<u>CHAPTER 12</u>

FUTURE TRAFFIC DEMAND

CHAPTER 12 FUTURE TRAFFIC DEMAND

12.1 General Methodology

The overall demand for traffic movement has been formulated using a combination of data from the traffic surveys (Chapter 10) and economic growth projections for Nicaragua (Chapter 11). The way in which traffic routes on the highway network is forecast using the traffic assignment model JICA STRADA(1).

The key modules in JICA STRADA that were used in this study are:

Network Editor:	to build, modify and test highway networks
OD Matrix Manipulator:	to construct traffic demand matrices
Incremental Assignment:	to assign traffic to the network
Highway Reporter:	to view traffic volumes and network statistics

12.2 Highway Network

The base year (2002) highway comprises 83 nodes and 113 links and is shown as Figure 12.2.1. Study roads are shown as red.

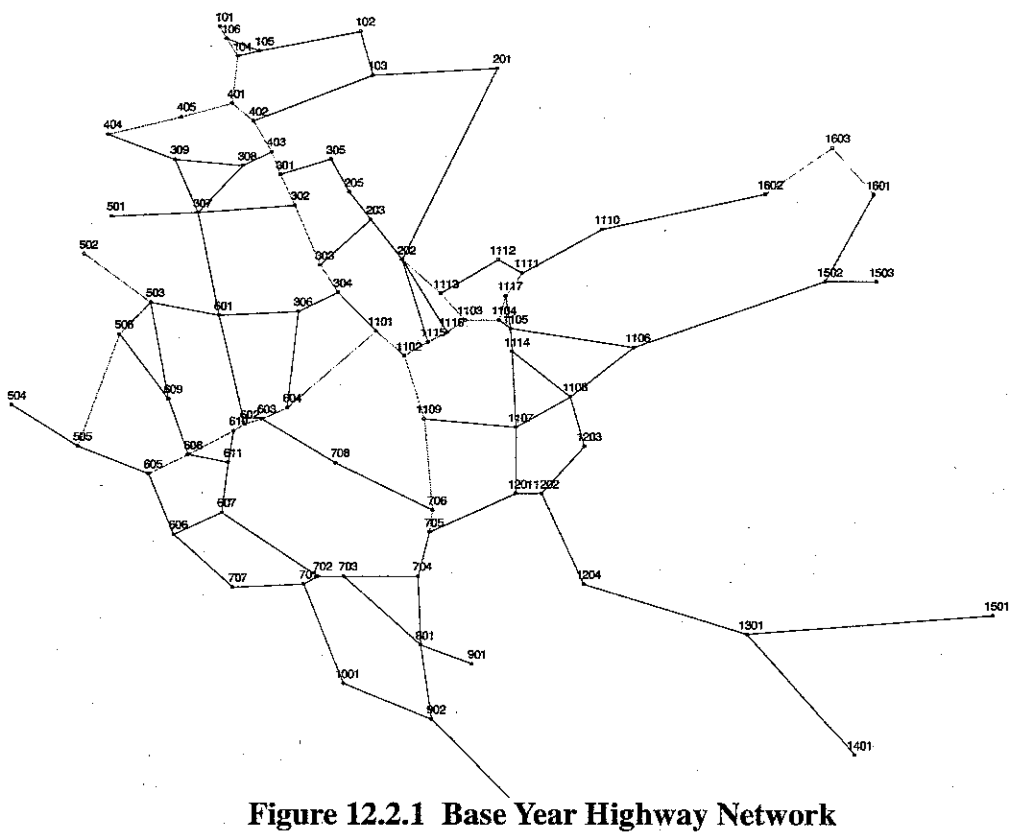


Figure 12.2.1 Base Year Highway Network

(1) JICA STRADA Version 2, International Cooperation Data Service Co., Ltd, JICA, 1997 - 2000

Figure 12.2.2. below shows the major roads on the highway network along with place name.

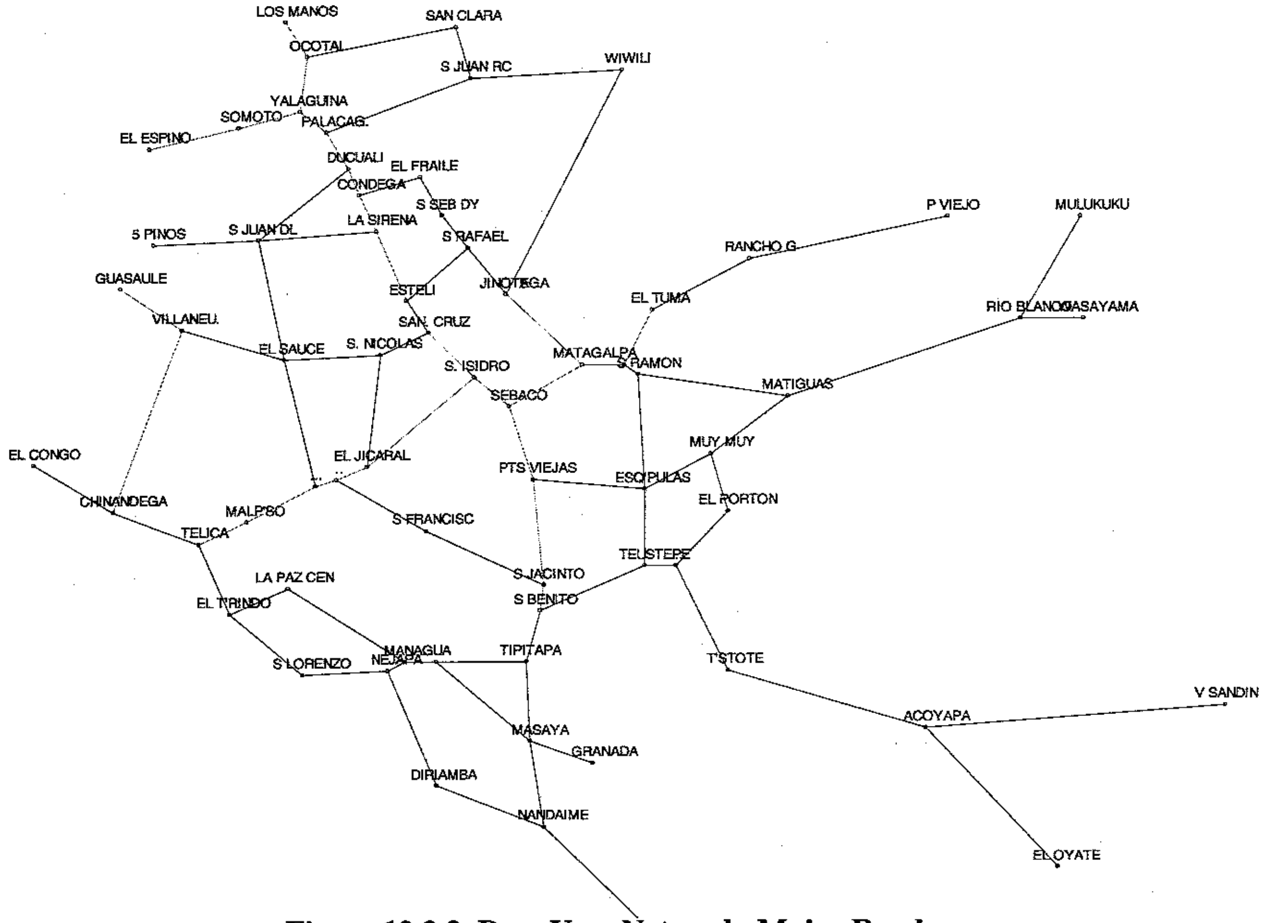


Figure 12.2.2 Base Year Network, Major Roads

All links were coded as to length, maximum velocity, capacity and volume-delay function (QV type 1 was used in each case). There is currently little congestion on the study roads. Six traffic modes were specified: car(1), utilities/pick-ups(2), buses(3), light goods(4), medium goods(5), and heavy goods(6). Traffic zones (1 to 45) are connected to the network at the nodes listed in Table 12.2.1.

12.3 Base Year Matrices

Base year (2002) matrices were constructed from the origin-destination interviews, factored to the traffic counts recorded in June 2002. For modes 1 through 3, the following procedure was adopted. All interviews were entered by site into nine separate matrices. For each mode and each site the matrix was factored to the site count for that mode of traffic. Sites were combined for each mode and double (or treble) counted trips removed. For modes 4 through 6, interview data were entered for each mode into five separate matrices representing: construction(1), industry(2), other primary(3), vacant/other(4), and agriculture(5). Because the matrices of interview data were small for each commodity type, they were combined by mode and calibrated against the traffic counts at the nine sites.

Table 12.2.1 Zone Connectors

Zone	Name	Node Connector	Zone	Name	Node Connector
1	Ocotal	104	24	El Sauce	601
2	San Fernando	102	25	El Jicarol	604
3	Honduras via Los Manos	101	26	Malpaisillo	608
4	Yalagüina	405	27	Leon	605
5	Honduras via El Espino	404	28	La Paz Centro	606
6	Quilali	103	29	Managua	701
7	Wiwili	201	30	Masaya	801
8	R.A.A.N.	1601	31	Carazo	1001
9	La Cruz del Rio Grande	1503	32	Granada	901
10	La Dalia	1108	33	Rivas	902
11	Matagalpa	1103	34	Costa Rica	1701
12	Telpaneca	402	35	Tipitapa	704
13	Jinotega	202	36	San Francisco Libre	708
14	La Concordia	203	37	San Jacinto	706
15	Condega	301	38	San Benito	705
16	Esteli	303	39	Ciudad Dario	1109
17	La Trinidad	304	40	Boaco	1202
18	San Juan de Limay	307	41	Esquipulas	1107
19	Honduras via Guasaule	502	42	Muy Muy	1106
20	Villanueva	503	43	Chontales	1301
21	Tonalá	504	44	Rio San Juan	1401
22	Chinandega	505	45	Bluefields	1501
23	Sebaco	1102			

12.4 Base Year Traffic Estimates

The base year validation is as shown in Table 12.4.1. Note that the model is not valid for roads other than the study roads.

The base year 12-hour matrices were factored to AADT volumes in accordance with the data set out in Chapter 10. These matrices were assigned to the network and the resultant traffic estimates are shown in Figure 12.4.1. Network data for 2002 are set out in Table 12.4.2.

Table 12.4.1 Base Year Validation, 12-hour Vehicle Flows, June 2002

Site		Car/Taxi	Utilities	Buses	Light Goods	Medium Goods	Heavy Goods	Total
1	Observed	255	317	286	133	158	259	1408
	Synthesised	257	325	282	123	89	179	1255
2	Observed	164	300	134	63	85	35	780
	Synthesised	170	308	126	126	79	38	847
31	Observed	224	335	91	105	122	66	942
	Synthesised	209	360	112	104	119	64	968
32	Observed	164	309	89	103	38	2	704
	Synthesised	165	328	97	100	46	27	763
4	Observed	97	288	81	120	18	14	617
	Synthesised	112	284	90	131	62	35	714
5	Observed	392	788	241	173	137	67	1796
	Synthesised	389	706	228	222	157	90	1792
6	Observed	472	763	294	398	137	39	2101
	Synthesised	550	936	266	366	131	110	2359
7	Observed	394	711	212	305	128	40	1789
	Synthesised	381	678	229	251	118	49	1706
8	Observed	559	1160	295	303	168	118	2602
	Synthesised	515	1193	261	326	142	111	2548
Total	Observed	2719	4970	1722	1700	989	637	12736
	Synthesised	2748	5118	1691	1749	943	703	12952

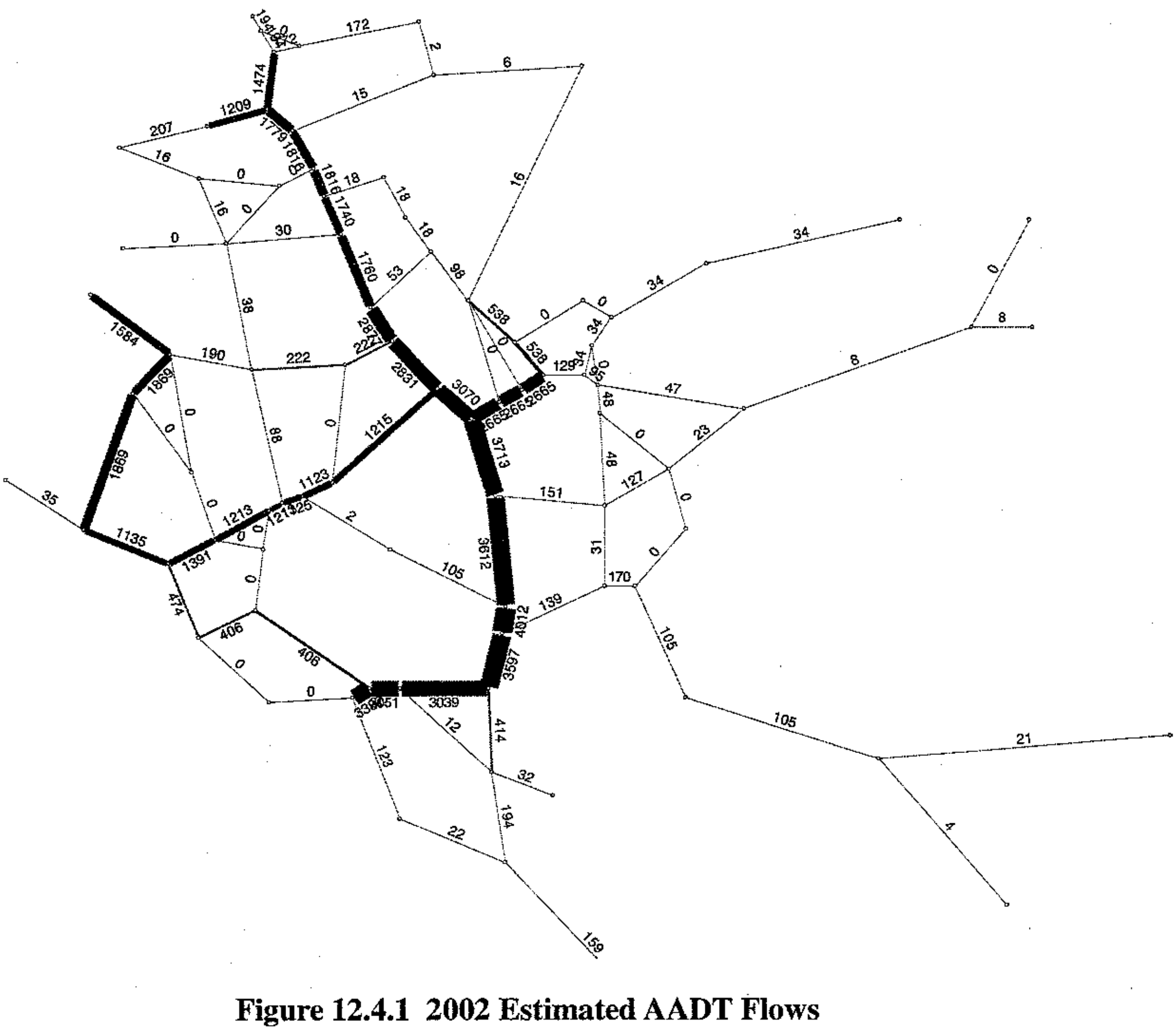


Figure 12.4.1 2002 Estimated AADT Flows

Table 12.4.2 Base Year (2002) Network Statistics, Estimated AADT

Mode	Vehicle Hours	Vehicle kms	Average Speed (km/hr)	Total Trips	Average Trip Length (km)
Car (1)	4069	253954	62.4	2367	107.3
Utlilities (2)	7111	443443	62.4	4409	100.6
Buses (3)	2614	157487	60.2	1419	111.0
Light Goods (4)	3099	191994	62.0	1515	126.7
Medium Goods (5)	1731	107714	62.2	726	148.4
Heavy Goods (6)	1479	88568	59.9	546	162.2
Total	20103	1243160	61.8	10982	113.2

12.5 Forecast Year Traffic

Forecast traffic demand matrices have been prepared for three years (i.e., 2003, 2010 and 2020) using the factors derived in Chapter 11. In the traffic surveys, no interviews were carried out on NIC.5 and so trips were added to the validation matrices between Zone 10 (La Dalia) and Zone 11 (Matagalpa) to match traffic counts taken by MTI in 2001. The trip totals in each forecast matrix are as summarised in Table 12.5.1.

Table 12.5.1 Forecast Year AADT Totals by Mode

Vehicles/ Year	2003	2010	2020
Cars	2493	3711	6521
Pick-ups	5006	7351	12811
Buses	1523	1939	2654
Light Goods	1533	2481	4136
Medium Goods	889	1432	2412
Heavy Goods	581	669	1539
Total	12028	17613	30073

Figures 12.5.1, 12.5.2 and 12.5.3 show traffic assignments for the three forecast years. Network statistics are shown in Table 12.5.2.

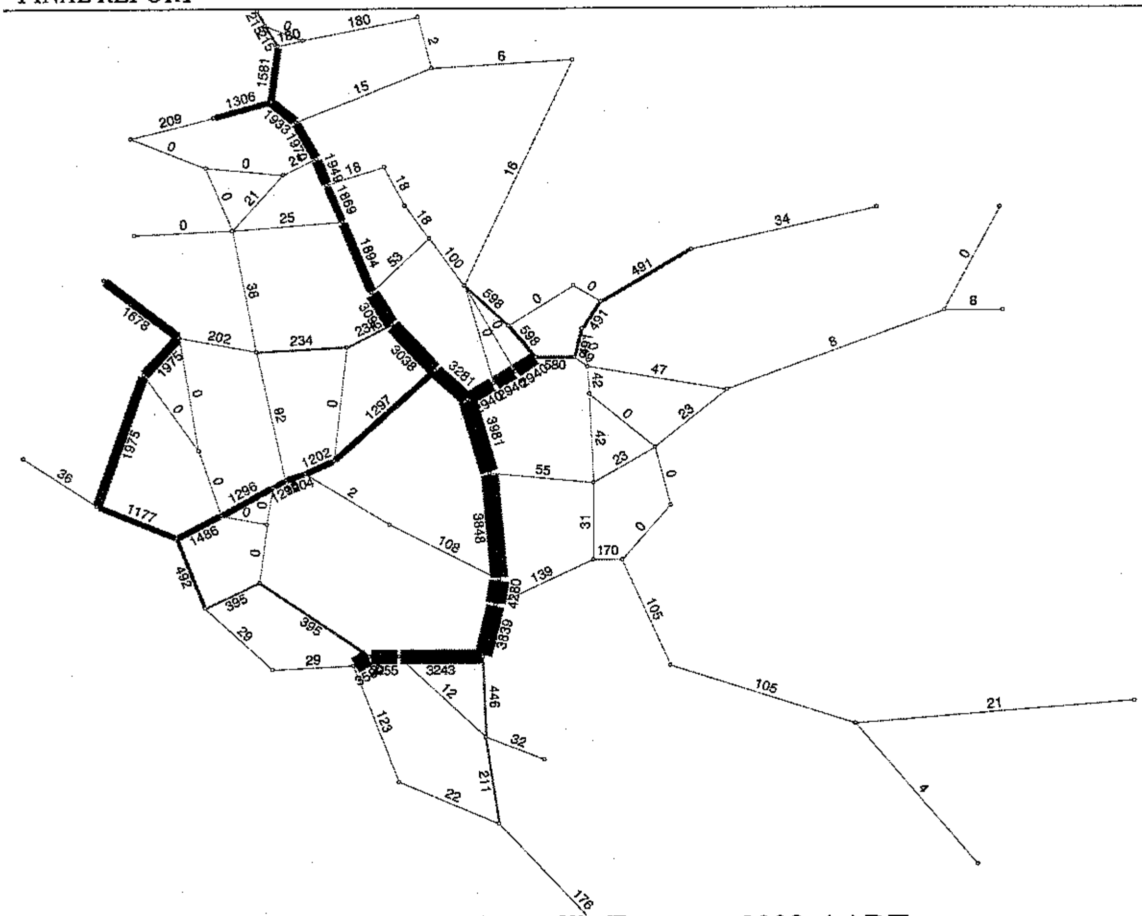


Figure 12.5.1 Traffic Forecast, 2003, AADT

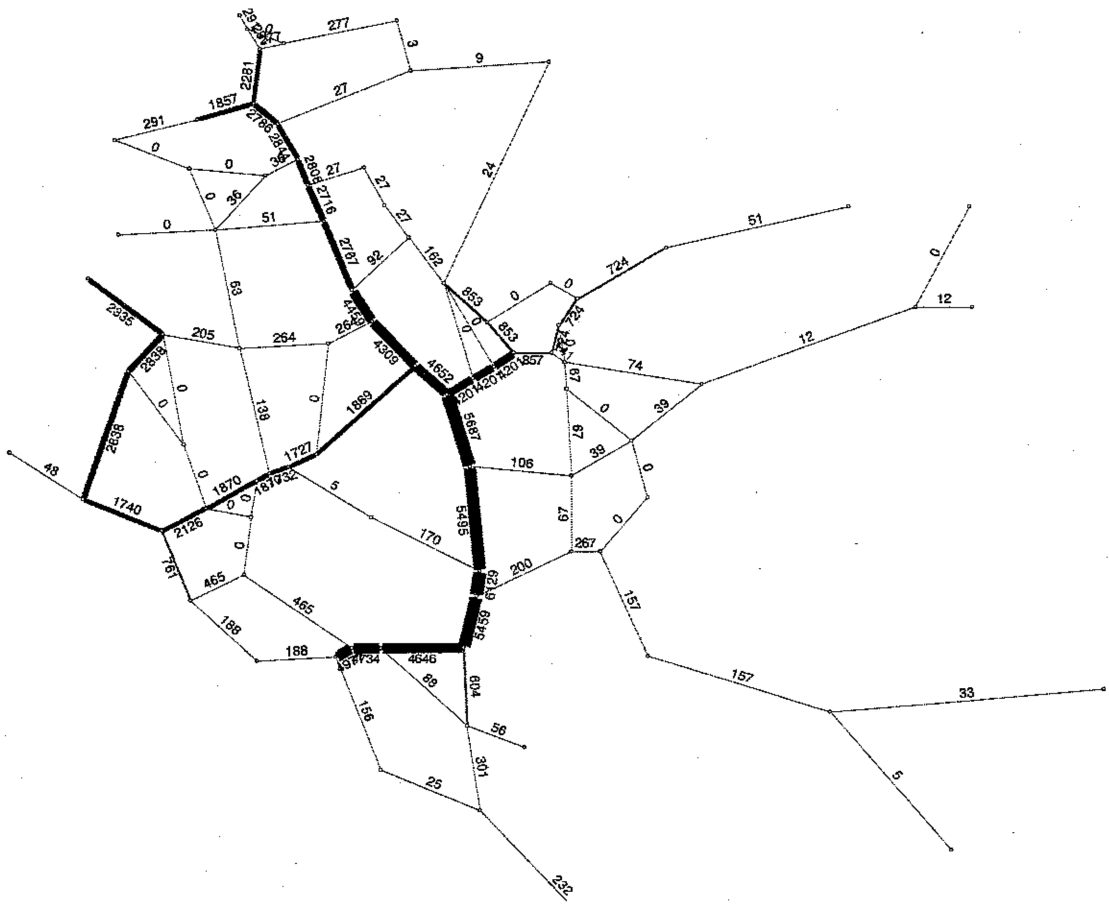


Figure 12.5.2 Forecast Traffic, 2010, AADT

Figure 12.5.3 Forecast Traffic, 2020, AADT

Table 12.5.2 Network Statistics for Forecast Year Traffic

Mode	2003		2010		2020	
	Vehicle Hours	Vehicle Km	Vehicle Hours	Vehicle Km	Vehicle Hours	Vehicle Km
Cars	4299	268075	6167	391813	11365	713975
Pick-ups	7586	472217	10991	691648	19747	1230257
Buses	2686	161758	3136	199148	4340	271850
Light Goods	3133	193383	4938	309370	9042	560748
Medium Goods	2121	131812	3105	199683	6042	379385
Heavy Goods	1560	93606	1684	107094	4146	260251
Total	21387	1320851	30021	1898756	54682	3416466

CHAPTER 13

EVALUATION OF TRAFFIC FORECASTS

CHAPTER 13 EVALUATION OF TRAFFIC FORECASTS

13.1 General Methodology

The traffic benefits that would result from disaster prevention measures are evaluated by calculating the dis-benefits to traffic of a disaster occurring. It is assumed that at each site a disaster would result in the closure of that particular link in the network and the need for traffic to re-route. When traffic re-routes to avoid the closed link it potentially incurs two types of dis-benefit:

i) increased vehicle operating costs due to additional travel distance; and
ii) increased passenger time costs.

These two parameters are evaluated by the JICA STRADA model in aggregate over the network for each vehicle mode in the form of vehicle-kilometres and vehicle-hours. These are then converted to monetary costs using the parameters set out in Table 11.3.1, which are expressed as the benefits of undertaking disaster prevention measures.

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 three years. Permanent measures incur a single capital costwith annual maintenance costs thereafter.

The benefit flow however is not guaranteed to occur, because a disaster may not strike even if no preventative measures are taken. That is, the probability of a disaster occurring will have an affect on a benefit stream. Preliminary engineering inspections of the sites have resulted in two parameters being used to calculate this affect and are as follows:

i) The maximum life of a road if no preventative measures are taken. This varies from 1 to 20 years and reflects the risk of a disaster occurring. Note that benefits only accrue after the lifetime of a road has ended.
ii) An indicator of the stability of a slope or bridge foundation that varies from 70 to 100. This score is used to factor down benefits, which then accrue each year after disaster prevention works have been implemented.

An example calculation sheet for evaluating costs and benefits is shown in Figure 13.1.1.

Average B/C	1.5

Cost-Benefit Analysis

Site No	Link 7	A-Node	405	B-Node	404
Site Name	Sites 18,19		Link Length (km)		18.7

Type of Disaster	BS	Permanent/Temporary (P/T)	T
Discount Rate (%)	10	Discount Period	21

Risk : Without Prevention Measures Road will fail in			years
Score	100	Benefit Factor	100

Base Case	
Maintenance Cost per km	1340
By Risk	B/C
By Score	B/C 1.5
Capital Cost Estimate US $	1369674

Mode	2003 Base	2003 Disaster	2010 Base	2010 Disaster	2020 Base	2020 Disaster	
1	268075	268115	391813	391891	713975	714321	Cars
2	472217	472678	691648	692283	1230257	1231245	Pick-ups
3	161758	161746	199148	199141	271850	271839	Buses
4	193383	193290	309370	309245	560748	560748	L Goods
5	*131812*	*131637*	*199683*	*199406*	*379385*	*378861*	*M Goods*
6	93606	94105	107094	107553	260251	261674	H Goods

<--- AADT Vehicle Kilometres input from *JICASTRADA* Traffic Model

Benefits, US $, per year

Veh. Op Cost 1000 km		2003		2010	2020
185.5	40	2708	78	5281	23425
215.1	461	36189	635	49848	77560
529.7	-12	-2320	-7	-1353	-2127
549.1	-93	-18639	-125	-25053	0
768.2	-175	-49068	-277	-77668	-146924
878.5	499	159998	459	147172	456267
Total		**128868**		**98228**	**408200**

Mode	2003 Base	2003 Disaster	2010 Base	2010 Disaster	2020 Base	2020 Disaster	
1	4300	4323	6167	6198	11365	11432	Cars
2	7586	7625	10991	11046	19747	19823	Pick-ups
3	2686	2694	3136	3146	4340	4351	Buses
4	3133	3164	4938	4983	9042	9111	L Goods
5	2121	2141	3105	3138	6042	6089	M Goods
6	1560	1581	1684	1704	4146	4202	H Goods

<--- AADT Vehicle Hours input from JICASTRADA Traffic Model

Benefits, US $, per year

Passenger VOT, 2002		2003		2010	2020
2.84	23	24486	31	39815	185993
1.09	39	15935	55	27111	80974
14.9	*8*	*44683*	*10*	*67383*	*160207*
1.04	31	12085	45	21165	70143
1.04	20	7797	33	15521	47779
0.75	21	5904	20	6784	41054
Total		**110890**		**177778**	**586150**
Value of Time	Base	1.027		1.239	2.678
Factors	Sensitivity	0.97		0.924	0.811

Year	Capital Cost US$	Maintenance Cost (US$)	Total Cost (US $)	Total Dis-counted Cost	Veh Km Benefits	Veh Hour Benefits	Risk Prof	Total Benefits	Discounted Benefits	Total Benefits	Discounted Benefits
								$ US M	$ US M	$ US M	$ US M
2002									*By Risk*		*By Score*
2003	1369674		1369674	1232706	128868	110890	0	0	0	0	0.0
2004	0	25058	25058	20297	124490	120445	0	0	0	0.2	0.2
2005	0	25058	25058	18267	120113	130001	0	0	0	0.3	0.2
2006	0	25058	25058	16440	115736	139556	0	0	0	0.3	0.2
2007	0	25058	25058	14796	111359	149112	0	0	0	0.3	0.2
2008	0	25058	25058	13317	106982	158667	0	0	0	0.3	0.1
2009	0	25058	25058	11985	102605	168223	0	0	0	0.3	0.1
2010	0	25058	25058	10786	98228	177778	0	0	0	0.3	0.1
2011	0	25058	25058	9708	129225	218615	0	0	0	0.3	0.1
2012	0	25058	25058	8737	160222	259452	0	0	0	0.4	0.1
2013	*0*	*25058*	*25058*	*7863*	*191219*	*300290*	*0*	*0*	*0*	*0.5*	*0.2*
2014	0	25058	25058	7077	222217	341127	0	0	0	0.6	0.2
2015	1369674	25058	1394731	354522	253214	381964	0	0	0	0.6	0.2
2016	0	25058	25058	5732	284211	422801	0	0	0	0.7	0.2
2017	0	25058	25058	5159	315208	463638	0	0	0	0.8	0.2
2018	0	25058	25058	4643	346206	504475	0	0	0	0.9	0.2
2019	0	25058	25058	4179	377203	545313	0	0	0	0.9	0.2
2020	0	25058	25058	3761	408200	586150	0	0	0	1.0	0.1
2021	0	25058	25058	3385	408200	586150	0	0	0	0.0	0.0
2022	0	25058	25058	3046	408200	586150	0	0	0	0.0	0.0
2023	0	25058	25058	2742	408200	586150	0	0	0	0.0	0.0
Total	2,739,347	501,152	3240499	1,759,149				0	**0**	8.5	**2.6**

Figure 13.1.1 Example Cost/ Benefit Calculation Sheet

13.2 Simulation of Disaster Sites in Traffic Model

Figure 13.2.1 shows the locations of 55 potential disaster sites in the traffic model network. These are located on the model links as listed in Table 13.2.1.

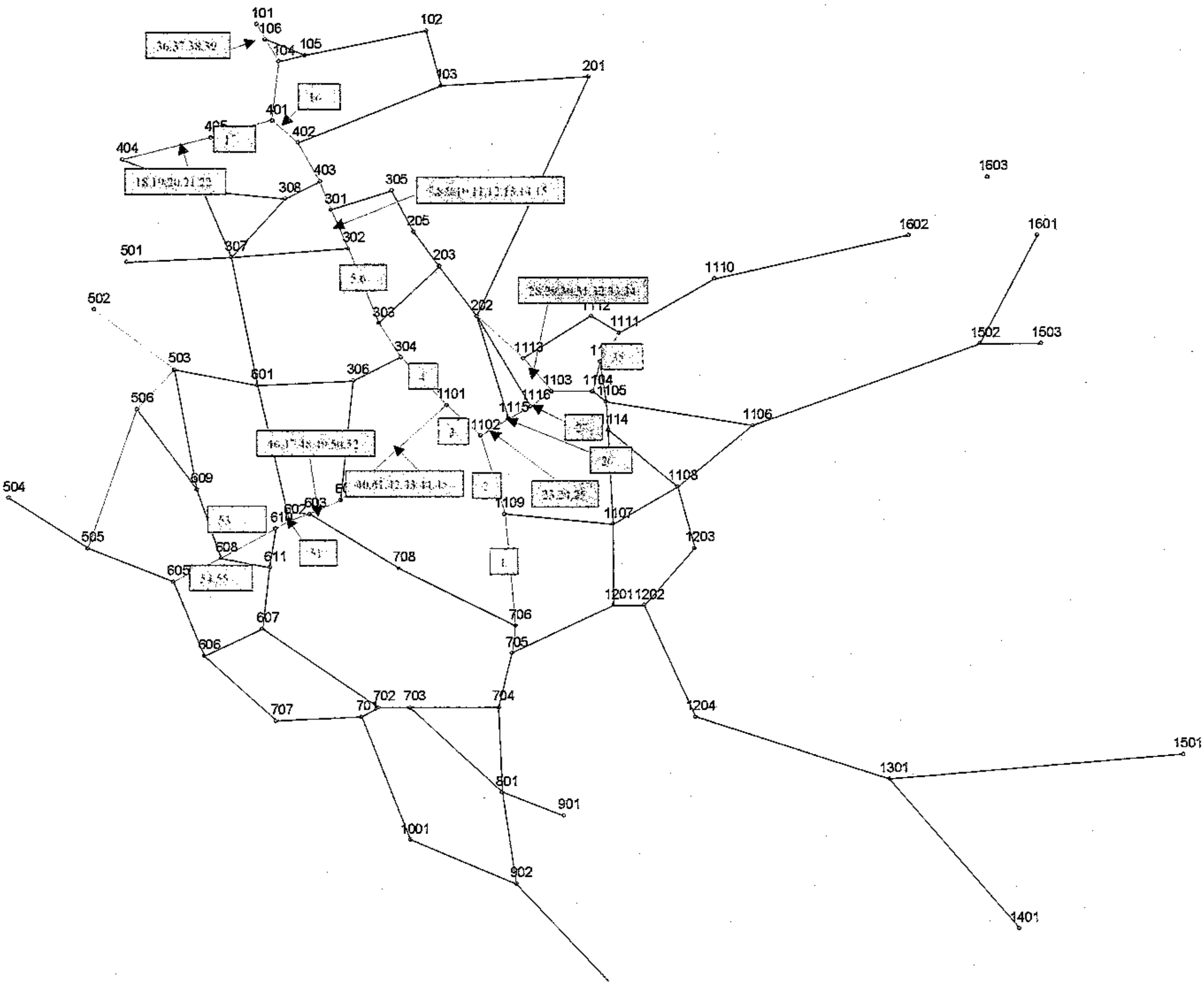


Figure 13.2.1 Disaster Sites

Table 13.2.1 Potential Disaster Links in Traffic Model

Link	A-Node	B-Node	Sites	Link	A-Node	B-Node	Sites
1	101	104	36,37,38,39	40	602	603	51
6	405	401	17	41	602	610	53,55
7	405	404	18,18,20,21	42	605	608	52
8	401	402	16	55	1102	1109	2
14	301	302	7,8,9,10,11,12,13,14,15	57	1109	706	1
22	302	303	5,6	82	1117	1111	35
32	304	1101	4	83	1115	1116	26
33	1101	1102	3	90	1102	1115	23,24,25
37	1101	604	40,41,42,43,44,45	91	1116	1103	27
38	603	604	46,47,48,49,50,54	94	1113	1103	28,29,30,31,32,33,34

Disaster sites were evaluated by removing the relevant link identified in Table 13.2.1 and performing a traffic assignment. Figure 13.2.2 shows an example for Sites 28 through 34 located on Link 94, which is the road between Matagalpa and Jinotega. A disaster in 2010 is forecast to result in the traffic flows as shown below.

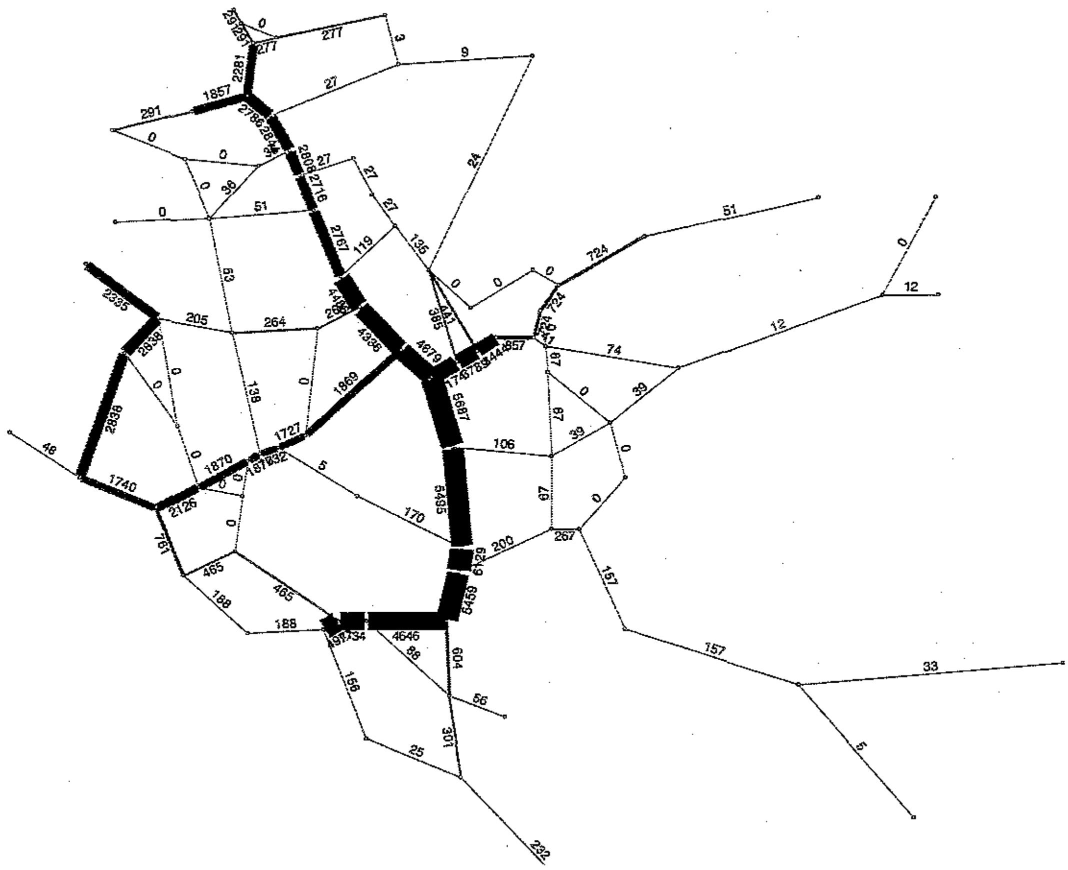


Figure 13.2.2 Forecast AADT Volumes, 2010, No Link 94

Network statistics for each vehicle type were extracted from JICA STRADA for the years 2003, 2010 and 2020 and input into the evaluation sheet. Data for intermediate years were estimated by linear interpolation. Benefits for years after 2002 were held constant at 2002 values. Benefit-to-cost ratios for each site were calculated and are shown in Table 13.2.2 and Figure 13.2.3.

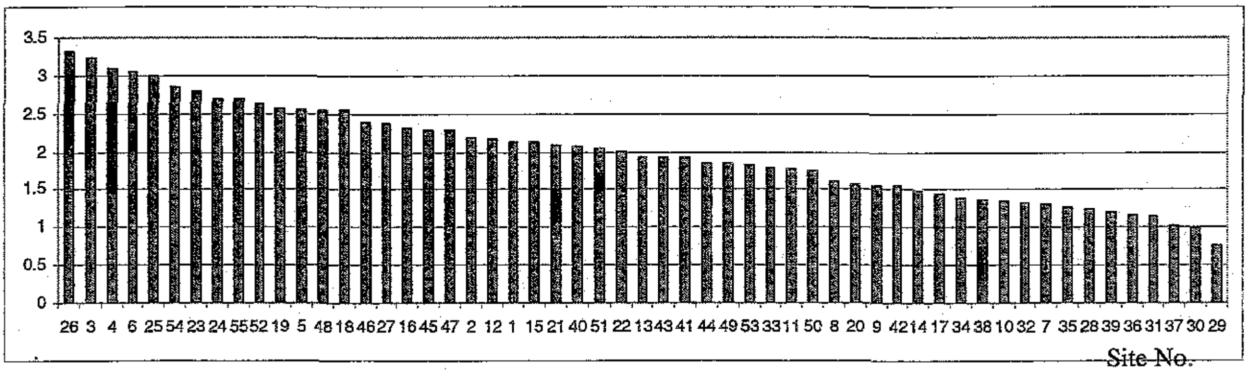


Figure 13.2.3 Cost/ Benefit Ratios of Disaster Sites (Log-scale)

Table 13.2.2 Benefit-to-Cost Ratio by Disaster Site

Site	Benefit-to-Cost Ratio
1	137
2	153
3	1720
4	1240
5	365
6	1155
7	20
8	41
9	36
10	22
11	59
12	146
13	85
14	31
15	134
16	202
17	28
18	353
19	374
20	37
21	121
22	103
23	613
24	500
25	1001
26	2083
27	238
28	18

Site	Benefit-to-Cost Ratio
29	6
30	10
31	14
32	21
33	62
34	25
35	18
36	14
37	11
38	23
39	16
40	115
41	85
42	35
43	85
44	71
45	200
46	245
47	197
48	361
49	70
50	55
51	112
52	436
53	69
54	730
55	488

It has not been possible to carry out all the sensitivity tests with lower levels of traffic. Table 13.2.3 shows the comparison of benefit-to-cost ratio for eight sites for the Base Case and sensitivity test levels of traffic. The benefit-to-cost ratios remain relatively high, even under lower-growth assumptions for traffic.

Table 13.2.3 Sensitivity Tests on Benefit-to-Cost Ratio

Site Number	*Benefit-to-Cost Ratio*	
	Base Case	*Sensitivity*
2	153	111
17	28	20
23	613	463
24	500	378
25	1001	757
36	14	10
37	11	7
38	23	16

13.3 Incorporation of Risk

Whilst the benefits reported in Section 13.2 are useful in preparing priorities for investment, they cannot be considered as *absolute* values. This is because at this stage the element of risk has not been considered. The benefits above all assume that without countermeasures, a disaster would strike by the end of the year 2003. This is extremely unlikely, and furthermore the risk element varies from site to site. This factor will be incorporated in the next stage of work.

CHAPTER 14

IDENTIFICATION OF DISASTER PREVENTION SPOTS

CHAPTER 14 IDENTIFICATION OF DISASTER PREVENTION SPOTS

14.1 General

The disaster critical spots identified in Chapter 6 of the Study require urgent, temporary or permanent countermeasures so that they can be transformed into disaster prevention spots. These spots are identified using various factors. The data used for designating a disaster critical spot are contained in chapters 8 to 13 and are as follows:

<Chapter 8>

- Hydrological survey: Evaluation of the progress regarding bridge foundation scouring
- Geological survey: Evaluation of the progress regarding rock weathering or collapse

<Chapter 9>

- Environmental survey: Evaluation of environmental impacts

<Chapter 12>

- Future traffic demand: Traffic forecast until the year 2020

<Chapter 13>

- Benefit-to-cost ratio: Evaluation of benefits and costs

It is difficult to designate a point a disaster critical spot based on economics only, since there are some spots where there are low traffic volumes. Low means traffic flows of less than 1000 vehicles AADT. Therefore, when evaluating roads and road sections for disaster criticality, a broader approach that incorporates level of stability, traffic volume, environmental impacts, development potential, natural conditions, benefits, required level of restoration, etc.should be considered.

14.2 Characteristics of Disaster Critical Spots

The characteristics of the 55 disaster critical spots on the Study roads that were identified in Chapter 6 are shown in Table 14.2.1. The types of disaster, the evaluation score, the types of countermeasures, and the rough cost estimates are described in the table. For instance, the stability score for the spots numbered 40 and 42 on NIC.26 is the same (i.e., 71 points), and the countermeasure is also the same (i.e., re-cutting of slope surface). However, the rough cost estimate for the construction of No. 42 indicates that it is about eight times greater because of the larger scale of the disaster it experienced.

14.3 Selection and Prioritisation of Disaster Critical Spots

14.3.1 Outline of Selection Techniques

As described in 14.2 above, the evaluation score of a disaster critical spot differs depending on the scale of a disaster. Moreover, note that it is very difficult to identify disaster prevention spots in terms of cost only. Therefore, it is necessary to create an evaluation index to assess overall importance. Therefore, in this Study, the selection of disaster prevention spots is carried out using the Analytic Hierarchy Process (hereafter referred to as "AHP"). AHP is a multi-criteria decision-making technique that assigns numerical values (or weights) to various types of evaluation criteria. AHP was applied to select 30 disaster-prevention spots from the 55 disaster critical spots. The hierarchical decision-making structure of AHP uses the "evaluation criteria" of "purpose" and "alternative spots" (see Figure 14.3.1).

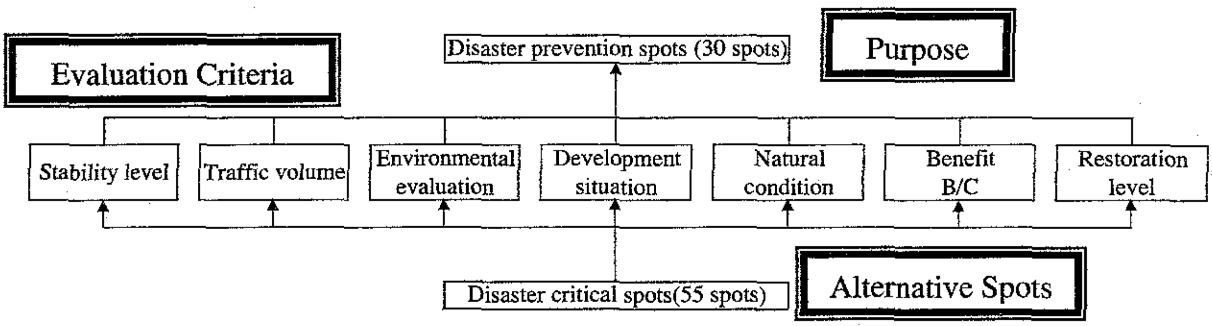


Figure 14.3.1 AHP Structure

Table 14.2.1 Characteristics of Disaster Critical Spots

Serial Number of Disaster Critical Spot	Objective Road	Type of Disaster	Score	Type of Countermeasure	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 Fall
R.C. : Rock Collapse
S.S. : Slope Slide
D.F. : Debris Flow
Bridge : Scouring of Foundation

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

14.3.2 Prioritizing Disaster Prevention Spots

The priority level for disaster prevention spots is decided in the two steps described below.

1) First Step (Setting of Evaluation Criteria)

a) Stability Level

The stability level of each spot is compared based on survey results. If the stability score is large, the priority is high.

b) Traffic Volume

The traffic volume for 2020 for each spot is compared. When the traffic volume is large, priority is high.

c) Environmental Evaluation

The environmental evaluation results of each spot are compared and when the score is small the priority is high.

d) Development Potential

The roadside development potential of each spot is compared. The spot of area where the development was completion is high priority.

e) Natural Conditions

Critical level is compared based on the results of the natural condition survey, which takes into account geology, hydrology, etc. When the critical level is large, the priority is high.

f) Benefits (Benefit/Cost)

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

g) Restoration Level

The level of difficulty of restoration is evaluated based on assuming the damage to be incurred by a disaster of maximum scale. When the difficulty level, which consists of restoration time, restoration yard spaces, necessity of special machinery, etc., is high the priority is high.

2) Second Step (Pair Comparisons of Evaluation Criteria)

a) Magnitude and Definition of Importance

Magnitude and definition of importance are as shown in Table 14.3.1 before the pair comparison of evaluation criteria is carried out.

Table 14.3.1 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

When importance is low, the magnitude uses a reciprocal number. For instance, when stability level is weakly more important then traffic volume, the magnitude is 3. On the other hand, the magnitude for traffic volume compared to stability level is 1/3.

b) Magnitude of Pair Comparison

The magnitude of pair comparisons for evaluation criteria was decided based on feedback from MTI as shown in Table 14.3.2. Moreover, the comparison of alternative spots was decided based on the evaluation scores produced by the JICA Study Team.

Table 14.3.2 Magnitude of Pair Comparison

	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

The weight for each evaluation criteria is presented in Appendix-III.

14.4 Identification of Disaster Prevention Spots

The priority of disaster prevention spots, as identified by AHP based on the magnitude of pair comparison, is shown in Table 14.4.1. The feasibility of the highest ranking 30 spots should be examined in this Study.

Table 14.4.1 Disaster Prevention Spots

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

R.F. : Rock Fall
R.C. : Rock Collapse
S.S. : Slope Slide
D.F. : Debris Flow
Bridge : Scouring of Foundation

R.E.C.V. : Recutting + Embankment + Counterweight + Vegetation

PART B

FEASIBILITY STUDY

CHAPTER 15

INTRODUCTION

CHAPTER 15 INTRODUCTION

15.1 General

In Part A of this Study, 30 disaster prevention spots were identified using a wide variety of selection criteria. In this part, or Part B, a Feasibility Study (hereafter referred to as the "FS") is carried out on these prevention spots in the nine chapters (including this chapter) listed below.

- Chapter 15 Introduction
- Chapter 16 Basic Design Standards
- Chapter 17 Detailed Examination of Countermeasures
- Chapter 18 Construction Plan and Cost Estimates
- Chapter 19 Environmental Impact Assessment
- Chapter 20 Project Evaluation
- Chapter 21 Implementation Program
- Chapter 22 Management System and Operation
- Chapter 23 Conclusions and Recommendations.

In order to implement the FS, a thorough review of countermeasures is carried out based on detailed geological survey data, hydrological survey results, topographic data, and the environment impact assessment. As described in Chapter 14, the 30 disaster prevention spots were selected applying the evaluation criteria shown below.

➢ **Stability Level**

Each spot was examined in the context of stability levels based on survey results.

➢ **Traffic Volume**

Forecast traffic volumes of spots for the years 2010 and 2020 were compared.

➢ **Environmental Evaluation**

Each spot was evaluated against a series of environmental items.

➢ **Development situation**

The potential development of roadside areas of each spot was compared.

➢ **Natural Conditions**

The critical levels of spots were compared applying the natural condition survey results and geological, hydrological and topographic data for the rainy season.

➢ **Benefit/Cost (B/C)**

The results of B/C evaluations were compared with the rough cost estimates of countermeasures in Part A of this Study.

➢ **Restoration Level**

The difficulty of restoration was evaluated assuming a disaster maximum in scale.

The above-mentioned items were considered not only to establish a system of maintenance work required by MTI, but also to enhance the traffic efficiency of the road network and to assist with the development of local area economies.

The target year for the FS has been set at 2020 based on the NTP. According to the NTP, the reasons for selecting 2020 as the target year is to strategically advance the economic development of Nicaragua and establish appropriate functions for the future transportation system of Nicaragua.

15.2 Disaster Prevention Spots for the Feasibility Study

Countermeasures taken up for consideration for the disaster prevention spots identified in Chapter 14 are as follows:

- i) Countermeasures for rocks falling or collapsing,
- ii) Countermeasures for rocks collapsing,
- iii) Countermeasures for slope sliding,
- iv) Countermeasures for debris flows, and
- v) Countermeasures for bridge foundation scouring.

Each of the above countermeasures deals with a different problem, such as weathered geology, seepage water, lava plateau characteristics, loose rocks, steep slope gradients, etc. The countermeasures proposed for each disaster prevention spot are as shown in Table 15.2.1.

Table 15.2.1 Disaster Prevention Spots and Countermeasures for Feasibility Study

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	Nic1	19	Bridge	Gabion mat
5	Nic26	55	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	Nic26	50	R.F.	Recutting + Shotcrete
11	Nic1	5	Bridge	Gabion mat
12	Nic26	52	Bridge	Gabion mat
13	Nic1	2	R.F.	Prevention net
14	Nic3	25	R.C.	Recutting
15	Nic26	54	Bridge	Gabion mat
16	Nic1	3	Bridge	Gabion mat
17	Nic1	1	R.F.	Barrier with gabion wall
18	Nic26	51	R.C.	Prevention net
19	Nic3	30	D.F.	Dam
20	Nic3	24	R.C.	Recutting
21	Nic26	49	R.C.	Recutting
22	Nic1	13	R.C.	Recutting + Shotcrete
23	Nic1	12	R.C.	Recutting + Shotcrete
24	Nic3	27	R.C.	Recutting
25	Nic1	11	R.C.	Recutting + Shotcrete
26	Nic1	7	R.F.	Prevention net
27	Nic26	44	R.F.	Recutting + Shotcrete
28	Nic5	35	R.F.	Recutting + Surface drainage + Vegetation
29	Nic3	34	R.C.	Recutting + Prevention net
30	Nic3	29	S.S.	R.E.C.V.

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

R.E.C.V. : Recutting + Embankment + Counterweight + Vegetation

The relationship between the objective roads and the number of disasters by types is as shown in Table 15.2.2.

Table 15.2.2 Relationship between Objective Roads and No. of Disasters by Type

	Rock falling	Rock collapsing	Slope Slide	Debris flow	Scouring Bridge foundation	Total
NIC. 1	3	4	0	0	6	13
NIC. 3	0	3	3	1	1	8
NIC. 5	1	0	0	0	0	1
NIC. 26	2	2	0	0	4	8
Total	6	9	3	1	11	30

CHAPTER 16
BASIC DESIGN STANDARD

CHAPTER 16 DESIGN STANDARDS

16.1 General (Applicable Geometric Design Standards)

16.1.1 Objective of Chapter

Applicable geometric standards for each disaster prevention spot are decided in this chapter using the results of the traffic volume survey carried out by the Study and cross-section width based on the geometric standards of Nicaragua (see Chapter 2).

16.1.2 Results of Traffic Volume Survey

Traffic volume for both the present and future for the disaster prevention spots is as shown in Table 16.1.1. All spots are classified at present as Class A3 roads (i.e., rural trunk roads) using the geometric standards shown in Chapter 2. On the other hand, many of spots can be reclassified in the future as Class A2 roads (i.e., suburban trunk roads) owing to potential future increases in traffic volume.

On the other hand, the study has decided to carry out its design work on the assumption that these roads will remain as Class A3 road for the following reason;

- Other International Donor has done the same in their work.
- The main function of this study is road –related disaster prevention and not road improvement itself.

16.1.3 Geometric Standards Applied

Based on the data contained in Table16.1.1, the geometric standards adopted for this Study are as shown in Table16.1.2. However, since the purpose of the Study is to prevent the occurrence of road-related disasters and not the improvement of roads, alignment improvements are only carried out when it is effective for preventing such disasters from happening.

Table 16.1.1 Results of Traffic Volume Survey

No		Traffic Volume		Functional Classification		Type of Terrain	Design Speed	Recommended Road Width	
		2002	2020	Exisiting	Future			Carriage Way	Sholder
NIC.1									
1	N001A290	3612	9785	A3	A2	Flat	80	3.3 - 3.65	1.0 - 1.8
2	N001A280	3713	9560	A3	A2	Flat	80	3.3 - 3.65	1.0 - 1.8
3	Junquillal	3070	8315	A3	A2	Flat	80	3.3 - 3.65	1.0 - 1.8
4	San Nicolas	2831	7757	A3	A2	Flat	80	3.3 - 3.65	1.0 - 1.8
5	Las Chanillas	1760	4865	A3	A2	Flat	80	3.3 - 3.65	1.0 - 1.8
6									
7	N001A240	1740	4797	A3	A2	Mountainous	60	3.3 - 3.65	1.0 - 1.8
8	N001B230	1740	4797	A3	A2	Mountainous	60	3.3 - 3.65	1.0 - 1.8
9	N001B170	1740	4797	A3	A2	Mountainous	60	3.3 - 3.65	1.0 - 1.8
10	N001B150	1740	4797	A3	A2	Mountainous	60	3.3 - 3.65	1.0 - 1.8
11	N001B120	1740	4797	A3	A2	Mountainous	60	3.3 - 3.65	1.0 - 1.8
12	Rio Inali	207	556	A3	A3	Hilly	70	3.3 - 3.65	1.0 - 1.8
13	RioTapacali	207	556	A3	A3	Hilly	70	3.3 - 3.65	1.0 - 1.8
NIC.3									
14	003B400	2665	6461	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
15	003B370	2665	6461	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
16	El Guayacan	2665	6461	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
17	N003B320	2665	6461	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
18	N003C230	2665	6461	A3	A2	Mountainous	60	3.3 - 3.65	1.0 - 1.8
19	N003E170	2665	6461	A3	A2	Mountainous	60	3.3 - 3.65	1.0 - 1.8
20	N003C150	2665	6461	A3	A2	Mountainous	60	3.3 - 3.65	1.0 - 1.8
21	N003C140	2665	6461	A3	A2	Mountainous	60	3.3 - 3.65	1.0 - 1.8
NIC.5									
22	N005A001	34	1289	A3	A3	Mountainous	60	3.3 - 3.65	1.0 - 1.8
NIC.26									
23	N026A006	1215	3392	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
24	La Banderita	1215	3392	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
25	N026B140	1125	3118	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
26	N026A150	1125	3118	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
27	N026B160	1125	3118	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
28	San Juan de Dio	1125	3118	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
29	Papalon	1319	3770	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8
30	Solis	1319	3770	A3	A2	Hilly	70	3.3 - 3.65	1.0 - 1.8

Table 16.1.2 Applicable Geometric Standards

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

16.1.4 Distance to Roadside Obstacles & Stopping Sight Distance

There are a few spots where sight distance for a road is poor due to such things as slope overhang. In such cases, safety can be improved by eliminating the cause of poor sight distance, which is set based mainly on design speed. The required minimum distance to roadside obstacles for stopping sight distance for a horizontal curve can be calculated using the formula below and is as shown in Figure16.1.1.

<u>Calculation Method of Distance to Roadside Obstacles</u>

$E = D^2/8Ra$

E: Distance to Roadside Obstacle (m)

D: Sight Distance ≒ S (m)

Ra: Radius (m)

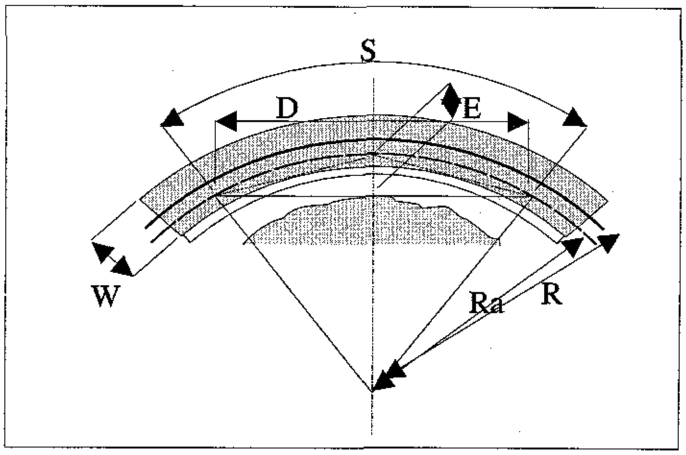


Figure16.1.1 Relation of Sight Distance and Radius

16.2 Design Standards

16.2.1 Standards for Slope Gradients

1) Embankment Gradient

In Nicaragua, embankment gradient is decided by traffic volume and embankment height. For example, a gentle slope is usually applied in the case of an embankment with a height of less than 1.2 m. The recommended standards for the gradients of embankment is shown in Table 16.2.1.

Table 16.2.1 Recommended Standards for Embankment Gradients by Road Type

Functional Classification			Minor Collector	Major Collector	Minor Arterial	Principal Arterial	Special Arterial
Number of Lanes			2	2	2	2	4
Future Average Daily Traffic (vpd)			0-400	400-1,800	1,800-3,000	> 3,000	> 3,000
Side-slope	On Fill	H < 1.2 m	3:1	3:1	4:1	4:1	4:1
		H > 1.2 m	1.5:1	1.5 :1	2:1	2:1	2:1

2) Cut Slope Gradient

The standards for the gradients of a cut slope in Nicaragua are decided by geological soundness and traffic volume (Table16.2.4). Geological soundness is classified into four types: sound rock, unknown soil, well-compacted soil, and poorly compacted soil. Note that it is not necessary to have detailed geological data. Recommended standards for the gradients of cut slopes are shown in Table 16.2.3.

It is worth mentioning here that tuff and muddy rock may affect the stability of slopes in many cases. Rock stability is considered taking into account two factors: hardness and loosing rate. In Nicaragua, rocks are classified into hard and soft, with rocks being classified as the former (or "I") when unconfined compression strength is more than 100kg/cm^2 and the latter (or "II") when unconfined compression strength is under 100kg/cm^2. Soil/sand is classified as III. As for the loosing rate, Rocks are classified into either A or B, with A being rocks that large. Below, both of the factors of hardness and loosing are combined to classify rocks (see Table 16.2.2).
Loosen quality B Rocks that loosen slowly case Table 17.3.4 for details.

Table16.2.2 Concept for Rock Classification

Rock Quality Classification According to Hardness		**Hard**		**Soft**
		I ←→	**II**	III
Rock Quality Classification According to Loose Rate **Large** ↕ **Small**	A	**I A**	**II A**	III
	B	**I B**	**II B**	

Table 16.2.3 Recommended Standards for Cut Slopes in Nicaragua Based on Rock Classification

Classification		Height of cut (m)	Degree of Cut θ(°)	1/tan θ	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

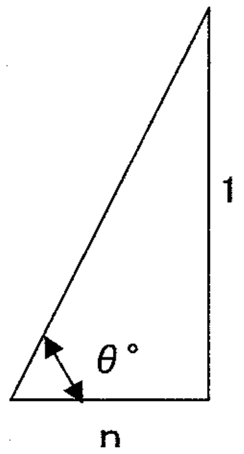
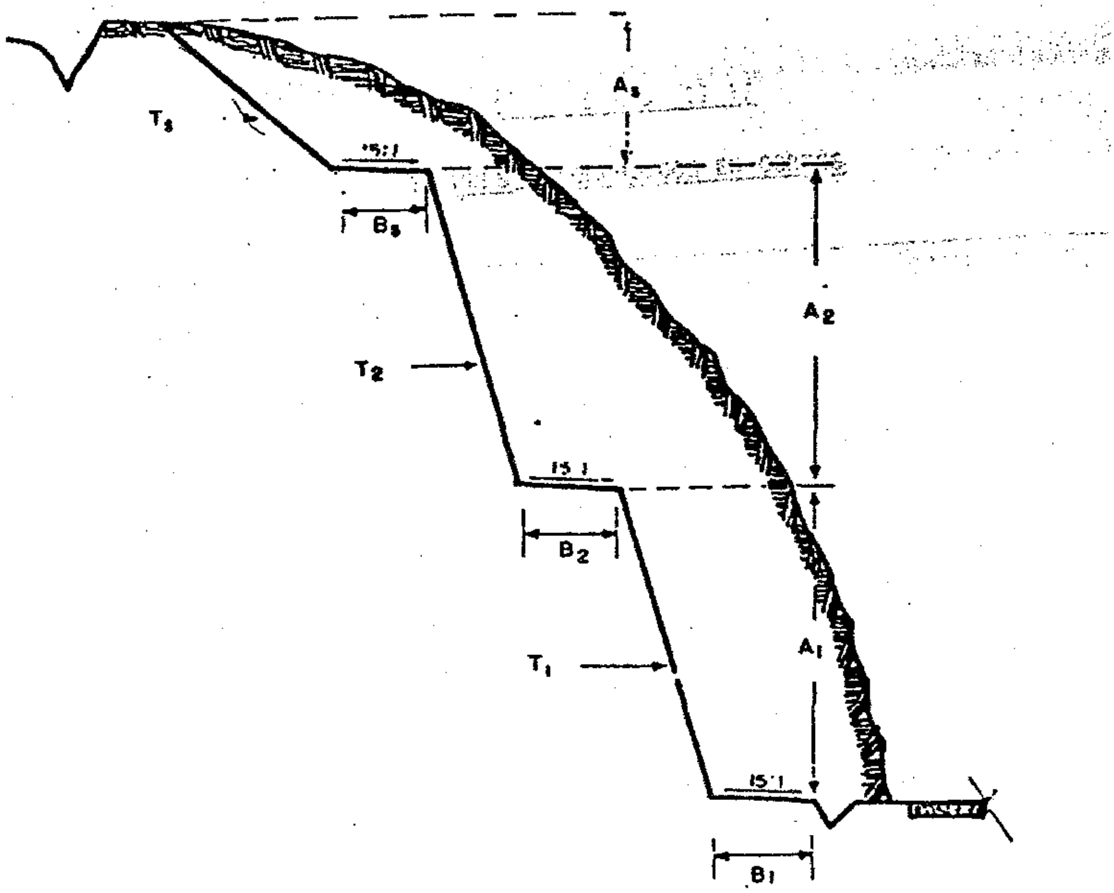


Table 16.2.4 Cut Slope Gradient Standards by Road Type

Functional Classification			Minor Collector	Major Collector	Minor Arterial	Principal Arterial	Special Arterial
Number of Lanes			2	2	2	2	4
Future Average Daily Traffic (vpd)			0-400	400-1,800	1,800-3,000	> 3,000	> 3,000
Side-slope	In Cut	Sound Rock	0 - 1/2:1	0 – 0.5:1	0 – 0.5:1	0 – 0.5:1	0 – 0.5:1
		Unknown Soil	1:1	1.5:1	1.5:1	2:1	2:1
		Well Compacted Soil	1:1	1.5:1	1.5:1	2:1	2:1
		Poorly Compacted Soil	1.5:1	1.5:1	2:1	2:1	2:1

3) Berm

The standard for berms for cut slopes is as shown in Figure 16.2.1, and has been adopted by MTI. However, the basis for the standard is not fully understood. . In this Study, a width of 1.5 has been adopted for berms.



ALTURA (A)	BANQUETA (B)	TALUD (T)
A_1 = 4 - 8 m *	B_1 = 0 - 1.5 m	T_1 = 1/8:1 - 1:1
A_2 A_n = 8 m	B_2 .. B_n = 1.5 - 4 m	T_2...T_n = 1/4:1 - 1.5:1
A_s = 8m. max.	B_s = 1.5 m. min.	T_s = 1.5:1

* CUANDO B_1 ES 0, A_1 DEBE LIMITARSE A 4 METROS

Figure 16.2.1 Beam Standard in Nicaragua

16.2.2 Structures

1) Estimation of Scouring Range

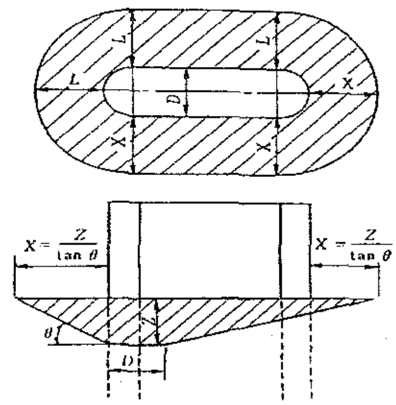
Scouring depth can be estimated based on the results of experiments conducted by the National Institute for Land and Infrastructure Management (formerly the Public Works Research Institute) of the Ministry of Land, Infrastructure, and Transport (see Figure 16.2.2). Note however that calculations in this table cover the range of ho/D<3.5.

(ho: Mean water depth during flooding, D: Width of pier)

The calculated value below is only a sample, and it therefore important to confirm the amount of scouring via on-site measurements.

Width of river: W = 31.6 m
Width of pier: D = 1.1 m
Velocity of high water level: V = 60.12 m/s
Mean water depth in flood: ho = 2.67 m
Average grain diameter of riverbed materials: dm = 3.0mm

ho/D = 2.43
Fr = $(V/(W\cdot ho))/\sqrt{(g\cdot ho)}$ = 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

Figure16.2.2 Area of Scouring

The value ho/D can be obtained from Z/D using the relationship between ho/dm and Fr (Figure16.2.3-Figure16.2.6) as a parameter.

Z/D =0.8
Z =0.96 m

The relationship between the angle of repose θ and average grain size is shown in Figure16.2.7.
Angle of repose θ = 32°
Tan θ = 0.62
X = Z/tan θ = 1.54 m

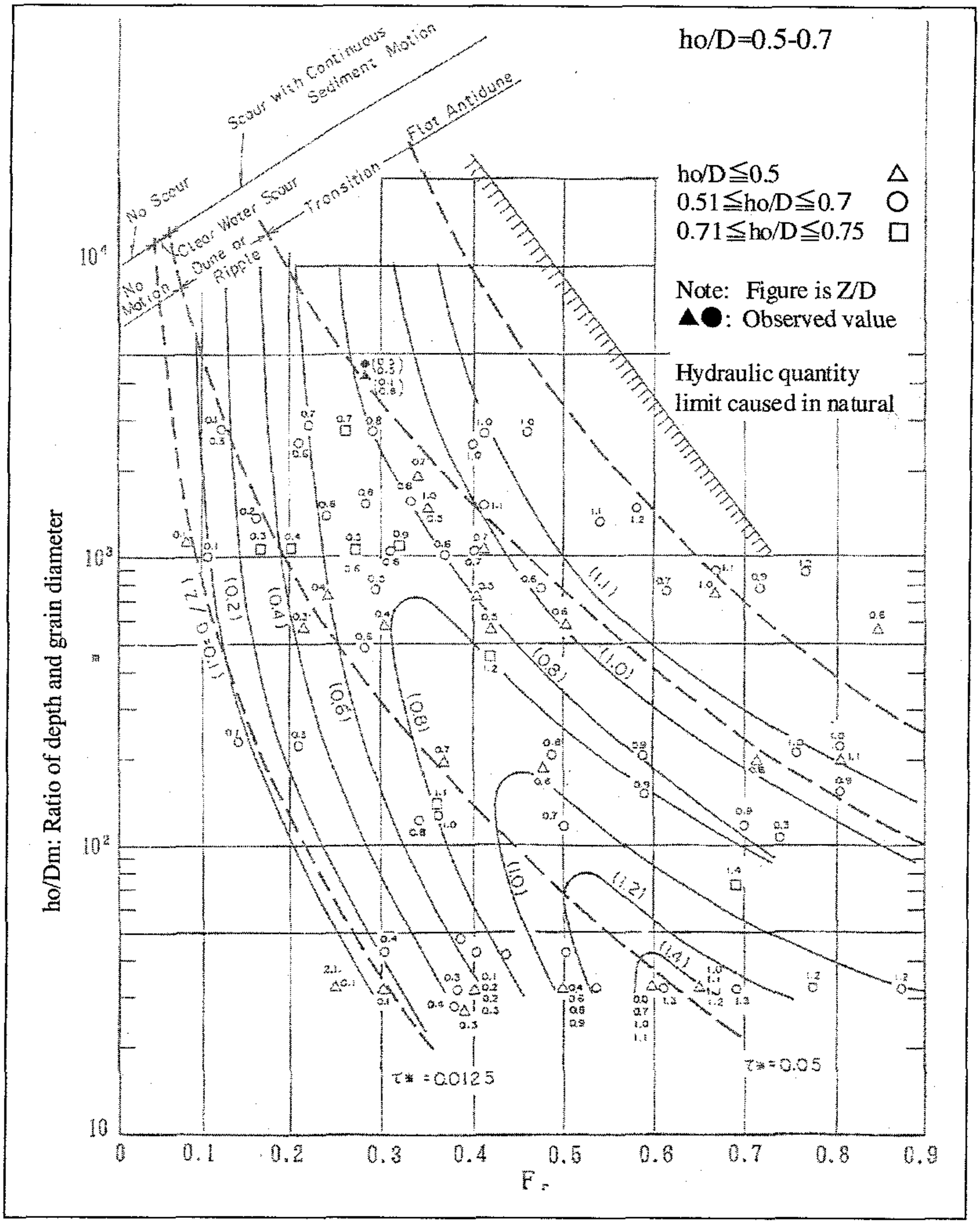


Figure 16.2.3 Assumption for Scouring Depth (ho/D = 0.5-0.7)

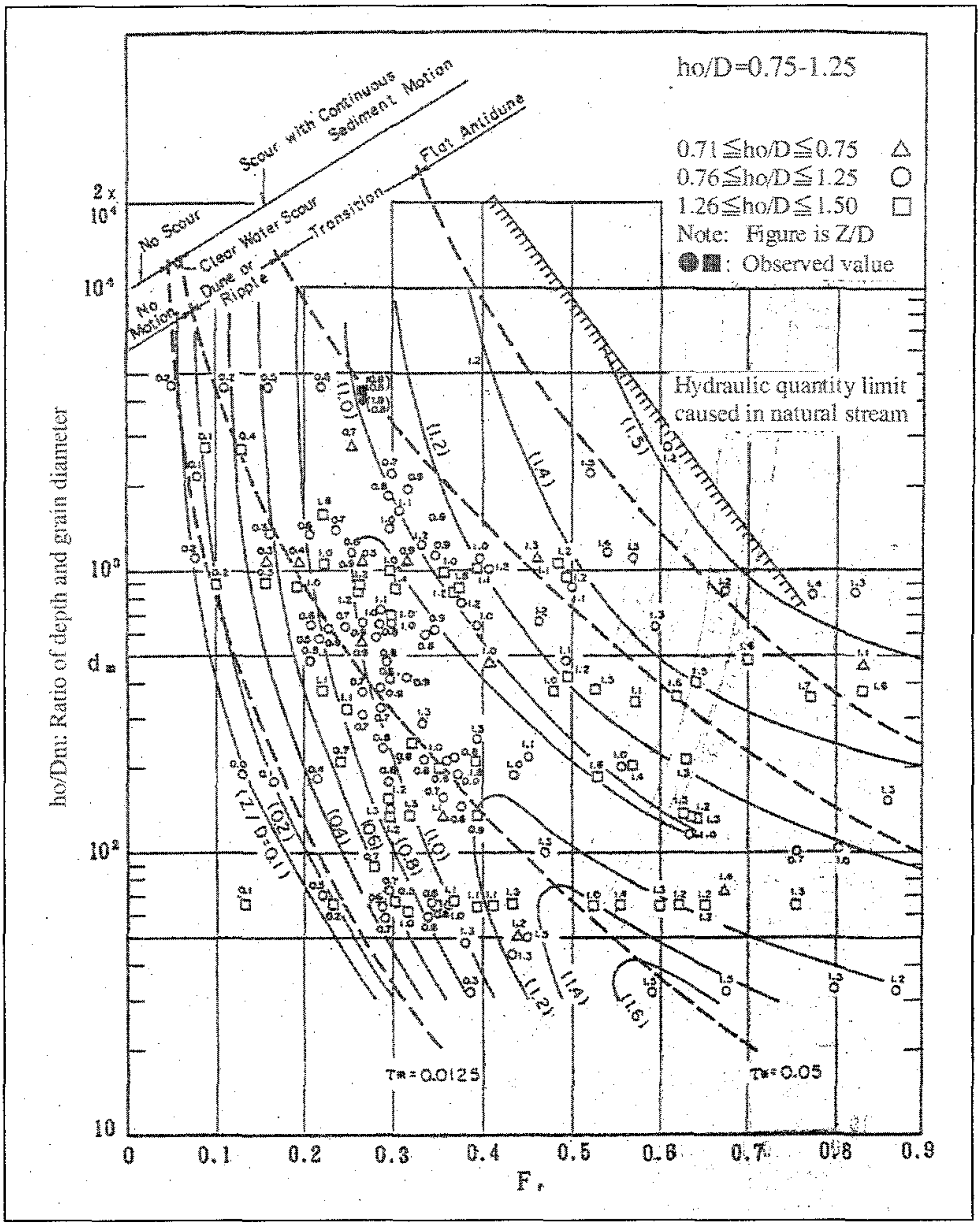


Figure 16.2.4 Assumption for Scouring Depth (ho/D = 0.75-1.25)

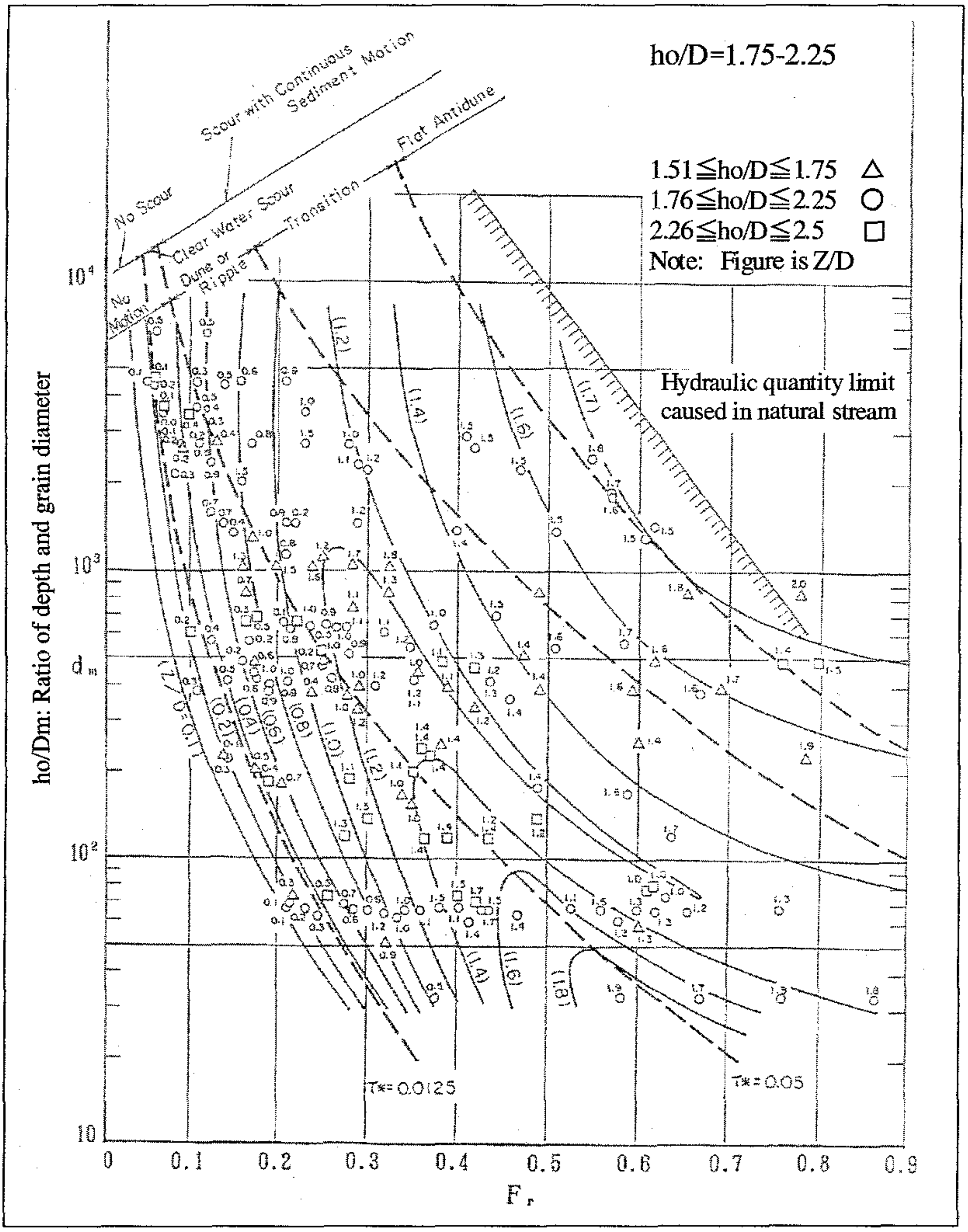


Figure 16.2.5 Assumption for Scouring Depth (ho/D = 1.75～2.25)

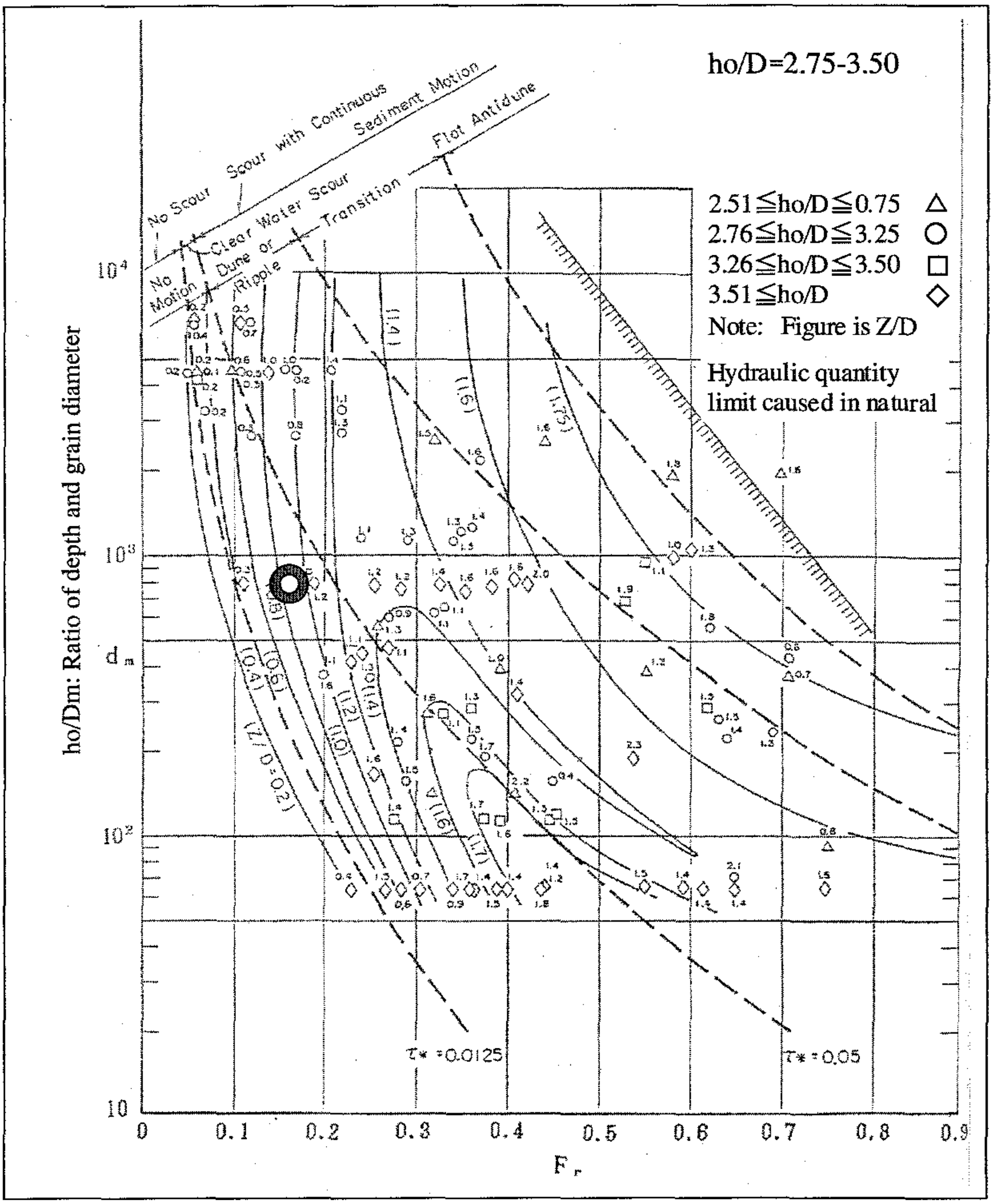


Figure 16.2.6 Assumption for Scouring Depth (ho/D = 2.75～3.5)

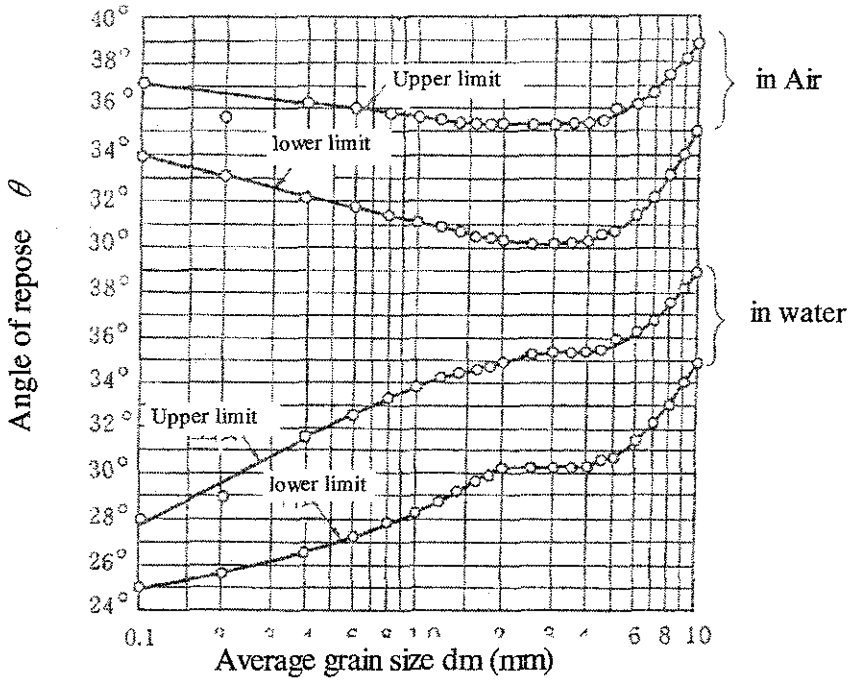


Figure 16.2.7 Relationship between Average Grain Size and Angle of Repose

2) Relation between Size and Flow Velocity of Rubble-mound and Block

Rubble-mounds and concrete blocks are placed around pier to prevent scouring. The size and shape of the concrete block are decided by the velocity of river. See Figure 16.2.8 and Table 16.2.5.

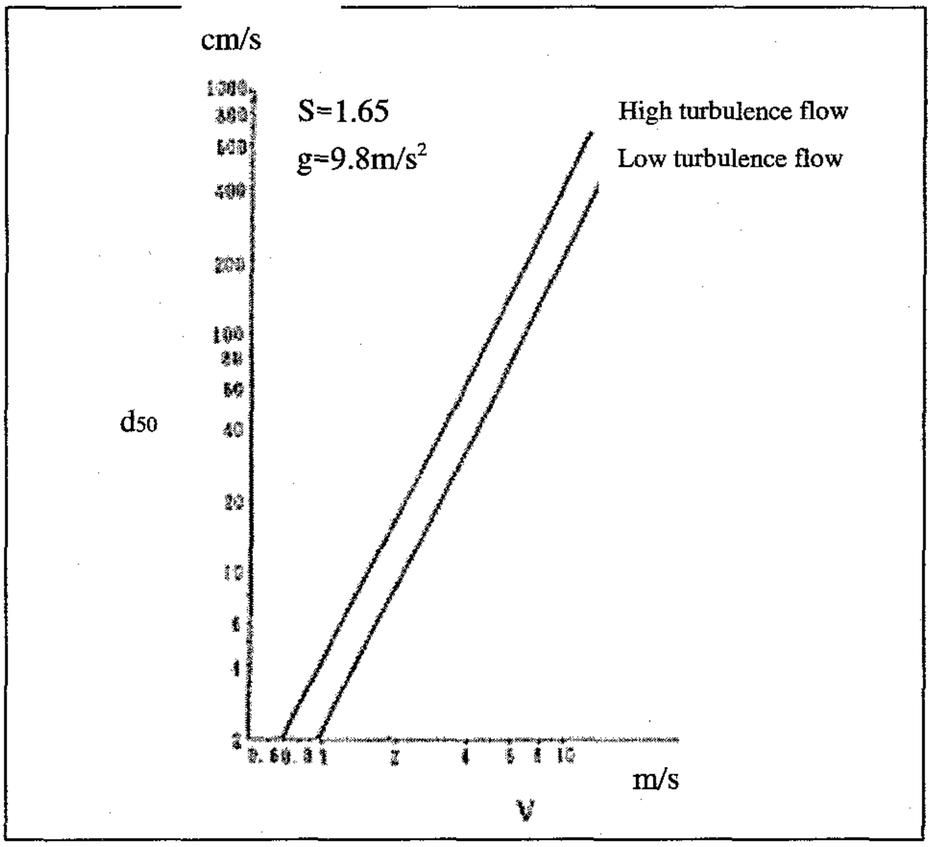


Figure 16.2.8 Relationship between Size of Debris and Velocity of Water Flow

Table 16.2.5 Relationship between Weight of Blocks and Velocity of Water Flow

Shape	Weight of Block (ton)	Velocity 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

16.3 Standard Typical Cross-section and Right-of-Way

16.3.1 Confirmation of Standard Value

As stated in Section 16-1, all disaster prevention spots are Class A3 roads (i.e., rural trunk roads). The typical cross-section and right-of-way of Class A3 roads are as shown in Table 16.3.1.

Table 16.3.1The typical cross-section and right-of-way of Class A3 roads

No.	Description Item		Trunk Road	
			Suburban	Rural
1	Number of Lanes		2 to 4	2 to 4
2	Lane Width (m)		3.30 - 3.65	3.30 - 3.65
3	Shoulder Width (m)		Int: 1.0 - 1.5, Ext: 1.5 - 1.8	Int: 0.5 - 1.0, Ext: 1.0 - 1.8
4	Road Right-of-Way (m)	Recommended Value	40 - 50	40 - 50
	Road Site Law (1952)	Nic 1	40 (international road)	
		Nic 3	20 (interstate trunk road)	
		Nic 5	20 (interstate trunk road)	
		Nic26	20 (interstate trunk road)	

Note: Int means inside curve; Ext means outside curve

As for the width of a shoulder on the inside of a curve (Int), since all the disaster prevention points are located on 2-lane, it is not taken into consideration. As for right-of-way, it is suitable to follow the existing law.

16.3.2 Standard Typical Cross Section

The typical cross-section for the Study roads in consideration of the above standard values is as shown in Figure 16.3.1.

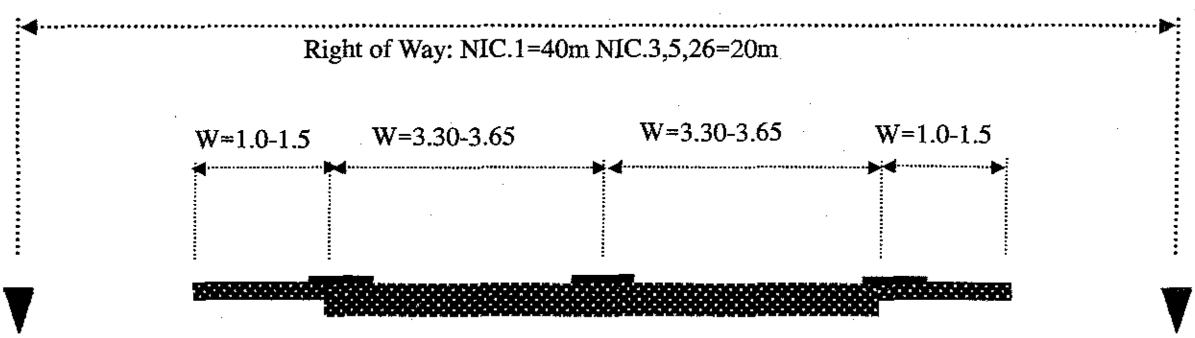


Figure 16.3.1 Standard Typical Cross-section and Right-of-way

16.3.3 Confirmation of Existing Road Width

The results of checking the existing road width of the disaster prevention spots are as shown in Table 16.3.2.

Table 16.3.2 Status of Existing Road Width

	No	Existing Width				Necessary Min. Width		Judge
		Remaining Width	Paved Width	Remaining Width	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

Because existing road shoulder width can not be confirmed, the width check of the Table 16.3.2 shows the result of the comparison by the existing paved width and the standard carriageway width. Standard value is satisfied as a carriageway width as shown in the table at the almost all points. However, as for two places of NIC.3, standard value isn't satisfied.

CHAPTER 17

CLOSE EXAMINATION OF COUNTERMEASURES

CHAPTER 17 DETAILED EXAMINATION OF COUNTERMEASURES

17.1 General

The objectives of this chapter are to confirm the status of disaster prevention spots and examine in detail possible countermeasures. First, the results of Phase 1 of the Study shall be re-examined by considering the effects of the rainy season in Phase 2, and then necessary modifications made if any unstable factors are observed. Second, various kinds of analyses on slope stability and bridge foundation scouring shall be performed. Third, and finally, appropriate countermeasures shall be proposed.

17.2 Confirmation of the Status of Disaster Prevention Spots

17.2.1 Consideration of Slope Surface Factors in Countermeasures

In brief, slope surface conditions in rainy and dry seasons differ in wet condition variations on the surfaces, changes associated with them and vegetation thickness.

Based on the Phase 2 study, it was found that slope surface wet conditions contained surface water, spring water with some hydraulic gradient and water film oozing. These wet conditions affect principally weathered layers consisting of a tuff group. It is observed that the wet conditions 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. The andesite rocks develop in mainly 4-5 m-thickness layers and also many auto-breccia rocks (when the rocks began hardening from lava, they were broken into small rock fragments because of being pushed away by continuous lava flow. Therefore, they are filled with the same rocks as crashed rock fragments.), occurring in brecciated condition on the slope surface. 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.

In the Phase 2 study, we reviewed the Stability Investigation Table of the Phase 1 study and then continued the site survey in accordance with the following flow chart (Figure17.2.1) to consider countermeasures against slope surfaces stability meeting the need of construction sites, with the intention of identifying the process of water flow in rainy season on each slope surface and the relation between the flow and the surface stability.

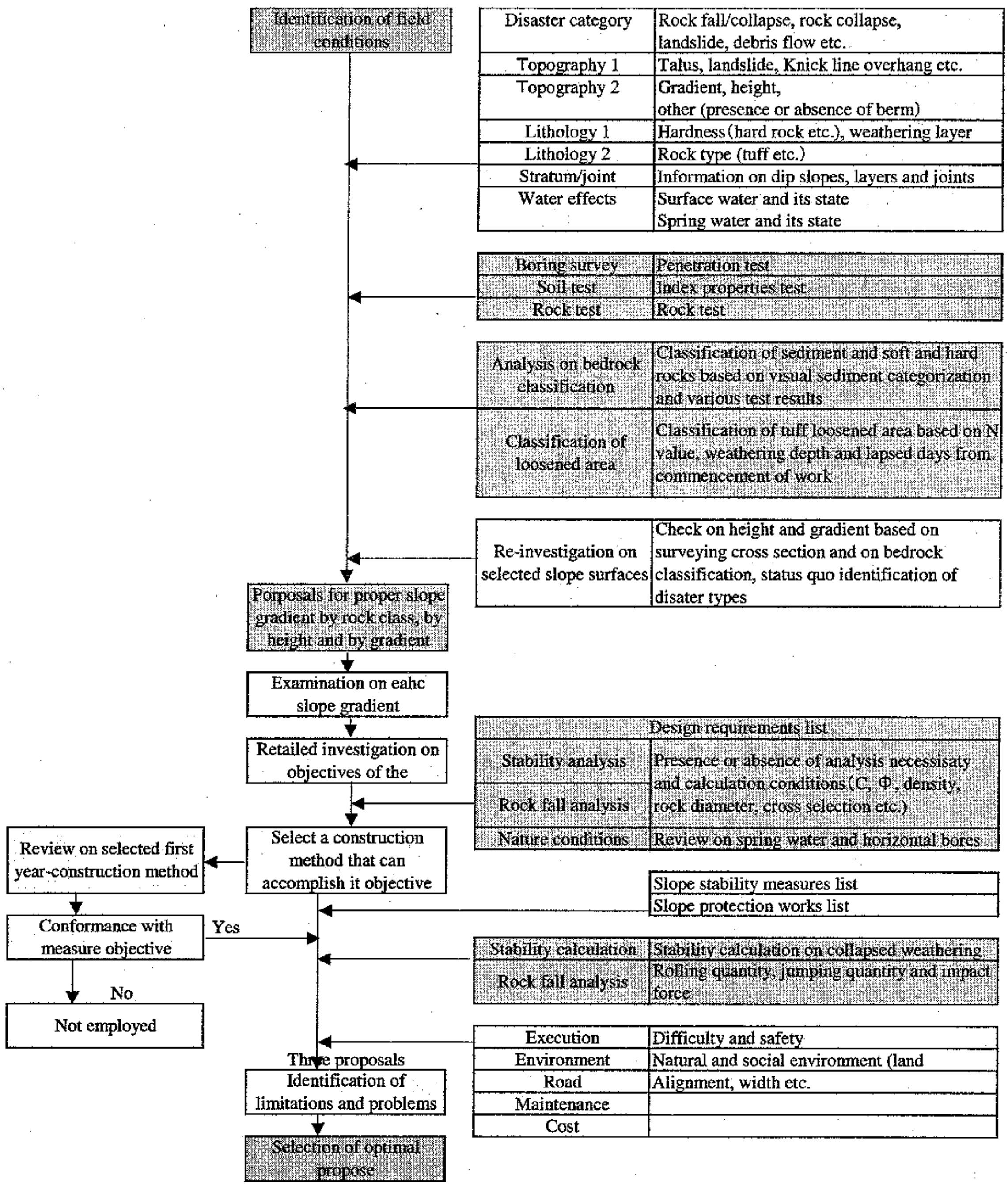


Figure 17.2.1 Selection Flow of Counter Measures against Slope Surface

Next, the Phase 2 study shows how evaluation in Phase 1 study has been changed after identifying the effects of mainly rainfall.

Review results of the Stability Investigation based the Phase 2 study is shown in Table 17.2.1. A bold letter in Table 17.2.1 shows the evaluating point that was changed by the Phase 2 study.

Table 17.2.1 Review Results List of the Stability Investigation based on the Phase 2 Study

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	R.F.	A	10
2	**78**	**84**	N001A280	73.2	R.F.	A	10
3	90	90	[illegible]	113.19	Bridge	B	6
4	100	100	San Nicolas	135.64	Bridge	C	2
5	90	90	Las Chanillas ([illegible])	150.33	Bridge	B	6
6	100	100	San Ramon	151.85	Bridge	C	2
7	84	84	N001A240	168.4	R.F.	B	6
8	**72**	**75**	N001B230	168.6	R.C.	B+	8
9	72	72	N001B200	169.8	R.C.	C	2
10	72	72	N001B190	170.7	R.C.	B−	4
11	**78**	**81**	N001B170	171.3	R.C.	B	6
12	**76**	**79**	N001B150	175.0	R.C.	A	10
13	**74**	**76**	N001B120	176.2	R.C.	A	10
14	76	76	N001A110	178.7	R.F.	B+	8
15	73	73	N001B100	187.3	R.C.	B−	4
16	**73**	**76**	N001B070	204.7	R.C.	B+	8
17	70	70	N001A050	214.7	R.F.	A	10
18	100	100	Rio Inali	226.89	Bridge	B−	4
19	100	100	Rio Tapacali	239.245	Bridge	C	2
20	75	75	N001B030	232.5	R.C.	B	6
21	73	73	N001A020	233.7	R.F.	C	2
22	73	73	N001A010	235.6	R.F.	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	R.C.	C	2
24	**72**	**75**	003B400	6.9	R.C.	B+	8
25	80	80	003B370	7.4	R.C.	B+	8
26	100	100	El Guayacan	119.05	Bridge	A	10
27	**74**	**76**	N003B320	22.1	R.C.	B+	8
28	**70**	**72**	N003B240	32.7	R.C.	B−	4
29	73	73	N003C230	32.8	S.S.	A	10
30	83	83	N003E170	35.2	D.F.	A	10
31	71	71	N003C160	35.9	S.S.	A	10
32	90	90	N003C150	38.9	S.S.	B+	8
33	90	90	N003C140	39.4	S.S.	A	10
34	**81**	**83**	N003B120	40	R.C.	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	R.F.	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	D.F.	A	10
37	70	70	N015E020	11.1	D.F.	A	10
38	70	70	N015E050	11.7	D.F.	B−	4
39	70	70	N015E060	13.5	D.F.	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.C. between San Ishidoro & Sebaco (km) (*Bridge: from Managua)	Type of disaster	Natural Condition Evaluation	Natural Condition Score
40	71	71	N026A010	9.0	R.F.	B	6
41	70	70	N026A020	12.7	R.F.	B	6
42	71	71	N026A030	19.9	R.F.	C	2
43	72	72	N026A040	20.9	R.F.	C	2
44	**70**	**78**	N026A060	24.7	R.F.	A	10
45	100	100	La Bandeita	170+952	Bridge	C	2
46	**76**	**78**	N026A100	29.3	R.F.	B	6
47	73	73	N026B110	29.8	R.C.	C	2
48	72	72	N026A130	33.6	R.F.	B	6
49	80	80	N026B140	34.0	R.C.	A	10
50	**85**	**87**	N026A150	34.2	R.F.	A	10
51	86	86	N026B160	37.0	R.C.	A	10
52	90	90	San Juan de Dios	156+705	Bridge	B−	4
53	71	71	N026B210	45.5	R.C.	B	6
54	90	90	Papalón	108+154	Bridge	C	2
55	100	100	Solis	107+533	Bridge	C	2
Sub-total			16spots				
Total			Nic.1,3,5,15,26				

R.F.	:Rock Falling
R.C.	:Rock Collapsing
S.S.	:Slope slide
D.F.	:Debris Flow
Bridge	:Scoring of fundation

15 points in boldface of 19 points in Table 7.2.1, picked up by this survey represent rainfall-affected slope surfaces. Next, key points of this investigation and its results are described.

1) Secondary Survey Notes

As mentioned above, since it can be considered that the bedrock in a surveyed area was affected by weathering force in the process of long-term geological time, the bedrocks on the slope surfaces lie in a certain weathering zone more or less. Weathering events include short-term weathering such as slaking and swelling. However, it might be justified that this weathering in the process of long-term geological time caused slope stability within "a loosened area of the bedrock." Based on this current state and the results of this survey, priority is given to the following points for disaster prevention.

i) Removal of unstable or potential unstable loose blocks or rolling stones
ii) Flattening the existing bedrock slope
iii) Removal of overburden load from the bedrock slope head which may fail in future (These countermeasures include mainly re-cutting of the slope.)
iv) Establishment of berms on the bedrock slope
v) Water Draining by horizontal bore holes and interceptors

a) Removal of Unstable or Potential Unstable Blocks or Rolling Stones

Some of the cut slopes surfaces require their forming for disaster prevention and maintenance due to that rock fall and collapse are repeated and that there are loose, overhanging or protruding blocks. Before forming the slopes, it should be noted which block on each slope to be removed, however, this survey focused on andesite rocks containing opening cracks, slopes subject to the risk of overhanging and toppling collapse and tuff with a wide loosened part.

In particular, the originally cracked andesite rocks form a causative factor inducing rock fall after weathering enlarges their apertures. Falling area, width and depth used for the Ritchie (1998)'s design of rock fall prevention works modicate more information since they are related to the design of rolling and jumping quantity of falling stones analyzed by this survey.

Symbols in the following table shall be based on the following figure.

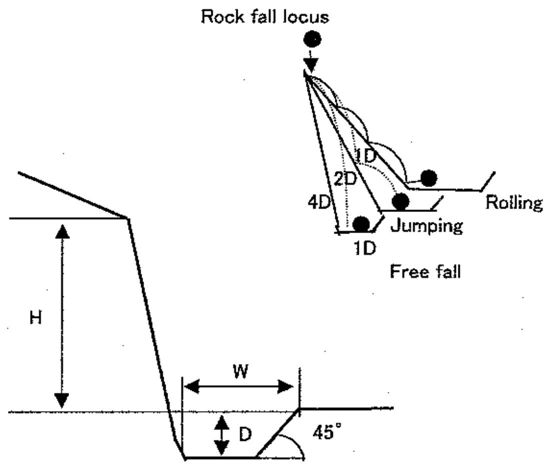


Figure 17.2.2 Rock Fall Locus Model

Table17.2.2 Ritchie's Design Case for Rock Fall Protection Works and This Survey-Based Rock Fall Analysis Calculation

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.

According to Ritchie's design case, free fall shall be about 4 D compared with ID of rolling.

The above two cases cannot be simply compared, but it might be said that Ritchie was conservative in setting countermeasures of groove width against rolling quantity.

b) Flattening the Existing Bedrock Slope

The cut standard in Nicaragua will be described in a later section. The key points are summarized in the following table (Table17.2.3).

Table 17.2.3 Cut Slope Standard in Nicaragua

Nicaragua's standard on cut slope			
	Rock Facies	Trunk road	Feeder road
Cut	On Sound Rock	0～1/2 : 1 (90°～63°) 〔0 : 1(90°)〕	0～1/2 : 1 (90°～63°) 〔0 : 1(90°)〕
	Well Compcted Soil	1 1/2～2 : 1 (34°～26°)	1～1 1/2 : 1 (45°～34°)
	Unkown Soil	1～1 1/2 : 1 (45°～34°)	〔1: 1 (45°)
	Not Well Compacted Soil	2 : 1(26°) 〔1 1/2 : 1(34°)〕	1 1/2 : 1(34°) 〔1: 1 (45°)〕

The cut slope gradient for bedrocks is left to the judgment of field engineers within the range of 63～90°. In fact, NIC.00 uses 0.75 × 1(about 55°) for many cracks-bearing bedrocks and 0.5 × 1(about 63°) for solid tuff. However, considering field conditions, the following features are identified.

a) Individual slope cannot be equally treated due to that andesite rock and tuff layers exist alternately or separately.

b) Some tuff, which has fast weathering characteristics, contributes to overhanging and toppling collapse of andesite overlaid or insufficient strength in a loosened area of tuff causes some small-scale landslides. For these reasons, tuff needs to be classified.

c) Some cuts have a slope height of 30 m or more. They have continuous rock fall and collapses and are not always stable even if they meet the Nicaragua's standard.

d) Some stratums such as granite-weathered sediment and unconsolidated soils Diluvial talus cannot be treated as Alluvial deposit.

In consideration of these features, each proper gradient was examined based on the existing slope height, gradient and its bedrock category. The results will be described in the next section.

c) Removal of Overburden Load from the Bedrock Slope Head which may Fail in Future (These Measures Include Mainly Re-Cut of the Slope)

There are distinctive landslides and collapses such as weathered tuff slope landslides in NIC.1 and NIC.3, slope destabilization by cutting the foot of ex-taluses in NIC.5 and collapse of a fractured zone in NIC.26 tuff. Stability analysis showed that removal of soil would significantly improve a safety factor. So, measures for the maximum reduction of overburden load on the slope were reviewed, and it was determined that loading berm could prevent collapse of embankment. Since the two methods of soil removal and loading berm cannot completely support current draining, particular attention should be paid to slope drainage.

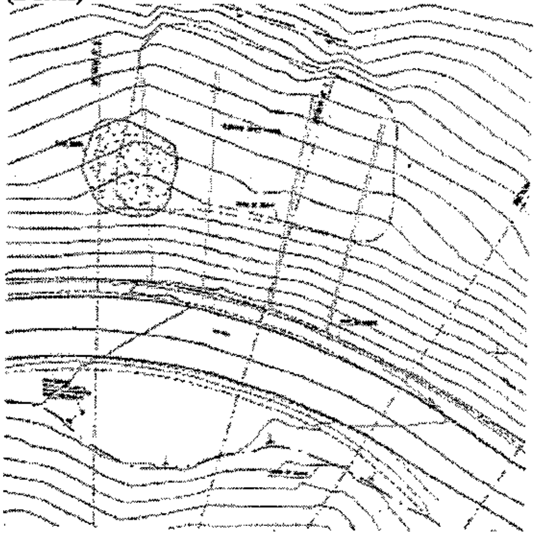
d) Establishment of Berms on the Bedrock Slope

Frequent spalling and small-scale collapse are found on tuff slopes in the area due to repetition of dry and wet conditions while tuff and andesite rock falling occurs frequently. The minimization of rock fall to roads can be made by establishing berms. This countermeasure is set as guidelines in Nicaragua, but berms can be established at intervals of 4 to 8 m according to filed conditions. Alternate existence of many cracks-bearing andesite rocks and faster-weathering tuff layers was often found in this surveyed area. During a rainy season, water often exuded mainly from a boundary between the two layers in various ways. Assuming berm drainage, it is recommended that berms should be established near a boundary between stratums with much spring water, but a berm surface is actually placed at a lower part of relatively a softer layer or at an impervious layer due to slanted stratums.

e) Water Draining by Horizontal Bore Holes and Interceptors

In this survey, establishment of horizontal drain holes was reviewed with the intention of draining surface water and lowering a ground water level when re-cutting slope surfaces in landslide lands. It was determined that iron oxide-adhered and open cracks-bearing tuff bedrocks would be drilled to construct the holes. The bedrocks in NIC.3 and NIC.5 can be expected to have good drainage. Therefore, it is proposed that 4 to 5 horizontal drain bore holes should be established in a parallel with their length of 15 to 20 m (almost half of slope height of these bedrocks) in order to drain water in bedrocks behind landslide surfaces.

(Plan)



(Cross-section)

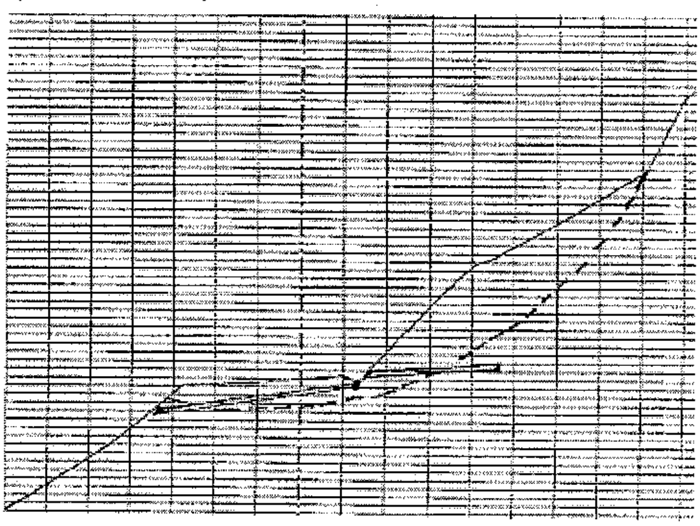


Figure 17.2.3 Horizontal Boring Drainage

2) Difference between the Conditions of Individual Slope Surfaces during Dry and Rainy Seasons and Measures against Slope Surfaces

Based on the above-mentioned reviews, the difference between the conditions of individual slope surfaces during dry and rainy seasons is summarized in the following table. Descriptions illustrated with photographs will be provided in a section of a design for measures against slope surfaces. Here, it is briefly shown in Table17.2.4.

Table 17.2.4 (1) Difference between the Conditions of Individual Slope Surfaces during Dry and Rainy Seasons and Countermeasures against Slope Surfaces for NIC.1

ID (km)	Spring Point	Rock-fall and Collapsing	Review on Countermeasures against Slope Failure
N001A290 (60.9km)	A little water exudes near a boundary between the remaining taluses and from loosened cracks.	Falling of 10 to 50 cm-small blocks are often seen. The blocks do not hit the road due to its wide margin, but slope collapse may affect the up lane due to loose of the slope.	It is recommended that berms should be established in order to reduce rock fall impacts, but the measures reviewed are removal of loosened blocks and rolling stones, drainage of slope shoulders and toes and establishment of net works since the road has a large margin.
N001A280 (73.2km)	8 continuous spring points are seen during dry and rainy seasons. Further water exudes from colluvial deposits during the rainy season	A some 2 m-slide scarp can be clearly seen. The slide movement is currently at rest on the scarp, but there is a danger of sliding when heavy rain causes increase of the water level. Collapse of the scarp may totally block the road.	Colluvial deposits need be stabilized due to their potential movement after heavy rain.
N001A240 (168.4km)	Surface water exudes in a sheet shape from a boundary between andesite and tuff through andesite cracks. In this survey, spring points cannot particularly be observed.	Since a small overhang ridge was cut, a weathering layer of tuff remained across the slope. Rock fall will offer low visibility for the road. So, cars on the down lane will be exposed to diaster dangers. Small collapses are found at 10 points.	Grasses and small- and medium-size tress grown on the slope surface are effective in slope stabilization and rock fall prevention. The proposals for removal of loosened blocks and rolling stones and placement of partial nets at the denuded land were reviewed.
N001B230 (168.6km)	This slope is connected with the above slope. Its bedrock has more blocks than that of the above slope. A little water 175.0exudes near a boundary between andes176.2ite and tuff rocks.	The bedrock is weathered to soil near a boundary between andesite and tuff rocks where small-scale collapse and rock fall continue. There are andesite rocks on a height at a blind corner. A 50 cm or more-diameter rock may hit cars on the down lane.	As the above slope, it has higher weathering depth, while grasses and small- and medium-size tress were re-grown. So, the proposals for removal of loosened blocks and rolling stones and placement of partial nets were reviewed.

ID (km)	Spring Point	Rock-fall and Collapsing	Review on Countermeasures against Slope Failure
N001B170 (171.3km)	There are two points where storm water through andesite cracks exudes from the cracks and a boundary between andesite and tuff rocks.	The tuff is originally resistant to weathering, but it is located at the end of a small ridge where a weathering layer remains and andesite rocks fall. Low visibility for the down lane will cause disaster dangers.	It is located at the end of a small ridge where a weathering layer remains and severe tuff spalling is observed. In addition, opening cracks in andesite rocks are further expanded, while toppling collapse or falling from higher points can be seen. There are blind corners. Only removal of loosened blocks cannot contribute to fundamental improvement. So, a proposal for re-cut.
N001B150 (175.0km)	Surrface water exudes and water springs from vertical cracks of andesite rocks and lower tuff.	Tuff containing cooling joints repeated its spalling, providing toppling collapse and falling. Cars on the up lane will be exposed to disaster dangers.	A 1 m or more-diameter block sometimes falls to the down lane from a crack space. So, a proposal for re-cut of upright sections and sparying works was reviewed.
N001B120 (176.2km)	It is located at the ridge end overhanging on the river and normally has no spring water. Two spring points were observed during a rainy season.	The bedrock is not in good state due to fault involvement. But, dyke rocks along fault are harder. Repeated and full collapses will make the road completely impracticable. There are no bypass roads near here.	Sharp cut gradient is taken due to worse bedrock and steeper topography. There are past collapse records and no bypass roads. So, a proposal for 55° re-cut.

Table 17.2.4 (2) Difference between the Conditions of Individual Slope Surfaces during Dry and Rainy Seasons and Countermeasures against Slope Surfaces for NIC.3

ID (km)	Spring Point	Rock-fall and Collapsing	Review on Countermeasures against Slope Failure
N003B400 (6.9km)	Water penetrates along cooling joints, and there are two points where water springs from a boundary between layers.	Lower welded tuff at the foot became grained, repeated toppling collapse near a boundary between the two layers. The fluidization of tuff at heavy rain will block the road.	A proposal for cutting an upright section in toppling collapse at the angle of 60°was reviewed.
N003B370 (7.4km)	It has the same stratum, but no particular spring water. It has collapse records at heavy rain.	Lower welded tuff at the foot became grained, repeated toppling near a boundary between the two layers. The tuff fluidization at heavy rain will block the road. This may affect the up lane.	A proposal for cutting an upright section in toppling collapse at the angle of 60°was reviewed.

ID (km)	Spring Point	Rock-fall and Collapsing	Review on Countermeasures against Slope Failure
N003B320 (22.1km)	There is a hotel. Flow of miscellaneous waste water and surface water is concerned. There are two spring points on the slope surface.	It is located at the end of a small ridge where tuff became soil. It is impossible to cut the slope due to influence on the hotel.	A weathered layer of tuff belongs to Bedrock Category III. So, it is determined that slopes with gradients at 45° or less will be stabilized. But, in the case of these gradients, since the slope cut will affect the hotel, a proposal for establishing some structure was reviewed.
N003C230 (32.9km)	There are flows of surface water and groundwater. Some of groundwater springs at two point of embankments.	There is a slide scarp on the slope surface which may fluctuate at heavy rain. If water penetrates embankment cracks, the slope will collapse, which may affect traffic.	Since it belongs to Bedrock Category III, it needed be re-cut at the angle of 45～55°
N003E170 (35.2km)	There is no spring water. But, Hurricane Mitch caused flash flooding and water spurts on the hillside.	Generally, tuff and andesite rocks are thermally deformed, with their rapidly hardening and softening variations. Spalling, rock fall and piping-based shallow collapse are seen on the slope, which are likely to result in hazard to moving traffic on the up and down lanes.	It is located at a alteration zone of tuff and andesite rocks, with their rapidly hardening and softening variations. So, it was proposed to re-cut the slope at the angle of 55° A proposal for constructing a simple dam in a small valley was reviewed.
N003C150 (38.9km)	Surface running water at ordinary rain, water springs on a middle part of embankment there are waterways on bedrock at heavy rain are seen.	Thermally deformed tuff was weathered on the cut with some tuff slide. The tuff may fluidize at heavy rain, which affects the up and down lanes.	It is a weathered layer of thermally deformed tuff and belongs to Bedrock Category III. A proposal to re-cut it at the angle of 45°.
N003C140 (39.4km)	There are no distinctive water spring and seepage. The bedrock contains many cracks and becomes red with iron oxide.	Thermally deformed tuff was weathered on the cut side with some tuff slid. The tuff may fluidize at heavy rain, which affects the up and down lanes.	It has the same measures as the above. Waterways were confirmed in bedrocks. So, horizontal drainage works were reviewed.

Table 17.2.4 (3) Difference between the Conditions of Individual Slope Surfaces during Dry and Rainy Seasons and Countermeasures against Slope Surfaces for NIC.5

ID (km)	Spring Point	Rock-fall and Collapsing	Review on Countermeasures against Slope Failure
N005A010 (24.5km)	8 spring points and seepage from entire talus layers were confirmed. But dry season was a little water quantity.	Continuous small collapses and rock fall occur on a talus whose condition keeps unstable. The continuous collapses cause hazard to moving traffic. The talus may fully collapse.	Due to that the foot of Diluvial taluses was cut, some remaining on the slope became instable. It belongs to Bedrock Category III. The current slope gradient is 41°to 48°and instable. So, a proposal for 40˜ 35°slope stabilization,

Table 17.2.4 (4) Difference between the Conditions of Individual Slope Surfaces during Dry and Rainy Seasons and Countermeasures against Slope Surfaces for NIC.26

ID (km)	Spring Point	Rock-fall and Collapsing	Review on Countermeasures against Slope Failure
N026A060 (24.7km)	There are spring points. In general, there are many seepage points from cracks (8 points).	Bedrocks generally consist of I B hard rocks. But spalling and small collapses on their weathering layers and falling of blocked tuff are observed. Currently, traffic moving is ensured by removal of stones.	There are no problems about slope stability. So, a proposal for slope surface forming and spraying works was reviewed.
N026B140 (34.0km)	There are two spring points around the shuttered zone.	There is an about 50 m-width fractured zone where rock fall and collapse always are repeated. The bedrocks in the fractured zone belong to Bedrock Category III, where rock fall from a slide scarp and collapses frequently occur, being hazard to traffic moving all through the year. In addition, the bedrocks around the fractured zone are unstable, with a lot of spalling and rock fall.	This is an area where volcanic rocks around the fractured zone contain black schist and there were a big crustal movement. The depth of the crush zone is affected by weathering. Rock fall and collapses always continue on the zone. So, a proposal for 40°re-cut,.
N026A150 (34.2km)	Currently, water seepage is observed. There were concentrated surface running water and springs at Hurricane Mitch.	This is an area with agglomerates where igneous activities are generated. Rock fall and collapses frequently occur on the whole slope due to the existence of a 20 m-drop fault and its overall alteration. There were a great collapse at Hurricane Mitch. Collapsed soils are always removed.	The bedrocks around the slope toe belong to Bedrock Category I B, but the bedrocks on the slope were weathering. So, a proposal for 55°slope re-cut.
N026B160 (37.0km)	Two spring points were observed under this survey.	There are some areas where expansion of andesite cracks causes toppling collapse. Potential large block fall will hit people and cars.	A proposal for removal of loosened blocks and rolling stones and full net works was reviewed.

17.2.2 Consideration of Countermeasures for Scouring

Of the 30 disaster prevention spots selected, 11 are bridges and are as shown in Figure 17.2.4. The present condition of each bridge is described in Table 17.2.5. In addition, a summary of the survey results for each bridge is given in Appendix B1.