3.6 Stability Survey

3.6.1 Survey Organization

A survey team should comprise the following staff:

1. Engineer : 1 person who is able to judge the disaster condition
2. Assistants : 2 persons who assist to the engineer with survey tools
3. Driver : 1 person with vehicle

3.6.2 Execution of Stability Survey

After screening the objective spots, the survey team should enter the score of each item onto the stability survey sheets, and they should measure the size of damage and sketch this on the inspection sheet. The important points to be surveyed are as follows.

- Preparation of "Past Disaster record" sheets,
- Confirmation of the location of inspection spots from maps,
- Drawing and writing the necessary contents on the "Record of inspection Spots" sheet,
- Detailed entry of each item onto the "Stability Survey" sheet,
- To check vulnerable conditions on the "Stability Survey" sheet,
- To write the score of each item on the "Stability Survey" sheet,
- To draw the site location and its characteristics on the "Figure of Survey Result" sheet, and
- To write the whole contents on the "Table of Survey Result" sheet.

The survey team should arrange the survey results of all objective spots. The responsible engineer should discuss the results with the team.

3.6.3 Survey Result of Objective Roads

1) NIC.1

1) – 1. Survey of Slopes

NIC. 1 runs through a mountainous area north of San Benito, and between Esteli and El Espino. There were 36 inspection spots found after the screening, of which 13 were rock falling and 23 were rock collapsing. These all require a stability survey.

1) - 2. Survey of Bridges

There were 22 bridges inspected for scouring of foundations. The objective bridges for inspection had the following characteristics :

- The river flow was not controlled.
- The depth of the abutment foundation was not stable.
- Scouring of the wing wall was observed.

2) NIC. 3

2) – 1. Survey of Slopes

NIC. 3 is almost wholly located within a mountainous area with cuttings and embankment slope sections. 40 inspection spots were recorded after the screening. The vulnerable items were rock falling, rock collapsing, slope slide and debris flow. There were 20 rock falling sites, 15 rock collapsing sites, 4 slope slide sites and a large scale of debris flow.

2) - 2. Survey of Bridges

There were two bridges at Los Cocos and El Guayacan, identified following the screening. A part of El Guayacan bridge foundations has sunk from scouring due to Hurricane Mitch.

3) NIC. 5

There was only one place identified for inspection after screening. The vulnerable item is rock falling, located at the cutting section of 24.6 km west of Matagalpa.

4) NIC. 15

4) – 1. Survey of Slopes

NIC. 15 runs along a narrow section between a mountainous area and river area from Las Manos, at the border, to Ocotal and runs through a hilly area to the intersection at NIC. 1 at Yalaguina. There were 18 numbers inspection spots, of which are 9 were spots of rock falling, 5 spots of rock collapsing and 4 spots of debris flow. Between Las Manos and Ocotal construction works are being carried out with the assistance of the Government of Sweden (to be completed by July 2002).

4) – 2. Survey of Bridges

The vulnerable bridge sites following screening are characterized by:

- Gradient of riverbed is very steep.
- Bridge abutments are located in river bends.
- Riverbanks are protected only by gabion mats.

There were 4 bridges identified as inspection spots after the screening.

5) NIC. 24

5) – 1. Survey of Slopes

There were 2 places for inspection spots, which were one rock falling and one rock collapsing site.

5) – 2. Survey of Bridges

There were 7 bridges identified for scouring of bridge foundations after the screening. The objective bridges for inspection are due to :

- The river flow is not controlled.
- The depth of the abutment foundation is not stable.
- Traces of scouring were observed around the piers.

6) NIC.26

6) – 1. Survey of Slopes

There were 21 inspection spots, of which 15 were the rock falling, and 6 were rock collapsing, all on the mountainous and hilly section.

6) – 2. Survey of Bridges

There were 18 inspection bridges identified after the screening. The objective bridges for inspection are due to :

- The river flow is not controlled.
- The depth of the abutment foundation is not stable.
- Traces of scouring were observed around the piers.

3.6.4 Calibration of Survey Result

1) Objectives

The stability survey was carried out by trial surveys by engineers, and it appeared that there were individual difference in the results of the survey scores. It is difficult to do comparable evaluations. When only one engineer carries out the survey, the stability evaluation of cut/ embankment slope and natural slope will depend upon the relative evaluation with conditions at other survey spots. Therefore, the scores of survey results should be compared with and be calibrated against other results.

2) Time and Method to Carry out the Calibration

a) Time to Carry out the Calibration

① At the beginning of the survey, when surveys have been completed in more than ten (10) spots along the same route (or nearby routes) with the same items of inspection, the survey results should be ordered according to the final scoring of each stability survey sheet. The score and total evaluation of each item regarding the stability survey sheet should be reviewed if necessary.

If survey spots surveyed number less than ten, then the calibration should be carried out at all the spots.

② The slope condition of each objective road should be possible to be evaluated and given a different score. Therefore, in case of every month after the survey was carried out or in case of the survey was carried out by other engineer, the final score of the stability survey should be ordered from high evaluation, which is from the survey start point to ten (10) spots. And the score and total evaluation of each item regarding the stability survey sheet should be reviewed if necessary.

③ As noted above, the score of the stability survey and the total evaluation that carried out the calibration should be also referred to other survey spots. Figure 3.6.1 shows the inspection flow and the calibration time.

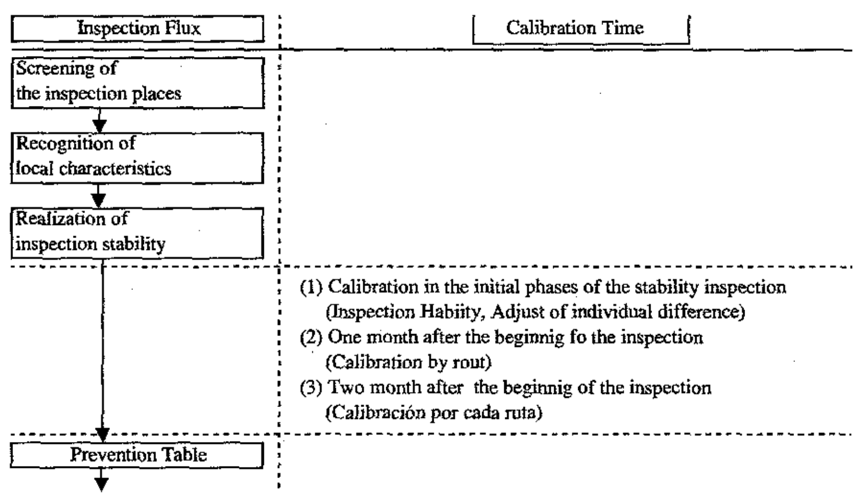


Figure 3.6.1 Inspection Flux and Calibration Time

b) Calibration Method

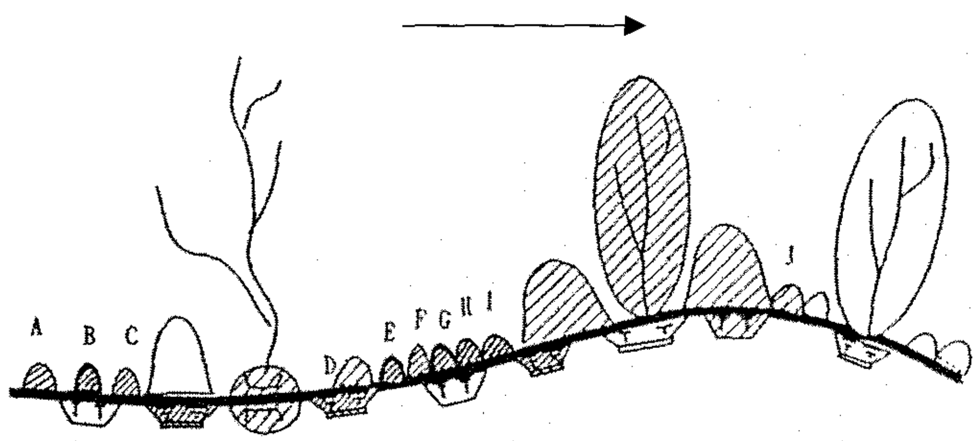
In the initial stage of the execution of the stability survey, when more than ten (10) survey spots have finished, as shown in Figure 3.6.2, the results will be ordered as shown in Table 3.6.1.

Table 3.6.1 Calibration of Initial Stages of Stability Survey (Example)

Order	1	2	3	4	5	6	7	8	9	10
Places of Inspection (Score)	A (80)	F (80)	G (60)	B (55)	D (50)	C (50)	H (40)	I (30)	J (20)	E (20)
Calibration Ejecution	Ídem	Ídem	Ídem	B (70)	Ídem	C (60)	Ídem	Ídem	J (40)	Ídem

Commentary	As a result of the calibration, doubt spots are B, C, J. These spots was reviewed and changed the scoring and the order such as below.

Order	1	2	3	4	5	6	7	8	9	10
Places of Inspection (Score)	A (80)	F (80)	B (70)	G (60)	C (60)	D (50)	H (40)	J (40)	I (30)	E (20)



Carried out of the stability survey →

← Review of the stability survey results (Calibration)

Figure 3.6.2 Calibration of the results of the Stability Survey

After the stability survey has been carried out, the calibration should be re-done every month by route and the inspection score should be checked against the objective of the evaluation as shown in Table 3.6.2.

Table 3.6.2 Calibration of Each Route (Example)

Order	1	2	3	4	5	6	7	8	9	10	Note
Route A: Place of Inspection (Score)	A (80)	F (80)	B (70)	G (60)	C (60)	D (50)	H (40)	J (40)	I (30)	E (20)	
Route B: Place of Inspection (Score) Review	e (90)	h (90)	a (70) ↓ (80)	b (70) ↓ (80)	I (70)	c (60)	j (50)	d (30) ↓ (40)	f (30)	g (20)	In contrast of Route A, the evaluation of theRoute B is a little lower.
Route C: ;	;	;	;	;	;	;	;	;	;	;	

C) In the Case of the Stability Survey being carried out by Two (2) or more Engineers

Where stability surveys are carried out by more than two (2) engineers, the score of each engineer should be compared and be reviewed in terms of a) above if necessary.

3) Survey Items to be carried out in the calibration

There are two key survey items to be considered in the calibration. These items are the dispersion of score at the many following disaster spots:

- Rock-falls and collapsing
- Rock Collapsing

3.7 Disaster Potential and Critical Spots

3.7.1 General

Based on Sections 3.5 "Assessment Items/ Scores of Disaster Potential/ Critical Spots" and 3.6 "Stability Survey", the disaster potential spots and the disaster critical spots are identified by scores of 60 points / 70 points or more.

The identified spots of the objective roads are shown in Table 3.7.1 through Table 3.7.10.

3.7.2 NIC. 1

1) Vulnerable Slopes

Table 3.7.1 Identified Disaster potential/ Critical Spots of Slopes on NIC. 1

No	Distance from Managua(km)	Serial No.	Type of disaster	Length (m)	Height (m)	Angle (degree)	Score	Disaster Potential Spot	Disaster Critical Spot
1	50.0	30	R.F.	230	64	43°	61	*	
2	52.4		R.F.				59		
3	54.0		R.C.				54		
4	55.7		R.F.				57		
5	57.4		R.C.				57		
6	59.3		R.C.				59		
7	60.5		R.C.				45		
8	60.9	29	R.F.	890	24	56°	70	*	*
9	71.6		R.C.				42		
10	73.2	28	R.F.	350	8	40°	78	*	*
11	84.0		R.C.				50		
12	129.1		R.C.				42		
13	142.7	27	R.C.	370	50	63°	68	*	
14	157.0	26	R.C.	110	12	63°	68	*	
15	167.2	25	R.C.	280	8	66°	55		
16	168.4	24	R.F.	600	30	66°	84	*	*
17	168.6	23	R.C.	280	30	70°	72	*	*
18	169.0	22	R.F.	120	50	70°	69	*	
19	169.8	20	R.C.	200	28	60°	72	*	*
20	170.7	19	R.C.	440	64	60°	72	*	*
21	171.3	17	R.C.	460	30	63°	78	*	*
22	173.9	16	R.F.	500	30	43°	67	*	
23	175.0	15	R.C.	130	15	60°	76	*	*
24	176.2	12	R.C.	360	40	60°	74	*	*
25	178.7	11	R.F.	240	28	60°	76	*	*
26	183.5		R.F.				39		
27	184.3		R.C.				47		
28	187.3	10	R.C.	220	10	60°	73	*	*
29	195.8	8	R.C.	120	8	60°	68	*	
30	204.7	7	R.C.	120	16	63°	73	*	*
31	206.4		R.C.				56		
32	214.7	5	R.F.	110	12	43°	70	*	*
33	231.9	4	R.C.	400	50	60°	66	*	
34	232.5	3	R.C.	200	50	60°	75	*	*
35	233.7	2	R.F.	230	28	50°	73	*	*
36	235.6	1	R.F.	145	9	80°	73	*	*
Total								23	16

		Potential	Critical
R.F.	:Rock Fall	: 10	: 7
R.C.	:Rock Collapsing	: 13	: 9
S.S.	:Slop slide	: 0	: 0
D.F.	:Debris Flow	: 0	: 0

2) Vulnerable Bridges

Table 3.7.2 Identified Disaster Potential/ Critical Spots of Bridges on NIC. 1

No.	Station (km)	Bridge Name	Length (m)	Span Length (m)	Year	Score		Disaster Spots	
						Abutment	Pier	Potential	Critical
1	35+190	Los Novios	6.70	5.60	1938	50	--		
2	39+868	La Estatua	8.70	7.50	1938	50	--		
3	40+960	Qda. Honda	7.00	5.00	1938	45	--		
4	42+433	*El Matadero*	14.30	13.50	1938	35	--		
5	84+430	El Venado	72.50	19+29+19	1973	30	25		
6	87+437	Qda. La Chingastosa	21.00	19.50	1973	30	--		
7	107+992	Zajón Negro	21.70	20.70	1957	20	--		
8	108+980	Río Viejo	99.00	26.8+(3)22.6	1953	55	55		
9	113+190	Zanjón Blanco	29.30	9+9+9	1956	75	90	*	*
10	125+220	La Trinidad	63.80	18.7+23.4+18.7	1957	70	60	*	
11	135+640	San Nicolas	18.60	17.60	1957	100	--	*	*
12	*135+860*	*El Hatillo*	*15.50*	14.50	1957	70	--	*	
13	150+330	Las Chanillas (R.Esteli)	62.00	17.8+24+17.8	1958	70	90	*	*
14	150+925	El Rastro	19.00	18.00	1957	30	--		
15	151+850	San Ramón	15.50	13.80	1957	100	--	*	*
16	158+650	La Sirena	54.00	14.4+21.8+14.4	1956	60	65		
17	159+470	Río El Tular	56.00	14.5+20.8+14.5*	1956	80	85	*	
18	184+670	Condega (Río Pire)	63.60	18.6+23.4+18.6	1954	70	60	*	
19	191+680	Ducuali(Río Pueblo Nuevo)*	82.00	19.3+39.3+19.3	2000	45	50	*	
20	*192+033*	*Qda. Ducuali*	*7.45*	*6.50*	1954	60	--		
21	226+890	Río Inali	64.0	19+24+19	1954	90	100	*	*
22	233+245	RíoTapascali	109.0	17.8+21.3+26.7+21.3+17.8	1954	75	90	*	*
			Total					*11*	*6*

*The Ducuali Bridge length is less than the river width.

3.7.3 NIC. 3

1) Vulnerable Slopes

Table 3.7.3 Identified Disaster potential/ Critical Spots of Slopes on NIC. 3

No	Distance from Managua(km)	Serial No.	Type of disaster	Length (m)	Height (m)	Angle (degree)	Score	Disaster Potential Spot	Disaster Critical Spot
1	3.9	42	R.C.	130	13	55°	74	*	*
2	5.4	41	R.C.	60	15		57		
3	6.9	40	R.C.	170	20	46°	72	*	*
4	7.4	37	R.C.	90	20	48°	80	*	*
5	7.8	36	R.F.	93	23	46°	61	*	
6	8.3	35	R.C.	60	15		74	*	
7	9.3	34	R.C.	90	20+20		42		
8	9.6	33	R.C.	30	7+20		42		
9	22.1	32	R.C.	150	14	76°	74	*	*
10	23.5	31	R.C.	170	13	55°	69	*	
11	24.8	30	R.C.	55	12	53°	64	*	
12	26	29	R.C.	220	20	51°	69	*	
13	26.8	28	R.F.	50	12+20		54		
14	27.3	27	R.F.	80	7+20		54		
15	28.8	26	R.C.	60	10		59		
16	30.8	25	R.F.	140	23	40°	62	*	
17	32.7	24	R.C.	110	14	57°	70	*	*
18	32.9	23	S.S.	180	26	40°	73	*	*
19	33.8	22	R.F.	80	15	37°	64	*	
20	34	21	R.F.	50	15		53		
21	34.4	20	R.F.	68	12	43°	69	*	
22	34.8	19	R.F.	55	15	48°	67	*	
23	35	18	R.F.	125	21	49°	61	*	
24	35.2	17	D.F.	150	30	43°	83	*	*
25	35.9	16	S.S.	140	26	52°	71	*	*
26	38.9	15	S.S.	192	30	34°	90	*	*
27	39.4	14	S.S.	45	9	62°	90	*	*
28	39.8	13	R.F.	90	30		58		
29	40	12	R.C.	180	28	67°	81	*	*
30	40.7	11	R.F.	70	25		50		
31	45.9	10	R.F.	50	20		56		
32	49.5	9	R.F.	20	15		46		
33	51.2	8	R.F.	60	12	56°	57		
34	51.6	7	R.F.	20	15		56		
35	51.9	6	R.F.	40	15		59		
36	54.9	5	R.F.	90	16	50°	63	*	
37	55.3	4	R.F.	86	20	64°	63	*	
38	55.6	3	R.F.	60	15		56		
39	57.1	2	R.F.	150	10		49		
40	57.5	1	R.C.	90	15		52		
Total								23	11

		Potential	Critical
R.F.	:Rock Fall	: 8	: 0
R.C.	:Rock Collapsing	: 10	: 6
S.S.	:Slop slide	: 4	: 4
D.F.	:Debris Flow	: 1	: 1

2) Vulnerable Bridges

Table 3.7.4 Identified Disaster Potential/ Critical Spots of Bridges on NIC. 3

No.	Station (km)	Bridge Name	Length (m)	Span Length (m)	Year	Score		Disaster Spots	
						Abutment	Pier	Potential	Critical
1	119+050	El Guayacan	17.5	3.3	1945	100	100	*	*
2	122+053	Los Cocos	7.0	3.3	1945	70	--	*	
		Total						2	1

3.7.4 NIC. 5

Table 3.7.5 Identified Disaster potential/ Critical Spots of Slopes on NIC. 5

No	Distance from Matagalpa (km)	Serial No.	Type of disaster	Length (m)	Height (m)	Angle (degree)	Score	Disaster Potential Spot	Disaster Critical Spot
1	24.6	1	R.F.	200	87	50°	76	*	*
				Total				1	1

		Potential	Critical
R.F.	:Rock Fall	: 1	: 1
R.C.	:Rock Collapsing	: 0	: 0
S.S.	:Slop slide	: 0	: 0
D.F.	:Debris Flow	: 0	: 0

3.7.5 NIC. 15

Table 3.7.6 Identified Disaster potential/ Critical Spots of Slopes on NIC. 15

No	Distance from Managua(km)	Serial No.	Type of disaster	Length (m)	Height (m)	Angle (degree)	Score	Disaster Potential Spot	Disaster Critical Spot
1	9.9	1	D.F.	45	7		70	*	*
2	11.1	2	D.F.	65	8		70	*	*
3	11.2	3	R.F.	135	50	44°	67	*	
4	11.5	4	R.F.	80	24	45°	65	*	
5	11.7	5	D.F.	70	3		70	*	*
6	13.6	6	D.F.	100	1		70	*	*
7	21.1						50		
8	26.2						58		
9	26.6						50		
10	27.6						49		
11	28.0						46		
12	28.8						43		
13	29.5						56		
14	31.3						56		
15	32.7						43		
16	34.9						51		
17	41.7						54		
18	42.1						48		
				Total				6	4

		Potential	Critical
R.F.	:Rock Fall	: 2	: 0
R.C.	:Rock Collapsing	: 0	: 0
S.S.	:Slop slide	: 0	: 0
D.F.	:Debris Flow	: 4	: 4

3.7.6 NIC. 24

1) Vulnerable Slopes

Table 3.7.7 Identified Disaster potential/ Critical Spots of Slopes on NIC. 24

No	Distance from Managua(km)	Serial No.	Type of disaster	Length (m)	Height (m)	Angle (degree)	Score	Disaster Potential Spot	Disaster Critical Spot
1	17.5	1	R.F.	190	21	44°	55		
2	28.5	2	R.C.	140	16	55°	63	*	
Total								1	0

		Potential	Critical
R.F.	:Rock Fall	: 1	: 0
R.C.	:Rock Collapsing	: 1	: 0
S.S.	:Slop slide	: 0	: 0
D.F.	:Debris Flow	: 0	: 0

2) Vulnerable Bridges

Table 3.7.8 Identified Disaster potential/ Critical Spots of Bridges on NIC. 24

No.	Station (km)	Bridge Name	Length (m)	Span Length (m)	Year	Score		Disaster Spots	
						Abutment	Pier	Potential	Critical
1	132+055	El Hogar (La Mora)	5.6	4.5		20	--		
2	143+000	San Ramón1	20.5	20.0	2001	70	55	*	
3	183+988	Chocolatero	8.6	7.7		50	--		
4	189+111	La Culebra	14.4	13.0		70	--	*	
5	197+929	Río Negro	64.8	29+2(30)+29	2001	50	40		
6	198+675	San Antonio	10.3	9.0	1968	35	--		
7	201+520	Tecomapa	16.3	15.0	1968	40	--		
Total								2	0

3.7.7 NIC. 26

1) Vulnerable Slopes

Table 3.7.9 Identified Disaster potential/ Critical Spots of Slopes on NIC. 26

No	Distance from Managua(km)	Serial No.	Type of disaster	Length (m)	Height (m)	Angle (degree)	Score	Disaster Potential Spot	Disaster Critical Spot
1	9.0	1	R.F.	105	18	43°	71	*	*
2	12.7	2	R.F.	235	13	62°	70	*	*
3	19.9	3	R.F.	160	20	53°	71	*	*
4	20.9	4	R.F.	115	19	65°	72	*	*
5	22.7	5	R.F.				64	*	
6	24.7	6	R.F.	160	16	55°	70	*	*
7	26.6	7	R.F.				37		
8	28.5	8	R.F.	65	12	50°	67	*	
9	29.1	9	R.F.				59		
10	29.3	10	R.F.	77	19	41°	76	*	*
11	29.8	11	R.C.	110	13	58°	73	*	*
12	30.0	12	R.C.	100	16	66°	68	*	
13	33.6	13	R.F.	60	11	58°	72	*	*
14	34.0	14	R.C.	300	16	65°	80	*	*
15	34.2	15	R.F.	150	52	54°	85	*	*
16	37.0	16	R.C.	90	24	76°	86	*	*
17	39.1	17	R.F.				41		
18	39.8	18	R.F.				40		
19	40.3	19	R.F.				50		
20	40.8	20	R.F.				53		
21	45.5	21	R.C.	280	32	52°	71	*	*
Total								15	12

		Potential	Critical
R.F.	:Rock Fall	: 10	: 8
R.C.	:Rock Collapsing	: 5	: 4
S.S.	:Slop slide	: 0	: 0
D.F.	:Debris Flow	: 0	: 0

2) Vulnerable Bridges

Table 3.7.10 Identified Disaster potential/ Critical Spots of Bridges on NIC. 26

No.	Station (km)	Bridge Name	Length (m)	Span Length (m)	Year	Score		Disaster Spots	
						Abutment	Pier	Potential	Critical
1	104+182	La Cotorra	8.6	7.0	1963	40	--		
2	104+657	Figueroa	9.4	5.5	1963	40	--		
3	105+300	Santa Ana	8.2	5.5	1963	55	--		
4	106+020	Los Pedrones	6.4	3.7	1963	60	--		
5	106+687	Quimera	17.7	5+5+5	1964	65	65		
6	107+533	Solís	7.2	4.6	1963	100	--	*	*
7	108+154	Papalón	5.1	3.5	1963	90	--	*	*
8	108+784	La Higuera	9.5	5.8	1963	55	--		
9	114+044	San Jacinto	7.6	6.9	1964	50	--		
10	119+963	La Milagrosa	8.6	7.0	1964	60	--		
11	125+674	Santa Amalia (Malpaisillo)	16.5	15.4	1964	30	--		
12	145+617	El Caimito	31.8	10+10.2+10	1966	55	45		
13	148+051	Tionoste	19	18.0	1966	30	--		
14	156+785	San Juan de Dios	17.9	7.5+7.5	1965	90	70	*	*
15	164+125	El Jicaral	130	4(32.5)	2001	70	55	*	
16	169+544	Las Pilas	8.5	8.0	1966	70	--	*	
17	170+952	La Banderita	31.6	6.6+15.4+6.6	1966	100	65	*	*
18	190+265	La Manga No. 1	10.6	9.3	1966	55	--		
Total								6	4

3.7.8 Identification of Disaster Critical Spots

The total number of critical spots was 55 consisting of 15 spots (27%) of Rock-falls, 20 spots (36%) of Rock collapsing, 4 spots (7%) of Slope slide, 5 spots (9%) of Debris flow and 11 spots (20%) of Bridge scouring, on all the objective roads as shown in Table 3.7.11.

Table 3.7.11 Total Number of Disaster Critical Spots

Road Name	Disaster Items					No. of Critical Spots	Total Distance (km)	No. of critical spots per km
	Rock-Falling	Rock-Collapsing	Slope Slide	Debris Flow	Bridge Scouring			
NIC. 1	7	9	0	0	6	22 (40%)	237	0.09
NIC. 3	0	6	4	1	1	12 (22%)	60	0.20
NIC. 5	1	0	0	0	0	1 (2%)	48	0.02
NIC. 15	0	0	0	4	0	4 (7%)	43	0.09
NIC. 24	0	0	0	0	0	0 (0%)	77	0
NIC. 26	7	5	0	0	4	16 (29%)	99	0.16
Total	15 (27.3%)	20 (36.4%)	4 (7.2%)	5 (9.1%)	11 (20.0%)	55 (100%)	564	0.10

The number of critical spots on each objective road is 22 spots (40 %) on NIC. 1, 12 spots (22%) on NIC. 3, 1 spot (2 %) on NIC. 5, 4 spots (7 %) on NIC. 5 and 16 spots (29 %) on NIC. 26.

The probability of risk of the critical spots can be expressed as the number of potential road disasters per kilometer. The average probability of risk is 0.10 spots/km. The highest is 0.20 spots/km on NIC. 3, with the second being 0.16 spots/km on NIC. 26. On the other roads risk is lower with 0.09 spots/km on NIC. 1 and NIC. 15, and 0.02 spots/km on NIC. 5.

The highest risk of disaster is from rock-collapsing, the second from the rock-falling, the third from scouring of bridge foundations, followed by debris flow and slope slide.

CHAPTER 4

COUNTERMEASURES
/ROUGH COST ESTIMATE
TO DISASTER CRITICAL SPOTS

CHAPTER 4 COUNTERMEASURES / ROUGH COST ESTIMATION TO DISASTER CRITICAL SPOTS

4.1 General

The stability survey score of the disaster critical spots is different individually with the disaster items, the disaster situation, the disaster scales, the disaster frequency and so on. Therefore, the countermeasures against roads disaster prevention should be studied in consideration of the natural condition, the environmental one and the construction materials/ equipments in Nicaragua country and the MTI maintenance budgets.

4.2 Objectives

4.2.1 Views of Countermeasures

The objectives and the views of countermeasures for road disaster are the following items.

- To prevent the occurrence of unexpected disaster,
- To pass smoothly without blocking a road section to traffic and people,
- To keep property of public and private, and
- To decrease maintenance and rehabilitation cost for road.

4.2.2 Definition of Countermeasures

As described in the above-mentioned Section 4.1, each disaster critical spot is a various situation for stability. Countermeasures to the disaster critical spots are divided into the following three categories in consideration of disaster characteristics.

- Permanent Countermeasures,
- Temporary Countermeasures, and
- Emergency Countermeasures.

1. Permanent Countermeasures

Permanent countermeasures are defined as the following items.

- The lifetime of countermeasures should be least twenty (20) years during the maintenance work.
- An adequate budget for permanent countermeasures should be safeguarded at all times.

2. Temporary Countermeasures

Temporary Countermeasures are defined as the following items.

- The lifetime of countermeasures should be at least ten (10) years during the maintenance work.

3. Emergency Countermeasures

Emergency countermeasures are defined as the following items

- It means that a serious and dangerous spot must be improved immediately.
- The lifetime of countermeasures should be until the next rainy season or less than a half year.
- It is necessary to decide upon the implementation of temporary countermeasures or permanent ones during the lifetime of the emergency countermeasures.

4.3 Basic Policy of Countermeasures

4.3.1 Basic Policy

The basic policies of countermeasures are set in consideration of the following items.

- Almost materials for construction are produced from Nicaragua own country.
- Special materials for construction are also possible to be imported easily from the neighbor country.
- Construction cost is relatively cheap.
- Improvement of disaster critical spots needs not only materials but also the techniques of labors, workers and engineers.

4.3.2 Procurement of Construction Materials/ Equipments

Construction materials and Equipments are possible to procure in Nicaragua and neighbor countries as shown in Table 4.3.1 and 4.3.2. Besides many types of countermeasures are possible to apply in Nicaragua as shown in Table 4.3.3.

Table 4.3.1 Procurement of Construction Materials

Items	Nicaragua	Neighbor Country	Remarks
Portoland cement	○		
Coarse aggregate	○		
Fine aggregate	○		
Plywood panel	○		
Steel form		○	
Reinforcing bar		○	
Admixture		○	
PC bar		○	

Note: ○; Possible for procurement

Table 4.3.2 Procurement of Construction Equipments

Items	Capacity	Nicaragua	Neighbor Country	Remarks
Bulldozer	15t	○		
Back hoe	0.6m^3	○		
Tire roller	10t	○		
Road roller	10t	○		
Vibrating roller	10t	○		
Dump truck	11t	○		
Truck	10t	○		
Welder	300A	○		
Truck crane	20t	○		
Truck crane	45t		○	
Trailer	20t	○		
Hydraulic	1300kg		○	
Truck mixer	4.5 m^3		○	
Jumbo breaker	1300kg		○	
Compressor	5 m^3/min		○	
Generator	25kvA-150kvA		○	

Note: ○; Possible for procurement

Table 4.3.3 Type of Countermeasures and Construction Records in Nicaragua

Classification	Countermeasure Type	Construction Record	Construction Possibility
(1) Earth Work	Removal	○	--
	Recutting	○	--
	Rock splitting	○	--
	Embankment	○	--
(2) Vegetation	Hydroseeding	×	□
	Vegetation	○	--
(3) Surface Drainage	Crest ditch	○	--
	Berm ditch	○	--
	Toe ditch	○	--
(4) Structure	Stone pitching	○	--
	Shotcrete	×	□
	Sprayed concrete crib	×	△
	Gabion Wall	○	--
	Stone masonry wall	○	--
	Gravity-type retaining wall	○	--
	T-shaped retaining wall	○	--
	Pilling	○	--
(5) Protection	Prevention net	×	△
	Prevention fence	×	□
	Barrier with concrete wall	×	□
	Rock bolt	×	□
	Rock shed	○	--
	Concrete dam	○	--
(6)Bridge protection	Concrete revetment	○	--
	Stone riprap	○	--
	Gabion mat for pier	○	--
	Dumped rock	○	--

Note: ○; There are results. ×; Results none

--; There are results. □; Possible

△; It is necessary to advice technically for the materials and equipments.

4.4 Design Standard

The gradient of cut and embankment slope is adopted NIC.2000 in Nicaragua. However After inspection survey in this Study, its gradient has been adopted as shown in each tables.

4.4.1 Embankment Slope

Embankment slope is decided by traffic volume and embankment height in Nicaragua. Gentle slope in consideration of the roadside land use is applied when embankment height is less than 1.2m. A recommendable slope standard is shown in Table 4.4.1.

Table 4.4.1 Recommendable Embankment Slope Standard

Functional Classification			Miner Collector	Major Collector	Miner Arterial	Principal Arterial	Special Arterial
Number of Lane			2	2	2	2	4
Future Average Daily Traffic (vpd)			-400	400-1,800	1,800-3,000	-3,000	Over 3,000
Side-slope	On Fill	H < 1.2 m	3 : 1 (2 : 1)	3 : 1 (2 : 1)	4 : 1 (3 : 1)	4 : 1 (3 : 1)	4 : 1 (3 : 1)
		H > 1.2 m	1 1/2 : 1 (1 1/2 : 1)	1 1/2 : 1 (1 1/2 : 1)	2 : 1 (1 1/2 : 1)	2 : 1 (1 1/2 : 1)	2 : 1 (1 1/2 : 1)

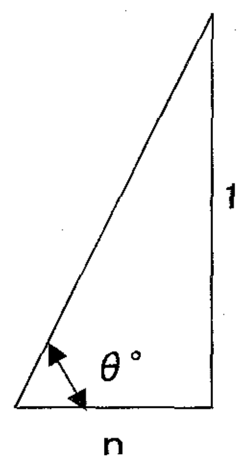
Figures in brackets are existing values in Nicaragua.

4.4.2 Cut Slope

The standard of cut slope in Nicaraguan is decided by geological sound and traffic volume. Geology is being classified in four types of the sound rock, unknown soil, well compacted soil and not well compacted soil, it isn't being decided from the detailed rock kind, geology and physics character. A recommendable cut slope standard is shown in Table 4.4.2.

Table 4.4.2 Recommendable Cut Slope Standard

Classification		Height of cut (m)	Degree of Cut θ(°)	1/tanθ	n	:	1
hard rock	I B	10 ≧ H	80	0.1763	0.2	:	1
		10 < H ≦ 20	80	0.1763	0.2	:	1
		20 < H ≦ 30	60	0.5774	0.6	:	1
		H > 30	60	0.5774	0.6	:	1
soft rock	II B	10 ≧ H	65	0.4663	0.5	:	1
		10 < H ≦ 20	65	0.4663	0.5	:	1
		20 < H ≦ 30	55	0.7002	0.8	:	1
		H > 30	55	0.7002	0.8	:	1
	I A	10 ≧ H	60	0.5774	0.6	:	1
		10 < H ≦ 20	60	0.5774	0.6	:	1
		20 < H ≦ 30	50	0.8391	1	:	1
		H > 30	50	0.8391	1	:	1
	II A	10 ≧ H	55	0.7002	0.8	:	1
		10 < H ≦ 20	55	0.7002	0.8	:	1
		20 < H ≦ 30	45	1.0000	1	:	1
		H > 30	45	1.0000	1	:	1
soil/sand	III	10 ≧ H	45	1.0000	1	:	1
		10 < H ≦ 20	40	1.1918	1.2	:	1
		20 < H ≦ 30	35	1.4281	1.5	:	1
		H > 30	30	1.7321	1.8	:	1



4.5 Classification of the Countermeasures

4.5.1 Applicable Countermeasures

The applicable countermeasures are shown in Table 4.5.1 against slope failures and shown in Table 4.5.2 against bridge foundation scouring.

Table 4.5.1 Applicable Countermeasures against Slope Failures

Classification	Type of Work	Type of Slope Failure											
		Rock-fall/ Collapsing			Rock collapsing			Slope Slide			Debris Flow		
		E	T	P	E	T	P	E	T	P	E	T	P
(1) Earth Work	Removal	○	○	○	○	○	○	○	○	○	○	○	○
	Recutting	○	○	○	○	○	○	○	○	○	○	○	○
	Rock splitting	○	○	○	○	○	○	×	×	×	○	○	○
	Embankment	○	○	○	×	×	×	○	○	○	△	△	×
(2) Vegetation	Hydroseeding	○	○	○	△	△	△	○	○	○	○	○	○
	Vegetation	○	○	○	×	×	×	○	○	○	○	○	○
(3) Surface Drainage	Crest ditch	○	○	○	△	△	○	○	○	○	×	×	×
	Berm ditch	△	○	○	△	○	○	△	○	○	×	×	×
	Toe ditch	△	○	○	△	○	○	△	○	○	×	×	×
(4) Structure	Stone pitching	○	○	△	×	×	×	○	○	△	×	×	×
	Shotcrete	△	○	○	△	○	○	△	△	△	△	○	○
	Sprayed concrete crib	×	△	○	×	△	○	×	△	○	×	△	○
	Gabion Wall	○	○	△	○	○	△	○	○	△	○	○	△
	Stone masonry wall	△	○	○	△	○	○	△	○	○	△	△	△
	Gravity-type retaining	△	○	○	△	○	○	△	○	○	△	△	△
	T-shaped retaining wall	×	△	○	×	△	○	×	△	○	×	△	△
	Pilling	×	×	×	×	×	×	△	○	○	×	×	×
(5) Protection	Prevention net	△	△	×	△	○	○	×	×	×	×	×	×
	Prevention fence	×	△	○	△	○	○	×	×	×	×	×	×
	Barrier with concrete	×	△	○	△	○	○	×	×	×	×	×	×
	Rock bolt	△	×	×	○	○	○	×	×	×	×	×	×
	Rock shed	×	×	△	×	△	○	×	×	×	×	△	○
	Concrete dam	×	×	×	×	×	×	×	×	×	×	○	○

Note: E; Emergency Countermeasures, T; Temporary Countermeasure
P; Permanent Countermeasure
○; Most Appropriate, △; Applicable, ×; Not Applicable

Table 4.5.2 Applicable Countermeasures against Bridge Foundation Scouring

Classification	Type of work	Abutment			Pier		
		E	T	P	E	T	M
Bridge protection	Concrete revetment	×	○	○	×	○	○
	Stone riprap	△	○	○	○	○	○
	Gabion mat for pier	×	×	×	○	○	△
	Dumped rock	○	×	×	○	×	×

Note: E; Emergency Countermeasures, T; Temporary Countermeasure

P; Permanent Countermeasure

○; Most Appropriate, △; Applicable, ×; Not Applicable

4.5.2 Rock-falling, Collapsing

1) Emergency Countermeasures

A selection procedure for emergency countermeasures in the case of rock-falling/collapsing is shown in Figure 4.5.1.

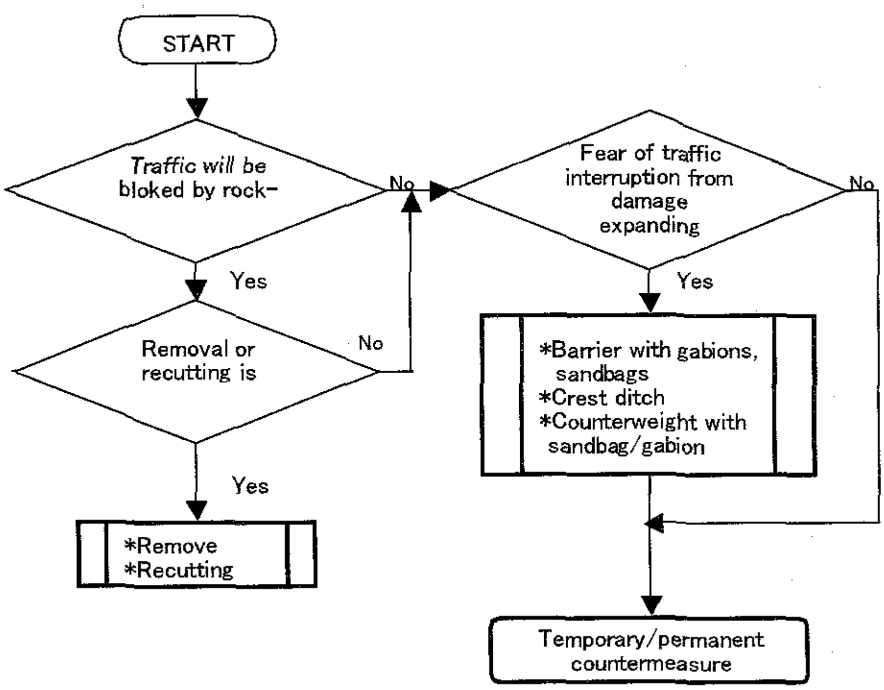


Figure 4.5.1 Selection of Emergency Countermeasure in Case of Rock-fall/Collapsing

2) Temporary/Permanent Countermeasures

The flow charts in Figure 4.5.2 and Figure 4.5.3 explain the selection procedure for a temporary and permanent countermeasure.

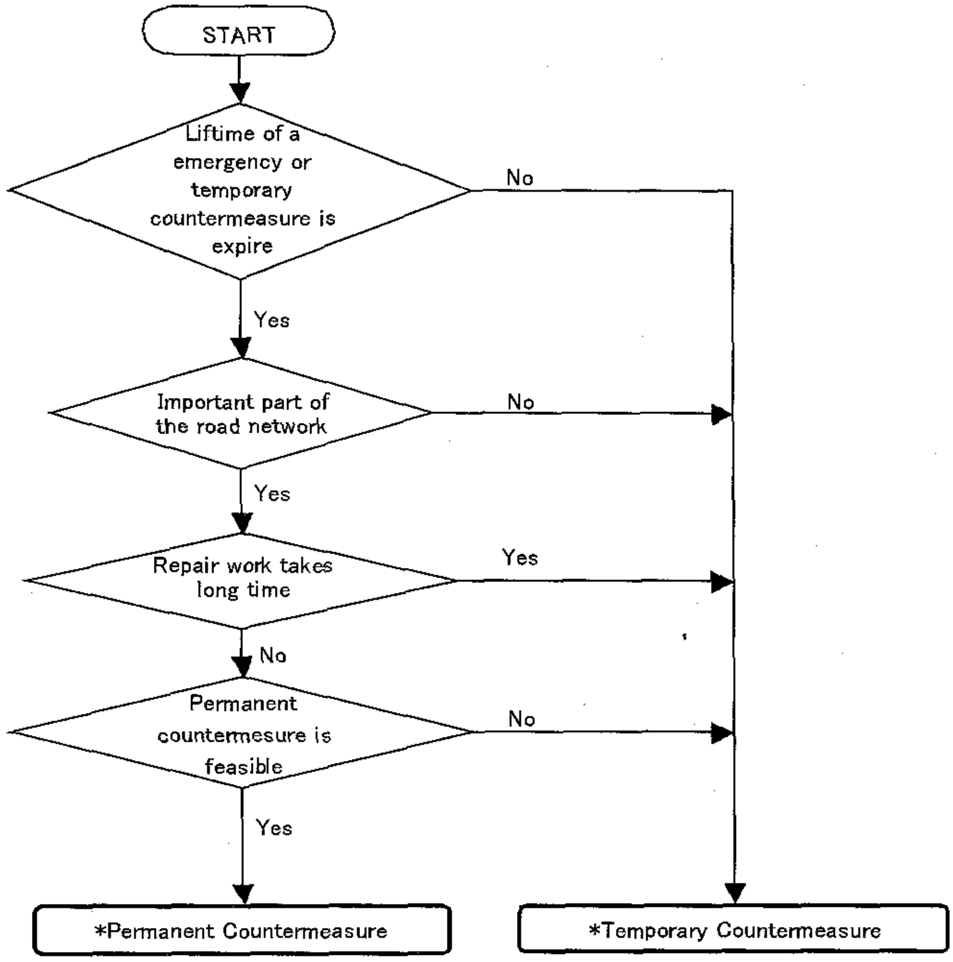


Figure 4.5.2 Selection of Temporary and Permanent Countermesure

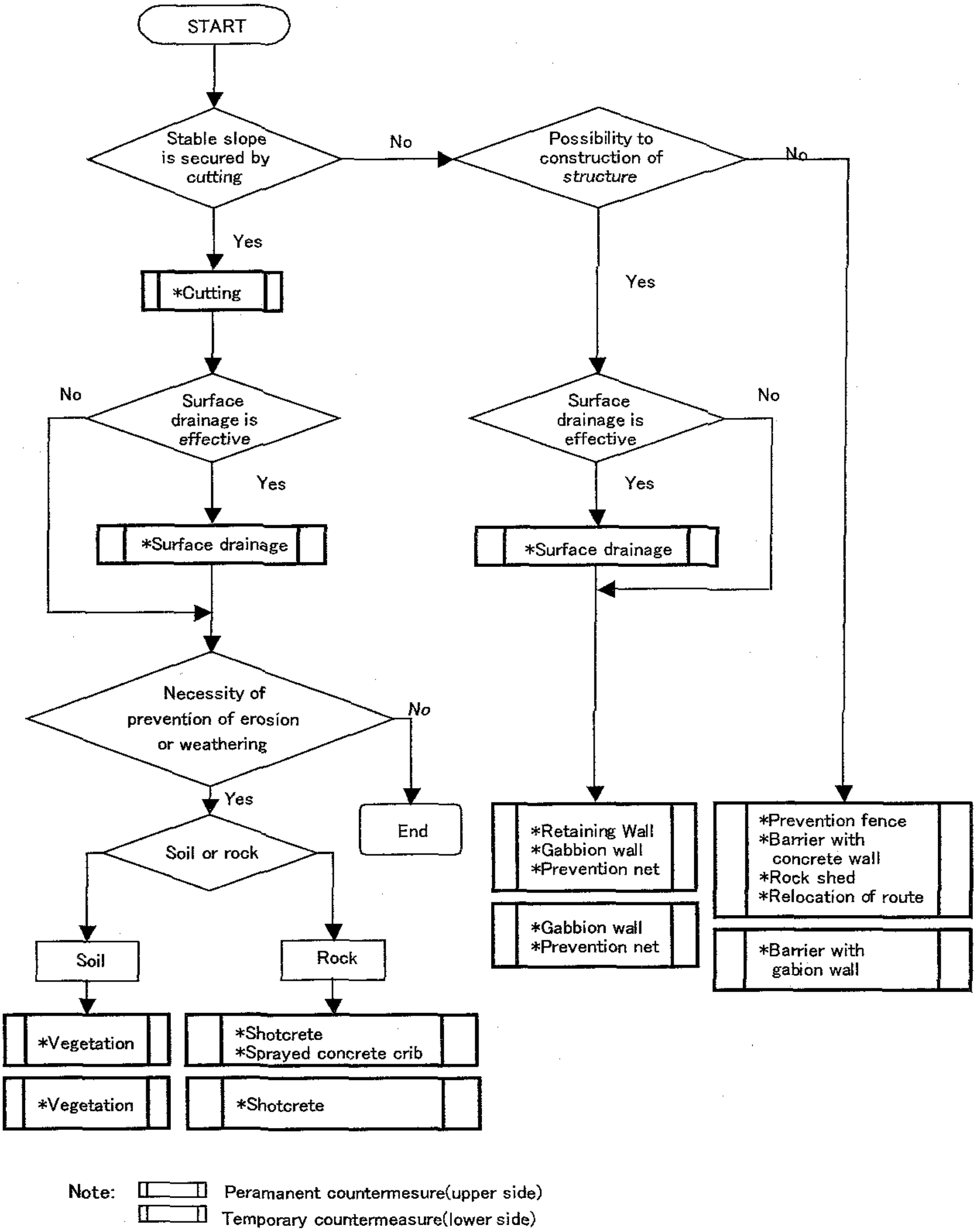


Figure 4.5.3 Selection of Temporary and Permanent Countermeasure for Rock-fall/Collapsing

4.5.3 Rock collapsing

1) Emergency Countermeasures

A selection procedure for emergency countermeasures in the case of rock collapsing is shown in Figure.4.5.4.

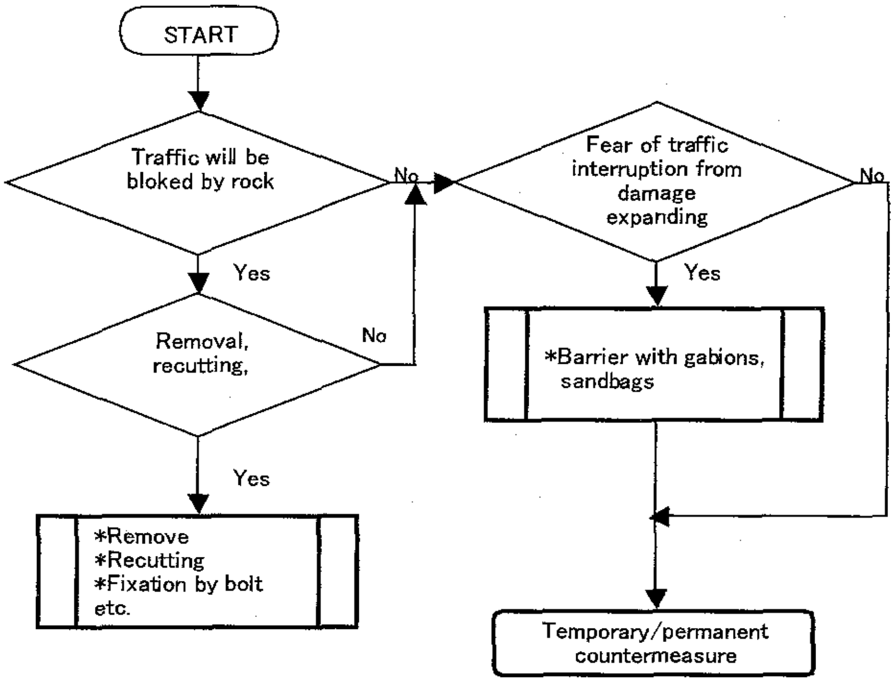


Figure 4.5.4 Selection of Emergency Countermeasure in Case of Rock Collapsing

2) Temporary/Permanent Countermeasures

The flow charts in Figure 4.5.2 and Figure 4.5.5 explain the selection procedure for a temporary and permanent countermeasure.

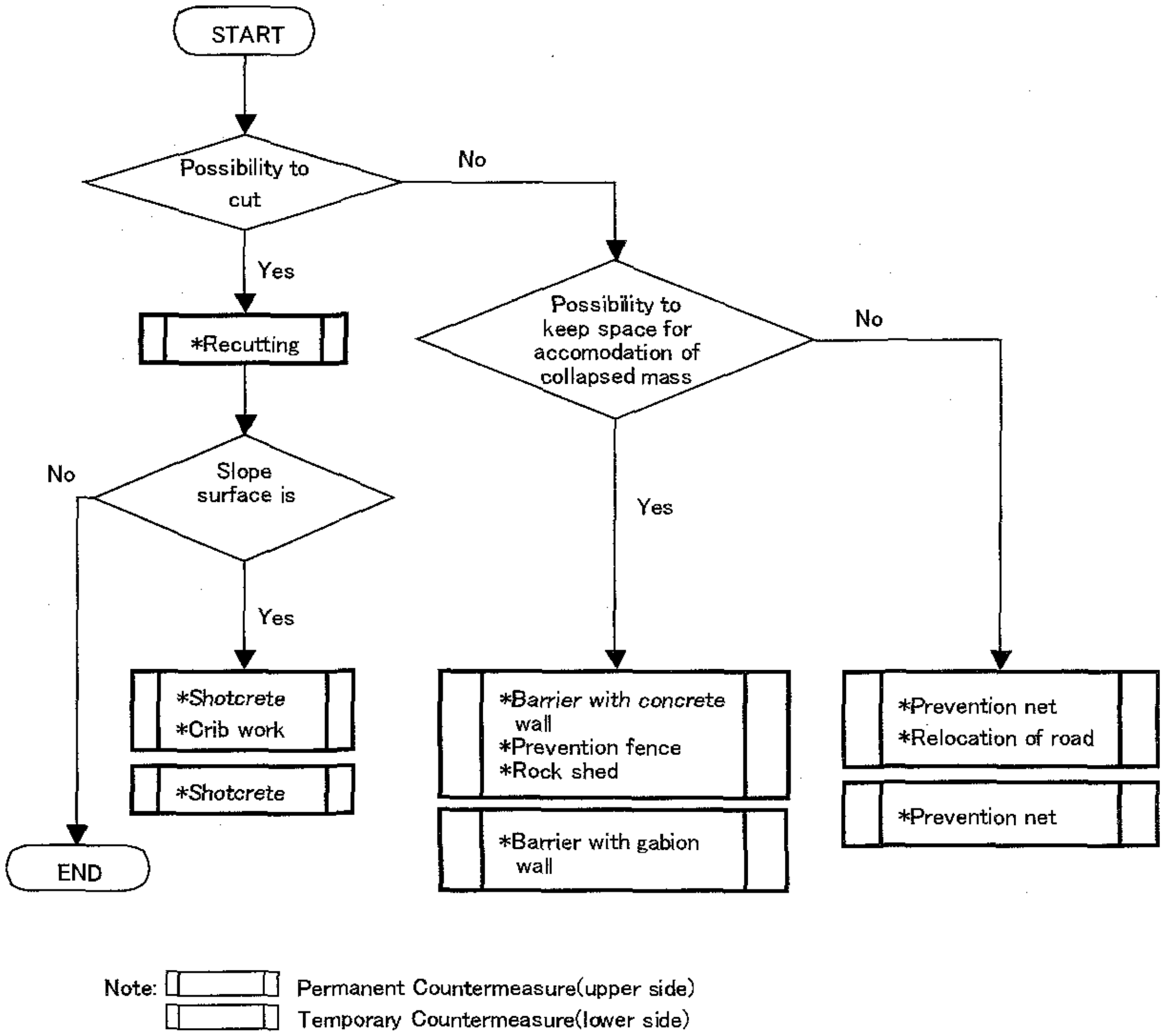


Figure 4.5.5 Selection of Temporary and Permanent Countermeasures for Rock Collapsing

4.5.4 Slope Slide

1) Emergency Countermeasures

A selection procedure for emergency countermeasures in the case of slope slide is shown in Figure.4.5.6.

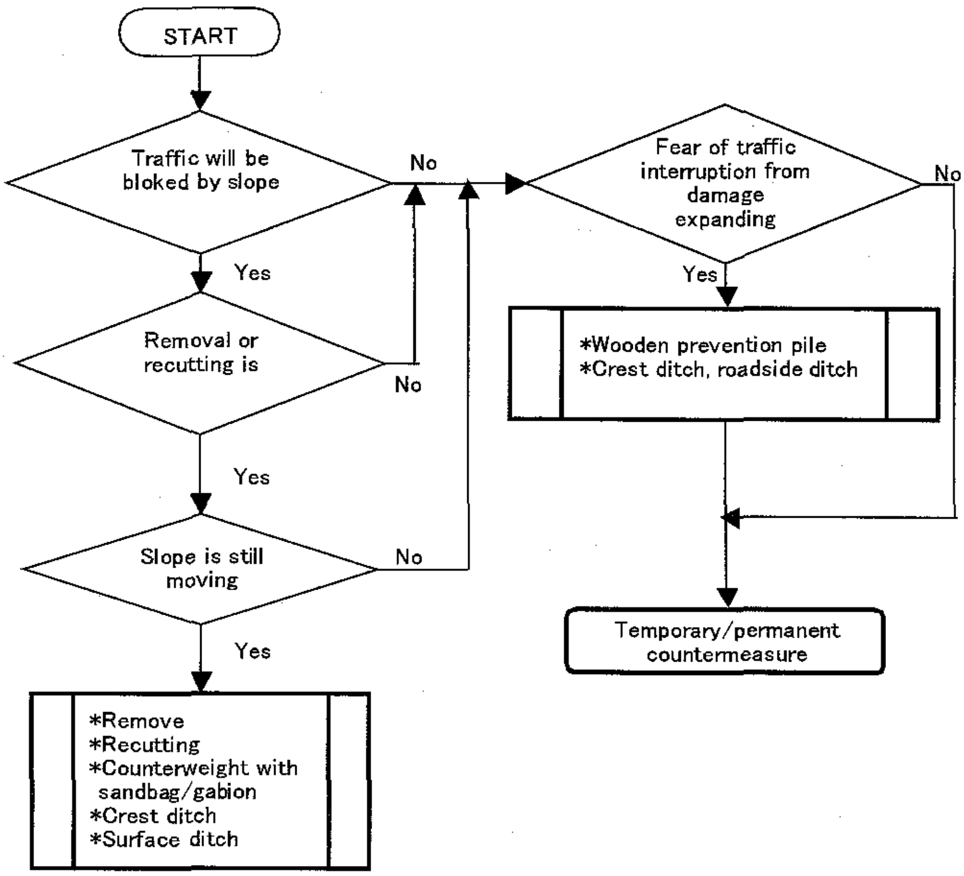


Figure 4.5.6 Selection of Emergency Countermeasure in Case of Slope Slide

2) Temporary/Permanent Countermeasures

The flow chart in Figure 4.5.2 and Figure 4.5.7 explain the selection procedure for a temporary and permanent countermeasure.

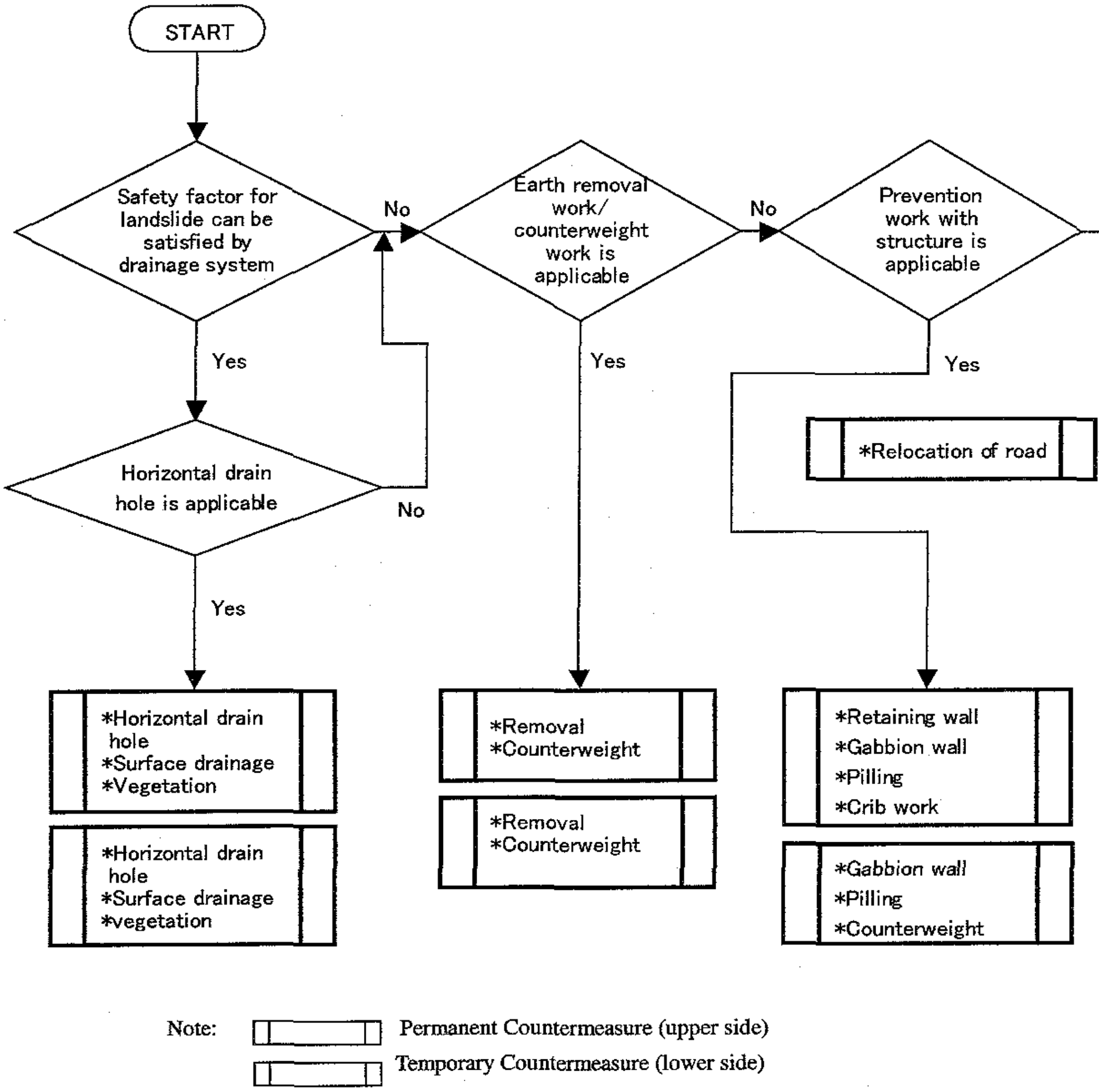


Figure 4.5.7 Selection of Countermeasure for Slope Slide

4.5.5 Debris Flow

1) Emergency of Countermeasures

If debris flows are anticipated in new further, the following countermeasures will be effective prevention against the debris flow to reach the road surface:

-To remove debris,

-To block debris with fence or retaining wall or dam, and

-To control traffic flow.

2) Temporary/Permanent Countermeasures

The flow chart shown in Figure 4.5.8 explains the selection procedure for emergency and temporary/permanent countermeasures.

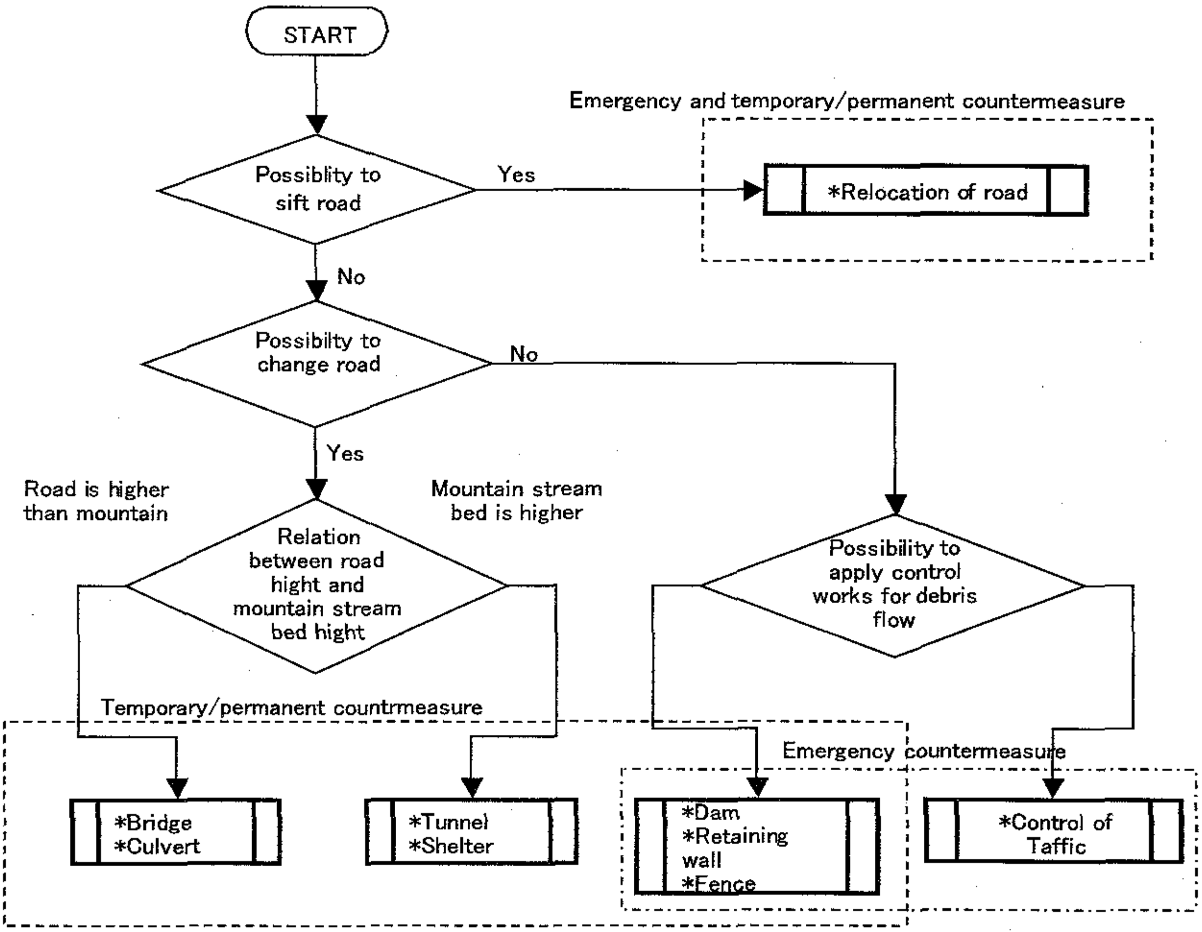


Figure 4.5.8 Selection of Countermeasure for Debris Flow

4.5.6 Bridge Foundation Scouring

1) Emergency Countermeasures

A selection procedure for emergency countermeasures in the case of bridge foundation scouring is shown in Figure 2.5.9.

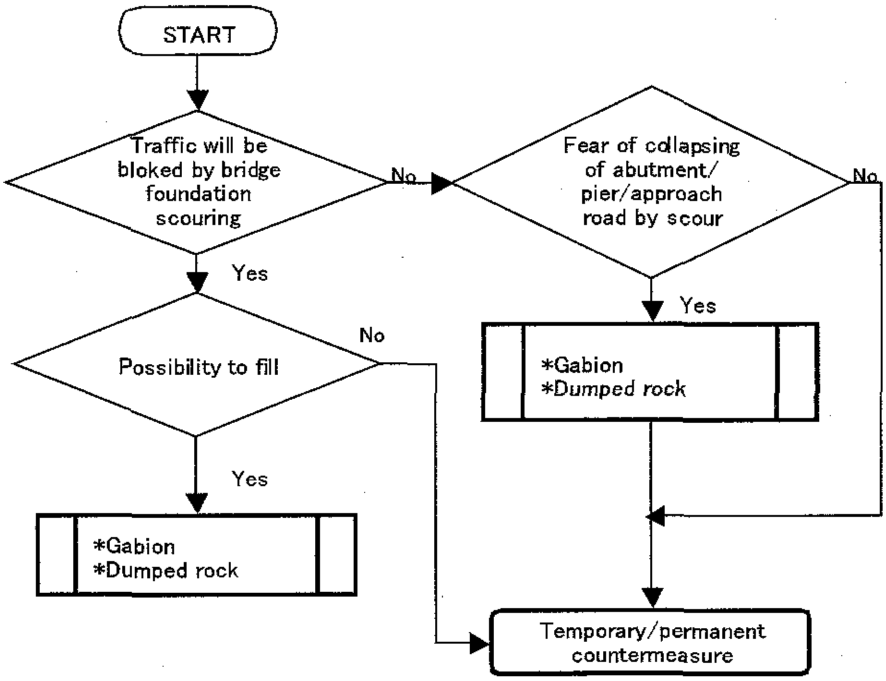


Figure 4.5.9 Selection of Emergency Countermeasure in Case of Bridge Foundation Scouring

2) Temporary/Permanent Countermeasures

The flow chart shown in Figure 2.5.10 explain the selection procedure for temporary and permanent countermeasure

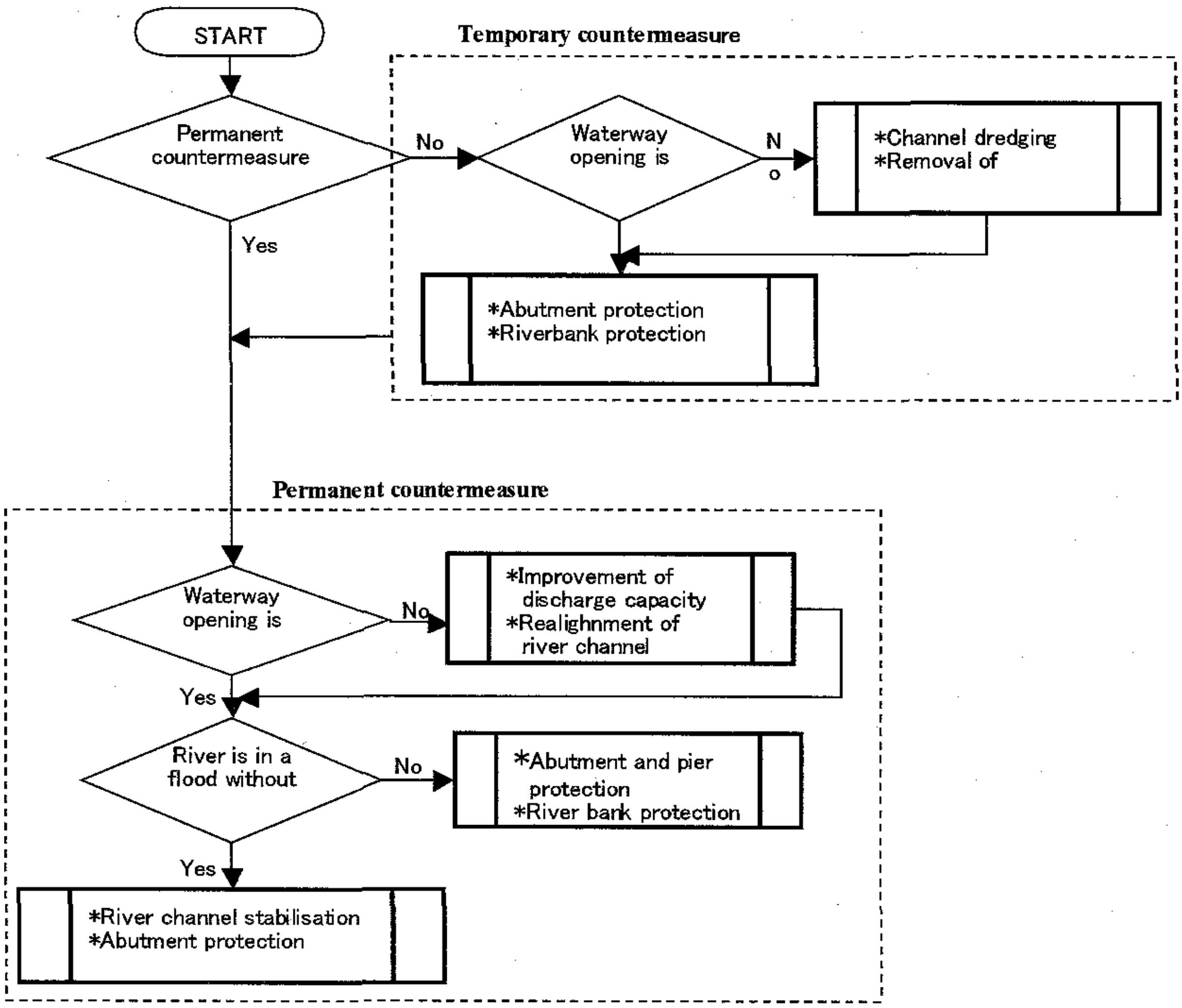


Figure 4.5.10 Selection of Tenporary/Permanent Countermeasure in Case of the Bridge Foundation Scouring

4.5.7 Classification of Countermeasures

Countermeasures for disaster critical spots are classified into six groups in consideration of their purposes and applicability. The relation between objects of prevention countermeasures and types of construction works is shown in Figure 4.5.11.

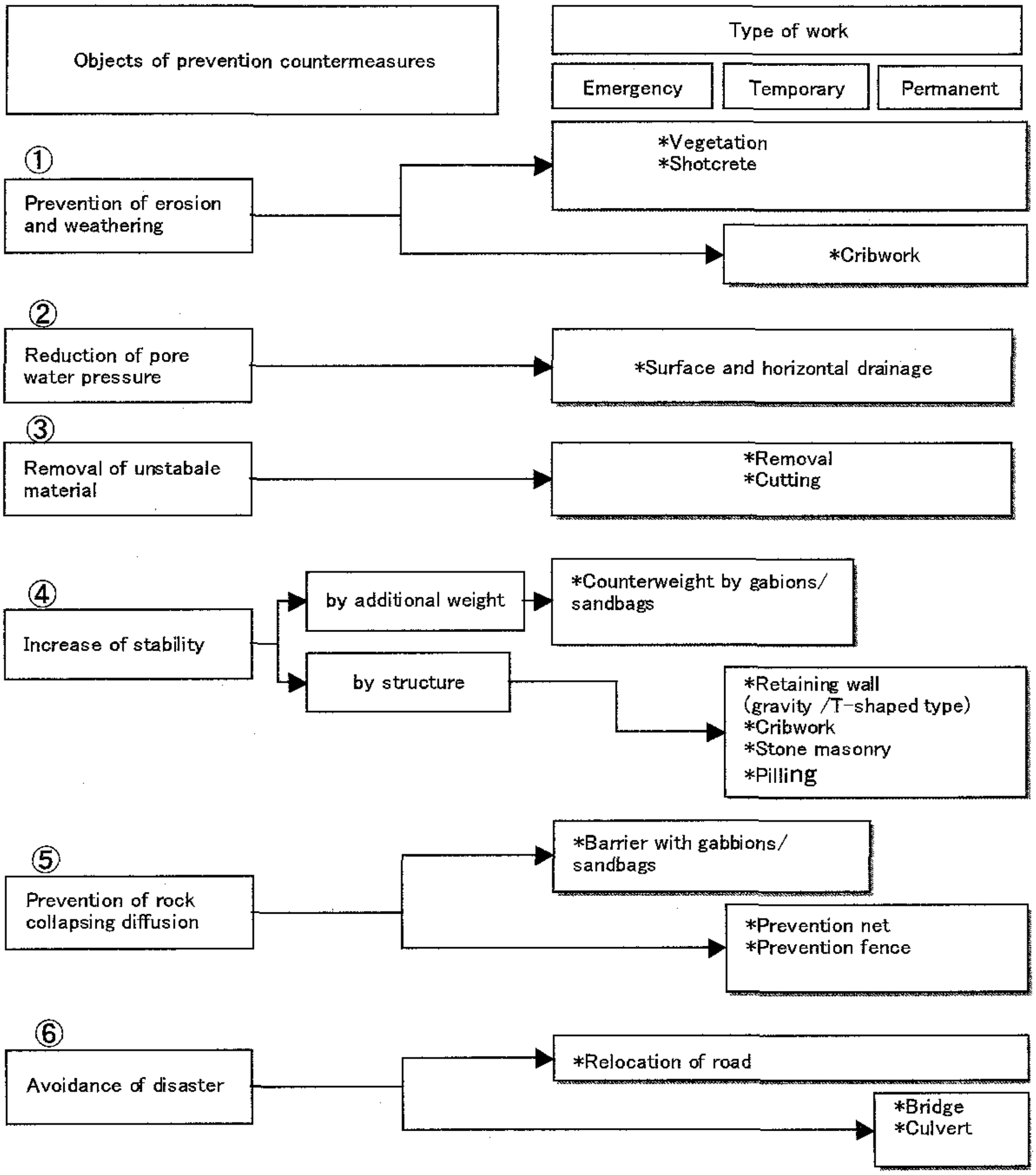


Figure 4.5.11 Relation between Objects of Prevention Coutermeasures and Types of Construction Work

4.5.8 Countermeasures for Objective Roads

Countermeasures for each critical spot of objective roads are shown in following tables. Presented countermeasures have been studied in article 4.5.3 to 4.5.10.

1) NIC. 1

Table 4.5.3 Type of Countermeasure for Slope Damage on NIC.1

No	Location	Classification of road Disaster	Score	Type of Countermeasure		Quantity (m^2)
1	60.9	Rock-fall	70	Barrier with gabion wall +	T	440(m)
2	73.2	Rock-fall	78	Prevention net	T	7,000
3	168.4	Rock-fall	84	Prevention net	T	19,703
4	168.6	Rock collapsing	72	Prevention net	T	5,363
5	169.8	Rock collapsing	72	Prevention net	T	6,466
6	170.7	Rock collapsing	72	Recutting + Shotcrete	P	15,242
7	171.3	Rock collapsing	78	Recutting + Shotcrete	P	8,754
8	175.0	Rock collapsing	76	Recutting + Shotcrete	P	2,252
9	176.2	Rock collapsing	74	Recutting + Shotcrete	P	4,988
10	178.7	Rock-fall	76	Prevention net	T	7,760
11	187.3	Rock collapsing	73	Recutting + Shotcrete	P	2,540
12	204.7	Rock collapsing	73	Prevention net	T	2,217
13	214.7	Rock-fall	70	Recutting + Shotcrete	P	1,935
14	232.5	Rock collapsing	75	Prevention net	T	3,695
15	233.7	Rock-fall	73	Recutting + Surface drainage +Vegetation	T	8,407
16	235.6	Rock-fall	73	Recutting + Shotcrete	P	1,389

Note: E; Emergency countermeasure, T; Temporary countermeasure
P; Permanent countermeasure

Table 4.5.4 Type of Countermeasure for Bridge Foundation Scouring on NIC.1

No	Location	Classification of road Disaster	Score	Type of Countermeasure		Quantity (m^2)
1	113+190	Bridge foundation scouring	90	Gabion mat	T	252
2	135+640	Bridge foundation scouring	100	Gabion mat	T	18
3	150+330	Bridge foundation scouring	90	Gabion mat	T	666
4	151+850	Bridge foundation scouring	100	Gabion mat	T	117
5	226+890	Bridge foundation scouring	100	Gabion mat	T	41
6	233+245	Bridge foundation scouring	100	Gabion mat	T	18

2) NIC.3

Table 4.5.5 Type of Countermeasure for Slope Damage on NIC.3

No	Location (km)	Classification of road Disaster	Score	Type of Countermeasure		Quantity (m^2)
1	3.9	Rock collapsing	74	Recutting	T	1,046
2	6.9	Rock collapsing	72	Recutting	T	1,369
3	7.4	Rock collapsing	80	Recutting	T	1,049
4	22.1	Rock collapsing	74	Recutting	T	5,287
5	32.7	Rock collapsing	70	Recutting + Shotcrete	P	1,836
6	32.9	Slope damage		Recutting + Embankment +Counterweight +Vegetation	P	3,460
7	35.2	Debris flow	75	Dam	P	100(m)
8	35.9	Slope damage	71	Recutting + Embankment +Counterweight +Vegetation	P	4,352
9	38.9	Slope damage	90	Recutting + Embankment +Counterweight +Vegetation	P	4,526
10	39.4	Slope damage	90	Recutting + Embankment +Counterweight +Vegetation	P	284
11	40.0	Rock collapsing	85	Recutting + Prevention net	P	2,272

Table 4.5.6 Type of Countermeasure for Bridge Foundation Scouring on NIC.3

No	Location	Classification of road Disaster	Score	Type of Countermeasure		Quantity (m^2)
1	119+050	Bridge foundation scouring	100	Reconstruction wing wall	P	8

3) NIC.5

Table 4.5.7 Type of Countermeasure for Slope Damage on NIC.5

No	Location (km)	Classification of road Disaster	Score	Type of Countermeasure		Quantity (m^2)
1	24.6	Rock-fall/collapsing	76	Recutting + Surface drainage + Vegetation	T	55,600

4) NIC.15

Table 4.5.8 Type of Countermeasure for Slope Damage on NIC.15

No	Location (km)	Classification of road Disaster	Score	Type of Countermeasure		Quantity (m)
1	13.6	Debris flow	70	Gabion wall	T	100
2	11.7	Debris flow	70	Gabion wall	T	70
3	11.1	Debris flow	70	Dam	T	65
4	9.9	Debris flow	70	Dam	T	45

5) NIC.26

Table 4.5.9 Type of Countermeasure for Slope Damage on NIC.26

No	Location (km)	Classification of road Disaster	Score	Type of Countermeasure		Quantity (m^2)
1	9.0	Rock-fall/collapsing	71	Recutting	T	841
2	12.7	Rock-fall/collapsing	70	Recutting	T	2,724
3	19.9	Rock-fall/collapsing	71	Recutting	T	6,683
4	20.9	Rock-fall/collapsing	72	Recutting	T	1,595
5	24.7	Rock-fall/collapsing	70	Recutting + Shotcrete	T	2,050
6	29.3	Rock-fall/collapsing	76	Barrier with gabion	T	77(m)
7	29.8	Rock collapsing	73	Prevention net	T	956
8	33.6	Rock-fall/collapsing	72	Recutting + shotcrete	T	780
9	34.0	Rock collapsing	80	Recutting	T	2,472
10	34.2	Rock-fall/collapsing	85	Recutting + shotcrete	T	9,641
11	37.0	Rock collapsing	86	Prevention net	T	2,226
12	45.5	Rock collapsing	71	Prevention net	T	6,472

Table 4.5.10 Type of Countermeasure for Bridge Foundation Scouring on NIC.26

No	Location	Classification of road Disaster	Score	Type of Countermeasure		Quantity (m^2)
1	107+533	Bridge foundation scouring	100	Gabion mat	T	90
2	108+154	Bridge foundation scouring	90	Gabion mat	T	54
3	155+785	Bridge foundation scouring	90	Gabion mat	T	248
4	170+952	Bridge foundation scouring	100	Gabion mat	T	369

4.6 Rough Cost Estimate

4.6.1 Construction Quantity

The six routes have fifty-five (55) disaster critical spots in total. Construction quantities for the critical spots are estimated based on countermeasure types. A list of construction quantities is shown in Table 4.6.1.

Table 4.6.1 Construction Quantity

Classification	Type of Work	Remarks	Unit	Quantities
(1)Surface drainage	Crest ditch	0.5×0.5 1:1	m	670
	Berm ditch	U-0.3×0.3	m	2,355
	Toe ditch		m	715
	Vertical ditch	U-0.3×0.3	m	613
(2)Horizontal	Horizontal drain hole	PVC PIPE f 0.04	m	400
(3)Vegetation	Seed spraying with pump		m^2	30,754
	Seed-mix spraying with a gun		m^2	0
(4)Structure	Shotcrete	t=10cm	m^2	53,879
	Sprayed concrete crib		m^2	0
	Concrete block crib		m^2	0
	Gabion mat		m^3	770
(5)Structural support	Stone riprap wall		m^2	0
	Gravity-type retaining wall		m^3	0
	Gabion wall		m^3	2,440
	T-shaped retaining wall		m^3	2,108
	Prevention piles		m^3	0
	Foot protection with stone riprap		m^3	0
	Foot protection with concrete		m^3	0
(6)Earth work	Removal		m^3	11,087
	Rock cutting		m^3	50,017
	Rock pre-splitting	Rock blasting	m^3	111
	Soil cutting		m^3	79,344
	Embankment		m^3	52,241
(7)Rockfall preventione dvice	Prevention net		m^2	64,130
	Prevention fence		m^2	0
	Barrier with gabion mat		m^3	308
	Barrier with concrete wall		m^3	0
(8)Anchoring	Rock bolt		each	0
(9)Riverbank protection	Concrete revetments		m^3	0
	Gabion mat		m^3	1,958
	Stone riprap with mortar		m^3	0
(10)Abutment and pier protection	Gabion foot protection		m^3	0
	Sheet-pile toe wall		m^2	0

4.6.2 Unit Cost

As MTI has no estimates of classification items for construction work, the estimates of unit costs for construction have been got from four private local construction companies in Nicaragua. However each unit cost based on the estimates was discussed in and decided by MTI. And each unit cost was averaged. As some work items have no market price due to lack of experience in Nicaragua, unit costs for some works are estimated based on the Japanese market price. A list of unit costs is shown in Table 4.6.2.

Table 4.6.2 Unit Costs

Classification	Type of Work	Remarks	Unit	Unit Cost (US$)
(1)Surface drainage	Crest ditch	0.5×0.5 1:1	m	65.12
	Berm ditch	U-0.3×0.3	m	49.49
	Toe ditch		m	60.78
	Vertical ditch	U-0.3×0.3	m	49.49
(2)Horizontal drainage	Horizontal drain hole	PVC PIPE ϕ0.04	m	27.00
(3)Vegetation	Seed spraying with pump		m^2	6.05
	Seed-mix spraying with a gun		m^2	8.14
(4)Structure	Shotcrete	t=10cm	m^2	48.30
	Sprayed concrete crib		m^2	-
	Concrete block crib		m^2	-
	Gabion mat		m^3	43.67
(5)Structural support	Stone riprap wall		m^2	66.91
	Gravity-type retaining wall		m^3	120.10
	Gabion wall		m^3	143.97
	T-shaped retaining wall		m^3	424.24
	Prevention piles		m^3	-
	Foot protection with stone riprap		m^3	66.91
	Foot protection with concrete		m^3	391.25
(6)Earth work	Removal		m^3	5.87
	Rock cutting		m^3	92.83
	Rock pre-splitting	Rock blasting	m^3	109.50
	Soil cutting		m^3	5.93
	Embankment		m^3	14.70
(7)Rockfall prevention device	Prevention net		m^2	33.65
	Prevention fence		m^2	-
	Barrier with gabion mat		m^3	97.49
	Barrier with concrete wall		m^3	625.13
(8)Anchoring	Rock bolt		each	218.25
(9)Riverbank protection	Concrete revetments		m^3	380.20
	Gabion mat		m^3	97.49
	Stone riprap with mortar		m^3	66.91
(10)Abutment and pier protection	Gabion foot protection		m^3	43.67
	Sheet-pile toe wall		m^2	-

4.6.3 Rough Cost for Each Objective Road

Rough costs for each objective road are shown in Table 4.6.3 to Table4.6.10.

Table 4.6.3 Construction Cost of Countermeasure for Slope Damage on NIC.1

No	Location	Classification of road Disaster	Type of Countermeasure		Quantity (m^2)	Cost (×1000US$)
1	60.9	Rock-fall	Barrier with gabion wall +	T	440(m)	253
2	73.2	Rock-fall	Prevention net	T	7,000	236
3	168.4	Rock-fall	Prevention net	T	19,703	812
4	168.6	Rock collapsing	Prevention net	T	5,363	315
5	169.8	Rock collapsing	Prevention net	T	6,466	364
6	170.7	Rock collapsing	Recutting + Shotcrete	P	15,242	1,772
7	171.3	Rock collapsing	Recutting + Shotcrete	P	8,754	639
8	175.0	Rock collapsing	Recutting + Shotcrete	P	2,252	184
9	176.2	Rock collapsing	Recutting + Shotcrete	P	4,988	385
10	178.7	Rock-fall	Prevention net	T	7,760	456
11	187.3	Rock collapsing	Recutting + Shotcrete	P	2,540	197
12	204.7	Rock collapsing	Prevention net	T	2,217	125
13	214.7	Rock-fall	Recutting + Shotcrete	P	1,935	175
14	232.5	Rock collapsing	Prevention net	T	3,695	208
15	233.7	Rock-fall	Recutting + Surface drainage +Vegetation	T	8,407	116
16	235.6	Rock-fall	Recutting + Shotcrete	P	1,389	152
Total						6,389

Note: E; Emergency countermeasure, T; Temporary countermeasure
P; Permanent countermeasure

Table 4.6.4 Construction Cost of Countermeasure for Bridge Foundation Scouring on NIC.1

No	Location	Classification of road Disaster	Type of Countermeasure		Quantity (m^3)	Cost (×1000us$)
1	113+190	Bridge foundation scouring	Gabion mat	T	252	25
2	135+640	Bridge foundation scouring	Gabion mat	T	18	2
3	150+330	Bridge foundation scouring	Gabion mat	T	666	65
4	151+850	Bridge foundation scouring	Gabion mat	T	117	12
5	226+890	Bridge foundation scouring	Gabion mat	T	41	4
6	233+245	Bridge foundation scouring	Gabion mat	T	18	2
Total						110

Table 4.6.5 Construction Cost of Countermeasure for Slope Damage on NIC.3

No	Location (km)	Classification of road Disaster	Type of Countermeasure		Quantity (m^2)	Cost (×1000us$)
1	3.9	Rock collapsing	Recutting	T	1,046	70
2	6.9	Rock collapsing	Recutting	T	1,369	91
3	7.4	Rock collapsing	Recutting	T	1,049	35
4	22.1	Rock collapsing	Recutting	T	5,287	177
5	32.7	Rock collapsing	Recutting + Shotcrete	P	1,836	174
6	32.9	Slope damage	Recutting + Embankment +Counterweight +Vegetation	P	3,460	670
7	35.2	Debris flow	Dam	P	100(m)	429
8	35.9	Slope damage	Recutting + Embankment +Counterweight +Vegetation	P	4,352	248
9	38.9	Slope damage	Recutting + Embankment +Counterweight +Vegetation	P	4,526	191
10	39.4	Slope damage	Recutting + Embankment +Counterweight +Vegetation	P	284	30
11	40.0	Rock collapsing	Recutting + Prevention net	P	2,272	133
Total						2,248

Table 4.6.6 Construction Cost of Countermeasure for Bridge Foundation Scouring on NIC.3

No	Location	Classification of road Disaster	Type of Countermeasure		Quantity (m^3)	Cost (×1000us$)
1	119+050	Bridge foundation scouring	Reconstruction wing wall	P	8	3

Table 4.6.7 Construction Cost of Countermeasure for Slope Damage on NIC.5

No	Location (km)	Classification of road Disaster	Type of Countermeasure		Quantity (m^2)	Cost (×1000us$)
1	24.6	Rock-fall/collapsing	Recutting + Surface drainage + Vegetation	T	55,600	744

Table 4.6.8 Construction Cost of Countermeasure for Slope Damage on NIC.15

No	Location (km)	Classification of road Disaster	Type of Countermeasure		Quantity (m)	Cost (×1000us$)
1	13.6	Debris flow	Gabion wall	T	100	58
2	11.7	Debris flow	Gabion wall	T	70	40
3	11.1	Debris flow	Dam	P	65	279
4	9.9	Debris flow	Dam	P	45	193
Total						570

Table 4.6.9 Construction Cost of Countermeasure for Slope Damage on NIC.26

No	Location (km)	Classification of road Disaster	Type of Countermeasure		Quantity (m^2)	Cost (× 1000us$)
1	9.0	Rock-fall/collapsing	Recutting	T	841	56
2	12.7	Rock-fall/collapsing	Recutting	T	2,724	115
3	19.9	Rock-fall/collapsing	Recutting	T	6,683	446
4	20.9	Rock-fall/collapsing	Recutting	T	1,595	121
5	24.7	Rock-fall/collapsing	Recutting + Shotcrete	P	2,050	159
6	29.3	Rock-fall/collapsing	Barrier with gabion	T	77(m)	44
7	29.8	Rock collapsing	Prevention net	T	956	52
8	33.6	Rock-fall/collapsing	Recutting + shotcrete	P	780	60
9	34.0	Rock collapsing	Recutting	T	2,472	191
10	34.2	Rock-fall/collapsing	Recutting + shotcrete	P	9,641	748
11	37.0	Rock collapsing	Prevention net	T	2,226	131
12	45.5	Rock collapsing	Prevention net	T	6,472	364
Total						2,527

Table 4.6.10 Construction Cost of Countermeasure for Bridge Foundation Scouring on NIC.26

No	Location	Classification of road Disaster	Type of Countermeasure		Quantity (m^2)	Cost (×1000us$)
1	107+533	Bridge foundation scouring	Gabion mat	T	90	9
2	108+154	Bridge foundation scouring	Gabion mat	T	54	5
3	155+785	Bridge foundation scouring	Gabion mat	T	248	24
4	170+952	Bridge foundation scouring	Gabion mat	T	369	36
Total						74

4.6.4 Total Cost

Total rough construction costs for each road are shown in Table 4.6.11.

Table 4.6.11 Total Cost of Each Route

Road No.	Cost (1,000US$)
NIC. 1	6,499
NIC.3	2,251
NIC. 5	744
NIC. 15	570
NIC. 24	0
NIC. 26	2,601
Total	12,665

US$1=C$13.9