CHAPTER 6 IDENTIFICATION OF DISASTER CRITICAL SPOTS

6.1 Disaster critical Spots

Based on the pre-conditions for evaluation of road disasters, the following places have been identified as disaster critical spots having over 70 scores of the stability survey on each disaster potential spot as shown in Table 6.1.1. The total number of critical spots is 55, consisting of 20 spots (36%) of Rock Collapsing, 15 spots (27%) of Rock Falling, 11 spots (20%) of Bridge Scouring, 5 spots (9%) of Debris Flow and 4 spots (7%) of Slope Slide on all the objective roads.

Table 6.1.1 Total Number of Disaster Critical Spots

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

The total number of the critical spots by road shows 22 spots (40%) on NIC 1, 16 spots (29%) on NIC 26, 12 spots (22%) on NIC 3, 4 spots (7%) on NIC 15, 1 spots (2%) on NIC 5 and 0 spots on NIC 24.

When the risk is analyzed per kilometer, the highest value is 0.2 spots/km of NIC 3, second is 0.16 spots/km of NIC 26 and third is 0.09 spots/km of NIC 1 and NIC 15.

6.2 Recommendation of Slope Gradient to NIC.15

After surveying all slopes on NIC.15, the following recommendations are made, as shown in Figure 6.2.1 and Figure 6.2.2 :

- The geological characteristics between Yalaguina and Ocotal are mainly volcanic clastic rock.
- The geological characteristics of Octal and Los Manos are granite (Mainly highly weathered and decomposed).

- These decomposed granites are loosened by reason of release of stress due to construction from cutting slopes.
- Volcanic clastic rock increases the risk of collapse where the thickness of weathering layer is about 3 meters or the slope gradient is steep.
- The rock falls and collapses occur when the permitted range of the relationship between slope heights and slope gradient is exceeded
- The decomposed granite requires the most safety measures to stabilize slopes.
- The most important thing for keeping slopes safe is not to exceed the permitted range of the relation slope height and slope gradient by rock characteristic.

Figure 6.2.1 Volcanic Clastic Rock

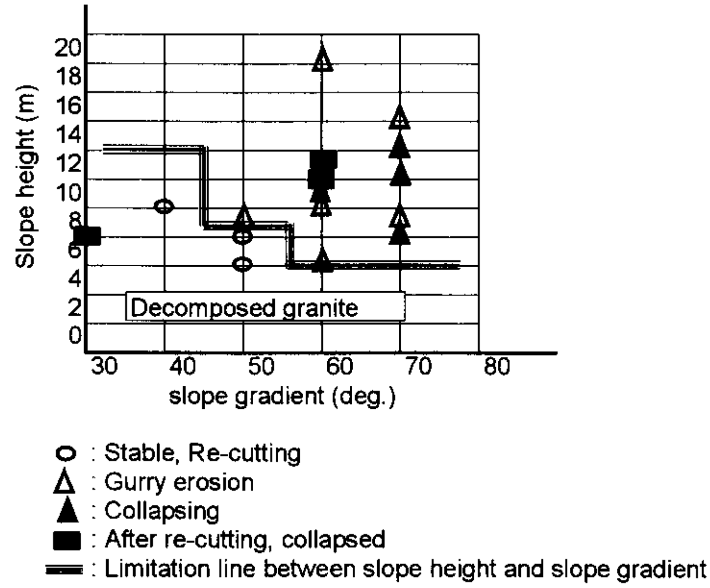
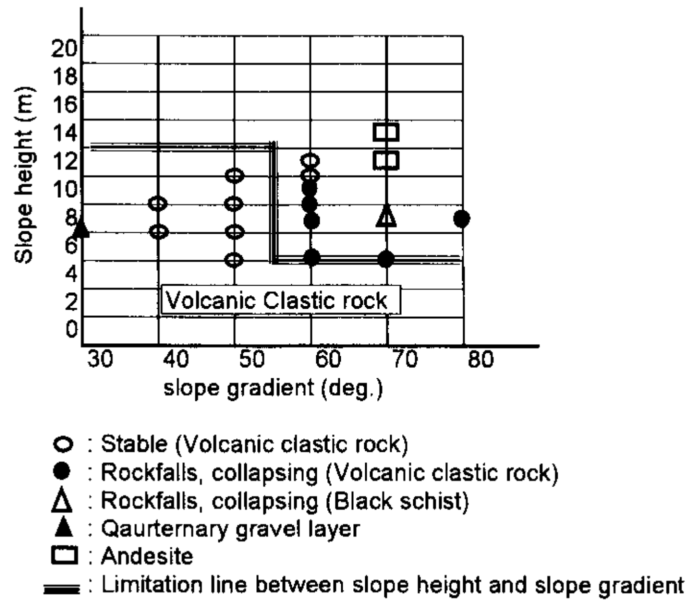


Figure 6.2.2 Decomposed Granite



CHAPTER 7 COUNTERMEASURES AND ROUGH COST ESTIMATE

7.1 General

The countermeasures against roads disaster prevention should be studied in consideration of the natural condition, the environmental one and the construction materials/ equipments in Nicaragua country and the MTI maintenance budgets.

7.2 Objectives

7.2.1 Views of Countermeasures

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

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

7.2.2 Definition of Countermeasures

Each disaster critical spot is a various situation for stability. Countermeasures to the disaster critical spots are divided into the following three categories in consideration of disaster characteristics.

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

1) Permanent Countermeasures

Permanent countermeasures are defined as the following items.

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

2) Temporary Countermeasures

Temporary Countermeasures are defined as the following items.

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

3) Emergency Countermeasures

Emergency countermeasures are defined as the following items

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

7.3 Basic Policy of Countermeasures

7.3.1 Basic Policy

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

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

7.3.2 Procurement of Construction Materials/ Equipments

Construction materials and Equipments are possible to procure in Nicaragua and neighbor countries as shown in Table 7.3.1 and 7.3.2. Besides many types of countermeasures are possible to apply in Nicaragua as shown in Table 7.3.3.

Table 7.3.1 Procurement of Construction Materials

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

Note: ○; Possible for procurement

Table 7.3.2 Procurement of Construction Equipments

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

Note: ○; Possible for procurement

Table 7.3.3 Type of Countermeasures and Construction Records in Nicaragua

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

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

--; There are results. □; Possible

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

7.4 Classification of the Countermeasures

7.4.1 Applicable Countermeasures

The applicable countermeasures are shown in Table 7.4.1 against slope failures and shown in Table 7.4.2 against bridge foundation scouring. The flowcharts of selection for each countermeasure against damage items are presented in Chapter 7 of Main Text.

Table 7.4.1 Applicable Countermeasures against Slope Failures

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

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

Table 7.4.2 Applicable Countermeasures against Bridge Foundation Scouring

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

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

7.4.2 Classification of Countermeasures

Countermeasures for disaster critical spots are classified into six groups in consideration of their purposes and applicability. The relation between objects of prevention countermeasures and types of construction works is shown in Figure 7.4.1.

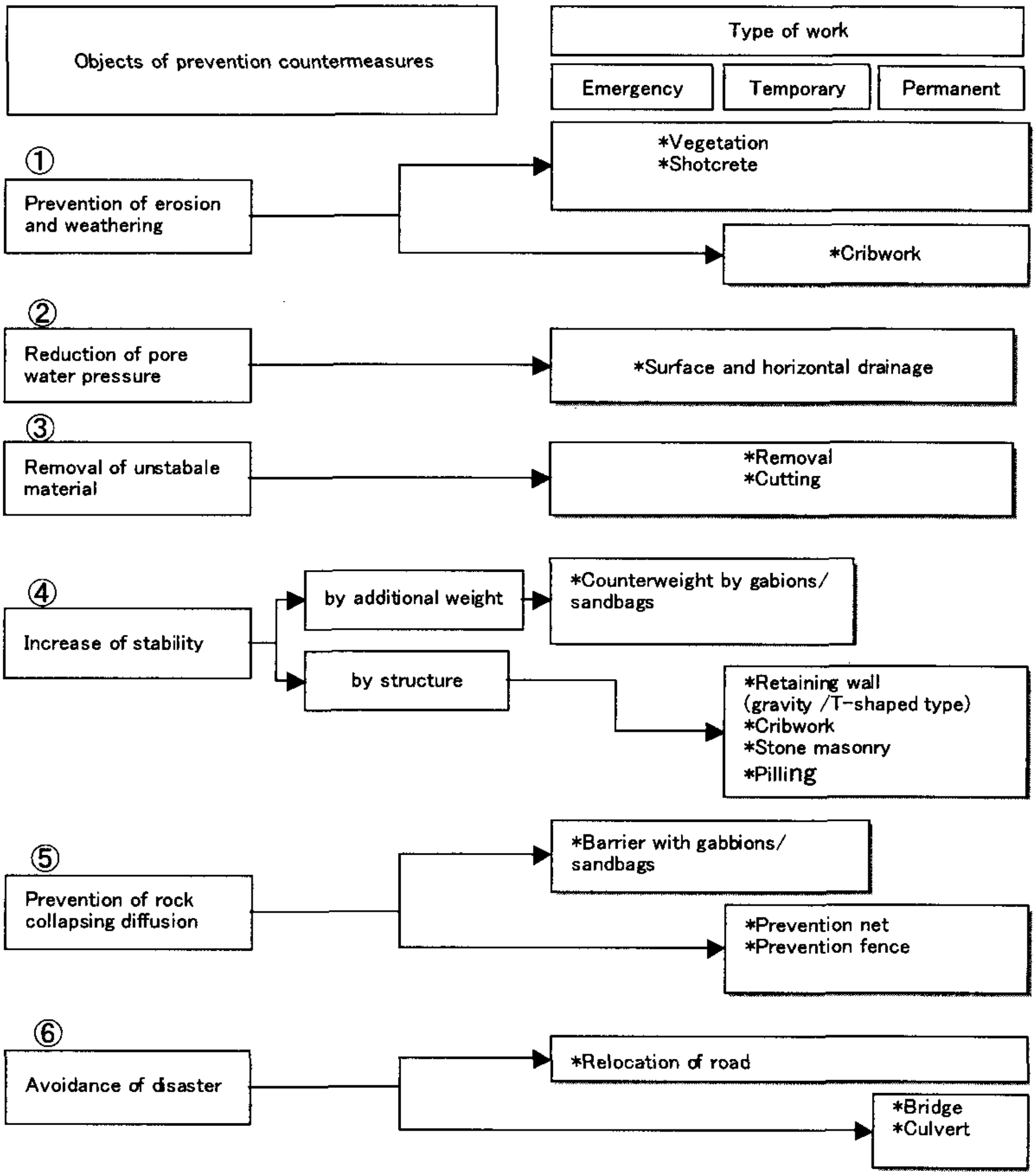


Figure 7.4.1 Relation between Objects of Prevention Coutermeasures and Types of Construction Work

7.4.3 Countermeasures for Objective Roads

Countermeasures for each critical spot of objective roads are shown in following tables. Presented countermeasures have been studied in article 7.4.3 to 7.4.10.

1) NIC. 1

Table 7.4.3 Type of Countermeasure for Slope Damage on NIC.1

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

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

Table 7.4.4 Type of Countermeasure for Bridge Foundation Scouring on NIC.1

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

2) NIC.3

Table 7.4.5 Type of Countermeasure for Slope Damage on NIC.3

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

Table 7.4.6 Type of Countermeasure for Bridge Foundation Scouring on NIC.3

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

3) NIC.5

Table 7.4.7 Type of Countermeasure for Slope Damage on NIC.5

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

4) NIC.15

Table 7.4.8 Type of Countermeasure for Slope Damage on NIC.15

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

5) NIC.26

Table 7.4.9 Type of Countermeasure for Slope Damage on NIC.26

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

Table 7.4.10 Type of Countermeasure for Bridge Foundation Scouring on NIC.26

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

7.5 Rough Cost Estimate

7.5.1 Unit Cost

As MTI has no estimates of classification items for construction work, the estimates of unit costs for construction have been got from four private local construction companies in Nicaragua. However each unit cost based on the estimates was discussed in and decided by MTI. And each unit cost was averaged. As some work items have no market price due to lack of experience in Nicaragua, unit costs for some works are estimated based on the Japanese market price. A list of unit costs is shown in Table 7.5.1.

Table 7.5.1 Unit Costs

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

7.5.2 Rough Cost for Each Objective Road

Rough costs for each objective road are shown in Table 7.5.2 to Table 7.5.9.

Table 7.5.2 Construction Cost of Countermeasure for Slope Damage on NIC.1

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

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

Table 7.5.3 Construction Cost of Countermeasure for Bridge Foundation Scouring on NIC.1

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

Table 7.5.4 Construction Cost of Countermeasure for Slope Damage on NIC.3

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

Table 7.5.5 Construction Cost of Countermeasure for Bridge Foundation Scouring on NIC.3

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

Table 7.5.6 Construction Cost of Countermeasure for Slope Damage on NIC.5

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

Table 7.5.7 Construction Cost of Countermeasure for Slope Damage on NIC.15

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

Table 7.5.8 Construction Cost of Countermeasure for Slope Damage on NIC.26

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

Table 7.5.9 Construction Cost of Countermeasure for Bridge Foundation Scouring on NIC.26

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

7.5.3 Total Cost

Total rough construction costs for each road are shown in Table 7.5.10.

Table 7.5.10 Total Cost of Each Route

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

US$1=C$13.9

CHAPTER 8 NATURAL CONDITION SURVEY

8.1 Purpose of the Survey

The natural condition surveys are executed at the disaster critical spots where identified in Chapter 6. The investigation items are a measurement investigation, a geological survey, and a hydrological survey. When the flow of the natural condition surveys by the main investigation is shown in Figure 8.1.1.

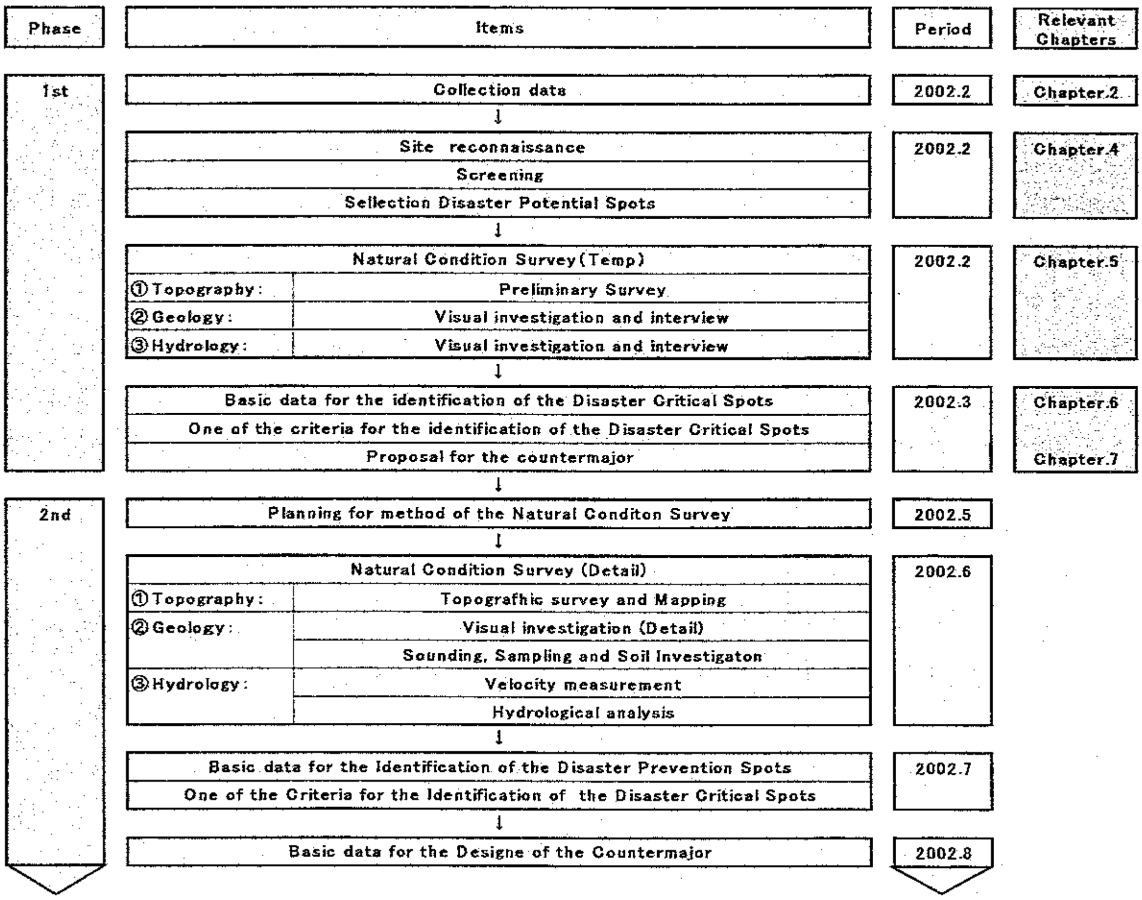


Figure 8.1.1 Flowchart for the National Condition Survey

8.2 Hydrological Survey

8.2.1 General

The hydrological surveys are executed in the river of 11 bridges, which are presented in the main text as Table 8.2.1.

The flow velocity is measured in the straight-line part where the width of a river and depth are constant. The research methodology has the method with a surface float and a stick float and the method with a current-meter. It will measure it in two days different with a current-meter in the main investigation.
MTI has no fixed opinions of the hydrological survey concerning the bridge design, and has been decided the opinion according to each situation usually. “Return Preiod” is most generally adopted for 50 years as for probable flood peck runoff year's setting but; It is likely to be set importantly in the route by return period for 100 years and 25 years.

The watershed is decided by using the topographical map, which the contour line enters. The topographical map of 1:50,000 are used usually. After the decision of the watershed, the selection conditions of the valley and the river, the geographical features conditions, and flood concentration times and conditions of the altitude, the river inclination, and the run-off coefficient, etc. are decided.

To evade the extreme contradiction between the stations to the data of the weather and the rainfall, a double mass-haul curve etc. are used and analyzed. It examines by using a general probability method for the parameter. The probable rainfall is calculated by the IDF (Rainfall Intensity Duration Frequency) curve by a regional rainfall's of each watershed using the Isohyeteal method in a different return period (return period for 25, 50 and 100 years). The HEC-RAS model is used for the analysis.

8.2.2 Survey Result

1) Flow velocity Investigation

The survey result of flow velocity is shown in the main text as Table 8.2.2. However sufficient survey results are not obtained because it is no water in the river in spite of the rainy season. Therefore the survey results should be only the reference data.

2) Hydrological Analysis

Peak flow estimation is shown in Table 8.2.1 (as Table 8.2.7 of the main text). Rainfall data and "IDF curve" of the objective area are presented in the main text as between Figure 8.2.1 and Figure 8.2.5.

The peak flow is generally analysed by the below Rational method.

The Rational formula is Qp=0.278CIA

Where,

Qp= Peak discharge (m3/s)

0.278 is a unit conversion factor to SI units.

C=Runoff coefficient(dimensionless)

I =Rainfall intensity (mm/hr), is estimated from the rainfall intensity-duration-frequency (IDF) curves.

A =drainage basin area (km^2)

Tc = (Lc^3 /(Hmax-Hmin))^ 0.385 (California formula)

Table 8.2.1 Peak Flow Estimation

Watershed	A	TC	I(mm/h)			C	Qp(m^3/s)		
Return Period T (Years)	(km^2)	(hours)	25	50	100		25	50	100
Tapascalí	147.11	3.0	35	40	45	0.62	886.75	1013.4	1266.8
Inalí	84.80	2.0	41.7	45.7	50.0	0.59	579.58	635.18	694.94
San Ramón	2.7	0.5	96.8	107.7	117.7	0.48	34.85	38.78	42.38
Las Chanillas	114.61	3.0	35	38	42	0.6	668.61	725.92	802.33
San Nicolás	6.10	0.5	96.8	107.7	117.7	0.42	68.89	69.94	83.77
El Guayacan	28.3	2.0	38.7	43.1	48.1	0.49	149.08	166.03	185.29
El Junquillal	49.8	2.0	38.7	43.1	48.1	0.46	246.28	274.28	306.10
Las Banderitas	7.70	1.0	61.1	66.1	73.8	0.46	60.12	65.04	72.62
San Juan de Dios	9.00	1.0	61.1	66.1	73.8	0.44	67.22	72.72	81.19
Solís	0.80	0.5*	105.9	114.7	123.4	0.45	10.59	11.47	12.34
Papalón	0.60	0.5*	105.9	114.7	123.4	0.46	8.12	8.79	9.46

*For Solis and Papalon the intensity values from IDF are rounded to nearest value (30 minutes)

3) Water Level estimation

Water level is divided into two groups according to the scale of rivers. The calculation results of water level are shown in the Table 8.2.2 and Table 8.2.3 (as Table 8.2.8 and Table 8.2.9 of the main text). Three spots are predicted to overflow as the calculation result. And the luck of discharge capacity is also predicted to be scoured the foundation of piers and abutments. Tapascalí Bridge, Inalí Bridge and Las Chanillas Bridge are a large discharge volume respectively. Therefore these three bridges are predicted to be scoured at the spots of piers and abutments due to the luck of discharge capacity against upstream river width.

a) Group 1

This group were considered the Study sites with drainage areas smaller than 10 km^2: Solís, Papalón, La Banderita, San Nicolás, San Juan de Dios and San Ramón (see Table 8.2.2).
The main characteristics of these sites are:

- Channels walls are almost vertical, moderate depth (5 to 9 m)
- Widths are between 40 and 100 m
- Peak flow estimates lower than 100 m^3/s being the highest estimated magnitude for a 100 years return period.

b) Group 2

This group were considered the Study sites with bigger drainage areas between 28.3 and 147.11 km^2: El Guayacán, El Junquillal, Las Chanillas, Inalí and Tapascalí .
The main characteristics of these sites are:

- Channels depths are less than 6 m
- Widths are between 40 and 120 m.
- The sites Las Chanillas, Inalí and Tapacalí are with channel width bigger than 100 m.

Table 8.2.2 Water Level at the Bridge Cross Section for Group 1

Watershed	Velocity (m/s)			Flow (m³/s)			Water Level at the bridge section (m)			Bridge EL (m)
Return Period	(years) 25	50	100	25	50	100	25	50	100	
Solís	2.28	2.34	2.37	10.59	11.47	12.34	-4.61	-4.58	-4.55	0.28
Papalón	2.47	2.61	2.76	8.12	8.79	9.79	-3.2	-3.14	-3.08	0.30
San Juan de Dios	1.04	1.05	1.07	67.22	72.72	81.19	-0.28	-0.21	-0.11	-0.03
La Banderita	1.19	1.22	1.26	60.12	65.04	72.62	-6.37	-6.25	-6.06	-0.01
San Nicolás	1.72	1.78	1.84	68.89	64.94	83.77	-4.13	-4.22	-3.80	0.40
San Ramón	2.36	2.46	2.54	34.85	38.78	42.3	-3.4	-3.33	-3.26	0.48

Water levels are not tied to a geodesic Benchmark.

Table 8.2.3 Water Level at the Bridge Cross Section for Group 2

Watershed	Velocity (m/s)			Flow (m³/s)			Water Level at the bridge section (m)			Bridge EL (m)
Return Period	(years) 25	50	100	25	50	100	25	50	100	
El Junquillal	1.86	1.89	1.91	246.28	274.28	306.10	0.92	0.98	1.04	0.205
El Guayacán	1.02	1.04	1.07	149.08	166.03	185.29	>0.86*	>0.86 *	>0.86 *	0.86
Ls Chanillas	4.76	4.88	5.03	668.61	725.92	802.33	-4.1	-3.95	-3.75	0.18
Inalí	4.69	4.80	4.92	579.58	635.18	694.94	-3.61	-3.46	-3.3	0.32
Tapacalí	2.65	2.78	2.90	886.75	1013.44	1266.80	295.76	296.06	296.61	299.618

Water levels are not tied to a geodesic Benchmark besides Tapacali

* *Road Elevation*

8.3 Geological Survey

8.3.1 Objectives and Survey Method

1) Boring, Sounding and Sampling

The boring exploration is executed at cut slope and embankment slope, and bridge foundation. The spots of cut slope and embankment slope are to obtain the basic data in order to evaluate the stability of a whole slope. The spots of bridge foundation are to obtain the basic data in order to evaluate the stability of bedrock in consideration of the riverbed topography, the sediments to river and the deterioration of bedrock, etc. Furthermore the basic materials are sampled, and the standard penetration tests are executed at each spot.

2) Investigation Method

The investigation method is based on the ASTM standard in Nicaragua. The materials sampled by sampler are examined to understand the physical property of the objective stratum, grain size analysis, the specific gravity test of soil particle, the moisture content, and LL/PL. Furthermore, in order to confirm the physical properties of bedrocks, rock samples are examined the unconfined compressive test and the unit weight test.

3) Selection of Boring Location

In order to decide the boring positions and its numbers, the objective spots are investigated by visual inspection for the second time. Cut slope and embankment one are classified into five categories as shown in Table 8.3.1 and Figure 8.3.1 (as Table 8.3.1 and Figure 8.3.1 of the main text). Bridge foundation is classified into two categories as shown in Table 8.3.2 and Figure 8.3.2 (as Table 8.3.2 and Figure 8.3.2 of the main text). The arrangement of the boring exploration is set as Table 8.3.3 (as Table 8.3.3 of the main text).

Table 8.3.1 Classification Item of Boring Exploration (Slope)

Class	Characteristics	Quantity of Boring
Type-A	Repeatedly because it is a state of the alternation of strata even if it is a single-layer or a combined stratum composition; It is a place where rock faces and weathering are understood easily. When the bore location can be assumed to be one place, and the average stratum composition etc. which affect stabilizing is evaluated.	BH=1
Type-B	The change is seen in the stratum composition and the state of weathering on site. When the average stratum composition etc. which affect stabilizing can be evaluated by the thing to execute the bore by at least two places.	BH≧2
Type-C	The degree of the stratum composition and weathering is complex. When the evaluation of the stability of the entire slope, which includes the face of slope, is needed, and the bore in at least three places or more needed. And, when it set up the erosion and torrent control dam aiming at the thing to assume the riverbed inclination of the road crossing location to be 3° or less in the place where the generation of the avalanche of sand and stone is forecast.	BH≧3
Type-D	For instance, the exposed bedrock omits boring when most information is appreciable in the hard rock etc. by watching for stability.	BH=0
Type-E	The point that the degree of the geological features composition and weathering is extremely complex because of the alteration of the fault and the volcanic. Things except the above-mentioned.	It depends on the situation. Arbitrariness.

Table 8.3.2 Classification Item of Boring Exploration (Bridge)

Class	Characteristics	Quantity of Boring
Type- α	The stratum composition of the point in the bridge: from the distribution of plane geographical features, the crossing geographical features, and the open rock of the river when average geological features and thickness, etc. are appreciable by the bore one place. Especially, when the plain part and the length of bridge were short etc, it applied.	BH=1
Type- β	The change is forecast from the above-mentioned to the fluvial landscape and the stratum composition, and when average geological features and thickness, etc. are appreciable by the bore in two places or more.	BH≧2

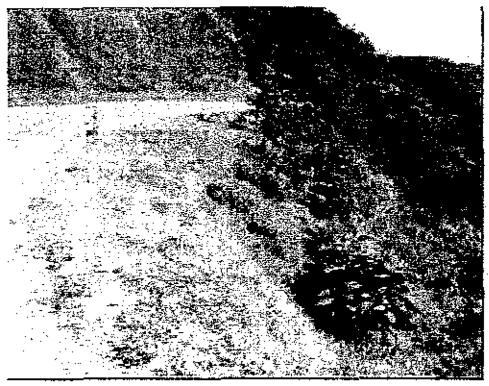
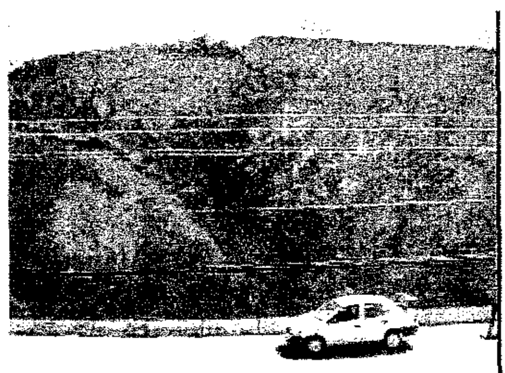
Example of Type-A	Serial-No.8 (ID- No.001B230) Because the composition of the face of slope is large the range where simplicity and the visual investigation can be done, and is also same weathering condition; Especially, the face of slope is not bored. To examine the slope failure, which includes the road, the toe of slope or the road shoulder executes one-place bore.	
Example of Type-B	Serial-No.32 (ID- No.003C150) It is in geographical features of the slope and there are weathering of tuffs, which influence easily and an argillation in a slope movement. And, there is small-scale movement (The flat terrain forms to the leg of the cliff like the belt) in the slope. And, the difference has been generated in the shoulder. The change in the geological features composition is understood by executing the bore in two or more.	
Example of Type-C	Serial-No.35 (ID- No.005A010) Example of inclusion of face of slope collapse shown in NIC.5 of seepage water of stratum composition and lava plateau on back slope and influence on stability of the entire face of slope. Because height the face of slope and width require the examination of stability including the entire road long, plural bores are executed by arrangement to be able to do an overall evaluation.	
Example of Type-D	Serial-No.22 (ID- No.001A010) There is no vegetation and it is a bedrock situation of the entire face of slope and the rock eyes are composed on the mass of agglomerate because of the andesite lava flow of the receiving board. The evaluation of the degree of weathering and stability is possible cases in watching enough.	

Figure 8.3.1 Example for the Classification Item of Boring Exploration (Slope)

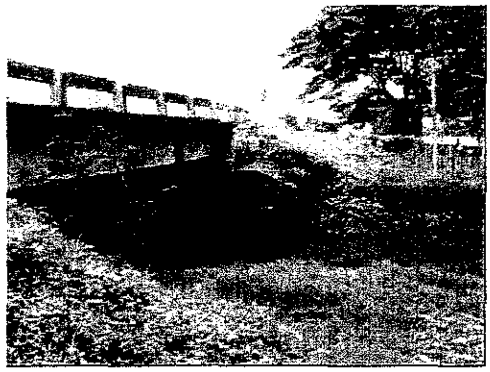
Type- α	Serial-No.4 (ID- San Ramón) It is a bridge in the comparatively short length of bridge laid on geographical features in which the change does not exist in the plain part. As for the stratum composition, a big change need not be assumed in both banks, and a geological features composition and thickness, etc. boring singular average are appreciable.	
Type- β	Serial-No.45 (ID- La Banderita) The bridge exists in sag vertical alignment in the valley of the mountainous area. There is a possibility that there is a change in the stratum composition in the right side shore and left bank in the river. It executes two or more bores and the geological features composition and thickness, etc. are evaluated by doing.	

Figure 8.3.2 Example for the Classification Item of Boring Exploration (Bridge)

Table 8.3.3 Arrangement of Boring Exploration

Route No. Nic.1

Sireal Number of Disaster Critical spots	ID.No	Kilometer from Managua (km)	Type of Boring
1	N001A290	60.9	A
2	N001A280	73.2	C
3	Junquillal	113.19	α
4	San Nicolas	135.64	α
5	Las Chanillas (REsteli)	150.33	β
6	San Ramón	151.85	β
7	N001A240	168.4	A
8	N001B230	168.6	A
9	N001B200	169.8	D
10	N001B190	170.7	D
11	N001B170	171.3	A
12	N001B150	175.0	A
13	N001B120	176.2	A
14	N001A110	178.7	A
15	N001B100	187.3	D
16	N001B070	204.7	A
17	N001A050	214.7	A
18	Río Inali	226.89	β
19	RíoTapacalí	233.245	β
20	N001B030	232.5	D
21	N001A020	233.7	D
22	N001A010	235.6	D

Route No. Nic..3

Sireal Number of Disaster Critical spots	ID.No	Distance from Sebaco(km) (*Bridge: from Managua)	Type of Boring
23	003B420	3.9	A
24	003B400	6.9	B
25	003B370	7.4	A
26	El Guayacan	119.05	α
27	N003B320	22.1	A
28	N003B240	32.7	A
29	N003C230	32.9	B
30	N003E170	35.2	C
31	N003C160	35.9	B
32	N003C150	38.9	B
33	N003C140	39.4	B
34	N003B120	40	A

Route No. NIC.5

Sireal Number of Disaster Critical spots	ID.No	Distance from Matagalupa (km)	Type of disaster
35	N005A010	24.6	C

Route No. Nic.15

Sireal Number of Disaster Critical spots	ID.No	Distance from Las Manos (km)	Type of Boring
36	N015E010	9.9	C
37	N015E020	11.1	C
38	N015E050	11.7	A
39	N015E060	13.6	A

Route No. Nic.26

Sireal Number of Disaster Critical spots	ID.No	Distance from I.C. between San Ishidoro & Sebaco (km) (*Bridge:from Managua)	Type of Boring
40	N026A010	9.0	D
41	N026A020	12.7	D
42	N026A030	19.9	D
43	N026A040	20.9	D
44	N026A060	24.7	A
45	La Banderita	170+952	β
46	N026A100	29.3	A
47	N026B110	29.8	D
48	N026A130	33.6	A
49	N026B140	34.0	A
50	N026A150	34.2	C
51	N026B160	37.0	A
52	San Juan de Dios	156+785	α
53	N026B210	45.5	A
54	Papalón	108+154	α
55	Solis	107+533	α

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

8.3.2 Survey Result

1) Evaluation of Survey Result

Based on the survey result of the first phase, the properties of geology on cut slope and embankment one are evaluated again taking account of the progress of weathering and collapsing, and the progress of weathering in geological features. Bridge foundation are evaluated again taking account of the progress of scouring and the results of hydrological analysis.

2) Evaluation of the Slopes

A: The weathering and collapsing reached a high advanced stage, and the emergency has increased. The potentiality of risk, including the advanced stage of weathering inside of the slopes, is high (10 points).

B Plus (B+): Approximately medium between A and B (8 points).
B: The weathering and collapsing reached a medium stage. The potentiality of risk, including the medium stage of weathering into inner part, is medium (6 points).
B Minor (B -): Approximately medium between B and C (4 points).

C: The weathering and collapsing didn't progress so much. The weathering didn't reach at inner part of the slope (2 points).
D: Totally decayed completely. Otherwise, countermeasure was totally accomplished. For that reason, this case is to be excluded from the evaluation (0 point).

3) Evaluation of the Scouring for Foundation of Bridge

A: The scouring reached an advanced stage, and the emergency has been increased. There is a remarkable restriction for the flow velocity and flow volume, including narrow cross section of streamway, and the factor of scouring progress is very remarkable. (10 points)

B Plus (B+): Approximately medium between A and B (8 points).
B: The scouring reached a medium stage. There is a medium restriction for the flow velocity and flow volume on the bridge crossing part (6 points).
B Minor (B -): Approximately medium between B and C (4 points).

C: The scouring didn't progress so much. There is no restriction for the flow velocity and flow volume exists on the bridge crossing part (2 points).
D: The Bridge was totally fell down. Otherwise, countermeasure has been totally accomplished. For those reasons, this case is to be excluded from evaluation (0).

Note: The above-mentioned is an evaluation to the detailed investigation, which won't turn out in the stability survey sheets.

Because various, natural condition item is assumed to the scour of the bridge foundation, an integrated evaluation is examined by the mean etc. of each the following items.

However, an integrated evaluation is assumed to be A in the case where as many as two A grades or more attach according to the situation.

Details	Category	Situation
Velocity	A	Velocity(observed value or calculated value) 5m/ s more
	B	3m/ s -5m/s
	C	Less than 3m/s
Discharge Quantity	A	There is record of overflow above the superstructure in the past. Or, when it extremely underestimates the section to flowing quantity in the calculation.
	B	When a state near the overflow situation happens in the past. Or, when it underestimate the section to flowing quantity in the calculation a little
	C	There is no overflow record at all at all in the past. Or, when it is quite unquestionable in the past, the section in the bridge: to flowing quantity in the calculation.
Soil	A-C	It is the same as the evaluation of the slope.
Scoring	A	When the factor to cause progress is seen by an extreme scour. E.g. The river width narrows extremely in the part of the bridge crossing point. Section change of degradation site etc.
	B	When the factor to cause progress is seen by the scour in some degree.
	C	There is no special cause factor.

The above-mentioned result is shown in Table 8.3.4 (as table 8.3.5 of the main text).

Table 8.3.4 Evaluation of the Natural Conditions Survey

Serial No.	ID No.	Evaluation	Point	Serial No.	ID No.	Evaluation	Point
1	N001A290	A	10	29	N003C230	A	10
2	N001A280	A	10	30	N003E170	A	10
3	Junquillal	B	6	31	N003C160	A	10
4	San Nicolas	C	2	32	N003C150	B+	8
5	Las Chanillas	B	6	33	N003C140	A	10
6	San Ramon	C	2	34	N003B120	B	6
7	N001A240	B	6	35	N001A050	A	10
8	N00B230	B+	8	36	N015E010	A	10
9	N001B200	C	2	37	N015E020	A	10
10	N001B190	B−	4	38	N015E050	B−	4
11	N001B170	B	6	39	N015E060	B−	4
12	N001B150	A	10	40	N026A010	B	6
13	N001B120	A	10	41	N026A020	B	6
14	N001A110	B+	8	42	N026A030	C	2
15	N001B100	B−	4	43	N026A040	C	2
16	N001B070	B+	8	44	N026A060	A	10
17	N001A050	A	10	45	La Banderita	C	2
18	Rio Inali	B−	4	46	N026A100	B	6
19	Rio Tapacali	C	2	47	N026B110	C	2
20	N001B030	B	6	48	N026A130	B	6
21	N001A020	C	2	49	N026B140	A	10
22	N001A010	B−	4	50	N026A150	A	10
23	003B420	C	2	51	N026B160	A	10
24	003B400	B+	8	52	San Juan de Dios	B−	4
25	003B370	B+	8	53	N026B210	B+	6
26	El Guayacan	A	10	54	Papalón	C	2
27	N003B320	B+	8	55	Solis	C	2
28	N003B240	B−	4				

CHAPTER 9 ENVIRONMENTAL SURVEY

9.1 The Law of Environmental Impact Assessment

The Study projects are not assessed as the objective project shown in the environmental impact assessment in Nicaragua. However, all of projects need the permission of MARENA in spite of the scale of projects. Furthermore in order to apply the permission for projects, a private company and a public agency must procedure respectively under Nicaragua law.

9.2 Condition of Natural Environment and Social Environment

9.2.1 Forest

When the tree is deforested by the project, four afforestations are obligated to one deforestation in Nicaragua. It is necessary to build these costs into the project budget, and the afforestation part is directed by MARENA or INAFOR.

9.2.2 Fauna and Flora

A "Red data book" is published based on the Washington Treaty, and specified to conserve the valuable fauna and flora in Nicaragua. These conservations are classified into the following eight categories, which include also the historical place and the heritage.

- National Park,
- Biological Conservation area,
- National Heritage,
- Historical Heritage,
- Wildlife Protection Area,
- Hereditary Resource Conservation area,
- Natural Conservation area, and
- Biodiversity.

9.2.3 Land Ownership

Property ownership is recognized as a right in Nicaragua. According to Clause 44 of the constitution: "Individual ownership is assured for real estate and property and for the means of the production."

9.2.4 Rights of Way

Rights of way in Nicaragua are as laid down in the Roadside Law (1952) and are as follows.

- International road: 40m
- Pacific Ocean-Atlantic Ocean Road: 40m
- Trunk Road: 20m
- Rural Road: 20m

However, this legislation does not apply to landowners before the law's enactment. Moreover, in cases where right of way is not registered, and where cities may recognize individual registration in a right of way, the law is not enforced.

9.2.5 Water Rights/Fishery Rights/Common Rights

Water rights are not fully established in Nicaragua. As for fishery rights (commercial fishing), they have been established for the Pacific Ocean, Atlantic Ocean, lakes and two rivers (the Tisma and San Juan rivers).

9.2.6 Conservation of Areas for Indigenous People

Three areas are specified as conservation areas for indigenous people living on the Atlantic coast. Other conservation areas have not been designated because the residences of indigenous people overlaps with that of other people. In these areas, there is no regulation of development.

9.2.7 Solid Waste

MARENA provides guidance on how to specify waste and the appropriate disposal site of different types of waste in the EIA stage. Therefore, a disposal site can be specified if a project and its waste can be specified. For example, removed asphalt is re-crushed by MTI and re-used as a base course for roads.

9.3 Environmental Impact Factors

Ten items have been selected to evaluate negative impacts: resettlement, economic activity, traffic and public facilities, waste, groundwater, lakes and rivers, fauna and flora, landscape, water pollution, and noise and vibration. Reasons for this selection are described below.

1) Resettlement

Almost disaster spots except bridge foundation damages are the object of resettlement. There is almost no resettlement. However only land acquisitions for construction work need at critical spots. It is supposed to need resettlement at three critical spots.

No.31: Three private houses exist on a mountainside where work is to take place. Therefore, re-cutting and the use of prevention nets should be avoided. There is also a property on the valley side of the road and measures that do not require the need to relocate residents should be implemented.

2) Economic Activity

Where facilities that generate income exist, impacts at the target point are evaluated. There are six objective spots. Five spots are cultivated land. One spot is a hotel under construction.

3) Traffic and Public Facilities

As for traffic and public facilities, all the target roads carry buses and other public service vehicles. Therefore, all sites were anticipated the effects due to lane regulation from the planned construction.

4) Waste

Construction waste will occur at all points where construction is to take place. This must be dealt with in accordance with Law No.217 and with the guidance of MARENA.

5) Groundwater

There are wells close to the points of the proposed work sites. Generally, non-confined water (free flowing water) is being used from all wells, which are around 5-6m in depth, and it is therefore expected that they would be sensitive to even slight changes in geography. Therefore, measures that cover slopes with structures, such as shotcrete, should be avoided. Permeation catchment pits should be considered when a slope is covered by a structure.

6) Lakes and Rivers

As for lakes and rivers, 3 points where dams are planned were anticipated the influence of impact. The rivers at these 3 points are used for cleaning dishes by local people.

7) Fauna and Flora

There are many precious fauna and flora and conservation areas (such as national parks) near some of the target roads as shown below. Therefore, when a target point exists in one of these areas, it has the potential to have an adverse impact.

- Cerro Tomabu Area
- Cerro El Arenal Area
- Cordillera Dipilto y Jalapa Area

8) Landscape

Target points inside conservation areas, except for the bridge foundation countermeasure at Site 4, shall give careful consideration to the landscape.

9) Water Pollution

All points are considered, because some water pollution will occur as a result of measures to protect slope construction and prevent the scouring of bridge foundations.

10) Noise and Vibration

Where schools and hospitals exist close to a target point, these facilities require quiet. Construction work must therefore include the installation of soundproof facilities or use low-noise machinery at these points.

CHAPTER 10 TRAFFIC SURVEYS

10.1 Survey Methodology

Traffic plan are executed based on the National Transportation Plan (NTP : February 2002). Two types of survey were carried out:

i) Direct classified counts; and

ii) Origin-Destination interviews.

Both types of survey were undertaken at the 9 locations set out in Figure 10.1.1. Traffic counts were carried out over a 12-hour day (06.00 to 18.00) at all 9 locations, with 24-hour counts undertaken at survey sites 2 and 6. The target interview rate was set at 30% to 50% of all traffic. The classified counts were taken at 15-minute intervals. Ten vehicle types were recorded: car, pick-up, minibus, bus, light goods, medium goods, heavy goods, tractor, motorcycle, and bicycle.

Less than 30% of bicycles were interviewed, but this category is not so important as motorized transport to the study outcome. In every other vehicle category, over 40% of traffic was interviewed, with a total sample rate of well over 50%. This is considered very satisfactory in statistical terms.

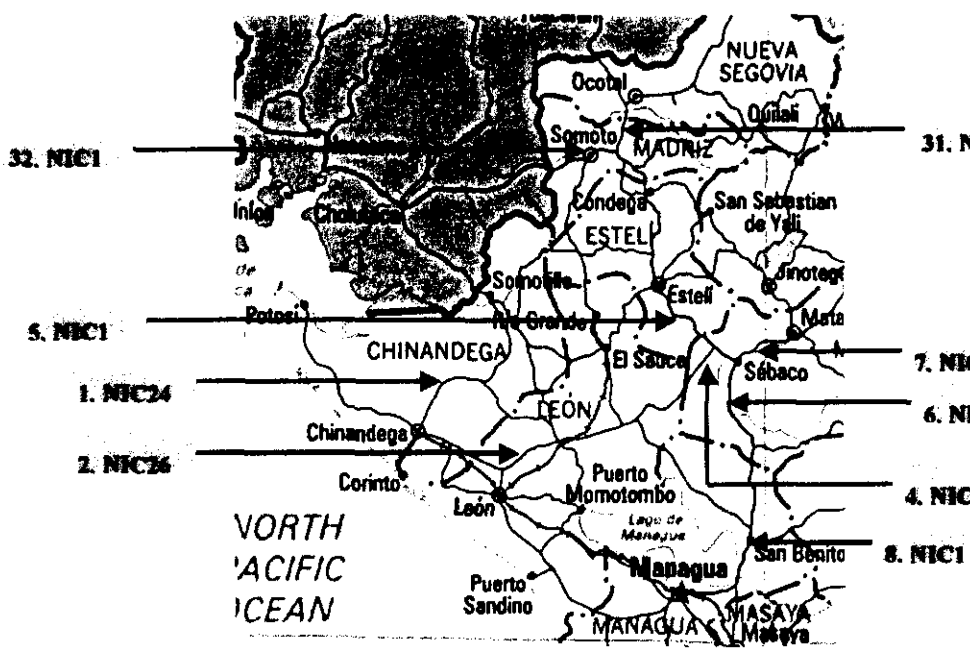


Figure 10.1.1 Survey Location

10.2 Aggregate Traffic Count Results

Figure 10.2.1 (Figure 10.3.2 of the main text) shows the hourly profiles over the 12-hour day for each site. Sites 1, 2, 31, 32, 4 and 7 all display relatively flat profiles over the day. However, the sites on NIC 1 tend to have greater variation. Site 5 (Santa Cruz, NIC.1) shows a strong peak in the evening between 16.00 and 17.00 hours. Site 6 (Sebaco, NIC.1) shows a peak in the morning (06.00 to 07.00), and at Site 8 (San Benito, NIC.1) much higher volumes were observed after 12.00 than in the previous six hours.

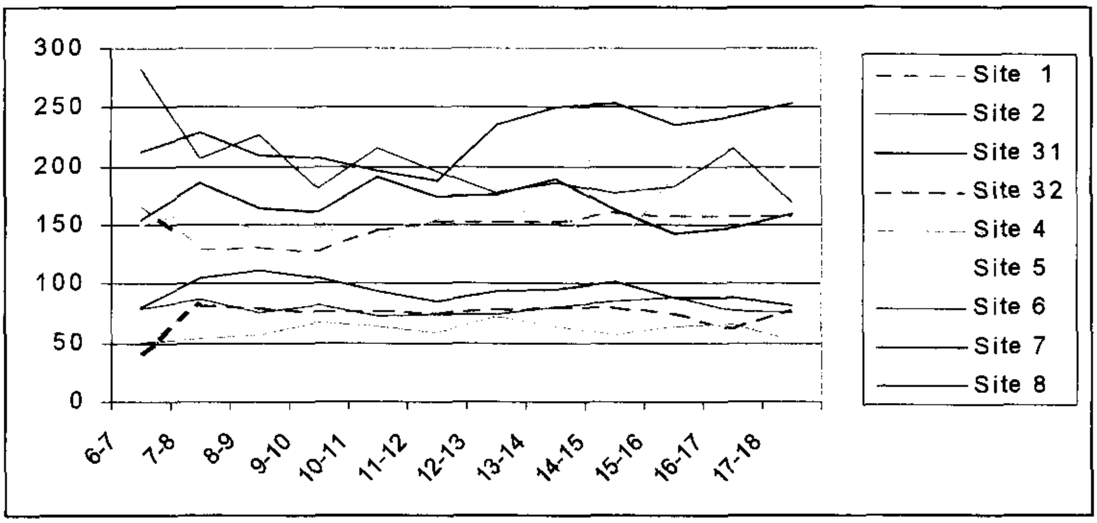


Figure 10.2.1 Hourly Total Traffic Variations, 06.00 to 18.00 Hours, All Sites

Figure 10.2.2 (Figure 10.3.3 of the main text) shows the hourly profile of observed traffic at the two sites where 24 counts were undertaken. The peak hour at Site 2 (Telica, NIC.26) was found to be 15.00 to 16.00 hoursand accounted for 7.1% of the total 24-hour traffic observed. The peak hour at Site 6 (Sebaco, NIC.1) was 06.00 to 07.00 hours and accounted for 8.3% of the total 24-hour traffic was observed. At Site 2, 76.5% of the 24-hour traffic was observed during the 12-hour day, whereas at Site 6 it was lower at 70.7%.

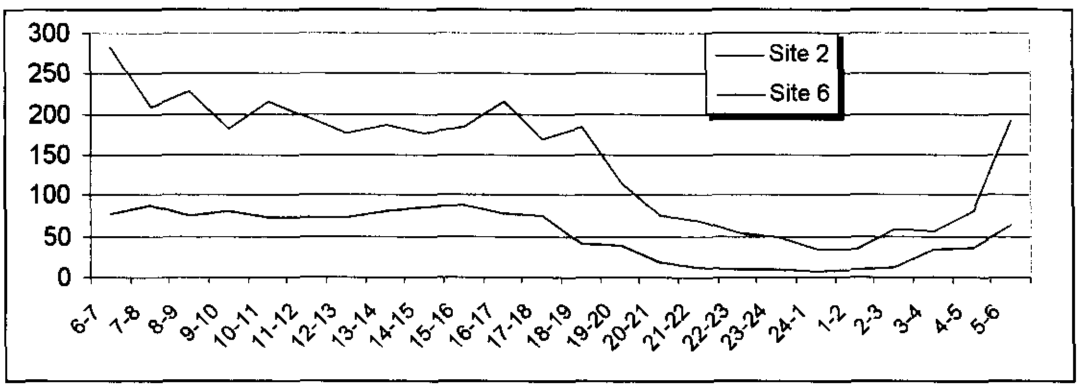


Figure 10.2.2 Hourly Total Traffic Variations, 24 Hours, Sites 2 and 6

Data for converting 12-hour counts to 24-hour counts is available for 20 main roads in Nicaragua for the year 2001, as shown in Figure 10.2.3 (Figure 10.3.4 of the main text). The data from the surveyed sites 2 and 6 are also included. The data from Site 2 is seen to be very close to the observed average, so this latter value has been adopted.

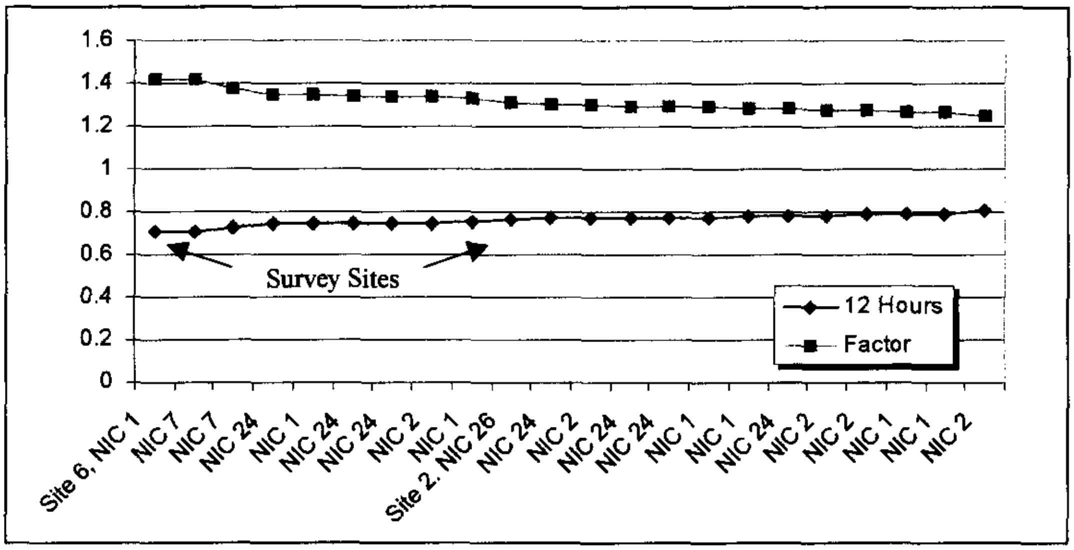


Figure 10.2.3 Observed Relationships between 12-hour and 24-hour Counts

The resultant proportion of daily traffic occurring in the 12-hour period is 0.762, and the conversion factor from 12-hours to 24-hours is 1.31.

The application of the above results in a total factor for converting the observed 12-hour flows to Annual Average Daily Traffic (AADT) volumes is summarized in Table 10.3.4. The resultant AADT's are shown in Table 10.2.1 (Table 10.3.5 of the main text).

Table 10.2.1 AADT Conversion Factors

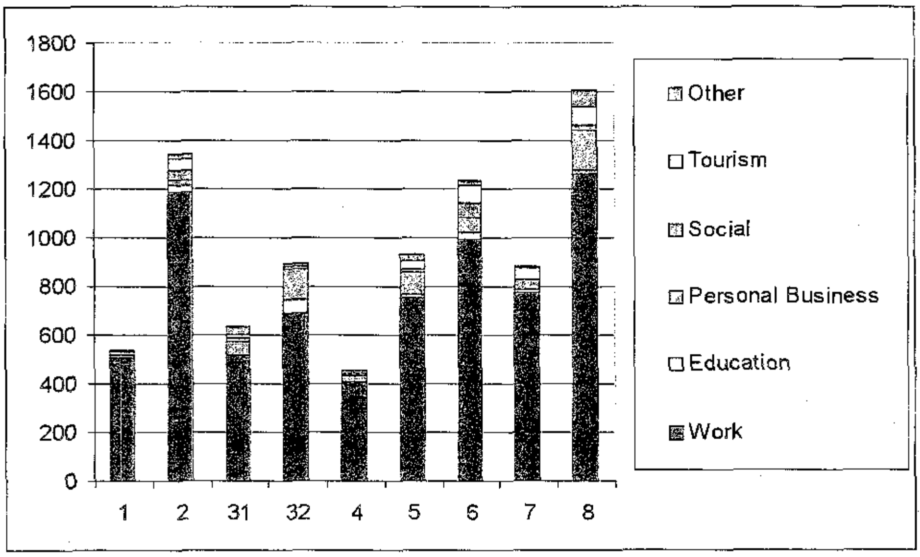
Conversion Item	Factor
12-hour to 24-hour	1.31
Tuesday/Wednesday to Average Weekday	1.0943
June to Average Month	1.05
12-hour to AADT	1.51

AADT's constructed from the surveyed counts have been compared with historic data from MTI for these sites. The estimated AADT's for motorized traffic (excluding bicycles and tractors) are shown in Figure 10.3.5 for the years 1997 to 2002. In aggregate at the nine sites, traffic has grown by an average of 10.4% per year over this 5-year period.

10.3 Aggregate Interview Result

Figure 10.3.1 (Figure 10.4.2 of the main text) shows the distribution of journey purposes by site. At every site, interviewed vehicles were dominated by trips to, from and in the course of work. On average, 83% of all trips interviewed gave work as their journey purpose. At Site 1 this figure rose to 92%. Personal business, including shopping, accounted for 7% of respondents.

Figure 10.3.1 Number of Interviews at Each Site by Journey Purpose



CHAPTER 11 SOCIO-ECONOMIC FRAMEWORK

11.1 Objectives and Method

The purpose of this chapter is to establish the socio-economic framework for Nicaragua within which traffic forecasts can be made. In addition, the conditions for estimating economic benefits that flow from investment in highway protection will be established. As a general rule, there is a strong relationship between economic conditions and traffic volumes. The key determinants of traffic growth adopted for this study are as follows:

- Population
- Economic activity and sector growth
- Income levels

There is a strong relationship between income and car ownership. As data on personal incomes are not available, use has been made of Gross Domestic Product (GDP) as a proxy. Research has demonstrated that there is also a strong link between GDP per head and personal car ownership.

Benefits that flow from investment in transport are conventionally measured as the sum of the following:

- Vehicle operating cost savings
- Time savings

Vehicle operating costs have been estimated using the method and data provided for the National Transport Plan for Nicaragua (February 2001). Some prices, e.g. fuels, have been updated for this study. Time savings have been estimated using the values provided in the National Transport Plan and have not been modified.

11.2 Background Data and Forecasts

Figure 11.2.1 shows the growth in the population of Nicaragua over the period 1980 to 2002. During this period population grew by 87% at an average annual growth rate of 2.9%.

The age structure of the population is extremely skewed towards younger-age groups. As a consequence, population growth in the future is expected to be much higher than in the past. Figure 11.2.2 shows forecast population growth to the year 2020. Growth between 2002 and 2020 is estimated to be 78%, or an annual rate of 3.25%.

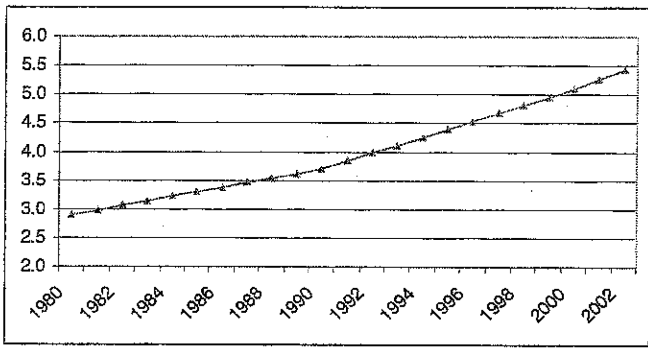


Figure 11.2.1 Nicaragua population, 1980 to 2002, Millions

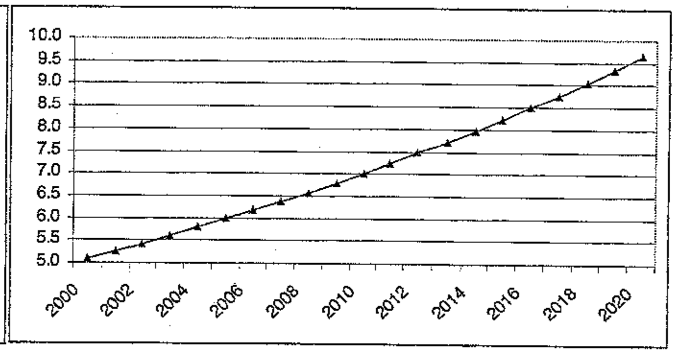


Figure 11.2.2 Forecast population of Nicaragua to 2020, Millions

Figure 11.2.3 (Figure 11.2.4 of the main text) shows GDP per head for the period 1980 to 2000 and the forecast from 2000 to 2020. Average GDP per head fell drastically from the mid-1980s over a 15-year period, leading to one of the lowest figures in the western hemisphere. From 1998, GDP per head began to grow again, and it is now forecast that it will rise by 2.3% per annum until 2020.

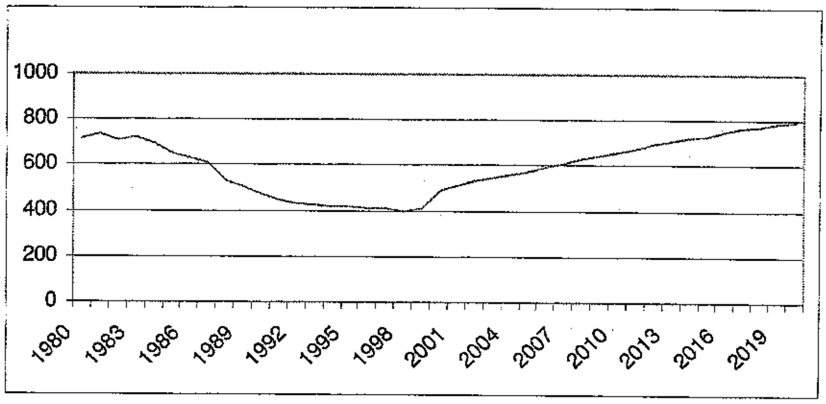


Figure 11.2.3 Average GDP per Head (US$), Nicaragua, 1980 to 2020

Figure 11.2.4 shows car ownership in selected Latin American and Asian countries for 1996. These have been chosen to provide relatively close comparisons with Nicaragua, both above and below. In Figure 11.2.5, these values have been plotted against GDP per head estimates for the same year. This *scatter gram* shows a general relationship between GDP and car ownership that can best be described by the following formula:

y = 0.0349x - 3.4031 ***where y is car ownership per 1000 population and x is GDP per head***

Using the above relationship, it is forecast that whilst GDP will increase by a factor of 1.62 over the 20 years to 2020, car ownership will increase by a factor of 1.78 over the same period, or an average annual growth rate of 2.9%.

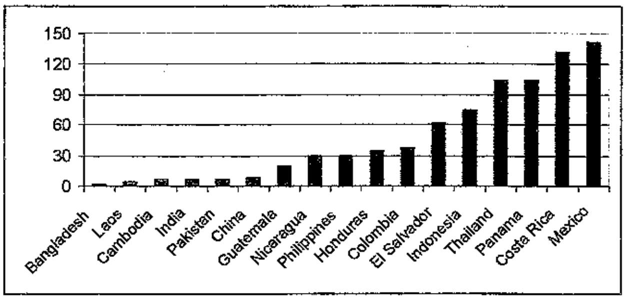


Figure 11.2.4 Vehicle Ownership (per 1000 population)

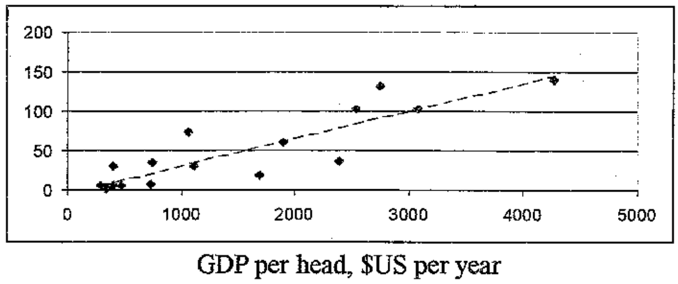


Figure 11.2.5 GDP per Head and Vehicle Ownership per 1,000 Population

11.3 Vehicle Operating Costs

Parameters for vehicle operating costs were taken from the National Transport Plan, 2001. Fuel and lubricant costs were updated to 2002 values. Vehicle occupancies were taken from the 2002 surveys, as they more accurately reflect conditions on the study roads than does the national average. Passenger time values were not included in vehicle operating costs (per 1000 km), but calculated separately and converted to costs per vehicle-hour. In this way, the traffic model output (Chapter 12 in the main text) can be used to directly estimate passenger time savings and hence costs.

The composition of vehicle operating costs by vehicle type are as shown in Figure 11.3.1 The fuel component of cost tends to be much higher in Nicaragua than in many other countries due to the cost of gasoline (Cordoba 29.99, US$ 2.13 per litre).

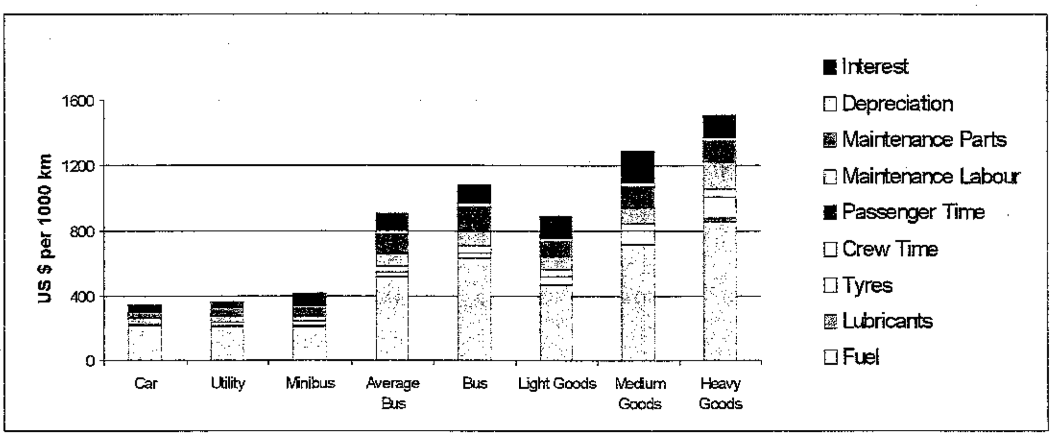


Figure 11.3.1 Vehicle Operating Costs, Nicaragua 2002, US$ per 1000km

11.4 Traffic Growth Factors

For this study two forecast years have been established: 2010 and 2020. The traffic matrices described in Chapter 12 of the main text have been factored according to Table 11.4.1 of the main text in line with the economic projections above.

Growth in traffic is very dependant on economic growth. The GDP forecasts are relatively optimistic, predicting a sustained growth in the economy of around 5% over a 20-year period. In order to assess the effects of lower growth, a sensitivity test has been developed. In this test, it is assumed that the economy grows at 60% of the forecast rates in Table 11.2.1 of the main text across all sectors equally. When this reduced growth is converted into the traffic growth factors, the values in Table 11.4.2 of the main text result.

Table 11.4.1 Traffic Growth Factors to 2010 and 2020

	Growth 2002 to 2010	Growth 2002 to 2020	Functional Description
Cars	1.57	2.74	Population growth x vehicle ownership growth
Pick-ups	1.57	2.74	GDP growth x vehicle ownership growth
Buses	1.29	1.78	Population
Goods (Agriculture)	1.68	2.87	Agriculture Sector Growth
Goods (Other Primary)	1.19	1.60	Other Primary sector growth
Goods (Industry)	1.66	2.79	Industrial sector growth
Goods (Construction)	1.65	2.91	Construction sector growth
Goods (Vacant, other)	1.62	2.70	Average economic growth

Table 11.4.2 Traffic Growth Factors (sensitivity test)

	Growth 2002 to 2010	Growth 2002 to 2020
Cars	1.31	1.83
Pick-ups	1.21	1.48
Buses	1.29	1.78
Goods (Agriculture)	1.21	1.48
Goods (Other Primary)	1.07	1.19
Goods (Industry)	1.20	1.45
Goods (Construction)	1.20	1.48
Goods (Vacant, other)	1.12	1.38

Values of time are expected to rise in line with average GDP per head. The factors to be applied to passenger costs per vehicle hour (see Table 11.3.1) are set out in Table 11.4.3 of the main text. In the sensitivity test, values of time are forecasted to fall, owing to a decrease in GDP per head, because population is forecast to rise at a higher rate than GDP.

Table 11.4.3 Growth Factors Applied to Value of Time, at 2002 US$ Values

	2002 to 2010	2002 to 2020
Base Case	1.239	0.924
Sensitivity Test	2.678	0.811

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.

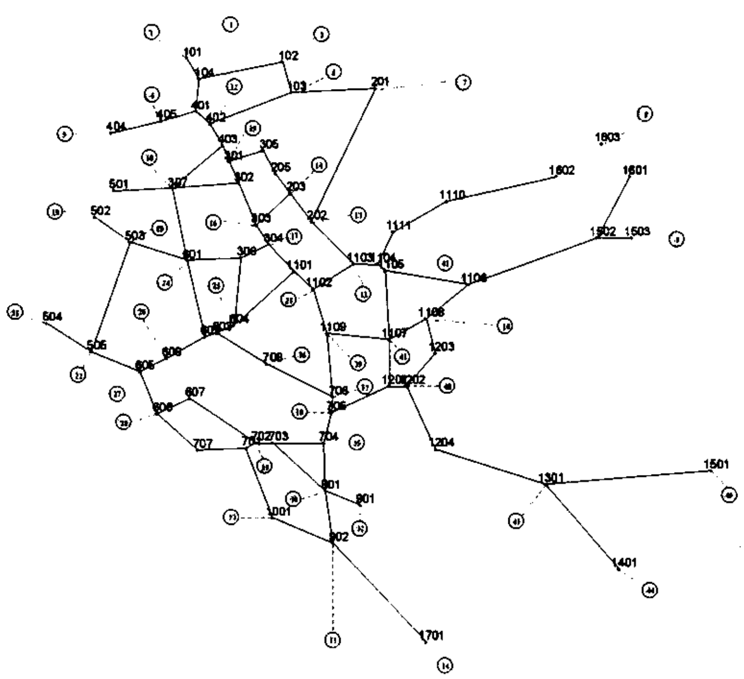


Figure 12.2.1 Base Year Highway NNetwork

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

12.3 Base Year Traffic Estimate

The base year validation is as shown in Table 12.2.1. 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 of the main text. Network data for 2002 are set out in Table 12.2.2.

Table 12.2.1 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

Table 12.2.2 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

12.4 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 12.3.1.

Table 12.3.1 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 in the main texr show traffic assignments for the three forecast years. Network statistics are shown in Table 12.3.2.

Table 12.3.2 Network Statistics for Forecast Year Traffic

	2003		2010		2020	
Mode	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

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 of the main text, which are expressed as the benefits of undertaking disaster prevention measures.

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 in the main text.

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.

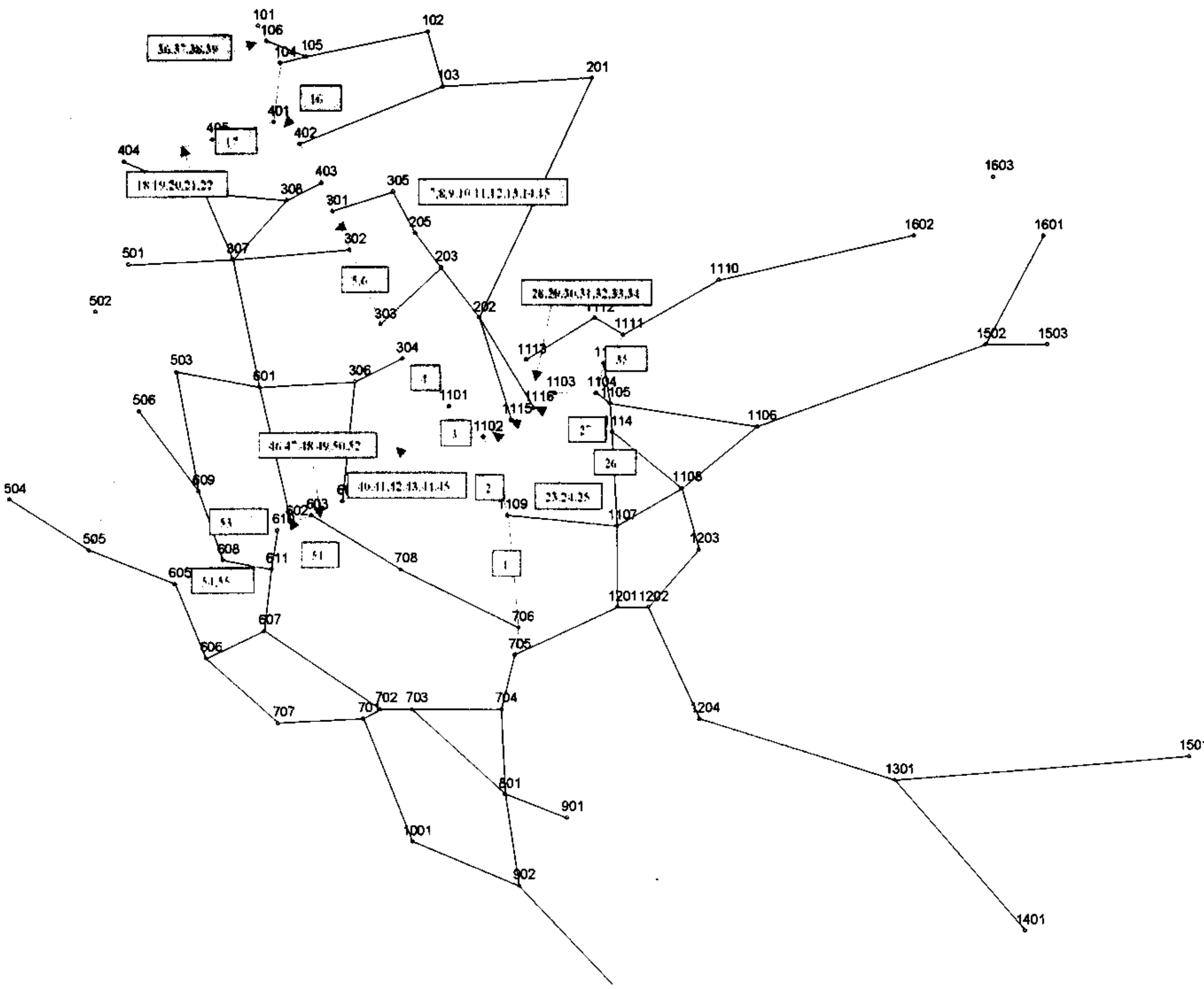


Figure 13.2.1 Disaster Sites

Figure 13.2.2 in the main text shows an example for Sites 28 through 34 located on Link 94, which is the road between Matagalpa and Jinotega. 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 in the main text.

It has not been possible to carry out all the sensitivity tests with lower levels of traffic. Table 13.2.1 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 13.2.1 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

CHAPTER14 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. 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, 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).

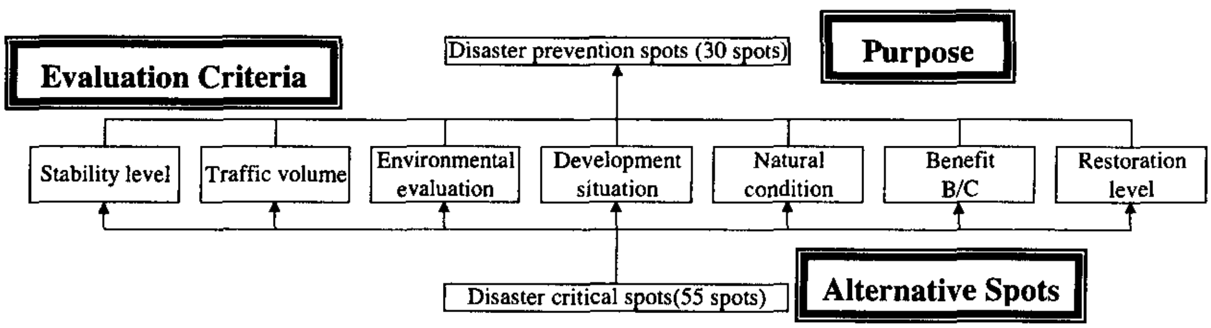


Figure 14.3.1 AHP Structure

Table 14.2.1 Characteristics of Disaster Critical Spots

Serial Number of Disaster Critical 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

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

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 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

PART B

FEASIBILITY STUDY

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.

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.

CHAPTER 16 DESIGN STANDARDS

16.1 Geometric Standard Applied

The geometric standards adopted for this Study are as shown in Table16.1.1.

Table 16.1.1 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

16.2 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. Geological soundness is classified into four types: sound rock, unknown soil, well-compacted soil, and poorly compacted soil as shown in Table 16.2.2.

Table 16.2.2 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

It is worth mentioning here that tuff and muddy rock may affect the stability of slopes in many cases. Rock stability is considered based on 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 as shown in Table 16.2.3.

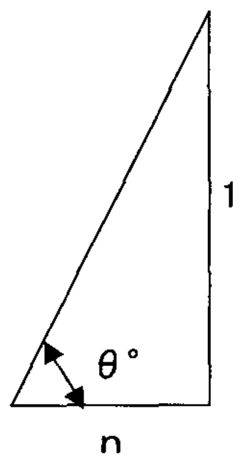
Table16.2.3 Concept for Rock Classification

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	

Recommended standards for the gradients of cut slopes are shown in Table 16.2.4.

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



16.2.2 Structures

1) Estimation of Scouring Range

Scouring depth is calculated based on Japanese Standard as shown in Figure 16.2.1. Note however that calculations in this table cover the range of ho/D<3.5.

Where:

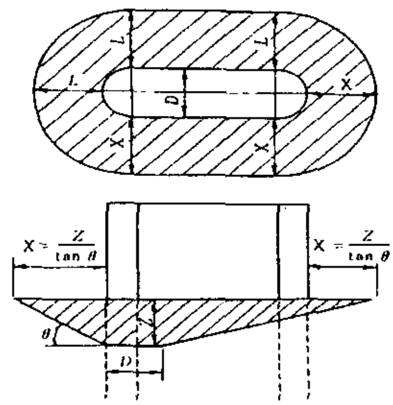
ho: Mean water depth during flooding,

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·ho))/v(g·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

Figure16.2.1 Area of Scouring

The value ho/D can be obtained from Z/D using the relationship between ho/dm and Fr, which are presented in Figure16.2.3 to Figure16.2.6 as a parameter in the main text.

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

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 as shown in Table 16.2.5.

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	1.020	3.310
	2.012	3.700
	3.036	3.970
	4.014	4.150
	5.025	4.310

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

16.3.1 Confirmation of Standard Value

All disaster prevention spots are Class A3 roads. The typical cross-section and right-of-way of Class A3 roads are as shown in Table 16.3.1.

Table 16.3.1 Typical Cross-section/ Right-of-way

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

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.

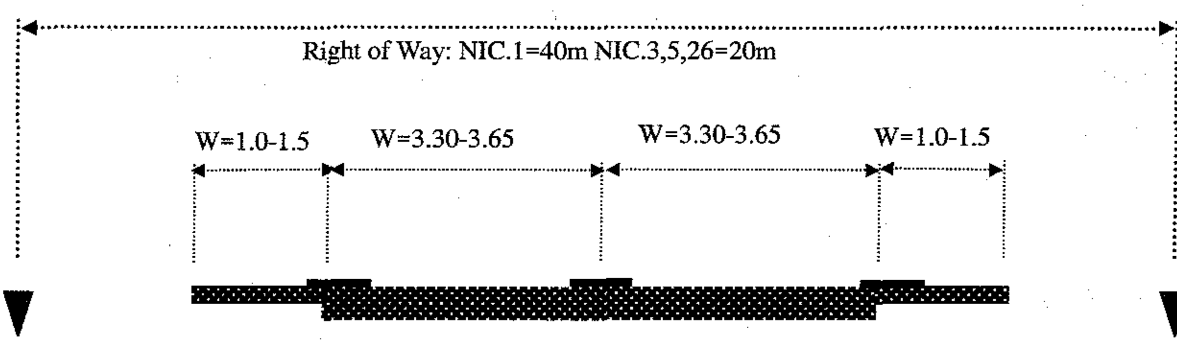


Figure 16.3.1 Standard Typical Cross-section and Right-of-way

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

As for two places of NIC.3, standard value isn't satisfied.