7.2 Japan Philippine Friendship Highway (Road 1 group)

7.2.1 Japan Philippine Friendship Highway

The Road-1 group mainly investigated earthquake-damage conditions of the Japan Philippine Friendship Highway (Pan Philippine Highway). The investigated sections are shown in Figure 7.2.1.

The Pan Philippine Highway of about 2,100 km is a principal road running through the Philippines from south to north, from Aparri on the northern extremity of Luzon Island via the capital, Manila, through Samar and Leyte Islands to Davao, a city on southern Mindanao Island. The construction of the Highway, as a part of economic cooperation with Philippine government by the Japanese government, is based on a yen credit agreement concluded on February, 1969; using the loaned yen funds (10.8 billion yen, work section: 1,481 km), construction equipments and bridge materials necessary for the road construction were purchased from Japan, and the design and construction of the road were done by the Philippine side. Also, for the domestic money necessary for the execution of the project, several times a part of the counterpart funds of the commodity aid for the Philippine government was earmarked. The project was commenced in July, 1969. Later, a car-ferry improvement projects connecting Luzon-Samar and Leyte-Mindanao were added, and all the lines were almost completed in 1980. After the Highway was completed, the Pan Philippine Highway has played an important role as a principal road; traffic volume has been on the increase. In 1983, a 150 km expansion project, from Aparri to the western city of Laoag was carried out. Further, for the sections superannuated by the increase in traffic on Luzon Island, recently, a rehabilitation project (pavement, bridges and slope protection) for the Pan Philippine Highway was planned, and the execution plan had already been completed. At this point in time, the Highway encountered the earthquake.

Figure 7.2.2 shows a standard section of the Pan Philippine Highway. Cement concrete pavement of two-lanes is the standard. Since the 23cm-thick pavement is not reinforced by reinforcing materials such as steel wires, pavement with poor quality base materials has been damaged by heavy traffic. Further, in mountainous areas and hilly areas, there are many cut-bank structures. For these cases, the standard earth work grade is shown in Table 7.2.1. However, in the mountainous areas cut work generally has been done using the critical grade which obtained by the stability of the execution of the works, since application of the standard grade does not agree with the actual conditions due to the huge volume of earth work. For drainage, simple ditches are constructed at the toes of slopes. Though low stone masonry retaining walls are properly constructed, special slope protection methods, such as sodding or spraying are not used at the cut slope faces. Therefore, accompanying the progress of the weathering of the surface, slope failures occur often and traffic has sometimes been suspended.

Figure 7.2.3 shows the organization of DPWH, which controls the national highways. The DPWH controls the national highways, the provincial roads and the Barangay roads and construction and maintenance management is covered by 14 Regional Offices established throughout the country, 94 District Offices, City Engineering Offices and also Regional Equipment Depots. Generally, projects are contracted to contractors, and maintenance management is directly operated by the DPWH. For those foreign aid projects among the national projects, individual offices which manage design and construction are established; PJHL (Philippine Japan Highway Loan) is in charge of the construction of the Pan Philippine Highway.

7.2.2 Conditions of Damage

(1) Outline

Damage to the Pan Philippine Highway by the earthquake is serious, covering a 76 km section which runs through mountainous section between San Jose (kms 160) and Aritao (kms 236). Figure 7.2.4 shows an outline of the damaged section. In the Bayombong district (km 265), north of Aritao, a few cracks occurred on the shoulders, while on the road between San Jose and Aritao, the traffic has been shut down due to slope failure of the road. Since large-sized faults were produced along the road in the neighborhood of Digdig (kms 183), it is thought that the strong shaking of the earthquake motion centered around the mountainous areas. According to investigation by a helicopter, in addition to slope failure along the Pan Philippine Highway, slope failure on surrounding mountainsides was observed; the scope of this slope failure spreads to Bagio and its surroundings. The most prominent feature of the earthquake damage along the Highway may be that a great number of continuous slope failures occurred not only on the artificially cut slopes but also on the natural slopes. However, the slope failures are all shallow surface sliding. These districts have the regional characteristic that there are few trees on the surface of the mountains and slope protection measures are not used on the slopes. Particularly, under an environment promoting weathering, that is, the heavy rains and the high temperatures in the tropics, weathered surfaces which barely balance the static force of rainwater erosion, will be shaken off at a stroke by strong vibrations. By the way, the rainfall per year from 1976 to 1984 in Santa Fe (kms 215) on the north side of Dalton Pass (kms 208, 1000 meters above sea level) and San Jose to the south of that were 1500 to 3400 mm in Santa Fe and 1700 to 3200 mm in San Jose, and sometimes these districts are visited by heavy rains accompanying the progress of typhoons. Since the Pan Philippine Highway runs along the fault topography with a NW-SE direction branching off from the Philippine fault, the geological features there are disturbed and changed in quality by its influence. The geology is composed of the following: the basement is composed of granite and diorite of the Mesozoic era, Cretaceous period; diabase and andesite of the Paleogene period to Neogene period; and sandstone, mudstone and limestone of the Neogene. Terrace gravel of the Quarternary period Diluvium covers the basement; the alluvium is composed of sand, gravel and clay of Quarternary period Alluvium; then there is talus sediment and the present riverbed sand gravel. The basement is in an unstable state; many viscous parts can be observed due to disturbances by the faults. Furthermore, since the granite mainly distributed in the Santa Fe neighborhood has become decomposed granite, the slopes are very unstable.

Where there were slopes composed of hard rock, low slopes (less than 10 m) and gentle grade natural slopes, slope failure hardly occurred. Furthermore, compared with the many slope failures, there is little damage to the structures, such as stone masonry retaining walls and gabions which reinforce the lower parts of slope faces. One of the features of the disaster is that damages are hardly observed on the structures with a base rigidly connected with the sound natural ground.

Some pavements were damaged. Cracks were caused by settlement of the bank shoulders, there were damages from falling stones and there was thrusting up of pavement slabs by the earthquake motion. At the places where faults cross the road, whole the road surfaces slid laterally (about 2 m to the axis line), and the pavement slabs were badly damaged. However, it is not enough to make traffic come to a standstill.

There are 24 bridges, 10 to 40 m long, between San Jose and Aritao. Since the road is along a mountainous region, most of them are bridges crossing valleys on a small scale. In flat places, there are three fairly long bridges: the 78 m girder second Puncan Bridge (kms 176.6), the 66 m truss

Digdig Bridge (kms 181.5) and the 60 m concrete Kirang Bridge (kms 234.9). The bridges were hardly damaged, except for the Manicla Bridge (kms 164.5, l = 15 m, due to falling of the bridge the Bailey Bridge is being temporarily used). At the places where there is the approach banking to the bridges, some cracks were observed on the banking shoulder parts.

In addition to the damages to the road itself, due to the above-mentioned collapsing of slopes, there were outflows of huge amounts of muddy sands, and because of this, there were great damages from flowing mud and from drifting wood in the low-lying areas (rivers) of the region.

(2) Rehabilitation conditions and secondary disasters

After the earthquake, the damaged roads have been rehabilitated through concentrated efforts by the DPWH since the Pan Philippine Highway is the principal road which supports the huge northern hinterlands. A great quantity of heavy machinery (bulldozers, shovels, graders, dump trucks, etc.) was distributed to each damaged place. During our investigation also, more than 40 pieces of heavy machinery (from the DPWH and from private organizations) were at work; these operations are being supported by the military. Therefore, when our investigating group arrived at the actual places, it was about two weeks after the earthquake, but only three or four sections with traffic suspensions due to slope failure remained owing to remarkable progress of the clearing work. (The Dalton Pass ridge is the most difficult location for construction.) The fortunate part about the disaster was that the slope failures were just surface sliding. Consequently, by removing earth and sand, a minimum of one lane could be secured. However, due to the rainy season (from June to September), secondary failures of loosened slopes, flow of loosened mud from valleys, drifting wood in the rivers, and accumulation of drifting wood at the bridges (most remarkable at the second Puncan Bridge) occurred. From these disturbances, in some places traffic was suspended again. People have suffered from these secondary disasters after the earthquake.

(3) Distribution of the damages

Table 7.2.2 shows the kinds of and the distribution of the damage along the Pan Philippine Highway according to visual observation, and Figure 7.2.5 shows the distribution along the kilometer markers. Table 7.2.3 is a list of the places which had slope failures. The number of the places with slope failure reached more than 200 and totaled about 12 km. Most of the slope failures occurred continuously along the direction of the road.

(4) Type of the damage

As shown in Figure 7.2.6, the types of investigated damage were divided into slope failure (cut-bank), damage to the pavements, and secondary disasters.

On the slopes of cuts, there were cases in which a whole weak layer of soil slid down, and cases in which clods of earth on the upper parts broke off and slid down. In the case of rock slopes, the rock falls were divided into the sliding down and collapse of weathered layers and the falling of rocks from joints. Though the collapses were limited to the surfaces, the volume of collapsed materials was large due to the high slope heights. On the slopes of banks, the sliding was divided into the settlement of shoulders which did not affected the road surfaces very much, and the sliding at the boundary faces between natural ground and the bank materials which considerably affect the road surface, and which must be taken into consideration for future rehabilitation.

There were two remarkable types of damage to pavement: the slippage of pavement slabs caused by faults, and the thrusting of pavement slabs due to earthquake motion.

As described above, there were secondary disasters, such as subsequent slope failures, mud flow, avalanches of earth and stone, and drifting wood.

(5) Condition of the faults

Based on the lateral slippage damage produced on the road surfaces, the positions of the faults are shown in Figure 7.2.7. The direction of roall the faults crossing the road was about N20°W. If the condition of the accuracy of the drawings is considered, they are not strictly accurate, but the faults are distributed nearly along the same line. The slippages on the roads were laterally 1.5 to 2 m to the left. Slippages in an up and down direction were not remarkable.

7.2.3 Recommendation for Restoration

The remarkable feature of the earthquake damage to the Pan Philippine Highway is that more, expanded fresh slope faces occurred than before. If the faces are exposed to weather, rapid weathering advances due to the serious weather conditions; the surfaces loosen, and slope failures occur during every rainy season. Along the route of the road, slope failures have occurred frequently. The earthquake happened when slope protection work through a rehabilitation project on the Pan Philippine Highway were just about to be introduced. Though dangerous slope faces increased, it is necessary to overcome these difficulties with one-lane traffic and traffic control as tentative measures. However, from the importance of the role of the Pan Philippine Highway, improvement work such as slope protection, and grade-up, including reexamination of the road alignment, are necessary as soon as possible.

For the present restoration and maintenance management of Pan Philippine Highway, the following three stages of measures are suggested.

(1) Urgent restoration procedure for road recovery

- For removing collapsed soil, it is necessary to confirm well the stability of the remaining cut faces. In the cases where the cut face is unstable, the width of the road should be kept to a minimum by regulating the removal of the collapsed soil.
- To investigate the possibility of dangerous secondary collapses, open cracks at the upper parts of the faces of the slopes should be inspected.
- Avoid the use of a bank as a road.
- Traffic control should be put into operation in rainy season.
- Recutting of the faces of the slopes and rounding of the upper parts of the faces of the slopes should be done.
- At the toes of the slopes, structures such as catch walls, stone masonry retaining walls, concrete walls and gabion should be constructed.
- At the toes of banks, structures for scour protection, such as gabion, should be constructed,
- Cracked parts in banks should be filled in after reexcavation.
- To protect against mud flow from valleys and against avalanches of earth and stones, structures such as fences, H-type steel fences and concrete walls should be constructed.

(2) Improvement procedure

- Execution of engineering survey (topographical, geological) for condition of stability of slopes.
- Slope protection design
- Execution of slope protection construction

  Examples: soft rock slope: concrete spraying;
  talus slope: sodding berms, drainage ditches, crib works;
  bank slope: sodding stone pitching, stone masonry walls.

(3) Medium-long term plans

- Reexamination of the road alignment
  The conditions of this route, located in a sharp mountainous area, having 30 to 100 m class cuts, and valleys, with no leeway for the road width, are extremely severe. For ensuring a stable slope gradient and for general slope protection, there are some difficult locations which cannot be dealt with economically and technically; even when work has been conducted maintenance management needs to be given a great deal of effort. Though the Dalton Pass is one of these difficult positions, it is thought that, for the growth of the hinterland, a reexamination of the road alignment using bridge and tunnels will become economically feasible.

- Examination of the applicability of erosion control work
  This is somewhat exceeding the scope of the subject of road defenses, but from the outflows of mud and sand after the earthquake in the mountainous areas, damages were inflicted, such as drifting wood and riverbed rising in the flatlands, and mud flow and avalanches of earth and stone at road crossing places. As the rainy season continues, life in the flat areas will be threatened by outflows of sand from the mountainous areas. To prevent such sand outflows, fact-finding research into sand outflows and forecasting of future outflow volume is required. Also, the applicability of erosion control work (Sabo works) that can protect the environments of the mountains and rivers should be examined.

7.2.4 Damage Photographs

The condition of damages from the earthquake, between San Jose and Aritao, the investigated section of the Pan Philippines Highway, are introduced here by photographs. Photos 7.2.1 to 7.2.34 show examples which correspond to the kind of damages described in 7.2.2. Photos 7.2.1 to 7.2.4 show the status of cut slope failures. Between Dalton Pass and Santa Fe, many falling rocks of limestone as in Photo 7.2.5 or 7.2.6 can be observed; as the clearing of the road continues, the volume blocking off the roads is considerably reduced. Photos 7.2.7 and 7.2.8 are distant views of the road seen from a helicopter; we saw at a glance that the topography conditions were serious. Photos 7.2.9 and 7.2.10 show aerial photographs of the Dalton Pass which is one of the hardest parts; Photo 7.2.11 shows ground photography in the same position. After three weeks had passed since the earthquake, the clearing work had progressed satisfactorily even though the scale of the collapse was huge; traffic may tentatively be opened soon. Not only at the slopes along the road but also at natural slopes, large scale slope failures as shown in Photo 7.2.12 were observed.

Photos 7.2.13 and 7.2.14 show examples of the shoulder settlement; if the sliding was at the boundary of cut-banks, the scale of bank collapse spread more like that in Photos 7.2.15 and 7.2.16.

While such large collapses have happened continuously, there are also examples of almost no damage. Photo 7.2.17 shows a hillside with a low gradient slope, Photo 7.2.18 slope protection performed through vegetation, Photo 7.2.19 a stone masonry retaining wall at a cut, Photo 7.2.20 a stone pitch for bank slope protection, and Photo 7.2.21 wire mats (Gabion) for scour protection at the toe of a bank slope. Thus, the places with slope protection proved to be effective for not only for weathering but also against the earthquake.

Next, Photo 7.2.22 shows an example of damage to pavement slabs caused by thrusting up. Photos 7.2.23 and 7.2.24 show a case of the road being crossed by faults. Photo 7.2.25 shows the state of a fault running on the hills lateral to the road.

Furthermore, we will now introduce examples of the secondary disasters. Photo 7.2.26 shows open cracks on the upper parts of the face of a slope, observed from a helicopter; this is an example of the danger of shallow slope failure. Thus, helicopters are quite useful for the investigation of disasters. Photos 7.2.27 and 7.2.28 show an example of new slope failure being produced by rains. Photo 7.2.29 and 7.2.30 show an example of the road surface covered by the mud flow accompanying rains.

These districts were affected significantly by mud and sand outflows from the mountains after the earthquake; the actual conditions can be easily grasped in Photos 7.2.31 and 7.2.32. There are many trees mixed in the saoil, and there is a lot of drifting wood in the rivers. Photo 7.2.33 shows an example of drifting wood cast on the riverbanks. Photo 7.2.34 shows drifting wood accumulated at the position of the second Puncan Bridge, with the bridge exposed to danger.

Ground investigation is suitable for detailed observation, while helicopters should be used for an overall grasp. The size of the scale of the outflow of sand in these districts was impressive.

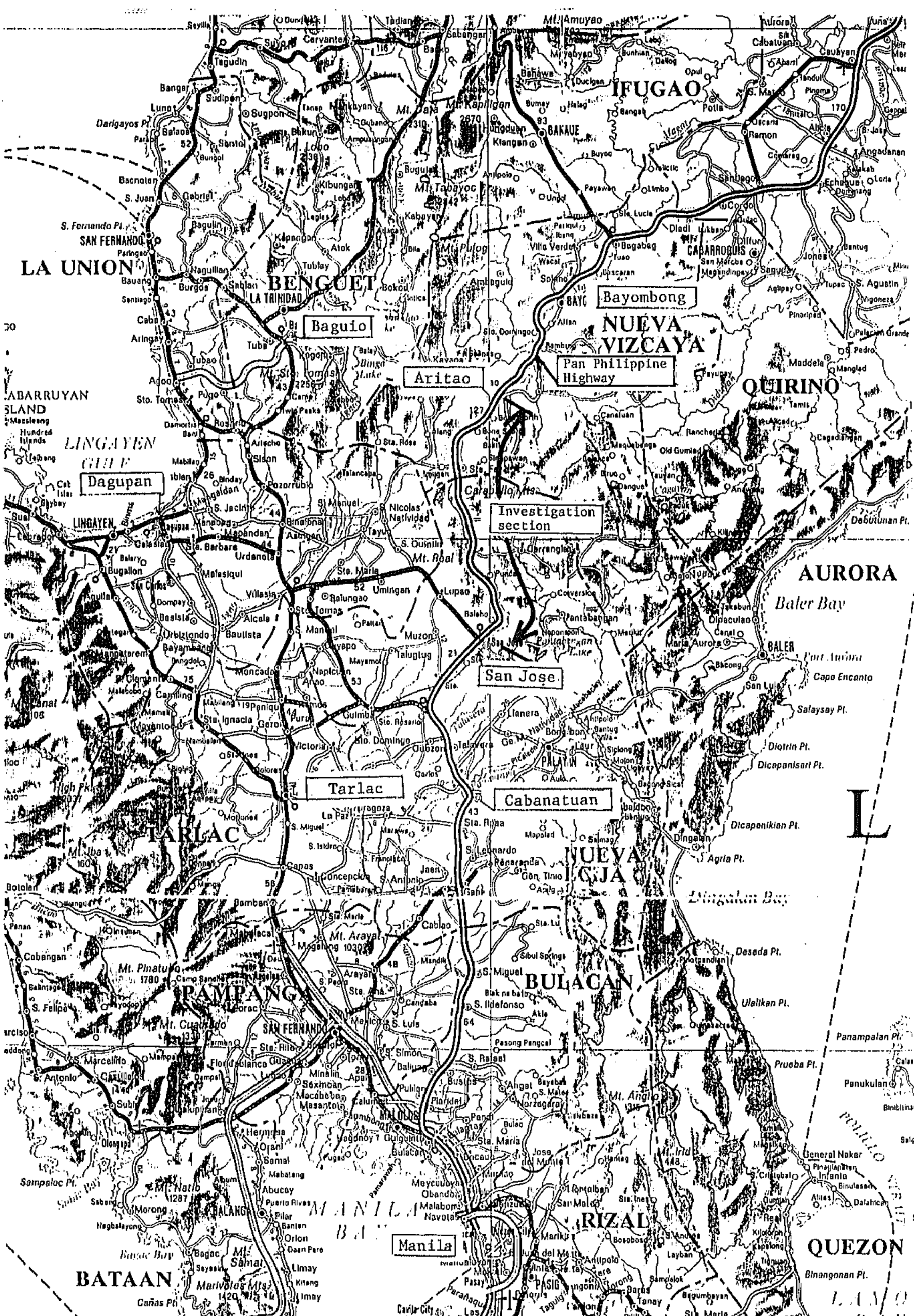


Figure 7.2.1 Pan Philippine Highway and the investigated section

Scale
0 10 20 30 40 50 km

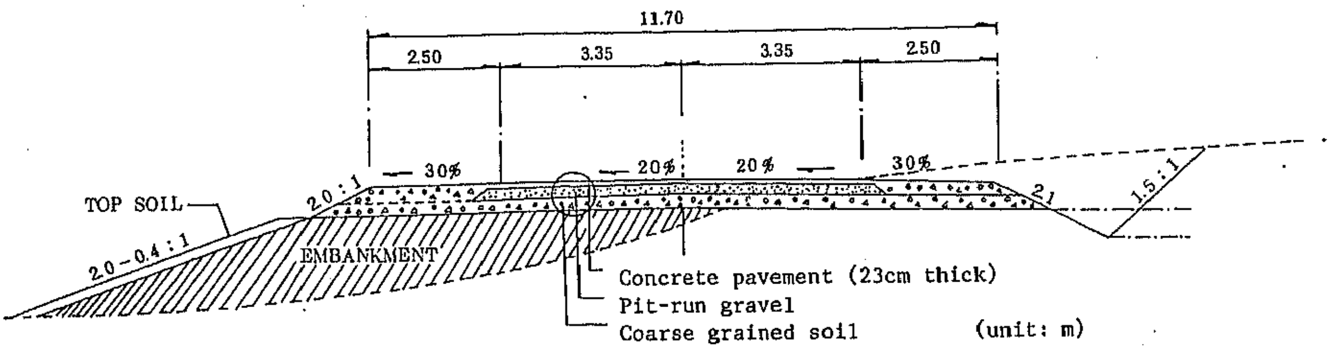


Figure 7.2.2 Standard section of road

Table 7.2.1 Standard slope grade for cut-banking (embankment of 2m or more height)

Nature of the natural ground	Cut	Banking
Soil	1.5 : 1	1.5 : 1
Soft rock	0.5 : 1 to 1 : 1	1.5 : 1
Hard rock	Natural gradient•(after blasting) Target value = 0.5 : 1	1.5 : 1 to 1.25 : 1

The numbers in the table show the gradients (horizontality : vertically).

Berms are constructed every four meters (berm width: 1.5m).

• Stable cut face with loosened earth removed after blasting.

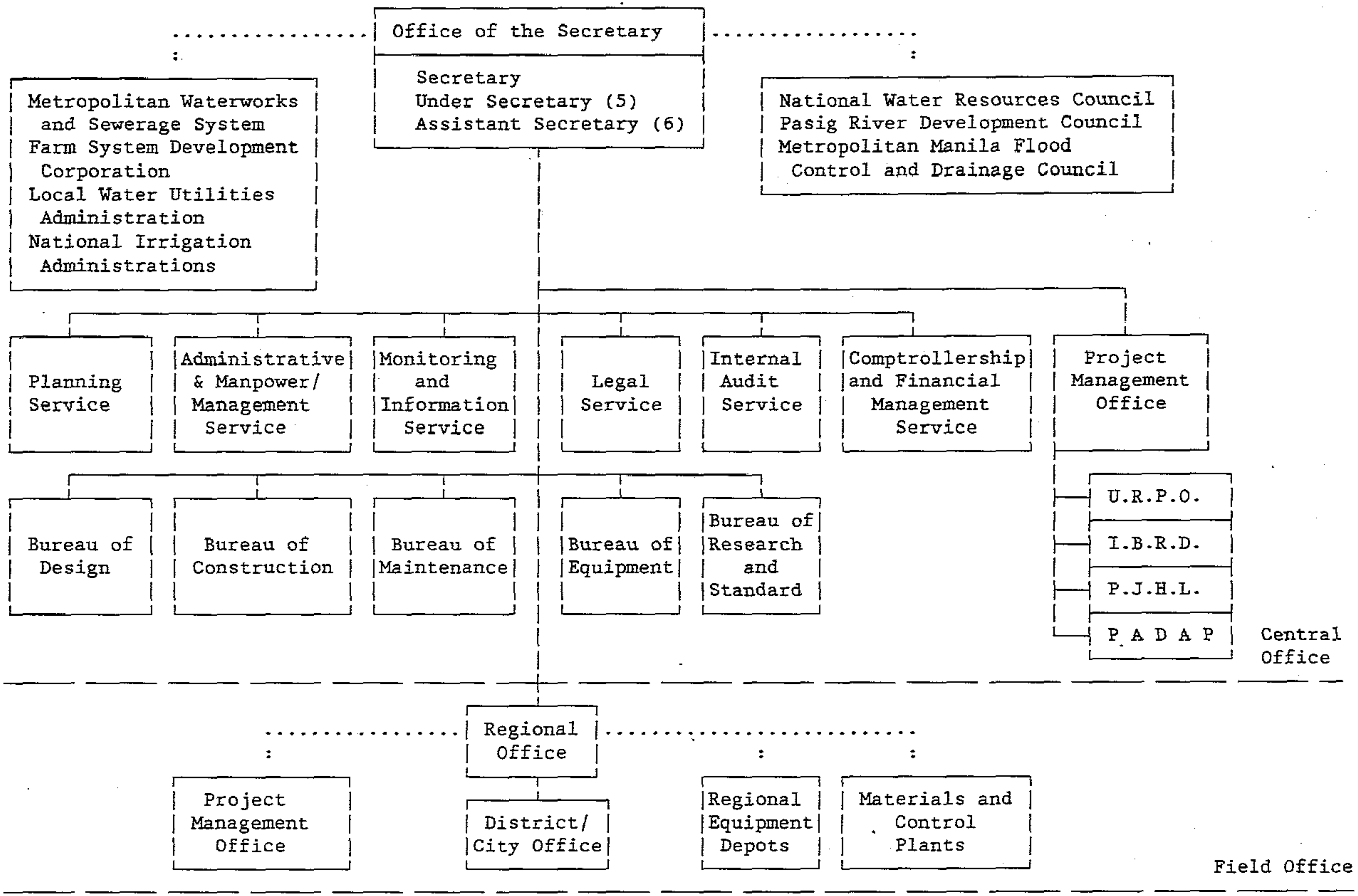


Figure 7.2.3 Organization of DPWH

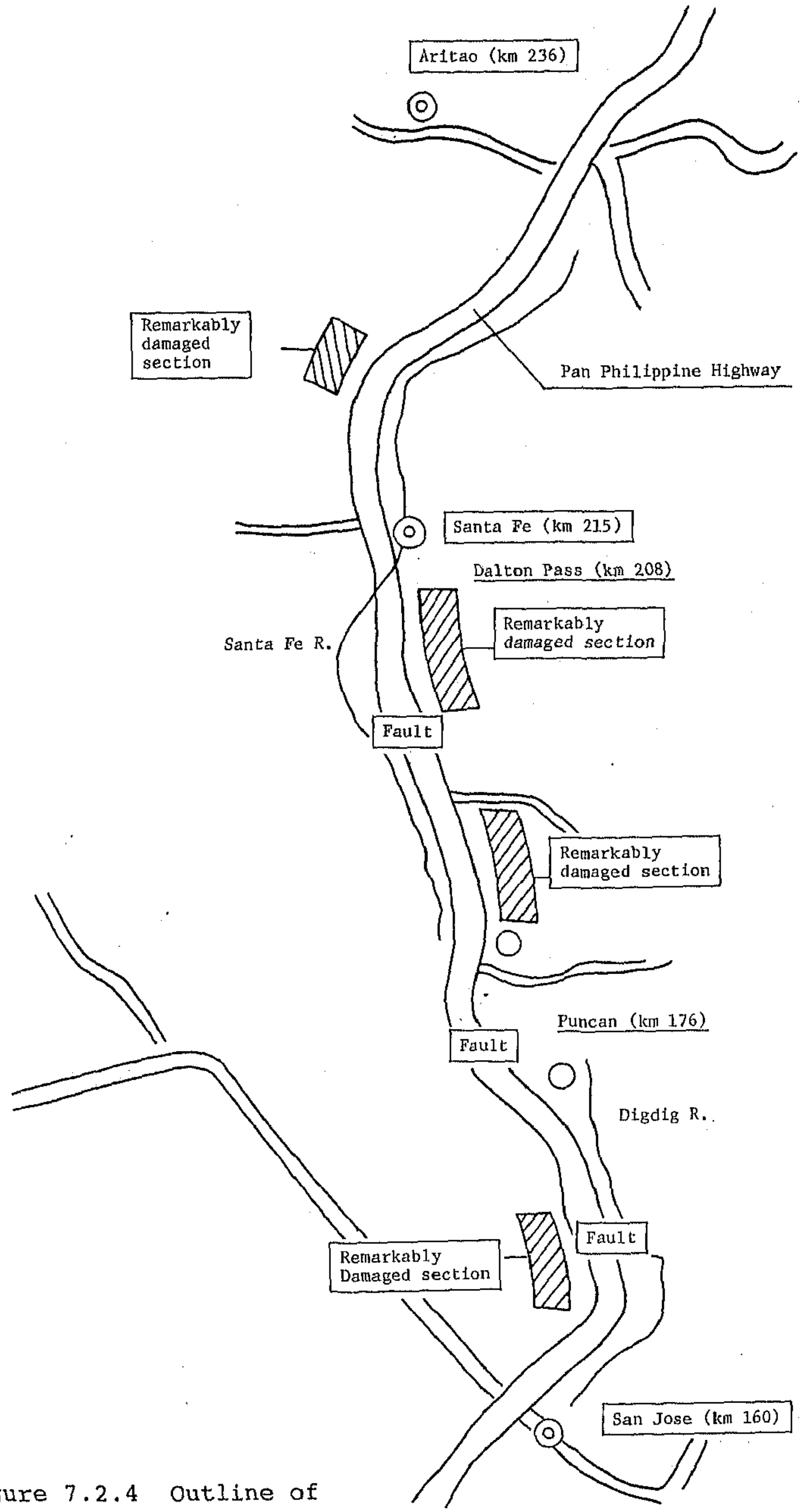


Figure 7.2.4 Outline of the damaged section

Table 7.2.2 Outline of damages (number of damaged places)

Section	Cut slope			Bank slope		Pavement		Others
	Large	Med.	Small	Large	Small	Thrust up	Faults	
Kms 160 (San Jose) to Kms 183 (Digdig)	36	10	10	3	6	12	9	Mud flow Accumulation of drifting wood
Kms 183 (Digdig) to Kms 200	51	9	2	3	5	9	2	Mud flow Drifting wood
Kms 200 to Kms 208 (Dalton)	30	34	15	5	21	3	2	
Kms 208 (Dalton) to Kms 215 (Sta. Fe)	18	7	37	3	6	2		
Kms 215 (Sta. Fe) to Kms 236 (Aritao)	11		11	1	12			
Total	146	60	75	15	50	26	13	
	281 places			65 places				

Note: Cut slope ; Large: more than 30 m of slope height
Medium: 15 to 30 m
Small: less than 15 m
Bank slope; Large: collapse from the boundary of the cut-bank
Small: shoulder settlement

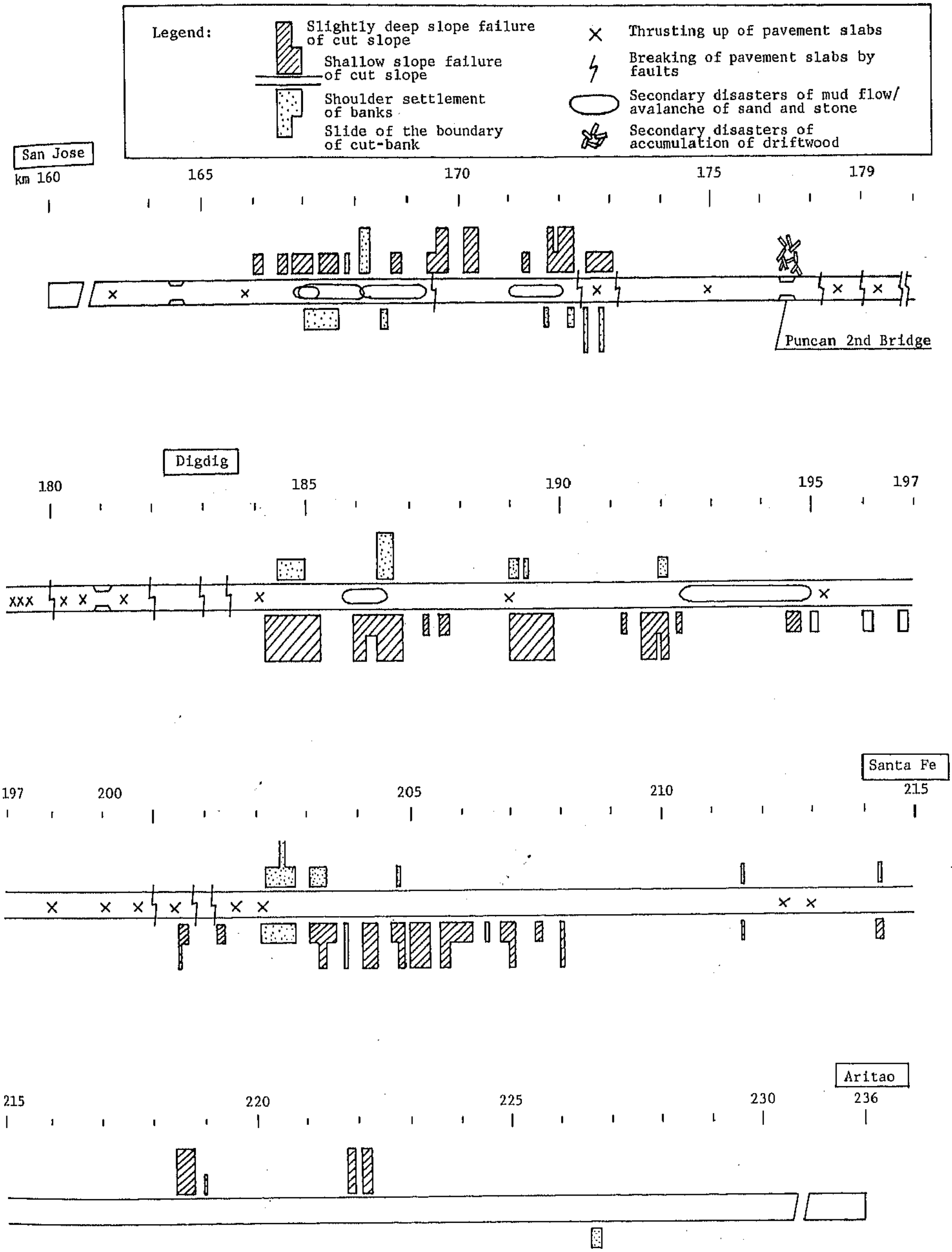


Figure 7.2.5 Distribution of the damages along the highway

(1) Slope failure (cut-bank)

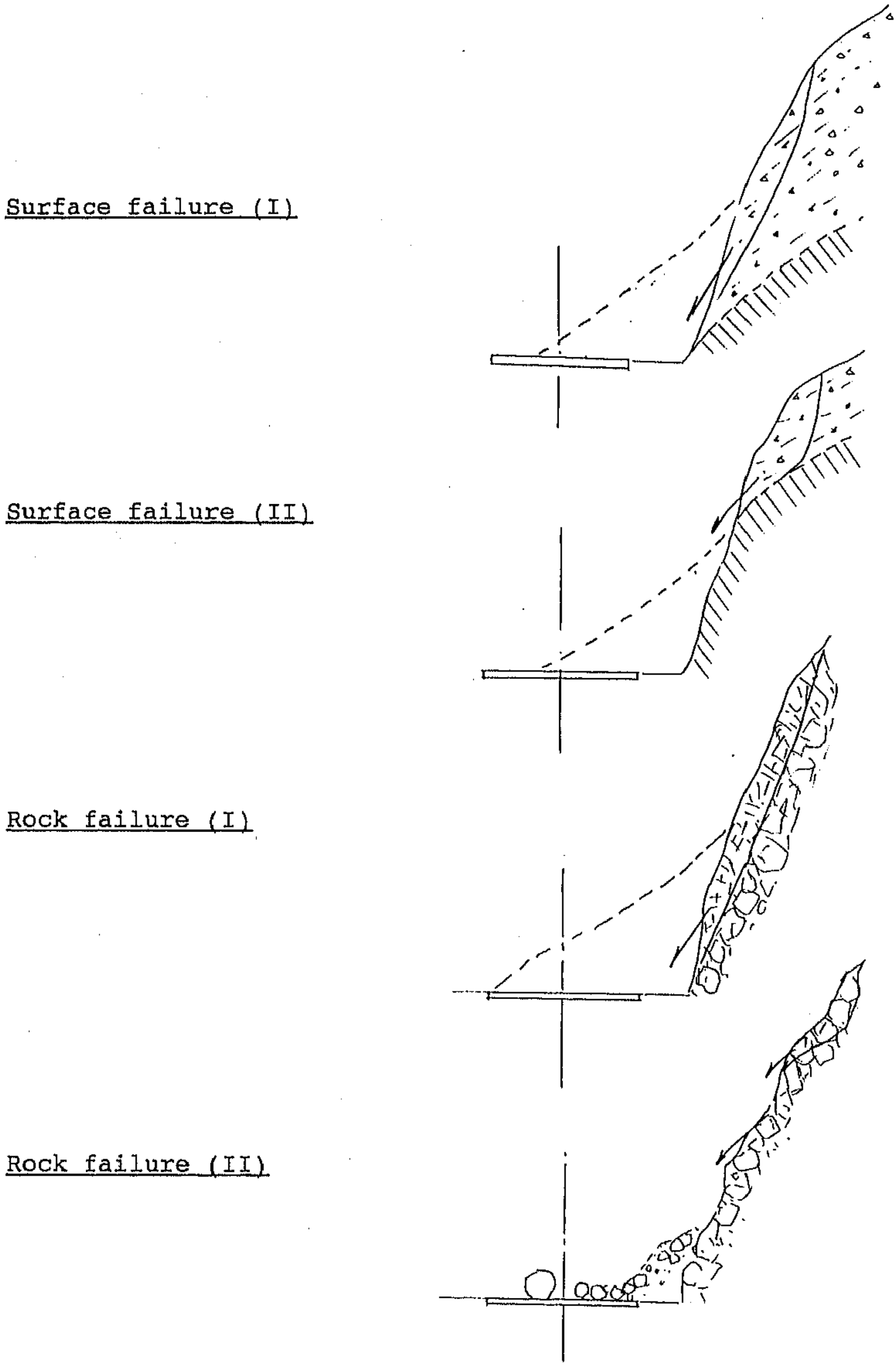
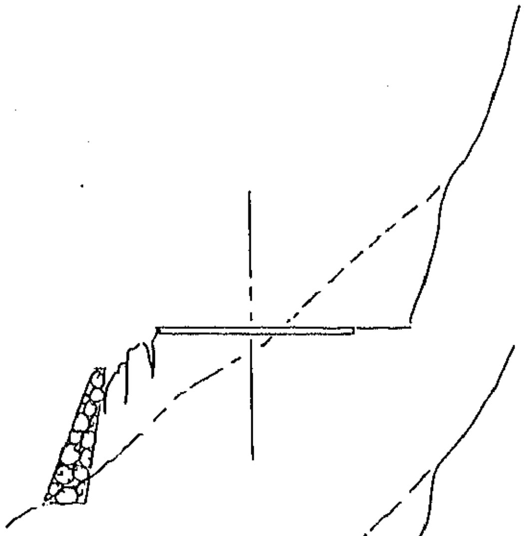
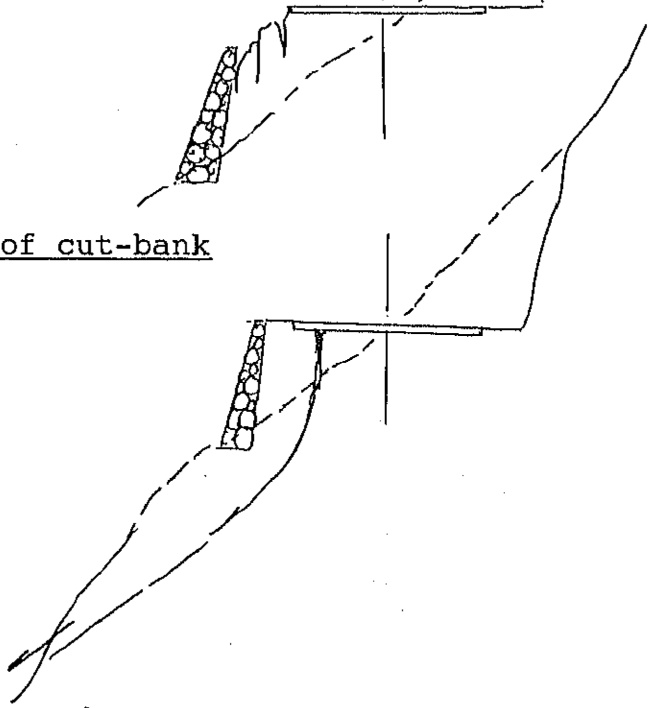


Figure 7.2.6 Types of damage (1/3)

Shoulder settlement

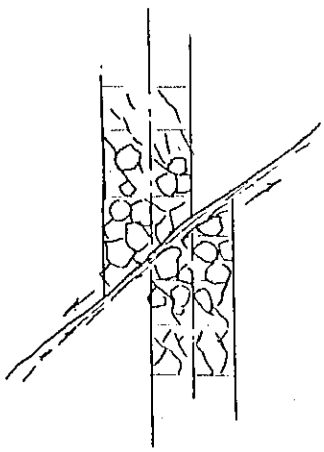


Slide of boundary of cut-bank



(2) Damage to pavement

Slippage due to a fault

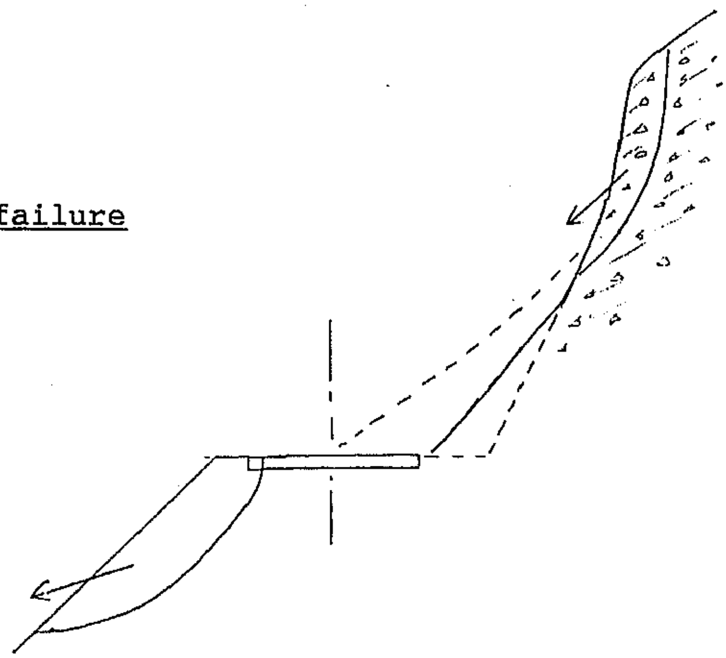


Thrusting up of pavement slabs by earthquake motion

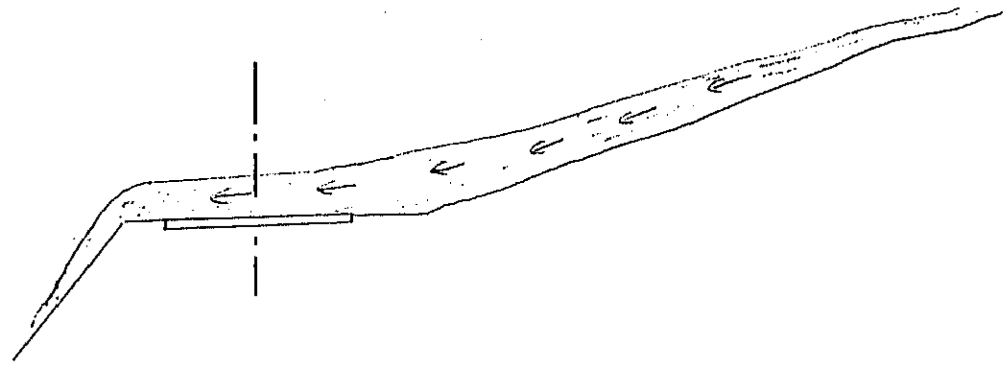
Figure 7.2.6 Types of damage (2/3)

(3) Secondary disasters

Surface failure



Mud flow/avalanche of earth and stones
from upper valleys



Accumulation of drifting
wood at a bridge

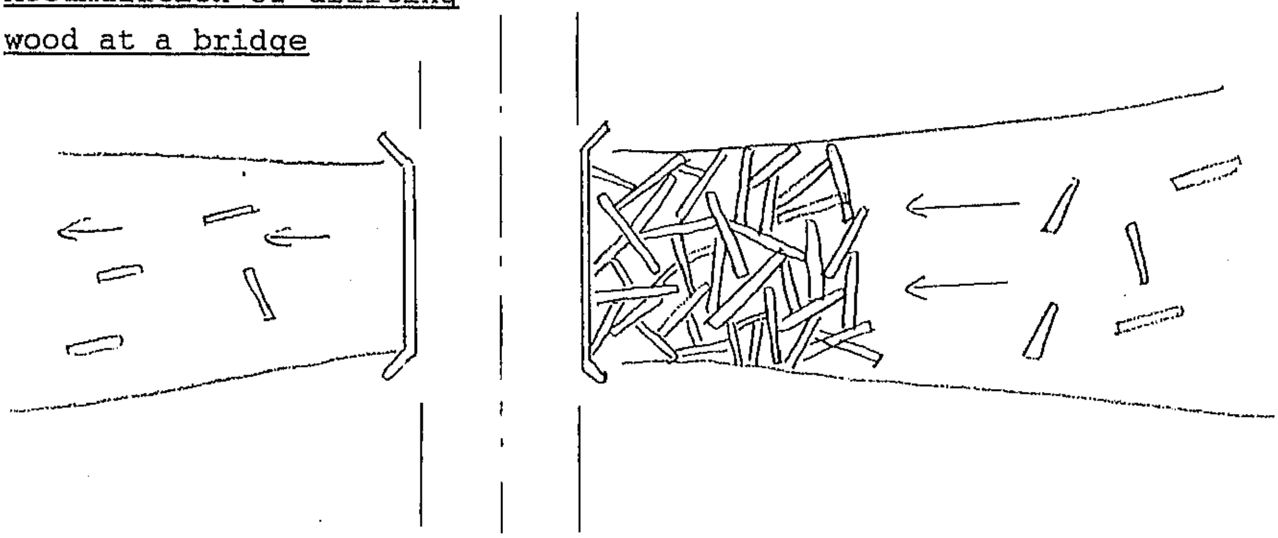


Figure 7.2.6 Types of damage (3/3)

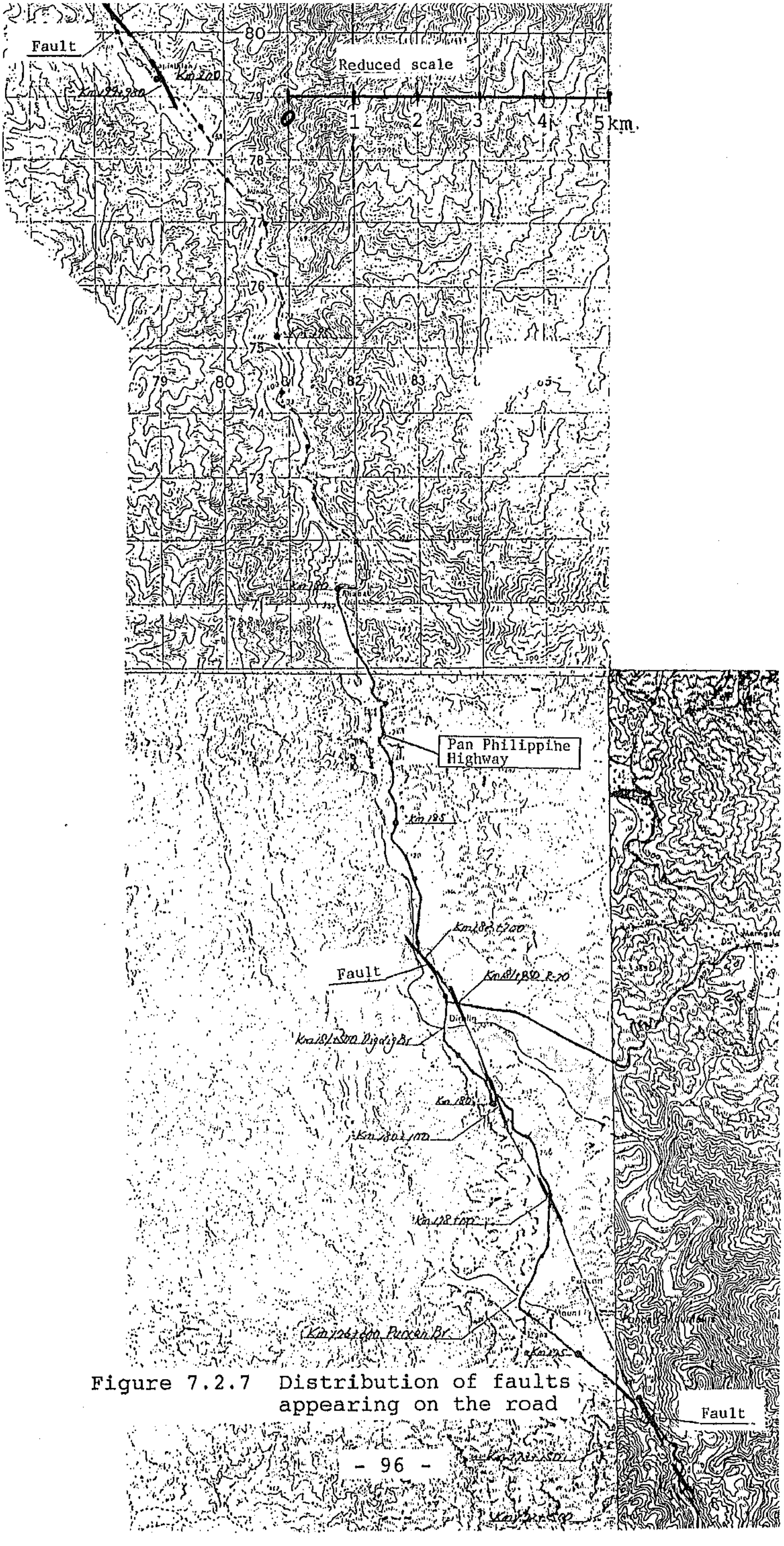


Figure 7.2.7 Distribution of faults appearing on the road

Table 7.2.3 List of slope failure places
(San Jose - Aritao) (1/3)

	Distance mark (km)	Cut slope				Bank slope	
		Type of disaster	Hight (m)	Length (m)	Fallen materials	Type of disaster	Length (m)
1	166.00 - 166.20	SF1	20	200	Common soil		
2	166.50 - 166.70	RF1	30	200	Rock		
3	166.80 - 167.20	RF1	40	400	Rock		
4	167.00 - 167.30					SS	300
5	167.30 - 167.50	SF1	30	200	Common soil	SS	200
6	167.50 - 167.70	SF1	50	200	Common soil	SS	200
7	167.80 - 167.90	SF1	50	100	Common soil		
8	168.09 - 168.30	SF2	40	210	Common soil		
9	168.50 - 168.60					SS	100
10	168.70 - 168.80	RF1	20	100	Rock		
11	168.80 - 168.90	SF1	25	100	Common soil		
12	169.40 - 169.50	RF1	20	100	Rock		
13	169.50 - 169.60	RF1	30	100	Rock		
14	169.60 - 169.80	SF2, RF1	30	200	Com.Soil/Rock		
15	170.10 - 170.15	SF1	30	50	Common soil		
16	170.15 - 170.25	SF2	50	100	Common soil		
17	170.30 - 170.40	RF2	50	100	Rock		
18	171.30 - 171.35	RF1	30	50	Rock		
19	171.40 - 171.45	SF1	30	50	Common soil		
20	171.75 - 171.80					SS	50
21	171.80 - 171.90	SF2	40	100	Common soil		
22	171.90 - 171.95	RF1	20	50	Rock		
23	172.00 - 172.20	SF2	60	200	Common soil		
24	172.20 - 172.30	RF2	60	100	Rock		
25	172.20 - 172.30					SS	100
26	172.50 - 172.55					SF	50
27	172.55 - 172.60	RF1	20	50	Rock		
28	172.80 - 172.90	RF1	40	100	Rock	SF	100
29	173.05 - 173.10	RF1	30	50	Rock		
30	184.20 - 174.25	RF1	30	50	Rock		
31	184.30 - 184.45	SF1	30	150	Common soil		
32	184.45 - 184.70	RF2	50	250	Rock	SS	250
33	184.70 - 185.00	RF2	50	300	Rock	SS	300
34	185.10 - 185.30	RF2	40	200	Rock		
35	185.95 - 186.05	SF2	35	100	Common soil		
36	186.15 - 186.20	RF2	30	50	Rock		
37	186.30 - 186.40	SF1	25	100	Common soil		
38	186.40 - 186.70	RF2	40	300	Rock	SF	100
39						SS	200
40	186.70 - 186.90	RF2	40	200	Rock		
41	187.30 - 187.40	SF1		100	Common soil		
42	187.60 - 187.70	SF1	30	100	Common soil		
43	187.70 - 187.80	SF1	20	100	Common soil		
44	189.00 - 189.20	RF2	40	200	Rock	SS	200
45	189.20 - 189.30	RF2	50	100	Rock		
46	189.30 - 189.40	RF2	50	100	Rock	SS	100
47	189.40 - 189.50	RF2	50	100	Rock		
48	189.50 - 189.60	SF2	40	100	Common soil		

Table 7.2.3 List of slope failure places
(San Jose - Aritao) (2/3)

	Distance mark (km)	Cut slope				Bank slope	
		Type of disaster	Hight (m)	Length (m)	Fallen materials	Type of disaster	Length (m)
49	189.60 - 189.90	RF2	40	300	Rock		
50	191.25 - 191.30	SF1	30	50	Common soil		
51	191.60 - 191.80	RF2	40	200	Rock		
52	191.80 - 191.90	RF2	40	100	Rock		
53	191.95 - 192.00	SF1	30	50	Common soil	SS	50
54	192.00 - 192.15	RF2	40	150	Rock	SS	150
55	192.30 - 192.40	RF1	30	100	Rock		
56	194.50 - 194.60	SF1	20	100	Common soil		
57	194.60 - 194.65	SF1	20	50	Common soil		
58	194.70 - 194.80	RF1	30	100	Rock		
59	195.00 - 195.15	SF1	40	150	Common soil		
60	196.00 - 196.15	SF1	20	150	Common soil		
61	196.15 - 196.20	SF1	20	50	Common soil		
62	196.70 - 196.75	SF1	30	50	Common soil		
63	196.80 - 196.90	SF1	30	100	Common soil		
64	200.50 - 200.55	RF2		50	Rock		
65	200.55 - 200.65	SF1	20	100	Common soil		
66	200.65 - 200.70	SF1	20	50	Common soil		
67	201.25 - 201.30	SF1	15	50	Common soil		
68	201.30 - 201.35	SF1	15	50	Common soil		
69	201.35 - 201.40	SF1	10	50	Common soil		
70	202.10 - 202.20	SF1	20	100	Common soil		
71	202.20 - 202.30	SF1	20	100	Common soil	SS	100
72	202.35 - 202.40	SF1	25	50	Common soil	SS	50
73	202.40 - 202.50	SF1, RF1	25	100	Com.Soil/Roc	SS	100
74	202.50 - 202.60	SF1	40	100	Common soil	SF	100
75	202.60 - 202.80	SF1	40	200	Common soil	SS	200
76	203.05 - 203.20	SF1	20	150	Common soil	SS	150
77	203.25 - 203.40	SF2	40	150	Common soil	SS	150
78	203.40 - 203.45	SF1	30	50	Common soil		
79	203.45 - 203.50	SF1	30	50	Common soil		
80	203.50 - 203.60	SF1	40	100	Common soil		
81	203.75 - 203.80	SF2	40	50	Common soil		
82	204.10 - 204.40	SF2, RF2	30	300	Com.Soil/Rock		
83	204.60 - 204.70	SF1	30	100	Common soil		
84	204.75 - 204.80					SS	50
85	204.80 - 204.90	SF2	40	100	Common soil		
86	205.00 - 205.20	SF2	40	200	Common soil		
87	205.30 - 205.40	SF2	40	100	Common soil		
88	205.60 - 205.80	SF2, RF2	80	200	Com.Soil/Rock		
89	205.90 - 205.95	SF1	30	50	Common soil		
90	206.00 - 206.10	RF1	30	100	Rock		
91	206.10 - 206.15	SF1	30	50	Common soil		
92	206.15 - 206.20	SF1	30	50	Common soil		
93	206.20 - 206.25	SF1	30	50	Common soil		
94	206.50 - 206.60	SF1	30	100	Common soil		
95	206.80 - 206.95	SF1	30	150	Common soil		
96	207.00 - 207.10	RF2	20	100	Rock		

Table 7.2.3 List of slope failure places
(San Jose - Aritao) (3/3)

Distance mark (km)		Cut slope				Bank slope	
		Type of disaster	Hight (m)	Length (m)	Fallen materials	Type of disaster	Length (m)
97	207.50 - 207.55	RF1	20	50	Rock		
98	207.60 - 207.65	RF1	10	50	Rock		
99	208.00 - 208.10	RF2	20	100	Rock		
100	211.60 - 211.65					SS	50
101	214.25 - 214.30	RF1	10	50	Rock		
102	214.30 - 214.35	SF1, RF1	15	50	Com.Soil/Rock	SS	50
103	214.35 - 214.40	SF1, RF1	15	50	Com.Soil/Rock		
104	218.45 - 218.60	SF2	60	150	Common soil		
105	218.60 - 218.80	SF2	60	200	Common soil		
106	219.00 - 219.05	SF1	20	50	Common soil		
107	221.80 - 221.95	SF2	60	150	Common soil		
108	222.10 - 222.30	SF2	60	200	Common soil		
109	226.60 - 226.65					SS	50
110	226.75 - 226.80					SS	50
Total				11,710 (101 points)			3,550 (28 points)

Note: Explanation of symbols
Cuts
SF1: Surface failure (I)
SF2: Surface failure (II)
SF3: Rock failure (I)
RF2: Rock failure (II)
Banks
SS : Shoulder settlement
SF : Slide of the boundary of cuts-banks

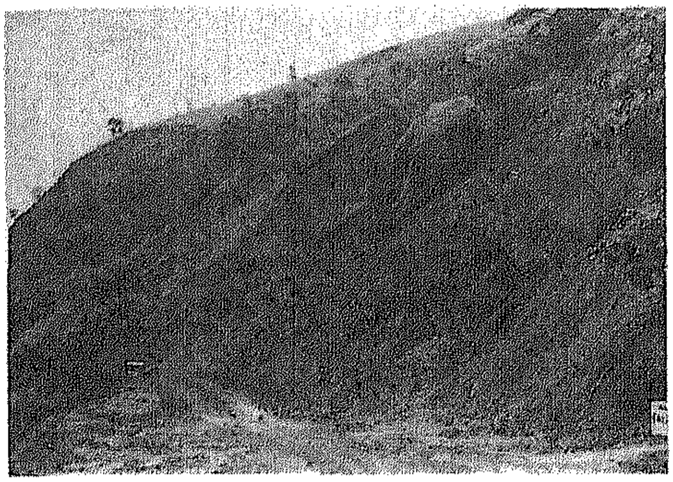


Photo 7.2.1 Surface failure.
(185 km position)

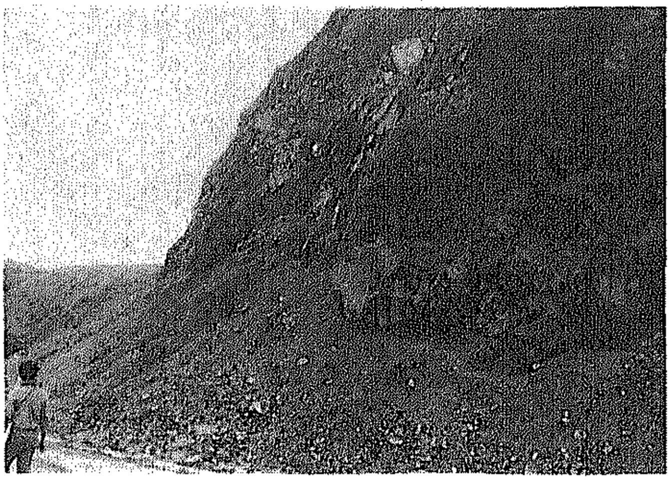


Photo 7.2.2 Surface failure.
(188 km position)

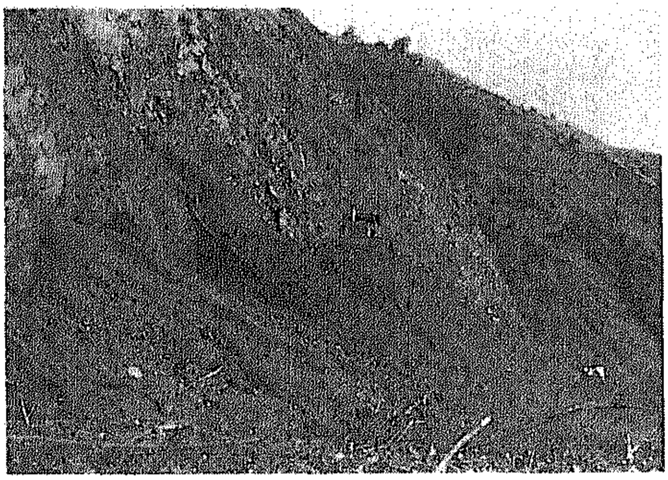


Photo 7.2.3 Road clearing work.
(170 km position)

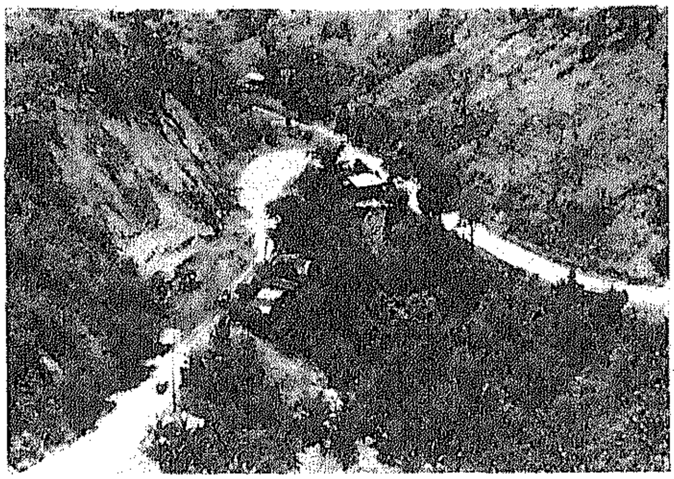


Photo 7.2.4 Road clearing work.
(207 km position)

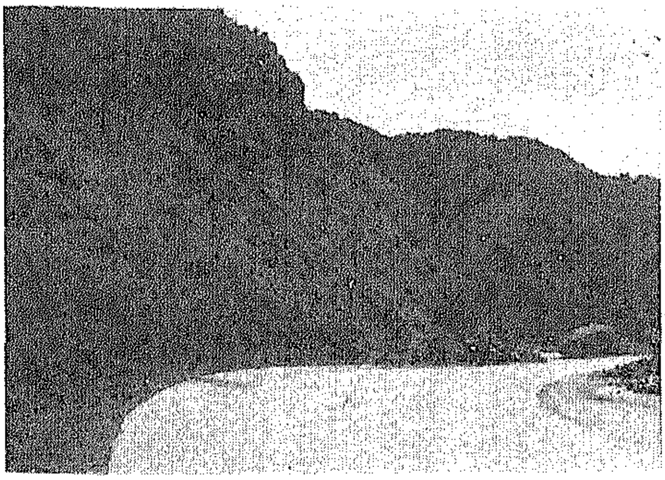


Photo 7.2.5 Huge fallen stone left as they are, closing one-lane. There are many stones just about to fall at the upper part of the slope-face. (208km position)

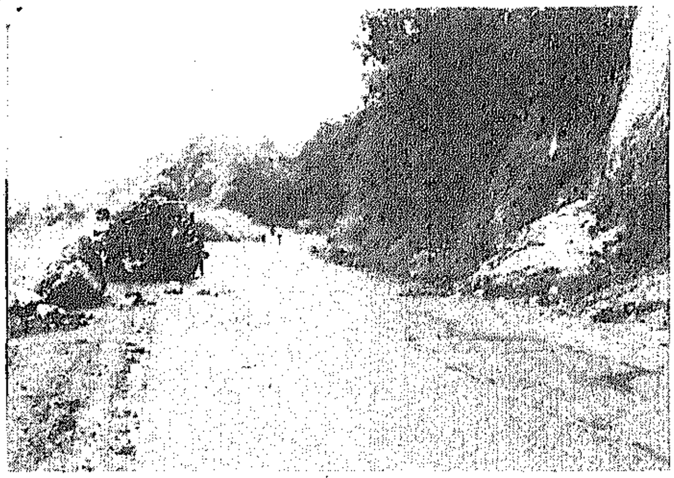


Photo 7.2.6 Fallen stones of limestone.
(213 km position)

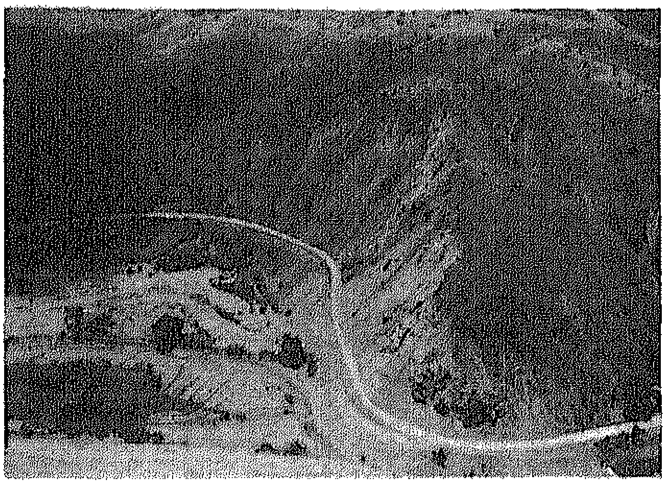


Photo 7.2.7 Road after finishing up clearing work after a huge slope and failure. There is a possibility of secondary disasters. We saw the marks of sand inflows to inflows to the lowlands. (203 km position)

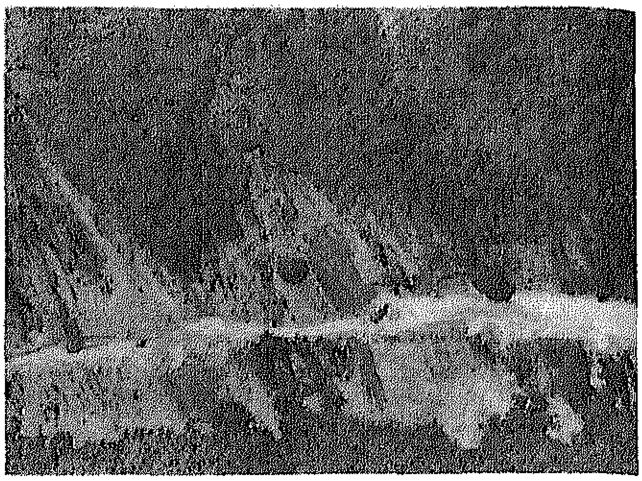


Photo 7.2.8 Slope face with huge fragmented rocks, clearing work by heavy machinery. (185 km position)

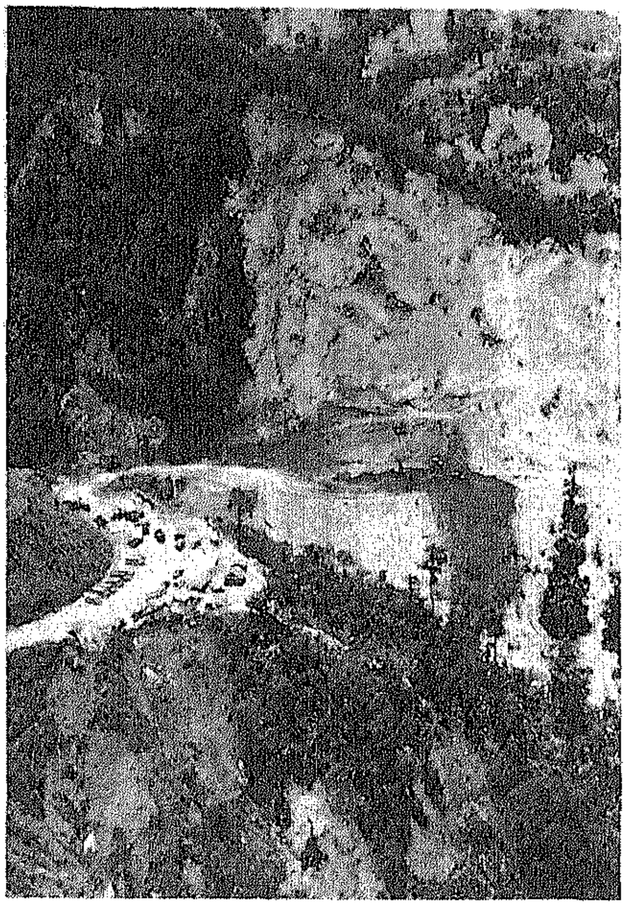


Photo 7.2.9 Huge slope failure at Dalton Pass: both height of the cut face and depth of the valley are 100 m class. At the left side, we saw the waiting shuttle trucks. (206 km position)

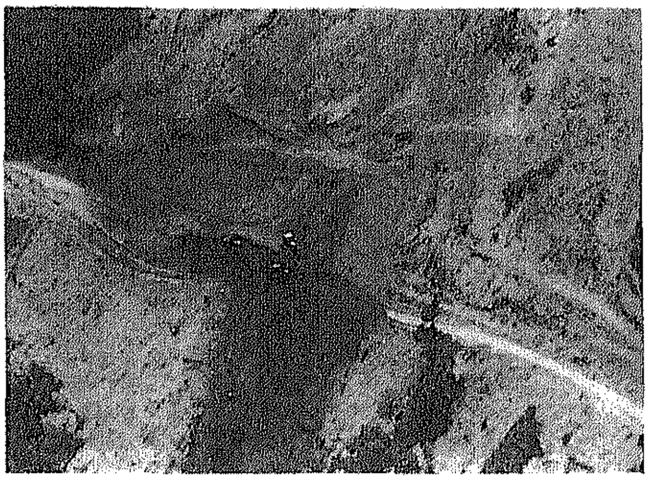


Photo 7.2.10 Clearing work by the heavy machinery at Dalton Pass when three weeks had passed after the earthquake. (206 km position)

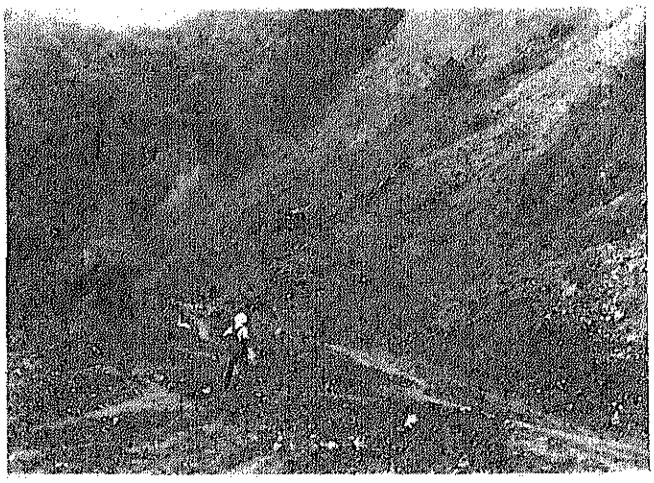


Photo 7.2.11 The same position as above.

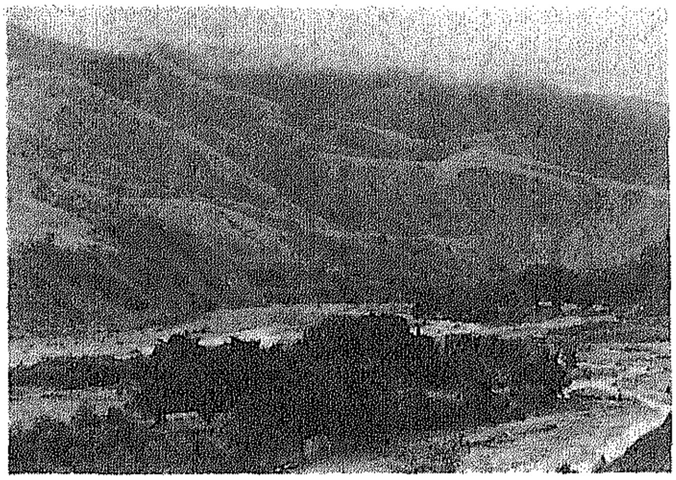


Photo 7.2.12 Environment surrounding the roads where there are large scale landslides and drifting wood. (187 km position)

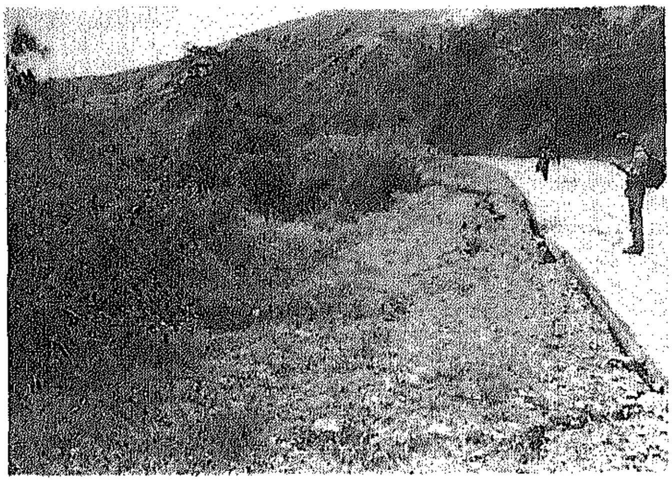


Photo 7.2.13 Settlement of the shoulders. (193 km position)

Photo 7.2.14 Collapse of the shoulders. (193 km position)

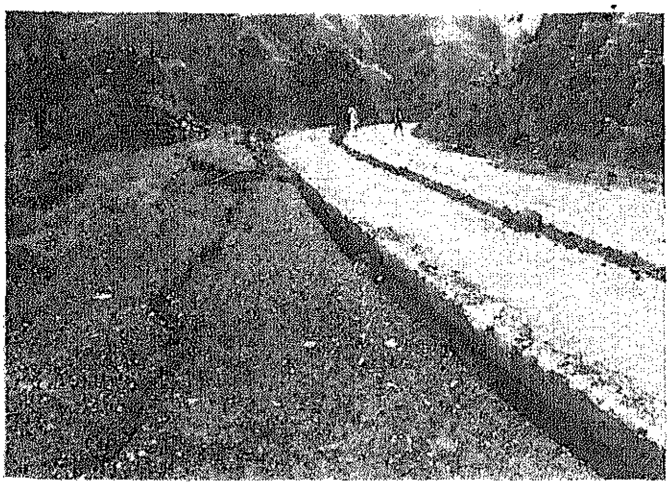


Photo 7.2.15 Opening of the shoulders by the sliding of the banks. (203 km position)

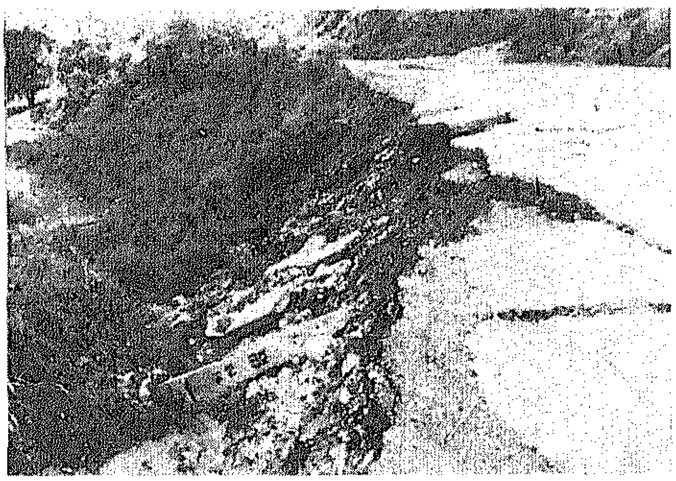


Photo 7.2.16 Collapse of banks. (173 km position)

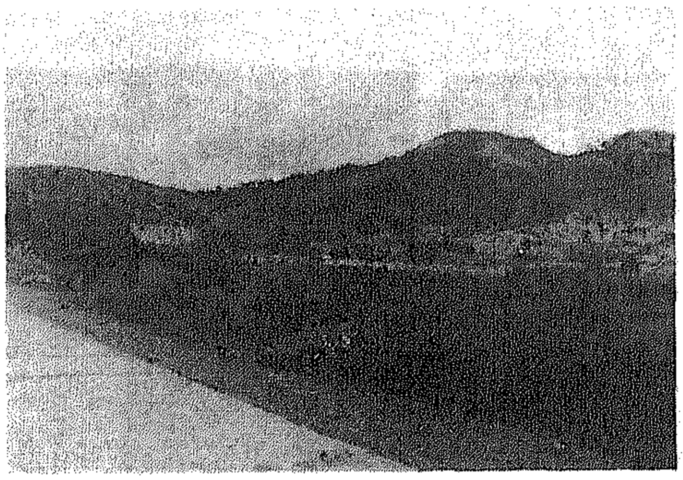
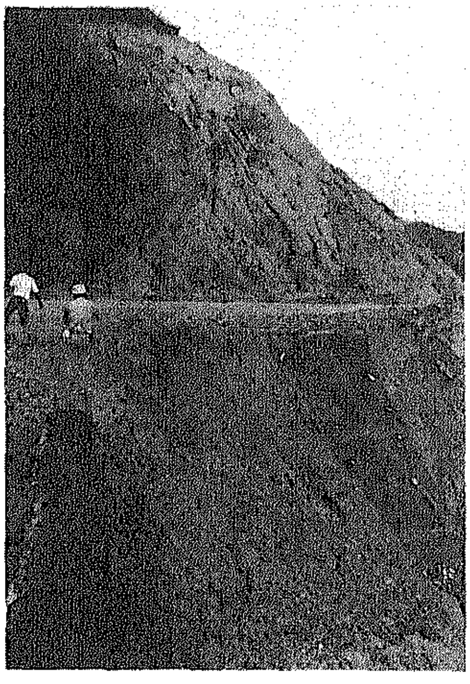


Photo 7.2.17 No damage at gently sloping mountains. (200 km position)

Photo 7.2.18 No damage at a slope face where vegetation was performed seed spraying) as pilot construction. (206 km position)

Photo 7.2.19 Small damage at a stone masonry retaining wall (wet masonry with cobblestones) as protection of the toe of the cut slope. (201 km position)



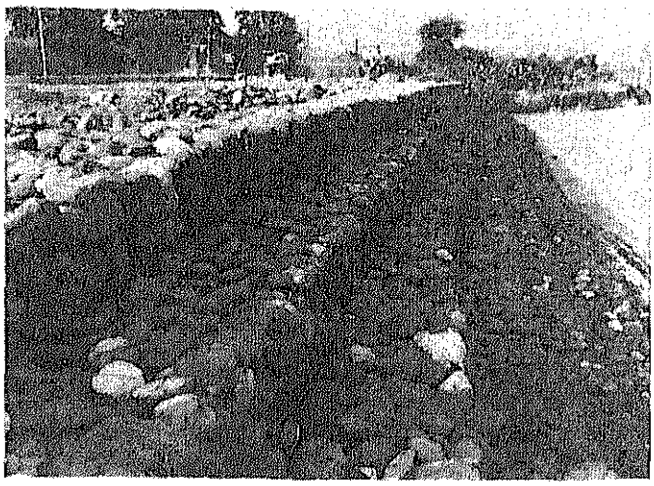


Photo 7.2.21 Wire mats (Gabion) and wire cylinders for scour protection of banking has little damage. (251 km position)

Photo 7.2.20 Stone pitching of the frame type protecting the slope face of a bank has little damage. (212 km position)

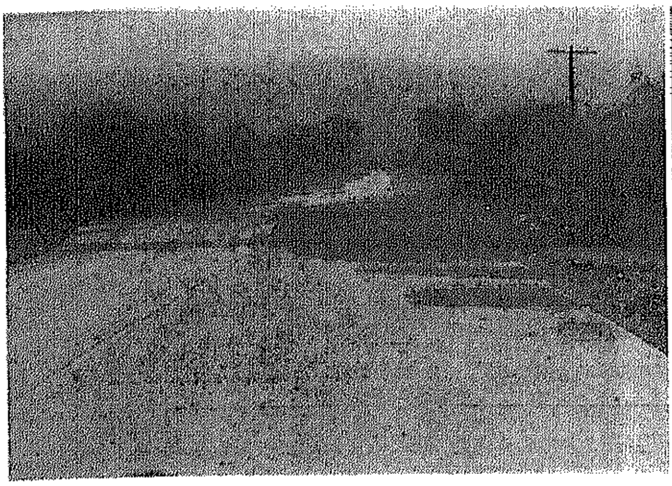


Photo 7.2.22 Thrusting up of pavement slabs at a low bank section. (164 km position)

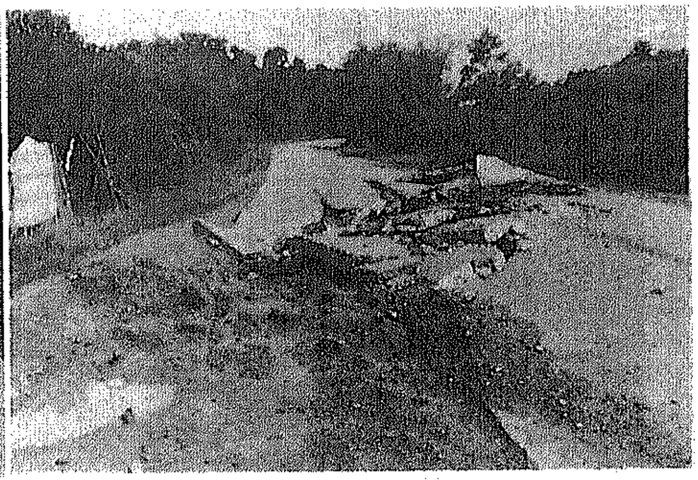


Photo 7.2.23 Road surface destroyed by a fault crossing the road. (183 km position)

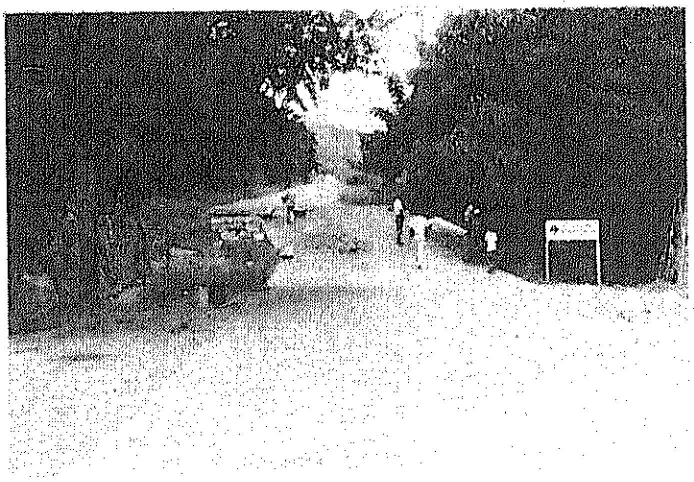


Photo 7.2.24 Road surface destroyed by a fault crossing the road. (180 km position)

Photo 7.2.25 A fault meandering across the hills after crossing the road. (180 km position)

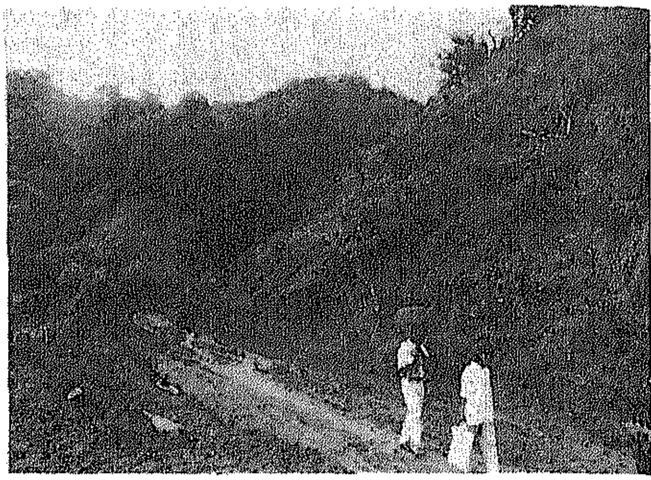


Photo 7.2.27 A slope becomes unstable due to rains. (205 km position)

Photo 7.2.26 We saw open cracks from which there is danger of secondary slope. failure at the upper parts of the slope.

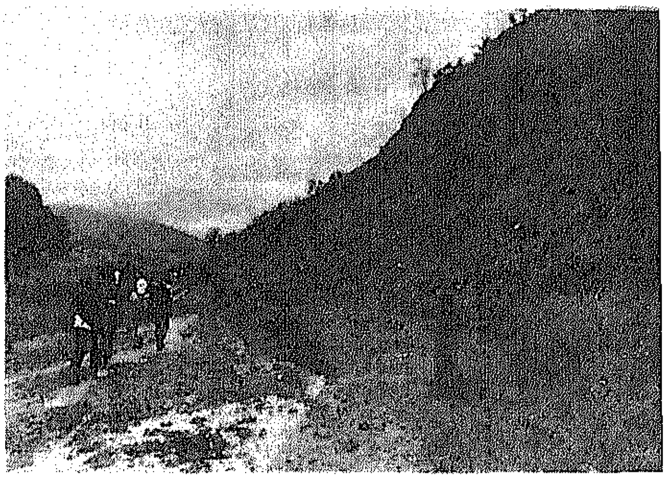


Photo 7.2.28 A slope becomes unstable due to rains. (195 km position)

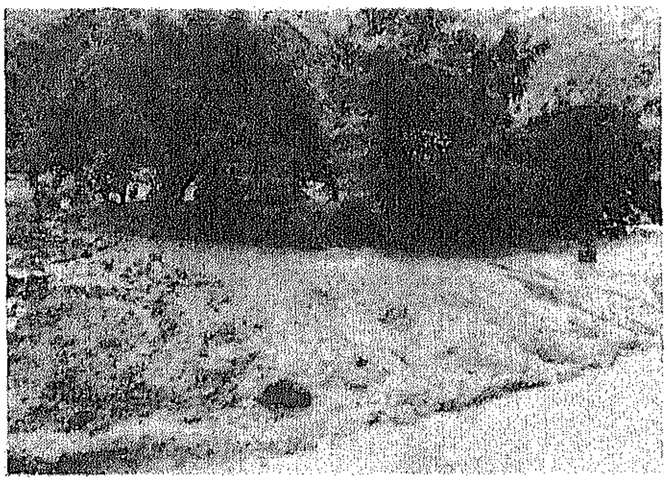


Photo 7.2.29 Outflow of mud from the valley due to rains. (194 km position)

Photo 7.2.30 Outflow of mud from the valleys. (194 km position)

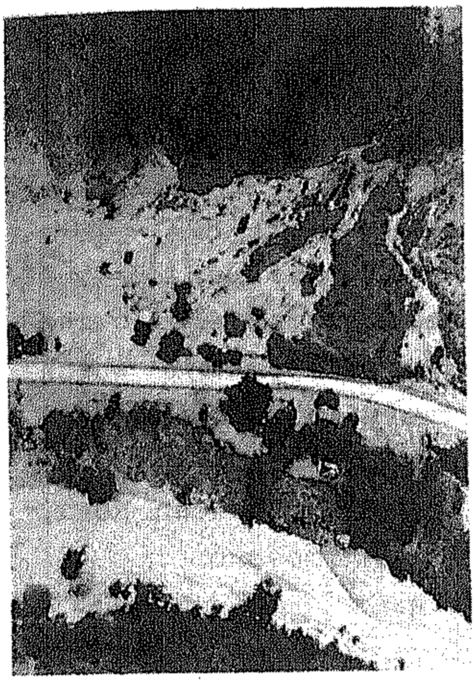


Photo 7.2.31 Conditions of sand outflow, viewed from the sky. (The road had been cleared)

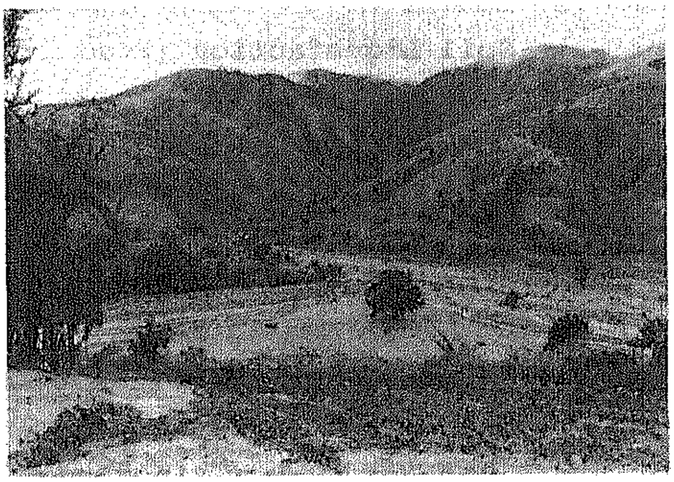


Photo 7.2.32 Conditions of sand outflow in the river. (195 km position)

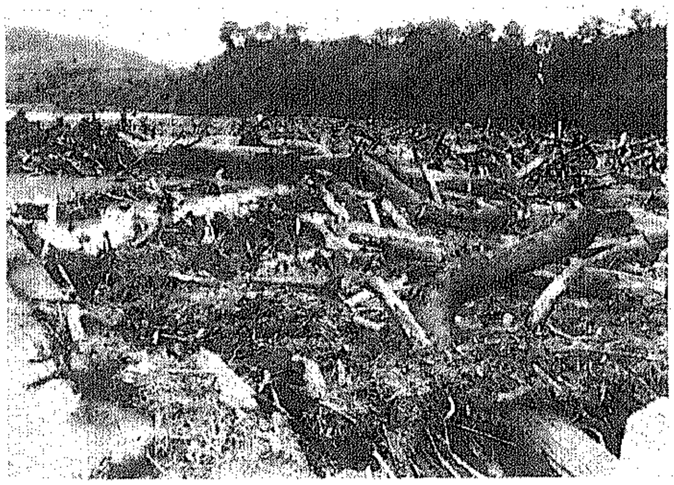


Photo 7.2.33 Drifted wood cast on the riverbank. (192 km position)

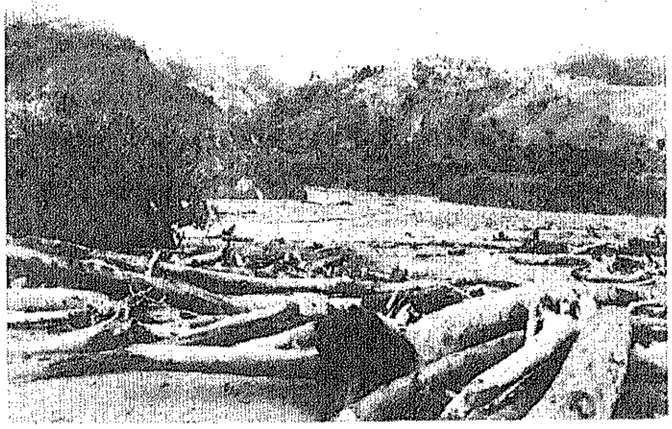


Photo 7.2.34 Accumulated condition of drifted woods at the second Puncan Bridge. (176 km position)