REPUBLIC OF BOLIVIA

BOLIVIAN NATIONAL RAILWAYS' REHABILITATION PROGRAM

FINAL REPORT

VOLUME II

MARCH 1980

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

REPUBLIC OF BOLIVIA BOLIVIAN NATIONAL RAILWAYS' REHABILITATION PROGRAM FINAL REPORT VOLUME II MARCH 1980 (JICA)

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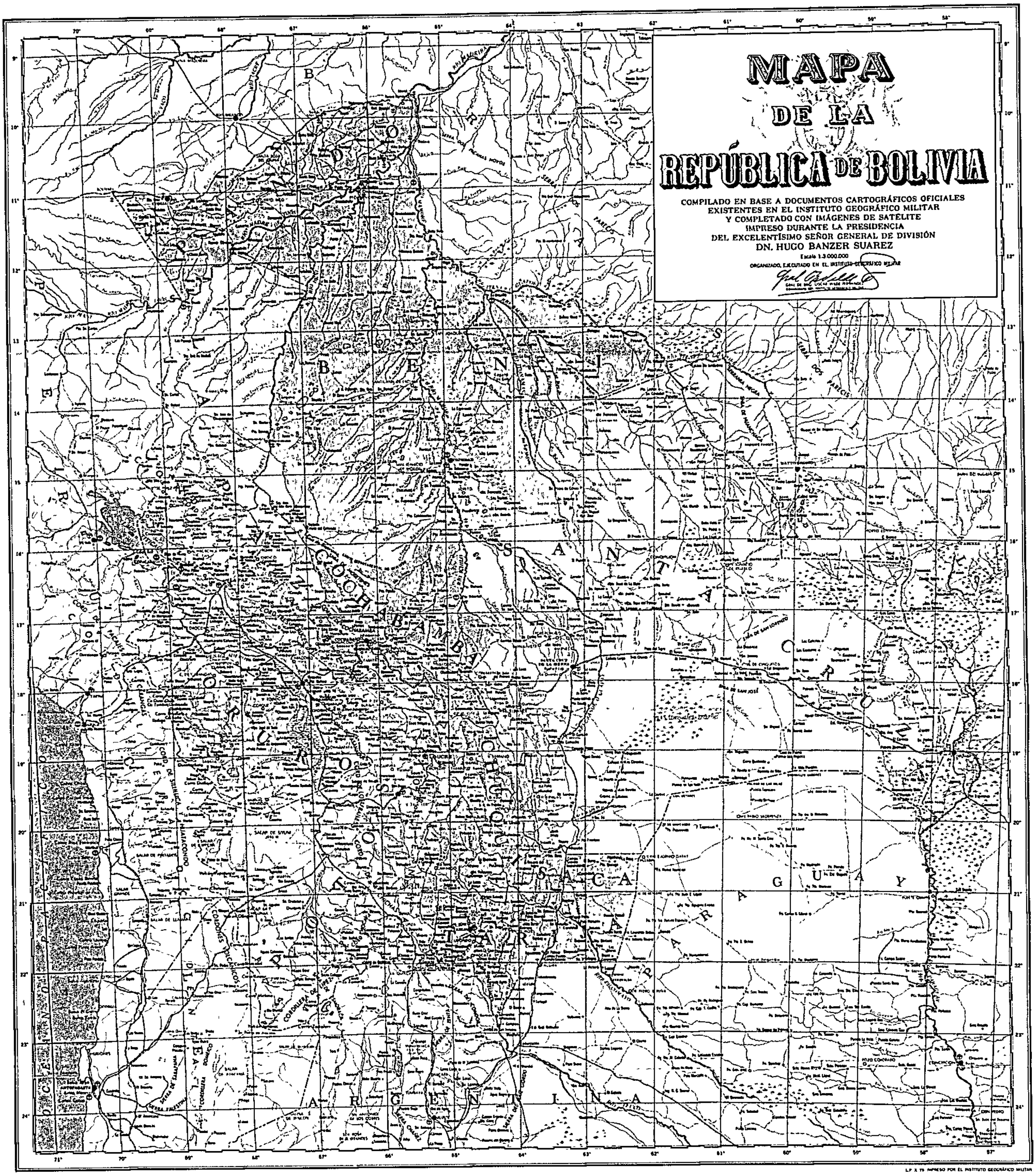


L.P. 3.75 IMPRESO POR EL INSTITUTO GEOGRÁFICO MILITAR

EDICIÓN (PRELIMINAR) I.G.M.

Escala 1:3 000 000

100 50 0 100 200 Kilómetros

PROYECCIÓN CÓNICA CONFORME DE LAMBERT

MERIDIANO CENTRAL 64° AL OESTE DE GREENWICH

PARALELOS STANDART 12° Y 20°

PROHIBIDA LA REPRODUCCIÓN PARCIAL Ó TOTAL

NOTAS GENERALES

LOS LIMITES INTERNACIONALES ESTAN DE ACUERDO CON LOS TRATADOS VIGENTES SUSCRITOS POR LA CANCILLERIA DE LA REPÚBLICA. LA DIVISIÓN POLÍTICA ESTA CONSIGNADA DE ACUERDO A LOS DECRETOS Y LEYES. LA CLASIFICACIÓN DE LA RED CAMINERA Y DEMÁS ELEMENTOS SE HAN EXTRACTADO DE LAS CARTAS EXISTENTES A ESCALAS 1:50 000 y 1:250 000

SIGNOS CONVENCIONALES

POBLACIONES
- Capital de la República
- Capital de Departamento
- Capital de Provincia de primera sección
- Capital de Provincia de 2a 3a 4a 5a sección
- Cantones
- Villorios

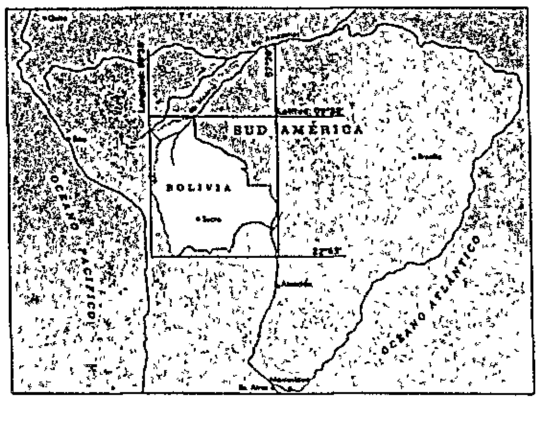
CAMINOS
- Ferrocarriles

LIMITES
- Nacional
- Departamental

DETALLES CULTURALES
- Aeropuerto
- Puerto fluvial
- Mina

LAGOS Y RIOS
- Cachuela
- Salar y Salitre

SITUACION GEOGRÁFICA DE BOLIVIA EN EL CONTINENTE



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RECOMMENDATION AND SUMMARY

RECOMMENDATION

The following are the result of the site survey conducted in July 1979 and also the result of the feasibility study made on the rehabilitation projects from damages and the tunnel construction project for the track line between Oruro and Cochabamba mainly by reference to the data furnished by ENFE.

(1) The section over about 75 km between Oruro and Cochabamba is featured by the serious problem, in that it is suffered from many disastrous damages in the rainy season every year, as the result of which not only vast sum of expenses for restoration are disbursed but also the decrease in income from the fare or any other economic loss is incurred by frequent suspension of the train operation service.

Especially, the two sections over 12 km in total length between 101 km and 110 km and between 113 km and 116 km are in pressing need of improvement, being confronted with more critical situations.

(2) Since the section in question over about 75 km is also featured by its brisk activity of erosion with heavy change of sub-soil conditions, construction of a tunnel is considered as the ideal plan on a permanent basis. However, this plan has its own drawbacks; it would require too much cost, affect the balancing in intensity against disastrous damages over the whole track line and, furthermore, lack flexibility to be required to follow after any possible future change of conditions. Therefore, the most realistic measures to be taken for this section would be basically to take necessary steps for restoration from each local damage, same as have conventionally been taken on the branch line of Cochabamba, and to relocate the track line by detour from the damaged portion if no further steps can be taken by any means to restore from each damage.

(3) The following measures are recommended for rehabilitation of the two sections in question.

1) For the 101 km ∿ 110 km section it is recommended that the existing track line now running on the extremely unstabilized foundation ground should be relocated on the opposite bank side with stabilized soil condition by detour from the continuously remaining damage on a large scale in the said section.

2) For the 113 km ∿ 116 km section it is recommended that the track formation should be raised up to the level which will be free from any possible damage.

The above two methods may be considered as the most appropriate measures to be taken so as to improve the whole branch line of Cochabamba into the well-balanced railway line.

(4) Although the tunnel construction project is purposed for possible saving of both operating and maintenance expenses, the result of the latest survey reveals that the effect from construction of a

tunnel is less than expected, for which no economic feasibility has been assured. It is therefore considered advisable to take up this project for review once again in the future when the situation will turn into a favorable prospect for large increase in the traffic volume.

SUMMARY

1. Damaged Conditions

(1) Topographic, geological and meteorological conditions

The railway line starting from Oruro runs across the plateau composed of sand and gravel sediments resulting from erosion of the surrounding natural ground, passes through the 4,130 m peak zone in a curve of horse-shoe shape and reaches the basin wide open at about E.L. 2,600 m alongside the valley of Rio Arque carving the eastern slope side of the Cardillera Oriental.

The Cardillera Oriental constitutes the alternations of hard sand-rock and shale of the Paleozoic era (Partially of the Mesozoic era). The mountainous area was formed up by orogenic movements in the Tertiary era with conspicuous folds and faults. Because of this, the base rock is rather of fragile quality with many joints.

On the eastern slope side it rains to a considerable amount during the rainy season but there is very little rainfall in the dry season. Besides that, the ground surface remains naked without plantation because the top soil remains undeveloped.

Under such circumstances, brisk activities of erosion are observed everywhere in this area, where there are large variations occurred to the ground surface condition. Such erosive activities are conspicuous especially in the tributary valley existing along the folding axial line striking in the NW-ES direction. There, the slope surface is suffered from land sliding or failure with developed formation of talus. Debris is generated here in bulk. Such debris is featured by a lump of small size, because its base rock is of sediment formation and space between joints is very narrow.

(2) Damages

Damages take place frequently in the section of steep grade and sharp curve of about 75 km length between 65 km and 140 km, running along the Rio Arque. As stated earlier, this section is conspicuous of erosive activities by rapid current carving the unstabilized fragile rock foundation. The railway line laid on the steep mountain side is suffered many often from disastrous damages arising from the slope surface and the rapid stream current.

In the rainy season every year, the train operation service is often suspended and, still more, the expenses to be inevitably spent for immediate measures of recovery reach a vast sum. Because of this, a part of track between 89 km and 94 km in the said section is being relocated now and this relocation work will shortly extend to the portion between 94 km and 96 km.

The breakdown of damages by conditions in this whole section is as follows:

Avalanche of debris	44	4,700 m
Slope failure	22	2,600 m
Land sliding	7	1,100 m
River bank erosion	28	7,000 m
River bed rise	6	-
Total	107	15,400 m

The following are the conditions of damage in each section involved in the rehabilitation project.

1) 101 km ∿ 110 km

In this section, large slope failures are experienced at four stops over a total length of 700 m on the river stream side, still showing a high danger of the re-occurrence with similar damages. Avalanche of debris in vast quantity occurred in many branch streams crossing the railway line, which caused the track to be buried and the bridges to be damaged out at 12 spots over a total length of 740 m. The bridge on the Rio Changolla is nearly to be buried under sediment due to remarkable rise of the river bed formation.

It seems that many potential dangers are concentrated mainly in this section, as compared with all the rest sections observed by the latest survey.

2) 113 km ∿ 116 km

This section is conspicuous of river coast erosion, thereby causing the subgrade of railway to have been washed out once and again at 3 spots over a total length of 630 m. Besides that, the main stream is narrowed with large quantity of debris flow from the Rio Pichacani on the opposite bank side. Because of this, the subgrade as well as the embankment are washed out many often.

2. Rehabilitation Plan

(1) Basic thought for preparation of rehabilitation plan

There exist the damaged sections over a total length of about 75 km on the branch railway line of Cochabamba. The purpose of planning the rehabilitation project is to prevent re-occurrence of damages in the two sections of about 12 km length which are suffered from damages on particularly large scale continuously and also to enable ENFE to provide its most stabilized transport service on one hand and to curb the expenses to be incurred incidental to occurrence of such damages on the other.

Except those specific sections involved in this rehabilitation project, all the rest are placed under the relatively good condition. Measures are being taken at present for improvement. It is therefore conceivable that the situation will take a favorable turn in the near future upon completion of such improvements.

It is further expected that by application of the appropriate rehabilitation plan to those sections involved in the project the whole section will be improved into the wellbalanced condition of railway track.

1) This area is featured by remarkable activities of both erosion and sedimentation and also by large transfigurations on the ground surface condition, which make it difficult to consider effective measures on a permanently fixed basis. For this reason, it becomes inevitable to determine that the fundamental measures to be taken will be to move the railway line partially on a case-by-case basis by judgement, from time to time, of to what extent each section has been damaged. Therefore, the rehabilitation plan proposed for the specific sections surveyed lately should be regarded as a part of such future rehabilitation program.

2) In drafting the rehabilitation plan, it is necessary that certain degree of flexibility should be incorporated into the plan to the possible extent, so that it may be varied with full adaptability to any future possible change of conditions. The scope of services to be included in the latest rehabilitation plan should allow for the content of work over a longrange projection of about 20 years.

3) The section between 48 km and 57 km + 650 m is proposed with tunnel construction, irrespective of restoration from damages, so that the existing steep grade and sharp curve in that section can be improved and the total length can be reduced to some extent.

   The tunnel construction plan has no particular problem to be solved technically, and the economic effect from execution of such plan is the sole determinant of its feasibility.

(2) Improvement plan

1) 48 km ∿ 57 km + 650 m

   The base rock formation in the proposed section for tunnel construction constitutes sand rock and shale of the Paleozoic era containing no large fault zones. Although there exist some unconsolidated sediments near the proposed tunnel entrance on the Oruro side, they can be avoided by detour of the route.

2) 101 km + 000 m ~ 110 km + 000 m

In this seciton the following three alternatives are considered:

Alternative-A	To follow the conventional method chiefly by lift-up of track formation level and improvement of the existing revetment from Point 103 km
Alternative-B	To relocate the existing route to the opposite bank side from Point 103 km
Alternative-C	To relocate the existing route to the opposite bank side from Point 101 km, by approximation to Alternative B

As for Alternative-A, it is not yet the measures of drastic improvement against disastrous damages and may be affected easily by any future possible damages. With regard to Alternative C, the section between 101 km and 103 km forms a terrain of similar talus to that existing alongside the conventional track line. To make the matter worse, because there exist two large branch valleys discharging debris outflow in the said section, the effect from new line construction by vast capital investment still remains very doubtful. For the reasons mentioned above, it is considered advantageous to adopt Alternative B and also to take the conventional measures against any disastrous damages in the section of the existing line.

3) 113 km + 000 m ~ 116 km + 000 m

The plan for this section is to lift up the track formation level allowing for the future possible rise of river bed formation.

4) Project cost

·48 km ~ 57 km + 650 m	236,104,000$b	Tunnel construction
·101 km ~ 110 km		
Alternative-A	294,276,000$b	Lifting of track formation and revetment from 103 km
Alternative-B	251,010,000$b	Re-routing of line to the opposite bank side from 103 km
Alternative-C	378,398,000$b	Re-routing of line to the opposite bank side from 101 km
·113 km ~ 116 km	123,560,000$b	Lifting of track formation level

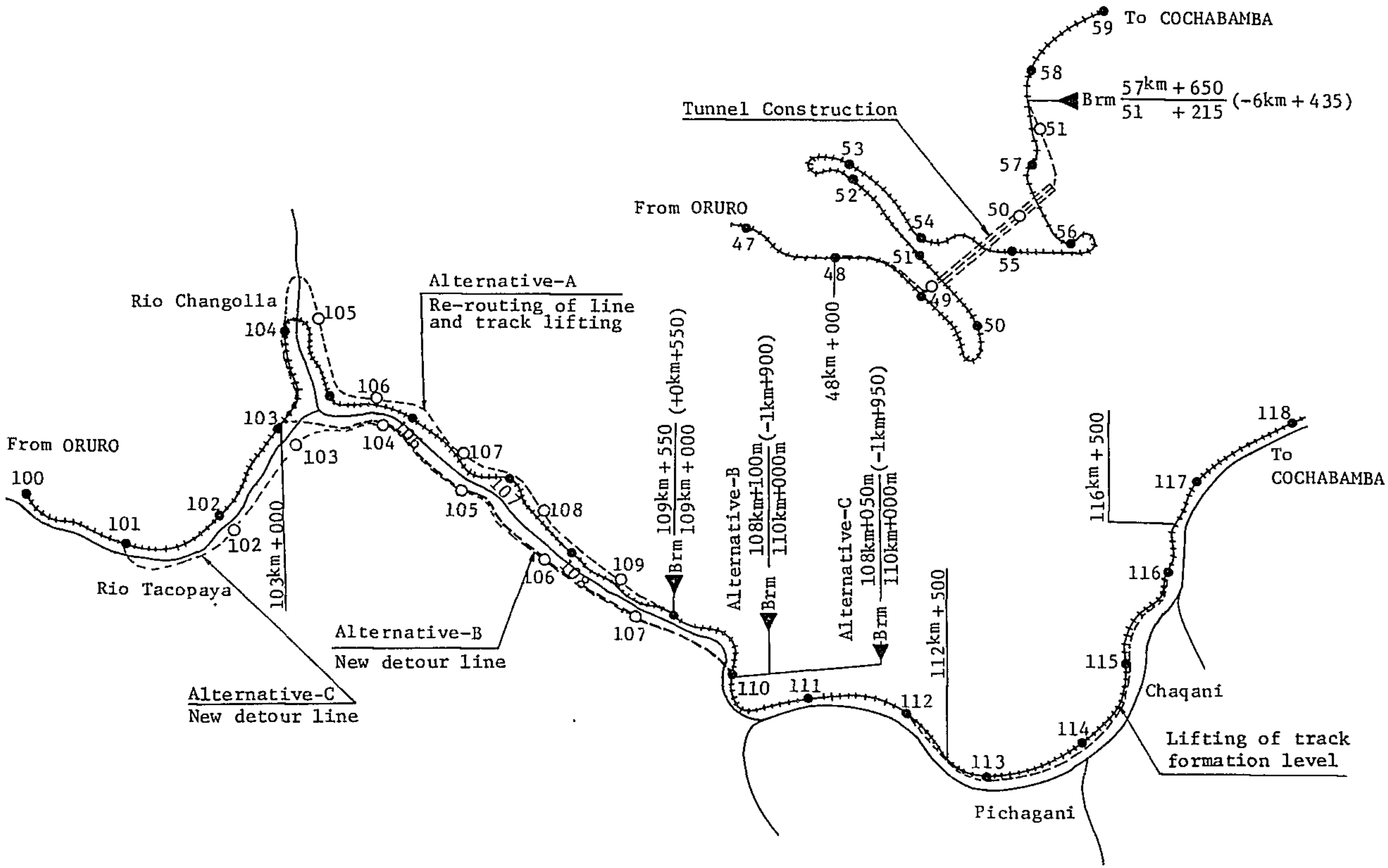


Fig. 1 Rehabilitation Project

3. Traffic Demand Forecast

The branch line of Cochabamba is the route of vital importance not only serving as the railway connecting Oruro as the industrialized city and Cochabamba as the nation's second largest city, but also being proposed for the future interconnection route between Eastern and Western railway system.

The traffic density at present is 653 passengers per km·day and 440 tons per km·day for freight. Although the past trend is fluctuated largely, it generally shows on increasing tendency as a whole.

(1) Method of demand forecast

This project is the rehabilitation plan solely to restore the lost function. Therefore, since there will be no demand increase to be anticipated from completion of the project, unlike the case of a development project of a normal pattern, the identical figures will be used for demand forecast, regardless of whichever case 'with project' or 'without project'.

The existing road between Oruro and Cochabamba is now being improved toward the scheduled completion by 1982. The up-to-date share ratio of the railway transport is estimated at 36 per cent for passengers and 20 per cent for freight.

Since the future railway transport must be forecasted on a competitive basis with the road traffic, the figures as estimated from the past trend are used after adjustment by setting-up of a sharing model on traffic volume.

As a result of road improvement, it is expected that the running time of a truck between Oruro and Cochabamba will be reduced from 8 hours to 8 hours minus 80 minutes or so. Consequently, the total volume of freight now being handled by domestic railway transport will be shifted by 4.2 per cent to the road transportation.

(2) Estimated future demand increases

As concerns the passenger traffic the recorded data for the said section is available only for the latest three years. Therefore, the future increases of passengers are estimated from the annual growth rate of population in the state of Cochabamba; namely, it will continue to further increase at the same rate of 1.86 per cent annually as is at present for a coming decade and, therefore, at an increased rate of 2.1 per cent on assumption that the population would cease to flow out of the state with growth of the local industries.

The future increases in freight transport are estimated from the latest 8 years' trend over the '71 - '78 period.

The result of demand forecast is as follows:

	1978	1990	2000
	(1,000 persons)		
Passenger	312	390	481
	(1,000 tons)		
Freight	168	222	263

4. Economic Analysis

Economic analysis has been made to determine if it is worth-while in the light of the national economy to execute the rehabilitation project of the existing Cochabamba branch line. In evaluating the economy of the project, the benefit has been measured for evaluation on assumption that the restoration work for the two proposed sections (101 km ∿ 110 km and 113 km ∿ 116 km) would be carried out during the overlapping period. The method of evaluation is same as in the case of the Eastern Line, in that if the cycling pattern of track damage - service suspension - immediate restoration, which would be anticipated in the case of 'without project', continues further in the future as well as in the past, any economic losses to be incurred upon both passengers and freight, together with the expenses to be required for restoration from damages, are measured as the benefits, in turn, in the case of 'with project' for comparison with the estimated construction costs for execution of the project.

Although the road exists as the alternative means of transport in parallel with the branch railway line of Cochabamba, it is not taken into account as the appropriate alternative means for evaluation of the project. The reasons for this are as follows:

- o Since the road passes through another different route of the valley away from the railway, it can not serve as the alternative means for those inhabitants living in the villages along and close to the railway line.
- o In view of the importance that the existing branch line of Cochabamba is planned as the route for future extension of the trans-continental railway, any other alternative route requiring abolition of the said route is not conceivable at this stage.

The result of economic analysis for the rehabilitation project in the said section indicates a rather favorable figure of I.R.R. = 10.28 per cent, thus suggesting the economic feasibility of the project. Because this evaluation does not cover any impact from suspension of the service on the Cochabamba branch line upon the train operation in all the rest sections and also the induced effect to arise from the reduced number of train operation days, it is conceivable that higher economic effect can be obtained if all such factors are taken into consideration.

As for the section proposed for tunnel construction (48 km ∿ 55 km), this project has been evaluated aside from the foregoing rehabilitation project, because the purpose of the said project is to reduce the maintenance cost of the track. Although evaluation has been made by conversion into the benefit of the possible decrease in the operating expenses to result from improved track alignment and shortening of running length after execution of the project, the project would not be economically feasible because of the small benefit to be produced therefrom. Since the benefit from tunnel construction is influenced largely by the scale of traffic volume, it is rather advisable to make further review of the project if the situation becomes encouraging in the future with prospect for large increase in the traffic volume.

The outline of the approach to the economic analysis is as follows:

(1) Analysis of two sections for restoration from damages

1) Number of train service suspension days

The past data indicate that the number of service suspension days because of disastrous damages are averaged at 58 days for the period of '75 - '79 in the whole branch line of Cochabamba. Then, the number of suspension days due to damages caused in th said two sections may be estimated as follows, by use of the estimated ratio of earthwork as 80 per cent in those sections:

$$58 \text{ days} \times 0.8 \doteqdot 46 \text{ days}$$

As calculated above, the estimated number of days in outage of train operation in this section amount to 46 days.

2) Loss on passenger traffic

The calculated losses for passenger traffic include the loss to be incurred to the peddlers because of their being deprived of their means of transport and the loss upon the wayside inhabitants for their being prevented to sell foods or drinks to the train passengers. The total loss in 1984 may be estimated as follows:

Loss to peddlers	598,000$b
Loss to wayside inhabitants	430,000$b
Total	1,028,000$b

3) Loss freight transport

The commercial value per ton of the goods to be handled by the railway transport may be estimated as follows:

Export	10,333 $b/ton
Import	25,833 $b/ton
Domestic (local)	14,082 $b/ton

By reference to the previous instances where the alternative measures were taken during the suspension period of train service, the future pattern of measures to be taken in the similar case is forecasted as follows:

	Export	Import	Local		Remarks
			→Cochabamba	→Oruro	
Custoday	45.0	100.0	68.0	42.5	Interest accrual and custoday charge
Field stock	45.0	-	17.0	42.5	Interest accrual
Subtotal	90.0	100.0	85.0	85.0	
Alternative transport	10.0	-	15.0	15.0	
Total	100.0	100.0	100.0	100.0	

The total loss to be incurred incidental to the train service suspension in 1984 can be estimated as follows by application of the pattern tabulated above.

10,566,000$b

4) Restration cost from damages

In case of 'without project', it is necessary to calculate the annual expenses to be required for immediate restoration from damages. The past data on such expenses disbursed for the '74 - '78 period show that the total costs are averaged as follows on a basis of 1979's price level.

Immediate restoration cost	5,510,000$b
Countermeasures against drought season	6,963,000$b
Total	12,473,000$b

Economic cost reflecting shadow price may be estimated at 11,719,000$b.

It appears that those expenses for immediate restoration would further continue their gradually increasing tendency since similar damages occur every year. The estimated rate of annual average increase in spending would be 6 per cent. Then, the costs in 1984 may be estimated at 15,683,000$b.

5) Other effects from execution of the rehabilitation project

In case that the project has been executed, it is expected that the maintenance cost can be reduced as the result of shortening in the total railway line length and renewal of the track structure. The possible decrease in the maintenance cost in

1984 is estimated at 1,151,000$b reflecting the shadow price indexes.

6) Total costs convertible to benefits (1984)

Passenger traffic loss	1,028,000$b
Freight transport loss	10,566,000$b
Restoration from damages	15,683,000$b
Track maintenance	1,151,000$b
Total	28,428,000$b

7) Project costs

The project costs for the two sections suffered from damages are estimated as follows by application of the shadow price indexes.

103km + 000m ∿ 110km + 000m	211,075,000$b
112km + 500m ∿ 116km + 500m	103,677,000$b
Total	314,752,000$b

(2) Tunnel construction project section

1) Savable cost of maintenance

The possible saving in the total maintenance cost is estimated at 1,617,000$b reflecting the shadow price indexes as the result of shortening by 6.4km of the existing total railway line length and improvement of the railway alignment.

2) Savable cost of train operation

The possible saving in the fuel consumption cost as the result of 6.4km shortening in the total running length and improvement of the steep grade is estimated at 160 liters per each train, thus resulting in a total saving of 730,000$b in 1984.

3) Project cost

The project cost is estimated at 198,076,000$b as adjusted by application of the shadow price indexes.

5. Financial Analysis

Comparative study is made, on behalf of the enterprise for which the self-supporting account system is required, between the sum of investment to be required in the case of 'with project' and the expenses, otherwise, for immediate restoration in case of without the project. Analysis has been made to seek the interest rate at the maximum endurable limit to the enterpriser, on assumption that the project would be financed by the external sources available and the investment cost could be paid off by the reduced income from the fare or freightage and the expenses disbursed for immediate restoration measures in case of 'without the project'. The result of such analysis indicates 7.14 per cent as the internal rate of return for the rehabilitation projects (2 sections).

From the results obtained as above, it may be said that the rehabilitation projects will be financially feasible if the projects can be financed by any low-interest loan funds available. However, the tunnel construction project seems to be hardly sound financially at the present stage. It is rather advisable to make further review if the situation turns to be encouraging in the future with prospect for large increase in the traffic volume.

The outlined analysis result is given hereunder.

1) Decrease of income from passenger fares (1984)

The possible decrease in the income from the passenger fares is estimated herein, on assumption that all the passengers travelling between Oruro and Cochabamba would be affected by suspension of the train operation during its full period.

Ordinary train	623,000$b
Ferro-bus	1,179,000$b
Total	1,802,000$b

2) Decrease of income from freightages (1984)

The possible decrease in the income from freightages is estimated for those freight to be handled by the alternative means of transport during suspension of the train operation service.

Local	116,000$b
Export	113,000$b
Total	229,000$b

3) Restoration costs from damages (1984)

Financial costs	16,692,000$b

4) Track maintenance cost saving (1984)

1,225,000$b

5) Total costs convertible to benefits (1984)

Decrease of income from passenger fares	1,802,000$b
Decrease of income from freightages	229,000$b

Restoration expenses	16,692,000$b
Track maintenance expenses	1,225,000$b
Total	19,948,000$b

6) Estimated project costs

103km + 000m ∿ 110km + 000m	251,010,000$b
112km + 500m ∿ 116km + 500m	123,560,000$b
Total	374,570,000$b

CHAPTER 1 INTRODUCTION

1-1 Purpose and Scope of Survey

The latest survey was conducted, in accordance with the request made by the Government of Bolivia, by the Japanese Government as a part of its technical cooperation overseas and executed by the Japan International Cooperation Agency (JICA) under the provisions of Japanese laws and regulations.

The survey was carried out within the 'scope of work' as mutually confirmed by both Governments, for the purpose of assuring technical, economic and financial feasibilities of the rehabilitation projects proposed for the railway division between Oruro and Cochabamba - 48km∿55km, 101km∿110km and 113km∿116km.

In order to achieve this purpose the site survey was conducted in July 1979. This report has been prepared after full review of the result obtained from this site survey and also the data furnished by the State Railway of Bolivia (ENFE).

It should be noted, however, that the review for preparation of this report was based upon the economic conditions prevailing at the time of the initial site survey. Later, the exchange rate of local currency was devaluated in November 1979 from 1 US$ = 20 $b (Bolivian Peso) to 1 US$ = 25 $b. It is therefore requested that in estimating the project cost and other costs the future price escalation should be taken into consideration.

1-2 Project Background

The specific section over about 75km between Oruro and Cochabamba on the Western Line of ENFE is suffered from many and frequent damages in the rainy season every year. Because of this, vast sum of expenses for restoration are spent and great economic loss is incurred incidental to suspension of the train operation service.

This railway line is really of vital importance as the inter-connection line between Oruro, the nation's industrialized city, and Cochabamba, the second largest in the country and also as the future liaison route between the east and the west of the Continent.

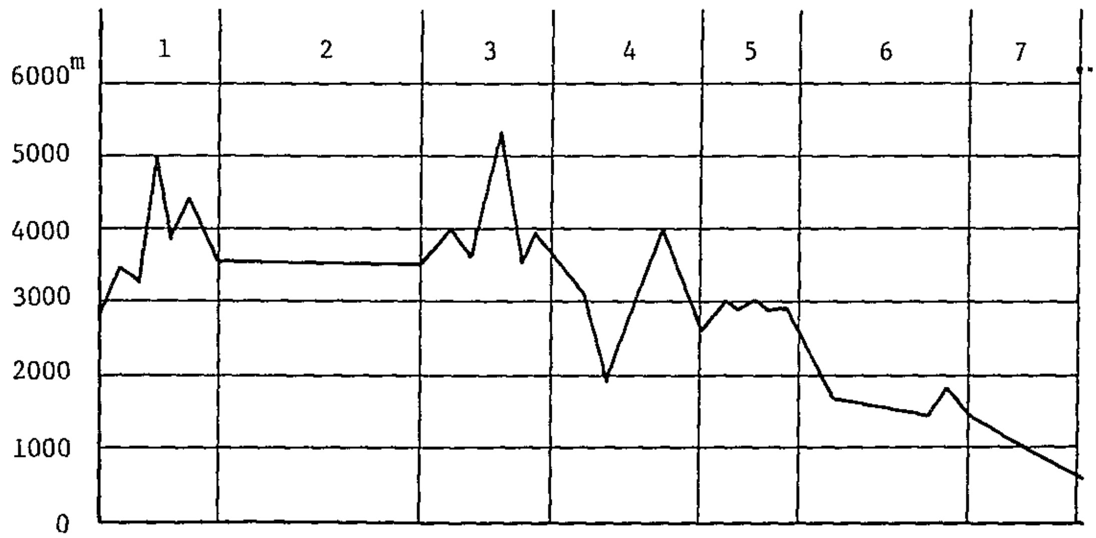
For this reason mentioned above, it is most necessary to secure the stabilized transport means, free from any future damages, by railway between Oruro and Cochabamba.

CHAPTER 2 DAMAGED CONDITIONS

2-1 Topographic Outline

At a general view of the topography between Oruro and Cochabamba on the Western Line, the section may be divided largely into Plateaus and Cordillera Oriental (Mountains). When the whole section is further divided, the Oruro - San Pedro section forms a plateau of 3,700 m in altitude, the San Pedro - La Cumbre (Peak point) is graded with gentle hilly slope like peneplain and the La Cumbre - Buen Retiro section is steeply sloped with V-shaped valley deeply carved in the mountain, except its summit, where the railway line runs along the Rio Arque, a rushing stream with an incline of 1/50 or more. The Buen Retiro - Cochabamba section consists of a plain wide open along the valley and a tectonic basin. (Fig. 2.1.1, 2.1.2)

Lots of land slide and slope erosion and debris are observed in the La Cumbre - Buen Retiro section running in parallel with a rapid current of the Rio Arque. The stream in this section flows in the direction as dominated by the strike of the existing geological structure. Consequent valleys in both main and branch streams along the weak zone of NW - SE striking are conspicuous by many occurrences of slope failure, slide and brisk erosion. At the bottom of the valleys in the main stream and its tributaries there remains much deposit of debris attributable to slope erosion and land slide, as the result of which the river bed has risen up remarkably, thus causing flood and collapse of embankment.



1. Cordillera Occidental
2. Plateaus
3. Cordillera Oriental
4. Ungas
5. Valleys (Cochabamba Mountains)
6. Chiquitos (Santa Cruz Plain)
7. Boliviachaco

Fig. 2.1.1 Cross-sectional Topographical Chart Model at 18°30'S'

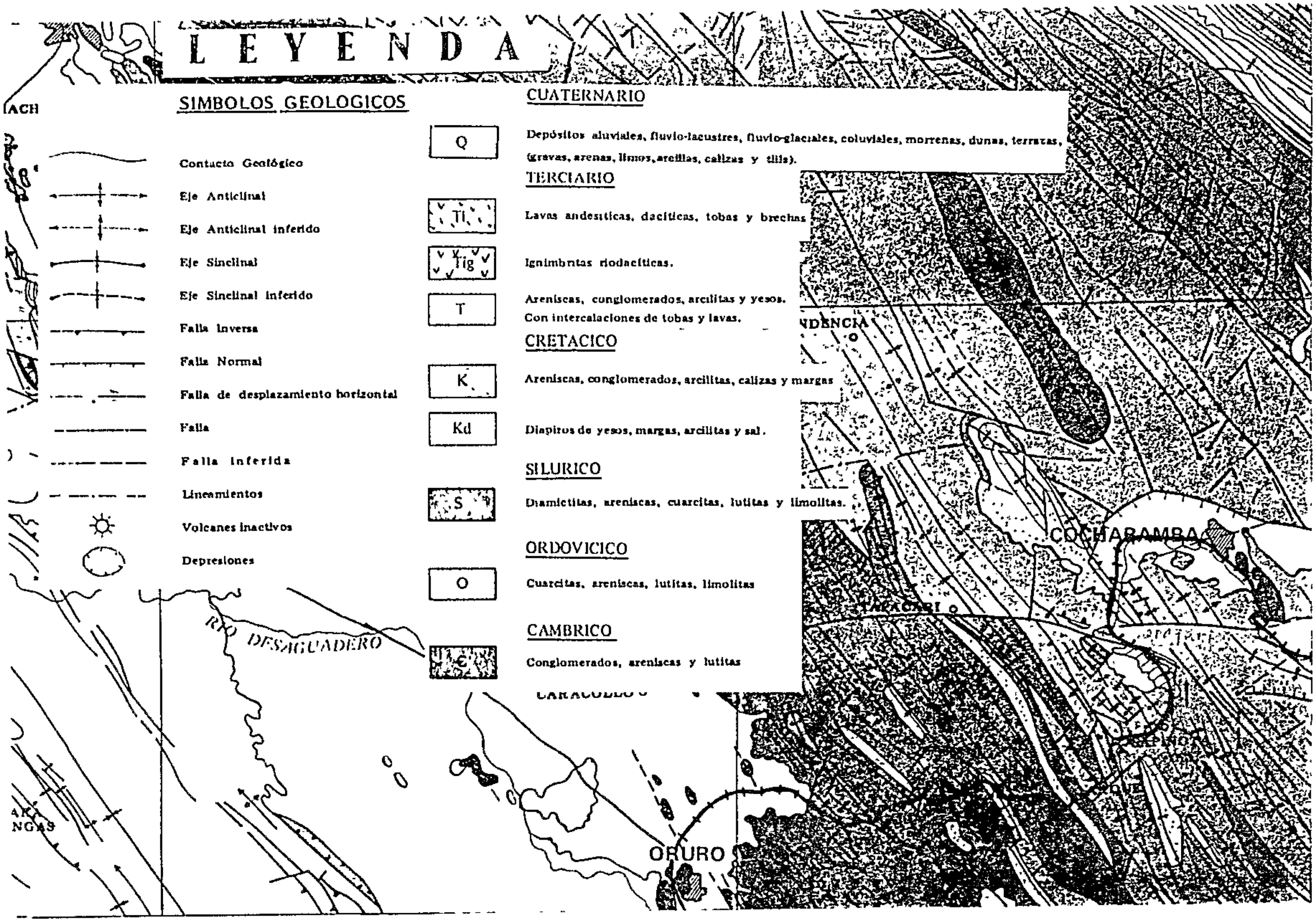


Fig. 2.1.2 Geological Outline View alongside Railways

2-2 Geological Outline

Plateaus consist of thick sediment of gravel supplied as the result of erosion in the surrounding natural ground. Cordillera Oriental consists of hard sand stone, shale and their alternation of Paleozoic era and partly of Methozoic era. By Tertiary tectonic movement the mountainous ground has been formed up with noticeable folding and fault in its stratum. As stated in the preceding section, the folding axis and the fault line are striking mainly in the NE - SE direction.

In the Rio Arque carving the eastern slope surface of Cordillera Oriental, the watercourse alongside the NW - SE weak zone is featured by slope failure and slide and talus while the other course in square to that zone forms a steep gorge with soaring cliffs. The valleys in branch streams are also developed in the direction of the weak zone, flowing out a great deal of debris. However, since the base rock consists of sedimentary rocks with small joint intervals, there seldom exists any rocks of huge size in excess of 1 m dia. Photo 2.2.1 shows the view alongside the railway taken by aerial photograph.

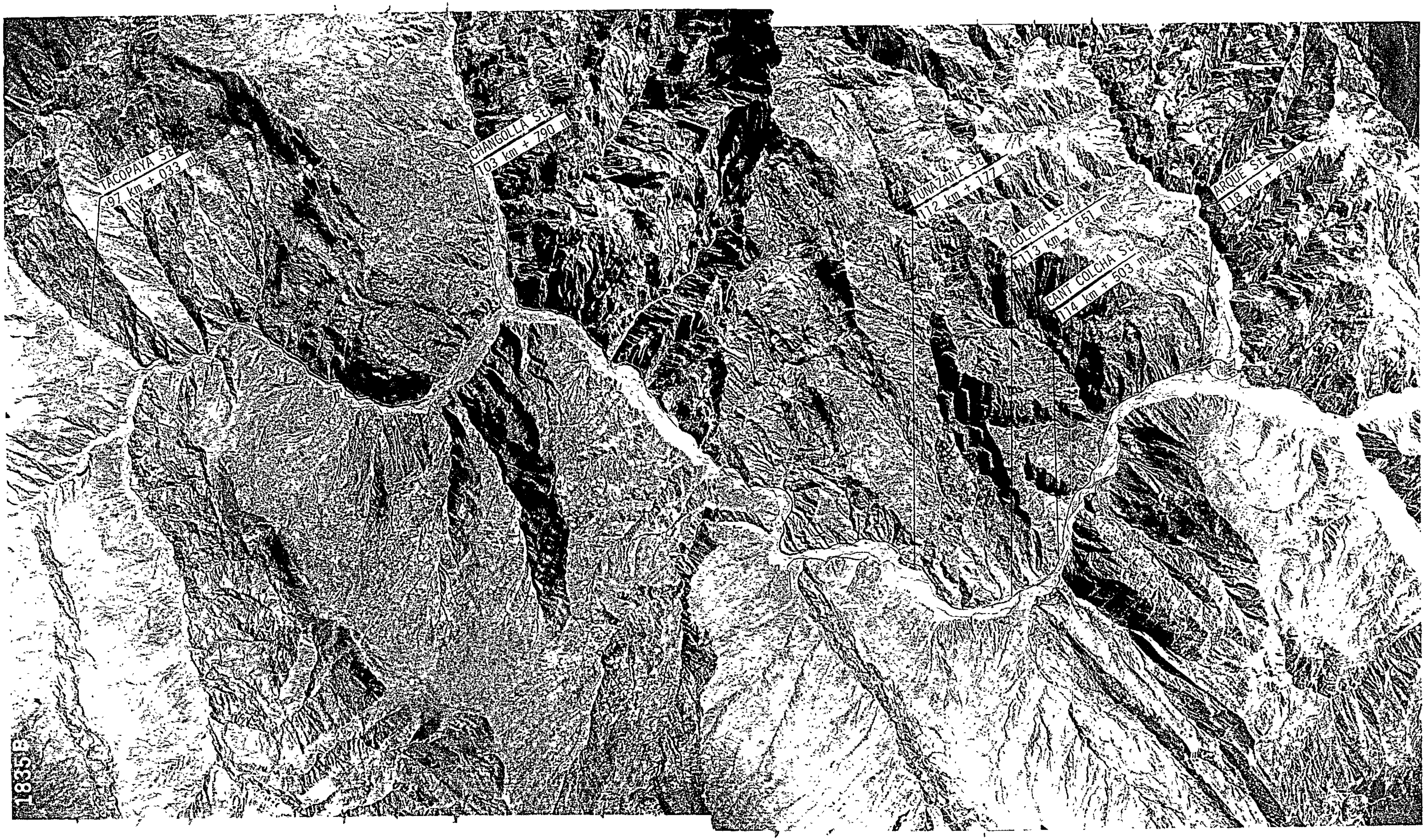
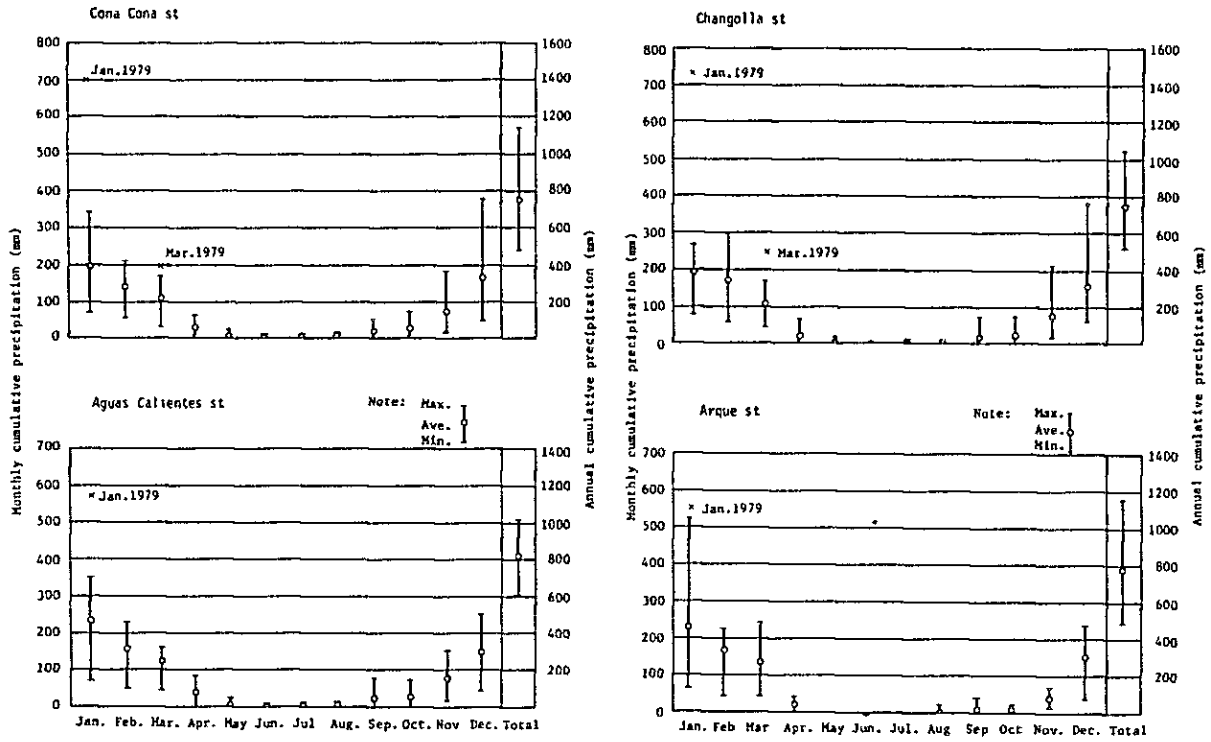


Photo 2.2.1 Aerial Photograph
(97 km - 120km)

2-3 Outlines of Meteorology and Plantation

Plateaus are known as dry areas of scanty rainfall not exceeding 800 mm or so in annual precipitation. On the eastern side of Cordillera Oriental it rains pretty more than in the plateaus, rather concentrated in the rainy season of November - March. Fig. 2.3.1 shows rainfall as recorded in each local area along the railway. In terms of temperature, the area can be likened to the temperate zones or the subtropical zones because of its high altitude, despite the area is situated in the tropical zones.

When viewed generally from plantation, the area is not well wooded because of very little rainfall in the dry season and scanty of top soil over the sloped surface. Therefore, the land is nearly naked with almost none of plantation, except only a few graves thinly grown with eucalyptus along the river.



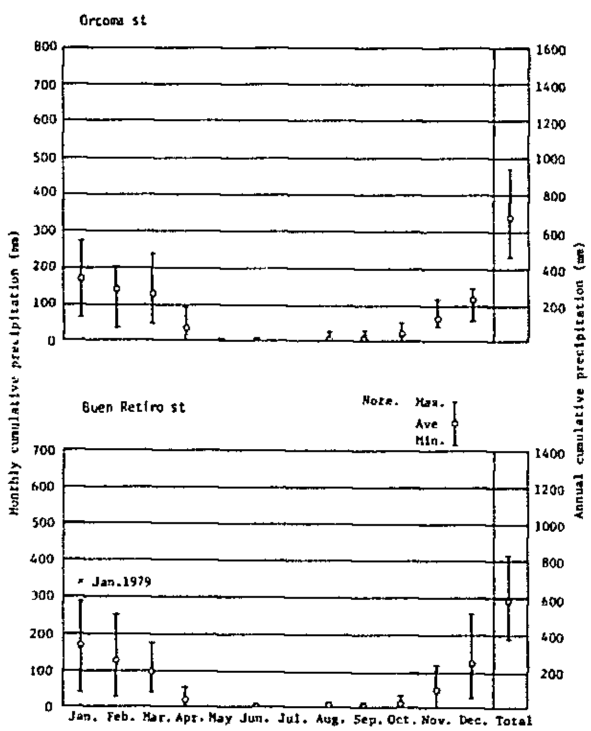


Fig. 2.3.1

Diagram of Monthly Precipitation (1970-1973, 1976-1978)

2-4 Disastrous Damages on Railway

In the Oruro - Cochabamba section of the Cochabamba branch, the railway division cursed with frequent damages is the section of a steep grade, extending about 75 km in distance between the points of near 65 km and 140 km alongside the Rio Arque. In this section, the track line of railway seems to be clinging to the steep mountainside, across the bridge on each branch stream, with railway construction standard of the worst conditions such as 30/1,000 in steepest grade and about 100 m in smallest curve radius.

The Rio Arque is joined by many tributaries in rapid current, with which this area is featured by active erosion and sedimentation. In other words, as most of these tributaries generate debris in avalanche, the main stream is conspicuous by high rise of its river bed with accumulation of sediment carried down from those tributaries. In some parts of the river basin, the bank is being eroded because of significant changes occuring in the water course.

In consequence of those, all kinds of disastrous damages took place in succession alongside the track line in the 65 km - 140 km section. Those damages may be classified as follows:

Avalanche of debris	44 spots	4,700 m
Slope failure	22 spots	2,600 m
Land sliding	7 spots	1,100 m
River bank erosion	28 spots	7,000 m
River bed rise	6 spots	-
Total	107 spots	15,400 m

2-4-1 Status of Damages by Cause

The conditions of major damages are as follows:

(1) Avalanche of debris

Damages from debris are observed in most of the branch streams at the rapid current of the Rio Arque. Such debris is featured by its rock fragment of relatively small size because rock at its generating origin has many cracks, after crumpled under the influence of tectonic movement in the Andes. Such being the circumstance, there are only a very few instances where bridges have been destroyed completely by avalanche of debris. Rather, bridges have been buried under such debris in most cases as observed.

Also, as is traced at and near the point of 96 km + 300 m or 114 km + 100 m, the main stream tends to be blocked up with debris carried from the branch stream on the opposite bank side, and the subgrade of the track may be scoured or washed away in same portions because the stream water thus blocked up tends to overflow on and along the railway line.

In and around the 123 km - 133 km section, there exists an expansion of debris sediment at the confluence of main and branch streams, where the sediment forms a large outfall fan. The railway running across it is buried by outflow of sand and soil everytime rain falls.

(2) Slope failure

Since the railway line runs on the cliff at the mountain base along the Rio Arque, it has many sections cut on one side and reclaimed on the other or of all cutting. As the mountain side surface is sloped steeply, the cut surface is likewise graded sharply. In addition to that, the natural ground in this area has its great geological weakness, because it is severely crumpled by influence of tectonic movement as aforestated. Therefore, land failure has taken place on many slope surfaces, particularly between 93 km and 128 km.

(3) Land sliding

Several damages apparently attributable to land sliding are observed throughout the surveyed section. Those damaged portions are affected, not by any abrupt movement of the ground, but by constant minimal movement, thus causing irregularities of track on a constant basis which require full-time maintenance care and repair work if and when necessary.

(4) River bed rise

The river bed tends to rise conspicuously in the Rio Arque and its large tributaries (Rio Sayari and Rio Changolla, etc.) with large quantity of sand and soil carried from the branch streams. It is raised by 1 to 1.5 m a year at its highest rise. Especially, near 87 km, 105 km and 122 km this becomes more remarkable with deficiency of free sectional opening under the bridge girder, submergence of the track and loss of the track subgrade at flood.

2-4-2 Status of damages by section

(1) Paradero - Cona Cona (65 km + 500 m - 72 km + 600 m)

This section is situated at upstream of the Rio Arque and the track is laid considerably high above the river bed. Under such condition, therefore, the possible danger of slope failure is limited to only a few, besides erosion as observed partly in the river.embankment.

(2) Cona Cona - Ventilla (72 km + 600 m - 77 km + 500 m)

The track in this section goes up with horse-shoe curve on the halfway steepest slope of the mountain side. There exist two zones of land slide in this section with conspicuous settling of the track.

(3) Ventilla - Aguas Calientes (77 km + 500 m - 85 km + 390 m)

There are two (2) points of land slide and two (2) branch streams generating avalanche of debris.

(4) Aguas Calientes - Tacopaya (85 km + 390 m - 97 km + 030 m)

The river bed rises noticeably near the 87 km point. In the section before and after this point and near 92 km the subgrade is marked most severely with erosion from the river flow. Near the 95 km point land slide is observed at two spots. At the point of 96 km + 300 m the main stream is nearly blocked up with debris flow carried from the branch stream on the opposite bank side and overflow resulting from such blockade of the stream leads to wash-out of the subgrade.

At present, in the section between 89 km + 500 m and 94 km the route changing work is under construction is being carried out. It is expected that the possible danger for damages may be eased to a considerable extent when the work will have been completed.

(5) Tacopaya - Changolla (97 km + 030 m - 104 km + 000 m)

The track in this section is damaged severely by erosion from the river flow. As measures for recovery, the route has been changed for the 99 km + 200 m - 99 km + 400 m span and the 100 km + 700 m - 101 km span respectively. Besides, there exists a swamp near Changolla Station as the generating source of debris, under which the bridge is buried.

(6) Changolla - Colcha (104 km + 000 m - 113 km + 600 m)

The bridge crossing the Rio Changolla has scarcely open sectional space under the girder due to uprising of the river bed. At and near the confluence with the Rio Arque, the bed tends to rise up by 1.0 - 1.5 m a year, and at the curve of the water flow the subgrade is washed out by influence of erosion. The railway runs across the branch streams constantly generating debris between 105 km and 108 km, and most of the existing bridges are experienced once or again in buried or washed damage in the past.

The slope surface is of steep cutting, having a dangerous potentiality of causing big land failure or slide with many unstabilized points.

This section is marked by not only the largest scale of damages but also the concentration of potentially dangerous spots.

(7) Colcha - Arque (113 km + 600 m - 118 km + 240 m)

At and near 114 km + 100 m, the main stream of the Rio Arque is buried with debris carried from the Rio Pichacani on the opposite bank side. As the result, the subgrade is washed away or the track is buried as normal disastrous damages in each year. At the curve of the stream, the bank is eroded and the subgrade is washed by influence of washing force of the stream.

(8) Arque - Higuerani (118 km + 240 m - 126 km + 200 m)

In this section there exist two large outfall fans with sediment of debris. Since the track runs across that zone, it is buried under the sediment here and there. Uprising of the river bed and erosion of the river bank are observed in some portions.

(9) Higuerani - Orcoma (126 km + 200 m - 132 km + 370 m)

This section also has two large outfall fans with sediment of debris. At and near 127 km + 500 m, the river bank is eroded severely by influence of the flow from the tributary Rio Sicaya on the opposite bank side.

(10) Orcoma - Irpa Irpa (132 km + 370 m - 141 km + 180 m)

There exist many remarkable rises of the river bed and noticeable erosion of the bank in the Rio Sayari and near 136 km.

Incidentally, Table 2.4.1 includes a list of dangerous points as discovered by the latest survey. Fig. 2.4.1 shows a record of disastrous damages experienced during the 1972 - 1979 period.

Table 2.4.1 List of Dangerous Point (65 km - 140 km)

* Especially dangerous

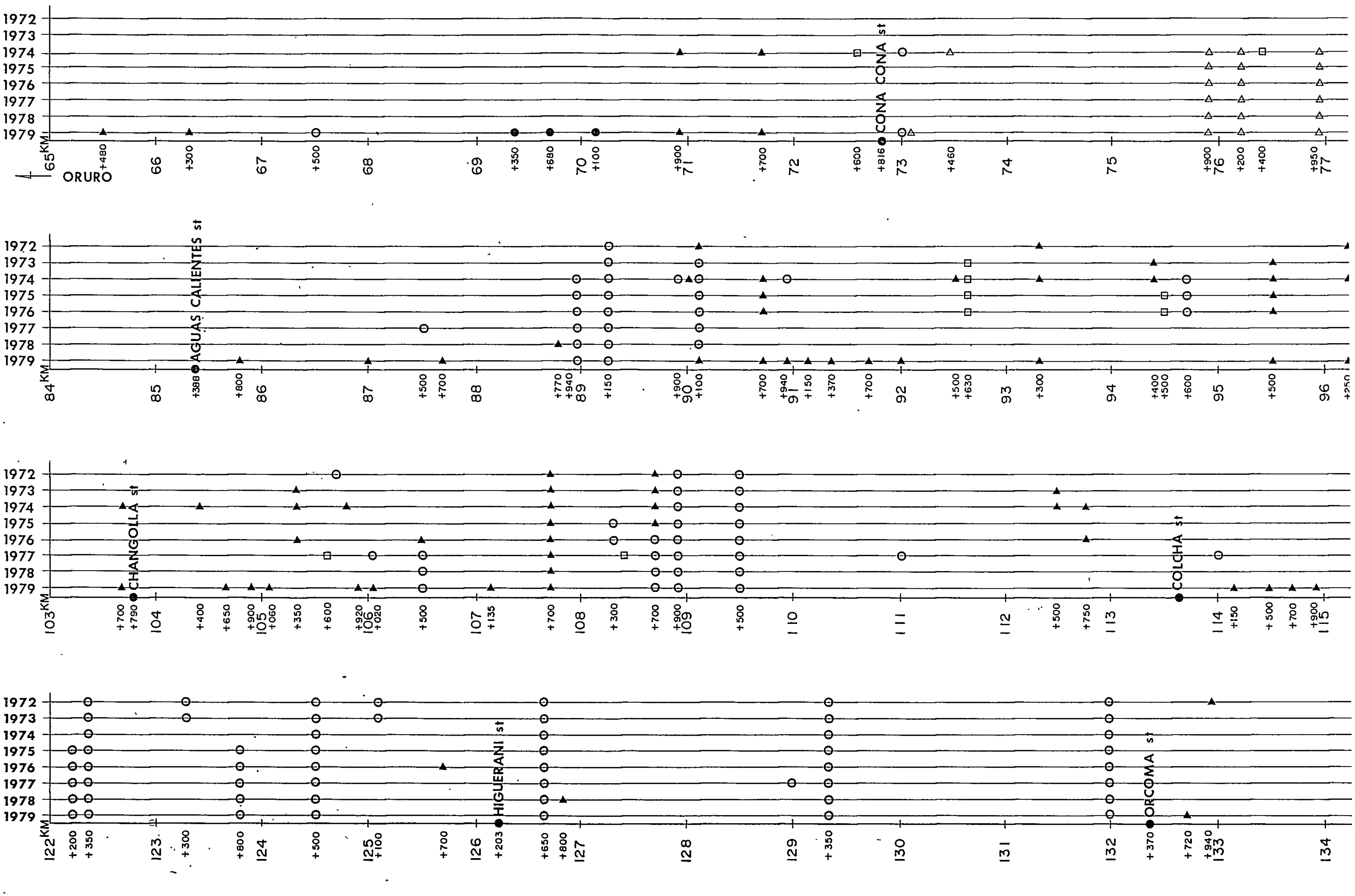
km post	Length	Contents
65 km + 500 m	20 m	Bank erosion
66 km + 000 m	30 m	Slope surface failure (Rock sliding)
66 km + 100 m	50 m	Bank erosion
66 km + 300 m	100 m	Bank erosion
66 km + 620 m	70 m	Bank erosion
66 km + 730 m	70 m	Slope surface failure (Rock sliding)
67 km + 450 m	50 m	Slope surface failure
69 km + 300 m	100 m	Slope surface failure
69 km + 500 m	300 m	Slope surface failure (Large catchment from mountains)
70 km + 700 m	50 m	*Debris sediment
71 km + 300 m	100 m	*Debris sediment (Swamp same as at 70 km + 700 m)
76 km + 100 m	200 m	*Land sliding (Setting and lateral movement, Weekly maintenance care required)
76 km + 900 m	100 m	*Land sliding
77 km + 900 m	100 m	Slope surface failure (Weathered rock five minutes)
79 km + 300 m	150 m	*Land sliding
82 km + 750 m	50 m	*Debris sediment (Box culvet buried)
83 km + 200 m	300 m	*Land sliding (Setting and lateral movement)
83 km + 500 m	40 m	*Debris sediment (Bridge buried)
85 km + 650 m	170 m	Bank erosion (Revetment under construction)
87 km + 000 m	300 m	*Bank erosion (Track looks like ladder uprising of river bed)
87 km + 900 m	200 m	Bank erosion
88 km + 200 m	40 m	Debris sediment (Bridge buried)
88 km + 900 m	20 m	*Debris sediment (Bridge buried every year)

89 km + 150	10 m	Debris sediment (Bridge buried every year)
91 km + 000	1500 m	Bank erosion
92 km + 500	30 m	Debris sediment
93 km + 700	100 m	Slope surface failure (Cutting under talus)
94 km + 000	100 m	Slope surface failure
94 km + 700	100 m	*Debris sediment (Bridge buried)
95 km + 700	100 m	Slope surface failure
96 km + 300	400 m	*Uprise of river bed (Due to debris sediment from opposite bank side)
96 km + 400	50 m	*Slope surface failure
96 km + 700	100 m	*Slope surface failure
98 km + 200	20 m	Slope surface failure
98 km + 350	30 m	Debris sediment (Outflow of rock sized at 1∿1.5m dia.)
98 km + 450	50 m	*Rock sliding
99 km + 000	400 m	*Bank erosion
99 km + 200	50 m	Slope surface failure (Cutting at talus)
100 km + 000	50 m	Bank erosion
100 km + 700	300 m	*Bank erosion (Due to debris sediment from opposite bank side)
101 km + 800	200 m	Bank erosion
102 km + 000	100 m	*Land sliding (Settlement)
102 km + 900	50 m	Debris sediment
103 km + 200	50 m	Debris sediment
103 km + 700	50 m	*Slope surface failure (Bridge buried)
104 km + 000	100 m	*Uprise of river bed (Rio Changolla)
105 km + 150	150 m	*Uprise of river bed *Bank erosion
105 km + 350	50 m	*Debris sediment (Pipe culvert buried)
105 km + 500	20 m	*Debris sediment
105 km + 600	500 m	Slope surface failure
105 km + 750	50 m	*Slope surface failure
105 km + 800	50 m	*Debris sediment (Truss bridge buried)
106 km + 000	{ 20 m	Debris sediment (Bridge buried)
	160 m	*Bank erosion

106 km + 100	20 m	*Debris sediment (Bridge buried)
	100 m	*Land sliding
106 km + 500	200 m	*Debris sediment (Bridge washed out)
106 km + 900	30 m	Debris sediment
107 km + 100	50 m	*Debris sediment (Truss bridge washed out or buried)
108 km + 000	100 m	*Debris sediment
108 km + 850	100 m	*Slope surface failure
109 km + 500	100 m	*Debris sediment
112 km + 000	50 m	*Debris sediment
114 km + 000	100 m	*Uprise of river bed (Due to soil sediment from opposite bank side)
114 km + 100	30 m	*Bank erosion
114 km + 200	300 m	*Bank erosion (Subgrade washed out)
115 km + 200	300 m	*Bank erosion
116 km + 750	50 m	*Debris sediment (Bridge washed out)
117 km + 100	100 m	Slope surface failure
117 km + 800	100 m	Bank erosion
117 km + 900	50 m	Debris sediment
118 km + 800	200 m	*Debris sediment
119 km + 600	30 m	Debris sediment
120 km + 250	150 m	*Bank erosion
120 km + 600	10 m	*Rock sliding
120 km + 800	100 m	Bank erosion
121 km + 100	100 m	*Land sliding
122 km + 000	300 m	*Debris sediment (Large out fall fan)
123 km + 200	50 m	*Debris sediment
123 km + 150	150 m	Bank erosion *Uprise of river bed
123 km + 700	750 m	*Debris sediment (Large out fall fan)
124 km + 600	600 m	Bank erosion
125 km + 200	50 m	Debris sediment
125 km + 700	50 m	Slope surface failure
126 km + 000	50 m	*Debris sediment

126 km + 150	10 m	Debris sediment
126 km + 600	300 m	*Debris sediment
126 km + 650	350 m	*Bank erosion
127 km + 300	100 m	Slope surface failure
127 km + 500	200 m	Bank erosion
128 km + 950	700 m	*Debris sediment (Large out fall fan)
130 km + 660	90 m	*Bank erosion
131 km + 050	10 m	Debris sediment (Bridge buried)
131 km + 850	300 m	*Debris sediment (Large out fall fan)
132 km + 900	100 m	*Debris sediment (Rio Sayari)
134 km + 700	300 m	Debris sediment
135 km + 350	75, 100 m	Debris sediment *Bank erosion
135 km + 900	200 m	Bank erosion
136 km + 500	30 m	Debris sediment
136 km + 700	30 m	Debris sediment
136 km + 800	650 m	Bank erosion
137 km + 200	20 m	Debris sediment
138 km + 800	30 m	Debris sediment
142 km + 200	500 m	*Slope surface failure

(Note) Figures in length are all roughly estimated by site reconnaissance.


1972
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CONA CONA st
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AGUAS CALIENTES st
103
104
105
106
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108
109
110
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112
113
114
115
CHANGOLLA st
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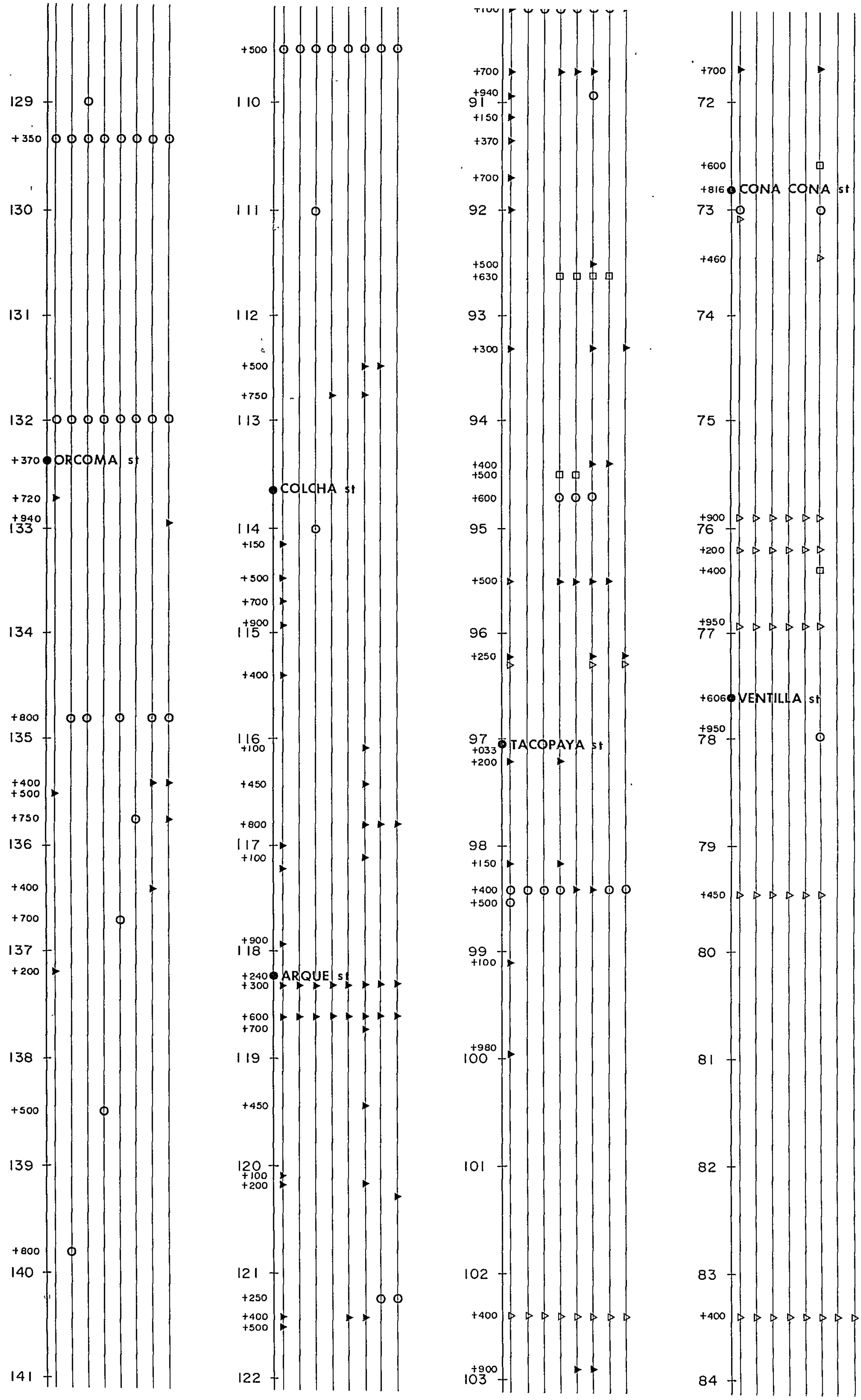
HIGUERANI st
ORCOMA st


CONA CONA st
VENTILLA st
TACOPAYA st
COLCHA st
ARQUE st
ORCOMA st
72 73 74 75 76 77 78 79 80 81 82 83 84
91 92 93 94 95 96 97 98 99 100 101 102 103
110 111 112 113 114 115 116 117 118 119 120 121 122
129 130 131 132 133 134 135 136 137 138 139 140 141

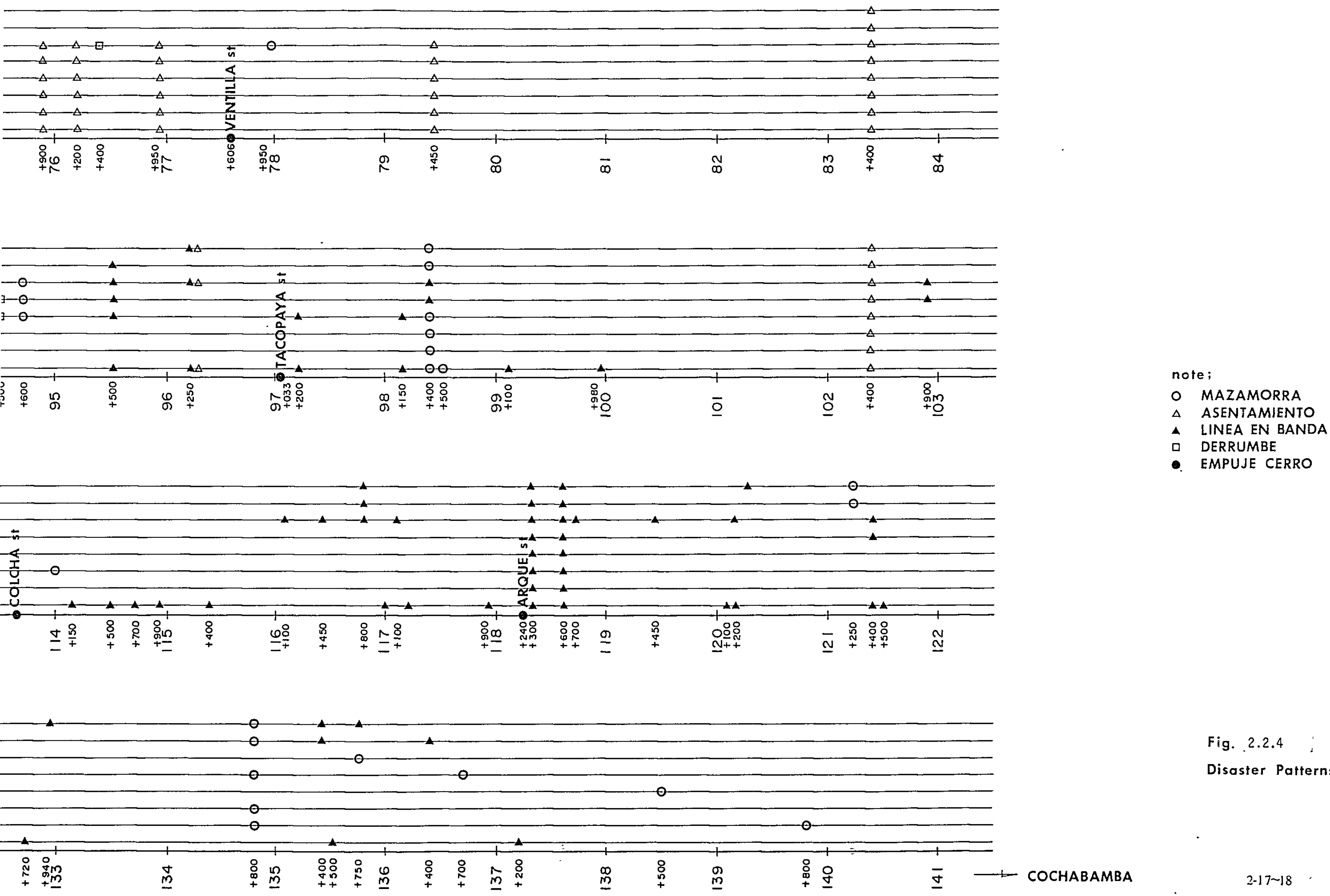
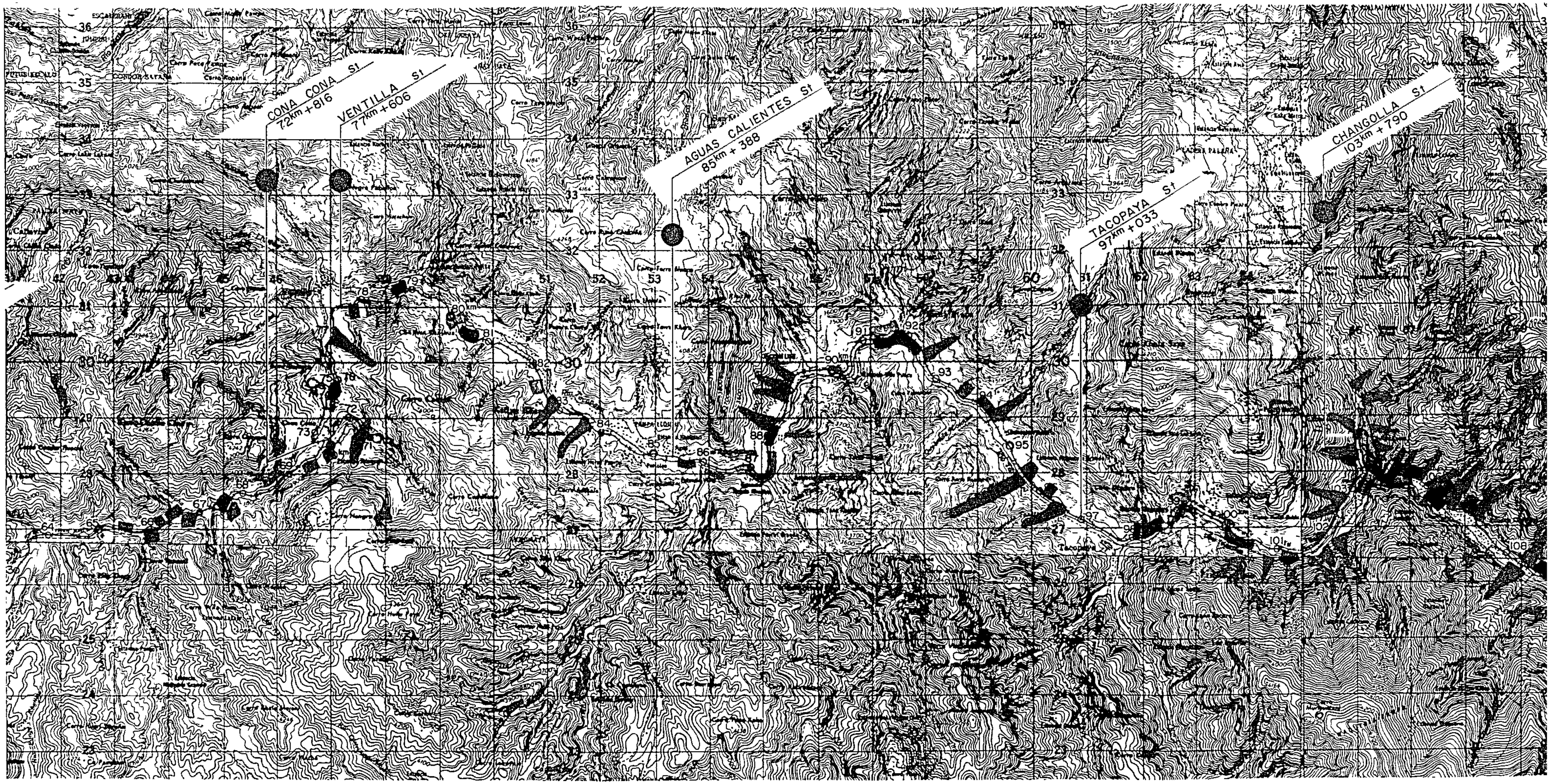


Fig. 2.2.4

Disaster Patterns by Rainfall



CONA CONA St
72km + 816
VENTILLA St
77km + 606
AGUAS CALIENTES St
85km + 388
TACOPAYA St
97km + 033
CHANGOLLA St
103km + 790

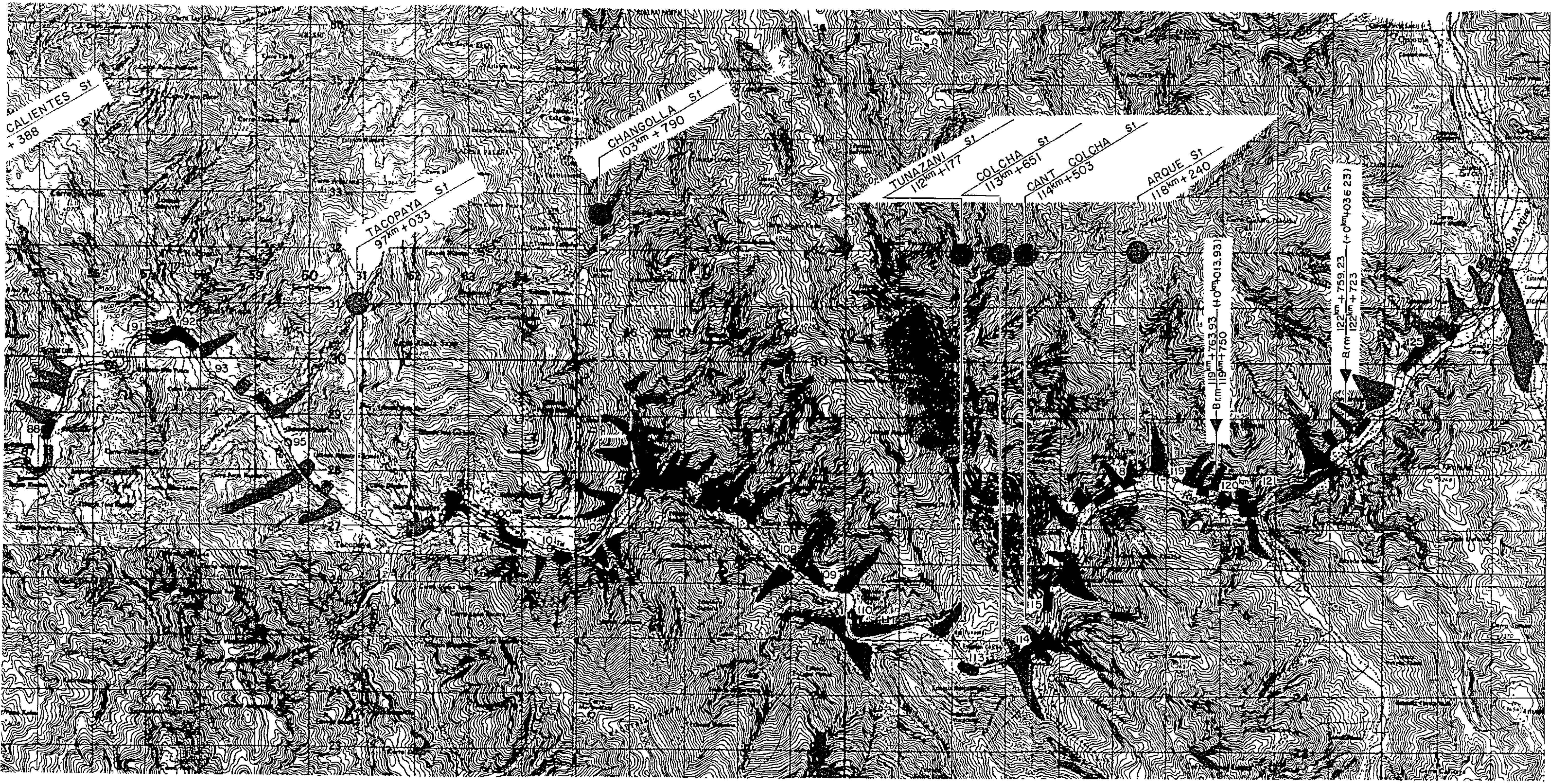


Fig. 2.2.5 Damaged Condition Map (1)

note:

Avalanche of Sand and Stone

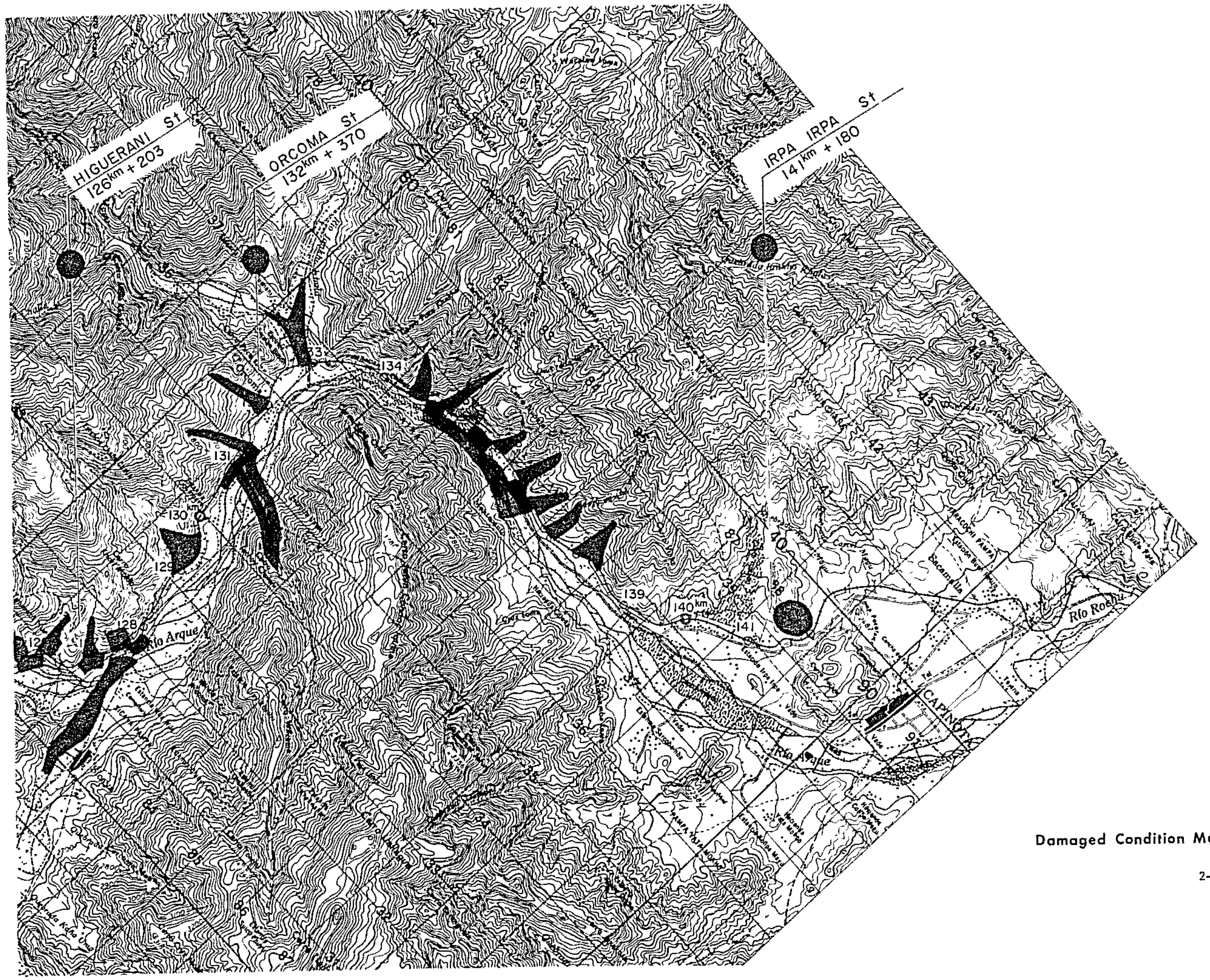
Collapse of Slope

Rock Fall

Land Slide

River Bed Lifting Up

Erosion of Revetment



Damaged Condition Map (2)

2-21~22

CHAPTER 3 REHABILITATION PLAN

3-1 Policy for Drafting of Rehabilitation Plan

The existing Cochabamba branch line (205 km between Oruro and Cochabamba) is one of the ENFE's most important lines serving as the transportation route, at present, between the country's capital La Paz and Cochabamba, the second largest city, and envisaging to serve in the future as the interconnection line between Eastern and Western railway system.

The purpose of drafting the rehabilitation plan is to suppress possible occurrence of disastrous damages on the line during the wet period every year and, at the same time, to curb spending for repair and maintenance against such damages.

3-1-1 Basic Thought for Rehabilitation of the Whole Damaged Section by General View

Within the section between Oruro and Cochabamba, lots of damages are observed in the steeply sloped section along the Rio Arque of about 75 km distance including those neighboring sections before and after the said section under this plan. As stated in Chapter 2, the phenomena of erosion and sedimentation are showing rapid progress by influence of the Rio Arque and its joined tributaries in rapid current. Because of this, the railway line laid on the mountain side along the Rio Arque is suffered, for almost all the way in that section, from any or every different type of damage, such as burying of track resulting from slope failure or avalanche of debris, destruction or wash-out of the track due to scouring or uprising of the river bed and damage or distortion of the subgrade. Besides, another unaffected section is also being involved into such damage with the ever-changing conditions of the terrain.
The whole area is featured, as a whole, by large and rapid changes beyond easy prediction.

Under such local conditions, it is rather difficult to take the preventive measures against possible disastrous damages on a permanent fixed basis. Therefore, the most appropriate measures to be taken for this section would basically be to adopt such a method that the track should be relocated, on a step-by-step basis, to the safer route by proper judgement from the condition of provoked damage.

3-1-2 Present Status of the Section Surveyed and Its Neighboring Sections

Throughout the whole damaged section of 75 km in total length, all the remainder except the section lately surveyed is relatively stabilized is now being rehabilitated steadily with the measures as aforestated. It is expected that the situation will keep on a favorable turn for the time being when the maintenance work with those measures will be completed.

Only the two (2) sections surveyed from 101 km to 110 km and from 113 km to 116 km are suffered from damages nearly all the ways from end to end and, still more, damages on significant scale. The problem is really in pressing need for solution since the train is being operated there with many unknown dangerous factors. Therefore, the whole section must be improved with well-balanced track construction by earliest implementation of the appropriate improvement plan.

The section between 48 km and 55 km is not affected by any damages but lies in the peak zone with steep grade and curvature in its intermediate portion. The track running in this section is hurted severely. It requires ever-increasing maintenance cost and, to make the matter worse, jeopardizes daily train operation as a dangerous path.

To relieve the track from such steep grade and curve, the short-cut route is being planned for improvement by tunnel construction. The project for tunnel construction does not pose any technical problem in particular. Rather, whether the project can be executed as planned or not depends solely upon the economic effect to be insured from construction of the tunnel.

3-1-3 General Policy for Planning of Rehabilitation Scheme

In view of the present condition and result of observation, the general policy to be determined as follows may be considered most appropriate for preparation of the rehabilitation scheme.

(1) The maximum possible flexibility should be allowed to the track structure, thereby to avoid, wherever possible, such structure as designed for fixed setting of the track formation level, so that any possible future track movement can be absorbed by such flexible design consideration. In case that the structure must be designed on a basis of fixed track position setting for some inevitable reason, this will have to be taken up for further review at the stage of detailed designing, then to determine the proper position of the track finally.

(2) It would be not only difficult but also of great influence upon the construction cost if the track-raising and other relevant factors are determined from the long-range forecast for possible change of conditions. Therefore, the plan should be projected within a limit of 20 years ahead or so in general, thus not including any further projection beyond that limit only with some provisions for any future actions to be taken thereafter if necessary.

3-2 Construction Standard

The construction standard applicable to drafting of the rehabilitation plan refer to the standard enforced at the time when the existing line was constructed and the standard of construction prepared specifically by the ENFE for the latest survey.

This standard is regarded as the most fundamental guideline for preparation of the rehabilitation plan, taking the following matters into special consideration.

- Maximum speed: 80 km per hour
- Standard track gauge: 1,000 mm
- To secure safety of train operation
- To plan various facilities with full economic consideration
- To design various facilities of such structure as may facilitate performance of the construction work
- To design various facilities of such structure as may be able to reduce maintenance workforce to minimum

(1) Track clearance

The track clearance in the straight track section will be as shown in Figs. 3.2.1, 3.2.2.

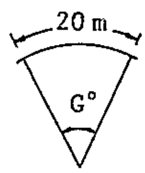
In the curved section, the clearance will be broadened as much as the bias of vehicle, so that the clearance between the fixed structure and the vehicle can be equalized to that provided in the straight track section.

(2) Maximum grade

The degree of grade is one of great influential factors to transport conditions and track maintenance costs. The maximum degree of grade in the straight section of the main line will be limited to 30/1,000.

The maximum degree of grade in the curved section will be reduced so moderately as to be able to compensate curve resistance as shown below:

$$\text{Max. grade in curved section } (I_{max}) = 10 - 0.54G \text{ (or } 12 - 0.54G\text{)}$$



Where, G denotes center angle for arc length of 20 m.

The grade of the main line within the station should be leveled off normally.

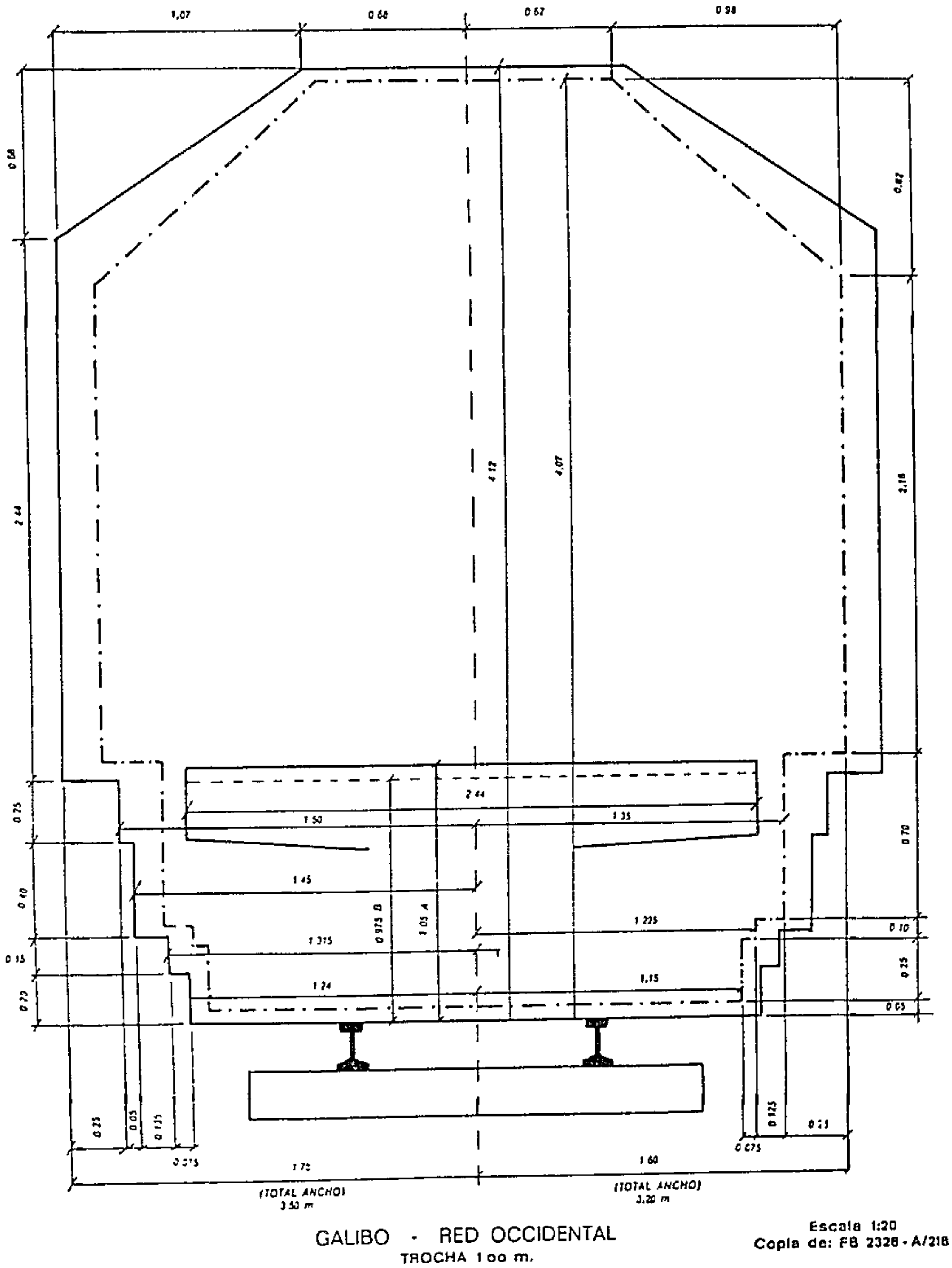


Fig. 3.2.1 Track Clear

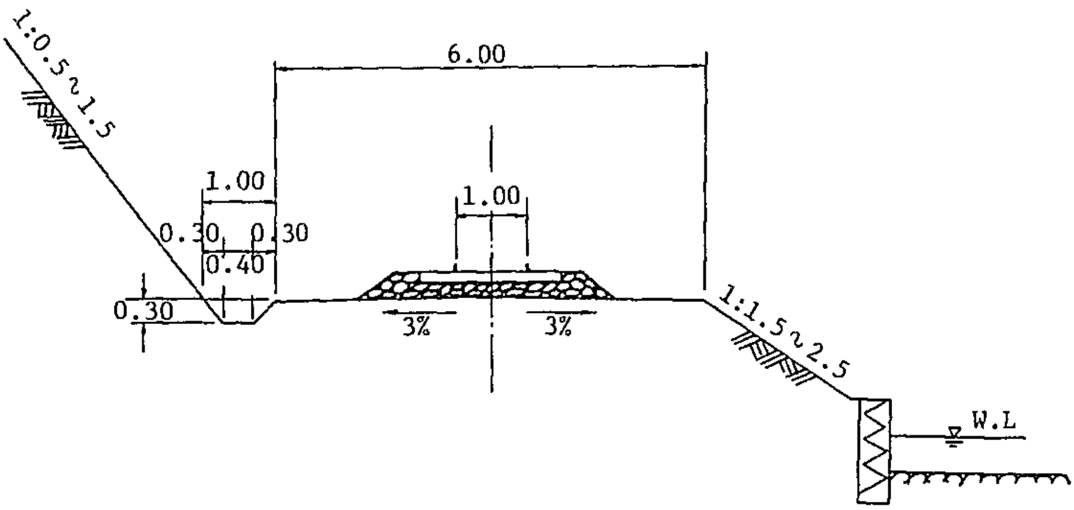


Fig. 3.2.2 The Formation Width for the Earthwork Section

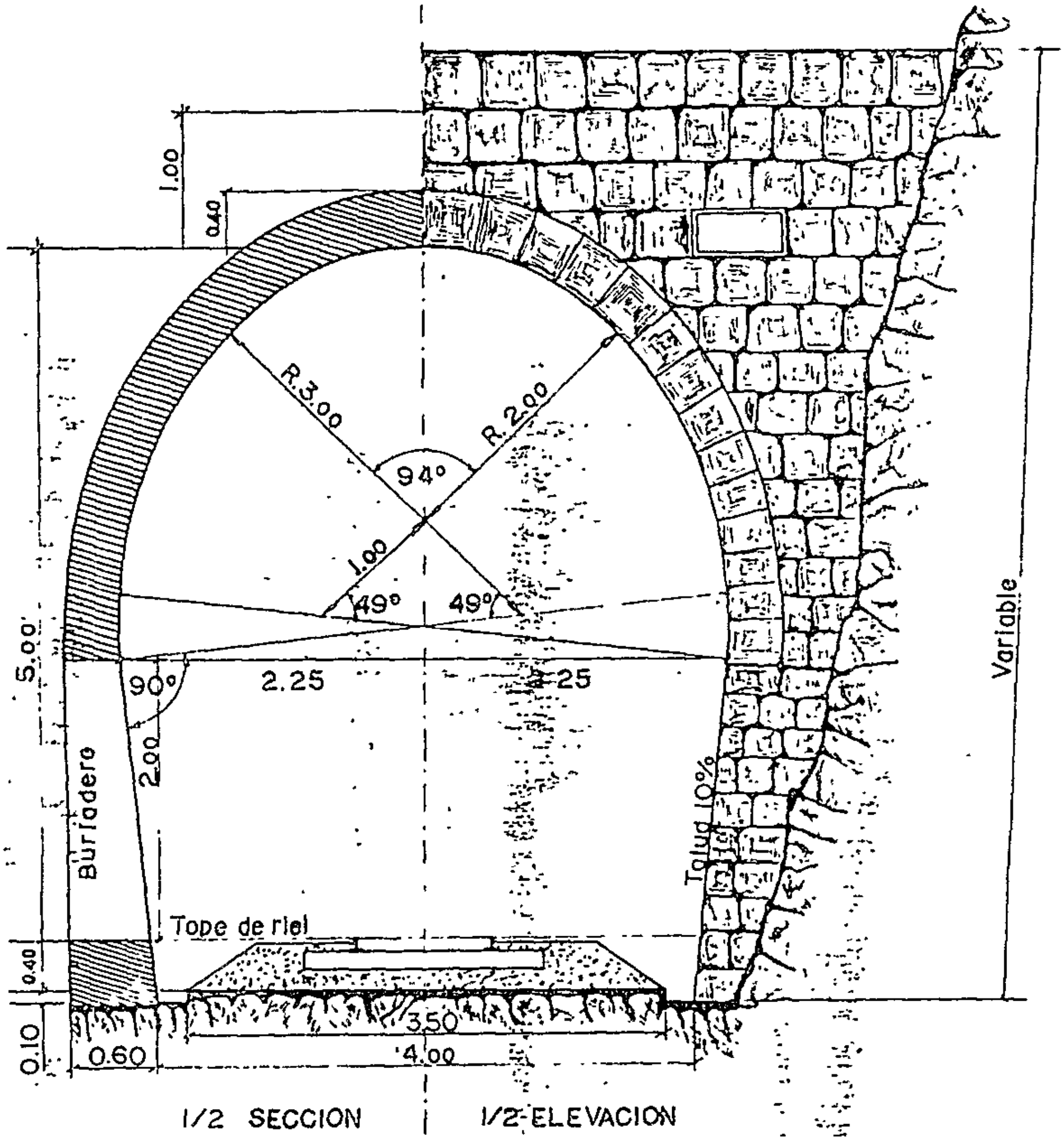


Fig. 3.2.3 Typical Section of Tunnel

(3) Longitudinal curve

The radius of such longitudinal curve will be 5,000 m.

(4) Minimum curve radius

The minimum curve radius for the main line will be 76.41 m (15° in center angle). The straight line of 100 m or longer will normally be inserted in the intermediate section between the two curves.

(5) Cant (Superelevation)

The maximum degree of cant is determined at 120 mm.

(6) Slack

Maximum slack will be 30 mm.

(7) Transition curve

The straight track line will normally be connected to the circular curve line through transition curve. The curve will be shaped into tertiary parabola.

Length of transition curve will be selected for the longest from among the three different conditions given below. To comply with the need for future speed increase, it is necessary to pre-set the length of transition curve with some extra length.

1) Minimum required length for safety security of train operation L_1 (m)

2) Rate of cant variation as determined from the aspect of riding comfort L_2 (m)

3) Length allowing for the probable variation rate of cant deficiency L_3 (m)

$$L_1 = 0.4C \text{ (or } 1.0C)$$
$$L_2 = 0.01C \cdot V$$
$$L_3 = 0.009Cd \cdot V$$

(8) Non-competitive conditions

In view of track maintenance convenience, competition between transition curve and longitudinal curve will be avoided.

(9) Formation width

The formation width for the earthwork section is as shown in Figs. 3.2.2, 3.2.3.

Embankment slope surface will be graded within a range of 1:1.5 ~ 1:2.5, though it may be determined properly depending upon material and height of embankment.

Cutting slope surface is graded within a range of 1:0.5 ~ 1:1.5, though it may be determined depending upon soil condition and cutting height.

(10) Bridges

Designed live load applicable to designing of the structure will be of Cooper E-40 load type as shown in Table 3.2.1.

Table 3.2.1 Cooper E-40 Load Type

E – 40		Wheel Distance	
t	lb	m	ft
9.05	20 000	2.44	8
18.1	40 000	1.52	5
18.1	40 000	1.52	5
18.1	40 000	1.52	5
18.1	40 000	2.74	9
11.8	26 000	1.52	5
11.8	26 000	1.83	6
11.8	26 000	1.52	5
11.8	26 000	2.44	8
9.05	20 000	2.44	8
18.1	40 000	1.52	5
18.1	40 000	1.52	5
18.1	40 000	1.52	5
18.1	40 000	2.74	9
11.8	26 000	1.52	5
11.8	26 000	1.83	6
11.8	26 000	1.52	5
11.8	26 000	1.52	5
5.95 t/m	4 000 lb/ft		
22.6	50 000	2.13	7
22.6	50 000		

(11) Track structure

The track structure will be designed by the following specifications (Fig. 3.2.4).

- Rail shall be 75 Lba/Yda (37.48 kg/m) or its equivalence (Fig. 3.2.5).
- Sleeper shall be made of timber with quality of quebracho whose dimension in the normal division shall be 0.12 × 0.24 × 2.00 m.
- Sleeper shall be spaced at a rate of 1,600 pieces per 1 km.
- Bridge sleeper shall be used for the bridge structure section.
- Ballast shall be filled with crushed stone to the thickness of 200 mm.
- Rail shall be fastened to sleeper by use of either screw spike of 1/2" × 5-3/4" or dog spike.
- The turnout to be used for the main line shall be a #8 turnout as shown in Fig. 3.2.6.

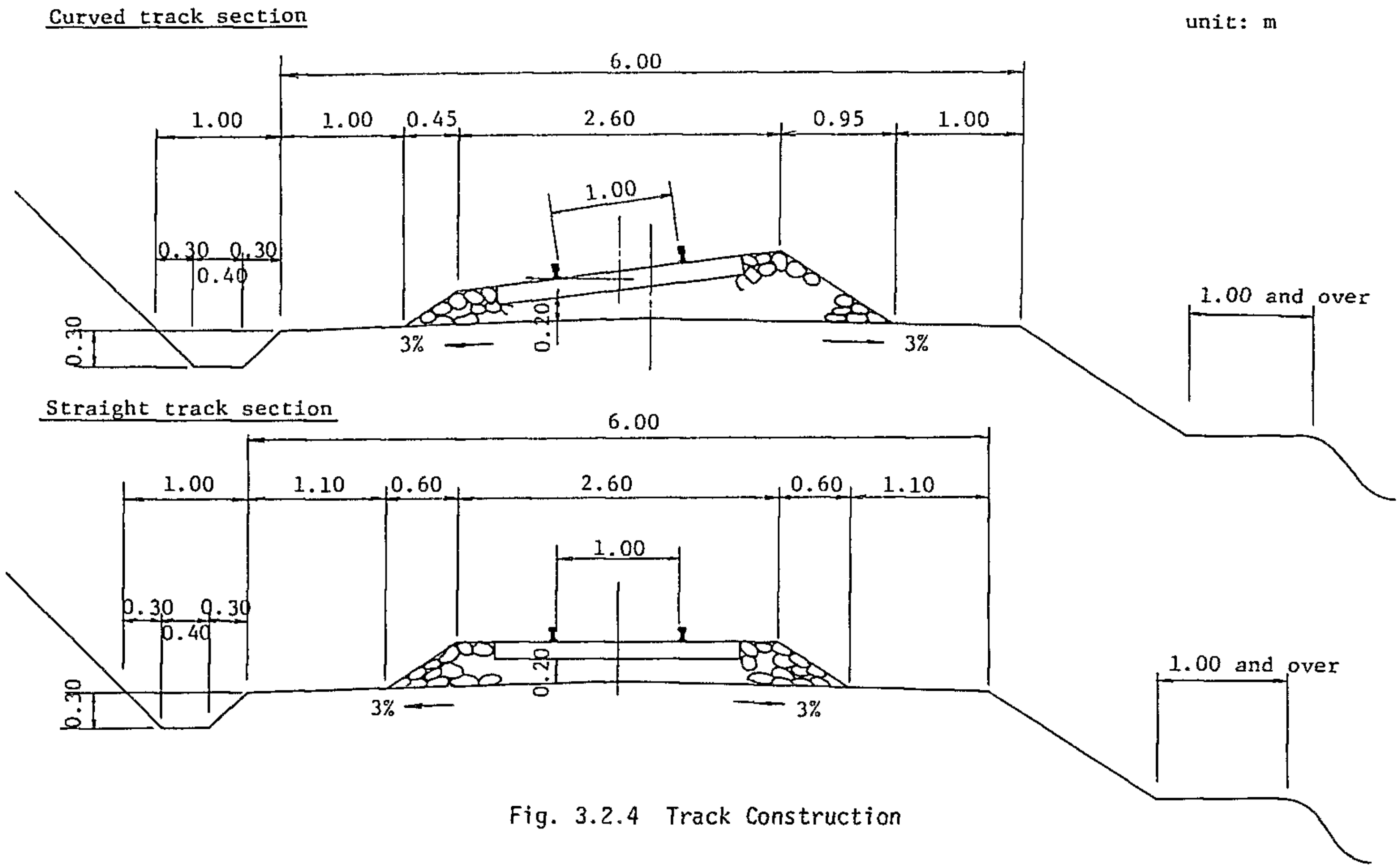


Fig. 3.2.4 Track Construction

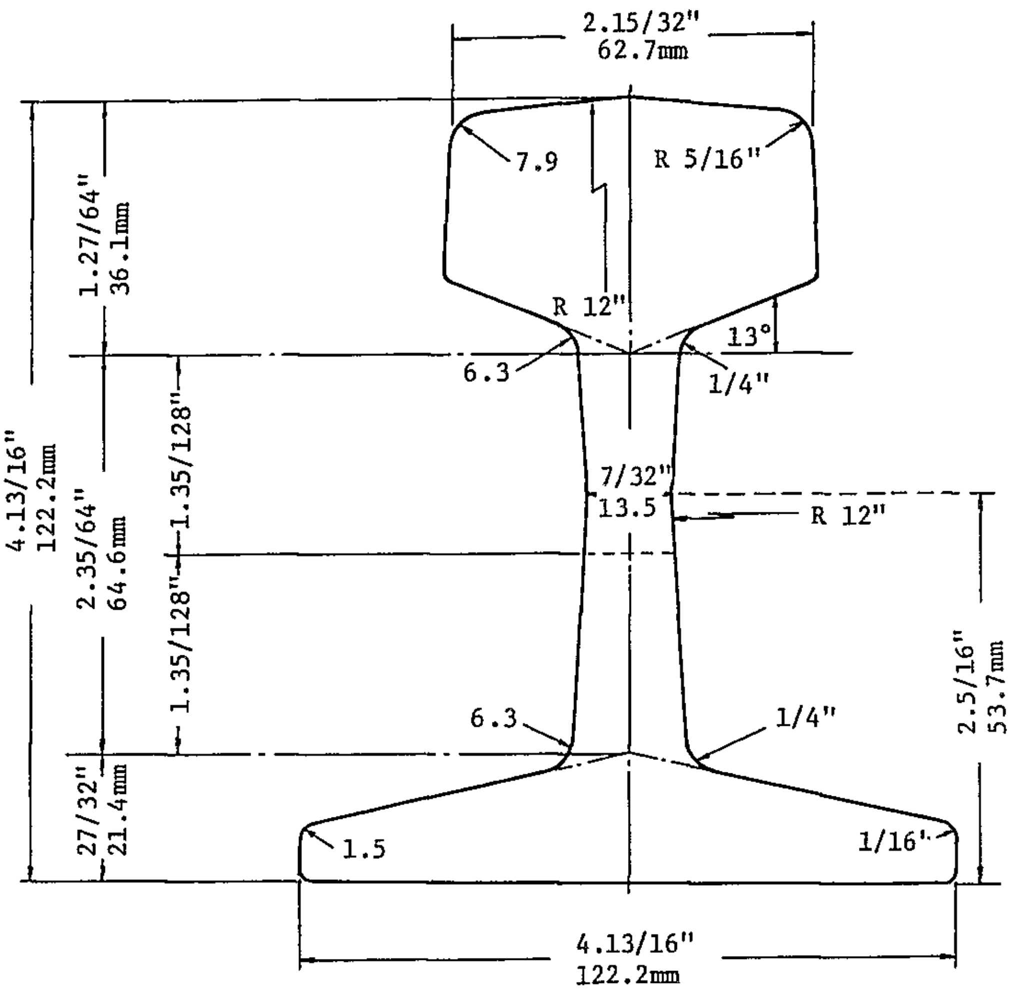


Fig. 3.2.5 Rail 75 Lba/Yda (37.48 kg/m)

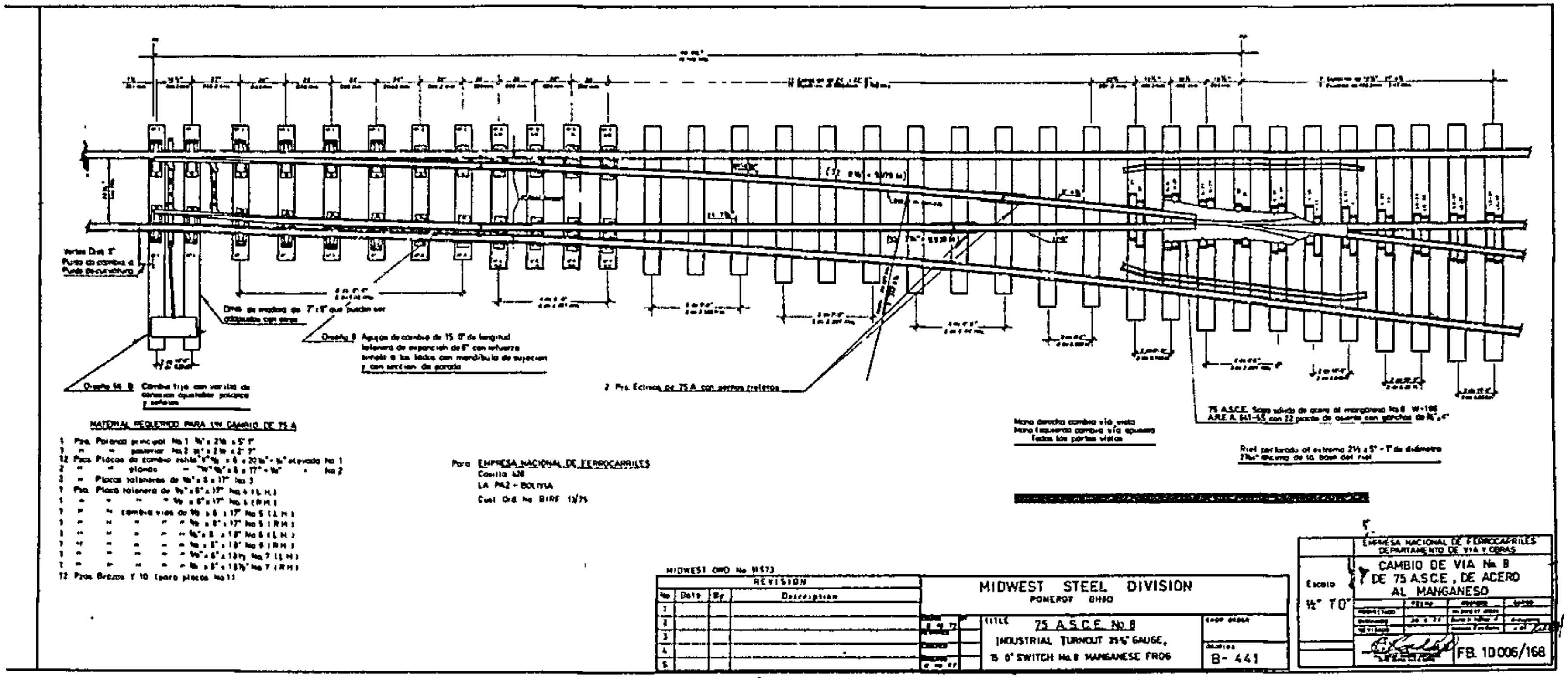


Fig. 3.2.6 Turnout (#8)

(12) Station facilities

The existing line is designed for single-track construction.

Station tracks will be designed for 750 m in effective length and 4.50 m in space between tracks with consideration to the occasion on which two up and down trains may pass over each other.

Construction of a station will include the station main building and the station master's residence.

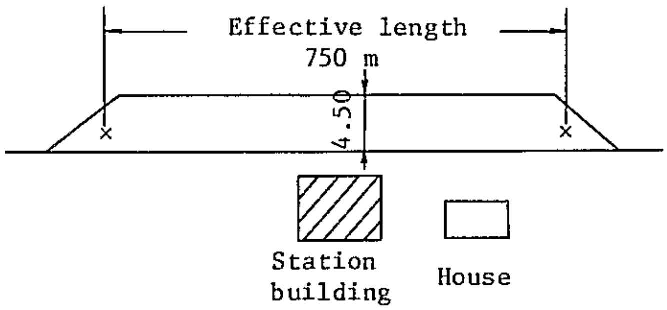


Fig. 3.2.7 Schematic View of Station

(13) Operation security system

The operation security system will normally be of station-to-station block, ticket system.

Inter-communication between stations will be made by means of both telephone and radio.

Railway markers will include kilometer posts and other posts for indication of grade, curve radius, circular curve, start and end points of transition curve, cant, slack, speed limit and clearance post of tracks at station.

3-3 Comparative Studies on Improvement Plans

The optimum plan will be selected after comparative studies on the following alternatives (Fig. 3.3.1).

3-3-1 48 km + 000 m ~ 57 km + 650 m (Tunnel Construction)

The railway line in this section is laid under the unfavorable conditions of 21/1,000 average grade and 95.67 m minimum curve radius, passing the maximum peak at 4,137 m altitude, where the maintenance care for the track is extremely difficult. Therefore, the existing track affects greatly the security of train running safety and, still more, requires larger maintenance cost per annum as compared with the track in any other sections.

Such being the circumstance, ENFE intends to make short-cut of the existing route by construction of a tunnel, as shown in Fig. 3.3.2, with a view to securing running safety of the train and also saving both maintenance costs and operating expenses.

The section is situated at the divide of Cordillera Oriental. At a general look on the geological condition near the proposed route for tunnel construction, it is observed that the base rock consists of alternation of sand rock and shale of the Paleozoic era and sand rock, seemingly without any large fault zones.

The tunnel is planned through the rock bed for its greater portion, except for the section of about 200 m with relatively thin earth covering toward the Oruro-side end, where it may run through unsolidificate sediments such as talus, etc.

Although such sediments may not originate so much ground water, the geological condition for that section does not seem to be favorable for the sake of maintenance even after completion of the tunnel. For this reason, in order to avoid such inconvenience to a possible extent, it is considered better to move the ENFE's originally planned route slightly to the south as shown in Fig. 3.3.2.

Prior to start of the construction work, all unconfirmed conditions of unsolidificate sediments and rocks must be checked by boring test.

3-3-2 101 km + 000 m ~ 110 km + 000 m

The existing railway line in this section runs alongside the left bank of the Rio Arque for its greater portion, except a certain portion making detour therefrom so as to cross the stream of Rio Changora, the largest tributary to the Rio Arque.

The valley is V-shaped to considerable depth with almost none of flat space at its bottom. The railway line is laid mostly in the cut and reclaimed section on the slope of mountain side.

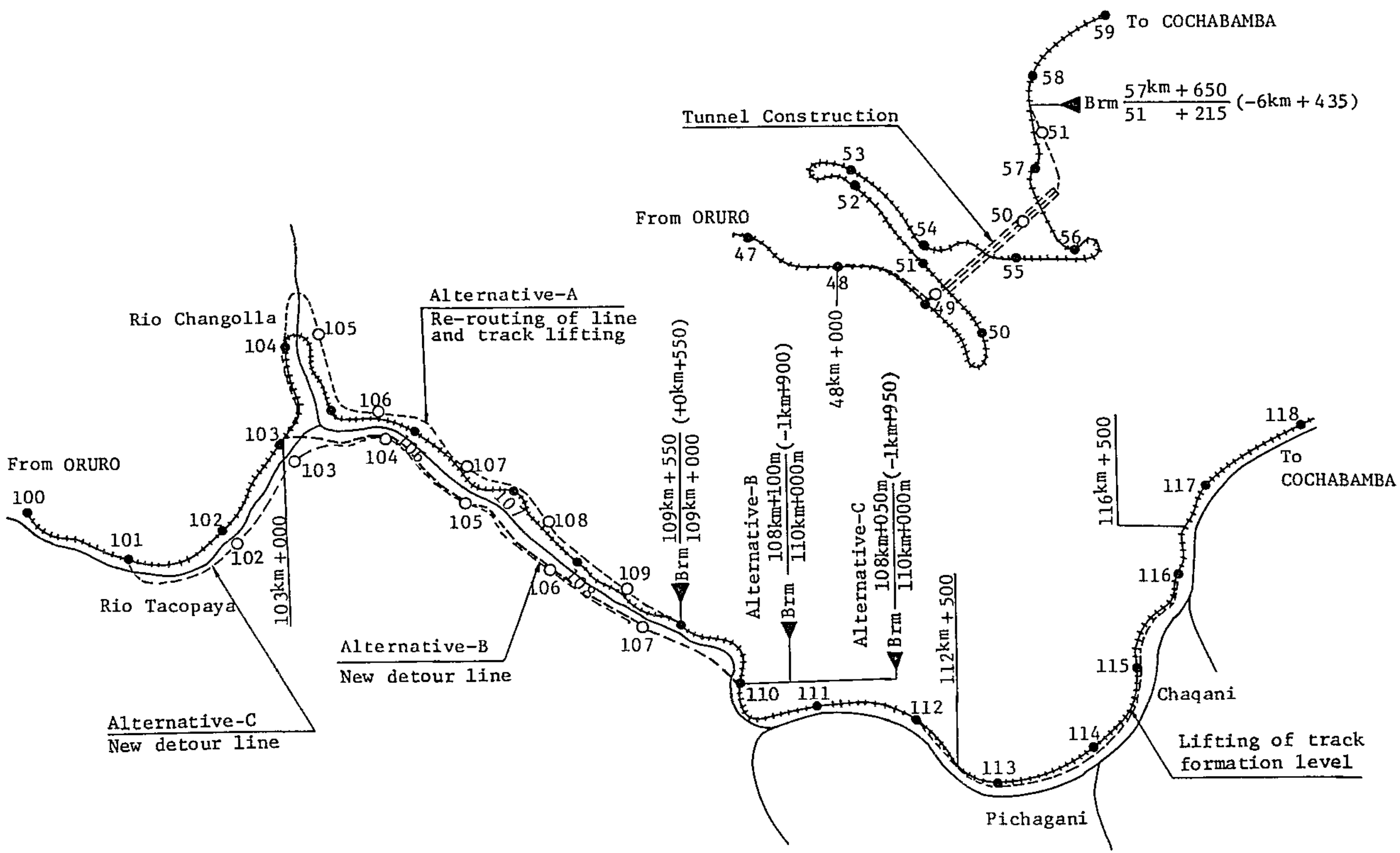


Fig. 3.3.1 Rehabilitation Project

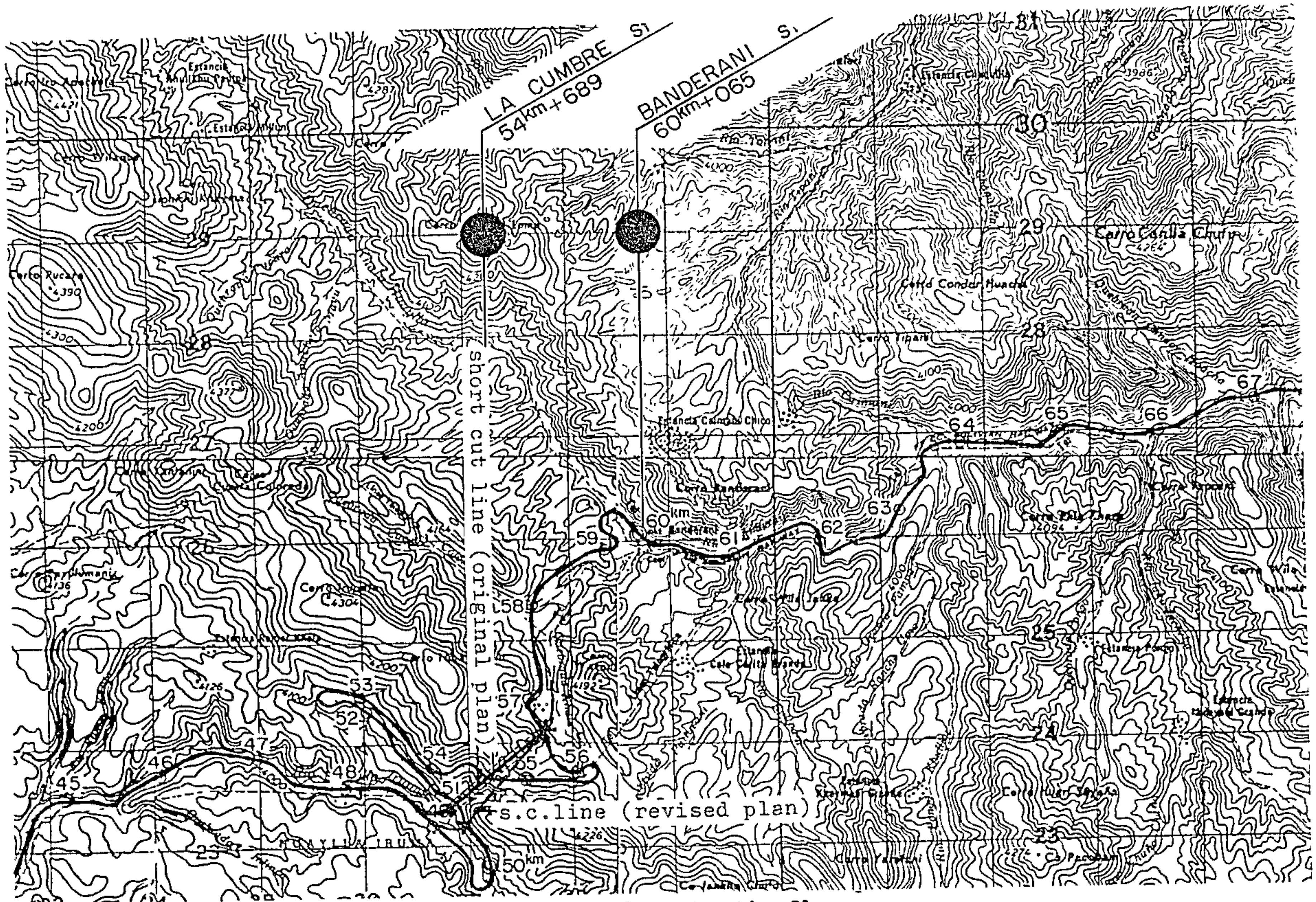


Fig. 3.3.2 Tunnel Construction Plan