5.5 Identification of Disaster Prevention Spots

5.5.1 General

The disaster critical spots where have been identified in Section 3.7 are necessary to prevent urgent countermeasures, temporary one or permanent one. And the countermeasures of these spots should be planned in consideration of various factor items. The disaster critical spots are evaluated as follows.

<Section 5.1>

- Hydrological survey : Evaluation of the bridge foundation scouring
- Geological survey : Evaluation of the rock weathering or collapsing

<Section 5.3>

- Environmental survey : Evaluation of environmental items

<ASection 5.4>

- Future traffic demand : Traffic forecast until year 2020
- Benefit to cost ratio : Evaluation by benefit and cost

The objective six (6) roads are ranked as a major transportation road. The disaster critical spots occur on the objective roads except NIC. 24. These spots are impossible to decide only the above-mentioned each Section. Because traffic volume is not only one of the factor to select the disaster critical spot but also environment in surrounding and slope damage condition or bridge scouring condition are important. Moreover, there are some spots where are little traffic volume. And it is assumed that the traffic demand could be low less than 1000 vehicles with AADT.

Therefore, the identification of disaster prevention spots on roads should be considered the evaluation indexes, which are stability level, traffic volume, environmental in surrounding, development plan in surrounding, natural condition, benefit and restoration level, etc.

5.5.2 Characteristics of Disaster Critical Spots

The characteristics of fifty-five (55) disaster critical spots on the objective roads are shown in Table 5.5.1. The table describes types of disaster, evaluation score, types of countermeasures and cost estimates. For instance, the stability scores of serial No.40 and 42 on NIC.26 are the same value with 71 points. And the countermeasure is also the same in re-cutting work on slope surface. However, the rough cost estimate for construction of the serial No. 42 shows a tendency to rise by about eight times because the scale of disaster is greatly different.

5.5.3 Selection Technique of Disaster Prevention spots

1) Outline of Selection Techniques

As described in the above-mentioned Section 5.5.2, the evaluation score of the disaster critical spots is different depending on disaster scale. Moreover, it is very difficult to identify the disaster prevention spots by using only the high cost or low cost. Therefore, it is necessary to arrange as a whole evaluation item with the importance level. In this plan, identification of the disaster prevention spots uses the Analytic Hierarchy Process (hereinafter referred to as "AHP").

The AHP is one of the techniques which human's decision making is shown by the numerical value for the uncertain situations and the various criteria. In short, thirty (30) disaster prevention spots should be identified from various candidates to the disaster critical spots. However, there are the "purposes" to be identified from fifty-five (55) spots and are some "alternative spots" to be finally selected. The AHP formulates a hierarchical structure of the decision making with the "evaluation criteria" between "purpose" and "alternative spots". The AHP structure is shown in Figure 5.5.1.

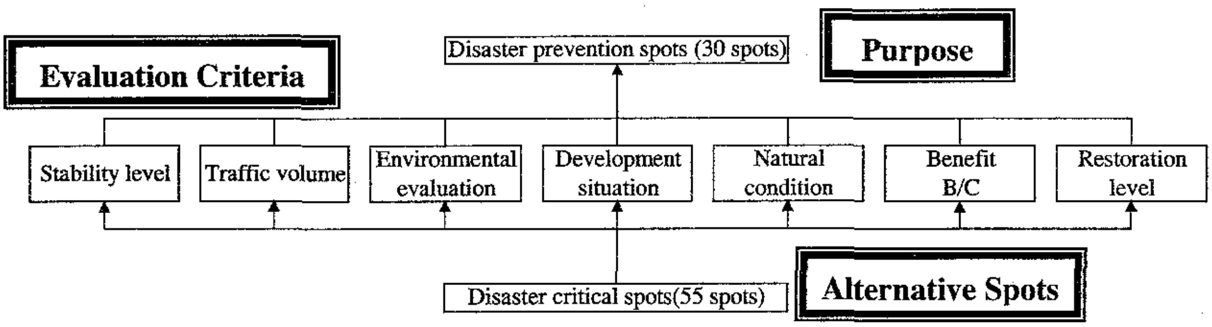


Figure 5.5.1 AHP Structure

Table 5.5.2 Characteristics of Disaster Critical Spots

Serial Number of Disaster Critical Spots	Objective Road	Type of Disaster	Score	Type of Countermeasures	Cost (US$1,000)
1	NIC.1	R.F.	70	Barrier with gabion wall	253
2	NIC.1	R.F.	78	Prevention net	236
3	NIC.1	Bridge	90	Gabion mat	25
4	NIC.1	Bridge	100	Gabion mat	2
5	NIC.1	Bridge	90	Gabion mat	65
6	NIC.1	Bridge	100	Gabion mat	12
7	NIC.1	R.F.	84	Prevention net	812
8	NIC.1	R.C.	72	Prevention net	315
9	NIC.1	R.C.	72	Prevention net	364
10	NIC.1	R.C.	72	Recutting + Shotcrete	1,772
11	NIC.1	R.C.	78	Recutting + Shotcrete	639
12	NIC.1	R.C.	76	Recutting + Shotcrete	184
13	NIC.1	R.C.	74	Recutting + Shotcrete	385
14	NIC.1	R.F.	76	Prevention net	456
15	NIC.1	R.C.	73	Recutting + Shotcrete	197
16	NIC.1	R.C.	73	Prevention net	125
17	NIC.1	R.F.	70	Recutting + Shotcrete	175
18	NIC.1	Bridge	100	Gabion mat	4
19	NIC.1	Bridge	100	Gabion mat	2
20	NIC.1	R.C.	75	Prevention net	208
21	NIC.1	R.F.	73	Recutting + Surface drainage + Vegetation	116
22	NIC.1	R.F.	73	Recutting + Shotcrete	152
23	NIC.3	R.C.	74	Recutting	70
24	NIC.3	R.C.	72	Recutting	91
25	NIC.3	R.C.	80	Recutting	35
26	NIC.3	Bridge	100	Reconstruction wing wall	3
27	NIC.3	R.C.	74	Recutting	177
28	NIC.3	R.C.	70	Recutting + Shotcrete	174
29	NIC.3	S.S.	73	R.E.C.V.	670
30	NIC.3	D.F.	83	Dam	429
31	NIC.3	S.S.	71	R.E.C.V.	248
32	NIC.3	S.S.	90	R.E.C.V.	191
33	NIC.3	S.S.	90	R.E.C.V.	30
34	NIC.3	R.C.	72	Recutting + Prevention net	133
35	NIC.5	R.F.	76	Recutting + Surface drainage + Vegetation	744
36	NIC.15	D.F.	70	Gabion wall	58
37	NIC.15	D.F.	70	Gabion wall	40
38	NIC.15	D.F.	70	Dam	279
39	NIC.15	D.F.	70	Dam	193
40	NIC.26	R.F.	71	Recutting	56
41	NIC.26	R.F.	70	Recutting	115
42	NIC.26	R.F.	71	Recutting	446
43	NIC.26	R.F.	72	Recutting	121
44	NIC.26	R.F.	70	Recutting + Shotcrete	159
45	NIC.26	Bridge	100	Gabion mat	36
46	NIC.26	R.F.	76	Barrier with gabion	44
47	NIC.26	R.C.	73	Prevention net	52
48	NIC.26	R.F.	72	Recutting + Shotcrete	60
49	NIC.26	R.C.	80	Recutting	191
50	NIC.26	R.F.	85	Recutting + Shotcrete	748
51	NIC.26	R.C.	86	Prevention net	131
52	NIC.26	Bridge	90	Gabion mat	24
53	NIC.26	R.C.	71	Prevention net	364
54	NIC.26	Bridge	90	Gabion mat	5
55	NIC.26	Bridge	100	Gabion mat	9

Type of Disaster
R.F. : Rock Falling
R.C. : Rock Collapsing
S.S. : Slope Slide
D.F. : Debris Floiw
Bridge : Scouring of Foundation

Type of Countermeasures
R.E.C.V. Recutting + Embankment
+ Counterweight
+ Vegetation

2) Priority Level for Disaster Prevention Spots

The priority level for the disaster prevention spots is consisted of the first step and the second step.

a) The First Step (Setting of evaluation criteria)

Evaluation criteria of the first step are seven items as follows. These items are every important for identifying the disaster critical spots.

- Stability Level

Each spot is compared from the stability level of the survey results.
When the stability score is large, the priority is high.

- Traffic Volume

Each spot is compared from the traffic volume in year 2020.
When the traffic volume is large, the priority is high.

- Environmental Evaluation

Each spots is compared from the evaluation result of the environmental items.
When the point is small, the priority is high.

- Development situation

Each spot is compared from the development area of roadside.
The spot of area where the development was completion is high priority.

- Natural Condition

The critical level is compared based on the natural condition survey result of geology, hydrology and these results of rainy season, etc.
When the critical level is large, the priority is high.

- Benefit (Benefit/Cost)

The result of B/C is compared based on the countermeasure costs of the first phase in this Study.
When the B/C is large, the priority is high.

- Restoration Level

The difficult level of restoration is evaluated based on the maximum disaster scale to be assumed.
When the difficult level, which is restoration time, restoration yard spaces and necessity of special restoration machines, etc., is high, the priority is also high.

b) The Second Step (Pair Comparisons of Evaluation Criteria)

➢ Magnitude and definition of importance

The magnitude and the definition of importance are prepared as shown in Table 5.5.3 before the pairs of evaluation criteria are compared.

Table 5.5.3 Magnitude and Definition of Importance

Magnitude of Importance	Definition
1	Equal importance
3	Weak importance
5	Strong importance
7	Very strong importance
9	Absolute importance

2, 4, 6 and 8 of he magnitude, use at the middle above-mentioned table. When the importance is low, the magnitude uses the reciprocal number

For instance, when the stability level is weakly important against the traffic volume, the magnitude is 3. To the contrary, the traffic volume is 1/3 against the stability level.

➢ Magnitude of Pair Comparison

The magnitude of pair comparison for evaluation criteria was decided based on the intention of the MTI as shown in Table 5.5.4. Moreover, the comparison of each alternative spots was decided based on the evaluation point that the JICA Study Team had evaluated.

	Stability level	Traffic volume	Environment evaluation	Natural condition	Benefit B/C	Restoration level	Development situation	Weight
Stability level	1	3	5	3	7	3	9	0.36676
Traffic volume	1/3	1	3	1	5	1	7	0.16733
Environment evaluation	1/5	1/3	1	1/5	3	1	7	0.08395
Natural condition	1/3	1	5	1	5	1	7	0.18000
Benefit B/C	1/7	1/5	1/3	1/5	1	1/5	3	0.03826
Restoration level	1/3	1	1	1	5	1	7	0.14303
Development situation	1/9	1/7	1/7	1/7	1/3	1/7	1	0.02068
								1.00000

Table 5.5.4 Magnitude of Pair Comparison

The weight to the each evaluation criteria is presented in Appendix-5.

5.5.4 Identification of Disaster Prevention Spots

The priority of the disaster prevention spots identified by AHP based on the magnitude of pair comparison is shown in Table 5.5.5. The identified thirty (30) spots are ranked as the feasibility study.

Table 5.5.5 Disaster Prevention Spots

Priority	Objective Road	Serial No. of Critical Spots	Type of Disaster	Type of Countermeasures
1	Nic3	26	Bridge	Reconstruction wing wall
2	Nic26	45	Bridge	Gabion mat
3	Nic1	6	Bridge	Gabion mat
4	Nic26	55	Bridge	Gabion mat
5	Nic1	19	Bridge	Gabion mat
6	Nic1	18	Bridge	Gabion mat
7	Nic1	4	Bridge	Gabion mat
8	Nic3	32	S.S.	R.E.C.V.
9	Nic3	33	S.S.	R.E.C.V.
10	Nic1	2	R.F.	Prevention net
11	Nic26	50	R.F.	Recutting + Shotcrete
12	Nic1	5	Bridge	Gabion mat
13	Nic3	30	D.F.	Dam
14	Nic3	25	R.C.	Recutting
15	Nic1	1	R.F.	Barrier with gabion wall
16	Nic1	3	Bridge	Gabion mat
17	Nic26	52	Bridge	Gabion mat
18	Nic26	54	Bridge	Gabion mat
19	Nic3	24	R.C.	Recutting
20	Nic26	49	R.C.	Recutting
21	Nic5	35	R.F.	Recutting + Surface drainage + Vegetation
22	Nic26	51	R.C.	Prevention net
23	Nic1	7	R.F.	Prevention net
24	Nic1	12	R.C.	Recutting + Shotcrete
25	Nic3	27	R.C.	Recutting
26	Nic1	13	R.C.	Recutting + Shotcrete
27	Nic26	44	R.F.	Recutting + Shotcrete
28	Nic1	8	R.C.	Prevention net
29	Nic3	29	S.S.	R.E.C.V.
30	Nic1	11	R.C.	Recutting + Shotcrete
31	Nic1	14	R.F.	Prevention net
32	Nic3	31	S.S.	R.E.C.V.
33	Nic3	34	R.C.	Recutting + Prevention net
34	Nic1	16	R.C.	Prevention net
35	Nic1	17	R.F.	Recutting + Shotcrete
36	Nic26	41	R.F.	Recutting
37	Nic3	23	R.C.	Recutting
38	Nic26	46	R.F.	Barrier with gabion
39	Nic26	40	R.F.	Recutting
40	Nic1	15	R.C.	Recutting + Shotcrete
41	Nic26	48	R.F.	Recutting + Shotcrete
42	Nic1	10	R.C.	Recutting + Shotcrete
43	Nic26	47	R.C.	Prevention net
44	Nic1	9	R.C.	Prevention net
45	Nic26	53	R.C.	Prevention net
46	Nic26	43	R.F.	Recutting
47	Nic15	36	D.F.	Gabion wall
48	Nic15	37	D.F.	Gabion wall
49	Nic26	42	R.F.	Recutting
50	Nic1	20	R.C.	Prevention net
51	Nic3	28	R.C.	Recutting + Shotcrete
52	Nic1	21	R.F.	Recutting + Surface drainage + Vegetation
53	Nic1	22	R.F.	Recutting + Shotcrete
54	Nic15	39	D.F.	Dam
55	Nic15	38	D.F.	Dam

CHAPTER 6

ESTABLISHMENT

OF DISASTER PREVENTION SPOTS

CHAPTER 6 ESTABLISHMENT OF DISASTER PREVENTION PLAN

6.1 Evaluation of Adequate Countermeasures

6.1.1 Importance to Road

The road should be used for the user smoothly. The traffic volume of objective roads is forecasted to increase about three times in year 2020 by this Study. Therefore disaster prevention measures are important for the objective roads. The fact is the same situation not only the objective roads but also other major trunk roads.

1) Existing road Width

The existing road width is shown in Table 6.1.1. Two spots on NIC 3, where are ID N003B370 and the El Guayacan, are against the Standard.

Table 6.1.1 Review of Existing Road Width

No		Existing Width				Necessary Min. Width		Judge
		Remainder Width of Left side	Paved Width	Remainder Width of Right side	Total Width	Lane	Total	
NIC.1								
1	N001A290	6.49	7.38	10.96	24.83	6.6	9.0	OK
2	N001A280	0.92	7.95	7.48	16.36	6.6	9.0	OK
3	Junquillal	-	7.35	-	7.35	6.6	9.0	OK
4	San Nicolas	-	7.32	-	7.32	6.6	9.0	OK
5	Las Chanillas	-	7.34	-	7.34	6.6	9.0	OK
6	San Ramón	-	7.39	-	7.39	6.6	9.0	OK
7	N001A240	2.73	6.97	3.54	13.25	6.6	9.0	OK
8	N001B230	2.57	6.85	7.02	16.43	6.6	9.0	OK
9	N001B170	2.32	7.78	3.37	13.48	6.6	9.0	OK
10	N001B150	1.63	8.69	2.66	12.97	6.6	9.0	OK
11	N001B120	2.11	7.82	2.18	12.10	6.6	9.0	OK
12	Rio Inali	-	7.33	-	7.33	6.6	9.0	OK
13	RioTapacali	-	8.88	-	8.88	6.6	9.0	OK
NIC.3								
14	003B400	1.99	6.74	1.57	10.30	6.6	9.0	OK
15	003B370	5.78	6.23	3.82	15.83	6.6	9.0	NG
16	El Guayacan	-	6.35	-	6.35	6.6	9.0	NG
17	N003B320	4.44	7.25	2.81	14.50	6.6	9.0	OK
18	N003C230	1.83	6.70	2.07	10.60	6.6	9.0	OK
19	N003E170	0.55	7.81	2.83	11.20	6.6	9.0	OK
20	N003C150	2.95	7.81	2.80	13.56	6.6	9.0	OK
21	N003C140	3.97	7.10	2.46	13.54	6.6	9.0	OK
NIC.5								
22	N005A001	2.02	6.72	5.03	13.78	6.6	9.0	OK
NIC.26								
23	N026A006	2.44	6.72	3.89	13.05	6.6	9.0	OK
24	La Banderita	-	7.35	-	7.35	6.6	9.0	OK
25	N026B140	3.17	6.68	7.95	17.80	6.6	9.0	OK
26	N026A150	3.88	6.72	3.60	14.20	6.6	9.0	OK
27	N026B160	3.47	6.76	4.81	15.03	6.6	9.0	OK
28	San Juan de Dio	-	7.26	-	7.26	6.6	9.0	OK
29	Papalon	-	7.32	-	7.32	6.6	9.0	OK
30	Solis	-	7.31	-	7.31	6.6	9.0	OK

2) Geometric Standard

In order to safeguard the carriageway against slope damages, the objective road should be considered the following geometric standard .as shown in table 6.1.2.

Table 6.1.2 Applicable Geometric Standard

No.	Description	Trunk Road	
		suburbans	rurals
1	Classification	A2	A3
2	Design Vehicle	WB-20	WB-15
3	Type of Terrain	P O M	P O M
4	Design Speed	90 80 70	80 70 60
5	Number of Lanes	2 to 4	2 to 4
6	Lane Width, mts	3.30 - 3.65	3.30 - 3.65
7	Shoulder Width, mts	Int: 1.0 - 1.5, Ext: 1.5 - 1.8	Int: 0.5 - 1.0, Ext: 1.0 - 1.8
8	Surface Type	Pav	Pav
9	Stop Distance, mts	110-170	85-140
10	Passing Distance, mts	480-600	410-540
11	Minimum Curve Radio	195-335	135-250
12	Maximum Curve Grade	5° 53' - 3° 25'	8° 29' - 4° 35'
13	Maximun Vertical Grade	8	8
14	Superelevation, percentage	10	10
15	Transversal slope %	1.5 - 3	1.5 - 3
16	Shoulder Slope, %	2 - 5	2 - 5
17	Bridge Width, meters	Variable	Variable
18	Bridge Design Load, (AASHTO)	HS20-44+25%	HS20-44+25%
19	Road Right Width, mts	40-50	40-50
20	Median Width, mts	4 -10	2 - 6
21	Service Level	C-D	C-D
22	Type of Access Control	Partial Control	Without Control

Notes:
Pav.= Asfaltic pavement
P= Plane O= Ondulated M=Mountainous

3) Standard Typical Cross-section and Right-of-way

The objective roads should be obeyed the Standard as shown in Table 6.1.3 and Figure 6.1.1.

Table 6.1.3 Standard Typical Cross-section and Right-of-way

1	Number of Lanes		2 to 4	2 to 4
2	Lane Width, mts		3.30 - 3.65	3.30 - 3.65
3	Shoulder Width, mts		Int: 1.0 - 1.5, Ext: 1.5 - 1.8	Int: 0.5 - 1.0, Ext: 1.0 - 1.8
4	Road Right Width, mts	Recommendation Value	40 - 50	40 - 50
	Road Site Law (1952)	Nic 1	40 (International road)	
		Nic 3	20 (State trunk road)	
		Nic 5	20 (State trunk road)	
		Nic26	20 (State trunk road)	

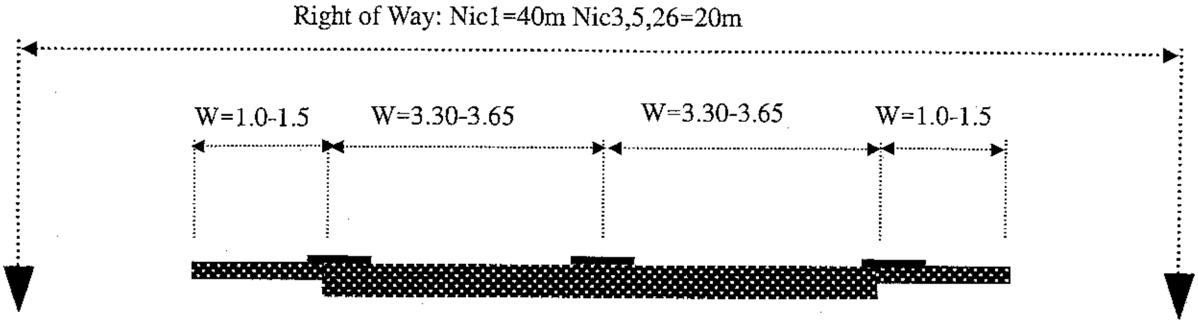


Figure 6.1.1 Standard Typical Cross-section and Right-of-way

Furthermore the recommendable slope gradients are shown in Table 4.4.1 and 4.4.2.

6.1.2 Scale of Disaster

Disaster scale to the carriageway for planning disaster prevention measures is composed of the following contents:

- Influence level of seeped water volume and weathered rocks depth in rainy season and dry seasons,
- Jumping height and rolling distance of unstable rocks from slope to the carriageway,
- Volume of slope slide to the carriageway,
- Influence by bridge foundation scouring, and
- Amount by the shift of road alignment.

1) Measures to the Seeped Water and Weathered Rocks in Rainy and Dry seasons

Just after rainy season, surface water, spring water with some hydraulic gradient and water film oozing were found to contain on wet conditions of slope surface. These wet conditions affect principally weathered layers consisting of a tuff group. The review of such as phenomenon for countermeasures is shown in Table 6.1.4.

2) Measures to the Jumping and Rolling of Unstable Rocks

The wet conditions of slope surface induce new fall of rocks due to repeated dry and wet conditions, reduce bearing capacity due to hair crack-based spalling promotion or collapse due to increasing pore water pressure. This weathering process of the tuff group shifts much-cracked andesite rocks overlaid to overhanging blocks or generates toppling, which will soon lead to falling of the andesite rocks as shown in Figure 6.1.2 and Table 6.1.5. In addition, since the andesite rocks were originally produced by lava flow, they include vertical cooling joints (generates shrinkage cracks generated from lava cooling), the development of their weathering provides a causative factor to cause rock fall.

Table 6.1.4 Influence Level of Slope Surface by Seeped Water and Weathering in Rainy and Dry Season

Route No. Nic.1

Serial Number of Disaster Critical spots	Score of first Phase	Score of Second Phase	ID.No	Kilometer from Managua (km)	Type of disaster	Natural Condition Evaluation	Natural Condition Score
1	70	78	N001A290	60.9	RF	A	10
2	78	84	N001A280	78.2	RF	A	10
3	80	90	Jucuapa	118.19	Bridge	B	6
4	100	100	San Nicolas	135.64	Bridge	C	2
5	90	90	Las Cuevitas (El Ermita)	150.93	Bridge	B	6
6	100	100	San Rafaela	151.85	Bridge	C	2
7	84	84	N001A240	168.4	RF	B	6
8	72	75	N001B230	168.6	RC	B+	6
9	72	72	N001B200	169.8	RC	C	2
10	72	72	N001B180	170.7	RC	B-	4
11	78	81	N001B170	171.3	RC	B	6
12	76	79	N001B150	175.0	RC	A	10
13	74	76	N001B120	175.2	RC	A	10
14	76	76	N001A110	178.7	RF	B+	8
15	73	73	N001B100	187.3	RC	B-	4
16	73	76	N001B070	204.7	RC	B+	8
17	70	70	N001A050	214.7	RF	A	10
18	100	100	Rio Inali	226.89	Bridge	B-	4
19	100	100	Rio Tapacali	233.245	Bridge	C	2
20	75	75	N001B030	232.5	RC	B	6
21	73	73	N001A020	233.7	RF	C	2
22	73	73	N001A010	235.6	RF	B-	4
Sub-total			22spots				

Route No. Nic.3

Serial Number of Disaster Critical spots	Score of first Phase	Score of Second Phase	ID.No	Distance from Sebaco(km) (*Bridge: from Managua)	Type of disaster	Natural Condition Evaluation	Natural Condition Score
23	74	74	003B420	3.9	RC	C	2
24	72	75	003B400	6.9	RC	B+	8
25	80	80	003B376	7.4	RC	B+	8
26	100	100	El Guayacan	115.05	Bridge	A	10
27	74	76	N003B320	22.1	RC	B+	8
28	70	72	N003B240	32.7	RC	B-	4
29	73	73	N003C230	32.9	SS	A	10
30	83	83	N003E170	35.2	DF	A	10
31	71	71	N003C160	35.9	SS	A	10
32	90	90	N003C150	35.9	SS	B+	8
33	90	90	N003C140	39.4	SS	A	10
34	81	83	N003B120	40	RC	B	6
Sub-total			12spots				

Route No. NIC.5

Serial Number of Disaster Critical spots	Score of first Phase	Score of Second Phase	ID.No	Distance from Matagalpa (km)	Type of disaster	Natural Condition Evaluation	Natural Condition Score
35	76	80	N005A010	24.6	RF	A	10
Sub-total			1spots				

Route No. Nic.15

Serial Number of Disaster Critical spots	Score of first Phase	Score of Second Phase	ID No	Distance from Las Manos (km)	Type of disaster	Natural Condition Evaluation	Natural Condition Score
36	70	70	N015E010	9.9	DF	A	10
37	70	70	N015E020	11.1	DF	A	10
38	70	70	N015E050	11.7	DF	B-	4
39	70	70	N015E060	13.6	DF	B-	4
Sub-total			4spots				28

Route No. Nic.26

Serial Number of Disaster Critical spots	Score of first Phase	Score of Second Phase	ID No	Distance from I.D. between San Ishidoro & Sebaco (km) (*Bridge: from Managua)	Type of disaster	Natural Condition Evaluation	Natural Condition Score
40	71	71	N026A010	9.0	RF	B	6
41	70	70	N026A020	12.7	RF	B	6
42	71	71	N026A030	19.9	RF	C	2
43	72	72	N026A040	20.9	RF	C	2
44	70	78	N026A060	24.7	RF	A	10
45	100	100	La Sorpresa	170+952	Bridge	C	2
46	76	78	N026A100	28.3	RF	B	6
47	73	73	N026B110	28.6	RC	C	2
48	72	72	N026A130	33.6	RF	B	6
49	80	80	N026B140	34.0	RC	A	10
50	85	87	N026A150	34.2	RF	A	10
51	86	86	N026B160	37.0	RC	A	10
52	90	90	San Juan de Dios	156+785	Bridge	B-	4
53	71	71	N026B210	45.5	RC	B	6
54	90	90	Papalón	106+154	Bridge	C	2
55	100	100	Sofía	107+532	Bridge	C	2
Sub-total			16spots				
Total			Nic.1,3,5,15,26				

RF Rock Falling
RC Rock Collapsing
SS Slope slide
DF Debris Flow
Bridge Scoring of fundation

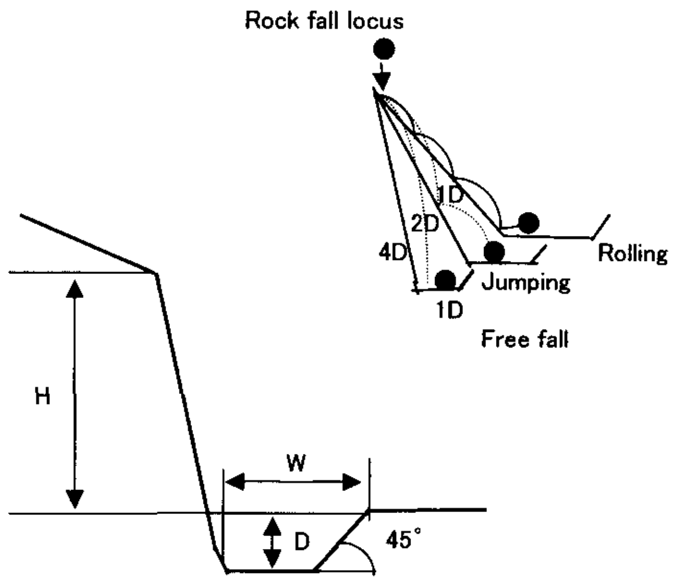


Figure 6.1.2 Model of Rock fall Locus by Ritchie's Design Case

Table 6.1.5 Calculation Result of Rock Fall Analysis

This survey-based calculation and Ritchie's design case for rock fall prevention groove works (1998)						
	Slope gradient (°)	Slope height (m)	This calculation example		Ritchie's design case	
			Rolling quantity (m)	Jumping quantity (m)	Groove width (W) (m)	Groove depth (D) (m)
Bedrock slope	80	5~10	2.0	5.0	3.7	1.0
		10~20	2.5	8.0	4.6	1.2
		>20	3.0	10.0	6.1	1.2
	70	0~10	1.5	2.8	3.7	1.0
		10~20	1.6	3.9	4.6	1.2
		>20	1.7	5.8	6.1	1.8'
		>30	2.0	6.5	7.6	1.8'
	60	5~10	1.2	2.8	3.7	1.2
		10~20	1.3	3.1	4.6	1.8'
		20~30	1.4	3.8	6.1	1.8'
		>30	1.7	3.9	7.6	2.7'
	50	0~10	0.4	0.0	3.7	1.0
		10~20	0.7	1.0	4.6	1.2
		>20	0.8	1.3	4.6	1.8'
	40	0~10	0.3	0.0	3.7	1.0
		10~20	0.3	0.0	3.7	1.5'
		>20	0.7	0.5	4.6	1.8'

('): In case of using prevention fences, 1.2m shall be applied.

In this calculation case, a block diameter shall be 1m.

3) Measures to the Slope Slide

A mechanism of slope slide occurs as shown in Figure 6.1.3. The results of slope stability analysis, geological data are obtained from the geological investigation, are shown in Table 6.1.6.

Figure 6.1.3 Mechanism of Slope Slide

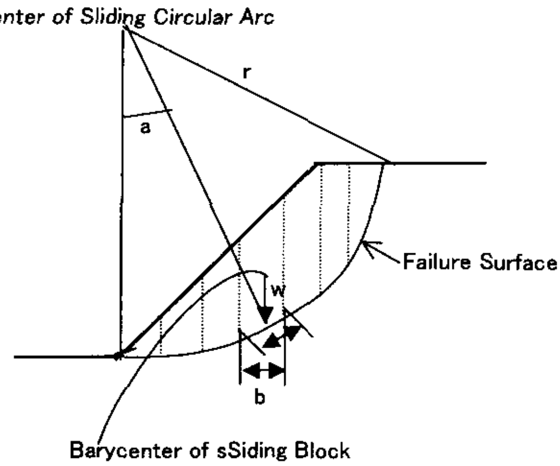


Table 6.1.6 Result of Slope Stability on Project Roads

NIC-1 A280	Cross Section	Fs	Notes
Back Analysis of stability	NIC1 A280 Normal groundwater level (+ EL.424m)	1.05	Rainy season
	NIC1 A280 High groundwater level (+ EL.430m)	0.97	At heavy rain in rainy season

NIC-3 C230	Cross Section	Fs	Notes
Back Analysis of stability	NIC-3 C230 Back analysis Normal groundwater + EL.1011m	1.06	Rainy season
Cutting Slope	NIC-3 C230 Medium groundwater + EL.1022m	1.01	At heavy rain in rainy season
	NIC-3 C230 High groundwater + EL.1032m	0.79	At downpour in rainy season
Large slope failure including the road	NIC-3 C230 Normal groundwater + EL.1011m	1.44	Rainy season
	NIC-3 C230 Medium groundwater + EL.1022m	1.17	At heavy rain in rainy season
	NIC-3 C230 High groundwater + EL.1032m	1.02	At downpour in rainy season
Back Analysis of stability of cut and fill	NIC-3 C230 Shoulder back analysis Normal groundwater + EL.1011m	1.00	Rainy season
Top weight of shoulder	NIC-3 C230 Shoulder counter weight Normal groundwater + EL.1011m	1.44	Rainy season
	NIC-3 C230 Shoulder counter weight High groundwater + EL.1022m	1.00	At heavy rain in rainy season

NIC-3 C150	Cross Section	Fs	Notes
Back Analysis of stability	NIC-3 C150 Back analysis Normal groundwater + EL.1366m	1.02	Rainy season
Cutting Slope	NIC-3 C230 High groundwater + EL.1379m	0.94	At heavy rain in rainy season
Large scale slope slide including the road	NIC-3 C150 Normal groundwater + EL.1366m	1.14	Rainy season
	NIC-3 C150 High groundwater + EL.1379m	0.99	At heavy rain in rainy season
Back Analysis of stability of cut and fill	NIC-3 C150 Shoulder back analysis Normal groundwater + EL.1011m	1.02	Rainy season
Top weight of shoulder	NIC-3 C150 Shoulder counter weight Normal groundwater + EL.1011m	1.14	Rainy season
	NIC-3 C150 Shoulder counter weight High groundwater + EL.1022m	1.01	At heavy rain in rainy season

NIC-3 C140	Cross Section	Fs	Notes
Back Analysis of stability	NIC-3 C14 Back analysis High groundwater + EL.1411m	0.91	At heavy rain in rainy season
Large scale slope failure including the road	NIC-3 C14 Normal groundwater + EL.1404m	1.40	Rainy season
	NIC-3 C14 general failure High groundwater + EL.1379m	0.99	At heavy rain in rainy season
Back Analysis of cut and fill	NIC-3 C14 Shoulder back analysis High groundwater + EL.1404m	0.90	At heavy rain in rainy season
Top weight of shoulder	NIC-3 C14 counter weight Normal groundwater + EL.1404m	1.15	Rainy season
	NIC-3 C14 counter weight High groundwater + EL.1379m	0.99	At heavy rain in rainy season

NIC-5	Cross Section		Fs	Notes
Back Analysis (1)	Back Analysis	NIC-5 Back analysis High ground water (+ EL.558m)	1.00	At heavy rain in rainy season
Recutting (earth removal)	Cut to 40 deg	NIC-5 θ =40 deg Normal groundwater (+ EL.550m)	1.04	Rainy season
		NIC-5 θ =40 deg Normal groundwater (+ EL.558m)	1.00	At heavy rain in rainy season
	Cut to 35 deg	NIC-5 θ =35 deg Normal groundwater (+ EL.550m)	1.21	Rainy season
		NIC-5 θ =35 deg Normal groundwater (+ EL.558m)	1.12	At heavy rain in rainy season
Back Analysis (2)	Back Analysis	NIC-5 Back analysis High ground water (+ EL.558m)	1.01	At heavy rain in rainy season
Recutting (earth removal)	Cut to 40 deg	NIC-5 θ =40 deg Normal groundwater (+ EL.550m)	1.10	Rainy season
		NIC-5 θ =40 deg Normal groundwater (+558m)	1.02	At heavy rain in rainy season
	Cut to 35 deg	NIC-5 θ =35 deg Normally groundwater (+550m)	1.12	Rainy season
		NIC-5 θ =35 deg High groundwater (+558m)	1.10	At heavy rain in rainy season

4) Influence by the Bridge Foundation Scouring

The depth of scouring can be estimated based on the result of experiment conducted by the National Institute for the Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport in Japan (former Public Works Research Institute) as shown in Figure 6.1.4.

The case, which calculates in this table, is a range of ho/D<3.5.

(ho: Mean water depth in flood, D: Width of pier).

The calculation example is shown as follows.

Width of river : W=31.6m

Width of pier : D= 1.1m

Velocity of High water level : V=60.12

Mean water depth in flood : ho=2.67m

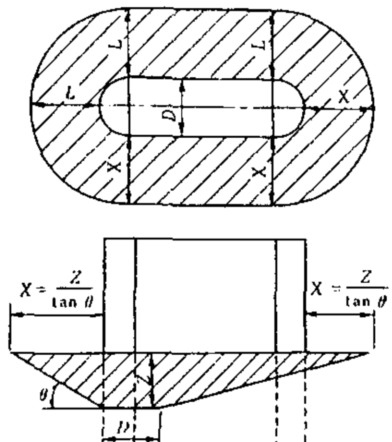
Average grain diameter of riverbed materials : dm=3.0mm

ho/D=2.43

Fr = (V/(W·ho))/$\sqrt{(g \cdot ho)}$ = 0.14

Ratio of depth and grain diameter

ho/dm=890



X: Horizontal distance of the range of scouring

Z: Maximum depth of scouring

θ :Angle of repose

D: Width of pier

Figure 6.1.4 Area of Scouring

Z/D can obtain ho/D from relation (Figure 6.1.5-6.1.8) between ho/dm and Fr as a parameter.

Z/D =0.8

Z =0.96m

The relation between the angle of repose ? and average grain size is shown by Figure 6.1.9.

Angle of repose ?=32°

Tan?=0.62

X=Z/tan θ =1.54m

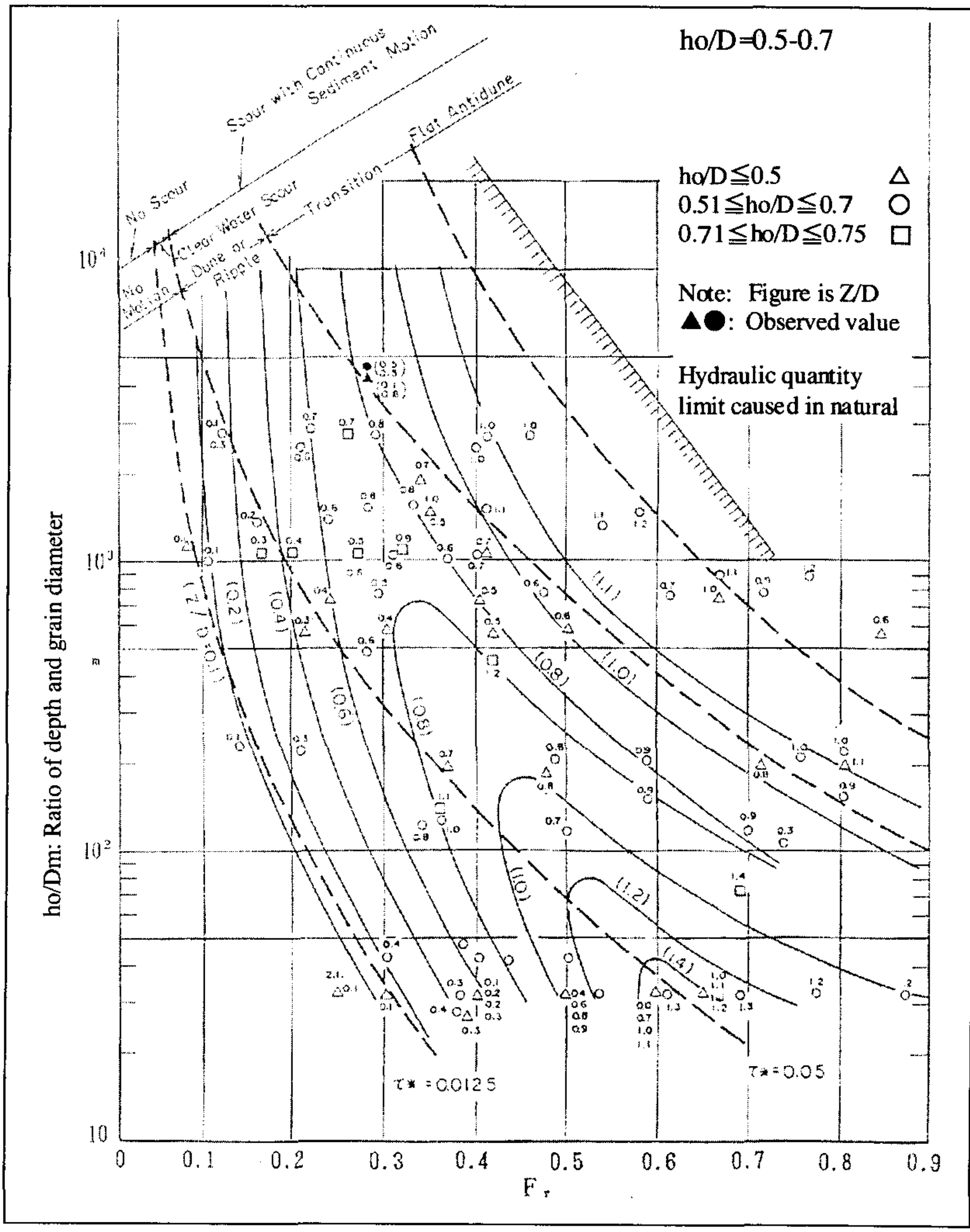


Figure 6.1.5 Assumption of Depth of Scour (ho/D= 0.5-0.7)

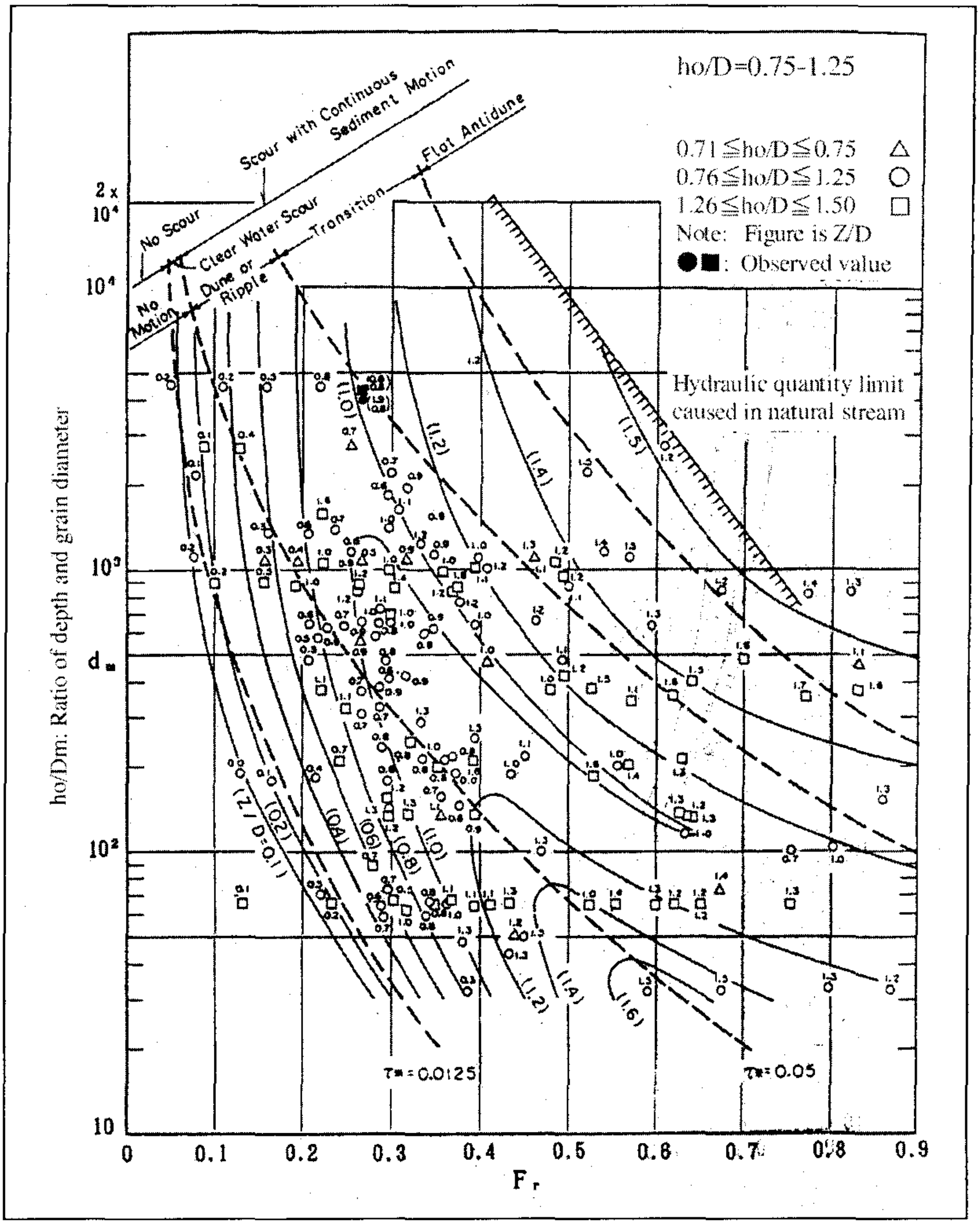


Figure 6.1.6 Assumption of Depth of Sour (ho/D= 0.75-1.25)

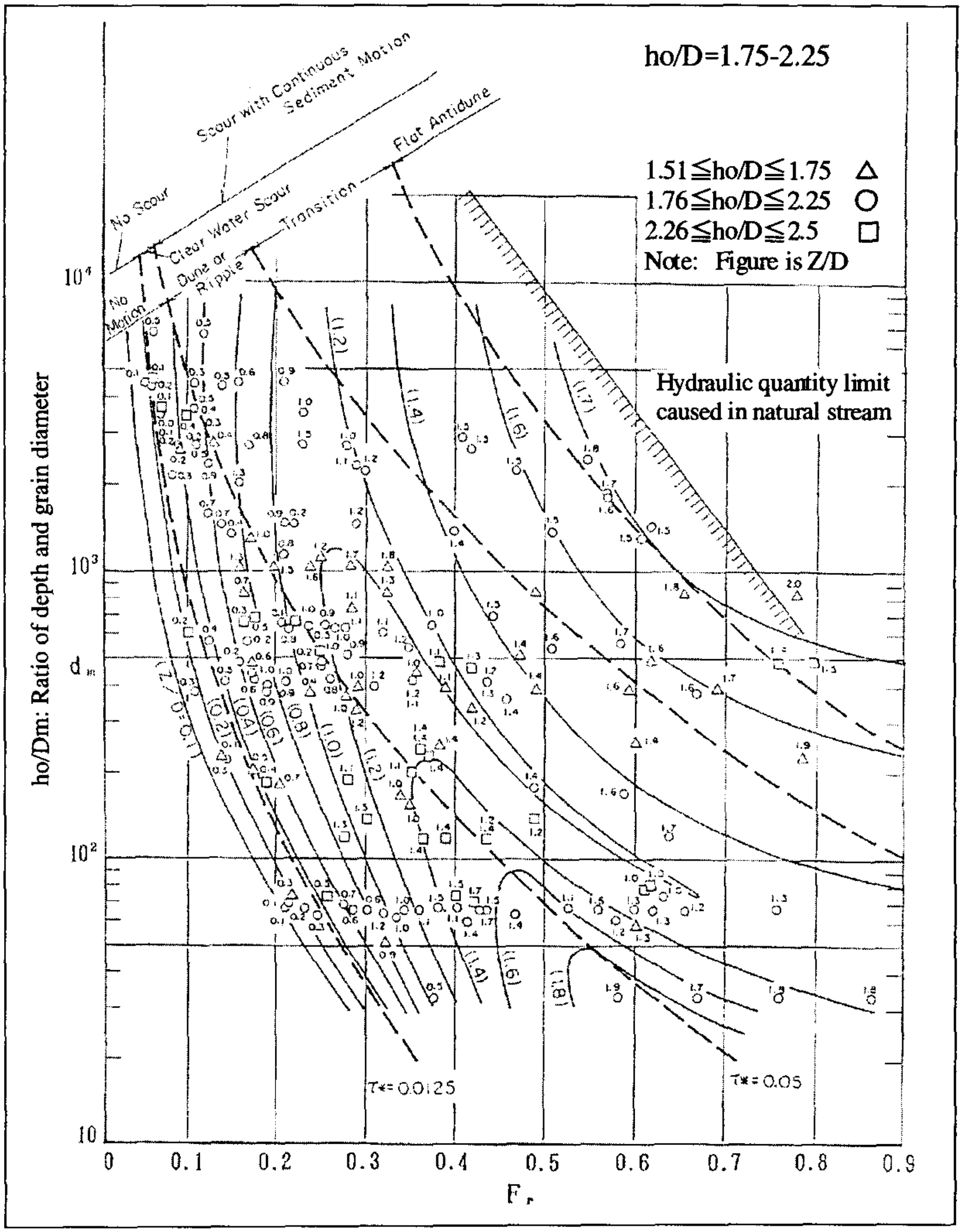


Figure 6.1.7 Assumption of Depth of Scour (ho/D=1.75～2.25)

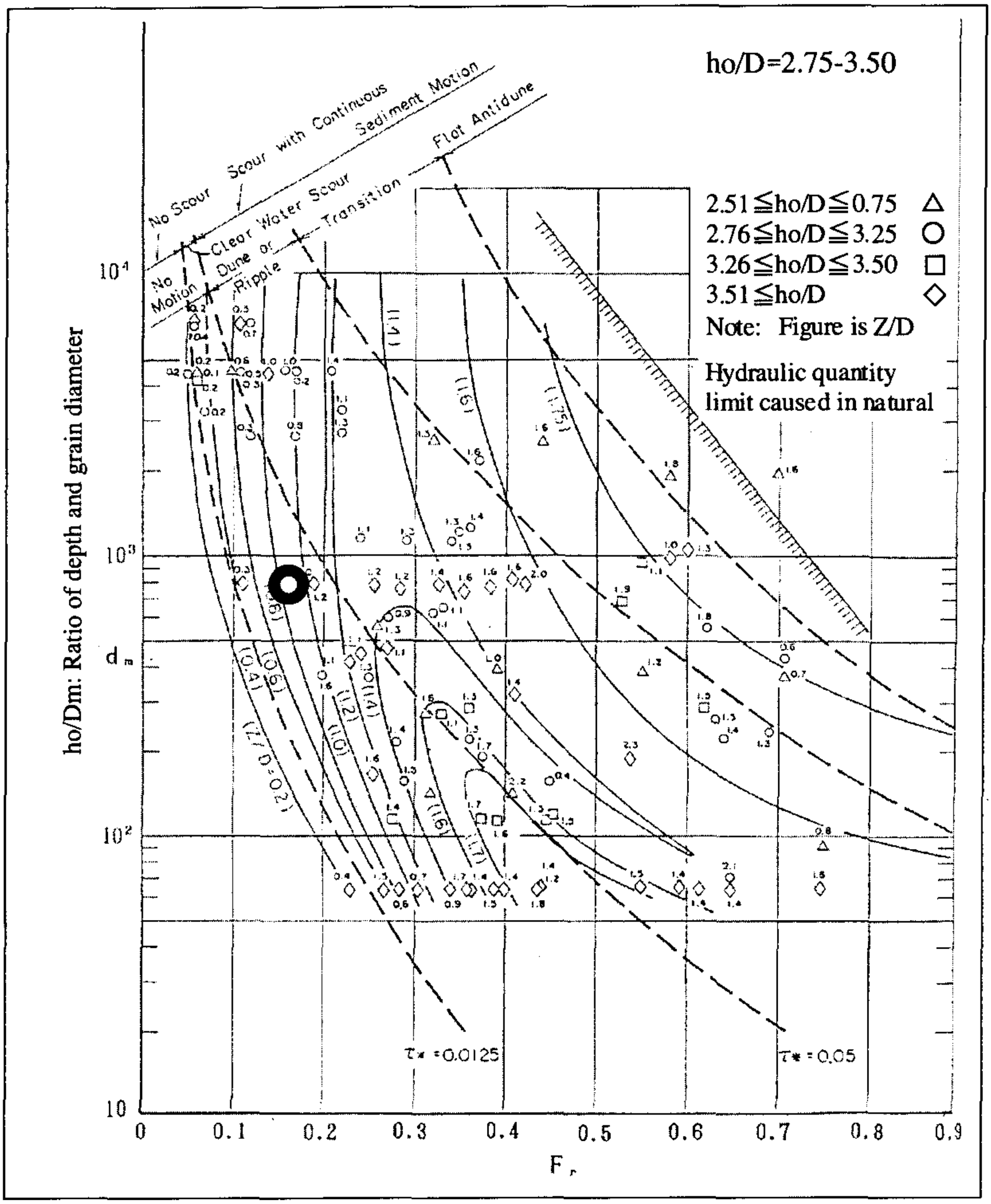


Figure 6.1.8 Assumption of Depth of Scour (ho/D=2.75~3.50)

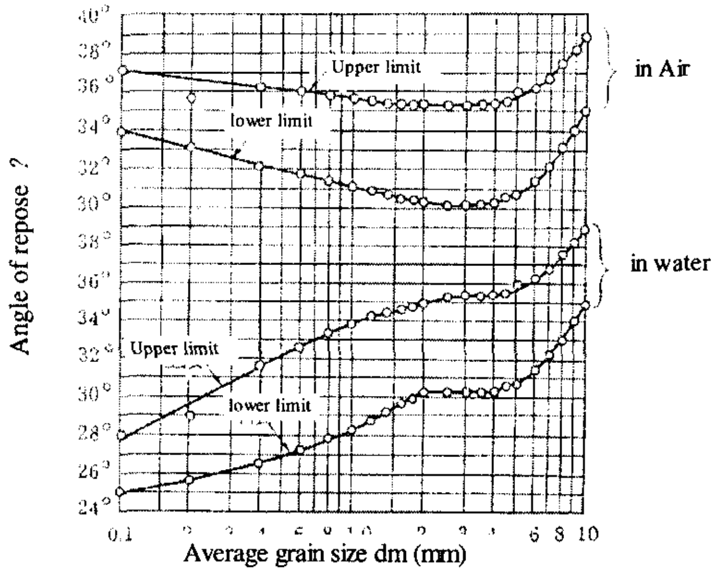


Figure 6.1.9 Relation between Average Grain Size and Angle of Repose

When the rubble and concrete block are used to the scouring part, the weight and size of those materials differs with the velocity of water flow. The value of relation between weight of block and velocity of water flow is shown in Figure 6.1.10 and Table6.1.7.

Figure 6.1.10
Relation between Size of Rubble and Velocity of Water

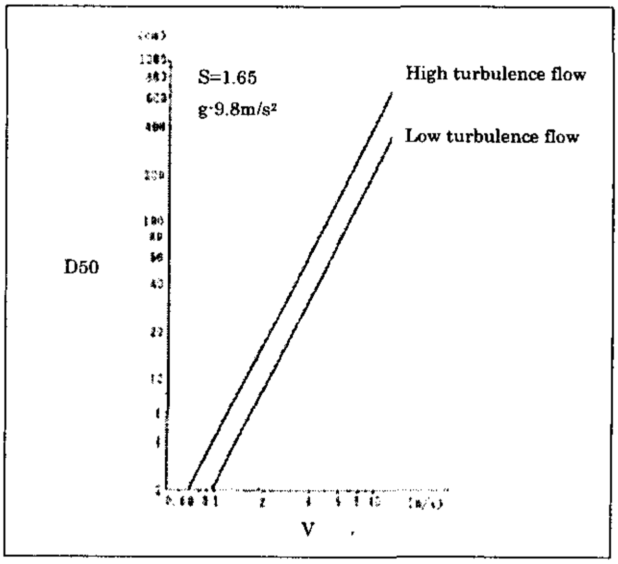


Table 6.1.7 Relation between Weight of Block and Velocity of Water Flow

Shape	Weight of Block (kg)	Velociity of Water Flow (m/s)
Flat type	1.0	2.5
	2.0	3.0
	3.0	3.5
	4.0	4.0
	5.0	4.5
	6.0	5.0

5) Amount by the Shift of Road Alignment

The countermeasure to the shift amount of the road alignment is shown in Figure 6.1.11.

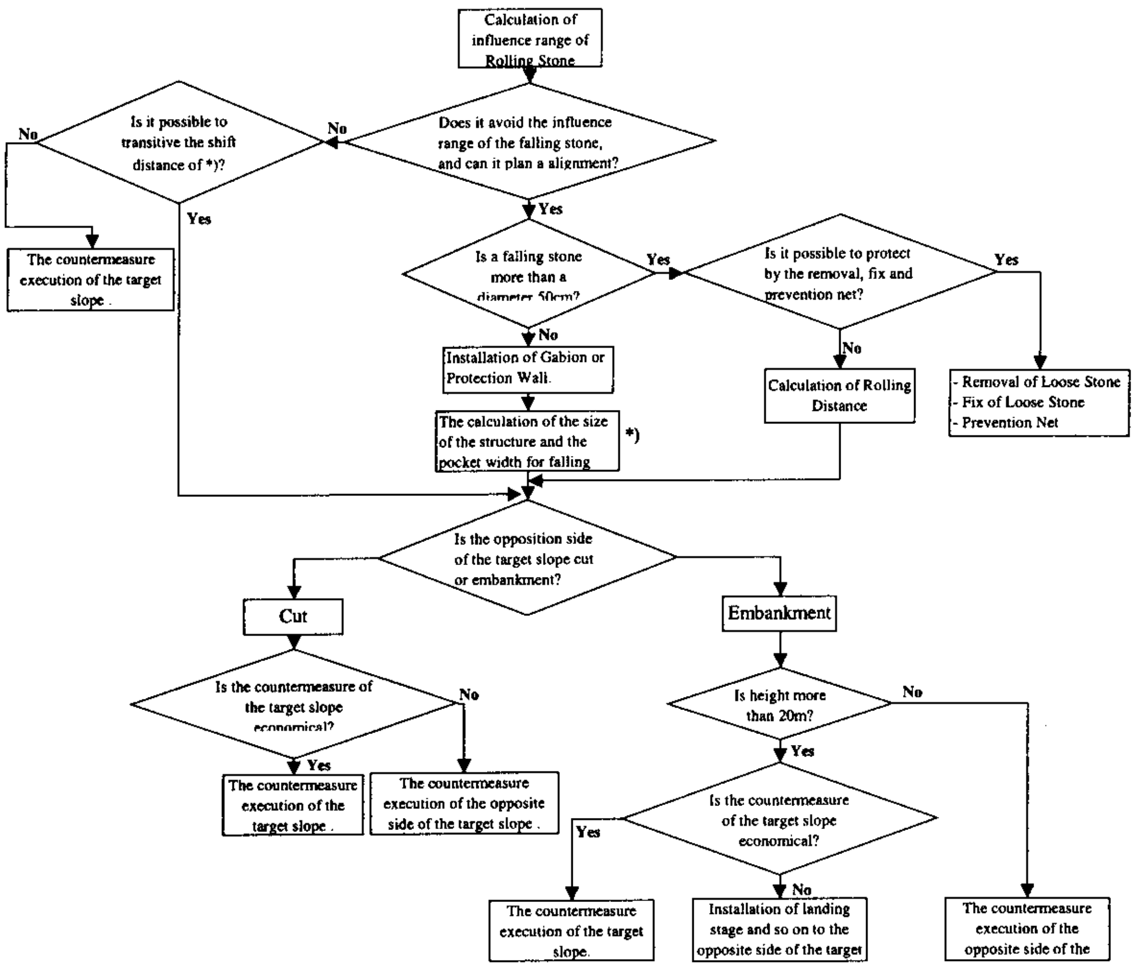


Figure 6.1.11 Flow of Countermeasure of Road Alignment Shift

The road situations of ach spot are shown in Table 6.1.8. The spot N003E170 on NIC3 is not enough to keep the curve radius. Its comparison of the countermeasures and the cost against the curve radius is shown in Table 6.1.9.

Table 6.1.8
Curve Radius of Each Spot

ID No.	Standard Min. Radius (m)	Existing Radius (m)	Range of Rolling Qt.
N001A290	135	1600	1.0
N001A240	135	250	1.0
N001B230	135	150	6.9
N001B170	135	180	7.4
N001B150	135	290	5.1
N001B120	135	220	7.0
N003B400	135	200	3.0
N003B370	135	400	3.0
N003B320	135	240	-
N003E170	135	45	3.0
N005A010	135	1800	1.0
N026A060	135	∞	2.7
N026A140	135	250	4.0
N026A150	135	150	7.0
N026A160	135	∞	2.7

Table 6.1.9 Countermeasures Comparison of N003E170

Route	Min. Radius	Vertical Grade	Component of Length	Rough Construction Cost US$1,000	Evaluation
Existing	R=45m	I= 7.9%	–	310	Safety to the debris flow and the falling stone of the scale made the target is secured. Safety is secured by the curve widening though a curve radius doesn't satisfy geometry standard. And, a construction cost is the most economical. ○
Route A	R=65m	I=14.3%	**Earth Work: 106m** Embankment (6,500m3) **Pavement: 912m2** **Br : 97m (805m2)**	1,774	Safety to the debris flow and the falling stone is secured. But, a curve radius and a vertical grade don't satisfy geometry standard. And, the construction cost is the most expensive, too. Because of this, it is inferior to the geometric safety and the economy. ×
Route B	R=135m	I=14.8%	**Earth Work: 120m** Embankment (5,000m3) **Pavement: 1,032m2** **Br: 93m (770m2)**	1,649	Safety to the debris flow and the falling stone is secured. But, a vertical grade becomes more than standard value, and there is a problem in hill claiming ability. Moreover, the construction cost is expensive and inferior to the geometric safety and the economy, too. △

*) Standard Max. Vertical Grade: 8.0%

6.1.3 Adequate Countermeasures

1) Cut and Embankment Slope

The adequate countermeasures for cut and embankment slope are shown in between Table 6.1.10 and Table 6.1.15. Countermeasure selection of each spot is presented in Appendix-6.

Table 6.1.15 Applicability of Each Measurement to Each River

Name	Rubble Gabion	Concrete	Concrete Block	Explanatory remarks
Junqillal	A	C	C	It is predictable that the settlement will occue due to the soft riverbed. The velocity of water flow is slow. The river always has water flow.
San Nicolas	A	C	C	The velocity of water flow is slow. The river always has water flow.
Las Chanillas	C	B	A	The velocity of water flow is fast.
San Ramon	A	C	C	It is predictable that the settlement will occue due to the soft riverbed.
Inali	C	B	A	The velocity of water flow is fast.
Tapacali	C	B	A	The velocity of water flow is rather fast. The river always has water flow.
El Guayacan	A	A	A	The velocity of water flow is slow. There is a season when the water flow in the river dissapears.
Solis	C	A	B	The velocity of water flow is fast. The riverbed is consisted of soft rock. The block is not economical because the width of river is narrow.
Papalon	C	A	B	The velocity of water flow is fast. The riverbed is consisted of soft rock. The block is not economical because the width of river is narrow.
San Juan de Dios	A	C	C	It is predictable that the settlement will occue due to the soft riverbed. The economical advantage is excellent.
La Banderita	A	C	C	The velocity of water flow is relatively fast. The economical advantage is excellent.

A : Advisable measure

B : Appliable measure

C : Measure difficult to apply

6.2 Construction Plan and Construction Cost

6.2.1 Construction Plan

1) General

The following items are studied for construction plan.

-Clarification of conditions for cost estimate,
-Quantities estimate of the each prevention spot,
-Investigation of unit rate of the each prevention countermeasure,
-Construction costs of the each prevention spot, and
-Maintenance costs on each route.

2) Conditions for Cost Estimate

The construction costs of each prevention spot are estimated as a direct cost. Furthermore the direct temporally cost, the common temporary cost, the site expenses as indirect cost and the overhead are estimated with a direct cost. But their costs are omitted due to the different condition according to the sites.

3) Unite rate

Unite rate surveyed in Nicaragua is shown in Table 6.2.1.

Table 6.2.1 Unite Rates

Classification	Type of Work	Remarks	Unit	Unit Rates
(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 f 0.04	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
	Concrete cribwork	0.3×0.3 @2.0m	m^2	100.00
	Concrete block crib	0.3×0.3 @2.0m	m^2	-
	Gabion mat		m^3	43.67
(5) Structure 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	-
	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	8.53
	Prevention fence		m^2	-
	Barrier with earth fill		m^3	-
	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	654.95
	Gabion mat		m^3	97.49
	Stone riprap with mortar		m^3	66.91
	Concrete cribwork for riverbed		m^2	39.49
(10)Abutment and pier protection	Gabion foot protection		m^3	43.67
	Sheet-pile toe wall		m^2	-
(11)Bridge structure	Steel bridge with concrete slab		m^2	406.24
	Gravity-type abutment		m^3	37.15
	Reversal T-type abutment(RC)		m^3	197.26
(12)Box culvert	Cast in place	3m×2m	m	1740.6

4) Construction Plan of Each Spot

The main equipments used by construction of each disaster prevention spot are shown in Table 6.2.2 and 6.2.3.

Table 6.2.2 Main Equipments List for Construction of Slope Damages

No	ID.No	Type of Disaster	Type of Countermeasure	Bulldozer	Back hoe	Pick hummer	Shotcrete machine	Truck crane	Vibration roller	Jumbo Breaker	Boring machine
1	N001A290	R.F	Recutting + Prevention net + Drainage		○	○		○			
2	N001A280	R.F	Horizontal drainage								○
3	N001A240	R.F	Recutting + Prevention net		○	○		○			
4	N001B230	R.C	Recutting + Prevention net		○	○		○			
5	N001B170	R.C	Recutting + Drainage		○	○				○	
6	N001B150	R.C	Recutting + Shotcrete + Drainage		○	○	○				
7	N001B120	R.C	Recutting + Drainage		○	○				○	
8	N003B400	R.C	Recutting + Drainage		○	○					
9	N003B370	R.C	Recutting + Drainage		○	○				○	
10	N003B320	R.C	Embankment + Concrete retaining wall + Vegetation	○	○	○			○	○	
11	N003C230	S.S + R.C	Recutting + Cribwork +Drainage Embankment + Vegetation + Drainage	○	○	○		○	○	○	
12	N003E170	D.F + R.C	Dam Recutting + Drainage	○	○	○		○	○	○	
13	N003C150	S.S + R.C	Recutting + Drainage Embankment +Vegetation	○	○	○			○	○	
14	N003C140	S.S + R.C	Recutting + Drainage Embankment +Concrete retaining wall + Vegetation + Drainage	○	○	○		○	○	○	
15	N005A010	R.F	Recutting + Drainage		○	○				○	
16	N026A060	R.F	Recutting + Shotcrete + Drainage		○	○	○				
17	N026B140	R.C	Recutting + Horizontal drainage + Drainage		○	○				○	○
18	N026A150	R.F	Recutting +Drainage		○	○				○	
19	N026B160	R.C	Recutting + Prevention net		○	○		○			

Note: R.F; Rock-fall/collapsing R.C; Rock collapsing S.S; Slope Slide
D.F; Debris flow

Table 6.2.3 Main Equipments List for Construction of Bridge Damages

No	Bridge Name		Type of Disaster	Type of Countermeasure	Bulldozer	Back hoe	Concrete breaker	Truck crane	Jumbo breaker
1	NIC 1	Junquillal	Bridge	Gabion mat		○		○	
2		San Nicolas	Bridge	Gabion mat		○		○	
3		Las Chanillas	Bridge	Concrete block		○		○	
4		San Ramon	Bridge	Gabion mat		○	○	○	
5		Inali	Bridge	Gabion mat Revetment +Stone masonry		○	○	○	
6		Tapacali	Bridge	Gabion mat Revetment		○	○	○	
7	NIC 3	Guayacan	Bridge	New bridge construction	○	○	○	○	○
8	NIC 26	Solis	Bridge	Stone riprap with mortar Gabion mat		○		○	
9		Papalon	Bridge	Stone riprap with mortar Gabion mat		○		○	
10		San Juan de Dios	Bridge	Gabion mat		○		○	
11		La Banderita	Bridge	Stone riprap wall Gabion mat		○		○	

Note: Bridge; Scouring of foundation

5) Work Quantities

(a) Summary of Work Quantities

The six roads have 19 slope damages and 11 bridge foundation damages regarding the disaster prevention spots in total respectively. Work quantities for the prevention spots are estimated based on countermeasure types and drawings. The summary of work quantities is shown in Table 6.2.4.

Table 6.2.4 Summary of Work Quantities

Classification	Type of Work	Remarks	Unit	Quantities		
				Slope	Bridge	Total
(1) Surface drainage	Crest ditch	0.5×0.5 1:1	m	2,758	0	2,758
	Berm ditch	U-0.3×0.3	m	4,115	0	4,115
	Toe ditch		m	2,934	400	3,334
	Vertical ditch	U-0.3×0.3	m	1,321	0	1,321
(2) Horizontal drainage	Horizontal drain hole	PVC PIPE f 0.04	m	546	0	546
(3) Vegetation	Seed spraying with pump		m^2	7,551	0	7,551
(4) Structure	Shotcrete	t=10cm	m^2	3,856	0	3,856
	Concrete cribwork		m^2	711	0	711
	Gabion mat		m^3	0	490	490
(5) Structural support	Stone riprap wall		m^2	0	1126	1,126
	Gravity-type retaining wall		m^3	164	0	164
	Gabion wall		m^3	0	0	0
	T-shaped retaining wall		m^3	1,077	0	1,077
(6) Earth work	Removal		m^3	0	0	0
	Rock cutting		m^3	60,011	0	60,011
	Rock pre-splitting	Rock blasting	m^3	0	108	108
	Soil cutting		m^3	40,394	0	40,394
	Embankment		m^3	27,354	3500	30,854
(7) Rockfall prevention device	Prevention net		m^2	26,032	0	26,032
	Prevention fence		m^2	0	0	0
	Barrier with gabion mat		m^3	0	0	0
	Barrier with concrete wall		m^3	0	0	0
(8) Anchoring	Rock bolt		each	0	0	0
(9) Riverbank protection	Concrete revetments		m^3	0	2107	2,107
	Gabion mat		m^3	812	3327	4,139
	Stone riprap with mortar		m^3	0	122	122
	Concrete cribwork for riverbed		m^2	0	0	0
(10) Abutment and pier protection	Gabion foot protection		m^3	0	0	0
(11) Bridge structure	Steel bridge with concrete slab		m^2	0	500	500
	Gravity-type abutment		m^3	0	58	58
	Reversal T-type abutment(RC)		m^3	0	487	487
(12) Box culvert	Cast in place	3m × 2m	m	14	0	14

(b) Work Quantities of Each Disaster Prevention Spot

Work quantities for each disaster prevention spot are shown in Table 6.2.5 – Table6.2.11.

a) NIC 1

Table 6.2.5 Work Quantities of Countermeasures for Slope Damages on NIC 1

No	ID No.	Type of Disaster	Type of Countermeasure		Unit	Quantity
1	N001A290	R.F	Recutting + Prevention net + Drainage	T	m^2	23,286
2	N001A280	R.F	Horizontal drainage	P	m	100
3	N001A240	R.F	Recutting + Prevention net	T	m^2	950
4	N001B230	R.C	Recutting + Prevention net	T	m^2	228
5	N001B170	R.C	Recutting + Drainage	P	m^3	36,028
6	N001B150	R.C	Recutting + Shotcrete + Drainage	P	m^2	252
7	N001B120	R.C	Recutting + Drainage	P	m^3	10,655

Note: R.F; Rock-fall R.C; Rock collapsing
P; Permanent countermeasure T; Temporary countermeasure

Table 6.2.6 Work Quantities of Countermeasures for Bridge Foundation Scouring on NIC 1

No	Bridge Name	Type of Disaster	Type of Countermeasure		Unit	Quantity
1	Junquillal	Bridge	Gabion mat	T	m^3	435
2	San Nicolas	Bridge	Gabion mat	T	m^3	114
3	Las Chanillas	Bridge	Concrete block	T	m^3	288
4	San Ramon	Bridge	Gabion mat	T	m^3	86
5	Inali	Bridge	Gabion mat Revetment +Stone masonry	T	m^3 m^2	1,138 1,758
6	Tapacali	Bridge	Gabion mat Revetment	T	m^3 m^2	238 640

Note: Bridge; Scouring of foundation
T; Temporary countermeasure

b) NIC 3

Table 6.2.7 Work Quantities of Countermeasures for Slope Damages on NIC.3

No	ID No.	Type of Disaster	Type of Countermeasure		Unit	Quantity
1	N003B400	R.C	Recutting + Drainage	P	m^3	290
2	N003B370	R.C	Recutting + Drainage	P	m^3	1,676
3	N003B320	R.C	Embankment + Concrete retaining wall + Vegetation	P	m^3	3,168
4	N003C230	S.S + R.C	Recutting + Cribwork +Drainage Embankment + Vegetation + Drainage	P	m^2 m^3	638 4,934
5	N003E170	D.F + R.C	Dam Recutting + Drainage	P	m m^3	20 2,670
6	N003C150	S.S + R.C	Recutting + Drainage Embankment +Vegetation	P	m^3	9,221 16,076
7	N003C140	S.S + R.C	Recutting + Drainage Embankment +Concrete retaining wall + Vegetation + Drainage	P	m^3	5,408 3,176

Note: R.C; Rock collapsing S.S; Slope Slide D.F; Debris flow
P; Permanent countermeasure

Table 6.2.8 Work Quantities of Countermeasure for Bridge Foundation Scouring on NIC.3

No	Bridge Name	Type of Disaster	Type of Countermeasure		Unit	Quantity
1	Guayacan	Bridge	New bridge construction	P	m^2	500

Note: Bridge; Scouring of foundation
P; Permanent countermeasure

c) NIC 5

Table 6.2.9 Work Quantities of Countermeasures for Slope Damages on NIC.5

No	ID No.	Type of Disaster	Type of Countermeasure		Unit	Quantity (m^3)
1	N005A010	R.F	Recutting + Drainage	P	m^3	10,760

Note: R.F; Rock fall
P; Permanent countermeasure

d) NIC 26

Table 6.2.10 Work Quantities of Countermeasures for Slope Damages on NIC.26

No	ID No.	Type of Disaster	Type of Countermeasure		Unit	Quantity
1	N026A060	R.F	Recutting + Shotcrete + Drainage	P	m^2	3,604
2	N026B140	R.C	Recutting + Horizontal drainage + Drainage	P	m^3	11,495
3	N026A150	R.F	Recutting +Drainage	P	m^3	2,113
4	N026B160	R.C	Recutting + Prevention net	T	m^2	1,568

Note: R.F; Rock fall R.C; Rock collapsing
P; Permanent countermeasure T; Temporary countermeasure

Table 6.2.11 Work Quantities of Countermeasures for Bridge Foundation Scouring on NIC.26

No	Bridge Name	Type of Disaster	Type of Countermeasure		Unit	Quantity
1	Solis	Bridge	Stone riprap with mortar Gabion mat	T	m^3	72 546
2	Papalon	Bridge	Stone riprap with mortar Gabion mat	T	m^3	50 408
3	San Juan de Dios	Bridge	Gabion mat	T	m^3	115
4	La Banderita	Bridge	Stone riprap wall Gabion mat	T	m^2 m^3	162 375

Note: Bridge; Scouring of foundation
P; Permanent countermeasure

(c) Summary of Each Spots Costs

a) NIC 1

Costs for each disaster prevention spot are shown in Table 6.2.12 – Table6.2.18.

Table 6.2.12 Construction Cost of Countermeasures for Slope Damages on NIC.1

No	ID.No	Type of Disaster	Type of Countermeasure		Unit	Quantity	Cost (US$1000)
1	N001A290	R.F	Removal + Prevention net + Drainage	T	m^2	23,286	335
2	N001A280	R.F	Horizontal drainage	P	m	100	10
3	N001A240	R.F	Removal + Prevention net	T	m^2	950	26
4	N001B230	R.C	Removal + Prevention net	T	m^2	228	6
5	N001B170	R.C	Recutting + Drainage	P	m^3	36,028	1,590
6	N001B150	R.C	Recutting + Shotcrete + Drainage	P	m^2	252	27
7	N001B120	R.C	Recutting + Drainage	P	m^3	10,655	814
Total							2,808

Note: R.F; Rock-fall R.C; Rock collapsing
P; Permanent countermeasure T; Temporary countermeasure

Table 6.2.13 Construction Cost of Countermeasures for Bridge Foundation Scouring on NIC.1

No	Bridge Name	Type of Disaster	Type of Countermeasure		Unit	Quantity	Cost (US$1000)
1	Junquillal	Bridge	Gabion mat	T	m^3	435	42
2	San Nicolas	Bridge	Gabion mat	T	m^3	114	25
3	Las Chanillas	Bridge	Concrete block	T	m^3	288	189
4	San Ramon	Bridge	Gabion mat	T	m^3	86	9
5	Inali	Bridge	Gabion mat Revetment +Stone masonry	T	m^3 m^2	1,138 1,758	828
6	Tapacali	Bridge	Gabion mat Revetment	T	m^3 m^2	238 640	282
Total							1,375

Note: Bridge; Scouring of foundation
T; Temporary countermeasure

b) NIC 3

Table 6.2.14 Construction Cost of Countermeasures for Slope Damages on NIC.3

No	ID No.	Type of Disaster	Type of Countermeasure		Unit	Quantity	Cost (US$1000)
1	N003B400	R.C	Recutting + Drainage	P	m^3	290	40
2	N003B370	R.C	Recutting + Drainage	P	m^3	1,676	175
3	N003B320	R.C	T-shaped retaining wall +Refilling+ Vegetation+ Drainage	P	m^3	3,168	239
4	N003C230	S.S + R.C	Recutting + Cribwork + Vegetation+ Drainage Embankment + Vegetation + Drainage	P	m^2 m^3	638 4,934	328
5	N003E170	D.F + R.C	Concrete dam + Box culvert Recutting + Drainage	P	m m^3	20 2,670	310
6	N003C150	S.S + R.C	Recutting + Drainage Embankment +Vegetation+ Drainage	P	m^3	9,221 16,076	918
7	N003C140	S.S + R.C	Recutting +Horizontal drainage + Drainage Embankment +T-shaped retaining wall + Vegetation + Drainage	P	m^3	5,408 3,176	749
Total							2,759

Note: R.C; Rock collapsing S.S; Slope Slide D.F; Debris flow
P; Permanent countermeasure

Table 6.2.15 Construction Cost of Countermeasures for Bridge Foundation Scouring on NIC.3

No	Bridge Name	Type of Disaster	Type of Countermeasure		Unit	Quantity	Cost (US$1000)
1	El Guayacan	B.F.S	New bridge construction	P	m^2	500	1,379

Note: Bridge; Scouring of foundation
P; Permanent countermeasure

c) NIC 5

Table 6.2.16 Construction Cost of Countermeasures for Slope Damageds on NIC.5

No	ID No.	Type of Disaster	Type of Countermeasure		Unit	Quantity	Cost (US$1000)
1	N005A010	R.F	Recutting + Drainage	P	m^3	10,760	389

Note: R.F; Rock fall
P; Permanent countermeasure

d) NIC 26

Table 6.2.17 Construction Cost of Countermeasures for Slope Damages on NIC.26

No	ID No.	Type of Disaster	Type of Countermeasure		Unit	Quantity	Cost (US$1000)
1	N026A060	R.F	Recutting + Shotcrete + Drainage	P	m^2	3,604	316
2	N026B140	R.C	Recutting + Horizontal drainage + Drainage	P	m^3	11,495	904
3	N026A150	R.F	Recutting +Drainage	P	m^3	2,113	210
4	N026B160	R.C	Removal + Prevention net +Drainage	T	m^2	1,568	13
Total							1,443

Note: R.F; Rock fall R.C; Rock collapsing
P; Permanent countermeasure T; Temporary countermeasure

Table 6.2.18 Construction Cost of Countermeasures for Bridge Foundation Scouring on NIC.26

No	Bridge Name	Type of Disaster	Type of Countermeasure		Unit	Quantity	Cost (US$1000)
1	Solis	Bridge	Stone riprap with mortar Gabion mat	T	m^3	72 546	66
2	Papalan	Bridge	Stone riprap with mortar Gabion mat	T	m^3	50 408	51
3	San Juan de Dios	Bridge	Gabion mat	T	m^3	115	5
4	La Banderita	Bridge	Stone riprap wall Gabion mat	T	m^2 m^3	162 375	31
Total							153

Note: Bridge; Scouring of foundation
P; Permanent countermeasure

6) Total Cost

Total construction cost for each route is shown in Table 6.2.19.

Table 6.2.19 Total Construction Cost

Objective Route	Cost (US$1000)		
	Slope	Bridge	Total
NIC 1	2,808	1,375	4,183
NIC 3	2,759	1,379	4,138
NIC 5	389	0	389
NIC 26	1,443	153	1,596
Total	7,399	2,907	10,306

US$1=C$14.4(exchange rate; October 14,2002)

7) Maintenance Cost

Main road maintenance cost is 1,340 US$ per year in MTI. Therefore maintenance cost for permanent countermeasures is assumed with 2 % per year after construction.

6.3 Environmental Impact Assessment

6.3.1 Description of Disaster Prevention Spots

1) General

The countermeasures for the disaster prevention spots planed by construction plan should be carried out the assessment of environmental impact. The consideration to the environment is judged with " The summary of general matters for environment observance in the construction stage" (Chapter 5 of NABCV in NIC 2000). Difficult items of evaluation and environmental consideration under construction are suggested as the notes in later article 3.

2) Evaluation of Environmental Consideration

a) Resettlement

Resettlement, its subject was a hotel under construction, was expected at one of the disaster prevention spots on NIC.3. However, the countermeasure of its spot was considered as shown in Table 6.3.1.

Table6.3.1 Consideration Contents for Resettlement of Residents

Site No.	Countermeasure	
	Draft	Final
N003B320	Re-cutting of the cut slope was expected to influence a hotel under construction.	Reversed T typed retaining wall was planed without re-cutting.

Table 6.3.2 shows the land acquisition for countermeasure work of each project road. Each spot is not influence of the land acquisition by Nicaraguan law.

Table 6.3.2 Consideration Contents for Land acquisition

NIC 1

No.	Owner of the land	Land use	Countermeasure
N001B120	No available information	Shrub and second growth vegetation	Re-cutting, Concrete frame + Cobble, Drainage, Removal of Bolder
N001B150	Paulo Gonzalez	Pasture land	Slope fairing, Shotcrete, Drainage
N001B170	Paulo Gonzalez	Pasture lands	Slope fairing, Concrete frame + Vegetation, Drainage, Removal of Bolder
N001A280	Nicasia Gutierrez	Pasture land	Re-cutting, Vegetation, Drainage
N001A290	Carlos Rodriguez	Pasture land, corn, wood	Barrier with wall, Dainage, Removal of Bolder

NIC3

No.	Owner of land	Land use	Countermeasure
N003B400	Rafael Rayos Torres	Pasture land	Re-cutting, Concrete frame + Vegetation, Drainage,
N003B370	No available information	Pasture land	Re-cutting, Concrete frame + Vegetation, Drainage,
El Guayacan	José Antonio Hernandez Gonzalez, José Manuel Gustamante	Pasture land Family house	Re-construction of Bridge
N003B320	Roger Castillo Palma	Recreation	Cantilever Retaining Wall, Back Fill
N003C230	Francisco Frey Gonzalez	Pasture land, forest (pine)	Re-cutting, Concrete frame + Vegetation, Drainage, Re-embankment
N003E170	Erick Kuhl (dueño del hotel Selva Negra), Felipe Lopez	Horticulture	Dam, Re-cutting, Concrete frame + Vegetation, Drainage
N003C150	Jorge Salazar	Coffee plantation	Re-cutting, Concrete frame + Vegetation, Drainage, Cantilever Retaining Wall
N003C140	Manuel Lanzas Ponce	Pasture land	Re-cutting, Concrete frame + Vegetation, Drainage, Cantilever Retaining Wall

NIC5

No.	Owner of land	Land use	Countermeasure
N005A010	Nicolas Lopez	Horticulture	Re-cutting, Concrete frame + Vegetation, Drainage

NIC26

No.	Owner of land	Land use	Countermeasure
N026A060	Fabian y José Altamirano	Corn and others	Slope fairing, Shotcrete, Drainage
N026B140	Abraham Mairena	Pasture land	Re-cutting, Concrete frame + Cobble, Drainage
N026A150	Abraham Mairena	Pasture land	Re-cutting, Concrete frame + Cobble, Drainage
N026B160	Pedro Urritia (father and son)	Pasture land, sometime corn	Prevention Net, Removal of Boulder

b) Economic Activity

4 spots of whole disaster prevention spots were concerned over against the surrounding economic activities. However, the drafts of countermeasures were considered such as the final one as shown in Table 6.3.3.

Table6.3.3 Consideration Contents for Economic Activity

Site No.	Countermeasure	
	Draft	Final
Junquillal (Nic1)	An influence to the irrigation of downstream side has been forecasted with the cofferdam under construction.	The irrigation is kept with the hale by half construction.
N003B320	As mentioned in the Table 5.3.1	As mentioned in the Table 5.3.1

N003C140	Influence by countermeasure construction has been forecasted at a coffee plantation.	A coffee plantation is kept with the construction of a wall.
N003C150	A coffee plantation was confirmed at the top of the slope.	The countermeasure is planed with existing slope gradient.

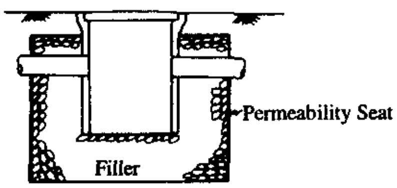
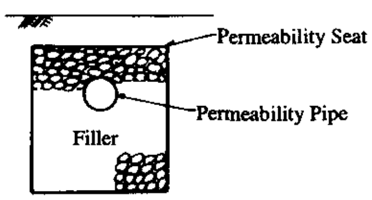
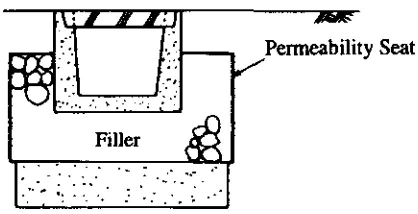
c) Ground Water

Three spots have used the shallow well with the unconfined ground water. The depth of a shallow well is 98 feet at N026B160 spot after resurveying. Therefore, there is no influence with construction because its well is a confined ground water. Other two spots have been considered the countermeasures to avoid the influence to the drain structure as shown in Table 6.3.4 and 6.3.5.

Table 6.3.4 Consideration Contents for Ground Water

Site No.	Countermeasure	
	Draft	Final
N005A010	Re-cutting + Vegetation + Drainage	Concrete Frame + Vegetation + Drainage (permanent catch pit)
N026B140	Re-cutting	Concrete Frame + Cobble + Drainage (permanent catch pit)
N026B160	Judgment as use of the non-confined water	Use of confined water.

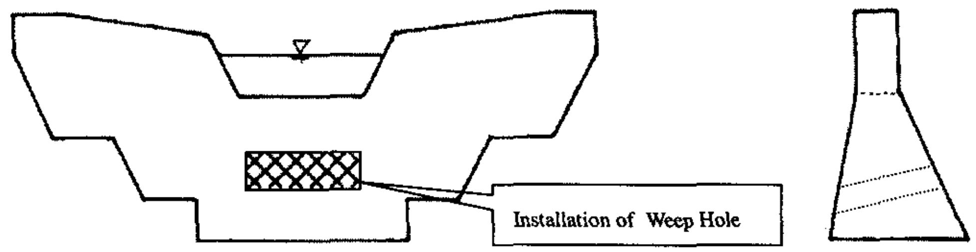
Table6.3.5 Drain Type for Infiltration of Underground Water

Sample Structure	Outline
	Infiltration Catch Pit Infiltration catch pit is the structure composed by catch pit that it has foramen and so on for the side and the bottom, and the filling material of the circumference. And, rainwater is made to permeate from that side and the bottom to the ground.
	Infiltration Trench Infiltration trench is the structure composed by a permeation pipe and the filling material of the circumference. And, rainwater is made to permeate from side and the bottom to the ground.
	Infiltration Side Ditch An infiltration side ditch is the structure composed by the side and the bottom that permeability concrete and/or the concrete that it has foramen are used for the side and the bottom, and the filling material of that circumference. And, rainwater is made to permeate from side and the bottom to the ground.

d) Lake and River

One spot has been concerned over about the influence of discharge volume to the river on NIC.3. However, its subject has been settled by installing the weep hole on the dam wall as shown in Table 6.3.6.

Table6.3.6 Consideration Item for River Use

Site No.	Dam
N003E170	

e) Fauna and Flora

The influence to the national conservation area has been concerned over directly and indirectly at two spots on NIC1 and NIC3. However, its subjects were settled by each method as shown in Table 6.3.7

Table6.3.7 Consideration Contents for Fauna and Flora

Site No.	Pending Contents	Mitigation Measure
San Nicolas (NIC1)	It was concerned over that water supply to the animal has been decreased by the cofferdam with the countermeasures work to the Cerro Tomabu national conservation area of the downstream side.	The riverbed protection is executed in dry season. Therefore it is not necessary to construct the cofferdam in the river.
N003C230	Because the spot was located in Cerro El Arenal national conservation area, the countermeasure should be restored.	It is the plan to restore by vegetating in the concrete frame. (Refer to Figure 6.3.1) The vegetation is carried out by a natural species or latent natural seeding. And, the embankment is planted with trees because of the harmony with the landscape of the circumference.

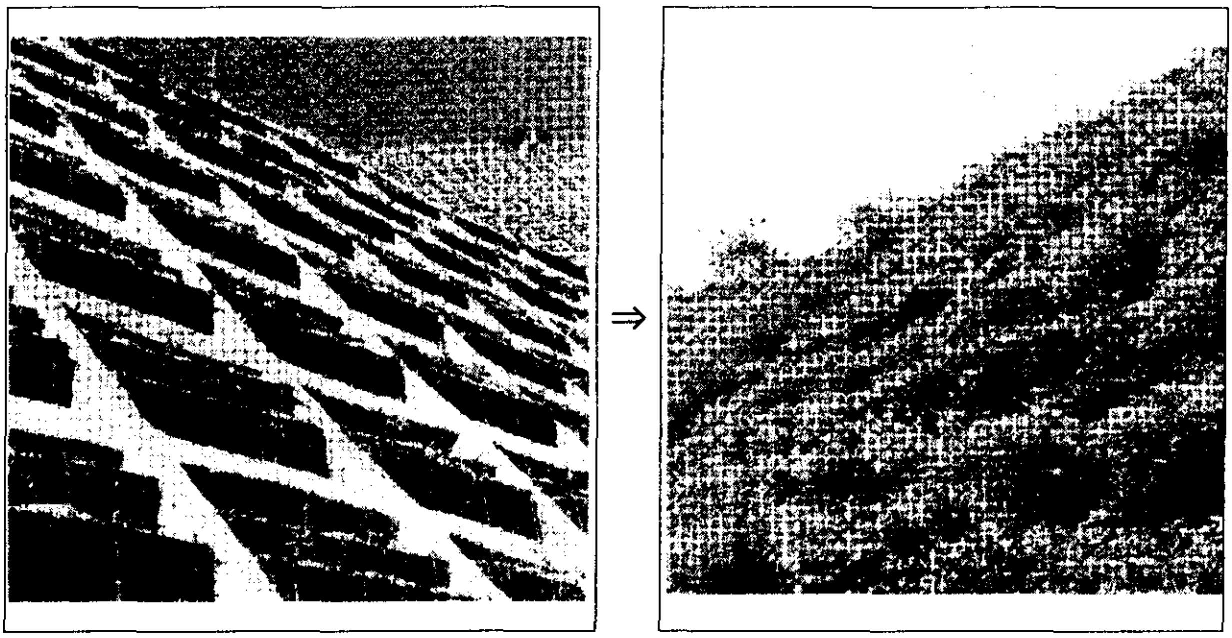


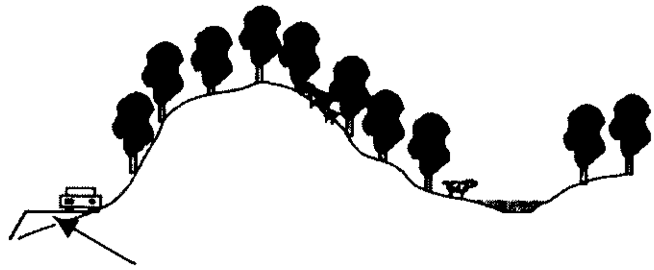
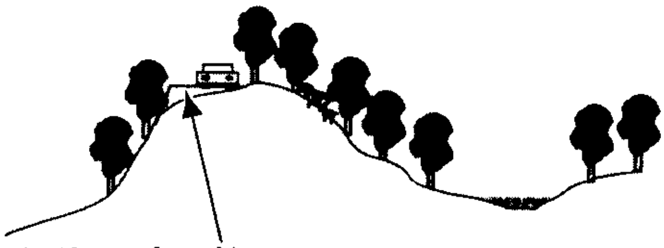
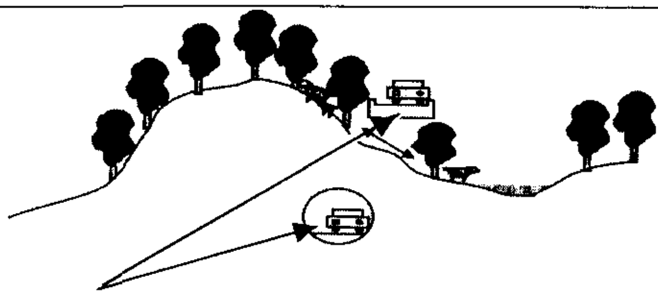
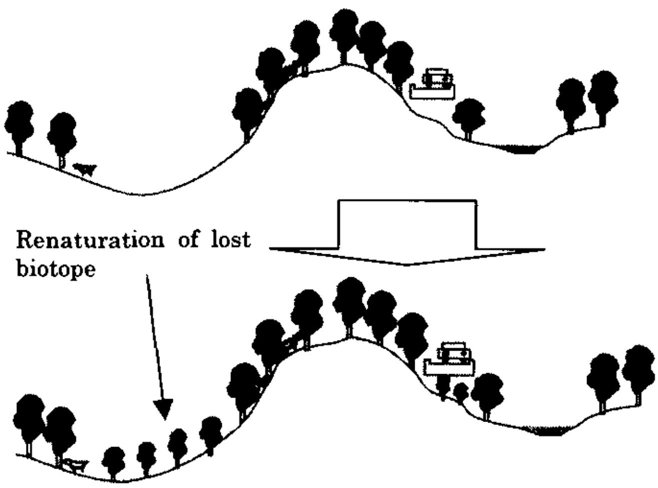
Figure 6.3.1 Greening of Concrete Frame

As described in Chapter 9, a tree that was cut down for the construction must be increased to 4 trees (referred to Table 6.3.8). The kind of trees should be selected taking account of the surrounding environment.

f) Landscape

N003C230 that a countermeasure was enforced directly in the national conservation area was made the target as a point to give careful consideration to the landscape. As above mentioned, this point has the plan to take countermeasure that it gave careful consideration to vegetation to match in the natural landscape of the circumference. And, the embankment is planted with trees by grass planting and/or seed coating as early as possible in accordance with the progress of the construction because of the harmony with the landscape of the circumference.

Table6.3.8 Method of Mitigation

Echelon	Explanation	
Avoiding		Avoidance from biotope and movement zone.
Minimizing		Avoidance from core biotope. Minimization of embankment and cut.
Balancing		An impact is made to balance in the same point.
Restoration or Compensation		It alternates the impact in other places. An alternate site is secured in other places. The impact which can't be avoided is compensated for. *Four tree-planting duties for one felling by the guidance of MARENA are contained here.

6.3.3 Notes to the Construction Work

Responsibility to the legal environment in a stage of a construction contract must refer to the section 108 of NIC2000. And, as for the points of concern with the environment at the stage of the basic design, the detailed design and the construction, it is important to confirm the mentioned items of NABCV) fully.
It is concerned here only with the environment consideration items that it should pay attention at the stage of the construction and it is evaluated by the detailed construction plan in the environment impact factor selected with IEE including the correspondence with NIC2000.

1) Facility for Life and Traffic (Refer to Nic2000 108.14, NABCV 5.1)
It makes effort not to influence a society infrastructure and access to the work place with the construction work, and it must not give the harm to the inhabitant in the field of the economical activities.
In case that the above is unacceptable, a contractor must provide the equal facility which can take its place of the existent access.

2) Waste (Refer to Environmental Basic Law Chap.3)

a) General
Generally surplus soil is used for the hole around the road, gully erosion, the reclamation of the borrow pit. It can't be damaged to circumferential vegetation and the arable land, and moreover throwing away to the river and the flow of the water can't be polluted in all the environments. And, it forbids throwing them away to the slope. It must get landowner's permission in advance when that disposal is done in the private land.

Waste material must be taken to the disposal site which is specified from the construction site at once. On this occasion, the quantity of the waste materials and a kind are specified, and it must get the permission of the related organization in advance. (Note: In advance, an interview with the cities mayor is given in advance to explain about the effect and the purpose of the construction.) And, it must consider that the conveyance of the waste materials doesn't become the high-cost for the project.

As for the removed asphalt waste, it is recycled that it is used for the sub-base of the road. Waste oil is collected by a special enterprise, and they are carried to the treatment plant for recycling. Adjustment with these enterprises about taking back of the waste oil from the workshop is necessary.
The waste materials of the concrete and the stone block are used in protection wall of embankment, slope and the erosion point. And, they can be buried in the road circumference area under the approval of adjustment organization about the environment and the natural

resources, MARENA, the cities public office and the landowner in advance. In case of inside right of way, the permission of MTI is necessary.

b) Control Method of Waste Material

How to control every kind of the waste must be enforced as mentioned in Table 6.3.9.

Table 6.3.9 Control Method of Waste Material

Category	Method
Waste Oil	Waste oil such as lubricating oil and fuel is collected by the special enterprise of the hydrocarbon. The contractor must adjust it properly between the nearest fuel stores of the construction site so that those enterprises may carry waste oil to the taking back refinery. 1) The contractor must prepare the workshop or the place of the oil exchange fraught with a transport pipe to oil tank or waste oil collection tank. 2) That place is made waterproof, and it must be controlled fully so that waste oil may not come out outside. 3) Generally that equipment is made by masonry that upper painting is done. 4) The contractor must store up waste oil in secrecy containers of 55 gallons for the collection by the recycling company. 5) Waste oil is used for the curing of the lumber for the pattern frame. The precise control of the waste oil is necessary because of that.
Surplus Soil	Generally surplus soil is separated the anorganic sabstance from the organic matter. Disposal of waste materials, the surplus soil and the excavation material shift to the activities which it is critical from the viewpoint of economical and environmental with many projects. Therefore, as for the specification of the place and that operation, characteristics in drainage, physically and geographical must be taken into consideration fully in each place. 1) The surplus soil of anorganic sabstance is used for the reclamation of the area with no vegetation, gully, boghole. Or it used for the reclamation of boghole collected embankment materials. 2) When any kind of waste including the surplus soil is disposed in the private land, landowner's permission should be necessary. 3) It forbids to throw solid waste away in the flow of the water and the mountainside slope completely. 4) Waste materials are gotten rid of from the construction site at once, and they must be carried to the final disposal place. 5) The surplus soil of the anorganic sabstance must not be accumulated on the unstable area and an important area from the viewpoint of environment and the place of the agriculture production. 6) When it can be carried to the disposal place of the neighborhood cities, inert waste is curried under the comprehension of the cities in advance to the disposal place. Generally the layer of organic matter which form the surface of the soil is mixed with the plant waste or the useful microorganism which supports the ventilation of the soil.

Category	Method
	A layer to grow a plant abounds of the nutritious element by the element of the organic matter and corrosion acid. 1) A layer of organic matter has indispensable biological and physics resources as to the development of the creature activities, the re-naturation and re-greening of the land where it was exposed. Therefore, it must be kept in the place where it is selected in advance. 2) A layer of organic matter is used for the re-naturation of slope which is formed by construction in the construction stage. 3) A surface must be made flat with less than the height 2m to prevent that from being compacted while it keeps the layer of organic matter. 4) It is desirable to mix it with the plant left to increase the containing rate of the organic material or the seed.
Removed Asphalt	Generally asphalt waste materials are recycled by a contractor as a sub-base of the road. These waste materials are put on the reclaimed land approved by the cities of about the construction site in case of others. Because a landscape is hurt and soil and arable land are polluted, asphalt waste materials must not be put by the side of the road. If suitable technology exists, recycling of the asphalt layer is wonderful substitutive technology.
Removed Concrete	Generally concrete waste materials occur from removal of the existent road or the concrete blender. This debris is used for the boundary of camp yard or road, and embankment protection. And, it can dispose of it in the management place of the cities, too. Or, it can be buried in the private land under the permission of landowner and MARENA, too. It is used for small drywall construction of embankment protection so that some of these waste materials may minimize the progress of the erosion.
Lumber	Generally the piece of the lumber is used as the timber pile of the topographic survey. The piece of the lumber is kept in order. Then, it is delivered to use it for the inhabitant around the construction site as a firewood. Because it has the possibility to induce fire, it isn't suitable to burn up the piece of the lumber. It is sent to the management place of the cities, and it can dispose of it in the final, too.
Stone	The chesil as a remainder of crushed stone is punished in vacant lot of excavation or cutting soil in quarry. And, it can be handed over to the cities public office and the village, too. The stone that appeared from excavation or cutting soil can be used for the drywall for embankment protection.
Waste Water	The wasted water produced in the washing process of the aggregate makes sediment occur except for the wastewater, too. This water is channeled to grit tank through the water way, and it is used as a washing water again. The mud which accumulates in grit tank is carried regularly to the dryness place, and carried to the final disposal area of surplus soil permitted in advance. As for the polluted water such as washing of the stone which isn't done the sanitary management in advance scrapping it directly in the river and so on isn't permitted even in no case. Construction campsite must be provided with the septic tank for the sewage treatment to promote accumulation and the resolution of the mud. This mud is dried regularly, and it must be locked up in the hole specified by environment supervisor of the project.

Category	Method
Others	The cement bag left in the place which be done the preparation of the concrete and the masonry under the insufficient control is contained in this category.

c) Water Pollution (Refer to Nic2000 108.31,205)

The contractor must put all necessary plans in action to protect a river, a lake, a lagoon, a pond, a swamp, a bay and coast against the harmful material of fuel and oil, the bituminous material, the calcium chloride and others. Then, the plan which minimizes the precipitation of that liquid material must be integrated into that operation.

The contractor submits the program which prevents the pollution of the water effectively to the technician before the working start of the project, and the contractor must get that approval.

d) Noise and Vibration (Refer to Nic2000 108.31,NABCV 5.3)

A contractor must formulate the rule of that operation and a control system about all the work which makes the unusual noise which gives an unpleasantness and a menace to stillness and the health of a worker and an inhabitant. It tries to decrease of the occurrence of the noise and the vibration in the construction site, and it must be avoided with a source of occurrence so far as it is possible. The rough finishing of the road surface must be avoided to make noise with the tire decrease about the fragile area of the environment. The contractor must keep passing of a vehicle such a large truck which take out loud noise as far away from the residence area as possible, as for the night, it must specially do so.

As for the residence area of the city circumference that daily stillness is kept, the machine which causes noise beyond 70 dB in Level A (the measurement of a distance 15m) can't be used from 6 p.m. until 7 a.m. However, it is excluded when it is in an emergency or when there is technician's special permission. When sterner local standard exists in comparison with this standard, local standard takes precedence over it in all the cases.

note: Level A

A-Weighted sound pressure level. It is written with L_A, and a unit is unified in **dB**.

e) Air Pollution (Refer to Nic2000 108.31,NABCV 5.3)

The following items must be observed about the air pollution.

- The motor of the construction machine is that the discharge of the carbon monoxide or the hydrocarbon is maintained in the minimum condition.

- Avoid burning of the plant waste which occurred with felling in the road site, making the borrow pit and the camp area so far as it is possible except that the standard of MTI or MARENA permits it.
- Use dust collector machine in the plant which dust such as asphalt and a concrete plant is made to discharge in.
- Avoid the discharge of the dust at the time of earth excavation and embankment construction by sprinkling with water to the unstable material so far as it is possible.
- Make it stabilize a conveyance road due to sprinkling with water or the relaxation medicine for the dust.
- Observe the law and the rule which should be applicable about the control of paints used for the construction, the dilution medicine, the concrete and the curing compound for the asphalt and so on.

These measures are strictly applicable when construction is carried out just near the city or the village. And, the special permission of MARENA must be able to get it before doing that work when the powdered dust of at least 4.5kg scatters in the atmosphere.

f) Other Precautions

Before the execution of the construction, MTI submits the document shown in appendix-1 to MARENA, and the need of the execution of EIA, consideration items to others environment are confirmed. After EIA and so on is carried out if necessary, and a general and/or an independent precaution is being indicated about the prevention reduction measure which a contractor should take in the environment permission handed over to the client.

6.3.3 Evaluation at Present

It is evaluated that a countermeasure is fully being planned about the minimization of the impact on the environment about the items which should be taken into consideration at the present stage. Final evaluation of every site is shown in the table 6.3.10.

Table 6.3.10 Evaluation of Each Spot for EIA

		Enviroment Item	Stage of EIA																													
			Nic.1													Nic.3								5	Nic.26							
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Social Environment	1	Inhabitant Transfer	B	B	D	D	D	D	D	D	B	B	B	D	D	B	B	B	B	B	B	B	B	B	B	D	B	B	B	D	D	D
	2	Economic Activity	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	B	D	D	D	D	D	D	D	D	D	D
	3	Facility for Life and Traffic	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	4	Waste	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
Natural Environment	5	Ground Water	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	6	Lake/Liver	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	7	Fauna/Flora	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	8	Landscape	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Pollution	9	Air Pollution	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
	10	Water Pollution	B	B	B	B	B	B*	B	B	B	B	B	B*	B*	B	B	B	B	B	B	B	B	B*	B	B	B	B	B*	B	B	B
	11	Noise/Vibration	D	D	D	D	B	D	D	D	D	D	D	D	D	D	D	B	B	D	D	D	D	D	D	D	D	D	B	D	D	D
Countermeasure by Fainal Survey			CW+ BR+ SD	R+S D+V	GM	GM	GM	GM	BR+ PN	BR+ PN	SF+ CF+ SD+ BR	SF+S +SD	R+C F+S D+G D+B R	GM	GM	R+C F+V +SD	R+C F+V +SD	NB	CW+ GD	R+C F+V +SD +GD +RE	D+R +CF +V+ SD	R+C F+V +SD +GD +RE	R+C F+V +SD +GD +CW	R+C F+V +SF +GD	SF+S +SD	GM	R+C F+S D+G D	R+C F+S D+G D	BR+ PN	GM	GM	GM

Note : GM (Gabion Mat) CM (Concrete Mat) NB (New Bridge) GW (Gabiaon Wall) CW (Concrete Wall) CF (Concrete Flame) R (Recutting) S (Shotcrete)
PN (Prevention Net) BR (Boulder Removal) CW (Counter Weight) D (Dam) V (Vegitation) C (Culvert) SD (Surface Drainage) GD (Ground Drainage)
RW (Reconstruction Wing Wall) RE (Re-embankment) SF (Slope Fairing) BP (Bank Protection)

NIC.1
1 N001A290
2 N001A280
3 Tunquillal
4 San Nicolas
5 Las Chanillas
6 San Ramon
7 N001A240
8 N001B230
9 N001B170
10 N001B150
11 N001B120
12 Rio Inali
13 Rio Tapacali
NIC.3
14 003B400
15 003B370
16 El Guayacan
17 N003B320
18 N003C230
19 N003E170
20 N003C150
21 N003C140
NIC.5
22 N005A001
NIC.26
23 N026A006
24 La Banderita
25 N026B140
26 N026A150
27 N026B160
28 San Juan de Dios
29 Papalon
30 Solis

6.4. Project Evaluation

6.4.1 General

When traffic re-routes to avoid the closed link it potentially incurs two types of dis-benefit:

- increased vehicle operating costs due to additional distance; and
- increased passenger time costs.

These two parameters are evaluated by the JICASTRADA model by running the model for two cases : with the affected link in place (a common base), and without the link in place. These are converted to monetary benefits using the parameters developed and set out in Table 6.4.1.

Table 6.4.1 Vehicle Operating Costs and Passenger Costs, Nicaragua 2002

Vehicle type	*Operating Cost per 1000 km, US $*	*Passenger Costs per vehicle hour*
Car	185.5	2.84
Utility	215.1	1.09
Average Bus	529.7	14.90
Light Goods	549.1	1.04
Medium Goods	768.2	1.04
Heavy Goods	878.5	0.75

Source : NIC2000 Transport Plan and year 2002 prices

The costs of disaster prevention measures are expressed in terms of the capital cost of works (assumed to be incurred in 2003) and the continued maintenance cost of the link. The costs of temporary prevention measures are assumed to recur every twelve years. Permanent measures incur a single capital cost, but annual maintenance costs thereafter. The additional cost factors are shown in Table 6.4.2. Revised costs are set out in Table 6.4.3. Locations of vulnerable sites are shown in Figure 6.4.1.

Table 6.4.2 Full Cost Breakdown of Countermeasures

Component	*% of Engineering Works*
Engineering works	100.0
Design	5.0
Construction Supervision	7.5
Client Costs	0.9
Transport of materials	5.0
Contingency	5.0
Total	123.4

Source : International norms

Table 6.4.3 Costs of Countermeasures by Site

Road	Site no.	Site ID	Full Economic Cost (US $)
NIC1	1	N001A290	413,370
NIC1	2	N001A280	12,339
NIC1	3	Junquillal	51,825
NIC1	4	San Nicolás	30,849
NIC1	5	Las Chanillas	233,215
NIC1	6	San Ramón	11,105
NIC1	7	N001A240	32,082
NIC1	8	N001B230	7,404
NIC1	11	N001B170	1,961,965
NIC1	12	N001B150	33,316
NIC1	13	N001B120	1,004,427
NIC1	18	Rio Inalí	1,021,702
NIC1	19	Rio Tapacalí	347,971
NIC3	24	003B400	49,358
NIC3	25	003B370	215,940
NIC3	26	El Guayacán	1,701,604
NIC3	27	N003B320	294,912
NIC3	29	N003C230	404,732
NIC3	30	N003E170	382,521
NIC3	32	N003C150	1,132,757
NIC3	33	N003C140	924,221
NIC5	35	N005A010	480,003
NIC26	44	N026A060	389,925
NIC26	45	La Banderita	38,252
NIC26	49	N026B140	1,115,482
NIC26	50	N026A150	259,127
NIC26	51	N026B160	16,041
NIC26	52	San Juan de Dios	6,170
NIC26	54	Papalón	62,931
NIC26	55	Solís	81,440
Total			**12,716,988**

Source : Tables 6.2.12 to 6.2.18, and Table 6.4.2

Table 6.4.4 lists the parameters used in the economic evaluation.

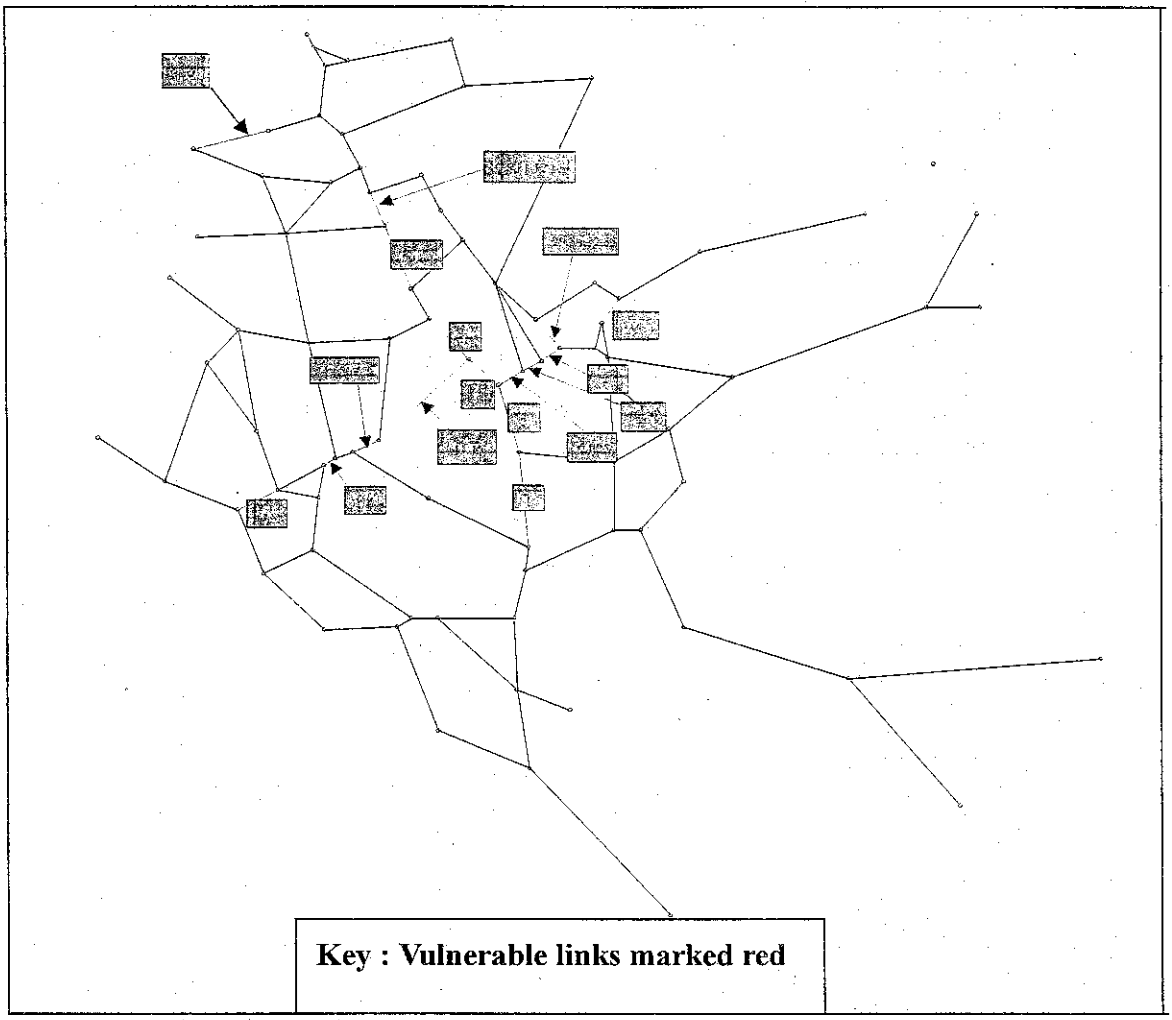


Figure 6.4.1 Locations of 30 Vulnerable Road Sites for Evaluation

Table 6.4.4 Economic Evaluation Parameters

Parameter	***Value***	***Source***
Discount Rate	10%	International Norm
Discount period	18 years	2003 to 2020
Implementation of counter measures	2003	Assumption
Start year of benefit flow	2004	Assumption

6.4.2 Economic Analysis

Two schemes have been incorporated into the future year JICASTRADA model tests as commitments : the upgrading of the San Benito to San Lorenzo section of NIC7, (Managua and Boaco) and the resurfacing of the Santa Cruz to San Nicolas link in Esteli. The implementation of these schemes result in lower journey times on the alternative routes to potential disasters at sites 1 and 4 respectively. The results of the economic evaluation are shown in Table 6.4.5.

The full cost-benefit analysis sheets for each link are provided in Appendix-7.

Table 6.4.5 Result of Economic Evaluation

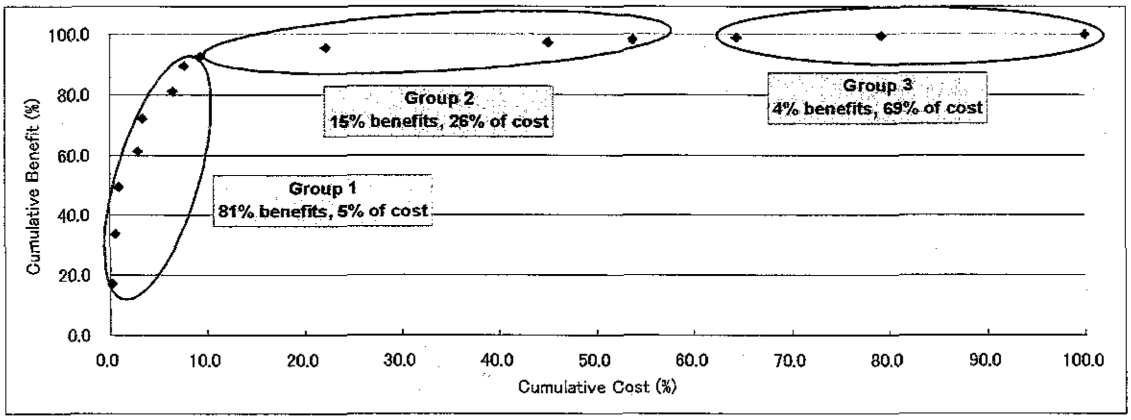
Site No	ID No.	Cost (US$)		Benefits($USM)		Benefits - Cost ($US)	Net Present Value ($US)	EIRR	B/C	Average	
		Total Cost (US$)	Total Dis-counted Cost	Total Benefits	Total Dis-counted Benefits					EIRR	B/C
1	N001A290	959,018	616,618	6,747,338	3,276,470	5,788,319	2,659,851	4%	5.31		
2	N001A280	16,535	14,190	516,136	454,254	499,601	440,064	44%	32.01		
3	Junquillal	120,235	77,307	2,189,560	1,091,941	2,069,325	1,014,634	12%	14.12		
4	San Nicolas	71,569	46,016	1,141,730	584,712	1,070,161	538,695	12%	12.71		
5	Las Chanillas	541,058	347,883	1,015,448	510,686	474,390	162,803	0.4%	1.47		
6	San Ramon	25,765	16,566	1,015,448	510,686	989,684	494,120	30%	30.83		
7	N001A240	74,431	47,857	1,855,991	937,770	1,781,559	889,914	19%	19.60		
8	N001B230	17,176	11,044	472,346	241,134	455,169	230,091	24%	21.83		
11	N001B170	2,629,033	2,256,222	2,670,153	2,401,084	41,120	144,861	0.3%	1.06		
12	N001B150	44,644	38,313	823,606	730,977	778,962	692,664	24%	19.08		
13	N001B120	1,345,933	1,155,072	1,589,184	1,394,328	243,252	239,256	0.5%	1.21		
18	Rio Inali	2,370,350	1,524,059	857,206	420,114	-1,513,143	-1,103,945	0%	0.28		
19	Rio Tapacali	807,293	519,064	454,892	223,324	-352,401	-295,740	0%	0.43	13.1%	12.3
24	N003B400	66,139	56,760	2,022,393	1,809,886	1,956,254	1,753,125	41%	31.89		
25	N003B370	289,359	248,326	1,023,196	910,609	733,837	662,283	4%	3.67		
26	El Guayacan	2,280,149	1,956,812	10,398,159	9,353,209	8,118,010	7,396,397	5%	4.78		
27	N003B320	395,182	339,143	531,581	468,155	136,400	129,012	69%	1.38		
29	N003C230	542,341	465,435	662,039	580,433	119,698	114,999	0.5%	1.25		
30	N003E170	512,579	439,892	785,681	696,845	273,102	256,952	1.0%	1.58		
32	N003C150	1,517,894	1,302,649	1,547,361	1,382,357	29,467	79,708	0.3%	1.06		
33	N003C140	1,238,456	1,062,837	1,276,078	1,138,202	37,621	75,365	0.3%	1.07	15.1%	5.8
35	N005A010	643,204	551,994	1,051,918	936,458	408,714	384,464	1.1%	1.70	1.1%	1.7
44	N026A060	522,500	448,406	734,632	650,901	212,132	202,494	0.8%	1.45		
45	La Banderita	51,258	43,989	188,552	161,995	137,294	118,006	4%	3.68		
49	N026B140	1,494,746	1,282,783	2,132,684	1,909,148	637,938	626,365	0.9%	1.49		
50	N026A150	347,231	297,992	475,861	418,007	128,630	120,015	0.7%	1.40		
51	N026A160	37,216	23,928	1,528,606	774,707	1,491,390	750,778	33%	32.38		
52	San Juan de Dios	14,314	9,203	466,350	236,538	452,036	227,335	26%	25.70		
54	Papalon	146,000	93,873	4,004,273	2,057,405	3,858,273	1,963,531	21%	21.92		
55	Solis	188,941	121,483	2,008,137	1,031,535	1,819,196	910,052	7%	8.49	11.7%	12.1
		19,310,546	15,415,719	52,186,537	37,293,870	32,875,991	21,878,151			12.8%	10.2

6.4.3 Budget Priorities

The analysis of a potential budget for disaster prevention measures has been carried out in two stages :

1. The creation of prioritised packages of work that maximise benefits, whilst minimising cost;
2. Linking the funding packages to potential funding sources.

Table 6.4.6 and Table 6.4.7 list the schemes by ranked according to benefit to cost ratio and to EIRR. In this table the cumulative costs and benefits are listed. This data is also shown in Figure 6.4.2. The schemes can be seen to fall into three distinct groups, which indicate the priorities for investment.



Source : Table 6.4.6

Figure 6.4.2 Scattergram of Ranked Schemes by Link

The groups of EIRR are : **Priority Group 1** : Contains 12 sites. These provide 81% of the total benefits for 5% of the total cost; **Priority Group 2** : Contains 7 sites . These provide 15% of the benefits for 26% of the total cost; and **Priority Group 3** : Contains 11 sites. These provide 4% of the benefits for 69% of the total cost.

These groups therefore provide the basis for prioritising investment, and creating work packages. The schemes in each group are set in Table 6.4.8. The work packages are set out in Table 6.4.9, and Figure 6.4.3.

Table 6.4.6 Ranked Schemes with B/C

Site No	ID No.	Cost (US$)		Benefits($USM)		Benefits – Cost ($US)	Net Present Value ($US)	EIRR	B/C	Average
		Total Cost (US$)	Total Dis-counted Cost	Total Benefits	Total Dis-counted Benefits					B/C
51	N026A160	37,216	23,928	1,528,606	774,707	1,491,390	750,778	33%	32.38	
2	N001A280	16,535	14,190	516,136	454,254	499,601	440,064	44%	32.01	
24	N003B400	66,139	56,760	2,022,393	1,809,886	1,956,254	1,753,125	41%	31.89	
6	San Ramon	25,765	16,566	1,015,448	510,686	989,684	494,120	30%	30.83	
52	San Juan de Dios	14,314	9,203	466,350	236,538	452,036	227,335	26%	25.70	Priority Group1
8	N001B230	17,176	11,044	472,346	241,134	455,169	230,091	24%	21.83	
54	Papalon	146,000	93,873	4,004,273	2,057,405	3,858,273	1,963,531	21%	21.92	
7	N001A240	74,431	47,857	1,855,991	937,770	1,781,559	889,914	19%	19.60	
12	N001B150	44,644	38,313	823,606	730,977	778,962	692,664	24%	19.08	
3	Junquillal	120,235	77,307	2,189,560	1,091,941	2,069,325	1,014,634	12%	14.12	
4	San Nicolas	71,569	46,016	1,141,730	584,712	1,070,161	538,695	12%	12.71	23.8
55	Solis	188,941	121,483	2,008,137	1,031,535	1,819,196	910,052	7%	8.49	
1	N001A290	959,018	616,618	6,747,338	3,276,470	5,788,319	2,659,851	4%	5.31	
26	El Guayacan	2,280,149	1,956,812	10,398,159	9,353,209	8,118,010	7,396,397	5%	4.78	Priority Group2
25	N003B370	289,359	248,326	1,023,196	910,609	733,837	662,283	4%	3.67	
45	La Banderita	51,258	43,989	188,552	161,995	137,294	118,006	4%	3.68	
35	N005A010	643,204	551,994	1,051,918	936,458	408,714	384,464	1.1%	1.70	
30	N003E170	512,579	439,892	785,681	696,845	273,102	256,952	1.0%	1.58	4.2
49	N026B140	1,494,746	1,282,783	2,132,684	1,909,148	637,938	626,365	0.9%	1.49	
5	Las Chanillas	541,058	347,883	1,015,448	510,686	474,390	162,803	0.4%	1.47	
44	N026A060	522,500	448,406	734,632	650,901	212,132	202,494	0.8%	1.45	
50	N026A150	347,231	297,992	475,861	418,007	128,630	120,015	0.7%	1.40	
27	N003B320	395,182	339,143	531,581	468,155	136,400	129,012	69%	1.38	Priority Group3
29	N003C230	542,341	465,435	662,039	580,433	119,698	114,999	0.5%	1.25	
13	N001B120	1,345,933	1,155,072	1,589,184	1,394,328	243,252	239,256	0.5%	1.21	
33	N003C140	1,238,456	1,062,837	1,276,078	1,138,202	37,621	75,365	0.3%	1.07	
32	N003C150	1,517,894	1,302,649	1,547,361	1,382,357	29,467	79,708	0.3%	1.06	
11	N001B170	2,629,033	2,256,222	2,670,153	2,401,084	41,120	144,861	0.3%	1.06	
19	Rio Tapacali	807,293	519,064	454,892	223,324	-352,401	-295,740	0%	0.43	
18	Rio Inali	2,370,350	1,524,059	857,206	420,114	-1,513,143	-1,103,945	0%	0.28	1.1
		19,310,546	15,415,719	52,186,537	37,293,870	32,875,991	21,878,151			10.2

Table 6.4.7 Ranked Schemes with EIRR

Site No	ID No.	Cost (US$)		Benefits($USM)		Benefits - Cost ($US)	Net Present Value ($US)	EIRR	B/C	Average
		Total Cost (US$)	Total Dis-counted Cost	Total Benefits	Total Dis-counted Benefits					EIRR
27	N003B320	395,182	339,143	531,581	468,155	136,400	129,012	69%	1.38	
2	N001A280	16,535	14,190	516,136	454,254	499,601	440,064	44%	32.01	
24	N003B400	66,139	56,760	2,022,393	1,809,886	1,956,254	1,753,125	41%	31.89	
51	N026A160	37,216	23,928	1,528,606	774,707	1,491,390	750,778	33%	32.38	
6	San Ramon	25,765	16,566	1,015,448	510,686	989,684	494,120	30%	30.83	Priority Group1
52	San Juan de Dios	14,314	9,203	466,350	236,538	452,036	227,335	26%	25.70	
8	N001B230	17,176	11,044	472,346	241,134	455,169	230,091	24%	21.83	
12	N001B150	44,644	38,313	823,606	730,977	778,962	692,664	24%	19.08	
54	Papalon	146,000	93,873	4,004,273	2,057,405	3,858,273	1,963,531	21%	21.92	
7	N001A240	74,431	47,857	1,855,991	937,770	1,781,559	889,914	19%	19.60	
3	Junquillal	120,235	77,307	2,189,560	1,091,941	2,069,325	1,014,634	12%	14.12	
4	San Nicolas	71,569	46,016	1,141,730	584,712	1,070,161	538,695	12%	12.71	30%
55	Solis	188,941	121,483	2,008,137	1,031,535	1,819,196	910,052	7%	8.49	
26	El Guayacan	2,280,149	1,956,812	10,398,159	9,353,209	8,118,010	7,396,397	5%	4.78	
1	N001A290	959,018	616,618	6,747,338	3,276,470	5,788,319	2,659,851	4%	5.31	Priority Group2
25	N003B370	289,359	248,326	1,023,196	910,609	733,837	662,283	4%	3.67	
45	La Banderita	51,258	43,989	188,552	161,995	137,294	118,006	4%	3.68	
35	N005A010	643,204	551,994	1,051,918	936,458	408,714	384,464	1.1%	1.70	
30	N003E170	512,579	439,892	785,681	696,845	273,102	256,952	1.0%	1.58	4%
49	N026B140	1,494,746	1,282,783	2,132,684	1,909,148	637,938	626,365	0.9%	1.49	
44	N026A060	522,500	448,406	734,632	650,901	212,132	202,494	0.8%	1.45	
50	N026A150	347,231	297,992	475,861	418,007	128,630	120,015	0.7%	1.40	
29	N003C230	542,341	465,435	662,039	580,433	119,698	114,999	0.5%	1.25	
13	N001B120	1,345,933	1,155,072	1,589,184	1,394,328	243,252	239,256	0.5%	1.21	Priority Group3
5	Las Chanillas	541,058	347,883	1,015,448	510,686	474,390	162,803	0.4%	1.47	
33	N003C140	1,238,456	1,062,837	1,276,078	1,138,202	37,621	75,365	0.3%	1.07	
11	N001B170	2,629,033	2,256,222	2,670,153	2,401,084	41,120	144,861	0.3%	1.06	
32	N003C150	1,517,894	1,302,649	1,547,361	1,382,357	29,467	79,708	0.3%	1.06	
19	Rio Tapacali	807,293	519,064	454,892	223,324	-352,401	-295,740	0%	0.43	
18	Rio Inali	2,370,350	1,524,059	857,206	420,114	-1,513,143	-1,103,945	0%	0.28	0.4%
		19,310,546	**15,415,719**	**52,186,537**	**37,293,870**	**32,875,991**	**21,878,151**			**12.8**

Table 6.4.8 Priority Groups of Disaster Prevention Schemes

GroupNo.	Site No.	ID No.	Road	Cost (US$)	Department
Group1	2	N001A280	Nic1	12,339	Matagalpa
	3	Junquillal	Nic1	51,825	Matagalpa
	4	San Nicolas	Nic1	30,849	Matagalpa
	6	San Ramon	Nic1	11,105	Esteli
	7	N001A240	Nic1	32,082	Esteli
	8	N001B230	Nic1	7,404	Esteli
	12	N001B150	Nic1	33,316	Esteli
				178,921	
	24	N003B400	Nic3	49,358	Matagalpa
	27	N003B320	Nic3	294,912	Matagalpa
				344,269	
	51	N026A160	Nic26	16,041	Leon
	52	San Juan de Dios	Nic26	6,170	Leon
	54	Papalon	Nic26	62,931	Leon
				85,142	
				608,333	
GroupNo.	**Site No.**	**ID No.**	**Road**	**Cost (US$)**	**Department**
Group2	1	N001A290	Nic1	413,370	Managua
				413,370	
	25	N003B370	Nic3	215,940	Matagalpa
	26	El Guayacan	Nic3	1,701,604	Matagalpa
	30	N003E170	Nic3	382,521	Matagalpa
				2,300,064	
	35	N005A010	Nic5	480,003	Matagalpa
				480,003	
	45	La Banderita	Nic26	38,252	Leon
	55	Solis	Nic26	81,440	Leon
				119,692	
				3,313,129	
GroupNo.	**Site No.**	**ID No.**	**Road**	**Cost (US$)**	**Department**
Group3	5	Las Chanillas	Nic1	233,215	Esteli
	11	N001B170	Nic1	1,961,965	Esteli
	13	N001B120	Nic1	1,004,427	Esteli
	18	Rio Inali	Nic1	1,021,702	Madriz
	19	Rio Tapacali	Nic1	347,971	Madriz
				4,569,280	
	29	N003C230	Nic3	404,732	Matagalpa
	32	N003C150	Nic3	1,132,757	Matagalpa
	33	N003C140	Nic3	924,221	Matagalpa
				2,461,711	
	44	N026A060	Nic26	389,925	Leon
	49	N026B140	Nic26	1,115,482	Leon
	50	N026A150	Nic26	259,127	Leon
				1,764,534	
				8,795,526	
Grand total				**12,716,988**	

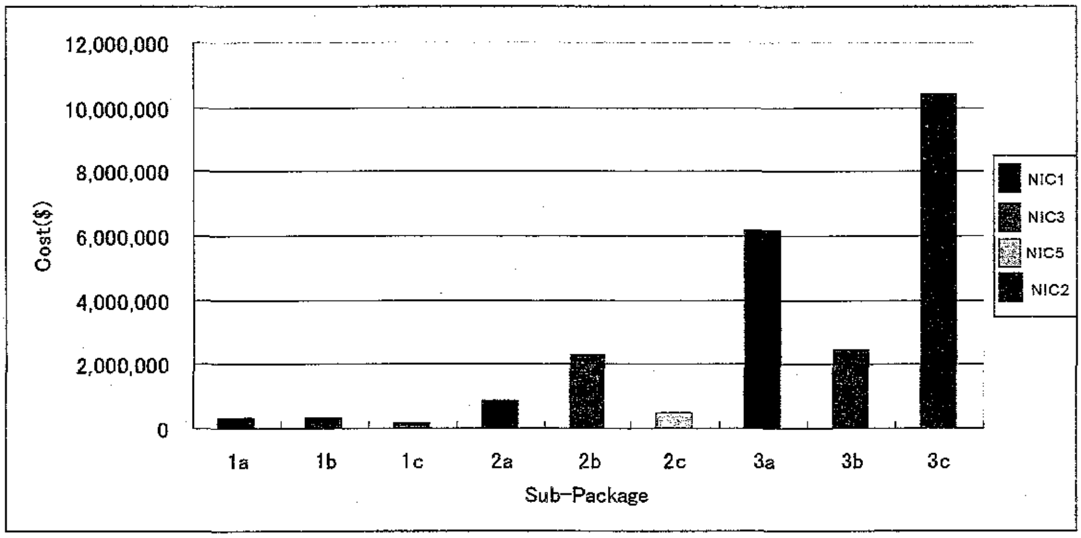
Table 6.4.9 Proposed Work Sub-packages in Priority Order

Package No.	Sub Package	Link	Site	Road	Cost (US$)
1	1a	2	N001A280	Nic1	12,339
		3	Junquillal	Nic1	103,650
		4	San Nicolas	Nic1	61,697
		6	San Ramon	Nic1	22,211
		7	N001A240	Nic1	64,165
		8	N001B230	Nic1	14,807
		12	N001B150	Nic1	33,316
	Cost				312,186
	1b	24	N003B400	Nic3	49,358
		27	N003B320	Nic3	294,912
	Cost				344,269
	1c	51	N026A160	Nic26	32,082
		52	San Juan de Dios	Nic26	12,339
		54	Papalon	Nic26	125,862
	Cost				170,284
Package 1 Cost					826,739

Package No.	Sub Package	Link	Site	Road	Cost (US$)
2	2a	1	N001A290	Nic1	826,740
	Cost				826,740
	2b	25	N003B370	Nic3	215,940
		26	El Guayacan	Nic3	1,701,604
		30	N003E170	Nic3	382,521
	Cost				2,300,064
	2c	35	N005A010	Nic5	480,003
	Cost				480,003
	2d	45	La Banderita	Nic26	38,252
		55	Solis	Nic26	162,880
	Cost				201,132
Package 2 Cost					3,807,939

Package No.	Sub Package	Link	Site	Road	Cost (US$)
3	3a	5	Las Chanillas	Nic1	466,429
		11	N001B170	Nic1	1,961,965
		13	N001B120	Nic1	1,004,427
		18	Rio Inali	Nic1	2,043,405
		19	Rio Tapacali	Nic1	695,942
	Cost				6,172,169
	3b	29	N003C230	Nic3	404,732
		32	N003C150	Nic3	1,132,757
		33	N003C140	Nic3	924,221
	Cost				2,461,711
	3c	44	N026A060	Nic26	389,925
		49	N026B140	Nic26	1,115,482
		50	N026A150	Nic26	259,127
	Cost				1,764,534
Package 3 Cost					10,398,414

Grand Total	15,033,093



Source : Table 6.4.9

Figure 6.4.3 Summary of Work Package Costs by Road

An economic evaluation of each work package has been carried out given the following assumptions:

- Costs allocated to each package determine the costs of works required to prevent disasters at all sites;
- Benefits accrue from the avoidance of a single disaster at a site within the respective package