table 6.1.3 (4) Types of Preventive Measures for Landslides

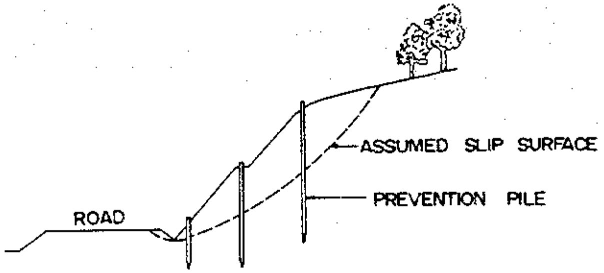
Classification	Type of Work	Functional Characteristics	Application	Illustration
(5) Structural support	Prevention piles	- To protect a slope from landslides by resisting earth pressure with piles.	- Generally applied to a cut of fill slope.	

Table 6.1.4 (1) Types of Preventive Measures for the Collapsing of Bridges

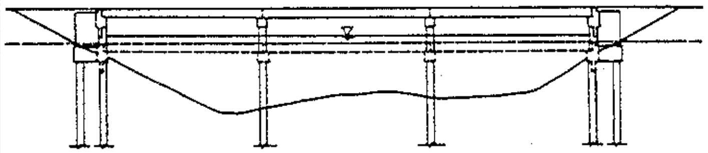
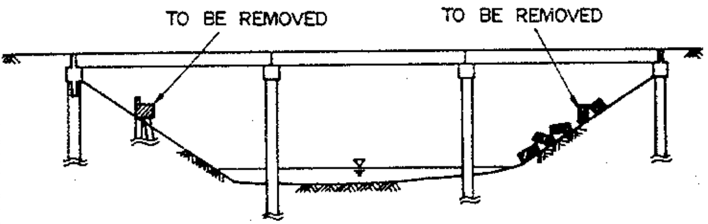
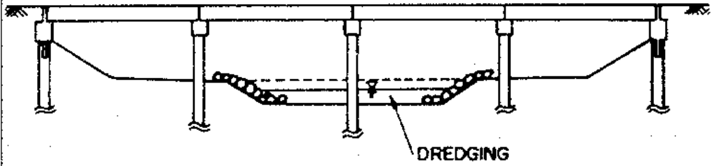
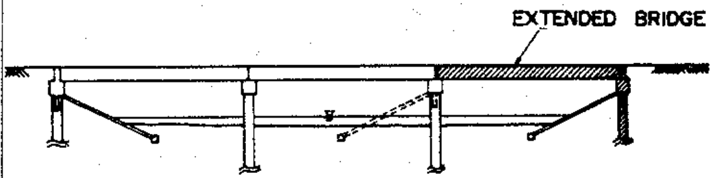
Classification	Type of Work	Functional Characteristics	Application	Illustration
(1) Improvement of discharge capacity	Raising of bridge elevation	- To increase discharge capacity	- Applicable to a short bridge.	
	Removal of obstacles in waterway	- To increase discharge capacity.	- Applicable to a short bridge.	
	Channel dredging	- To increase discharge capacity. - To stabilize a river channel.	- Applicable to long and short bridges.	
	Extension of bridge length	- To increase discharge capacity.	- Generally applied to a short bridge.	

Table 6.1.4 (2) Types of Preventive Measures for the Collapsing of Bridges

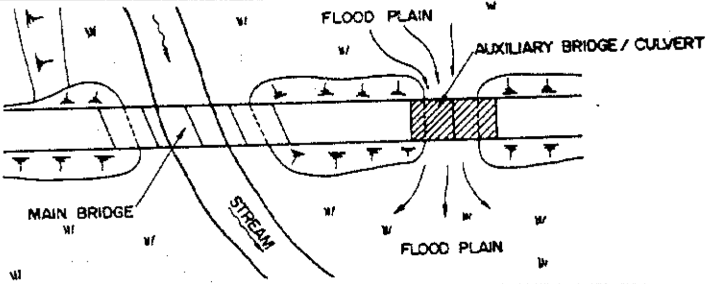
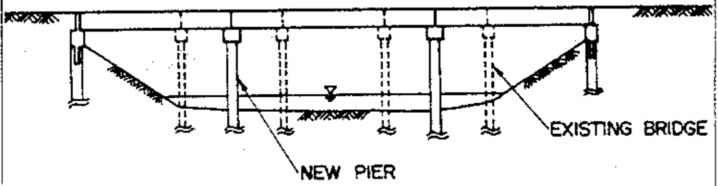
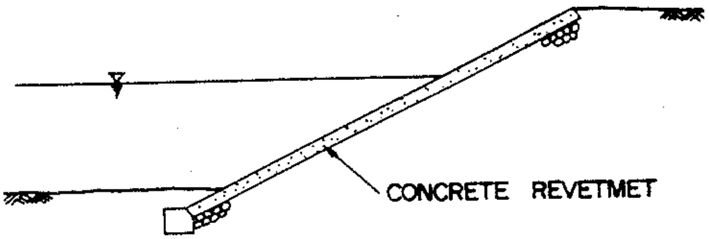
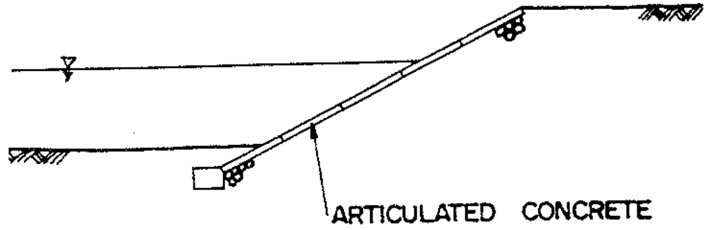
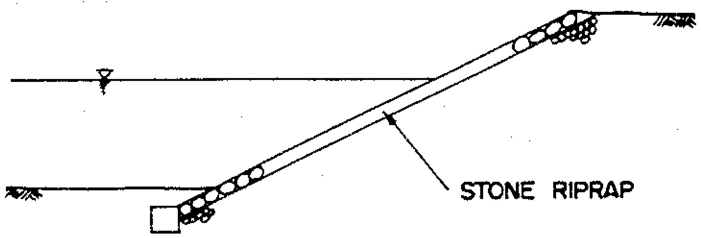
Classification	Type of Work	Functional Characteristics	Application	Illustration
(1) Improvement of discharge capacity	Auxiliary bridges / culverts	- To increase discharge capacity by adding an auxiliary bridge / culvert.	- Generally applied to a bridge in a flood plain.	
	Extension of span length	- To increase discharge capacity.	- Applicable to a short bridge.	
(2) Abutment and pier protection	Concrete revetments	- To protect an abutment fill slope from scouring.	- Usually applied to a slope gentler than 1.0 : 1.	
	Articulated concrete revetments	- To protect an abutment fill slope from scouring.	- Usually applied to a slope gentler than 1.0 : 1.	

Table 6.1.4 (3) Types of Preventive Measures for the Collapsing of Bridges

<table>
<tr><th>Classification</th><th>Type of Work</th><th>Functional Characteristics</th><th>Application</th><th>Illustration</th></tr>
<tr><td>(2) Abutment and pier protection</td><td>Stone riprap revetments (with mortar)</td><td>- To protect an abutment fill slope from scouring.</td><td>- Usually applied to a slope gentler than 1.0 : 1.</td><td>
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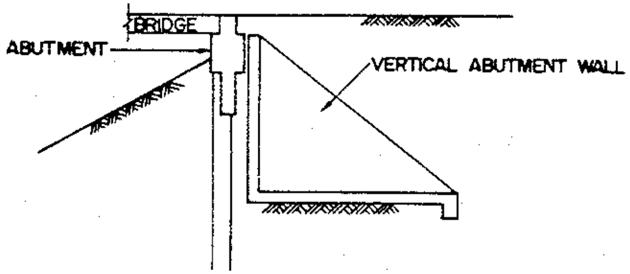
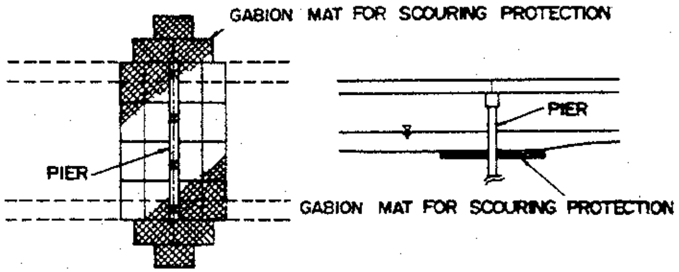
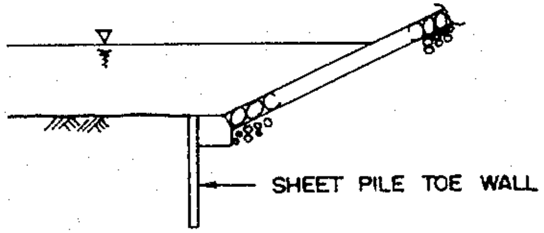
<tr><td></td><td>Vertical abutment wall</td><td>- To protect an abutment back fill from scouring.</td><td>- Effective for a pile-bent abutment.</td><td>
</td></tr>
<tr><td></td><td>Gabion foot protection</td><td>- To protect the foundation of a pier from being scoured by a river.</td><td>- All types of pier foundation.</td><td>
</td></tr>
<tr><td></td><td>Sheet-pile toe wall</td><td>- To protect the foundation of an abutment revetment from deep scouring.</td><td>- Applicable to a place with high velocity river flows.</td><td>
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</table>

Table 6.1.4 (4) Types of Preventive Measures for the Collapsing of Bridges

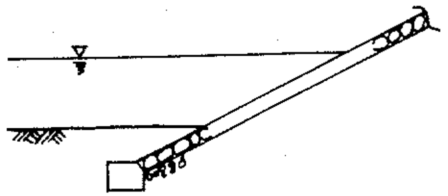
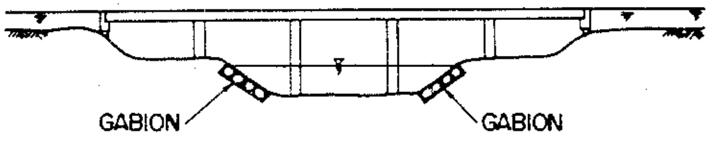
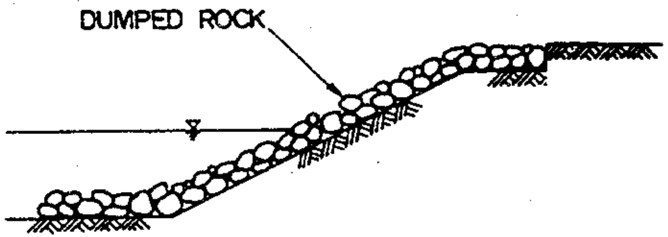
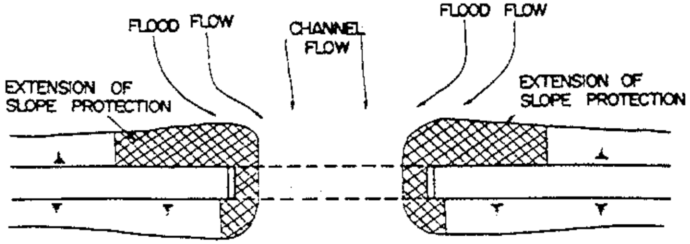
Classification	Type of Work	Functional Characteristics	Application	Illustration
(2) Abutment and pier protection	Deep embedment of bases	- To protect the foundation of an abutment revetment from deep scouring.	- Applicable to a place with high velocity river flows.	
(3) River channel stabilization	Stabilization with gabion	- To prevent the scouring of a river bank.	- Generally applied to a meandering river.	
	Stabilization with dumped rock	- To prevent the scouring of a river bank.	- Generally applied to a river prone to its channel.	
(4) Approach road protection	Protection of approach road embankment	- To prevent the scouring on the upstream side of an approach road.	- Generally applied to a bridge in a flood plain.	

Table 6.1.4 (5) Types of Preventive Measures for the Collapsing of Bridges

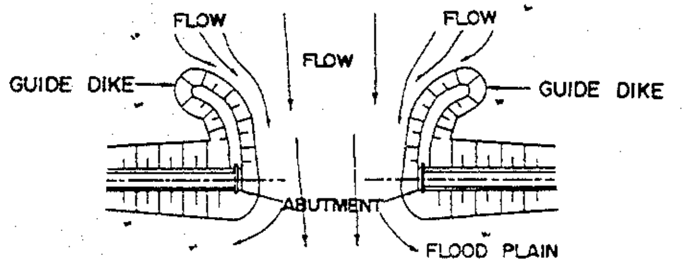
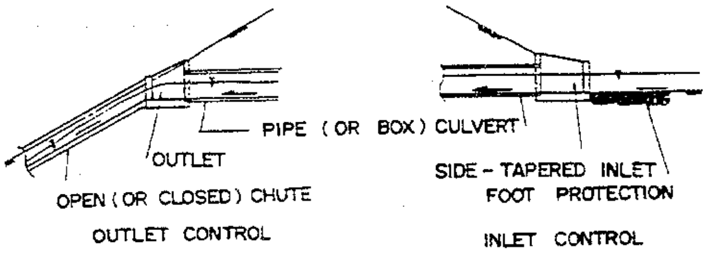
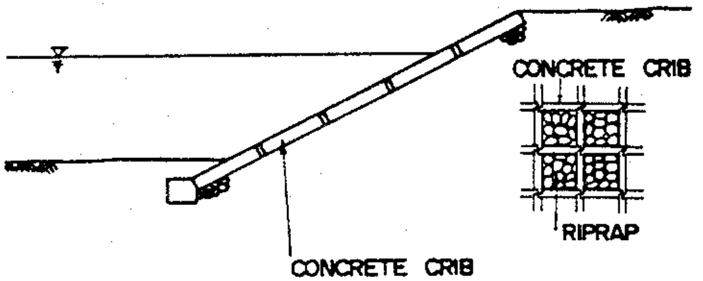
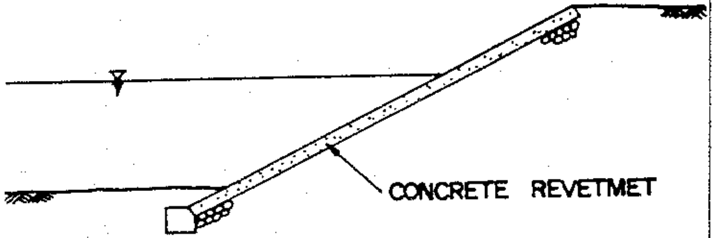
Classification	Type of Work	Functional Characteristics	Application	Illustration
(5) Training of stream	Guide dike	- To protect an abutment and / or approach road from high velocity water flows.	- Applied to a bridge in a flood plain.	
	Improvement of culvert inlet / outlet	- To prevent an approach road from being scoured by the impact of excess water not capable of being handled by a culvert.	- Applied to a culvert inlet / outlet.	
(6) Riverbank protection	Cribwork with stone riprap	- To protect a riverbank from scouring.	- Usually applied to a riverbank gentler than 1.0 : 1. - Applied to the outside bank at the bend of a river.	
	Concrete revetment	- To protect a riverbank from scouring.	- Usually applied to a riverbank gentler than 1.0 : 1. - Applied to the outside bank at the bend of a river.	

Table 6.1.4 (6) Types of Preventive Measures for the Collapsing of Bridges

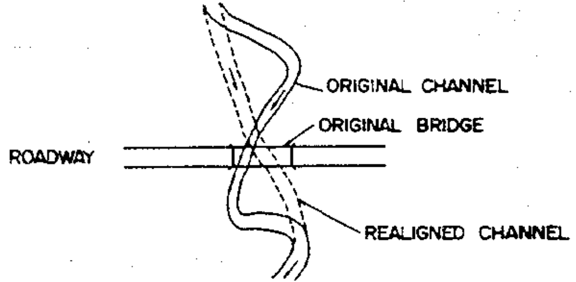
Classification	Type of Work	Functional Characteristics	Application	Illustration
(7) Realignment of river channel	Realignment	- To protect an abutment and / or approach road from the turbulence of a river flows.	- Applied to a meandering river.	

Table 6.1.5 (1) Types of Preventive Measures for the Collapsing of Embankment Road

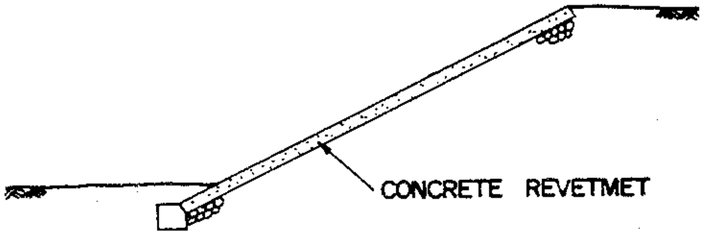
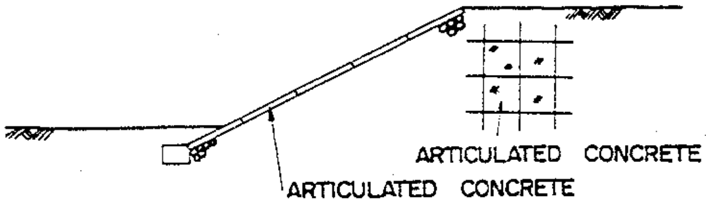
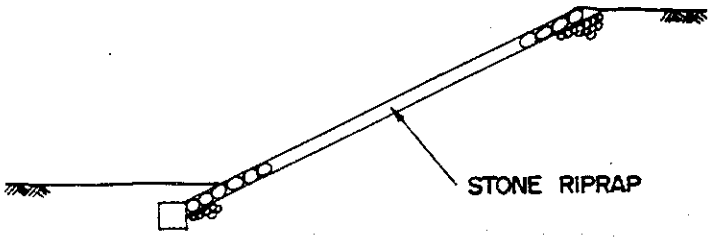
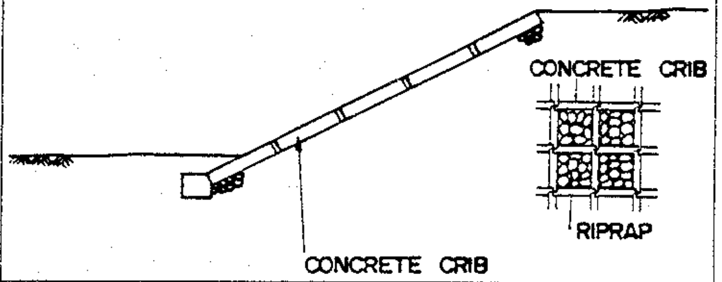
Classification	Type of Work	Functional Characteristics	Application	Illustration
(1) Protection of embankment slope	Concrete revetment	- To protect an embankment from scouring by covering it with cast-in-place concrete revetments.	- Usually applied to a slope gentler than 1.0 : 1.	
	Articulated concrete revetment	- To protect an embankment from scouring by covering it with precast concrete block.	- Usually applied to a slope gentler than 1.0 : 1.	
	Stone riprap with mortar	- To protect an embankment from scouring by covering it with stone riprap.	- Usually applied to a slope gentler than 1.0 : 1.	
	Cribwork with stone riprap	- To protect an embankment from scouring by covering it with a concrete crib with stone riprap.	- Usually applied to a slope gentler than 1.0 : 1.	

Table 6.1.5 (2) Types of Preventive Measures for the Collapsing of Embankment Road

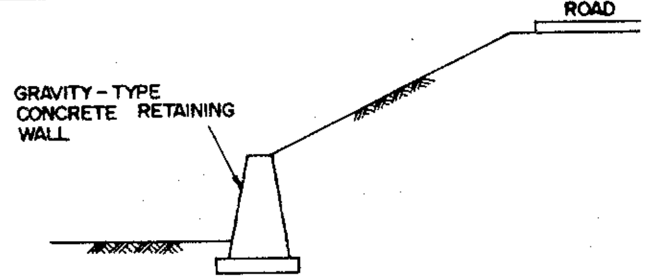
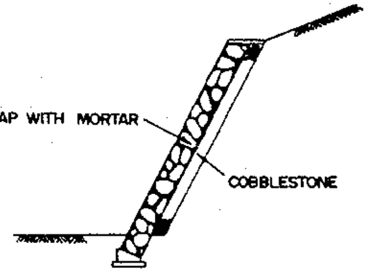
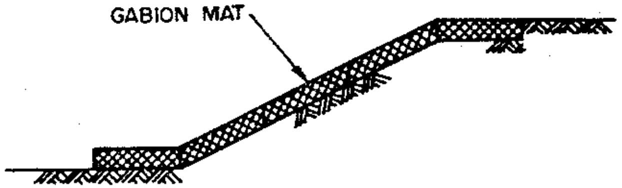
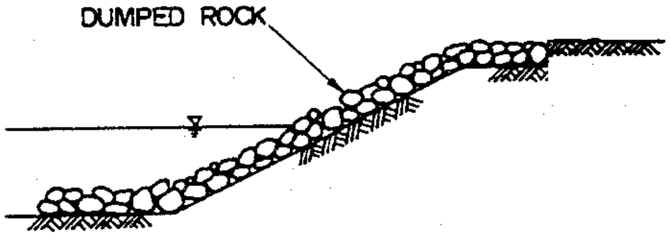
Classification	Type of Work	Functional Characteristics	Application	Illustration
(2) Protection for toe of embankment	**Gravity-type concrete retaining wall**	**- To protect an embankment by resisting earth pressure.**	**- Applicable to a wall less than 3 m high.**	
	Stone riprap retaining wall	**- To protect an embankment by resisting earth pressure.**	**- Applicable to a wall less than 5 m high.**	
	Gabion	**- To protect an embankment by resisting earth pressure.**	**- Mainly applied to an embankment slope with seepage water.**	
	Dumped rock	**- To protect a slope from scouring by high velocity water flows.**	**- Usually applied to a slope gentler than 1.5 : 1.** **- Applicable to a stream bank.**	

Table 6.1.5 (3) Types of Preventive Measures for the Collapsing of Embankment Road

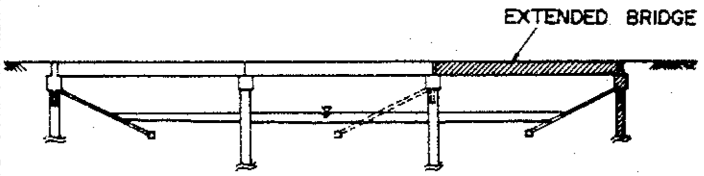
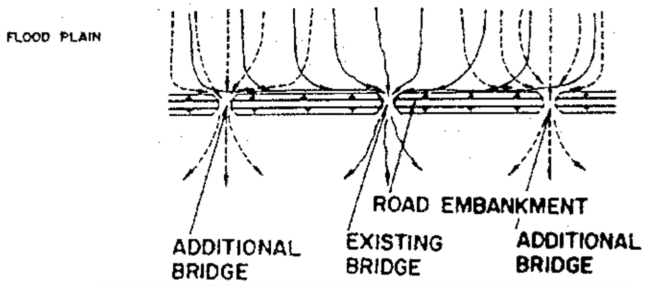
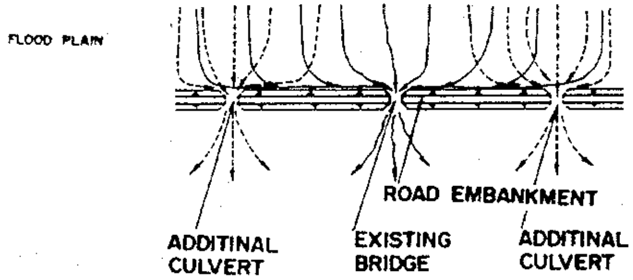
Classification	Type of Work	Functional Characteristics	Application	Illustration
(3) Improvement of drainage capacity	Extension of bridge length and / or enlargement of cross-sectional area of culvert	- To drain water runoff that crosses an embankment.	- Applicable to a bridge or culvert whose discharge capacity is insufficient.	
	Construction of additional bridges	- To drain water runoff that crosses an embankment.	- Applicable to an embankment with few drainage facilities.	
	Construction of additional culverts	- To drain water runoff that crosses an embankment.	- Applicable to an embankment with few drainage facilities.	

Table 6.1.6 Types of Preventive Measures for Road Flooding

Classification	Type of Work	Functional Characteristics	Application	Illustration
(1) Protection from submerging	Raising roadway elevation	- To protect a road surface from being submerged.	- Low embankment road in a flood plain.