REPUBLIC OF BOLIVIA

BOLIVIAN NATIONAL RAILWAYS' REHABILITATION PROGRAM

FINAL REPORT

VOLUME I

FEBRUARY 1980

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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

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PREFACE

In response to the request made by the Government of the Republic of Bolivia, the Government of Japan has decided to cooperate in conducting a feasibility study on the restoration from damage of the Santa Cruz - Columba section of the Eastern Line, and of the Oruro - Cochabamba section of the Western Line of the Bolivian National Railways, (ENFF) as well as in preparing a detailed reconstruction plan for the said Eastern Line.

For this purpose the Japan International Cooperation Agency (JICA), commissioned by the Japanese Government, dispatched to Bolivia a survey team consisting of nine experts, headed by Mr. Yoichi Tanabe, Project Director of International Department, the Japanese National Railways for a period of 31 days starting from July 12, 1979.

This report has been prepared on the basis of the field survey in Bolivia, further studies made by the team after its return to Japan and its discussions with officials concerned of the Government of Bolivia.

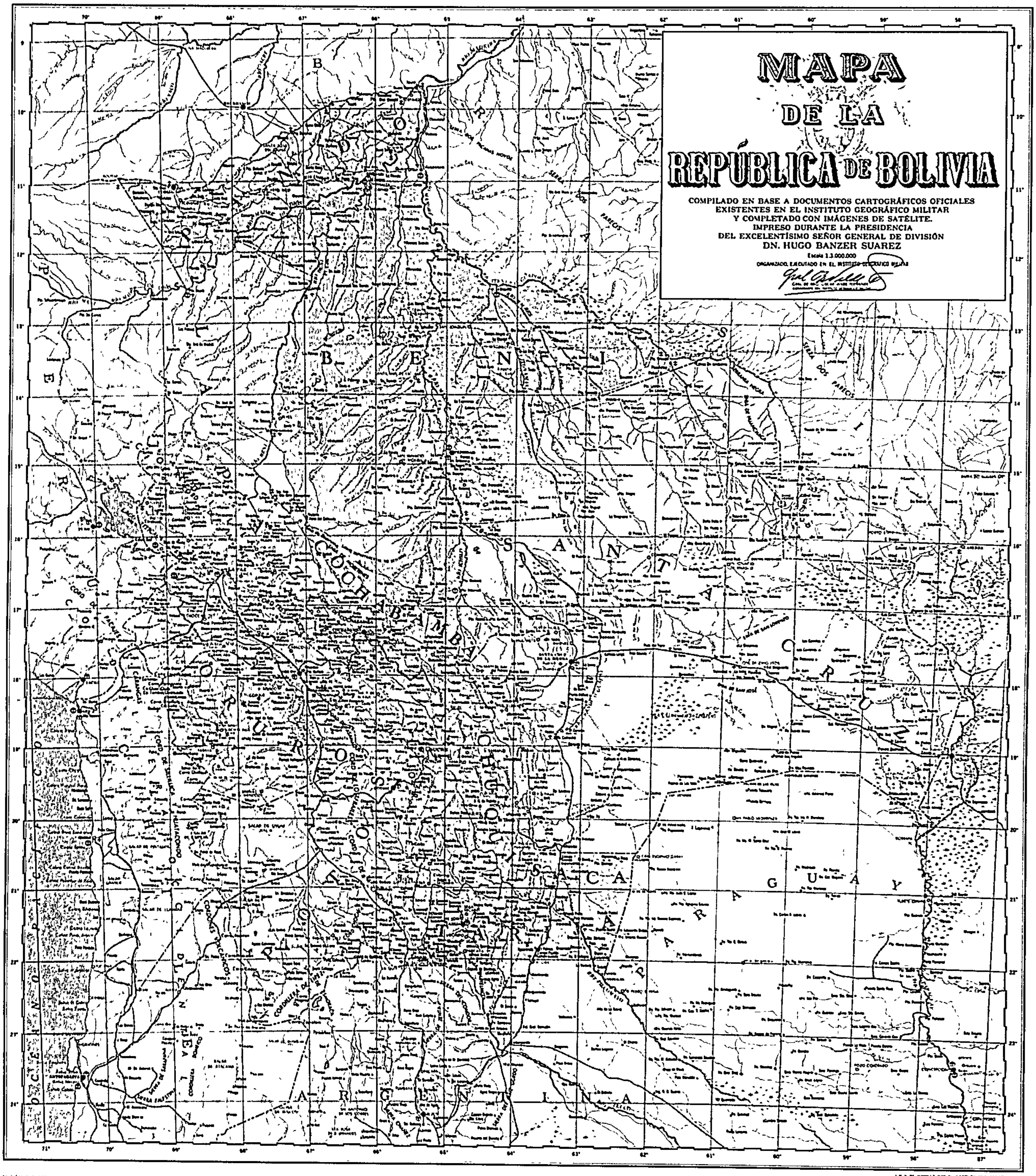
I hope this report will prove to be useful for formulating the rehabilitation plan and will contribute to closer relations between Bolivia and Japan.

I wish to express my deep appreciation to the Government and officials concerned of Bolivia for their cooperation extended to the study team.

Keisuke Arita

Keisuke ARITA

President,
Japan International Cooperation Agency.



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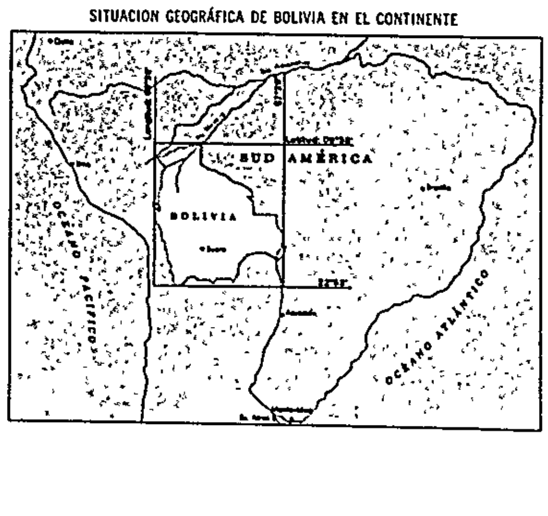
PROYECCIÓN CÓNICA CONFORME DE LAMBERT

SIGNOS CONVENCIONALES

NOTAS GENERALES

SITUACION GEOGRÁFICA DE BOLIVIA EN EL CONTINENTE



BOLIVIAN NATIONAL RAILWAYS' REHABILITATION PROGRAM

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RECOMMENDATION AND SUMMARY

I. RECOMMENDATION

The following is the summary of conclusion reached from the result of the field survey conducted in July, 1979 and also from the result of the feasibility study made for rehabilitation of the Santa Cruz - Corumba railway section by reference to the data furnished by courtesy of Bolivian National Railways (hereinafter ENFE).

1. The latest damage was caused evidently by the unprecedent scale of rainfall in the history of the said railway since its opening. Especially, greater damage was incurred to those structures crossing the streams in the mountainous area, where most of tangible structures were washed away or destructed by high rise of flood and avalanche of sand and stone. After occurrence of such disastrous damage, local topography was deformed to such extent that it may induce easily the damage of similar nature in the future. This must be borne in mind as the vitally important factor in drafting the rehabilitation plan.

2. In determining the rehabilitation plan, comparative studies have been made on five alternatives including, not only rehabilitation of the existing line, but also the plan for partial construction of a new line or the detour line construction plan away from the existing damaged section. For final choice the existing line rehabilitation plan has been compared with the detour plan by construction of a new 106 km line, as the result of which the detour plan has been proved to be advantageous over the other both economically and technically.

   The reason why the 106 km new detour line construction plan is of greater economic advantage can be fully explained by the fact that the rehabilitation plan of the existing line would require a greater number of bridges and other structures at many points to be restored and also need separate arrangements for renewal of the track, while the new detour line construction plan could establish most of the total railway line on the flat ground, thus reducing the number of bridge structures to be constructed.

	Existing line rehabilitation	New detour line construction
	(Million $b)	(Million $b)
Project cost	518	598
Track renewal cost	159	9
Total	677	607

3. When both plans are compared by any other factors to be considered besides the construction cost, the new detour line plan would need an extra track length of about 15 km with resultant increase, though not so much, in the operating cost. However, because the alignment of the railway could be improved significantly, there would be decrease in the maintenance cost, which could offset the increase of operating cost to the nearly equal to the other plan in the annual total management expenditure. Rather, the new detour line plan has its own advantage, in that it could reduce the running time of a train by about 20 minutes. In the case of the existing line rehabilitation plan, there would be still more expenditures to be anticipated for prevention of probable disastrous damages or for minor repair works to patch up small damages to be further incurred, those such costs are not included in this cost comparative study.

   The new detour line plan proposes a 12 ‰ grade section for the purpose of construction cost saving. This would seldom affect train operation over the whole section and could still provide possibility of improvement at any time.

   The problem involved in the new detour line plan can point to two villages alongside of the existing line. For this comparative study, the project cost includes the cost to be required for removal of the track between Robore and Chochis to be used as a public road, the cost for remodeling of the crossing section on the river bed and the extra cost to be incurred by bus operation.

   In conclusion, it is highly advisable for the Government to finally select the detour plan by construction of a new line with greater preferrability in both technical and economic aspects.

However, in view of the fact that the final choice from those two alternatives should be the matter to be left to discretion of the Bolivian Government, we refrained from taking up only one out of those two and made economic and financial analyses for both of the two (2) alternatives.

4. The result of economic and financial analyses on those rehabilitation plans has assured that either one of the two (2) alternatives has a greater feasibility, whose implementation will be of much significance not only to the nation's economy of Bolivia but also to the management of ENFE, since there would be greater loss to be incurred if the railway remains as it is without any measures to be taken for restoration from damage. Then, conclusion has been reached that prompt actions should be taken for implementation of the rehabilitation project.

	Existing line rehabilitation	New detour line construction
Economic internal rate of return	26.1%	28.3%
Financial internal rate of return	9.2%	10.2%

II. SUMMARY

1. Damaged Conditions

(1) Rainfall

The rain which brought a great damage to Eastern Line, continued from 13th to 17th of January, 1979 as recorded in the observation data available at Robore. The cumulative total of precipitation for the consecutive 3 days was recorded at 490 mm and the daily maximum reached as much as 250 mm. By reference to the precipitation data in the region for 12 years since 1968 this rainfall can be assessed at being equal to nearly 250-year probability precipitation.

(2) Damages

1) Mountainous area

The railway division between about 354 km and 364 km, about 10 km in total length, runs through the mountainous area, where damages incurred may be summarized as follows:

- Destruction of structures due to avalanche of sand and stone
- Erosion and washout of structures due to the swell of water in the stream
- Collapse of slope surface

In the mountainous area, all the crossing structures over rivers and streams were suffered from serious damages, either destroyed completely or washed away. This was evidently due to avalanche of sand and stone emerging with large destructive power from and upon swelling of the river. Such avalanche normally comes not only from the rainfall but also otherwise from some large influential factors such as topographic or geological conditions. In this region, there had been fortunately no occurrence of the avalanche over the past two decades since opening of the railway to the public traffic. However, as the result of latest damages, an extremely high probability of causing

reoccurrence of such avalanche can be apprehended toward the future, as evidently observed from the deposits of sand and stone which still remain in the river course as well as from the newly marked erosion front-line near the generating source of sand and stone avalanche.

2) Flat area

The flat area was flooded with pouring of high-risen water almost at the same time from each stream having a profound basin into the main river. As the result, the structures including embankments and bridges were collapsed or washed away. Besides those, the roadbed were buried under the deposit of soil or sand from avalanche and the river crossing the railway was nearly blocked out with high-risen river bed.

3) Damages over the whole line

The roadbed was washed away and the track was buried resulting from collapse or erosion of cut or embanked slope surfaces under heavy rainfall.

(3) Railway damages and temporary restoration

Damages and emergency measures taken for temporary restoration are as follows:

	No. of points in damage	Length (m)	Measures taken
Embankment washout		2,850	Restored slope surface at 1:1
Slope surface collapse		1,270	Restored
Roadbed washout		230	Restored
Soil and sand deposit		2,950	Removed
Destroyed bridge	1		Temporary bridge
Total	1	7,300	

(4) Assessed strength of temporarily restored structures against disastrous damage

It is obvious that any damage should occur again and again every year to such an extent as may hinder the transport if the structures still remain unfixed as they stand now.

Those damages to be anticipated annually in the future are:

- Destruction of river-crossing structures due to deficient sectional area of drainage
- Destruction of structures due to declined or suspended function of drainage
- Erosion and washout of earth structure from storm water
- Destruction of temporary bridges

What is more, there are various damages to be anticipated which may lead to all-out destruction or collapse of structures at the time of heavy rainfall or at the reoccurrence of avalanche of sand and stone. However, assessment made hereunder is based principally upon the result obtained from the survey of the present status of drainage capacity.

Deficiency in the required sectional area of the temporarily restored structure is estimated at 75 per cent of the total. The drainable section area covers only 22 per cent at average as against the required total section, corresponding to a strength of 40 mm per day at its conversion into precipitation.

2. Rehabilitation Plan

(1) Basic thought for preparation of plan

As the result of the latest disastrous damage, the transport operation in the Santa Cruz - Corumba section was suspended for a long interval which, in turn, brought a grave impact to the national economy of the Republic of Bolivia. Although such damages have been restored just temporarily by emergency measures, those present unstabilized conditions will not only require more and more costs

to patch up with every year, if they remain as they are now without any drastic measures, but also keep on shaking the national economy by frequent suspension of the transport operation.

Therefore, the purpose of the planned rehabilitation is to exterminate any potential source of such disastrous damages as lately experienced.

The rehabilitation plan will be drafted in line with the basic thought as stated hereunder.

1) Necessary measures will be taken for prevention of any such disastrous damage as may be foreseeable, on the basis of the survey result.

2) The measures will be taken for rehabilitation with priority to such specific structures that would be suffered from greater loss or damage at occurrence of the natural disaster and would require a considerably long span of period for restoration from damage. Once such measures are taken up, it should be planned perfectly with full care to insure that the investment would not mean any waste of money.

3) No measures will be taken for those structures which would require much cost notwithstanding less or damage to be anticipated and relative easiness in recoverly from damage.

(2) Projected precipitation from rainfall

The distribution function is determined by such assumption that the yearly maximum rainfall would constitute logarithmic regular distribution, by use of the daily rainfall-recorded data for the latest 12 years from 1968 to 1979 at Robore. Then, the rainfall of 170 mm per day of its 50-year probability equivalence is determined as the projected precipitation for this rehabilitation plan.

(3) Rehabilitation plan for the existing line (Alternative-A)

The plan is outlined as follows:

1) River-crossing section

Because the crossing section with potentiality of generating avalanche should require a sufficient sectional area to permit free passage avalanche of sand and stone, it will be designed for bridge construction type without use of piers in the stream.

In the crossing section where no such avalanche is anticipated, it will be designed for economic construction by either type of box culvert or bridge, whichever more economical, depending upon required drainage section (No. of bridge 18, box culvert 28).

Since the construction work must be carried out without suspension of train operation, it will be performed by installation of either a temporary by-pass track or temporary supports to the existing track.

2) Cutting or embankment

In any section where the surface is not sloped to its required grade, it will undergo re-cutting treatment as stipulated by the earthwork standard and, at the same time, will require improvement of the drain channel.

3) Railway line

The railway in the 16 km section which was submerged and buried under sand and stone will be raised to a higher elevation. The railway line in the three sections over 4.7 km will be moved and relocated because of expected advantage from doing so in both design and construction.

(4) Comparative studies on alternative plans

Besides the rehabilitation plan of the existing line (Alternative-A), the following alternative plans will be taken up for comparative studies with the aim to prepare the proper rehabilitation plan.

Alternative-B: To construct an 106 km new detour line leading to Robore, being branched off at Taperas and going round away from the damaged area

Alternative-C: To construct a new 13.4 km detour line in the El Porton - Chochis section suffered especially from greater damage and to rehabilitate all the rest of the existing line

Alternative-D: Similarly, to select a route on the opposite side of the river for construction of a 21.8 km line and to rehabilitate all the rest of the existing line

Alternative-E: Similarly, to make a detour line by excavation of a 6.8 km tunnel through Mt. Chochis and rehabilitate all the rest of the existing line

Required construction cost and track renewal cost for each of the four alternatives can be compared as shown in the table below:

(Unit: 1,000 $b)

Alternative	B	C	D	E
Project cost	598,394	785,356	690,302	1,871,382
Track renewal cost	8,720	151,165	144,815	155,544
Total cost	607,114	936,521	835,117	2,026,926
Route length (km)	105.8	89.9	94.0	89.6

From the result obtained as above, Alternative-B is selected as the preferred alternative and compared with Alternative-A rehabilitation of the existing line.

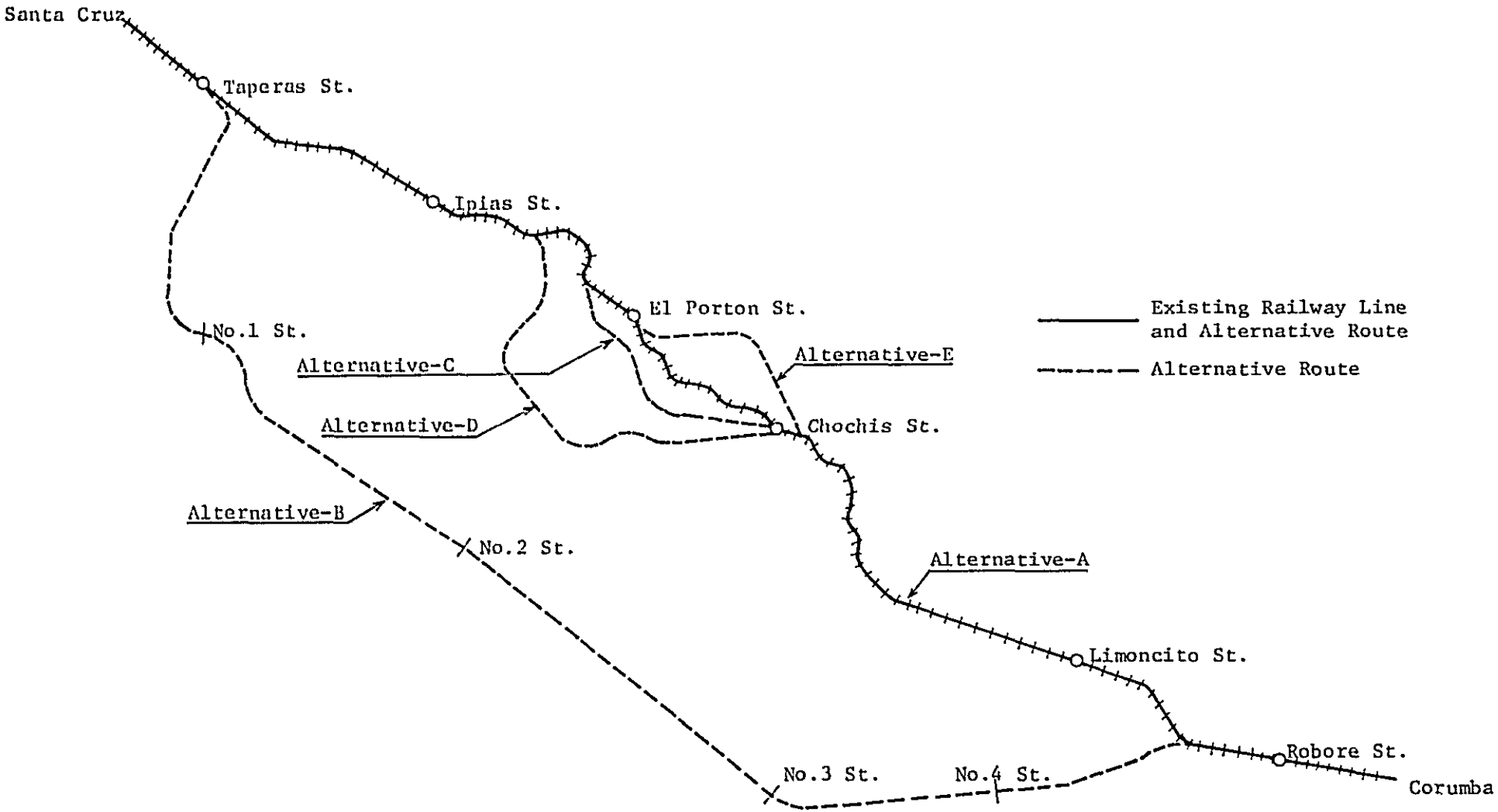


Fig. Alternative Route

(5) Selection of optimum plan

Alternative-A for rehabilitation of the existing line and Alternative-B for construction of a new detour line are compared below for final selection:

(Unit: 1,000 $b)

Alternative	A	B
Project cost	517,988	598,394
Track renewal cost	159,310	8,720
Total	677,298	607,114
Route length	90,500 m	105,800 m
Curve R=500 m and under	14,600 m	100 m
Grade 10‰	41,700 m	32,000 m
12‰	-	7,000 m
Running time		Reduce 22 min.

1) The existing line rehabilitation plan requires track renewal cost for the Taperas - Robore section separately and additionally. Therefore, for economic comparative study, it must be made by inclusion of such cost in Alternative-A.

2) Alternative-B will have longer railway route by 15 km Alternative-A and, therefore, will increase slightly maintenance and operation costs. On the other hand, however, as the result of improvement for curved sections the track maintenance cost will be reducible on the contrary. It can be said that there will be no large difference, as a whole, in the maintenance and operation cost between Alternative-A and -B.

3) Alternative-B proposes construction of new 12‰ graded track for one section for the purpose of saving the construction cost. This is quite acceptable without problems because the section from Taperas to Robore forms an upward slope. Improvement work can be done at any time, if necessary, without any loss to the construction cost.

4) After all, it has been made clear that Alternative-A for rehabilitation of the whole damaged section would require more cost because of wide spread and large scale of damage with the jeopardized site condition for any future possible damage. On the other hand, Alternative-B for construction of a new detour line can insure full safety against any damage and, what is more, can reduce design and constructional problems to the lesser extent, making no difference in the maintenance cost even with its extra route length and being more advantageous in the substantial construction cost over the other Plan. Besides those merits, Alternative-B intends shortening of the total running time and provides possibility to achieve new development effect.

5) The pre-requisite for determination of the new detour line construction plan is to decide abolition of the existing line between Taperas and Robore. Then, the substitute traffic route may be required to open for public convenience of the town people in Limoncito (500-population) and Chochis (4,000-population). To solve this problem it may be possible that the abolished route after removal of the track should be utilized as the public road. In conclusion, it is recommended from both economic and technical viewpoints that the new detour line construction plan should be adopted preferrably in so for as the circumstance may permit.

Alternative-B Construction Cost Breakdown

(Unit: $b 1,000)

Description	Domestic currency portion	Foreign currency portion	Total
Civil work	103,389	166,482	269,871
Track	51,053	119,124	170,177
Station facilities, etc.	2,534	5,386	7,920
Cost for land acquisition & road compensation others	16,210	29,384	45,594
Survey and design cost	0	31,345	31,345
Price escalation	24,251	49,236	73,487
Total	197,437	400,957	598,394

Alternative-B Construction schedule

Year	1	2	3
Survey and design	⊢———		
Construction work	⊢———	———	———⊣

3. Traffic Demand Forecast

The railway in the Republic of Bolivia is divided separately into Western and Eastern blocks, the total route length of which extends over 3,457 km consisting of 2,071 km in the Western Line and 1,386 km in the Eastern Line. Since a long time ago there has been an idea of connecting together the two separated blocks of railway network for construction of a transcontinental railway, for which several feasibility studies have been made so far. The latest one of those is the preliminary study conducted in 1976 by the Bolivia - Brazil joint consulting firm under the financial sponsorship of the Brazilian Government.

According to the survey result it is estimated that the railway traffic volume between Santa Cruz and Corumba would be 540,000 tons annually in 1979 when the 'Project' could be completed and would reach 1,000,000 tons in '90s (220,000 tons actually in 1978).

(1) Railway line between Santa Cruz and Corumba

The 651 km railway line between Santa Cruz and Corumba, as a division of the Eastern Line included in the latest rehabilitation project, was constructed in 1958 by the "Railway Joint Board" in compliance with the Railway Connection Agreement entered into in 1938 between Bolivia and Brazil. This railway serves not only as the important freight line for export and import to and from Brazil, with which this line is interconnected, but also as the only land transport facility between those two domestic cities.

In 1978 the share of the traffic volume in the total ENFE accounts for 21 per cent at passenger traffic and 22 per cent at freight traffic. The traffic density is 432 persons per km a day for passengers and 536 tons per km a day for freight.

(2) Traffic demand forecast on rehabilitation project

Inasmuch as the purpose of the rehabilitation project is not to improve transport capacity or efficiency of the existing line under this project but to restore the lost function after damage to the original level. Therefore, if the rehabilitation effect can be fully assessed and ascertained by successful completion of the project, there is no particular need of any long-range traffic demand forecast with much uncertainty. For this reason, traffic demand forecast on this project only covers 10 years ahead up to 1988 on assumption that further demand after that year would continue at a constant horizontal level.

In view of the nature contained in the rehabilitation project for recovery from damage, there will be no demand increase to be expected from development. Furthermore, since there is no other available means of public transport in the project section, there

will also be to be anticipated no demand decrease due to transfer of passengers or goods to the other means of transport, even though the project may remain undone. Therefore, the same figure obtained from traffic demand forecast apply to either case of "with project" or "without project".

(3) Figures for traffic demand forecast

The traffic volume in the Santa Cruz - Corumba section has been showing steady growth; 1.72 times in passenger traffic and 1.87 times in freight transportation for the latest decade. Forecast has been made for each of the two different patterns of increase, natural increase and new increase from industrial development, etc.

In order to avoid over-estimation for natural traffic increase, it has been based upon the figure obtainable from extension of the past actual trend or the figure calculated from the increase rate adopted by ENFE, whichever smaller by comparison.

The incremental freight transportation as may be expected from the development plan includes shipments of cement from the production plant now under way for construction at Yacuce (580 km apart from Santa Cruz).

The following is the result of traffic demand forecast in the year 1990:

		'78	'88
Passengers	Natural increase	259,000 persons	320,000 persons
Freight	Natural increase	220,000 ton	344,000 ton
	Increase from development	-	270,000 ton
	Total	220,000 ton	614,000 ton

4. Economic Analysis

Review is made herein to determine if it would be significant in the light of the nation's economy to complete rehabilitation of the railway between Ipias and Robore which still remains restored just temporarily. As the method of such review and evaluation, the economic loss incurred to passengers or freights, together with the costs to be required for restoration from damage, - such loss and cost can be evaluated as 'benefit' in the case of 'with project' - have been evaluated, on assumption that the vicious circle of occurrence of disastrous damage upon railway structure, suspension of train operation and temporary restoration by emergency measures would continue more and more if the rehabilitation project is not executed. Then, the loss and cost thus calculated have been compared with the cost to be required for execution of the project.

The following is the result of cost and benefit analysis on an assumed basis of the 30-year service life of the project:

Description		Existing line rehabilitation	New detour line construction
B/C ratio	Discount rate 10%	2.9	3.2
	Discount rate 12%	2.4	2.7
	Discount rate 15%	1.9	2.1
I.R.R.		26.1	28.3

The result of economic analysis reveals that both of the plans, for rehabilitation and new detour line construction, are sound and healthy in the economic aspect of the project. If the railway division between Ipias and Robore does not go into further improvement beyond the present level of temporary restoration, the artery interconnecting Bolivia and Brazil would be hampered greatly, as the result of which the economic growth of Bolivia would be impeded. In brief conclusion we see every reason to believe that the project should be completed for permanent restoration as soon as possible.

Explanations are given hereunder as to the summary of the analysis result.

(1) Suspension period of train operation

The degree of economic loss to be incurred to passengers or freights can be determined depending upon how long the train operation will be suspended. From this point of view, the period of service suspension must be forecasted as a future normal pattern of train operation.

Then, on the assumed basis that the present status of temporary restoration would induce, at any time, the disastrous damage with resultant suspension of train operation in the face of rainfall in excess of 40 mm per day, the number of days in suspension of train operation may be estimated as follows depending upon the degree of rainfall:

40 mm/day: 5 days
50 mm/day: 15 days
70 mm/day: 30 days

Then, the annual total number of days of suspension can be calculated to be 85 days per year by reference to the latest 10-year daily precipitation record and the number of days as standardized above.

(2) Passenger traffic loss

As for the passenger traffic, the economic loss is evaluated from the probable loss that may arise from individual dealers of commercial goods, estimated as nearly half of the total passengers traveling between Ipias and Robore, being deprived of their transport facilities. The number of such individual goods-carrying dealers to be affected by traffic suspension would be 3,875 persons (for single trip only) in 1983 (completion year of project). On assumption that each person would bring in the goods worthy of 7,000 $b the total loss would amount to 20,414,000 $b.

(3) Freight transport loss

The commercial value of freights per tonnage can be assessed as follows:

Export	20,705 $b/ton
Import	39,772 $b/ton
Local	36,243 $b/ton

From the patterns of countermeasures taken by cargo consigners against the traffic suspension from the latest damage, the future patterns of such countermeasures are assumed as follows for the probable suspension of train operation:

Description	Export	Import	Local	Remarks
Advanced forwarding	0.03	0.035	0.005	Interest and storage charge
Via air	0.03	0.035	0.005	-
Custody	0.38	0.85	0.97	Interest and storage charge
Open yard stock	0.50	0.08	-	Interest
Cease of off-operation	0.03	-	0.02	Loss
Lost value	0.03	-	-	Loss
Total	1.00	1.00	1.00	

By application of the diversified patterns as tabulated, the loss and cost to be incurred by traffic suspension would be calculated to the amount of 86,337,000 $b on the basis of the estimated freight transport in 1983.

(4) Costs for transportation of congested freights

Because of shortage in the present transport capacity to put back all the congested freights into the restored transportation, there is a need of providing one extra freight train available for return-trip operation. Therefore, the assessment of costs includes purchase price and operating cost of such additional train as the estimated cost for transportation of the congested goods.

Vehicle purchase price	
1 - Locomotive	27,370,000 $b
30 - Freight cars	10,215,000 $b
Total	37,585,000 $b
Operating cost during the period of recovery from congestion	399,000 $b

(5) Emergency restoration cost

The total cost required for emergency restoration from the latest damage amounted to 40,749,000 $b including the countermeasures cost against the dry season.

The future contingency cost is thereby estimated at 10,107,000 $b or 9,545,000 $b in shadow price, corresponding to about 1/4 of the total cost required for restoration from the latest damage, on the calculated basis of the following breakdown items:

Temporary bridge construction	:	1/2 of the latest restoration cost
Embankment and track reconstruction	:	1/3 of the latest restoration cost
Box structures and others temporarily restored	:	1/10 of the latest restoration cost

However, it is forecasted that the future contingency cost should continue to swell at an annual increase rate of 10 per cent, since the scale of damage would grow larger gradually under such anticipated condition that the damage should occur every year. On this assumption the forecasted total cost in 1983 would reach the amount of 9,545,000 $b × 1.4 = 13,363,000 $b.

(6) Total of lost costs

Besides such costs as estimated in the preceding items, there are to be considered some other extra costs arising from forced restrictions upon speed and hauled weight and occurrence of derailing accident, in the event that a train would be operated on the temporarily restored track if and when the damage occurs.

Apart from those others, the annual total of loss and cost in 1983 is estimated as follows covering the easily assessable four costs as estimated in the preceding items.

Passenger loss	20,414,000 $b
Freight loss	85,938,000 $b
Extra train operating cost	399,000 $b
Emergency restoration cost	13,363,000 $b
Total	120,114,000 $b

In addition to the above total, the vehicle purchase price of 37,586,000 $b must be taken into account in the year 1983.

(7) Cost to be incurred in connection with execution of the Project

With regard to the finally selected two (2) alternatives for rehabilitation of the existing line or for construction of a new detour line, the project cost can be compared as follows by conversion into economic costs on the shadow-price basis:

Existing line rehabilitation	438,058,000 $b
New detour line construction	507,424,000 $b

On assumption that track renewal would be made, the cost could be compared as follows:

Existing line rehabilitation	134,715,000 $b
New detour line construction	7,374,000 $b

The cost related to operation and maintenance are not included here, since the transport condition between those two alternatives are regarded as being identical.

5. Financial Analysis

For the period starting from 1964, the year in which ENFE was founded, up to 1973 the ENFE's financial situation was going from bad to worse. However, it began to take a favorable turn as the result of the financing aid granted by the government and the rate increase. Notwithstanding the rate increase of freightage, the transport volume of freight has

been on the steady increase and thus ENFE has been gaining more or less profit until 1977. In 1978, the account turned into deficit again, though not so much, because of increase in personnel expense, more than 50 per cent of the total operating expense, and also because of payments of interest now showing gradual increase.

The purpose of this financial analysis is to assess and evaluate feasibility of the proposed rehabilitation project in the light of profitability to be required necessarily as undertaking of a corporation.

The following is the calculated result (internal rate of return) to see the maximum payable rate of interest for the borrower, on assumption that the rehabilitation project would be financed by the borrowing fund and the capital cost could be covered by the probable decrease in the annual fare income and the contingency which would be incurred otherwise, were it not for implementation of the project.

The analysis result reveals that the proposed project is financially safe and sound.

Rate of interest	Existing line rehabilitation	New detour line construction
	9.2%	10.2%

Explanation is given hereunder by the summary of this analysis.

(1) Cost to be incurred in connection with execution of the project (not reflecting price variations)

1) Project cost

	$b	(US$)
Existing line rehabilitation	454,375,000	(22,719,000)
New detour line construction	524,907,000	(26,245,000)

2) Track renewal cost

	$b	(US$)
Existing line rehabilitation	139,746,000	(6,988,000)
New detour line construction	7,649,000	(382,000)

(2) Decrease in earnings from passenger fare

The probable decrease of fare income is calculated on assumption that all the passengers traveling through the Tapelas - Robore section would refrain from going on their trip while the train is left out of service. The probable decrease of the fare income in 1983 may be estimated to the amount of 3,746,000 $b from the total number of 40,984 passengers.

(3) Decrease in earnings from freightage

The probable decrease in the annual freightage income can be estimated from the total freightage of such items as may not require or rely upon the railway transport, while the train is left out of service, by means of air cargo, by loss of value or by suspension of operation. Such decrease in the annual total freightage in 1983 is calculated as tabulated below:

Description	Tonnage	Distance	Rate	Decrease in earnings
Export	873 ton	651 km	0.9 $b	511,000 $b
Import	1,680	645	0.9	975,000
Local	159	336	0.9	48,000
Cement	27,946	583	0.876	14,272,000
Total	30,658 ton	-	-	15,806,000 $b

(Note) The figure in the column of 'Rate' for cement does not include the operating cost during the suspension of train operation.

(4) Cost for transportation of congested freight

Vehicle purchase price	
1 - locomotive	27,370,000 $b
30 - freight cars	10,215,000 $b
Total	37,585,000 $b
Operating cost (1 round-trip per day)	399,000 $b

(5) Emergency restoration cost

By use of the financial cost calculated in the 'Economic Analysis' the contingency cost for emergency restoration is estimated at 10,107,000 $b × 1.4 = 14,150,000 $b.

(6) Total annual loss or expenditure

The total annual loss or expenditure is estimated as follows:

Decrease in passengers fare income	3,746,000 $b
Decrease in freightage	15,806,000 $b
Extra train operation cost	399,000 $b
Emergency restoration cost	14,150,000 $b
Total	34,101,000 $b

In addition to the above total the vehicle purchase price of 37,585,000 $b must be taken into account.

CHAPTER 1. INTRODUCTION

1-1 Purpose and Scope of Study

The latest study was conducted by the Japan International Cooperation Agency (JICA) in accordance with laws and regulations enforced in Japan, as a part of the overseas technical cooperation extended by the Government of Japan in response to the request made by the Government of the Republic of Bolivia.

The study was carried out as defined by the "Scope of work" mutually confirmed by both of the Governments. The purpose of the study was to assure technical, economic and financial feasibility of the proposed rehabilitation project in the El Porton - Robore section of the Eastern Line, thereby drafting the plan for rehabilitation.

In order to achieve this purpose, the site survey including aerial photography was conducted in July, 1979.

This report is the presentation of draft by summary of the survey result and by review of various data furnished by courtesy of the Bolivian National Railways (hereinafter ENFE).

Attention is hereby invited to the latest change in the exchange rate of the local currency; from 1 US$ = 20$b to 1 US$ = 25$b as of November 1979, after this report was prepared on the basis of the prevailing economic situation at the time when the site survey was conducted. It is therefore cordially requested that project and other costs should be re-estimated properly with due allowance to the influence from the possible price increase.

1-2 Project Background

The heavy rainfall attack in January, 1979 brought about serious damages over 50 km distance in the hilly zone near Robore, which is situated almost in the middle between Santa Cruz and Corumba (651 km) in the Eastern Line of the ENFE, and train operation came into suspension as the result.

The said railway is of vital importance to the Republic of Bolivia, in that it is the sole route established for land transportation between Bolivia and Brazil having steady increase in the traffic volume of both passengers and freight since its opening in 1958.

The Government of Bolivia proceeded promptly with arrangements of necessary funds for emergency recovery from damages and the National Railway authorities resumed the train operation in the said section. In fact, however, the damaged section has been restored only temporarily, for instance, by such emergency step as construction of embankment in the river-crossing section for passage of trains. Under the present circumstance, the section still in question may possibly cause traffic suspension again in the rainy season to come and, what is more, it still entails some operational restrictions in the running speed or in the number of cars for each train make-up. Therefore, it is now in pressing need to complete the permanent work for restoration and secure the stabilized railway traffic route.

1-3 Supervisory Committee and the Study Team

1-3-1 Supervisory Committee

Prior to starting the study, JICA organized the Supervisory Committee with the membership of 4 experts nominated for the sake of perfection of this study. This Committee supervises the study policy, items and procedure of investigation.

Chairman

E. MUTSURO	International Cooperation Officer Rolling Stock Industry Division Railway Supervise Bureau Ministry of Transportation

Member

H. OKAWA	Foreign Affairs Division Ministers Secretariat Ministry of Transportation
R. YAMADA	Civil Engineering and Electricity Division Private Railways Department Railway Supervise Bureau Ministry of Transportation
F. TACHIBANA	Special Technical Adviser Japan International Cooperation Agency (JICA)

1-3-2 Members of the Study Team from JICA

Team Leader	Eng. Yoichi TANABE Director International Department of the Japanese National Railways (J.N.R.)
Sub-Leader Geological Investigation	Eng. Keiya YOSHIKAWA The Technical Institute of J.N.R.
Plan for Prevention of Disaster	Eng. Yoshinori KUROKAWA The Technical Institute of J.N.R.
Plan for Rehabilitation of Railways	Eng. Hideaki ETOH International Department of J.N.R.
Design and Plan for Principal Structure	Eng. Misao UEDA Adviser to Japan Railway Technical Service (JARTS)
Economical Evaluation: Financial Analysis	Eng. Kenji MAEDA Adviser to JARTS
Hydrological Investigation	Eng. Yoshikazu ITOH Adviser to JARTS
Aerophotograph	Eng. Kinya NAKAMURA Adviser to JARTS
Plan for Railways: Prevision of Demand	L. Akira YASUZAWA Chief Administration Department, JARTS

1-4 Survey Tour Itinerary

The Survey Schedule of Bolivian National Railways' Rehabilitation Program

Sequence	Month & date	Week day	Schedule	Survey activities
1	July 10	Tue.	Departure from New Tokyo International Airport	
2	11	Wed.		
3	12	Thur.	Arrival in Lapaz; Courtesy call to Japanese Ambassador in Bolivia	Discussion on basic problems and survey details
4	13	Fri.	Discussion meeting at ENFE head office	Meeting with President and top executives of ENFE and local counterpart; Signed on S/W
5	14	Sat.	Discussion meeting at ENFE head office	Data assembling (Aerial photograph)
6	15	Sun.	Group No. 2 (Geology, anti-disaster, structure and rehabilitation plan) Lapaz → Santa Cruz	Group No. 1 (Demand forecast, economic evaluation and financial analysis); Data assembling
7	16	Mon.	(Anniversary of the founding of Lapaz State) Group No. 2 Santa Cruz → Robore	Group No. 1 Data assembling Group No. 2 Discussion meeting with Eastern Railway Bureau of ENFE about Route Survey
8	17	Tue.	Group No. 1 Visit to Ministry of Transportation Group No. 2 Site survey	Discussion meeting on road traffic conditions; Ipias ∿ El Porton Survey on geology, disaster prevention and structure
9	18	Wed.	Group No. 1 Visit to ENFE Head Office Group No. 2 Site survey	Hearing on transport condition at disastrous damage; El Porton ∿ Chochis Survey on geology, disaster prevention and structure
10	19	Thur.	Group No. 1 Visit to ENFE Head Office Group No. 2 Site survey	Discussion meeting on rainfall and economic analysis; Chochis ∿ Limoncito Survey on geology, disaster prevention and structure
11	20	Fri.	Group No. 1 Lapaz → Santa Cruz Group No. 2 Site survey	Discussion meeting with Eastern Railway Bureau of ENFE; Limoncito ∿ Robore Survey on geology, disaster prevention and structure

Se-quence	Month & date	Week day	Schedule	Survey activities
12	July 21	Sat.	Group No. 1 Santa Cruz → Robore Group No. 2 Site survey	Survey on damaged sections; Taperas ∿ Robore Survey on new alternative route
13	22	Sun.	Group No. 1 Site survey Group No. 2 Robore → Santa Cruz	Survey on damaged sections
14	23	Mon.	Group No. 1 Robore → Santa Cruz Group No. 2 Eastern Railway Bureau of ENFE	Meeting for briefing and discussion on survey results
15	24	Tue.	Visit to Eastern Railway Bureau of ENFE	Discussion meeting held by each diversified survey sector
16	25	Wed.	Visit to Eastern Railway Bureau of ENFE	Discussion meeting held by each diversified survey sector
17	26	Thur.	Visit to Eastern Railway Bureau of ENFE	Discussion meeting held by each diversified survey sector
18	27	Fri.	Visit to Eastern Railway Bureau of ENFE	Discussion meeting held by each diversified survey sector
19	28	Sat.	Santa Cruz → Cochabamba Meeting at Cochabamba Local Office of ENFE Cochabamba → Parotani	
20	29	Sun.	Group No. 1 Site survey	Survey on local road condition in areas of Parotani and Oruro
21	30	Mon.	Site survey on Western Line	Site survey for 113km-116km section (Oruro base depot)
22	31	Tue.	Group No. 1 Parotani → Oruro Group No. 2 Site survey on Western Line	Site survey for 101km-105km section (Oruro base depot)
23	August 1	Wed.	Group No. 1 Oruro Group No. 2 Site survey on Western Line	Discussion meeting on rehabilitation plan and alternative transport means; Site survey for 105km-110km section (Oruro base depot)
24	2	Thur.	Group No. 1 Cochabamba → Lapaz Group No. 2 Site survey on Western Line	Site survey for 113km-116km section (Oruro base depot)
25	3	Fri.	Group No. 1 Visit to ENFE Head Office Group No. 2 Cochabamba → Lapaz	Briefing on site survey results
26	4	Sat.	Visit to ENFE Head Office	Summarization of site survey results; Data sorting and filing
27	5	Sun.	Visit to ENFE Head Office	Preparation of progress report

Se-quence	Month & date	Week day	Schedule	Survey activities
28	August 6	Mon.	(Anniversary of Independence)	Data sorting and filing
29	7	Tue.	Visit to Japanese Embassy and ENFE Head Office	Report to Japanese Ambassador on survey results
30	8	Wed.	(Induction Ceremony of President)	Data sorting and filing
31	9	Thur.	Meeting at ENFE Head Office	Report to President and other top executives of ENFE on survey results; Presentation of progress report
32	10	Fri.	Preparation for departure	
33	11	Sat.	Departure from Lapaz	
34	12	Sun.		
35	13	Mon.	Arrival in New Tokyo International Airport	

CHAPTER 2. DAMAGED CONDITIONS

2-1 Topographic Outline

The disasters took place in the railway division, as shown in Fig. 2.2.1, alongside the Santiago mountains which range almost east and west on the plateau at 300 to 600 m above the sea level, forming a watershed of Amazon and Laplata river systems.

The highest peak in the mountains is Mt. Chochis of 1,290 m altitude, at the foot of which the railway is operating. On the slaint surface facing the south and the wide-open highland on its opposite side there are cliff to formed by influence of erosion from the main stream and swamps of the Chochis River and talus cone is developed at the mountain foot. Besides, large fans are formed in lower reaches of the branch streams.

In the lower reach of the Chochis River, the river bed is of very slow and gentle grade with wide spread of flood plain. The river flows down in shape of free meanders and leaves humid zones here and there in its flood plain.

2-2 Geological Outline

Geology of bed rocks in the mountains and the plateau consists of alteration of sandstone and slate of Paleozoic and its bedding plane is almost horizontal level.

The upper stratum, covering the Paleozoic stratum, in the mountains and the plateau on the railway starting side of Chochis Railway Station contains distribution of unstratified coarse red sandstone which is said to be of Mesozoic formation.

This sandstone forms up mountains and plateau such as Mt. Chochis, Cerro la torre, the opposite side plateau and the hilly zone ranging from Ipias to El Porton Station. All the slopes consisting of such sandstone are steep with exposure of rocks.

There exist talus deposit at the foot of Mt. Chochis and Cerro la torre and also fan deposit developed at lower reaches of swamps encroaching into Mt. Chochis. Scattered all over the ground of such fan deposit are greater boulder stones still bearing the marks of debris flow in the past.

The mountainside of Paleozoic sedimentary rocks at the downstream of the Chochis River, where there is no distribution of red sandstone, forms a gentle slope having the exposed bed-rocks weakened to a considerable extent.

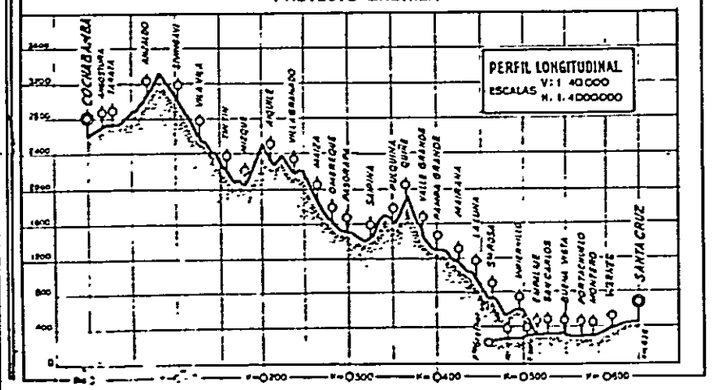
The flood plain existing downstream of the Chochis River appears partially to constitute a thick sediment carried down from the upstream, though the actual conditions of the sediment could not be fully clarified only by surface reconnaissance. In fact, however, it seems that at the bottom of swamps the newly sediment is not so thick that rocks are exposed here and there at the bottom.

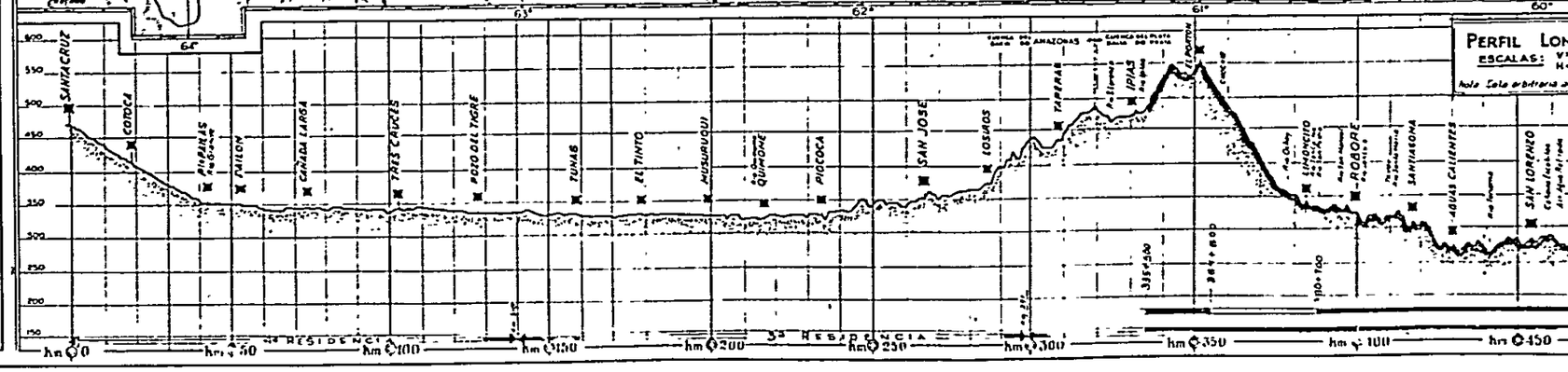
The plateau facing the railway line on the opposite side may be covered with a Deluvial deposit consisting of red sand which is not easily distinguishable from the weathered zone of bed rocks. Though thickness of Deluvial deposit still remains unclarified only by a surface reconnaissance, it may not be so thick as conjectured from the outcropped condition at the cliff. This stratum can be assured of its sufficient bearing capacity as a bed ground for any embankments and small bridges.

Suitability of soil as earth material for banking in the surveyed area is as shown in Appendix-1 indicating the soil test result on the downstream embankment. The soil consists mostly of sand containing inorganic silt and cohesionless clay at about 40 per cent of the total. Notwithstanding its relatively small specific gravity in soil particle, it may be undoubtedly suitable as banking material. Furthermore, since the soil on the upstream and also on the plateau may have its increased share of coarse grains, there seems to be no unsuitable quality of soil as a whole for banking. However, all soil available for this purpose is of such nature as may require slope protection for embankment upon its completion.

F.C. COCHABAMBA SANTA CRUZ

PROYECTO GRETHER





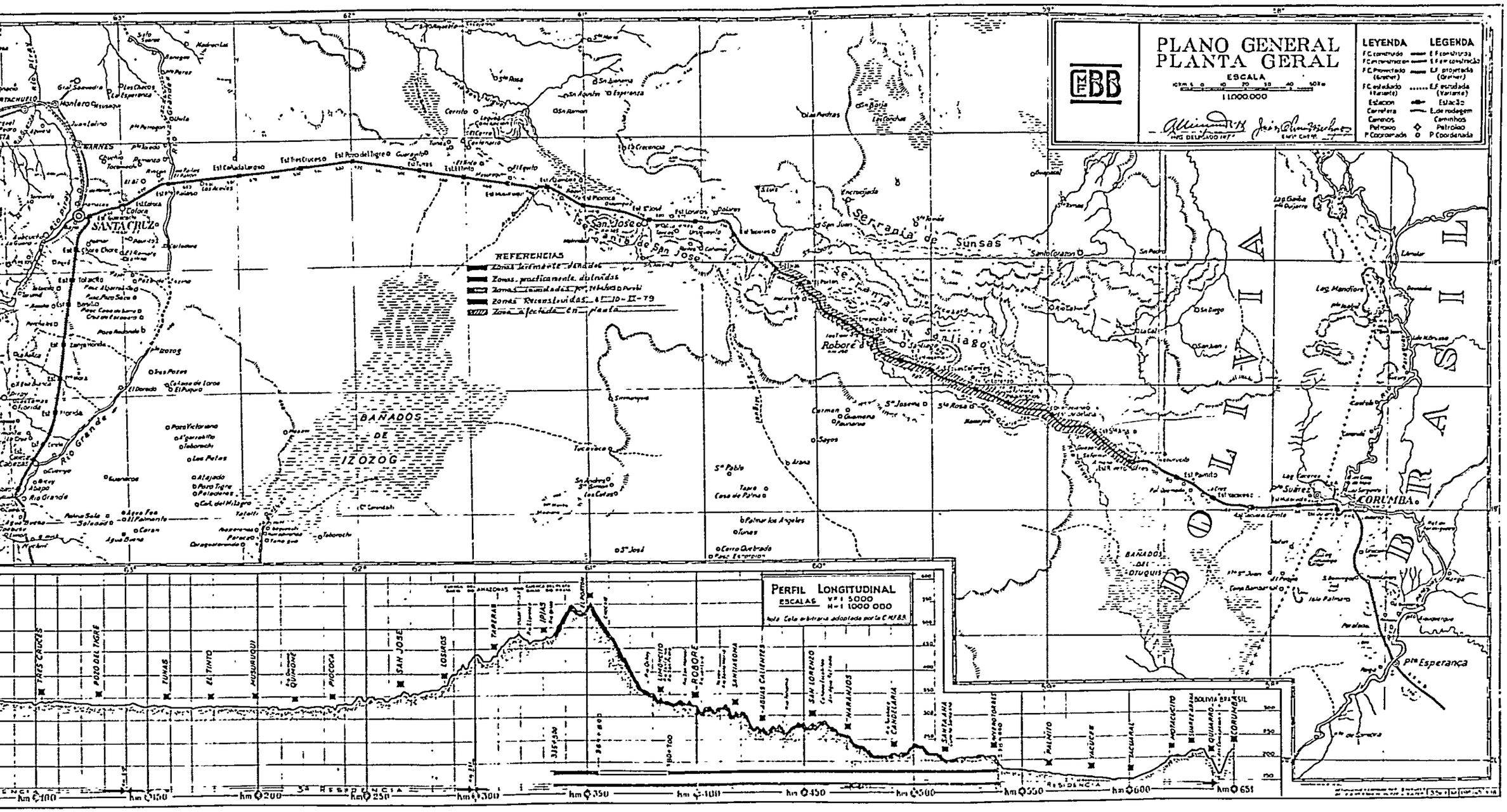


Fig. 2.2.1 Santa Crutz - Corumba Section Line Map

2-3 Climatic and Metrological Outline

The surveyed area is classified as the equator climate zone with annual total precipitation of about 1,000 mm. Rainfalls are concentrated into summer. A year can be divided largely into the rainy season lasting from October to March in the following year and the dry season starting from April and ending in September.

General plantation consists of thinly grown forests and grassy plains under the typical savannah climatic condition.

Rainfall in this region is normally brought by tropical frontogenesis with a peculiar pattern of local downpour, as the result of which there is a pretty large difference in total annual precipitation each year.

In and near the surveyed area, rainfalls are monitored at the air port offices in Robore and San Jose. More rainfalls are observed in Robore situated south than the other. Figure 2.3.1 is a summary of monthly precipitation record for 11 years of the 1968∿1978 period. This is a mere guess but it seems that as compared with the plain area there may be much more rainfall in El Porton and Chochis situated closer to Mt. Chochis where cold air current may hit against the mountainside and stimulate the stationary front.

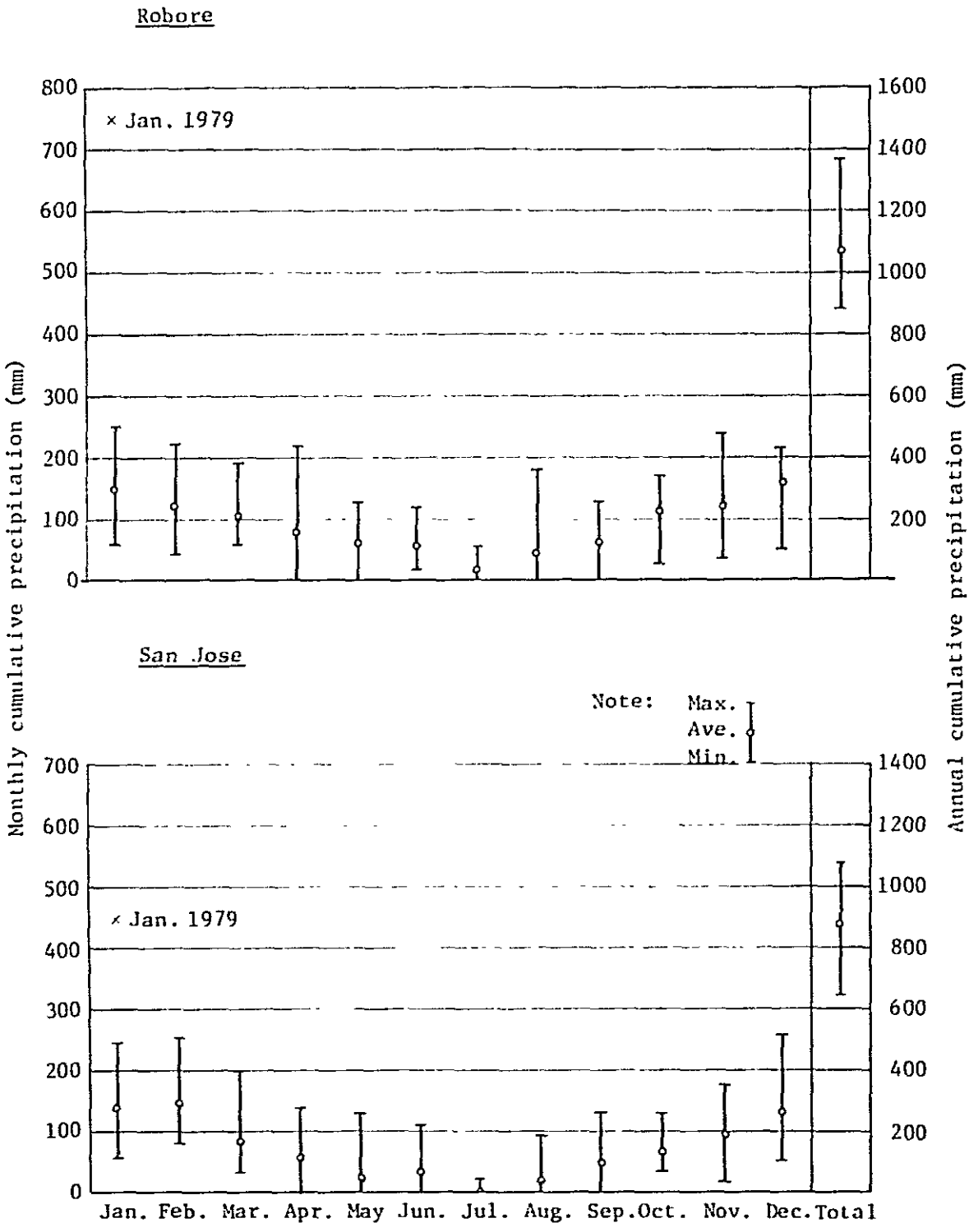


Fig. 2.3.1 Monthly Precipitation (1968 ∿ 1978)

2-4 Rainfall Condition and the Disaster

According to the latest observation record taken in Robore, it is noted that the rainfall lately experienced is undoubtedly abnormal, in that the cumulative total of precipitation from 13th to 17th January, 1979 reached 490 mm at a daily maximum of more than 250 mm. As the consequence greater damages were brought to the surveyed area and elsewhere.

Though the details are mentioned in Chapter 3, it can be concluded from the observation data available in Robore that the latest disastrous rainfall is quite an extraordinary occurrence at a probability rate of once every 250 years.

2-5 Slope Disasters and Flood Condition

The pattern of disasters incurred in the surveyed area can be divided generally into the mountainous and plain patterns. The mountainous pattern of disasters is characterized by slope rupture and avalanche of sand and stone due to the abnormally heavy rainfall while the plain pattern is featured by destruction of structures, due to overstay or overflow of stream water, and silted deposition.

Figure 2.5.1 shows those damaged conditions.

2-5-1 Mountainous Disasters

The mountainous disasters can be summarized as follows, each item of which is explained hereunder:

1) Avalanche of sand and stone
2) Natural and cutting slope surface collapse
3) Flood flow containing soil and sand

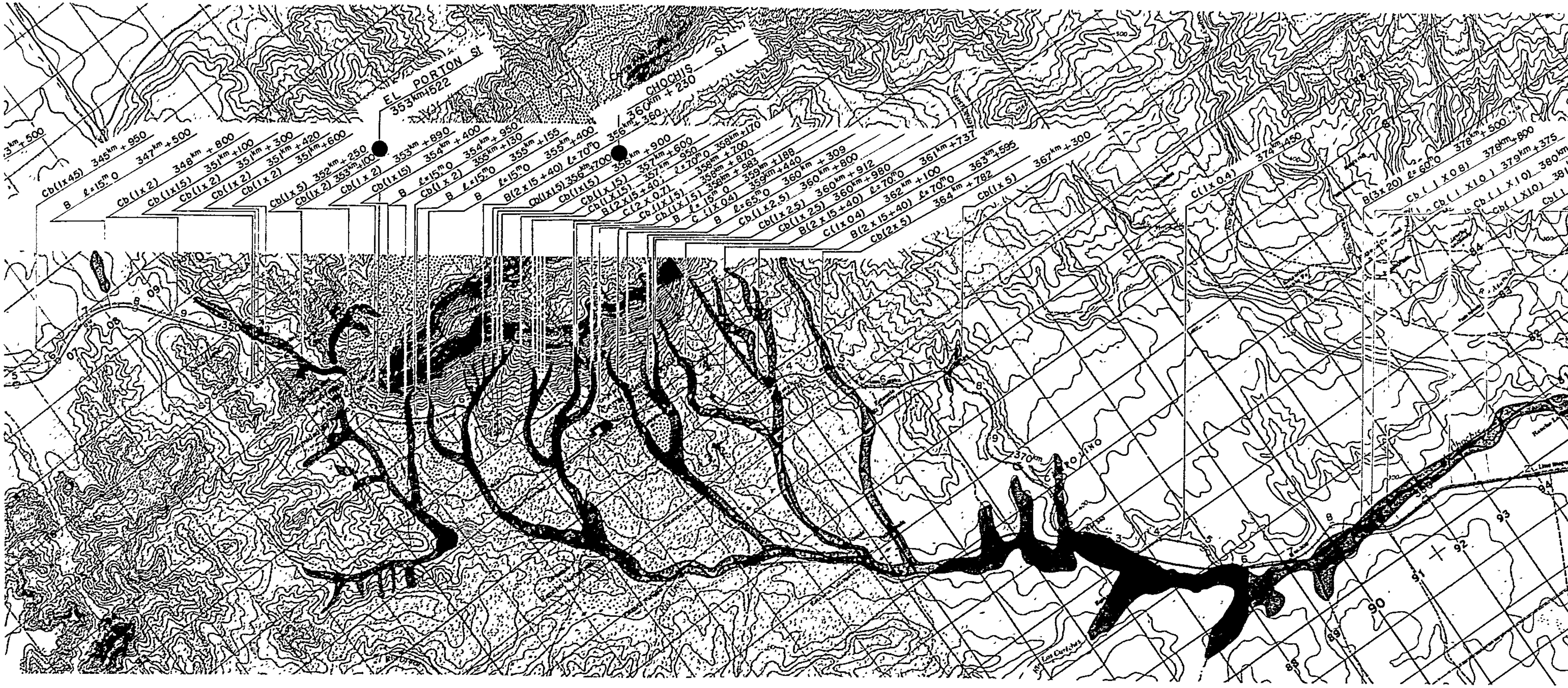
(1) Avalanche of sand and stone

Avalanche of sand and stone originates from the Chochis mountain, the cliff of the plateau on the right side of Chochis River and the talus deposit on the mountain side where surface water is apt to gather together in concentration. The red sandstone are distributed in all those areas. The avalanche of sand and stone runs down in the stream and breaks down the crossing section between the stream and the track because it is mostly constructed with embankment. A part of such avalanche of sand and stone is blocked out by the embankment and spread as deposit to the roadbed on both sides.

Normally, the avalanche of sand and stone tends, by nature, to stop flowing and begin to settle into deposit when it comes to the course of gentle grade after passing through the watercourse with expanded width out of the swamp end. However, actually as stated earlier, the avalanche of sand and stone far downstream after breaking through the embanked section of the railway because all the river-crossing sections, except the only one, were located in the current course of the stream. Besides that, from the 360 km 700 m to 900 m section where the track line runs through on the low embankment of the fan deposit, avalanche of sand and stone remains scattered all over the roadbed and deposited widely on the track line and its lower space.

Photos 2.5.1 and 2.5.2 are the aerial photographs of the damaged area. The area which looks whitish above in the picture is the spread scope of avalanche of sand and stone and its deposit coming out of its originating source.

The background cause for such avalanche of sand and stone, as traced back by reference to the rain observation record in Robore, can be explained as shown in Fig. 2.5.2.


EL PORTON St
353km+522
CHOCHIS St
360km+230
370km

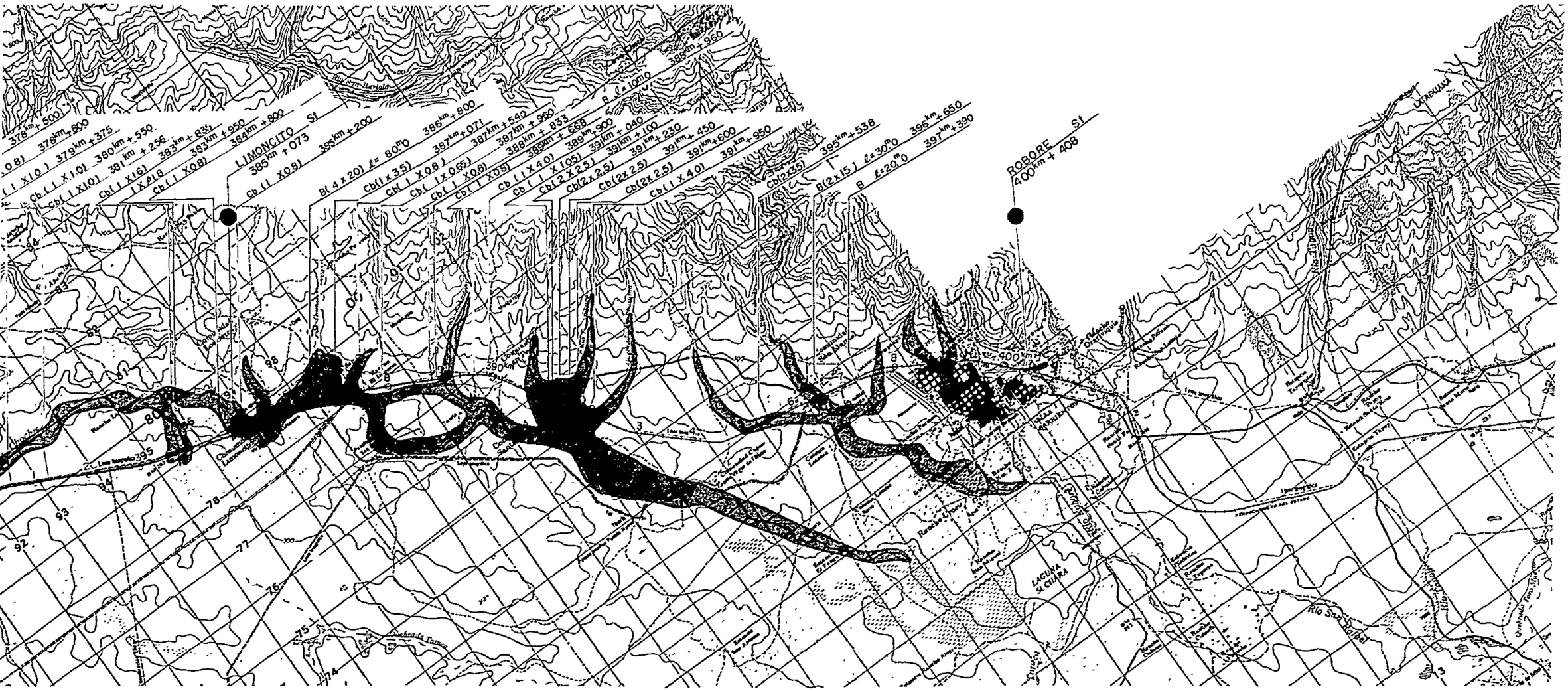


Fig. 2.5.1 Damaged Condition Map

- Avalanche of sand and stone
- Slope rupture
- Flood flow

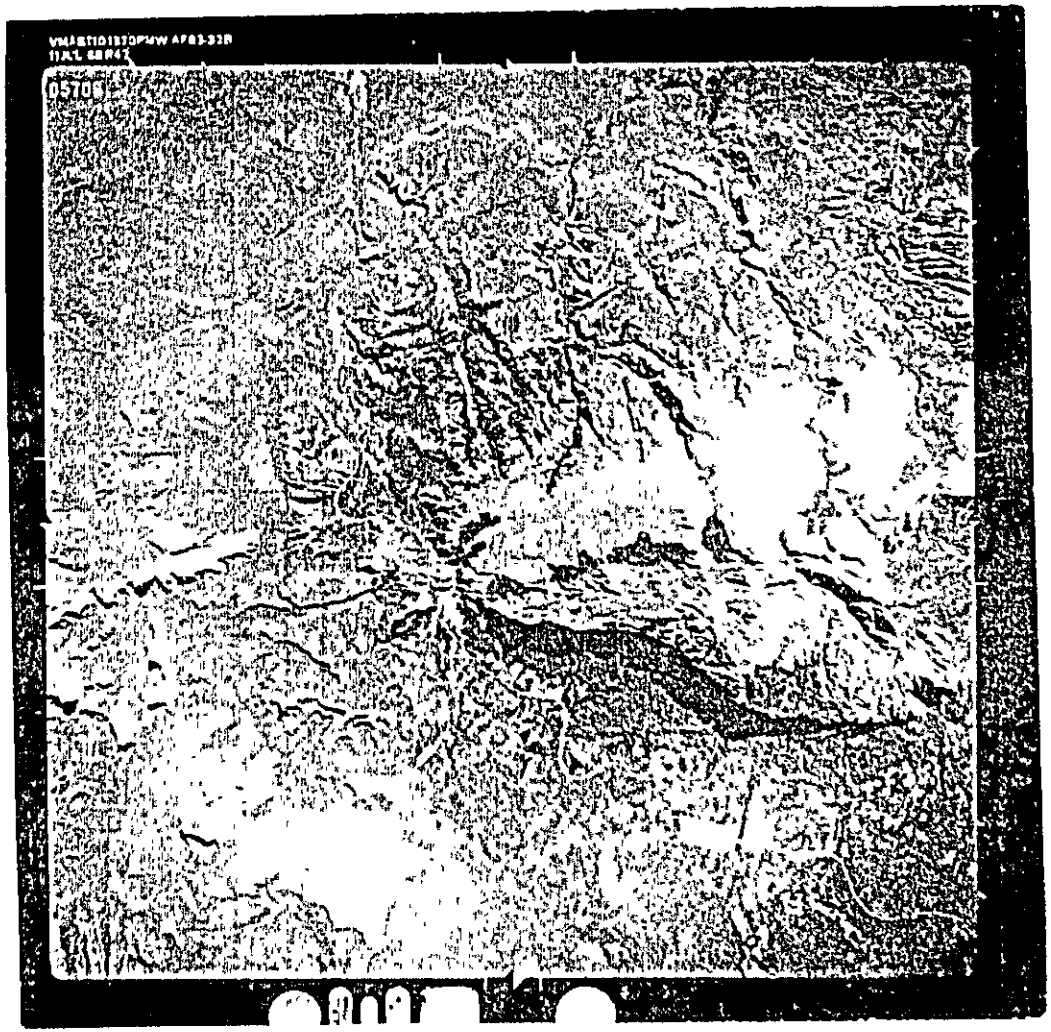


Photo. 2.5.1 Photo. Taken in July, 1968
(Before Disaster)

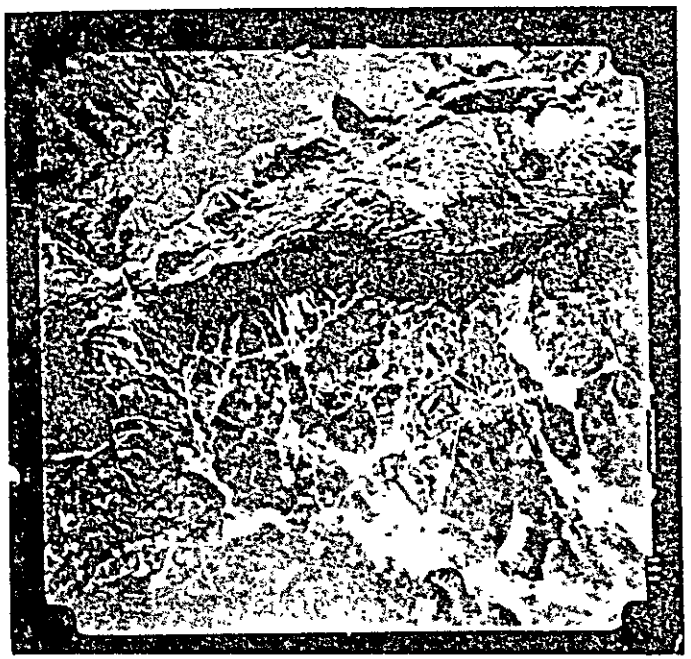


Photo. 2.5.2 Photo. Taken in July, 1979
(After Disaster)

· Precipitation: Based on measurement record by Robore air port office
· Rainfall and damaged conditions: As heard from station masters of El Porton, Chochis and Limoncito

Although there may be more precipitation at different time in mountainous areas, it is assumed here that rainfall condition would be same in both Chochis and Robore.

Effective precipitation strength $= \frac{h}{t}$

h = 280 (mm)
t = 24 (hour)

Effective precipitation strength = 11.7 mm/hour

Effective precipitation (h) = 280 mm

(Length between Robore and Chochis) = about 40 km

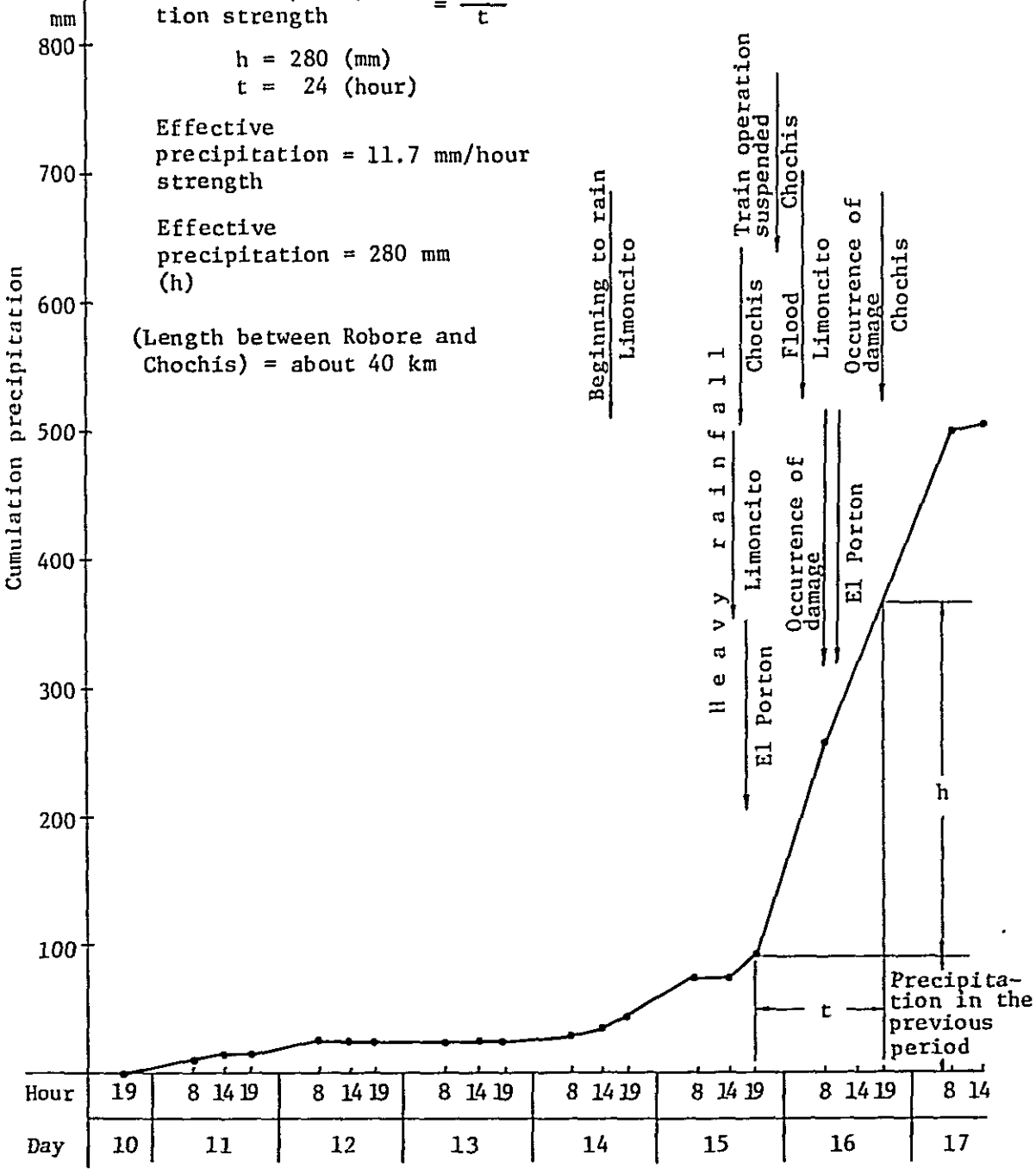


Fig. 2.5.2 Rainfall and Damaged Conditions (Jan. 10th ∿ 17th, 1979)

Although the rainfall in Chochis may be different considerably from that in Robore because the former is distanced about 40 km apart from the latter, an attempt has been made to seek, from Fig. 2.5.2, effective precipitation and effective precipitation intensity in and near Chochis, on assumption that the rainfall condition would have been almost same between those two different points of monitoring. When those figures obtained as above are plotted in Fig. 2.5.3 drawn from the actual instances of avalanche of sand and stone damages experienced in Japan, they may be located within Range III, from which it can be read out that Chochis and its environs had been placed under the most probable condition of causing such damage.

It is extremely difficult, however, to forecast future probability of being endangered by similar damage lately experienced from the avalanche of sand and stone, in view of the facts that there are to be considered various interrelated factors, such as local topography and geology accumulative precipitation and precipitation intensity, to be involved in the cause of such avalanche of sand and stone damage and, besides, that there is neither past record of damage nor detailed rainfall record locally available.

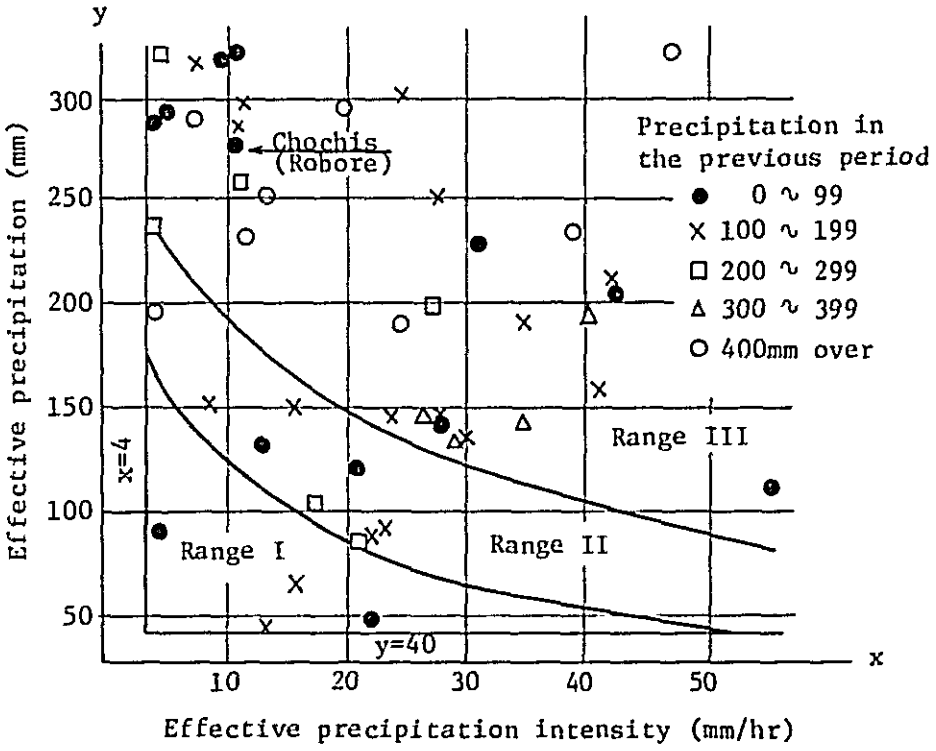
Suppose if the rain of 170 mm per day as the 50-year probable precipitation continued for 11 hours, it would certainly satisfy the condition of causing the avalanche of sand and stone damage in any cases. A long spell of such heavy rainfall may be conceivable in view of the topographic condition that the damaged section runs through at the foot of mountains forming a water shed of two large river systems.

The slope surface as the origin of the latest avalanche of sand and stone damage still remains unprotected, leaving the mark of new erosion front. At the bottom of ravine there still remain lots of deposit in an unstabilized status.

All those things considered, there to be a high danger of causing the avalanche of sand and stone on a similar scale to that experienced lately by 50-year probable precipitation or even by less than that.

Reference: Boundary conditions for avalanche of sand and stone occurrence (by reference to Fig. 2.5.3)

Effective precipitation (mm)	200	170	150	100
Effective precipitation intensity (mm/hour)	10	15	20	42
Rainfall duration hour (hour)	20	11.3	7.5	2.4



Range I: Damages seldom or never occur from avalanche of sand and stone

Range II: Big damages seldom or never occur though directly striken by slope rupture

Range III: Big damages to be brought by avalanche of sand and stone

Fig. 2.5.3 Relations Between Effective Precipitation - Effective Precipitation Intensity Versus Avalanche of Sand and Stone (Examples in Japan)

(2) Natural and cutting slope surface collapse

Ruptures are observed mainly in the surface of natural and cutting slope surface consisting of the greatly weathered zone of slaty rock, talus cone and colluvial deposit.

It is also observed that the roadbed of the cutting section is buried, though not on a large scale, due to collapse or outflow of soil and rock.

Since the cutting of the damaged section is generally sloped at a steep grade without any slope surface protection, there is high probability of causing similar damage in the rainy season to come.

Especially, the most unstabilized condition in the damaged section is observed in the both-side cut section near the point of 355 km 420 m between El Porton and Chochis, where there is displacement on the mountainside slope surface. Such displacement is also seen on the sheathing wall with cracks on it. Prompt action must be taken to proceed with the slope stabilization work on the mountainside.

(3) Flood flow containing soil and sand

Silted or colluvial deposits in the stream was swept away to the downstream. Such outflow of mud blocked up the ravine stream where it was intercepted by embankment and then plugged up passage of water in the culvert. If this condition remains further, there is a danger of causing overflow of flood water to the roadbed with silted deposit when heavy rainfall comes again. This sort of damage is observed mainly within the section of El Portion Station and around Cerro de Torre.

2-5-2 Damages in Plain Area

The railway comes down at point of about 375 km from the fan deposit area to the flood plain. From this point down to the terminating point the river runs over the gentle grade by free meandering. Because several tributaries, each having a wide expansion of catchment area, join the main stream with unsteady water course, the excess water was concentrated into the river and caused flood. This, along with the extremely insufficient effective flowing water section of bridges and culverts, caused damage or washout of bridges and culverts and collapse of embankments everywhere.

Near Limoncito Station, the water level rose up extraordinarily high, as the result of which track and buildings were submerged. Then, with declining of the water level the station building and the platform embankment were flown out and other buildings were also damaged more or less.

The railway comes again to pass through the fan deposit area from the point of 389 km 100 m, where the riverbed was raised up conspicuously by silted deposit outflown from the swamps of Chochis River crossing over the railway.

This affected badly the water passage capacity of the crossing bridges and culverts. Especially, from the 391 km to 392 km section silty sand spread over area to considerable thickness, which raised the river bed level equal to or higher than the roadbed of the railway.

2-6 Damages and Emergency Restoration of Railway

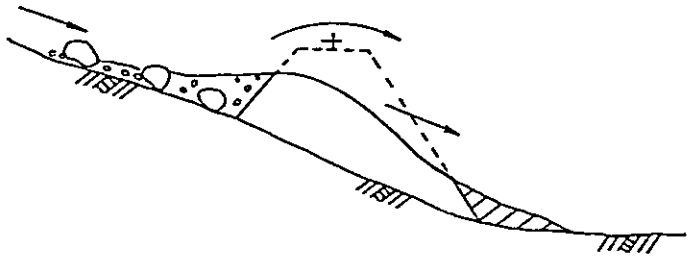
Damages on the railway occurred over a total length of about 65 km between the approximate points of 335 km and 400 km; especially, embankment and culverts crossing over the river were damaged most seriously. The conditions of such damages and their emergency restoration are detailed in Table 2.6.1, which may be summarized as follows:

	Length	Restoration
Embankment washout	2,850 m	Restored slope surface at 1 to 1
Slope surface collapse	1,270 m	Restored
Roadbed washout	230 m	Restored
Soil and sand deposit	2,950 m	Removed
Destroyed bridge	At one point	Temporary bridge
Total	7,300 m	

(1) Embankment damage

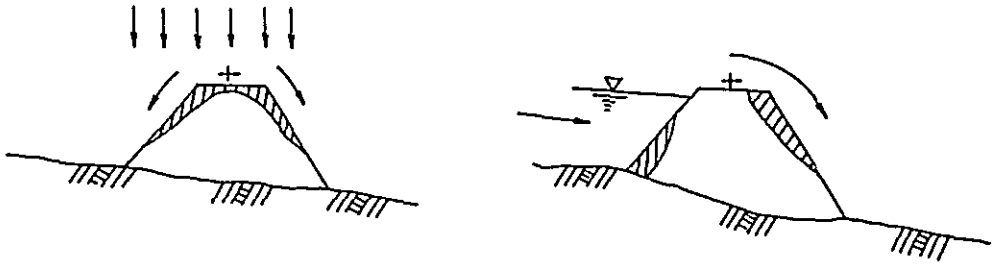
As observed from the crossing embankment in mountains between El Porton Station and Chochis Station, the embankment was collapsed not only by direct impact of the avalanche of sand and stone but also by overflowing of such avalanche of sand and stone impounded on the mountain side due to insufficiency of the water flowing section area of the crossing structure. Thus, culvert boxes and other structures were washed away and destroyed.

In the case of any other embankments at the river crossing or on the mountainside, where similar damages were incurred solely by mere flood flow, the existing drain channel crossing the river was not capable of admitting total inflow of water, as the result of which the slope end of the embankment was destroyed by impounding of water on the mountainside and complete collapse of the embankment was finally brought by loss of roadbed and destruction of downstream slope surface due to overflowing of river water.

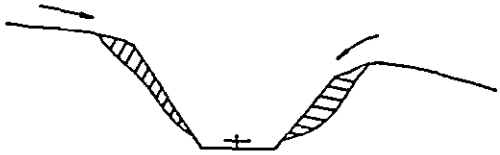


(2) Slope surface collapse

1) There are two different instances where collapse of the slope surface was incurred to the embankment. The one cause is because of erosion into the slope surface as the result of direct impact to or downflow over the slope surface without any protection by heavy storm rain. The other cause is attributable to scouring of the slope end by impounded flood flow or overflowing to give damage to the slope surface on the downstream side.

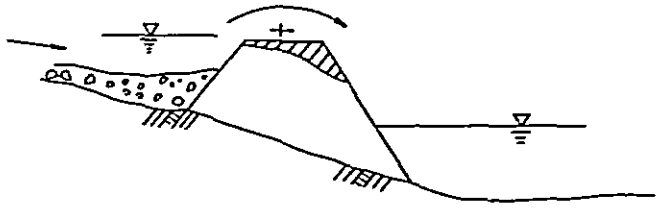


2) In the cutting section, inflow of storm water from mountains into the slope surface of the cut section caused collapse of the whole slope surface.

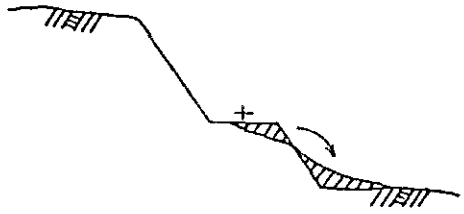


(3) Lost roadbed

1) The roadbed on the embankment was washed away by overflowing of flood flow.



2) In the cutting section, the roadbed was washed away by a large quantity of water flow containing with soil and sand from mountains.



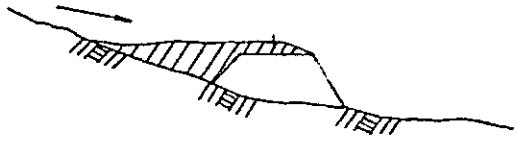
(4) Soil and sand deposit

The cause of soil and sand deposit may be sought from the following three cases:

1) Deposit due to slope surface collapse in the cutting section.

2) In the cutting section located close to the embankment, deposit arose from overflowing of the water containing soil and sand impounded on the upstream side of th embankment, down over the cut roadbed section.

3) In the low level embankment, deposit was formed up on top of the embankment by soil and sand from flood flow.



(5) Loss, damage or blockade of culvert

With destruction of the embankment, the culvert was washed away or destroyed at the same time. Many of the culverts were buried and blocked out with resultant loss of their functions by large deposit on the upstream side of the embankment.

(6) Loss and damage of bridge structure

Near the San Calros bridge, there occurred inflow of storm water in a large quantity from the wide expansion of catchment area, thus causing the change in the river course. As the result, due to the deficiency in the water flowing section area under the crossing bridge for the prolonged extension of the embankment, together with blockade by drift-woods, flood water was impounded far and wide, which finally caused destruction of the bridge.

Table 2.6.1 Damage at Each Point and Emergency Restoration

Km Post	Length	Damaged Conditions	Emergency Restoration	Present Sectional Area	Required Sectional Area	Sufficiency Rate
335 km + 500 m	100m	Erosion into embankment slope	Restored banking	-	-	-
350 + 700	50	Cut slope surface collapse	Removal of deposit from subgrade	-	-	-
350 + 900	30	Cut slope surface collapse	Removal of deposit from subgrade	-	-	-
351 + 500	300	Embankment washout	Resotred banking	0	9.4m^2	0
352 + 200	30	Roadbed washout Soil and sand deposit	Restored roadbed Cleaning of open channel	0.7m×1.25m 0.875m^2		
352 + 250	50	Roadbed washout (with avalanche) Emerging of river course of about 6m depth	Track girder erection ℓ=23m (3 spans)	5.7m×6.0m 34.2m^2	1.0m^2	100%
353 + 000	360	Banking & box culvert 2 culverts washed out	Restored with temporary track 0.6m dia. corrugated pipe	φ0.6m 0.3m^2	2.1m^2	13%
353 + 360	50	Cut section rupture Soil and sand deposit	Removal of deposit	-	-	-
353 + 400	100	Soil and sand deposit	Removal of deposit	-	-	-
353 + 600	In El Porton Sta. 200	Soil and sand deposit Erosion of roadbed	Removal of deposit Temporary setting of tie-girder (ℓ=10m)			

Note: Present sectional area means the section of the existing structure or the temporarily restored structure in its functional operation.

Km Post	Length	Damaged Conditions	Emergency Restoratin	Present Sectional Area	Required Sectional Area	Sufficiency Rate
353 km + 750 m	100m	Embankment washout	Restored banking	1.0m×1.6m = 1.6m²	3.2m²	50%
354 + 300	200	Embankment washout Soil and sand deposit	Restored banking Removal of deposit			
354 + 400	30	Buried embankment on upstream side		0	1.4m²	0
354 + 950	40	Buried embankment on upstream side (with avalanche)		0.7m×1.65m 1.1m²	2.1m²	55%
355 + 000	100	Soil and sand deposit	Removal of deposit from roadbed	-	-	-
355 + 100	50	Slope surface of embankment washout Culvert blockade	Restored banking	0	2.1m²	100%
355 + 150	50	Embankment washout Emerging of river course (with avalanche)	Track girder erection (ℓ=40m, H=4.7m) Restored banking	4.0m×4.7m 18.8m²		
355 + 200	50	Buried embankment on mountainside Culvert blockade Slope surface of embankment washout	Restored banking Tie-girder ℓ=2m, H=1m	2m×1m 2m²		
355 + 230	50	Soil and sand deposit	Removal of deposit from roadbed	-	-	-

Km Post	Length	Damaged Conditions	Emergency Restoration	Present Sectional Area	Required Sectional Area	Sufficiency Rate
355 km + 300 m	50m	Roadbed washout	Temporary setting of tie-girder (ℓ=2m, H=1.5m)	2m×1.5m 3.0m²	–	–
355 + 400	150	Embankment washout Emerging of river course (with avalanche) Culvert destruction	Restored banking Temporary setting of tie-girder (ℓ=3m, H=1m)	3m×1m 3.0m²	4.8m²	63%
355 + 700	500	Soil and sand deposit Cut section rupture	Removal of deposit from roadbed	–	–	–
356 + 160	60	Slope surface of embankment washout Culvert destruction	Temporary track Temporary setting of 0.8m dia. Hume pipe	φ0.8m 0.5m²	24.3m²	21%
356 + 360	150	Embankment washout (with avalanche)	Temporary track Connect by corrugated pipes(φ1.0×2)	3.0m×2.5m 4.5m²		
356 + 500	150	Soil and sand deposit	Removal of deposit from roadbed	–	–	–
356 + 700	50	Buried embankment on up-stream side Culvert blockade		0	1.2m²	0
356 + 900	40	Buried embankment on up-stream side Culvert blockade		0	0.9m²	0

Km Post	Length	Damaged Conditions	Emergency Restoration	Present Sectional Area	Required Sectional Area	Sufficiency Rate
357 km + 000 m	100m	Soil and sand deposit	Removal of deposit from roadbed	-	-	-
357 + 300	150	Soil and sand deposit	Removal of deposit from roadbed	-	-	-
357 + 360	20	Cut slope surface collapse	Removal of deposit from roadbed	-	-	-
357 + 560	50	Buried embankment on upstream side Culvert blockade		0	$0.7m^2$	0
357 + 700	50	Cut slope surface collapse Soil and sand deposit	Removal of deposit	-	-	-
357 + 825	40	Buried embankment on upstream side Culvert blockade		0		
357 + 950	30	Embankment washout	Restored banking	0	$1.6m^2$	0
358 + 120	100	Embankment washout (with avalanche) Culvert destruction	Restored banking Temporary setting of 2.0m dia. corrugated pipe	$\phi 2.0m$ $3.14m^2$	$11.3m^2$	28%
358 + 250	150	Cut slope surface rupture Soil and sand deposit	Removal of deposit	-	-	-
358 + 520	30	Embankment washout	Restored banking	$0.8m \times 1.1m$ $0.9m^2$	$0.4m^2$	100%
358 + 600	100	Soil and sand deposit	Removal of deposit	-	-	-

Km Post	Length	Damaged Conditions	Emergency Restoration	Present Sectional Area	Required Sectional Area	Sufficiency Rate
358 km + 700 m	20m	Embankment washout	Restored banking Temporary setting of tie-girder (ℓ=1.5m, H=0.5m)	1.5m×0.5m 0.75m²	1.2m²	63%
358 + 700	60	Buried embankment on up-stream side		-	-	-
358 + 800	100	Soil and sand deposit	Removal of deposit	0	1.8m²	0
358 + 950	30	Embankment washout	Restored banking	0.8m×1.15m 0.9m²	1.8m²	50%
359 + 100	100	Embankment washout (with avalanche) Culvert destruction	Restored banking	0	6.9m²	0
359 + 500	200	Soil and sand deposit	Removal of deposit	-	-	-
360 + 300	50	Embankment washout (with avalanche)	Restored banking (1:1)	3.3m×3.0m 9.9m²	9.2m²	100%
360 + 700	200	Soil and sand deposit	Removal of deposit	-	-	-
360 + 950	150	Embankment washout (with avalanche) Culvert destruction	Restored banking 0.6m dia. corrugated pipe Temporary setting of track girder (ℓ=5.4m, H=5.5m)	5.4m×5.5m 29.7m²	14.6m²	100%
361 + 737	50	Embankment washout (with avalanche)	Restored banking Increasing of 1.5m dia. corrugated pipe	φ1.5m 1.0m×1.4m 3.2m²	8.1m²	39%

Km Post	Length	Damaged Conditions	Emergency Restoration	Present Sectional Area	Required Sectional Area	Sufficiency Rate
363 km + 250 m	50m	Cut surface rupture	Removal of deposit from roadbed	-	-	-
363 + 595	70	Embankment washout (with avalanche)	Temporary setting of track girder after banking for track (ℓ=9.8m, H=5.4m)	5.8m×5.4m 31.3m²	19.2m²	100%
364 + 782	30	Embankment washout Culvert destruction	Restored banking Temporary setting of corrugated pipe (1.0m dia.) at 2 points	φ1.0m×2 1.6m²	52.7m²	3%
367 + 300	150	Embankment washout	Restored banking	0.8m×1.1m 0.9m²	39.2m²	2%
377 + 900	50	Embankment washout	Temporary setting of track girder (ℓ=30m, H=2.4m)	30m×2.4m 72.0m²	-	-
378 + 500	20	Abutment (back side) washout at bridge on Ochoi River	Restored temporarily by banking at back of abutment	9.8m×5.2m 52.8m²	377.4m²	14%
380 + 500	400	Embankment slope surface washed away by overflow	Restored banking	-	-	-
383 + 950	70	Embankment washout	Restored banking Temporary setting of pipe (1.7m dia.)	φ1.7m 2.3m²	-	-
386 + 600	500	Embankment washout	Restored by replacement with temporary track Track girder erection (ℓ=15.7m, H=3.7m ℓ=22.0m, H=2.8m)	15.7m×3.7m 22.0m×2.8m 119.7m²	521.3m²	23%
386 + 950	15	San Calros bridge destroyed				
387 + 071	3	Blockade of box culvert				

Km Post	Length	Damaged Conditions	Emergency Restoration	Present Sectional Area	Required Sectional Area	Sufficiency Rate
388km + 960m	20m	Abutment (back side) washout at bridge on San Pedoro River	Restored temporarily by banking at back of abutment	10.1m×4.5m 45.5m²	44.4m²	100%
391 + 100	750	Soil and sand deposit	Natural ground level still higher than track level even after removal of sand	-	-	-
391 + 230	10	Roadbed washout	Temporary setting of tie-girder (ℓ=10m, H=1.5m)	10m×1.5m 15m²	42.6m²	51%
391 + 450	10	Roadbed washout	Temporary setting of tie-girder (ℓ=6m, H=0.7m)	6m×0.7m 4.2m²		
391 + 600	5	Roadbed washout	Temporary setting of tie-girder (ℓ=3m, H=0.8m)	3m×0.8m 2.4m²		
392 + 500	100	Cut surface rupture	Removal of deposit from subgrade	-	-	-
395 + 538	20	Embankment washout Culvert destruction	Restored banking Temporary setting of 1.5m dia. corrugated pipe	φ1.5m 1.8m²	44.3m²	4%
396 + 650	20	Abutment (back side) washout at bridge on Manuel River	Restored temporarily by banking at back of abutment	9.8m×3.5m 35m²	93.8m²	37%
397 + 100	50	Roadbed washout	Restored roadbed	-	-	-
397 + 320	30	Embankment washout	Temporary setting of track girder (ℓ=26.4m, H=3.3m)	26.4m×3.3m 87.1m²	54.1m²	100%
400 + 300	15	Roadbed washout	Temporary setting of tie-girder (ℓ=3m, H=1m)	3m×1m 3m²	-	-

2-7 Anti-damage Strength After Emergency Restoration

The conditions of emergency restoration are as shown in Table 2.6.1. As long as the present status of things remains unimproved after restored temporarily, it is most likely that such damages as may affect the railway transport would occur each year in the future. Herein, for the purpose of economic and financial analysis to what extent the transport would be affected by similar damage is assessed properly.

Those damages to be anticipated every year would be as follows:

1) Structural damage due to shortage of water flowing section area
2) Structural damage due to decline or suspension of function for water flow passage
3) Erosion or destruction of earth structure by influence of storm water
4) Destruction of temporary bridge

Besides those damages above, there are to be anticipated various damages finally to the whole destruction of structures from heavy rainfall avalanche of sand and stone. For this assessment, anyway, the survey result on the existing drainage capacity of structures after emergency restoration is regarded as the marginal standard.

The sufficiency rate of the present section area in the totally required section area for the planned precipitation (see Chapter 3) is shown in Table 2.6.1 at each point of the restored railway line. The present condition of sufficiency as a whole is as shown in Table 2.7.1.

Table 2.7.1 Sufficiency Rate

Sufficiency Rate %	No. of	Cumulative Total Number of	Cumulative Percentage %
0	8	8	25
1 ∿ 10	3	11	34
11 ∿ 20	2	13	41
21 ∿ 30	3	16	50
31 ∿ 40	2	18	56
41 ∿ 50	2	20	63
51 ∿ 60	2	22	69
61 ∿ 70	2	24	75
100	8	32	100

Note: Velocity of flow is set at 3.0 m per second.

As shown in Table 2.7.1, 75 per cent of the total structures are insufficient in the flowing sectional area. The sufficiency rate for the totally required sectional area is only 22 per cent at average, which may correspond to about 40 mm per day in precipitation conversion.

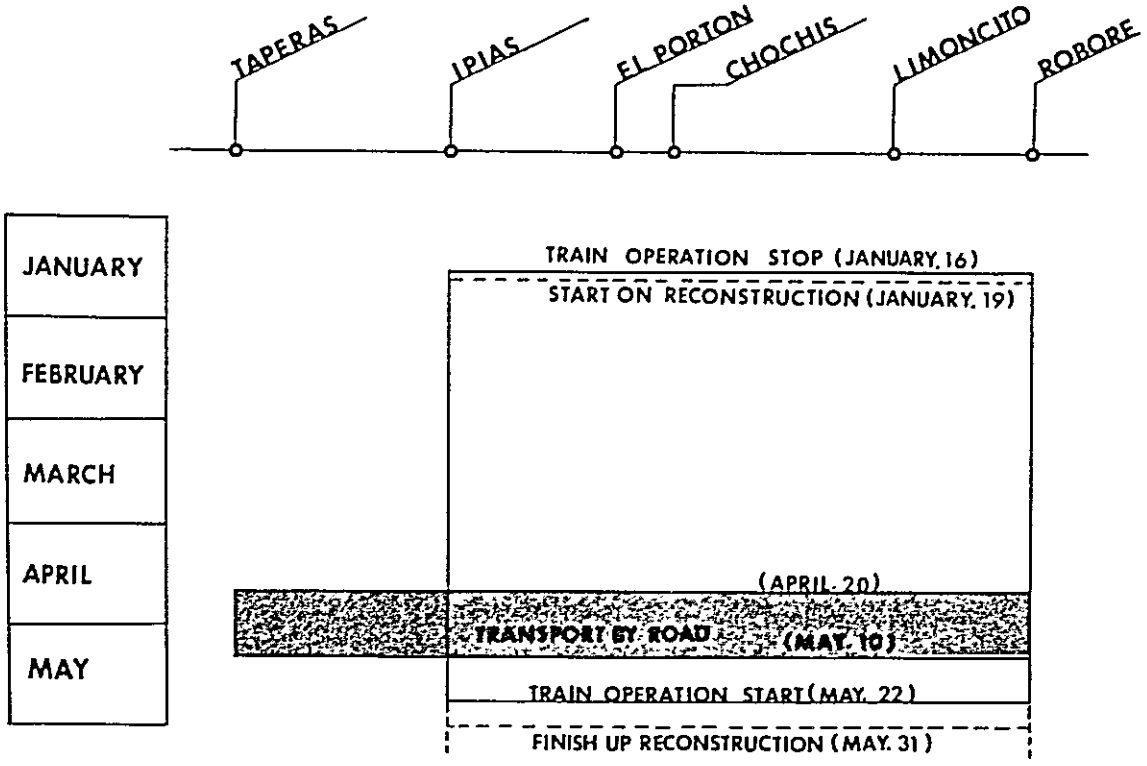
2-8 Effect upon Transportation and Necessary Countermeasures

(1) Train operation during occurrence of disaster

Heavy rainfall which began to come down on January 14th, 1979 brought disastrous damages everywhere along the railway; especially, the point near Robore in the Santa Cruz - Corumba section and the crossing point with Paragay River in the Corumba - Santoso were destroyed almost completely.

In the Santa Cruz - Corumba section, trains were put into 'thinned-out' operation when it began to rain. However, in the Ipias - Robore section where railway structures were destructed at many points, operation of trains was suspended completely for about 120 days from January 16th until May 21st.

The suspension period of train operation is shown in Fig. 2.8.1.



SOURCE : Information from Eastern General Office. ENFE

Fig. 2.8.1 The Suspension Period of Train Operation

(2) Measures taken for resumption of train operation

Total length of the commercial track line between Santa Cruz and Corumba extends to 651 km. Average transport distance in 1978 is 396 km for passenger traffic and 579 km for freight transport, showing evidently the typical pattern as a long-distance inter-regional transport system.

During the suspension period of operation, both of passenger and freight trains were operated temporarily in shuttle service between Santa Cruz and Ipias and between Robore and Corumba.

However, the long-time suspension of train operation in the Ipias - Robore section, nearly centered in the railway division, gave a fatal blow to both passenger and freight transport systems oriented rather intensely toward the long-distance service. For this period, the railway was utilized only as a part of the domestic transport system.

Figure 2.8.2 is the result of comparison on the passing freight train tonnage between Santa Cruz and Corumba.

- The passing tonnage in June, 1968 shows an average pattern of transport in the said railway division
- The freight volume in January, 1979 is decreased because of suspension entered into on and from January 16th.
- The passing tonnage in February, 1979 is declined sharply because of suspension entered into between Ipias and Robore. Only the domestic freight was in transit by train.

Paralysis in the transport system between Santa Cruz and Corumba, the economic artery in Santa Cruz State, caused high rise in commodity price and stagnate in economic activities.

This aroused strong requests by local community people and the traffic association to open the way for improvement. As the result, a temporary road was constructed as the emergency service mainly for freight transportation. As shown in Fig. 2.8.3, the road serves as the liaison route between Tapera and Robore. Its construction work started in the early part of March and, upon completion, it served for transportation of freight which had been long in congestion for 20 days from April 20th.

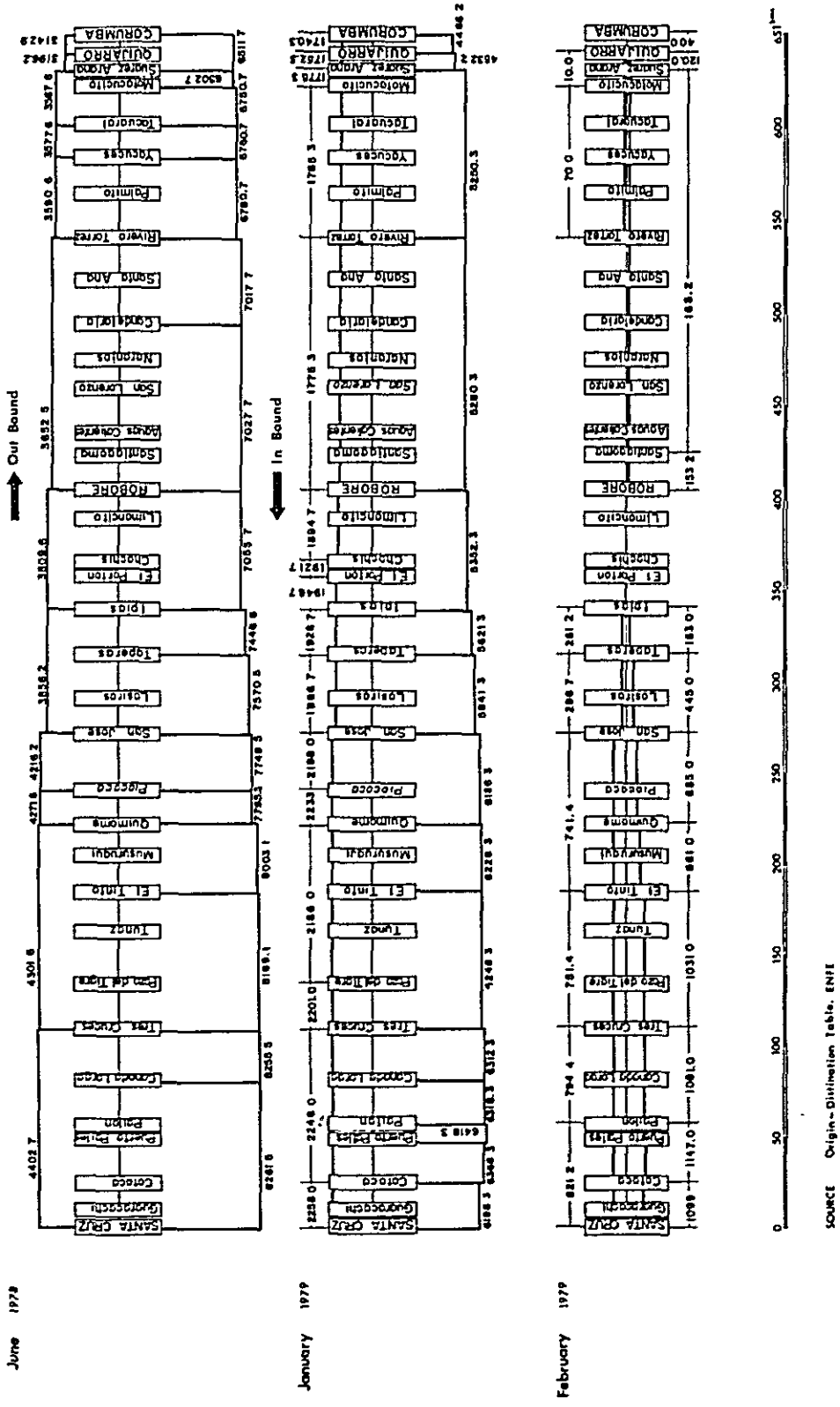
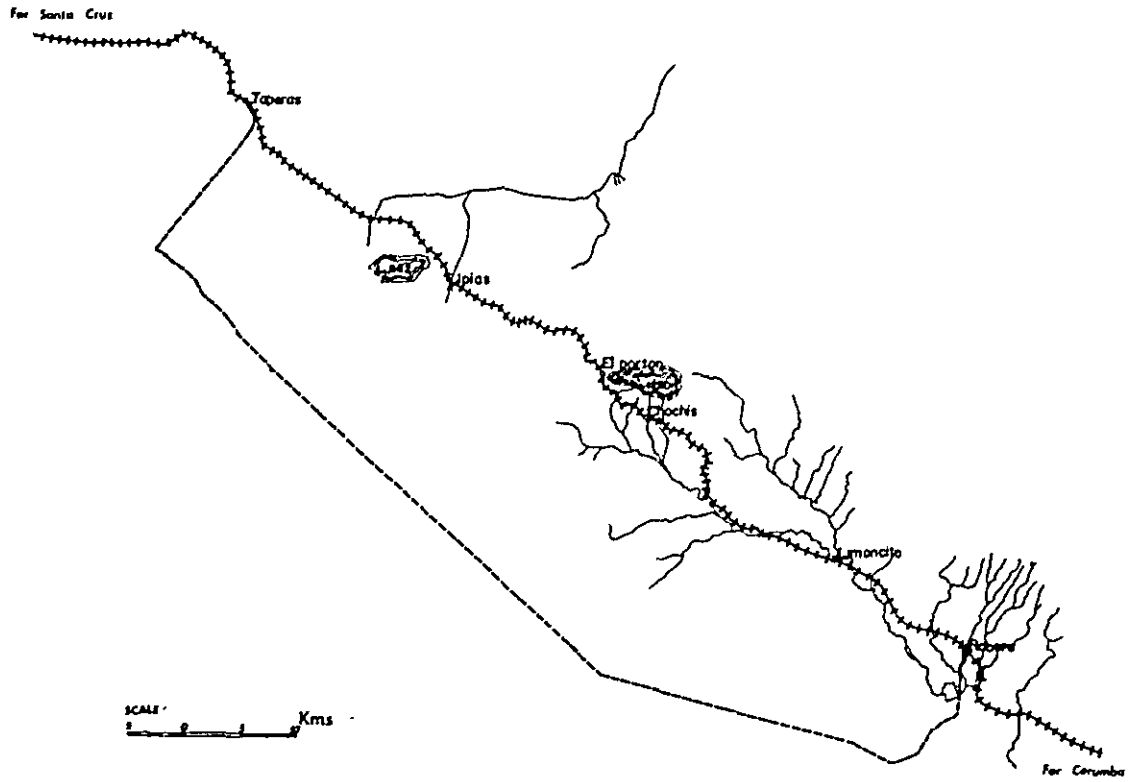


Fig. 2.8.2 No. of Passing Freight Volume

SOURCE Origin-Distination Table, ENFE



Source : SERVICIO NACIONAL DE CAMINOS

Fig. 2.8.3 The Map of the Temporary Road for Transportation

CHAPTER 3. REHABILITATION PLAN

3-1 Basic Thought for Preparation of Plan

The latest railway damage entailed suspension of transport service for a long period between Santa Cruz and Corumba and brought a grave consequence to the national economy in the Republic of Bolivia. Though the damaged section has been restored just temporarily, it is still anticipated that if this situation remains unimproved, not only annual expenses would be required for such emergency remedies each year but also the nation's economy would be kept hampered in its growth by frequent suspension of railway service.

The purpose of the rehabilitation plan is to prevent and exterminate any such probable source of damage in the future.

The rehabilitation plan should, therefore, reflect the following considerations:

1) Effective measures should be planned against any predictable damage on the basis of the latest survey result.

2) Such measures should be planned only for the rehabilitation project on such a scale that great loss and damage would be incurred by natural disaster and long time would be required for restoration once the damage occurs. The measures should be planned most elaborately so as to fully insure that the invested fund for rehabilitation would not come to naught.

3) No measures will be considered for the project of such nature that greater expenses would be required for restoration while the work would be rather easier with less degree of loss and damage even though it may occur.

3-1-1 *Determination of Planned Precipitation*

In determining the planned precipitation, it is estimated normally from the past rainfall observation data. The latest survey finds that the 11-year record taken at Robore Airport office for the period of 1968 to 1978 seems to be most definite data on rainfall, upon which the planned precipitation has been based.

As an approach to determination of the planned precipitation, the distribution function has firstly been determined on an assumed basis that the annual maximum daily precipitation would form logarithmic normal distribution.

Then, the planned precipitation is to be determined at the precipitation for the excessive probable year to be incorporated into the plan.

Figure 3.1.1 shows the distribution function as estimated from the annual maximum daily precipitation for the latest 11 years.(Appendix-4 for details). Figure 3.1.1 the planned precipitation on a 50-year probability for the rehabilitation plan is determined at 170 mm per day.

Incidentally, the precipitation of 250 mm per day for the rainfall, which caused the latest big damage in January, 1979, is estimated at being corresponding to about 250-year probability.

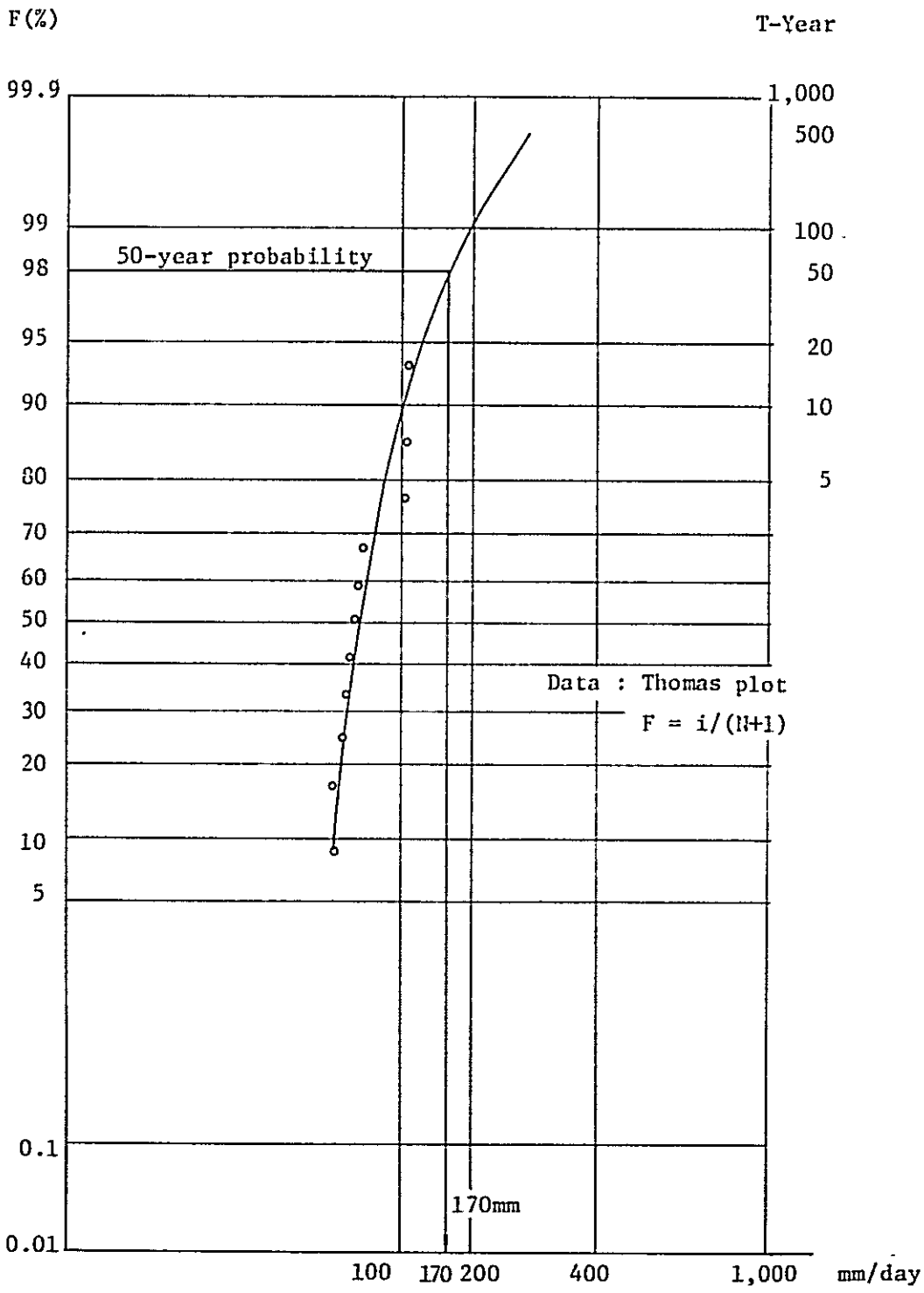


Fig. 3.1.1 Determination of Probable Precipitation

3-1-2 Estimation of Planned Discharge

(1) Setting of planned catchment area

The catchment area for the planned site has been set on the topographic map of 1/50,000 reduced scale by reference to the results obtained from the aerophotograph, site reconnaissance and survey.

Figure 3.1.2 shows each of 44-divided catchment areas for the existing line rehabilitation plan (Alternative-A).

Figure 3.1.3 shows each of 31-divided areas as set for the new detour line plan off the lately damaged section (Alternative-B) as an alternative to the former.

(2) Determination of run-off coefficient

The run-off coefficient for each catchment area set as aforementioned is to be determined with due consideration to the topography, geology and plantation of each divided area (Appendix-5).

In the 340 km to 370 km section of the existing line rehabilitation plan, the catchment area is small in mountains where it is sloped very steeply with relatively thin growth of plantation. On the other hand, the catchment area for the 370 km to 387 km section is a wide-open plain with large expansion of area.

As for the new detour line construction plan, the catchment area is gently sloped and flat as a whole.

In view of the above topographic features, the run-off coefficients for the two alternatives are as follows:

Existing line rehabilitation plan:

340 km to 370 km catchment area	f = 0.8
387 km to 400 km catchment area	f = 0.8
370 km to 387 km catchment area	f = 0.6

New detour line construction plan

Whole catchment area	f = 0.6

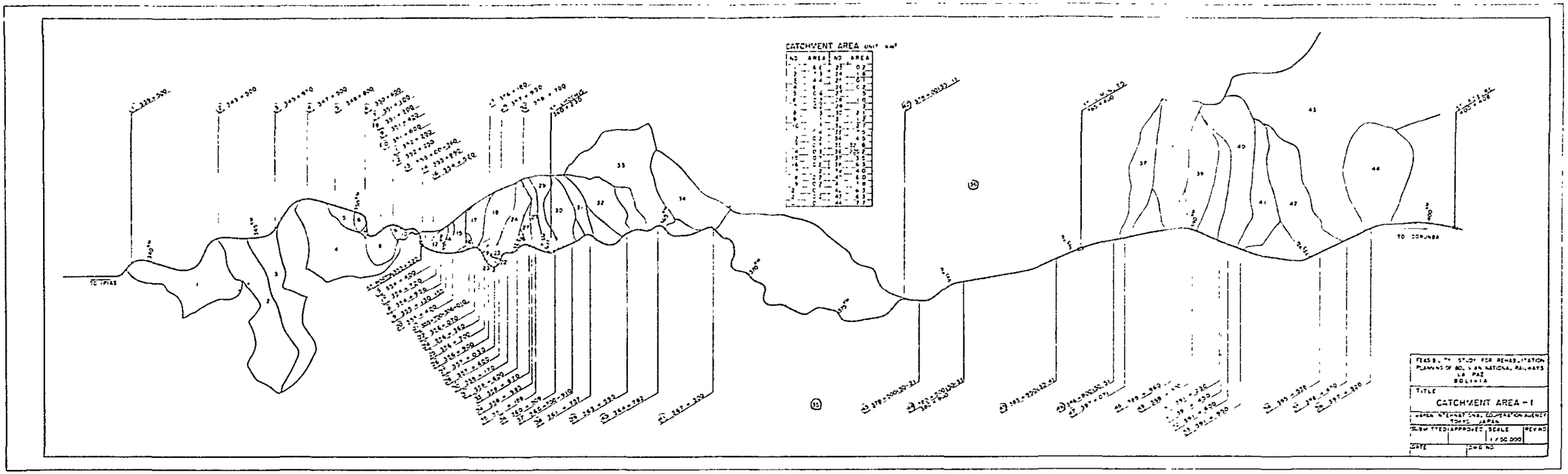
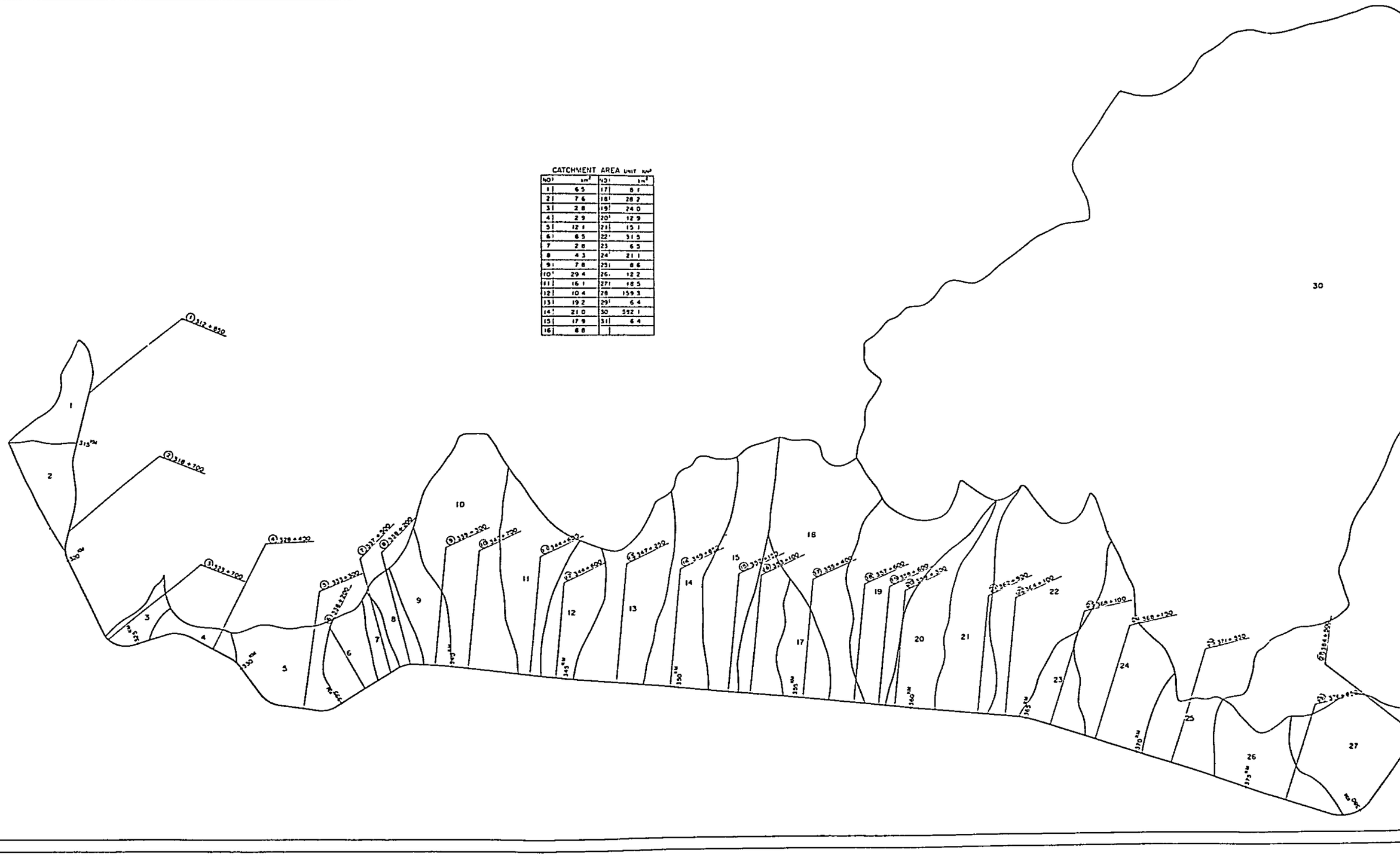


Fig. 3.1.2 Catchment Area (Alternative-A)

CATCHMENT AREA UNIT km²

NO.	km²	NO.	km²
1	6.5	17	8.1
2	7.6	18	28.2
3	2.8	19	24.0
4	2.9	20	12.9
5	12.1	21	15.1
6	6.5	22	31.5
7	2.8	23	6.5
8	4.3	24	21.1
9	7.8	25	8.6
10	29.4	26	12.2
11	16.1	27	18.5
12	10.4	28	159.3
13	19.2	29	6.4
14	21.0	30	592.1
15	17.9	31	6.4
16	8.8		



CATCHMENT AREA UNIT Km²

NO.	km²	NO.	km²
1	6.5	17	8.1
2	7.6	18	28.2
3	2.8	19	24.0
4	2.9	20	12.9
5	12.1	21	15.1
6	6.5	22	31.5
7	2.8	23	6.5
8	4.3	24	21.1
9	7.8	25	8.6
10	29.4	26	12.2
11	16.1	27	18.5
12	10.4	28	159.3
13	19.2	29	6.4
14	21.0	30	392.1
15	17.9	31	6.4
16	8.8		

Fig. 3.1.3 Catchment Area (Alternative-B)

FEASIBILITY STUDY FOR REHABILITATION PLANNING OF BOLIVIAN NATIONAL RAILWAYS LA PAZ BOLIVIA	
TITLE	CATCHMENT AREA-2
JAPAN INTERNATIONAL COOPERATION AGENCY TOKYO JAPAN	
SUBMITTED / APPROVED / SCALE	1/50,000 / REVISED
DATE / DWG NO.	

(3) Calculation for planned discharge

The following rational formula is used for conversion of planned precipitation into planned discharge in equivalence:

$$Q = \frac{1}{3.6} \cdot f \cdot r \cdot A$$

Where, Q: Planned high water discharge (m^3/sec)
f: Run-off coefficient
r: Average precipitation intensity with time of flood discharge reach(mm/hr.)
A: Catchment area (km^2)

In the formula above, time (T) of flood discharge reach and average precipitation intensity (r) with time of reach must be obtained by calculation. Time of flood discharge reach refers to time to be required until storm water flows into the stream course (inflow time) and time to be required for storm water to flow down in the stream course (flow-down time). Generally, when the stream course is developed well in the basin, the most of time for flood discharge reach stands for flow-down time while a greater majority is shared by inflow time in the catchment area where the stream course remains undistinguishable.

Herein, time of flood discharge reach may be estimated from the Bayern District Formula as shown below. However, in the catchment area covered by the new detour line plan, time of flood discharge reach for the 310 km to 385 km section, where stream course is not clearly distinguishable, will be a total of the value to be obtained from calculation by the Bayern District Formula plus 50 per cent addition as inflow time.

Bayern District Formula

$$W = 72 \, (H/L)^{0.6}$$

$$T = L/W$$

Where, T: Time of flood discharge reach (hr)
W: Flow-down velocity of flood (km/hr)
H: Difference in elevation (km)
L: Horizontal length up to the utmost upstream of basin (km)

Average precipitation intensity within time of flood discharge reach is to be estimated from the daily precipitation record available because of lack of hourly precipitation record.

The following Mononobe Formula is used to seek average precipitation intensity of time (T) from daily precipitation.

Mononobe Formula

$$r_T = \frac{R_{24}}{24} (24/T)^{2/3}$$

Where, r_T: Average precipitation intensity of time (T)(mm/hr)
R_{24}: Daily precipitation (mm/day)

Calculation results for each of the catchment areas, as defined in the preceding item, by use of the Formula above are shown in Tables 3.1.1 and 3.1.2 (see Appendix-6 for calculation detail process).

Table 3.1.1 Planned High Water Discharge (Alternative-A)

Area No.	Station	Area (km^2)	Planned High Water Discharge $Q(m^3/sec)$
1	339 km + 500 m	6.575	139.4
2	343 + 500	7.250	124.1
3	345 + 950	4.425	93.8
4	347 + 500	6.050	128.3
5	348 + 800	0.568	12.0
6	350 + 600	0.283	6.0
7	351 + 100	0.208	4.4
8	351 + 300	1.333	28.3
8	351 + 420		
8	351 + 600		
9	352 + 200	0.143	3.0
9	352 + 250		
10	353 + 000 353 + 360	0.293	6.2
11	353 + 890	0.443	9.4
12	354 + 400	0.193	4.1
12	354 + 520		
12	354 + 720		

Area No.	Station	Area (km^2)	Planned High Water Discharge $Q(m^3/sec)$
13	354km + 950m	0.300	6.4
14	355 + 130	0.293	6.2
15	355 + 400	0.683	14.4
16	355 + 700 356 + 010	0.225	4.8
17	356 + 070	1.193	25.3
17	356 + 180		
18	356 + 360	2.243	47.6
19	356 + 700	0.165	3.5
20	356 + 900	0.125	2.7
21	357 + 030	0.242	5.1
22	357 + 600	0.100	2.1
23	357 + 950	0.225	4.8
24	358 + 170	1.592	33.8
25	358 + 600	0.050	1.1
26	358 + 700	0.170	3.6
27	358 + 870	0.500	10.6
27	358 + 983		
28	359 + 188	0.975	20.7
29	360 + 310	1.308	27.7
30	360 + 700 360 + 910	2.067	43.8
31	361 + 737	1.150	24.4
32	363 + 595	2.716	57.6
33	364 + 782	7.458	158.1
34	367 + 300	4.517	95.8

Area No.	Station	Area (km^2)	Planned High Water Discharge Q(m^3/sec)
35	$378^{km} + 000^{m}$		
35	378 + 500	321.8	1132
35	380 + 500		
35	383 + 950		
36	386 + 800	527.0	1564
37	387 + 071	3.517	74.6
38	388 + 960	6.283	133.2
39	389 + 900	4.025	85.3
40	391 + 230		
40	391 + 450	6.025	127.7
40	391 + 600		
41	391 + 950	3.767	79.9
42	395 + 538	6.267	132.9
43	396 + 650	16.280	281.5
44	397 + 320	7.658	162.3

Table 3.1.2 Planned High Water Discharge
(Alternative-B)

Area No.	Station	Area (km^2)	Planned High Water Discharge $Q(m^3/sec)$
1	312 km + 850 m	6.45	54.8
2	318 + 700	7.55	51.8
3	323 + 700	2.75	32.8
4	328 + 400	2.85	33.0
5	333 + 300	12.13	112.6
6	336 + 200	6.53	62.8
7	337 + 500	2.78	30.5
8	338 + 200	4.33	40.6
9	339 + 300	7.80	67.3
10	340 + 700	29.35	170.7
11	343 + 450	16.13	106.5
12	344 + 600	10.35	69.7
13	347 + 250	19.18	125.1
14	349 + 650	21.00	123.2
15	352 + 150	17.93	101.0
16	353 + 100	8.78	65.3
17	355 + 400	8.08	73.0
18	357 + 600	28.18	148.4
19	358 + 600	24.00	142.4
20	359 + 300	12.85	76.5
21	362 + 900	15.13	90.8
22	364 + 100	31.48	177.9

Area No.	Station	Area (km^2)	Planned High Water Discharge Q(m^3/sec)
23	366 km + 100 m	6.45	60.5
24	368 + 150	21.08	130.3
25	371 + 550	8.63	77.2
26	376 + 850	12.25	76.4
27	384 + 500	18.50	154.2
28	404 + 500	159.25	517.6
29	406 + 500	6.40	73.2
30	407 + 900	582.10	1581.0
31	410 + 950	6.267	132.9

3-1-3 Construction Standard

The construction standard applicable to drafting of the rehabilitation plan refer to the standard enforced by the Comision Mixta Ferroviaria BOLIVIANO - BRASILENA at the time when the existing line was constructed and the standard of construction prepared specifically by the Bolivian National Railways (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: 90 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 Fig. 3.1.4.

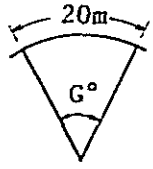
In the curved section, the clearance will be broadened as much as the bias of vehicle, so that the clearance between the fixed structure and the vehicle can be equalized to that provided in the straight track section.

(2) Maximum grade

The degree of grade is one of great influential factors to transport conditions and track maintenance costs. Normally, the maximum degree of grade in the straight section of the main line will be limited to 10/1,000. However, it may be allowed to 12/1,000 in view of economy unless any operational problems are anticipated specifically.

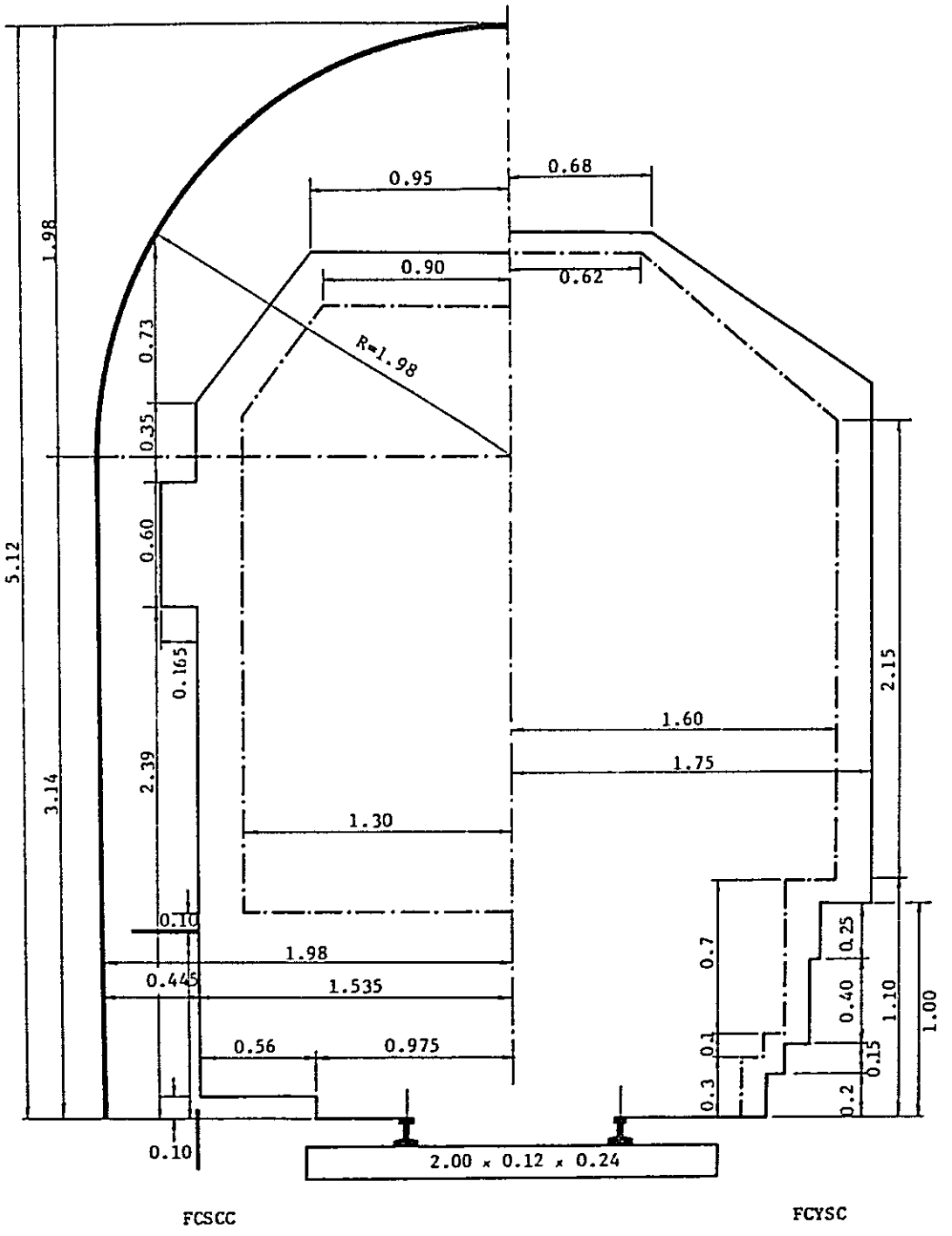
The maximum degree of grade in the curved section will be reduced so moderately as to be able to compensate curve resistance as shown below:

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



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.



Standard track gauge 1.00m

(Unit : m)

Fig. 3.1.4 Track Clearance

(3) Longitudinal curve

Longitudinal curve will be inserted so as to enable the train to keep running smoothly when it will pass over the changing point of grade.

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 301.612 m (3°48' 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 degree of cant accords with curve radius and train running speed and is expressed by the following formula 1):

$$C = \frac{G}{g \cdot R}\left(\frac{V_0}{3.6}\right)^2 = \frac{V_0^2}{0.127 \cdot R} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad 1)$$

Where, C: Degree of cant (mm)
G: Track gauge (1,000 mm)
V_0: Average train speed (km/hr)
R: Curve radius (m)

1) Maximum degree of cant

In consideration of the operating conditions between Santa Cruz and Corumba of the Eastern Line, the maximum allowable running speed will be 90 km per hour for a ferrobus and 70 km per hour for a train.

The limited speed in the curved section may be expressed by the following formula 2):

$$V_{max} = 3.8\sqrt{R} \text{ (km/hr)} \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad 2)$$

The value V_0 as used in the formula 1) seeking for the degree of cant denotes the average speed of a train passing over the curved section. It is generally expressed by the formula 3) below:

$$V_0 = \sqrt{\frac{\Sigma Vi^2}{N}} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots \quad 3)$$

Where, Vi: Speed of various types of trains passing over the curved section (km/hr)
N: Number of trains
V_0: Average speed (km/hr)

From the calculated results above, it is defined that the limited speed in the curved section will be as shown in Table 3.1.3 and the cant, as shown in Table 3.1.4.

From the above, the maximum degree of cant is determined at 110 mm.

Table 3.1.3 Limited Speed in Curved Section

Curve Radius	Ferrobus	Train
600 m and over	90 km/hr	70 km/hr
500 m and over	85 km/hr	70 km/hr
400 m and over	75 km/hr	70 km/hr
301.6 m and over	65 km/hr	65 km/hr

Note: · Speed unit is at a rate of 5 km per hour.
· Maximum running speed is determined at 90 km per hour for ferrobus and 70 km per hour for train.

Table 3.1.4 Set Degree of Cant and Its Deficiency

Unit: mm

Average Speed (km/hr)	Curve Radius (m)								
	301.6	400	500	600	800	1,000	1,200	1,500	2,000
65	110 (0)	83 (28)	80 (34)	75 (31)	56 (24)	45 (19)	38 (15)	30 (13)	23 (9)
72.5	-	104 (7)	83 (31)	75 (31)	56 (24)	45 (19)	38 (15)	30 (13)	23 (9)
77.9	-	-	96 (18)	80 (27)	60 (20)	48 (16)	40 (13)	32 (11)	24 (8)
80.6	-	-	-	85 (21)	64 (16)	51 (13)	43 (11)	34 (8)	26 (6)

Note: Figures in parentheses show deficiecy of cant.

The following conditions must be satisfied by cant.

1) The set value of cant shall be 70 per cent of the balanced cant at maximum speed.

2) Deficiency in the allowable degree of cant shall be 50 mm.

(6) Slack

Maximum slack will be 30 mm. Gradual decrease of slack will be made by total length of transition curve.

(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)

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

Where, C: Set degree of cant (mm)
Cd: Deficiency of cant (mm)
V: Max. train running speed (km/hr)

Table 3.1.5 Transition Curve Length

Curve Radius	Transition Curve Length
301.6 m	75 m (110 m)
400	80 (105)
500	85 (100)
600	80 (85)
800	60 (65)
1,000	50 (55)
1,200	40 (45)
1,500	35 (35)
2,000	25 (30)

Note: Transition curve length is specified at an unit of 5 m.
( ): in case of L_1=1.0C

(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 is regarded as the basic standard for designing of the track structure. The optimum width should be enough to maintain the specified configuration of track structure on it, to ensure safe support against train vehicle load and also to reflect full consideration to the convenience for track maintenance.

The formation width for the earthwork section is as shown in Fig. 3.1.5.

The said width is determined at 6.00 m.

The formation will be traversed with 3 per cent drain inclination.

(10) Earthwork

1) Embankment

General view of the embankment section is shown in Fig. 3.1.5.

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.

Earth-cutting will be made very close to the planned main line to get material for embankment. It will be spread out to the required thickness after cutting and rolled up to a dried density of 90 per cent and over as set forth by AASHO.

The trace after cutting of earth will be designed so as to be serviceable as the drain ditch.

2) Cutting

General view of the cutting section is shown in Fig. 3.1.5.

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.

In order to prevent inflow of storm water into the main line at any rainfall, either a drain ditch will be provided by the side more than 2.0 m apart from the slope shoulder or soil left after cutting will be embanked as a training dike.

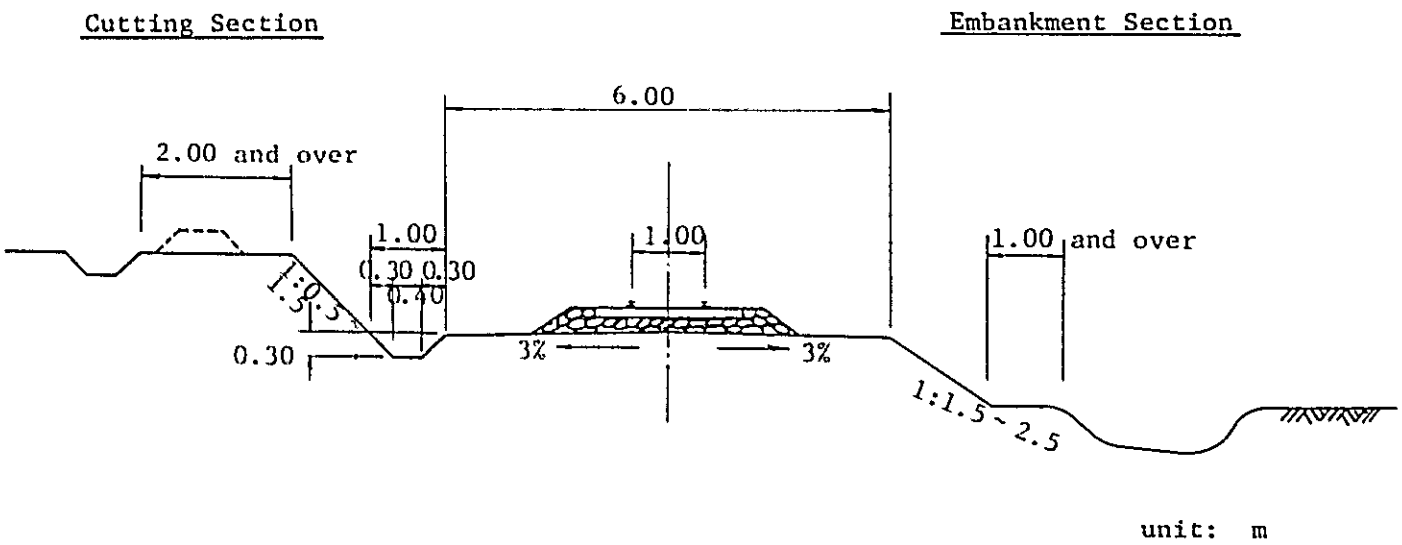


Fig. 3.1.5 The Formation Width for the Earthwork Section

(11) Bridges

Designed live load applicable to designing of the structure will be of Cooper E-40 load type as shown in Table 3.1.6.

Table 3.1.6 Cooper E-40 Load Type

E – 40		Wheel Distance		
t	lb	m	ft	
9.05	20 000			
18.1	40 000	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			

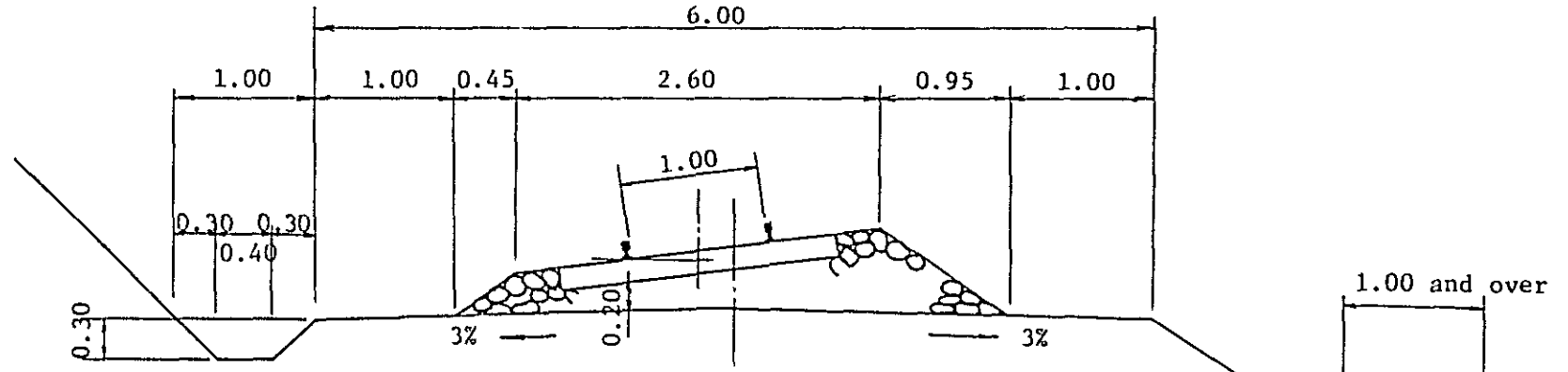
(12) Track structure

The track structure will be designed by the following specifications. (Fig. 3.1.6)

- Rail shall be 75 Lba/Yda (37.48 kg/m) or its equivalence. (Fig. 3.1.7)
- 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 #10 turnout as shown in Fig. 3.1.8.

Curved track section

unit: m



Straight track section

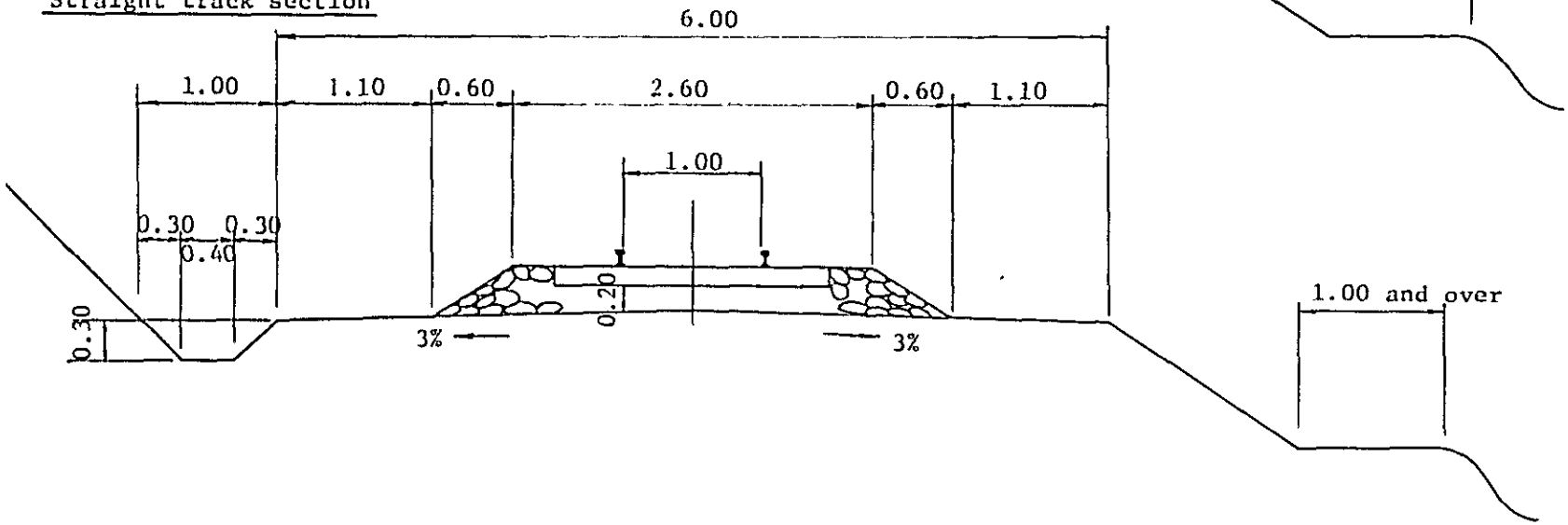
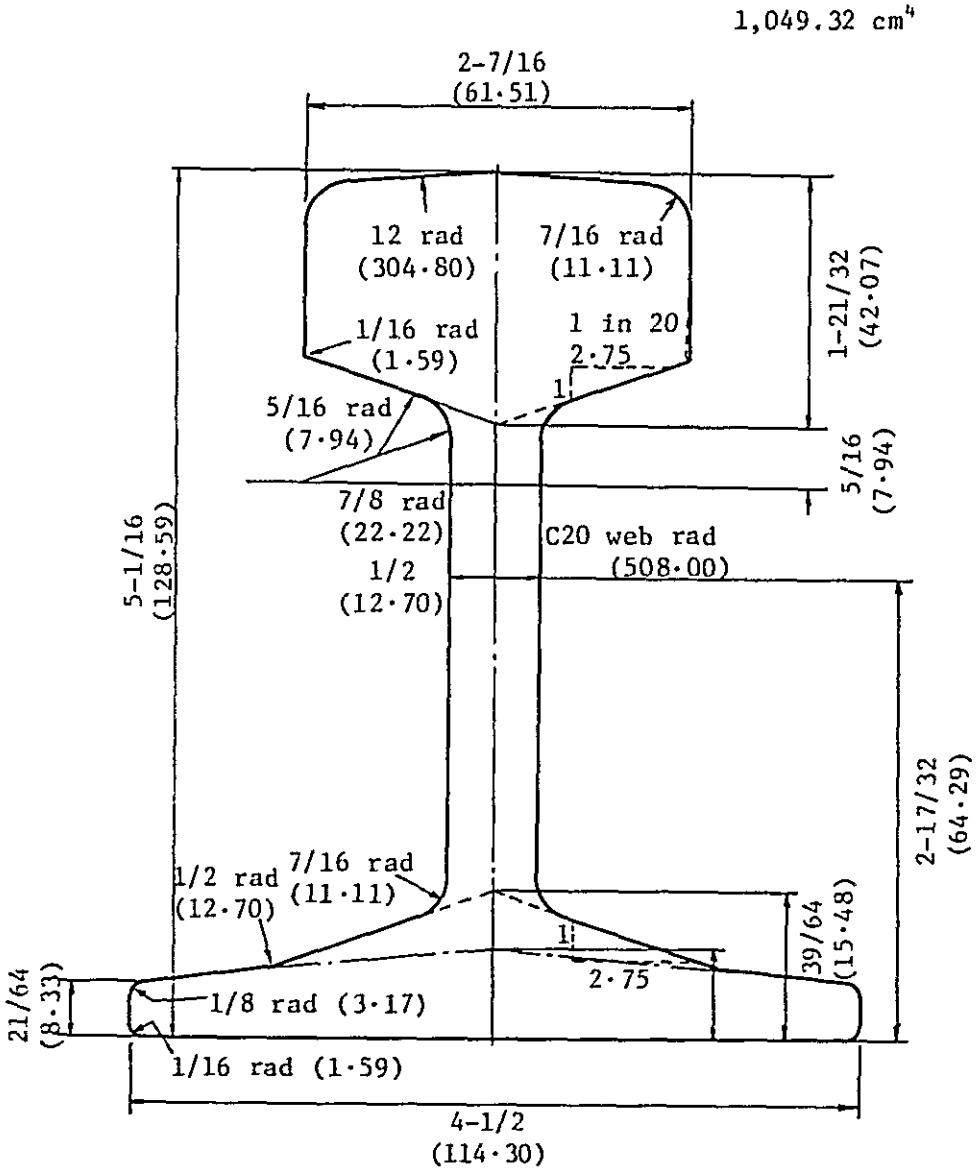
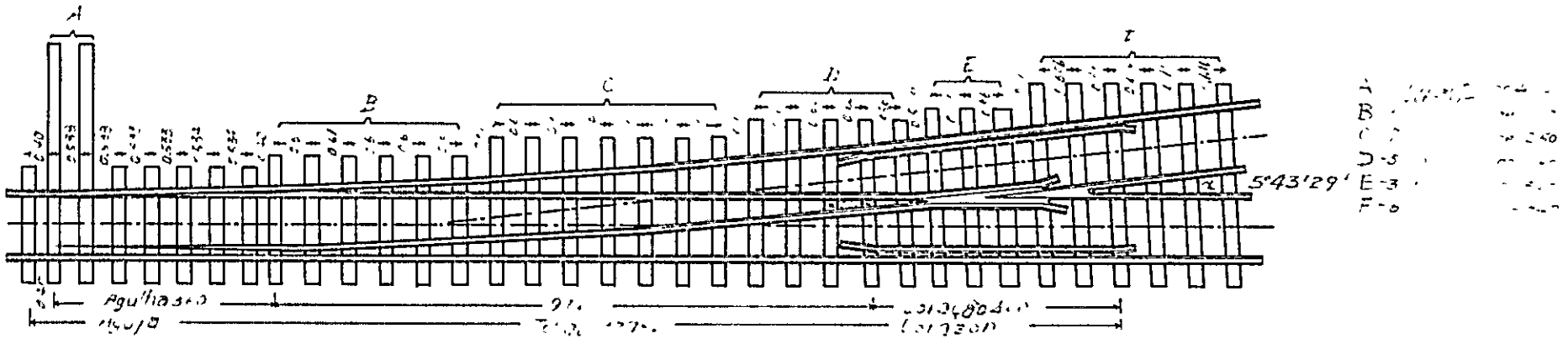


Fig. 3.1.6 Track Construction



Dimensions in inches
Approximate millimetre equivalents in brackets
75·55 lb per yard (37·48 kg per metre)

Fig. 3.1.7 Rail 75 Lba/Yda (37.48 kg/m)



Distribución de los durmientes en los cambios de vía

EFBB	COMISIÓN MIXTA FERROVIARIA BOLIVIANO - BRASILEÑA
CAMBIO Tg. 0,10	
ING JEFE	ING DELEGADO
462	L-1 | 41-1 | A-334

Fig. 3.1.8 Turnout (#10)

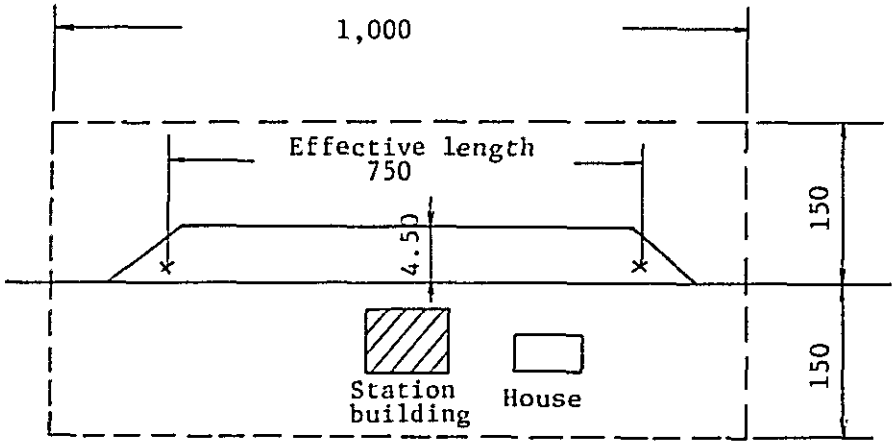
(13) Station facilities

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.

The required land area for each station will be 300,000 sq.m at average (see Fig. 3.1.9).



Unit : m

Fig. 3.1.9 Schematic View of Station

(14) 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 cuve, start and end points of transition curve, cant, slack, speed limit and clearance post of tracks at station.

3-2 Study on Each Alternative Rehabilitation Plan

3-2-1 Existing Line Rehabilitation (Alternative-A)

As stated in Chapter 2, the causes of the latest disastrous damage in the mountainous area are attributable to flash flood and sand and stone avalanche from the steep grade stream in the water course, together with insufficient water-passage capacity of the river-crossing structure of the railway. In the plain area, the river was flooded far and wide due to insufficient section area for water passage in the crossing section with the railway, and many structures were washed away or destructed.

The rehabilitation plan of the existing line should be carried out with the primary object of removing those causes. The plan is outlined hereunder as to restoration of each structure.

(1) Basic plan for rehabilitation

1) River-crossing section

a) Section in generating source of sand and stone avalanche

The pattern of bridge structure will be adopted basically so as to give adequate clearance and section area to the structure to permit full passage of the sand and stone avalanche.

The design consideration will be given to how to avoid erection of bridge piers in the water course, in so far as the circumstance may permit, and also to the necessity of providing the protection works for the bridge abutment against erosion (including slope protection and retaining works).

b) Section free from generating source of sand and stone avalanche

The structure will be designed for sufficient internal empty section area to permit passage of the probable discharge and the river course will be improved to some extent on the upstream side from the railway crossing section.

At the proposed construction site of structure the box culvert will be used if the embanked level is high or the bridge structure will be adopted if the level is low.

2) Embanked section

New embankment will have to be constructed after rolled to the fullest extent. Its slope surface needs protection by sodding.

In the section which may cause possible damage from impounded or concentrated water, the retaining protection wall will be provided, together with the improvement work for expansion of the side drain gutter.

For a long section of continuous embankment the flood opening bridge will be constructed to be well matched for the planned discharge.

3) Cut section

There still remain many slopes of steep grade in the cut section of the existing line, for which further cutting work will be required to obtain the moderate grade as specified by the applicable roadway diagraph.

Sodding work will be required for protection of the slope surface.

In consideration of the upper topographic condition above the cut section, the full drainage must be secured at the top of slope. Besides, for good drainage of the subgrade the side drain gutter and the cross drain ditch must be improved.

(2) Route (See Appendix Dwgs. 1 & 2)

In the existing route, the El Porton - Chochis section is designed at its plane curve and longitudinal grade as adaptable to the terrain to the maximum allowable limit of the railway construction standard, which means that there remains no room to be further improved in the route itself. Therefore, no route change will be made between El Porton and Chochis. In the Ipias - El Porton and Chochis - Robore sections the route will be partially changed where it is considered advantageous in the economic and constructional aspects.

In the section where trains are operated on the temporary line, such route will be set back to the original route in a pre-damage state.

1) Sections planned for route change (Fig. 3.2.1)

a)	338 km + 900 ∿ 340 km + 100	Length 1 km 200 m
b)	363 km + 000 ∿ 363 km + 700	Length 700 m
c)	377 km + 000 ∿ 393 km + 000	Length 16 km 000 m
		Total 17 km 900 m

Out of the section described above in which the route was changed, the rail level will be elevated by 2.5 m between the point of 377 km + 000 and the point of 393 km + 000.

Out of the section between the point of 377 km + 000 and the point of 393 km + 000, the most seriously damaged parts are around the point of 387 km + 000 and 391 km + 300, extending 2,800 m in total length. For these parts, new routes will be constructed, while the existing routes will be relocated for the rest of the sections.

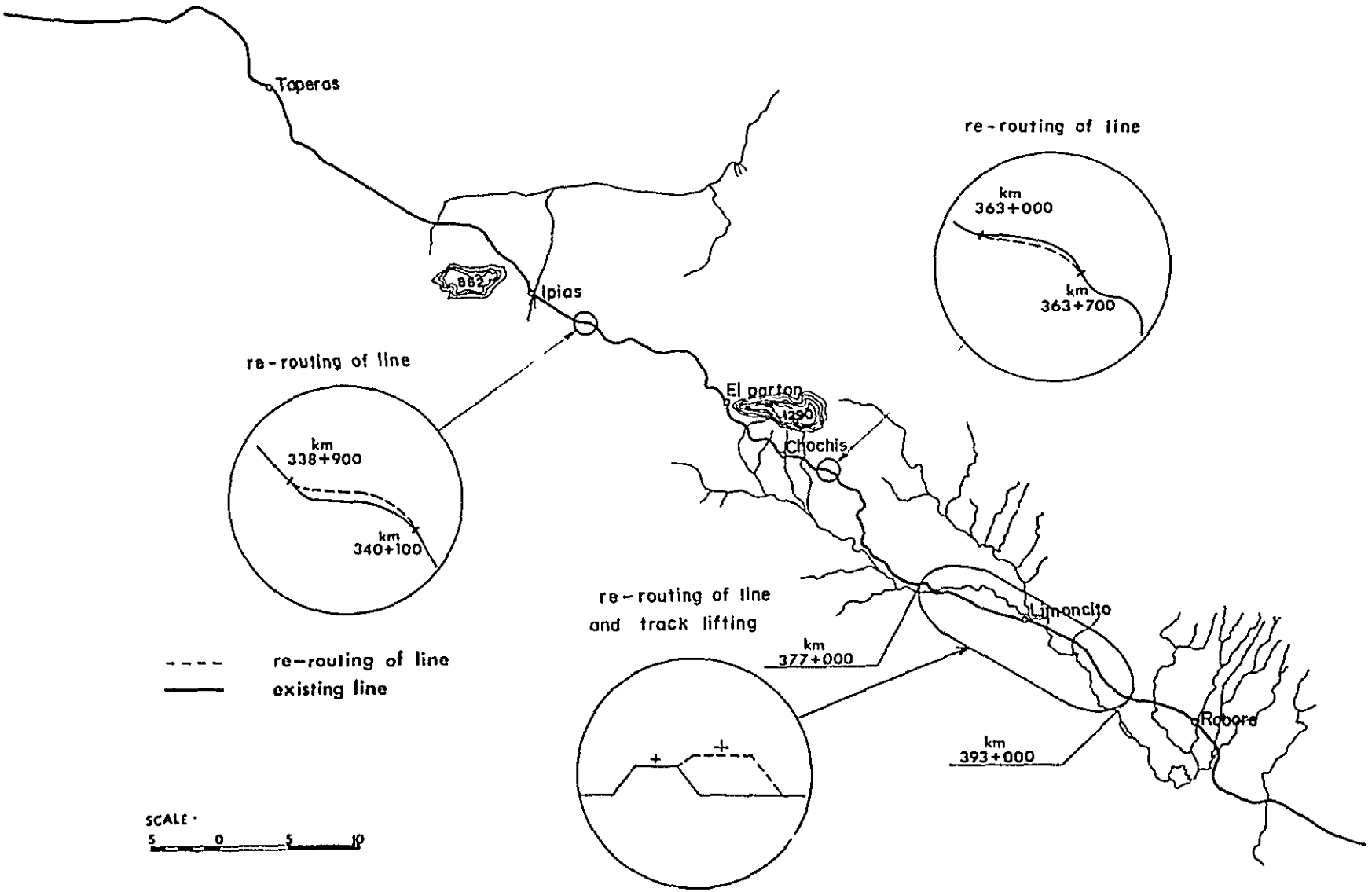


Fig. 3.2.1 Section Planned for Route Change of Existing Line

(3) Calculation for sectional area of structure for adequate drainage capacity

In calculating the required sectional area the most applicable method of calculation to the actual side condition will be used on the basis of the planned high-water discharge as calculated in Item 1-2 of Chapter 3.

The basic factor for calculation of the drainage capacity of the structure should be flow velocity of water. Although velocity can be attained from various formulas, the Manning's formula is used in this calculation.

1) Mean velocity of pure water

Manning's mean velocity

$$V = \frac{1}{n} \times R^{2/3} \times I^{1/2}$$

Where, V: Mean velocity of pure water (m/sec)
n: Coefficient of roughness (Table 3.2.1)
R: Hydraulic radius
I: Inclination

Table 3.2.1 Values of n for the Manning Formulas

Description of Channel	Range of n
Glazed brick	0.011~0.015
Brick in mortar	0.012~0.017
Neat cement	0.010~0.013
Concrete pipe	0.012~0.016
Plank flumes	0.010~0.016
Concrete-lined channels	0.012~0.018
Cement rubble	0.017~0.030
Dry rubble	0.025~0.035
Dressed stonework	0.013~0.017
Smooth metal flumes	0.011~0.015
Corrugated metal flumes	0.022~0.035
Earth canal, straight and uniform	0.017~0.025
Rock canal, trimmed smooth and uniform	0.025~0.035
Rock canal, rough	0.035~0.045
Sluggish, winding channels	0.022~0.030
Canals, stony bed, weeds along bank	0.025~0.040
Earth bottom, rubble sides	0.028~0.035
Natural channels:	
(1) Clean, straight, full stage, no pools	0.025~0.033
(2) As above with weeds and stones	0.030~0.040
(3) Winding, pools, shallows, but clean	0.033~0.045
(4) As above at low stages	0.040~0.055
(5) As (3) with weeds and stones	0.035~0.050
(6) As (4) with large stones	0.045~0.060
(7) Sluggish, weedy, or with deep pools	0.050~0.080
(8) Very weedy and sluggish	0.075~0.150

Here, the value n is attained as follows from Table 3.2.1.

Natural river	n = 0.035
Concrete channel	n = 0.015
Corrugated pipe	n = 0.035

Inclination degree is standardized at 1%.

2) Mean velocity of flow containing soil and sand

When water flow containing soil and sand runs through the channel, its velocity may be reduced below that of pure water.

The Japanese National Railways take the following formula for this calculation:

$$V_1 = V \times \frac{\gamma_w}{\gamma_w + \alpha(d_m - \gamma_w)}$$

Where, V_1: Mean velocity of water flow containing soil and sand (m/sec)
V: Mean velocity of pure water (m/sec)
γ_w: Specific gravity of pure water
d_m: Specific gravity of sand (Appendix 1)
α: Volumetric ratio of sand to water (Table 3.2.2)

Now, let it be assumed as $\alpha = 0.2$

$$V_1 = V \times \frac{1.0}{1.0 + 0.2 \times (2.6 - 1.0)} \fallingdotseq V \times 0.75$$

Table 3.2.2 Values of α

River	Percentage in Weight		Percentage in Volume	
	Ordinary	Flood	Ordinary	Flood
Var	0.357	3.70	0.223	2.31
Durance	0.145	0.364	0.091	0.223
Mississippi	0.067	0.147	0.042	0.092
Rhone	0.056	0.435	0.035	0.272
Nile	0.049	-	0.031	-
Donau	0.050	-	0.031	-
Ohio	0.029	-	0.018	-
Loire	0.020	-	0.013	-
Seine	0.004	0.274	0.0025	0.171
Rhein	-	1.00	-	0.625

3) Drainage capacity of section

$$Q = \alpha Q_2$$

$$Q_2 = A \times V$$

Where, Q: Drainage capacity (m^3/sec)
Q_2: Admittable quantity of discharge (m^3/sec)
α: Marginal allowance rate
A: Sectional area for drainage (m^2)
V: Mean velocity (m/sec)

In the area where flow containing soil and sand is anticipated, the marginal allowance should be taken at $\alpha = 0.8$ with consideration to the possible reduction of sectional area due to formation of soil and sand deposit. In the rest area, the rate is taken at $\alpha = 1.0$.

4) Sectional area designed for avalanche of sand and stone

The sectional area designed for avalanche of sand and stone should be not only adequate enough for the planned discharge but also 3 to 5 times as large as the size of sand and stone contained in the flow. Though this may be varied depending upon the actual condition of river course and to what extent the river is devastated, the required sectional area must be determined from the particular condition of each construction side.

It should be noted that the largest size of stone outflown to the damaged site is about 5.0 m in diameter.

(4) Planned construction of main structures (Alternative-A)

Main structures to be constructed as proposed by the existing line rehabilitation plan are as tabulated in Table 3.2.3 hereunder.

Table 3.2.3 Main Structures

Kilometerage	Bridge	Box Culvert	Pipe Culvert	Lower Sheathing	L-type Retaining Wall
$339^{km} + 500^{m}$	15m	(b×h)			
343 + 500	15m				
345 + 950		$4.5^{m} \times 3.0^{m}$			
347 + 500	15m				
348 + 800		2 × 1.5			
351 + 100		1.5 × 1.5			
351 + 300		2 × 1.5			
351 + 420		2 × 1.5			

Kilometerage	Bridge	Box Culvert	Pipe Culvert	Lower Sheathing	L-type Retaining Wall
351 km + 600 m		2 m × 1.5 m			
352 + 250		5 × 4			
353 + 100		2 × 1.5		459m³	1,775m³
353 + 890		2 × 2			
354 + 400		1.5 × 1.5			
354 + 950	15m				
355 + 130		2 × 1.5			
355 + 155	15m				
355 + 400	15m				
355 + 700				611m³	
356 + 180	15+40+15=70m				
356 + 700		1.5 × 1.5			
356 + 900		1.5 × 1.0			
357 + 300				230m³	
357 + 600		1.5 × 1.0			
357 + 950		1.5 × 1.5			
358 + 170	15+40+15=70m				
358 + 700		W-type 23.0m³			
358 + 870		1.5 × 1.5			
358 + 983		1.5 × 1.5			
359 + 188	15m				
359 + 440		U-type 8.0m³			
360 + 309	65m				
360 + 800		2.5 × 2.0			
360 + 912		2.5 × 2.0			
360 + 980		2.5 × 2.0			
361 + 737	15+40+15=70m				
362 + 100		U-type 8.0m³			
363 + 595	15+40+15=70m				
364 + 782		W×5.0×4.5			
367 + 300		5.0 × 5.0			
374 + 450		U-type 8.0m³			

Kilometerage	Bridge	Box Culvert	Pipe Culvert	Lower Sheathing	L-type Retaining Wall
km m 378 + 500	20 × 3 = 60m				
378 + 800		0.8m × 1.1m			
379 + 375		1.0 × 1.55			
380 + 550		1.0 × 1.5			
381 + 256		1.0 × 1.5			
383 + 835		1.6 × 1.6			
383 + 950			φ1.8 m		
384 + 800		0.8 × 1.5			
385 + 200		0.8 × 1.0			
386 + 800	20 × 4 = 80m				
387 + 071		3.5 × 3.0			
387 + 540		0.8 × 1.55			
387 + 960		0.65 × 2.0			
388 + 833		0.8 × 1.1			
388 + 960	10m				
389 + 668		0.8 × 1.5			
389 + 900		4.0 × 4.0			
391 + 040		1.05 × 1.5			
391 + 100		W×2.5×2.0			
391 + 230		W×2.5×2.0			
391 + 450		W×2.5×2.0			
391 + 600		W×2.5×2.0			
391 + 950		4.0 × 3.5			
395 + 538		W×3.5×3.0			
396 + 650	15 × 2 = 30m				
397 + 390	20m				
Total	650m	Box 4,722.5m³ W-type U-type 47.0m³	φ1.8m × 1	1,300m³	1,775m³

(5) Kind and quantity of work

The kind and quantity of work to be required for rehabilitation of the existing line are specified in Table 3.2.4.

Table 3.2.4 Kind and Quantity of Work (Alternative-A)

Kind of Work	Unit	Quantity	Remarks
Main track cutting	m^3	30,300	ℓ = 1,400 m
Main track embankment	"	779,300	ℓ = 17,300 m
Temporary track cutting	"	221,500	ℓ = 2,600 m
Temporary track embankment	"	742,700	ℓ = 7,700 m
L-type retaining wall	"	1,780	ℓ = 350 m
Lower sheathing work	"	1,300	ℓ = 850 m
Corrugated pipe φ1.8 m	No.	1	
Open drain channel	"	4	47 m^3
Box culvert	"	42	4,723 m^3
Bridge	m	650	923 t
Main track setting	"	17,720	
Temporary track setting and removal	m	13,020	

(6) Work plan

The restoration work of the existing line must be executed without suspension of routine train operations.

To meet this requirement, the temporary track method will be used for bridge erection and large-size culvert setting. Therefore, the temporary track will be laid, at first, in parallel with the existing track line and then construction work will be executed on the existing line after shifting of train operation to the temporary track (Fig. 3.2.2).

The open-cut method will be used for construction of the open channel and other similar structures of relatively small section area. Rail beam will be used as temporary supports to the rail of the existing line while the work is being executed under the train-run track line (Fig. 3.2.3).

In those sections where the route change is planned or the temporary track is used for operation at present, the track will be shifted to the new track after completion of the work at the site of construction.

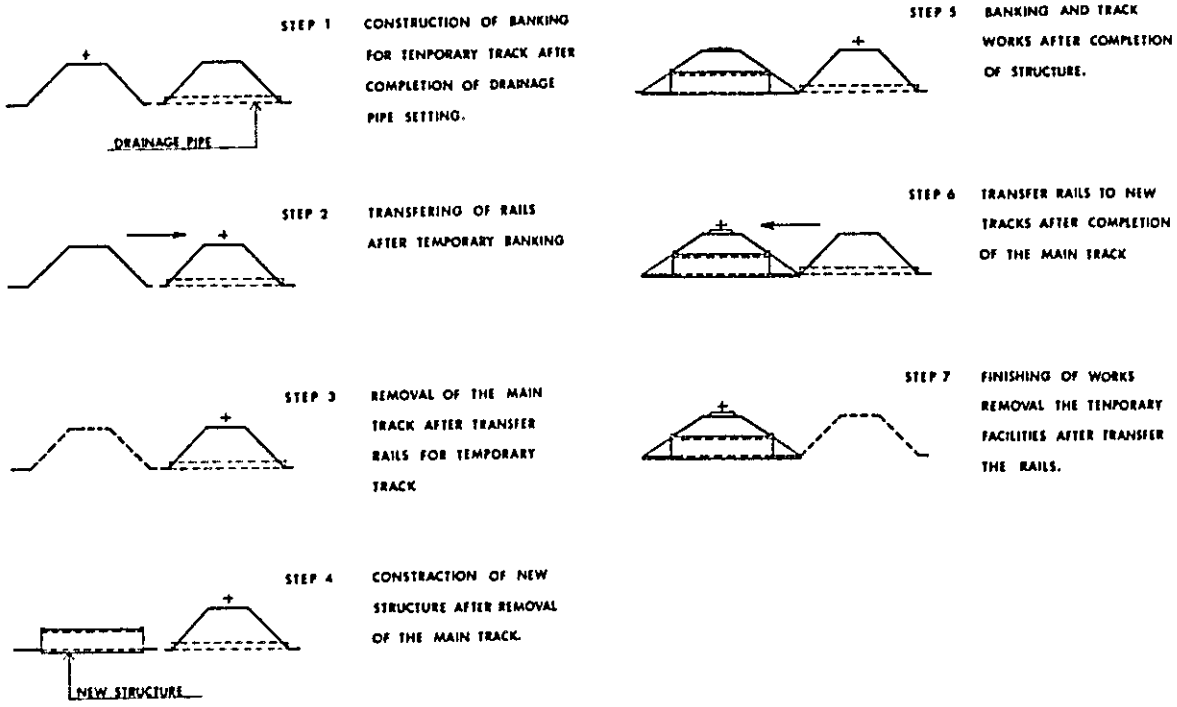


Fig.3.2.2 Temporary Track Method

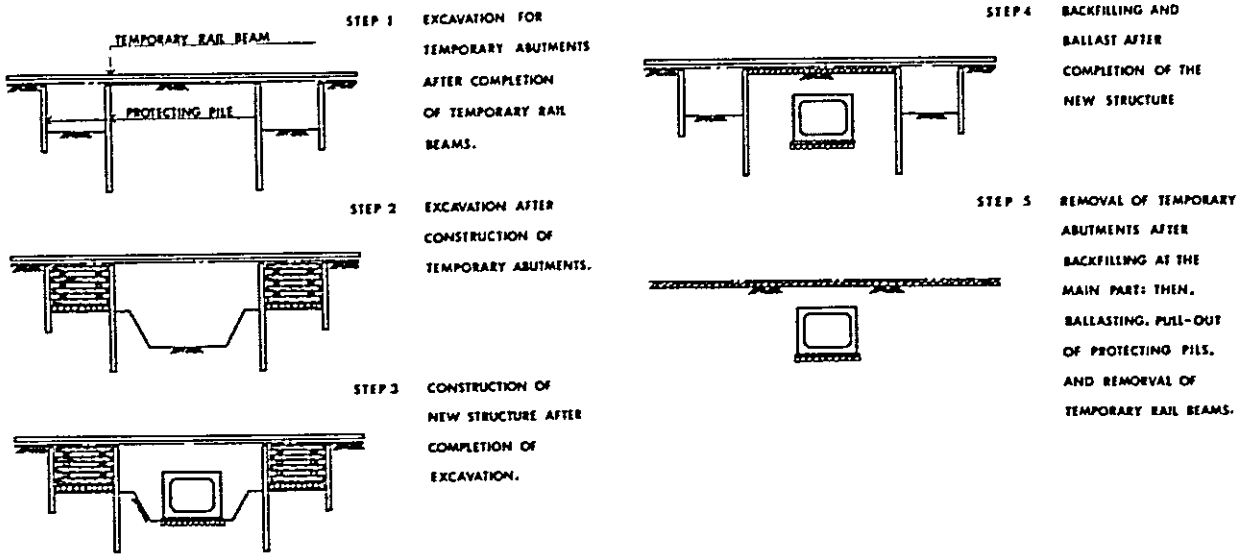


Fig. 3.2.3 Open-cut Method

The following are the proposed sections for temporary track construction in connection with construction of main structures:

Temporary track section

1)	343 km + 100 m ∿ 343 km + 900 m	800 m
2)	345 km + 250 m ∿ 346 km + 650 m	1,400 m
3)	346 km + 900 m ∿ 348 km + 100 m	1,200 m
4)	354 km + 720 m ∿ 362 km + 000 m	7,280 m
5)	364 km + 400 m ∿ 365 km + 160 m	760 m
6)	366 km + 850 m ∿ 367 km + 750 m	900 m
7)	395 km + 430 m ∿ 395 km + 640 m	210 m
8)	396 km + 530 m ∿ 396 km + 780 m	250 m
9)	397 km + 100 m ∿ 397 km + 320 m	220 m
	Total length	13,020 m

Design standard for temporary track construction

1)	Curve radius	Rmin = 100 m
2)	Longitudinal curve	Rmin = 5,000 m
3)	Grade	Imax = 20 0/00
4)	Straight line length between curves	Lmin = 20 m

3-2-2 Comparative Studies on Alternatives (Alternatives-B, C, D and E)

(1) Selection of alternative

In order to draft the most appropriate rehabilitation plan, the following four alternative plans will be taken up for comparative study, in addition to the existing line rehabilitation plan (Fig. 3.2.4).

Alternative-A	See 'Existing line rehabilitation plan' in Chapter 3-2-1.
Alternative-B	New detour line plan
Alternative-C	Downstream plan
Alternative-D	Opposite side of the river plan
Alternative-E	Tunnel construction plan

(2) Alternative routes

1) Alternative-B (Appendix Dwgs. 3 & 4)

This new detour line route will be branched off from the existing Taperas Station and connected to the Robore Station. The total length of the new detour line between the two stations will be 105 km 783 m, longer by 15 km 300 m as compared with the existing line length.

The route is planned to start from the point of 310 km 400 m at the end of Taperas Station, run toward south on the western side of Quebrada Cruz Rejala, make a detour at about 320 km + 400 m on the southern side of Cerro Cruz Rejala (602 m above sea level) and reach the 500 m high plateau at about 330 km + 000 m.

On this plateau the route will go straight forward in the south-east direction up to the point of about 4 km south of La Torre, where it will make a large detour on the south side in the north-east direction, then cross over the rivers Que Brada Toroca at 404 km + 500 m and Rio San Carlos at 407 km + 900 m and finally join the existing line route at 412 km + 200 m (at 396 km + 900 m on the existing line, after coming into the parallel line with the existing track at about 410 km (at 394 km + 500 m on the existing line).

The curve radius for the new detour line should be the allowable largest with due consideration to the plan worked out on a mere topographic map reduced to 1/50,000 and the expected economy in operation and maintenance. New railway stations will be limited to four (4) at a proposed distance of 20 km between the two stations.

Although it is known that the longitudinal grade should naturally be more ideal with its closer approximately to the horizontal level, this plan considers use of 12/1,000 grade at its steepest inclination with a view to reducing the construction cost to most minimum. The longest section designed at the 12/1,000 grade in the detour line reaches 6 km 883 m.

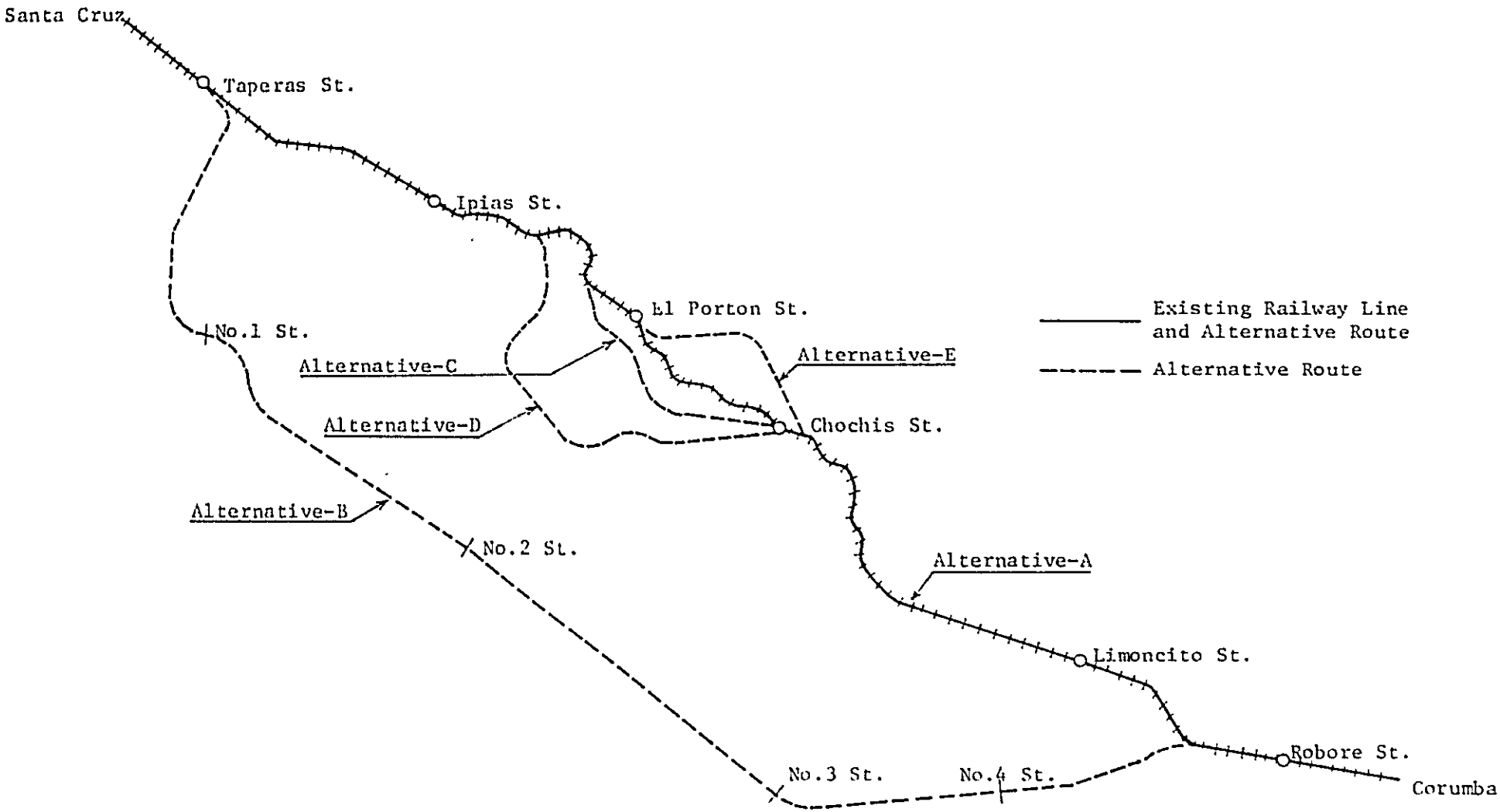


Fig. 3.2.4 Rough Sketch of Existing Line and Alternative Routes

As the means of compensation for inconvenience which the proposed abolition of Chochis and Limoncito railway stations would cause the inhabitants living nearby, this alternative plan considers the bus transport service by transferred use of the existing railway roadbed as the public road between Chochis and Robore.

Study on Maximum Grade

The following are the reasons why a grade of 12 0/00 has been adopted.

- *Tractive force at 12 0/00 grade*

  In the case where a locomotive is capable of tractive a weight of 1,200 tons (excluding locomotive weight) at a grade of 10 0/00, the tractive force may be declined by 15 0/0 at a grade of 12 0/00.

  Therefore, 1,200 tons × 85% = 1,020 tons

- *Transport ratio by up and down tracks from actual record of transport in 1978*

$$\frac{\text{from Santa Cruz to Corumba}}{\text{from Corumba to Santa Cruz}} = \frac{0.26}{1}$$

- *Relationship between train weight and tractive force may be as follows:*

	Train Dead Weight	Freight	Train Weight	Tractive Force
Santa Cruz → Corumba	30×15 =450 tons	750×0.26 =195 tons	645 tons	1,020 tons
Corumba → Santa Cruz	30×15 =450 tons	750 tons	1,200 tons	1,200 tons

As noted from the above comparison, the track from Santa Cruz to Corumba may still have its marginal tolerance of 1,020 - 645 = 375 tons, even though the track may be graded at 12 0/00. Therefore, even though freight transport may be increased from Santa Cruz to Corumba in the future, it would not produce any problem until the transport ratio by up and down tracks is increased up to a ratio of 0.76 to 1.

2) Alternative-C (Appendix Dwgs. 5 & 6)

This route is planned with an intention to make a detour from the existing El Porton - Chochis railway section which was damaged most seriously. The plan envisages new line construction over a total length of 9 km 600 m and also rehabilitation of the existing line in all the rest sections; the new line will be branched off at 350 km + 100 m, make a detour on the western side of the existing El Porton Station and connected to the existing line at 360 km + 300 m after passing the downreach of the existing line.

El Porton Station will be moved to the point of 350 km + 500 m.

3) Alternative-D (Appendix Dwgs. 7 & 8)

This plan proposes change of the existing route between El Porton and Chochis to the new route on the opposite side of the river in order to make a partial detour off the said section which was damaged most seriously.

The new route will be branched off from the existing line at 340 km + 700 m and connected again at 361 km + 600 m. The plan includes not only construction of a new line of 24 km 400 m in total length but also rehabilitation of the existing line in the rest sections.

The two existing stations, El Porton and Chochis will be relocated respectively to each new proposed site.

4) Alternative-E (Appendix Dwgs. 9 & 10)

This plan proposes construction of a tunnel route for complete protection from any future possible damage of the existing El Porton and Chochis section which was damaged most seriously.

The project covers rehabilitation of the existing line in the other sections as well as construction of the new line over a total length of 7 km 700 m.

5) Comparison of route length for each alternative

Route length can be compared as follows for each alternative on the condition that the project section for rehabilitation should be limited to the railway division between Taperas and Robore in all alternative cases. (Table 3.2.5)

Table 3.2.5 Existing Line Rehabilitation and Route Length for Each Alternative

Alternative	Route Length	Rehabilitation Length of Existing Line	New Route Length	Track Renewed Length
A	$90^{km}483^{m}$	$13^{km}020^{m}$	$4^{km}700^{m}$	$72^{km}763^{m}$
B	$105^{km}783$	$0^{km}220$	$101^{km}800$	$3^{km}763$
C	$89^{km}883$	$7^{km}440$	$13^{km}400$	$69^{km}043$
D	$93^{km}983$	$6^{km}040$	$21^{km}800$	$66^{km}143$
E	$89^{km}583$	$6^{km}140$	$12^{km}400$	$71^{km}043$

Note 1: Km length of existing line

Taperas Station 309 km + 925 m
Robore Station 400 km + 408 m

2: Rehabilitation length of existing line should be equalized to the total extension of the temporary track line.

3: Now route length should include the total length of route change, in the existing line.

6) Topographic and geological conditions

Topographic and geological conditions for each alternative route are as specified in Table 3.2.6.

Table 3.2.6 Comparison of Topographic and Geological Conditions of Alternative Routes

Alternative Route	Topography	Geology	Remarks
B	To be branched off at Taperas, come up on the plateau after running alongside the valley, pass through the almost flat top surface of the plateau, descend the gentle slope, cross over the flood plain of San Carlos River up to the juncture with the existing line and finally reach Robore Station.	The bed rock of plateau consists of red sand stone on starting side of railway and Paleozoic slate on terminating side. The proposed track line will pass over the Deluvial deposit covering the bed rock as above. Flood plain of Carlos River consists of Alluvial deposit. Depth of bearing stratum and condition of intermediate stratum remain unknown and require precise survey.	No slope damage problem will occur. The ground on the plateau is almost flat but special consideration is required for drainage of surface water in rain concentration. The section across San Carlos River needs special design consideration for drainage in case of flood.
C	To be branched off at 350 km 600 m between Ipias and El Porton, go upstream along the swamp, cross over the hilly side, descend the gentle slope surface of Mt. Chochis and the fan deposit and come to join the existing line at Chochis.	The hilly area for passage of this route consists of red sand stone. This piedmont is made up with ruptured soil and fan deposit.	The slope of mountain is graded steeply with the mark line of rupture everywhere. The railway section in proximity to this slope may be endangered by direct damage from possible avalanche of sand and stone. On the fan deposit area it may possibly be affected by spreading deposit of such avalanche of sand and stone.
D	To be branched off from the existing line at the point of swamp before the branched point of Alternative-C route, cross over the mountainous zone on western side of Route C, go down along the originating stream of Chochis River, go beyond the crest line of the mountain, come into the same swamp as Route C and finally get to Chochis.	The hilly area for passage of this route consists of red sand stone as its upper stratum and slate at lower stratum. The piedmont consists of ruptured soil and the fan deposit.	
E	To be branched off near El Porton, pass through the tunnel to be constructed in Mt. Chochis, go down the mountain side after meeting the talus cone, come to join the existing line near 361 km 800 m between Chochis and Limoncito.	The bed rock of the mountain, through which the tunnel is to be excavated, seems to consist of red sand stone. Talus cone is developed on the slope of both entrance.	No excavation problem may arise to the depth of natural ground because of unstratified rock, the excavation work may be done with relative easiness, except the section near the entrance which forms talus cone containing great boulder stones. The open section connected with the tunnel will be highly endangered by possible slope surface damage.

As the result of comparative sutdy on merit or demerit of each alternative route, especially from the topographic and geological points of view, it is recognized that Routes C, D and E would have no effect of full improvement as compared with Route A while Route B would cause no slope damage problem though there may be only the flood problem to be anticipated otherwise.

(3) Construction plan of structures

All the structures planned for each alternative should be designed for adequate sectional area of drainage for the planned discharge or for the additional avalanche of sand and stone to the planned discharge.

If the elevation after cutting in the earthwork section becomes especially high, tunnel construction is recommended, instead of cutting work, in the light of economy and workability.

The kind and quantity of work for each alternative are as specified in Table 3.2.7.

Table 3.2.7 Kind and Quantity of Work

Kind of Work	Unit	Alternative -B	Alternative -C	Alternative -D	Alternative -E
Main track cutting	m^3	1,420,000	105,200	1,338,300	30,300
Main track embankment	"	1,300,000	1,733,000	2,951,200	763,400
Temporary track cutting	"		70,000	12,200	
Temporary track embankment	"		551,000	140,600	151,300
Corrugated pipe setting ϕ1.8	No.		1	1	1
Open channel	"	150	2	2	2
Box culvert setting	"	11	27	23	29
Bridge	m	350	450	385	380
Tunnel	"		1,200		6,800
Main track setting	"	101,800	20,840	27,840	18,540
Temporary track setting and removal	"	220	7,440	6,040	6,140
Station facilities and security system	Station	4	1	2	2
Land acquisition and road compensation	set	1	-	-	-

(4) Work execution plan

1) Embankment work

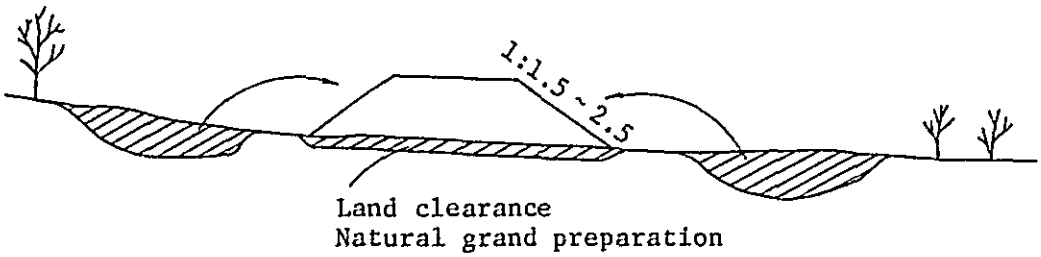


Fig. 3.2.5 Conceptional Drawing of Embankment Work

- The embankment section will be cleared of trees and bushes. Bad surface soil will be replaced for improvement.
- Embankment material should be available from the potential resources near and along the main line.
- The embankment work should be performed by mechanized operation.

  The zone excavated to obtain the embankment material will be designed for transferred use to the drain ditch.

2) Cutting work

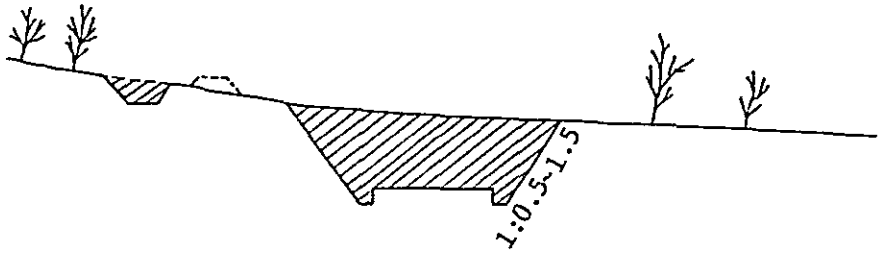


Fig. 3.2.6 Conceptional Drawing of Cutting Work

- The cutting section will be cleared of trees and bushes.
- The cutting work should be performed by mechanized operation.
- The subgrade should be leveled off. At the same time, the side gutter will be excavated without lining alongside the main line.
- Surplus of soil after excavation will be used for embankment work nearby as material or disposed into the borrowing pit provided near the main line.

- Cutting work includes the method of using rock-breaker or dynamite for blasting in anticipation of rock excavation as a part of the whole work volume.
- Drain ditch or small embankment will be provided on the upstream side.

3) Concrete work

Designed strength of concrete structures will be determined from the applicable method of quality control including quality of cement or aggregate and curing of concrete and also from the method of concrete placing.

Herein, designed strength of concrete is as follows:

Reinforced concrete	210 kg/cm^2
Plain concrete	180 kg/cm^2
Plain concrete	160 kg/cm^2

Concrete will be mixed mechanically by concrete mixer which will be carried into the construction site.

Careful study must be made for setting-up of cement procurement plan and schedule including its supplies, so that the progress of construction work would not be hampered.

Fine aggregate for concrete construction will be carried from Santa Cruz.

Coarse aggregate for concrete construction will be carried from quarries in Piococa or Yacuces.

Quality of aggregate available from Piococa and Yacuces quarries, as per specifications in Appendix 7, 8.

4) Reinforcing bar and member steel

Reinforcing bar for concrete structures and member steel for bridges will be imported.

5) Track construction material

Ballast and sleeper will be procured locally in Bolivia while rail, fish plate and rail spikes will be off-shore purchased.

6) Access road for construction

Construction equipment and material will be carried into the site through the following approaches.

In the case of Alternative-B, they will be carried to Taperas and Robore Stations by use of the existing line and delivered from each of those stations further to the construction site through the existing roads.

For alternatives C, D and E, the existing line can be made full use of for transportation to the construction site.

No road construction for this purpose is contemplated specifically.

3-2-3 Project Cost and Track Renewal Cost

Estimated project cost consists of the costs for detailed designing and engineering, construction work (including construction supervision) and contingency.

Since the construction work cost takes a greater majority of the project costs, the cost was estimated by study and review of various fundamental data on the previous records of railway and road construction works in Bolivia.

Those unit construction costs are estimated on the basis of the price level in July, 1979.

(1) Detailed design cost

a) The cost includes preparation of the topographic map on a reduced scale of 1/5,000 covering total width of 1.0 km, 0.5 km each on both sides from the center line of the planned route, together with surveying work at datum points and standard datum of leveling involved in the map.

b) Surveying works of center line, profile leveling and pile setting of center line of the planned route.

c) Soil survey

Survey for availability of embankment material and study on slope surface and soil compaction
Study on stress and bearing power of bridge foundation

d) Detailed design of planned structures

e) Preparation of tender documents including bill of quantities and technical specifications for the construction work

(2) Construction work costs (civil engineering work, track construction, station facilities and security system)

Since Alternative-B proposes construction of a new line, the extra cost will be incurred for road construction to compensate the local inhabitants for abolition of Chochis and Limoncito Stations and for the bus transport service to be furnished by ENFE.

The work will have to be performed without suspension of train operation on the existing line, the extra cost will be allowed for 10 per cent for the work to be done in access to the track and for 30 per cent for the work to be done across the work, taking into account the declined efficiency in such working condition.

With regard to the construction supervision cost, it is estimated at 3 per cent of the total construction cost for Alternative-B and 5 per cent for Alternatives A, C, D and E.

(3) Contingency

Contingency is estimated at 5 per cent for alteration in the bill of quantities and 7 per cent annually for price variation.

(4) Track renewal cost of existing line

Renewal of track will be made in the section utilizing the existing line for rehabilitation between Taperas and Robore.

Project cost for the rehabilitation plan of the existing line and for each of its alternatives are as broken down in Table 3.2.8.

Table 3.2.8 Project Cost and Track Renewal Cost

Unit: 1,000 $b

Description	Alternative -A	Alternative -B	Alternative -C	Alternative -D	Alternative -E
(1) Project cost	517,988	598,394	785,356	690,302	1,871,382
(2) Track renewal cost	159,310	8,720	151,165	144,815	155,544
(1) + (2)	677,298	607,114	936,521	835,117	2,026,926

From the result of comparative studies, the existing line rehabilitation plan (Alternative-A) and the new detour line plan (Alternative-B), which can be regarded as the surest and safest route construction against any possible future damage with minimum cost requirement, are taken up for further comparison by economic and financial analyses.

As the result of comparative study mentioned below, there seems to be only slight difference between track maintenance cost and operating cost of the railway to be compared for economic and financial analyses. Therefore, analysis is made on assumption that both of those costs would be same in total amounts.

Now, a comparison is made between track maintenance cost and operation cost for each of the two proposed alternatives; the existing line rehabilitation plan (Alternative-A) and new detour line construction plan (Alternative-B).

Track maintenance cost of the Eastern-Line in 1978 amounted to 77,000 $b per km including track renewal cost.

By exclusion of track renewal cost, track maintenance cost was reduced to 34,000 $b per km.

As the result of site survey, it was determined that track maintenance work for about 32 km section damaged lately would require double number of maintenance workforce as compared with any other normal sections. Therefore, assuming that the payroll cost would take a share of 70 per cent in total maintenance cost of $b 34,000 per km, the cost for the damaged section may be estimated at $1 \times 30\% + 2 \times 70\% = 1.7$.

Namely, $b 34,000/km × 1.7 ≒ $b 58,000/km.

Then, on the basis of distance, curve and grade of Alternative-A and Alternative-B, track maintenance cost can be compared with operating cost (fuel cost for locomotive operation) as follows:

Increment of track maintenance cost for 10 km extension:	$b 34,000 × 10 km =	$b 340,000
Reducible track maintenance cost due to improved alignment over 32 km: ($b 58,000/km - $b 34,000) × 32 km =		- $b 768,000
Increment in fuel cost due to grade difference over 10 km:		$b 430,000
Total (Balance)		$b 2,000

(5) Construction schedule

The construction schedule is set as follows:

Year	1	2	3
Survey and design	———		
Construction work		———	———

(a) Project Cost of Alternative-A

Unit: 1,000$b

Nature of work	Unit	Quantity	Unit price	Amount
1. Civil Work Cost			($b)	349,483
Main track cutting	M^3	30,300	62	1,879
Main track embankment	M^3	779,300	89	69,358
Temporary track cutting	M^3	221,500	57	12,626
Temporary track embankment	M^3	742,700	80	59,416
Corrugated pipe setting ϕ1.8m	NO	1	337,000	337
Open channel	NO	4	38,000	152
Box culvert	NO	42	1,030,000	43,260
L-type retaining wall	M^3	1,780	4,970	8,847
Lower sheathing	M^3	1,300	2,660	3,458
Bridge	M	650	231,000	150,150
2. Track Construction Cost				39,696
Main track setting	M	17,720	1,670	29,592
Temporary track setting & removal	M	13,020	776	10,104
3. Supervison Cost	%	5	389,179	19,459
4. Subtotal (①~③)				408,638
5. 1/5,000-scaled Map Central Line Surveying and Soil Survey	KM	69	145,000	10,005
6. Detailed Design Specifications and Tender Documents	Man, Month	68	225,000	15,300
7. Sabtotal (①~⑥)				433,943
8. Contingency (Variation in quantity)	%	5	408,638	20,432
9. Contingency (7% annual price variation)	%	14	454,375	63,613
10. Total (①~⑨)				517,988

(b) Track Renewal Cost of Alternative-A

Unit: 1,000$b

Nature of work	Unit	Quantity	Unit price ($b)	Amount
1. Track renewal	M	72,763	1,742	126,753
2. Work supervision	%	5	126,753	6,338
3. Contingency (Variation in quantity)	%	5	133,091	6,655
4. Contingency (Annual 7% price variation)	%	14	139,746	19,564
5. ① ~ ④ Total				159,310

(c) Project Cost of Alternative-B

Unit: 1,000$b

Nature of work	Unit	Quantity	Unit price	Amount
1. Civil Work Cost			($b)	269,871
Main track cutting	M^3	1,420,000	52	73,840
Main track embankment	M^3	1,300,000	74	96,200
Open channel	NO	150	180,000	27,000
Box culvert	NO	11	1,021,000	11,231
Bridge	M	350	176,000	61,600
2. Track Construction Cost				170,117
Main track setting	M	101,800	1,670	170,006
Temporary track setting & removal	M	220	776	171
3. Station Facilities and Security System	Set	4	1,980,000	7,920
4. Land Acquisition and Road Compensation	Set	1		8,400
5. Supervison Cost	%	3	456,368	13,691
6. Subtotal (①~⑤)				470,059
7. 1/5,000-scaled Map Central Line Surveying and Soil Survey	KM	106	145,000	15,370
8. Detailed Design Specifications and Tender Documents	Man, Month	71	225,000	15,975
9. Sabtotal (①~⑧)				501,404
10. Contingency (Variation in quantity)	%	5	470,059	23,503
11. Contingency (7% annual price variation)	%	14	524,907	73,487
12. Total (①~⑪)				598,394

(d) Track Renewal Cost of Alternative-B

Unit: 1,000$b

Nature of work	Unit	Quantity	Unit price ($b)	Amount
1. Track renewal	M	3,983	1,742	6,938
2. Work supervision	%	5	6,938	347
3. Contingency (Variation in quantity)	%	5	7,285	364
4. Contingency (Annual 7% price variation)	%	14	7,649	1,071
5. ① ~ ④ Total				8,720

(e) Project Cost of Alternative-C

Unit: 1,000$b

Nature of work	Unit	Quantity	Unit price	Amount
1. Civil Work Cost			($b)	557,034
Main track cutting	M^3	105,200	62	6,522
Main track embankment	M^3	1,733,000	89	154,237
Temporary track cutting	M^3	70,000	57	3,990
Temporary track embankment	M^3	551,400	80	44,112
Corrugated pipe setting ϕ1.8m	NO	1	337,000	337
Open channel	NO	2	38,000	76
Box culvert	NO	27	1,030,000	27,810
Bridge	M	450	231,000	103,950
Tunnel	M	1,200	180,000	216,000
2. Track Construction Cost				40,576
Main track setting	M	20,840	1,670	34,803
Temporary track setting & removal	M	7,440	776	5,773
3. Station Facilities and Security System	Set	1	1,980,000	1,980
4. Supervison Cost	%	5	599,590	29,980
5. Subtotal (①~④)				629,570
6. 1/5,000-scaled Map Central Line Surveying and Soil Survey	KM	68	145,000	9,860
7. Detailed Design Specifications and Tender Documents	Man, Month	80	225,000	18,000
8. Sabtotal (①~⑦)				657,430
9. Contingency (Variation in quantity)	%	5	629,570	31,479
10. Contingency (7% annual price variation)	%	14	688,909	96,447
11. Total (①~⑩)				785,356

(f) Track Renewal Cost of Alternative-C

Unit: 1,000$b

Nature of work	Unit	Quantity	Unit price ($b)	Amount
1. Track renewal	M	69,043	1,742	120,273
2. Work supervision	%	5	120,273	6,014
3. Contingency (Variation in quantity)	%	5	126,287	6,314
4. Contingency (Annual 7% price variation)	%	14	132,601	18,564
5. ① ~ ④ Total				151,165

(g) Project Cost of Alternative-D

Unit: 1,000$b

Nature of work	Unit	Quantity	Unit price	Amount
1. Civil Work Cost			($b)	470,613
Main track cutting	M^3	1,338,300	62	82,975
Main track embankment	M^3	2,951,200	89	262,657
Temporary track cutting	M^3	12,200	57	695
Temporary track embankment	M^3	140,600	80	11,248
Corrugated pipe setting ϕ1.8m	NO	1	337,000	337
Open channel	NO	2	38,000	76
Box culvert	NO	23	1,030,000	23,690
Bridge	M	385	231,000	88,935
2. Track Construction Cost				51,180
Main track setting	M	27,840	1,670	46,493
Temporary track setting & removal	M	6,040	776	4,687
3. Station Facilities and Security System	Set	2	1,980,000	3,960
4. Supervison Cost	%	5	525,753	26,288
5. Subtotal (① ~ ④)				552,041
6. 1/5,000-scaled Map Central Line Surveying and Soil Survey	KM	73	145,000	10,585
7. Detailed Design Specifications and Tender Documents	Man, Month	68	225,000	15,300
8. Sabtotal (① ~ ⑦)				577,926
9. Contingency (Variation in quantity)	%	5	552,041	27,602
10. Contingency (7% annual price variation)	%	14	605,528	84,774
11. Total (① ~ ⑩)				690,302

(h) Track Renewal Cost of Alternative-D

Unit: 1,000$b

Nature of work	Unit	Quantity	Unit price ($b)	Amount
1. Track renewal	M	66,143	1,742	115,221
2. Work supervision	%	5	115,221	5,761
3. Contingency (Variation in quantity)	%	5	120,982	6,049
4. Contingency (Annual 7% price variation)	%	14	127,031	17,784
5. ① ~ ④ Total				144,815

(i) Project Cost of Alternative-E

Unit: 1,000$b

Nature of work	Unit	Quantity	Unit price	Amount
1. Civil Work Cost			($b)	1,423,989
Main track cutting	M^3	30,300	62	1,879
Main track embankment	M^3	763,400	89	67,943
Temporary track embankment	M^3	151,300	80	12,104
Corrugated pipe setting ϕ1.8m	NO	1	337,000	337
Open channel	NO	2	38,000	76
Box culvert	NO	29	1,030,000	29,870
Bridge	M	380	231,000	87,780
Tunnel	M	6,800	180,000	1,224,000
2. Track Construction Cost				35,727
Main track setting	M	18,540	1,670	30,962
Temporary track setting & removal	M	6,140	776	4,765
3. Station Facilities and Security System	Set	2	1,980,000	3,960
4. Supervison Cost	%	5	1,463,676	73,184
5. Subtotal (① ~ ④)				1,536,860
6. 1/5,000-scaled Map Central Line Surveying and Soil Survey	KM	68	145,000	9,860
7. Detailed Design Specifications and Tender Documents	Man, Month	80	225,000	18,000
8. Sabtotal (① ~ ⑦)				1,564,720
9. Contingency (Variation in quantity)	%	5	1,536,860	76,843
10. Contingency (7% annual price variation)	%	14	1,641,563	229,819
11. Total (① ~ ⑩)				1,871,382

(j) Track Renewal Cost of Alternative-E

Unit: 1,000$b

Nature of work	Unit	Quantity	Unit price ($b)	Amount
1. Track renewal	M	71,043	1,742	123,757
2. Work supervision	%	5	123,757	6,188
3. Contingency (Variation in quantity)	%	5	129,945	6,497
4. Contingency (Annual 7% price variation)	%	14	136,442	19,102
5. ① ~ ④ Total				155,544

CHAPTER 4. TRAFFIC DEMAND FORECAST

4-1 General

Economic situations in the Republic of Bolivia shows its continuing tendency as a 'mono-cultural' structure depending solely upon exports of mineral products as the means of foreign currency acquisition.

The actual record of foreign currency revenue in 1978 shows that the export of mineral products such as tin, lead, zinc and antimony accounts for 60 per cent of the total export and only tin alone occupies as much as 42 per cent. In the recent years the export of oil and natural gas has been on the gradual increase to such an extent that in 1978 it accounts for 13 per cent of the total, appearing as the new potential source of foreign currency acquisition.

Table 4.1.1 shows the trend of gross domestic product (GDP) as classified by industrial divisions for the '70 ∿ '78 period. When compared by the annual increase rate for the latest eight years, the GDP's growth in the infrastructural division ranks the top at the rate of 8 per cent, followed by the service-producing division at 5.5 per cent and then by the production goods division at 5.0 per cent.

In comparison by sectors, the growth rate of oil refinery is recorded at 14.0 per cent, the highest of all. Looking back the past trend, however, it is noted that the growth rate had continued at a rapid pace until 1973 but declined substantially since that time.

The sector of transportation and communication in the infrastructural division follows the oil refinery industry, showing the second highest rate of 8.2 per cent. The cause for this can be sought from the facts that abundant natural resources must be made full use of for the sake of the nation's economic activities by infrastructural developments and that exchange of manpower resources must be stimulated by improvement of interregional communications. From the recent tendency of economic and industrial growth it may be imagined easily that the government is taking its active posture toward the socio-economic unification which has been in lagging progress so far.

Table 4.1.2 shows the composite ratio of gross domestic product by divisions.

Table 4.1.1 Trend on GDP by Divisions
('70-based price level, 1 million pesoes)

	1970	1971	1972	1973	1974	1975	1976	1977*	1978*	Annual Growth Rate
Capital goods div.	5,814	6,104	6,531	7,120	7,416	7,551	8,103	8,268	8,592	5.0
Agriculture	2,240	2,373	2,512	2,628	2,725	2,907	3,009	3,051	3,124	4.3
Mining	1,155	1,118	1,162	1,413	1,377	1,191	1,400	1,390	1,418	3.9
Oil refinery	118	233	318	429	377	296	312	237	226	14.0
Manufacturing	1,790	1,854	2,004	2,104	2,342	2,485	2,657	2,822	3,005	6.7
Construction	511	526	535	546	595	672	725	768	819	6.1
Infrastructural div.	1,098	1,180	1,262	1,352	1,543	1,728	1,821	1,948	2,024	8.0
Energy	167	179	190	211	232	237	260	268	279	6.7
Transport & communication	931	1,001	1,072	1,141	1,311	1,491	1,561	1,680	1,745	8.2
Service producing div.	5,593	5,839	6,106	6,388	6,811	7,362	7,723	8,246	8,584	5.5
Commerce & finance	2,365	2,445	2,551	2,668	2,854	3,104	3,323	3,585	3,786	6.1
Public	986	1,089	1,185	1,257	1,380	1,481	1,509	1,612	1,677	6.9
Housing	1,088	1,116	1,149	1,193	1,237	1,330	1,371	1,448	1,491	4.0
Others	1,154	1,189	1,221	1,270	1,340	1,447	1,520	1,601	1,630	4.4
Gross domestic product	12,505	13,123	13,899	14,860	15,770	16,641	17,647	18,462	19,200	5.5
Growth rate (%)	-	4.9	5.9	6.9	6.1	5.5	6.0	4.6	4.0	

Note: Indicated in '77 column are tentative figures.
Indicated in '78 column are predicted figures.

Source: Ministerio de Planeamiento y Coordinacion

Table 4.1.2 Composite Ratio of GDP by Divisions
('70-based price)

	1970	1971	1972	1973	1974	1975	1976	1977	1978
Capital goods div.	46.5	46.5	47.1	47.9	47.1	45.4	45.9	44.8	44.8
Infrastructural div.	8.8	9.0	9.1	9.1	9.8	10.4	10.3	10.6	10.5
Energy	1.3	1.4	1.4	1.4	1.5	1.4	1.5	1.5	1.4
Transport & communication	7.5	7.6	7.7	7.7	8.3	9.0	8.8	9.1	9.1
Service-producing div.	44.7	44.5	43.8	43.0	43.1	44.2	43.8	44.6	44.7
Gross domestic product	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

4-2 General Situation of Transport Facilities

Since the transport facilities now existing in the Republic of Bolivia are not as yet fully improved on a nationwide scale, the present situation is that natural resources existing in abundance over a wide expansion of its territory can, in no way, be incorporated effectively into the nation's economic activities.

In the transport network in this country, the railway traffic is developed as the principal axis ahead of the road and other transport means still lagging in improvement and expansion. Therefore, people depend highly upon the railway traffic, especially making greater use of it for export and import to and from foreign countries and for transportation of products in the mining industry.

The domestic traffic volume by transport means can be compared as shown in Table 4.2.1 and the railway traffic accounts for 28 per cent of the total.

Table 4.2.1 Comparison on Traffic Volume by Means of Transport (1974)

	Tonnage-km × 1,000	Share (%) in Subtotal	Share (%) in Total
Road	896,464	64.8	16.3
Railway	396,000	28.6	7.2
River	24,480	1.8	0.4
Lake (Titicaca)	31,700	2.3	0.6
Air	35,378	2.5	0.6
Sub Total	1,384,022	100.0	25.1
Pipe line	4,123,000	-	68.0
Total	5,507,022	-	100.0

Source: Plan de Desarrollo Economico y Social

For foreign trade this inland country needs a long-distance transportation route to the ports on either Pacific or Atlantic Ocean side via Brazil, Chile and Argentine. Because of this, there is high dependance upon the railway traffic and 87 per cent of the railway traffic volume are occupied solely by exported and imported commodities.

4-3 Railway Transport

4-3-1 General Situation

The railway network of Bolivia constitutes two regional divisions, as shown in Fig. 4.3.1, by separation into Western and Eastern regions. The total operating length extends over 3,457 km consisting of 2,071 km Western Line and 1,386 km Eastern Line.

The Western Line is purposed mainly for transportation of mineral products, interconnecting the mining area and the shipping port of Arica Antofagasta on the Pacific Ocean side.

The Eastern Line is operated as a tie-line between Santa Cruz and the Atlantic Ocean coast with growth of the regional development in and around Santa Cruz. The railway in the division between Santa Cruz and Corumba was constructed by the Railway Joint Board in accordance with the Bolivia-Brazil Bilateral Railway Connection Agreement in February, 1938 and entered into its commercial operation in 1953. After that time, this division was taken over by the Government of Bolivia in November, 1964 and commissioned to the organization of ENFE established in the same year.

4-3-2 Transcontinental Railway Construction Plan

Since long time ago, they have been thinking of a plan for construction of the transcontinental railway. In 1871, Vizconde Mava de Brazil financed the survey for feasibility study of the plan to construct a railway route starting from Santoso Port in Brazil and ending at Arica Port in Chile all the way across the territory of Bolivia.

The latest object of the survey of this kind was, as shown in Fig. 4.3.2, the interconnecting route between Aiguile of the Western Line and Santa Cruz of the Eastern Line. The preliminary survey was conducted by the Brazil-Bolivia joint ventured consulting firm with the fund financed by the Brazilian Government. The first phase of survey was completed in 1976 and the report on survey results was submitted to both of the Governments. If approval can be obtained, the survey will go into its principal stage.

Table 4.3.1 shows the future trend of freight transport volume by modes. As noted from the table, the estimated rate of railway traffic increases is 1.68 per cent by 1990 and 2.19 per cent by 1995 on the basis of estimation in 1980, taking almost equal share in transport with the load network.

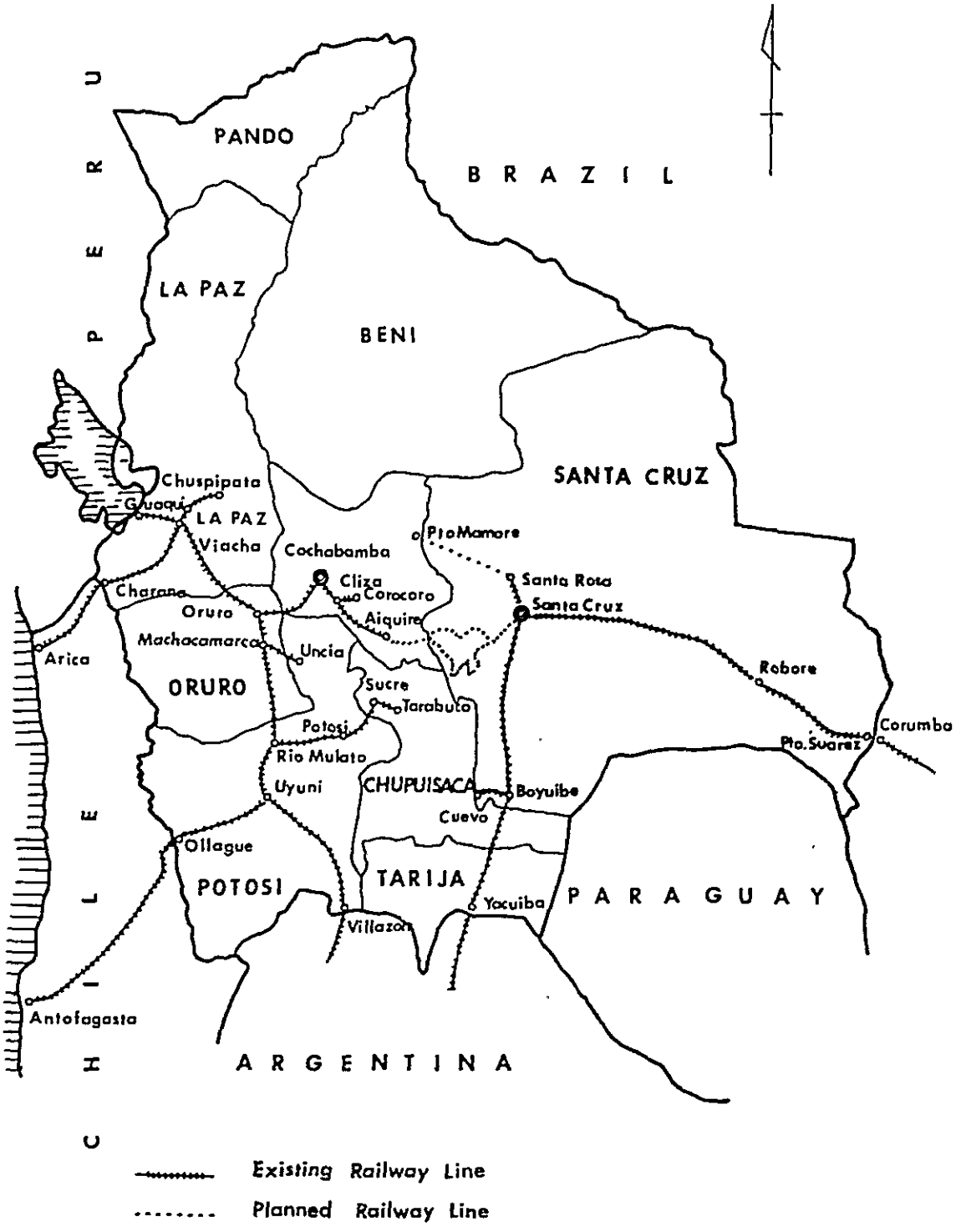
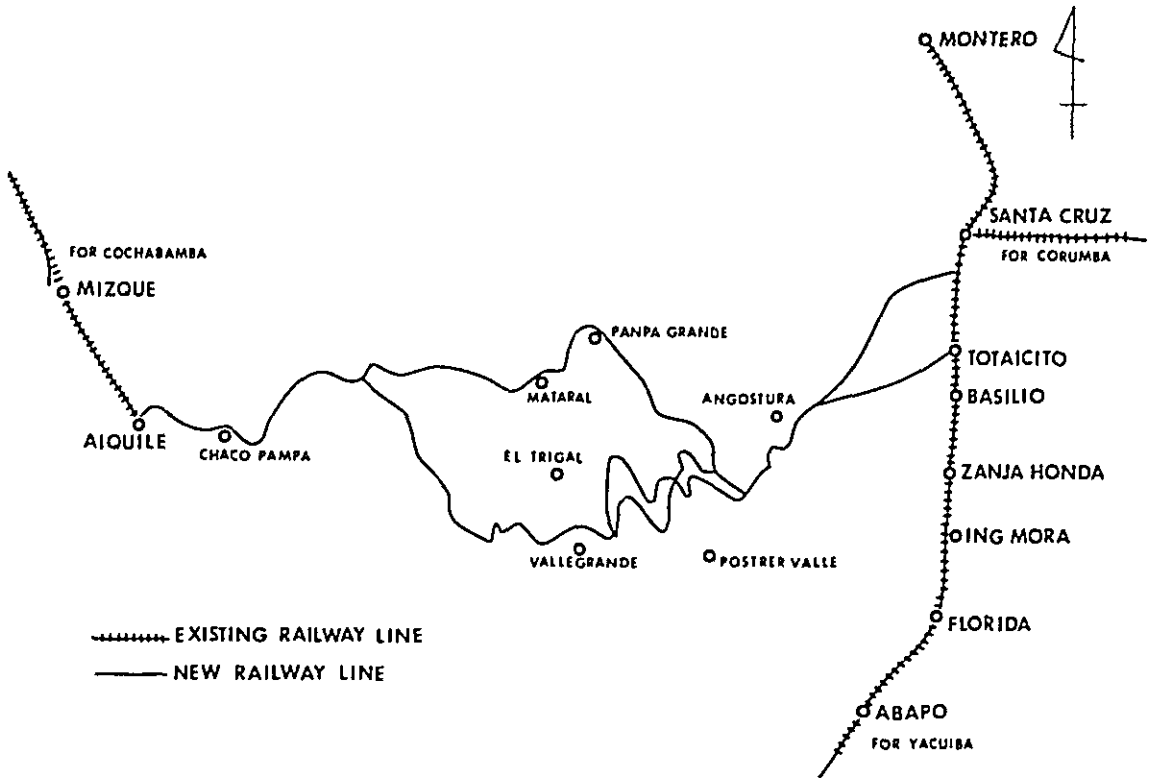


Fig. 4.3.1 Map of the ENFE Railway Network



Source. Anteproyecto de Ingenieria del Enlace Ferroviario Cochabamba-Santa Cruz

Fig. 4.3.2 Map of the New Railway Construction Project (Santa Cruz - Cochabamba)

Table 4.3.1 Predicted Freight Transport Volume by Modes Between Santa Cruz and Cochabamba

Year	Means of Transport		Total (ton)
	Road (ton)	Railway (ton)	
1979	499,547.93	541,176.87	1,040,724.80
1980	525,839.93	569,659.86	1,095,499.79
1981	553,709.45	599,851.53	1,153,561.28
1982	583,051.31	631,638.85	1,214,690.16
1983	613,954.93	665,117.76	1,279,072.69
1984	646,493.90	700,368.31	1,346,862.21
1985	682,985.56	739,901.00	1,422,886.56
1986	719,183.79	779,115.75	1,498,299.54
1987	757,294.39	820,402.23	1,577,696.62
1988	797,433.45	863,886.21	1,661,319.66
1989	839,696.60	909,671.28	1,749,367.88
1990	884,199.93	957,887.23	1,842,087.16
1991	931,066.40	1,008,655.24	1,939,721.64
1992	980,412.11	1,062,113.09	2,042,525.20
1993	1,032,373.65	1,118,404.76	2,150,778.41
1994	1,087,087.62	1,177,678.22	2,264,765.84
1995	1,149,286.82	1,245,060.71	2,394,347.53

Source: Anteproyecto de Ingenieria del en lace Ferroviario Cochabamba - Santa Cruz

4-3-3 Passenger Traffic

As shown in Table 4.3.2, the actual record on the total passenger traffic in 1978 amounts to 2,449,000 persons per year in both Eastern and Western Lines, which may be broken down as 434,000 persons a year (18%) for the Eastern and 2,015,000 persons a year (82%) for the Western.

The average as compared by railway divisions is shown in Fig. 4.3.3, in which the Oruro - Cochabamba section of the Western Line ranks the top at 312,000 persons a year, followed by the Santa Cruz - Corumba section of the Eastern Line at 259,000 persons a year.

The Santa Cruz - Corumba section plays a very important role not only as the trunk line internationally connected with that in Brazil but also as the principal means of transport in the domestic service because of no other similar transport facilities being available in Bolivia.

The past trend of passengers and passenger-kms is shown in Fig. 4.3.4. As noted from that, the increase rate of passengers for the '69 ∿ '78 period indicates 6.5 per cent for the Eastern Line and 2.4 per cent for the Western Line; the former far exceeds the latter. The cause of it is to be sought in the fact that the Eastern Line is the only monopolizing means of transport in this region upon which people depend entirely without any other available means while the Western Line is not so because bus and any other road transport services are readily available for the short-distance travellers through the existing highly developed road network between cities. At present, ENFE puts into operation for city-to-city service the 2-car coupled gasoline-fueled train named 'Ferrobus' for convenience of long-distance passengers. In the term of passenger-km, there is an increasing tendency such as 12.3 per cent in the Eastern Line and 2.2 per cent in the Western Line.

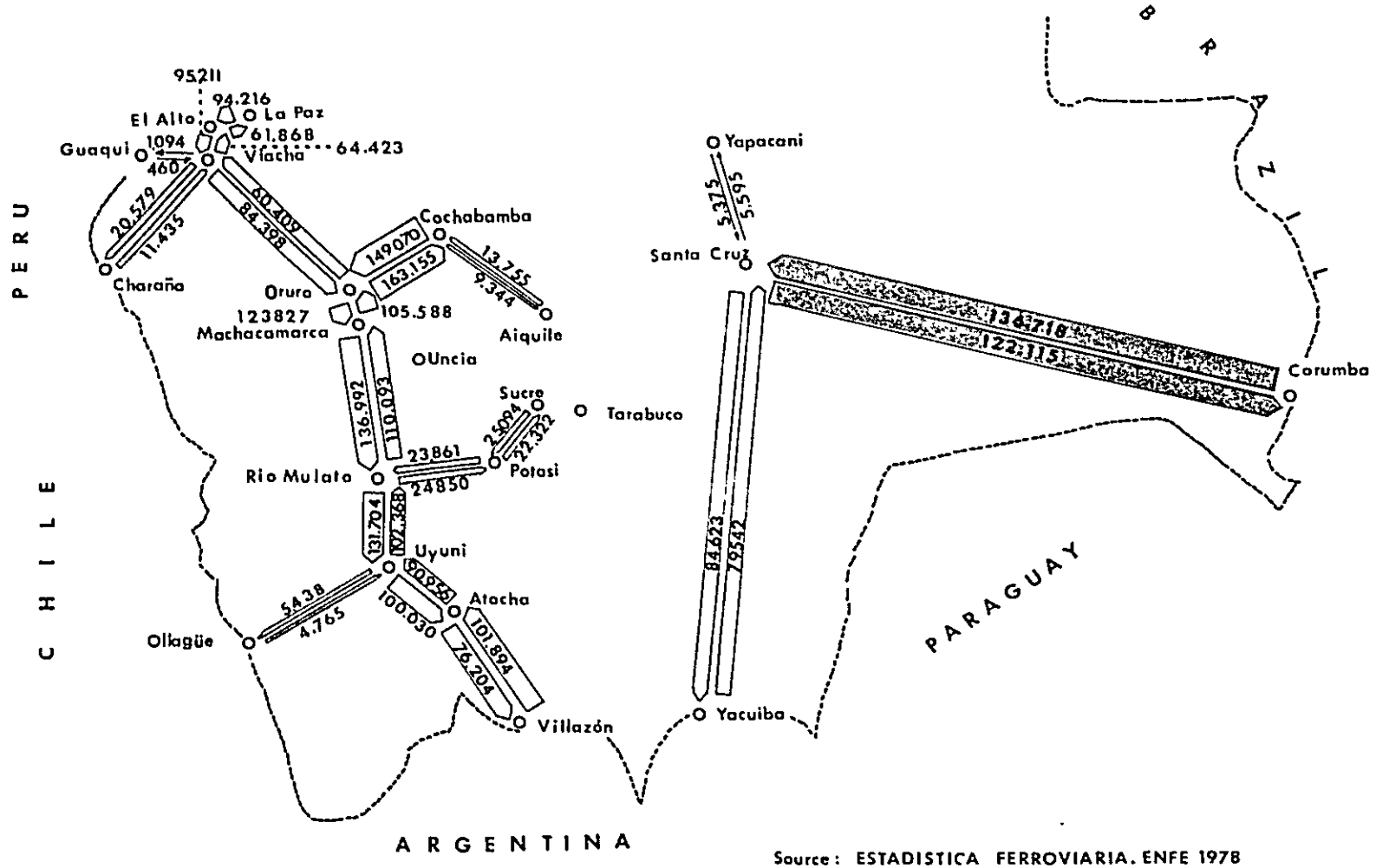
Table 4.3.2 Latest Status of Passenger Traffic (1978)

Unit: Person

		Km in Operation	Express	Ordinary	Ferro-bus	Rail Car	Total	Share
Western Line		2,071	303,391	1,238,676	448,190	25,146	2,015,403	82.3%
Eastern Line		1,386	0	312,417	102,016	19,535	433,968	17.7%
Divisional Share in Eastern Line	Santa Cruz ∿Corumba	643	0	55%	76%	45%	60%	-
	Santa Cruz ∿Yacuiba	539	0	45%	24%	0%	38%	-
	Santa Cruz ∿San Rosa	204	0	0%	0%	55%	2%	-
Total		3,457	303,391	1,551,093	550,206	44,681	2,449,371	100%

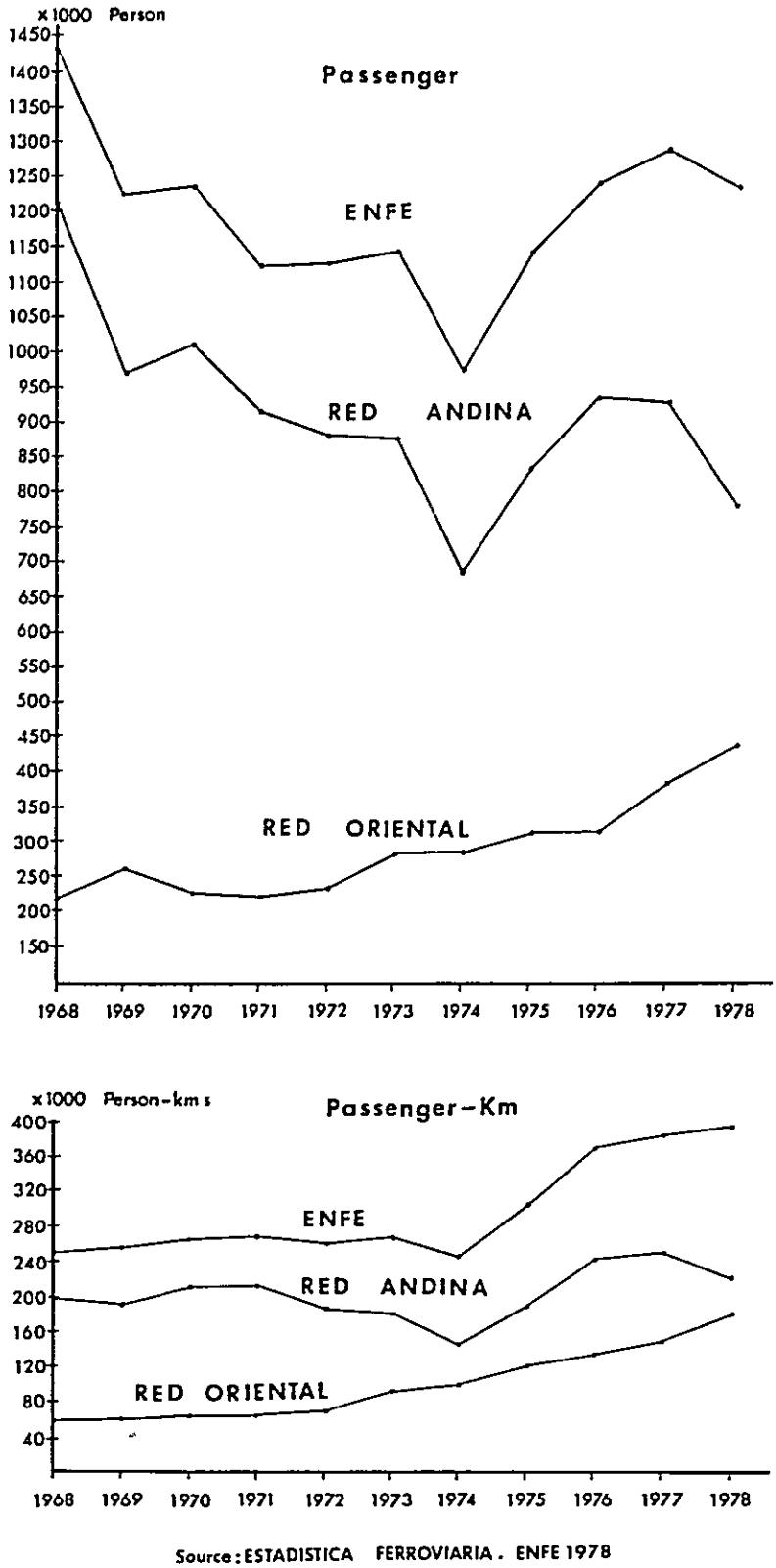
Source: Estadistica Ferroviaria ENFE 1978

ENFE
1978



Source: ESTADISTICA FERROVIARIA. ENFE 1978

Fig. 4.3.3 No. of Passing Passengers by Section



Source: ESTADISTICA FERROVIARIA. ENFE 1978

Fig. 4.3.4 No. of Passengers and Passenger Km-s

4-3-4 Freight Transportation

As shown in Table 4.3.3, the actual record on freight transport in 1978 shows a total of 3,458,000 tons a year, consisting of 384,000 tons a year (11%) for the Eastern Line and 3,074,000 tons (89%) for the Western Line. The total transport can be shared by 20 per cent for export, 67 per cent for import and 13 per cent for domestic; the freight for export and import takes the overwhelming majority in the total transport.

Transport by railway divisions is as shown in Fig. 4.3.5. The Western Ollague-Uyuni section, which interconnects Antofagasta and Uyuni, ranks the top at 440,000 tons a year (13% of the annual total), followed secondly by the Eastern Santa Cruz-Corumba section at 220,000 tons a year (6% of the total), which serves as one of the trunk lines for transport of freight as well as passengers in the Eastern Line.

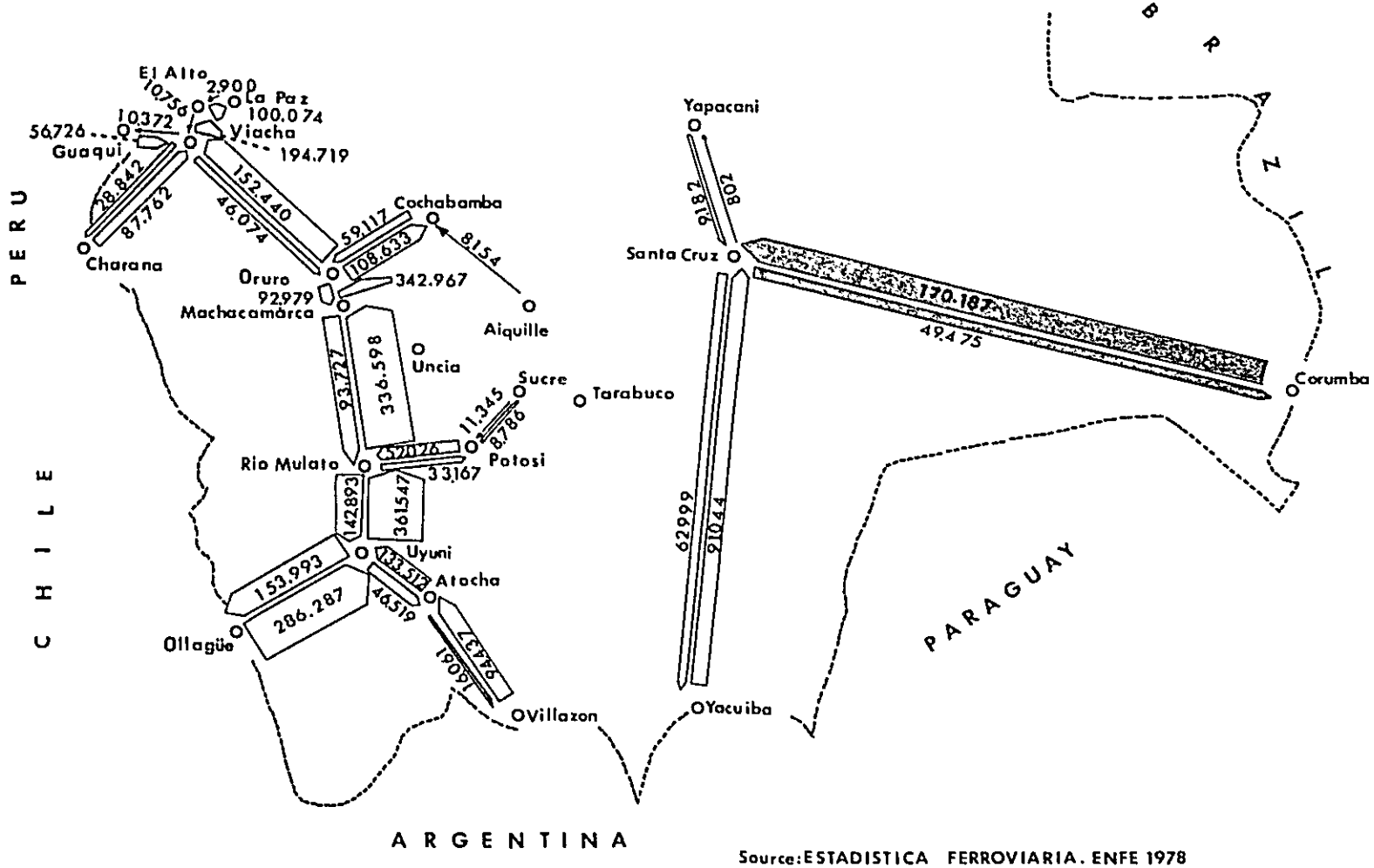
Table 4.3.3 Latest Status of Freight Transport (1978)

Unit: ton

		Km in Operation	Export	Import	Domestic	Total	Share
Western Line		2,071	603,209	2,105,191	365,605	3,074,005	88.9%
Eastern Line		1,386	79,550	223,451	80,688	383,689	11.1%
Divisional Share in Eastern Line	Santa Cruz ∿Corumba	643	41%	62%	59%	57%	-
	Santa Cruz ∿Yacuiba	539	59%	38%	29%	40%	-
	Santa Cruz ∿San Rosa	204	0%	0%	12%	3%	-
Total		3,457	682,759	2,328,642	446,293	3,457,694	100%

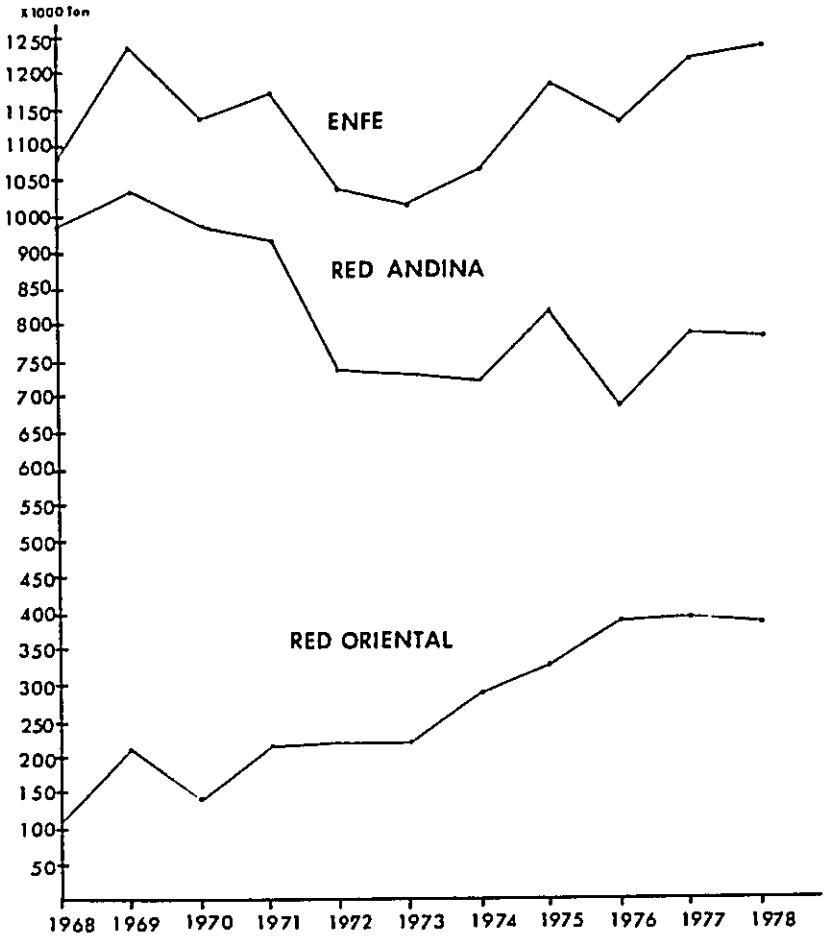
Source: Estadistica Ferroviaria, ENFE 1978

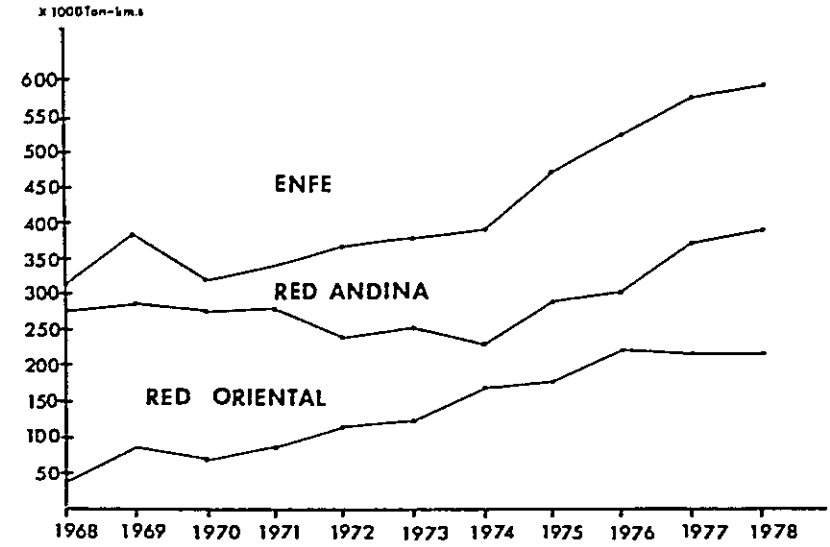
Figure 4.3.6 shows the past trend of freight transport by total tonnage and ton-kms for the '69 ∿ '78 period. In the term of increase rate, the Eastern Line has achieved 8.4 per cent in total tonnage and 10.3 per cent in ton - kms, while the Western Line gives a figure of 2.7 per cent in total tonnage and 3.7 per cent in ton-kms. In particular, the growth in the Eastern Line, where no other competitive means of transport is available, is notable.



Source: ESTADISTICA FERROVIARIA. ENFE 1978

Fig. 4.3.5 No. of Passing Freights by Section





Source: ESTADISTICA FERROVIARIA ENFE 1978

Fig. 4.3.6 No. of Freights and Ton-kms

4-4 Traffic Demand Forecast

Future traffic demand is forecasted for the Santa Cruz - Corumba section now under the proposed project of rehabilitation from damage. In the case of such rehabilitation project, no particular development effect could be expected even though the project would be carried out as planned (with Project). However, even though the project would remain undone (without Project), because of no other alternative means of transport, the result of future demand forecast would not make any difference between 'with Project' and 'without Project'.

Although the desired range of projection should extend to the terminating year of the project service life as the ideal pattern of forecast, only a decade of years from '79 to '88 has been taken up for future projection after review of the following points, and demand beyond the end of that period is assumed to continue at a flat fixed level:

- The purpose of this project is only to aim at recovery from damage. Therefore, that purpose may be regarded as having been achieved satisfactorily if the effect restored to the conventional function can be fully assured after implementation of the project.
- The export and import goods transport takes a greater share of more than 80 per cent of the total freight transport in the Santa Cruz - Corumba section. Although the same tendency may continue toward the future, it is difficult to estimate a clear picture of the international trade over a long range.
- In Santa Cruz State the regional development plan is made definite on a short-term basis, but not yet on a long-term basis.
- If forecast is made of transport demand to the end of the project service life, there would be need of considering the extra plan for improvement of signals and vehicles to absorb such future increases as forecasted.

4-4-1 Passenger Traffic Demand Forecast

(1) Natural growth traffic volume

The definition of 'natural growth traffic volume' means the natural increase of passenger traffic demand in consequence of population growth and/or higher living standard and, therefore, does not include such pattern of increase as may arise from any development factors.

Passenger traffic forecast has been made by application of the following two alternative cases.

Case 1: To trace back the past trend of traffic demand

Case 2: To apply the estimated increase rate over the whole Eastern Line, which is incorporated into the '80 ∿ '85 investment plan (tentative) now being worked out by ENFE, to the partial section between Santa Cruz and Corumba

As the result of forecast, the 10-year's increase rate is attained at 2.8 per cent in Case 1 and 2.1 per cent in Case 2, as shown in Fig. 4.4.1 and Table 4.4.1.

Although inter-regional transfer of population will become more and more brisk as time goes on toward further development of Santa Cruz State, this Report takes up a rather conservative figure as attained in Case 2 with an intention to avoid over-evaluation of the expected benefit from the project.

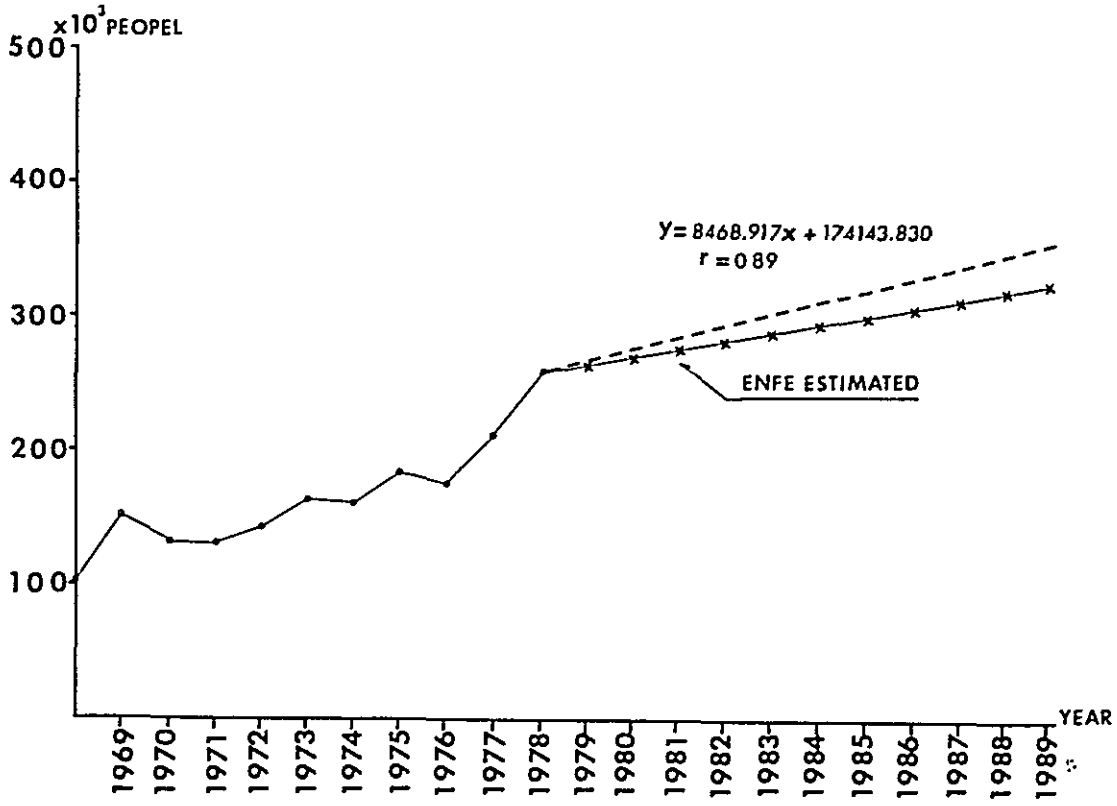


Fig. 4.4.1 Estimated Future Passenger Volume

Table 4.4.1 Forecast on Passenger Traffic Demand

Year	Actual Figure $\times 10^3$	Case 1	Case 2
1969	149,831		
1970	132,924		
1971	130,592		
1972	141,669		
1973	163,240		
1974	160,908		
1975	184,811		
1976	175,854		
1977	212,748		
1978	258,833		
1979		267,302	264,941
1980		275,771	271,115
1981		284,240	277,215
1982		292,709	283,341
1983		301,178	289,461
1984		309,646	295,627
1985		318,115	301,746
1986		326,584	307,871
1987		335,053	313,998
1988		343,522	320,121
Yearly growth rate		2.8%	2.1%

Note: Forecasted figures in Case 2 have been attained up to the year 1988, at an equal rate of increase, from the result of forecast in the "Plan Quinquenal de Rehabilitacion 1980 ∿ 1985".

(2) Development traffic volume

The definition of development traffic volume means the potential increase in traffic demand to be predicted from implementation of the new development project in the region.

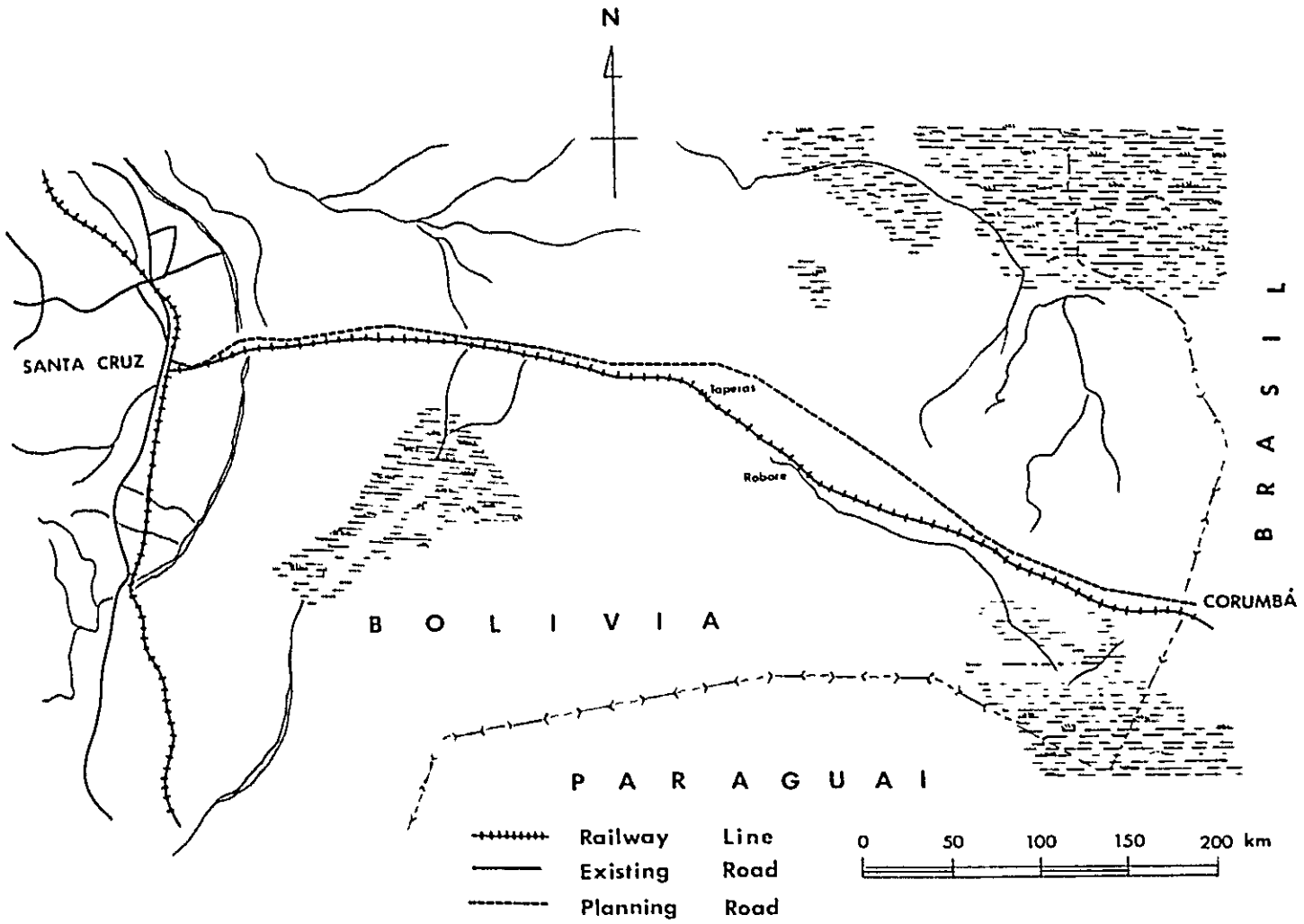
At present, in Santa Cruz State there is an on-going short-term development plan being executed by dividing the whole project area assured of developed effect into eight (8) blocks for urban re-development. Although Robore and San Jose are included in the 3rd block of the project area, there seems to be no particular ground to justify that railway passengers will increase evidently by implementation of the said development project. On this basis, no possible increase of traffic demand from the said development project is has been incorporated into the projection. Besides the above-mentioned project, there is another plan for Eastern - Western interconnection railway construction with probable increase of traffic volume from development, the preliminary survey for which has been completed in 1976. However, the continuity to the further survey on this project is still under study jointly by Bolivian and Brazilian governments and no definite prospect is established yet as to future progress of the project. Besides that, even if the interconnection railway may be constructed as planned, there would be no possibility of passenger increase being extended as far as Robore and its adjacent area. Therefore, the developed traffic increase from this project has been equally disregarded in the demand forecast.

(3) Joint share with other transport means available

Although in the railway division between Santa Cruz and Corumba there exist roads in each town and village where the railway station is located and also in a part of Santa Cruz City, there is no single once-through interconnected road running in parallel with the whole railway section. Under such circumstance, the railway traffic is the sole means of transport upon which people depend greatly.

Since long time ago there has been a new road construction plan over the whole length of the section. In 1972, the agreement on the road construction project between Santa Cruz and Corumba, as shown in Fig. 4.4.2, was signed by the governments of Bolivia and Brazil. However, since then the construction plan has been showing no concrete shape because of financial difficulty on both sides.

For this reason, any possibility of joint share with the road in transport has been disregarded within the projection period for future traffic demand.



Source : SERVICIO NACIONAL DE CAMINOS

Fig. 4.4.2 Road Construction Plan (Santa Cruz - Corumba)

4-4-2 Freight Transport Demand Forecast

(1) Natural traffic volume

Same as in the case of passenger traffic demand forecast, freight demand has been forecasted by application of the following two alternative cases.

Case 1: To trace back the past trend of traffic demand

Case 2: To apply the estimated increase rate over the whole Eastern Line, which is incorporated into the '80 ∿ '85 investment plan (tentative) now being worked out by ENFE, to the partial section between Santa Cruz and Corumba

As the result of forecast, the 10-year's increase rate is attained at 4.4 per cent in Case 1 and 5.8 per cent in Case 2, as shown in Fig. 4.4.3 and Table 4.4.2. Although there may be some future increase in foreign trade goods and also in domestic freight with progress of regional development in Santa Cruz State, this Report takes up a rather conservative figure as attained in Case 1 with an intention to avoid over-evaluation of the expected benefit from the project.

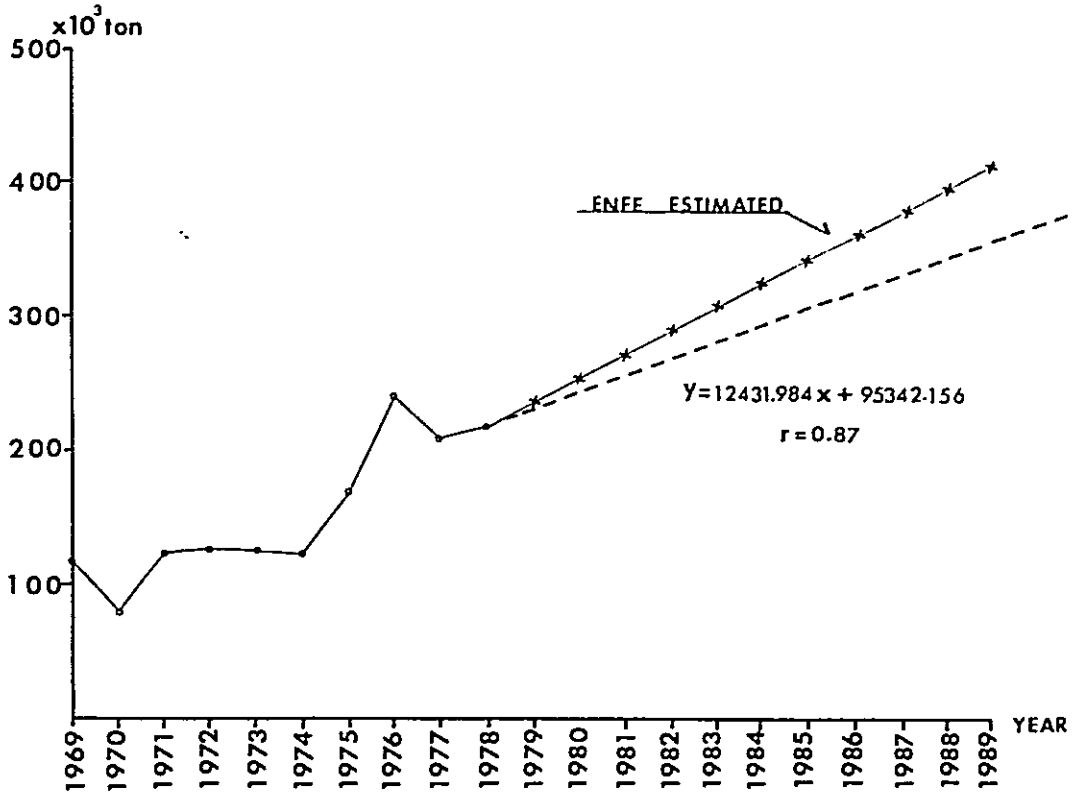


Fig. 4.4.3 Estimated Future Freight Volume

Table 4.4.2 Forecast on Freight Transport Demand (Natural Increase)

Year	Actual Figure $\times 10^3$	Case 1	Case 2
1969	117,260		
1970	80,080		
1971	123,552		
1972	126,984		
1973	125,840		
1974	122,198		
1975	169,020		
1976	241,457		
1977	209,332		
1978	219,662		
1979		232,094	237,389
1980		244,526	255,122
1981		256,958	272,853
1982		269,390	290,534
1983		281,822	308,256
1984		294,254	325,981
1985		306,686	343,715
1986		319,118	361,450
1987		331,550	379,197
1988		343,982	396,944
Yearly growth rate		4.4%	5.8%

Note: Forecasted figures in Case 2 have been attained up to the year 1988, at an equal rate of increase, from the result of forecast in the "Plan Quinquenal de Rehabilitacion 1980 ∿ 1985".

(2) Development traffic volume

The increment in the developed freight transport will be the volume of cement to be shipped out from the Yacuses cement plant which will be newly constructed at the site about 580 km apart from Santa Cruz City.

The construction work has already started and the plant is scheduled to enter into its initial operation in 1983, with production capacity of 345,000 tons per year. It is planned that for the time being after its start of production, the total cement product will be shipped out for export to Brazil and also for domestic consumption but, long ahead in the future, it will be supplies entirely to the domestic marked only. Table 4.4.3 shows the planned cement demand and production.

Table 4.4.3 Planned Demand and Production of Cement

Unit: 1,000 tons

Year	Domestic Demand	Production	Export and Non-export	
			Brazil	Bolivia
1978	95			
1979	106			
1980	120			
1981	135			
1982	150			
1983	168	240	120	120
1984	190	310	150	160
1985	210	330	150	180
1986	235	345	135	210
1987	265	345	105	240
1988	295	345	75	270
1989	331	345	45	300
1990	370	345	0	345

(3) Joint share with other transport means available

Since the road construction project between Santa Cruz and Corumba does not yet take its concrete shape, any possibility of joint share with the other means of transport has been disregarded, same as in the case of passenger traffic demand forecast.

(4) Future transport volume

Future transport demand of freight will be summed up as shown in Table 4.4.4, reflecting the total of natural transport increase plus developed transport increase from completion of the Yacuses cement plant.

Table 4.4.4 Future Freight Transport Demand

Unit: 1,000 tons

Year	Natural Growth	Developed Transport	Total
1979	222		222
1980	245		245
1981	256		256
1982	269		269
1983	282	120	402
1984	294	160	455
1985	307	180	487
1986	319	210	529
1987	332	240	572
1988	344	270	614
1989	344	300	644
1990	344	345	689

CHAPTER 5 ECONOMIC ANALYSIS

5-1 The Method of Economic Analysis

5-1-1 Basic Conception

Ipias - Robore section has had a death blow by a heavy rain in the middle of January, 1979 and the train operation has suspended for about 120 days. At present, although the train operation is running on with the route of emergency repair, not only the track may again be destroyed and the train operation is repeatedly suspended, but also it requires more cost of emergency repair, when the rainy season comes, unless it is otherwise ultimately rehabilitated.

Since Santa Cruz - Corumba railway is a sole mode of land transportation as well as an international route linking to the port of Santos in Brazil, it becomes a very important route for the Republica of Bolivia and requires an ultimate emergency restoration of railway facilities and structures.

The purpose of this economic analysis is to judge whether or not the rehabilitation project of railway facilities and structures on Ipias - Robore section makes its execution worth significant, i.e. whether or not it is economically feasible.

Figure 5.1.1 shows a work flow of economic analysis. In case of no execution of the project (without project), supposing that such a pattern may continue for the future that the route having been made a current emergency repair may again receive the same calamity, the service is suspended for days and an emergency repair is made, the analysis measures a sum of the economic loss which the passenger and freight may receive and the repair cost during a period of suspended service, comparing it to a total cost of the project execution (with project), thus making a verification of the project.

The economic cost estimation conforms to the following conditions.

(1) The project life is to be for thirty (30) years, taking account of the economic service life of the earth structure which may be newly constructed.

(2) Bolivian official exchange rate is to be fixed at $b 20.00 per US$1.00, without a shadow price for any foreign currency, as it is relatively stable since 1972 devaluation and there is little difference between a foreign currency and its actual rate.

(3) Since a supply-demand relationship of unskilled labor market is not on an equilibrium, even though the potential unemployment rate in Santa Cruz province is relatively low, such labor wage is estimated at 20% lower than the actual wages, by using the shadow prices which ENFE applies to such unskilled labors.

(4) All the foreign purchase materials and equipment shall be subject to an exemption from the customs duty in accordance with the policy of the Bolivian government, while 5% of the total domestic purchase cost shall, as ENFE applies, be subject to an equivalent sum to the tax.

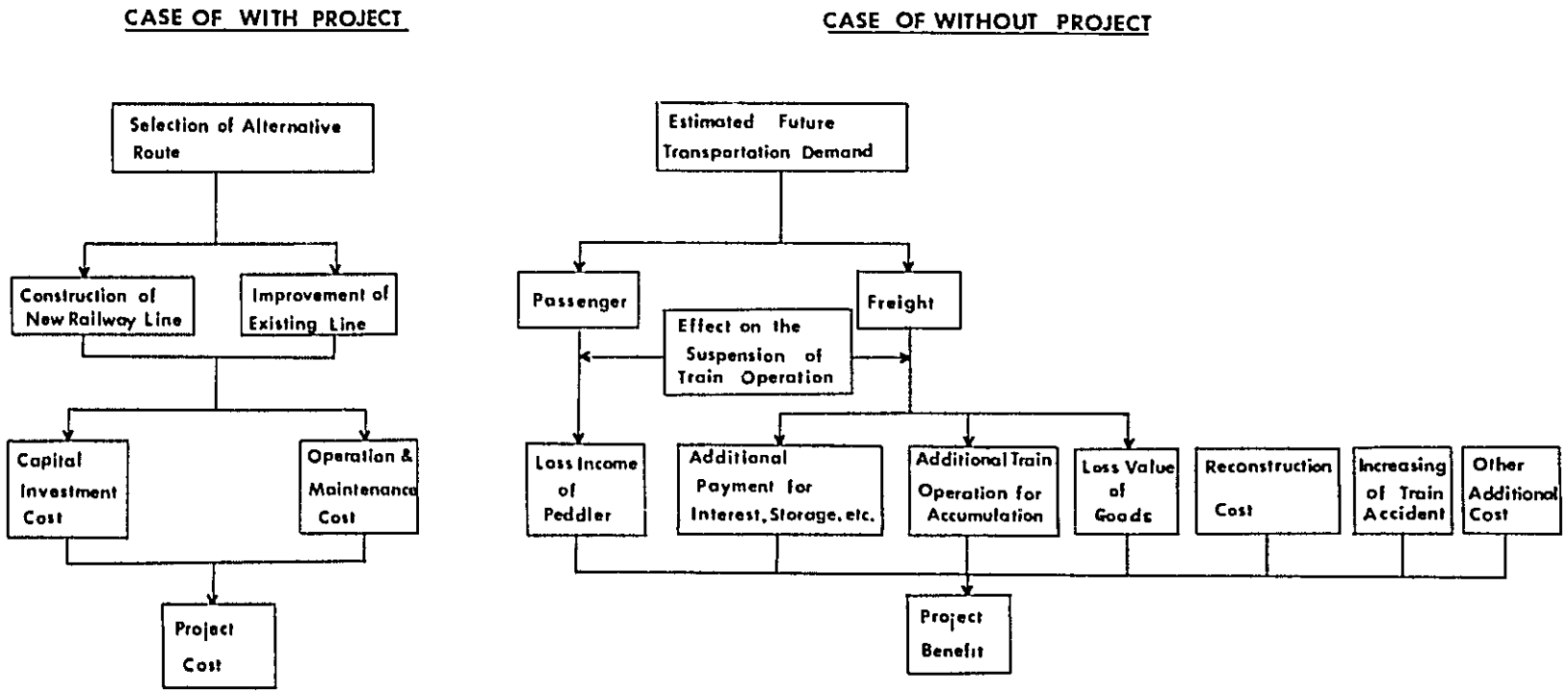


Fig. 5.1.1 Work Flow of Economic Analysis

5-1-2 Assumption on Service Suspension Period

The benefit estimation of the project execution (case of with project) includes as the objects the economic losses of passenger and freight and the emergency restoration cost, which may incur when the present route having been made an emergency repair is again destroyed in a rainy season.

Since these economic losses and emergency restoration cost vary with a number of service suspension days and a time of such calamity occurrence, the service suspension period is assumed in accordance with the rainfall statistics during the past ten (10) years.

Since 65% of the total cross section waterways may become a lack of cross sectional area with a rainfall of 40 mm/day in the section of Ipias - Robore which has currently been repaired on an emergency basis, it is assumed with a rainfall of more than 40 mm/day to repeat such a pattern as overflow - corrosion - collapse - service suspension.

Further, as for the service suspension period, it is assumed for the future to have thirty (30) days at a rainfall of 70 mm/day, fifteen (15) days at 50 mm/day and five (5) days at 40 mm/day, judging from the calamity scale and rainfall of this year (See para. 2.3, Chapter II).

The rainfall statistics at Robore during the past ten (10) years are plotted in Figure 5.1.2, which can be classified into such three groups as mid-September to November, December to February and March to April, through a judgement made on the rainfall distribution by month.

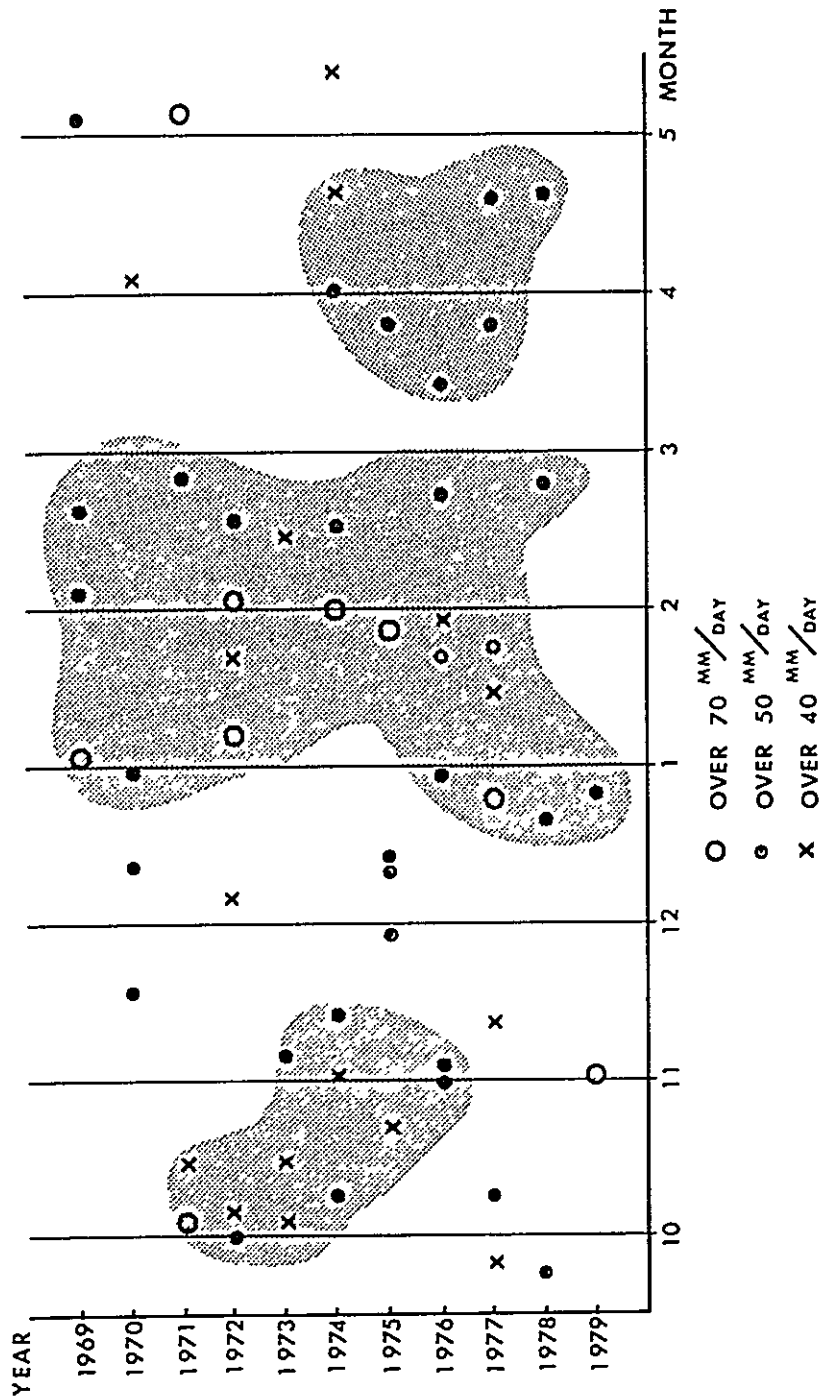


Fig. 5.1.2 Data of Rainfall Past 10 Years

Therefore, an estimate of service suspension pattern shall result in as shown in Table 5.1.1, below, based on a correlation between the rainfall volume and frequency, i.e. it is assumed to have twenty-five (25) days during the first term of rainy season, fourty-five (45) days during the middle term and fifteen (15) days during the last term, amounting to eighty-five (85) days in total.

Table 5.1.1 Transport Service Suspension Period

Group	Volume of rainfall (mm/day)	Frequency of rainfall (times)	No. of service suspension days corresponding to the volume of rainfall (days)	No. of service suspension days	* Service suspension period
1st-term	40 50 70	8 10 2	5 15 30	40 150 60 } x1/10 = 25	Oct. 1 ~ Oct. 25
Mid-term	40 50 70	5 16 6	5 15 30	25 240 180 } x1/10 = 45	Dec. 15 ~ Jan. 30
Last term	40 50 70	3 7 1	5 15 30	15 105 30 } x1/10 = 15	Mar. 15 ~ Mar. 30

(Note) * Service suspension period is determined, based on a judgement made through rainfall locations by group.

5-1-3 Concept of Freight Evaluation

In the freight evaluation of this economic analysis, a method is used to estimate as an additional cost to capital goods the interest rate as might be paid by the shippers for their held-up cargoes generated from the service suspension.

The commercial values of freight in the economy which are a basis for estimation of such interest rate are estimated to subtract the import and export duties and the sales tax to be treated as a transfer cost from the selling prices suveyed by commodity in the market which deals with the cargoes transported in the route of Santa Cruz - Corumba.

Table 5.1.2 tabulates the commercial sales values by trade in terms of export, import and domestic as well as by goods actually transported in 1978, based on which the average sales value amounts to 20,705 $b/ton in export, 39,772 $b/ton in import and 36,243 $b/ton in domestic goods transported.

The total volume of freight handled during the service suspension due to the calamity in 1979 can be classified into such categories as freights by alternative mode of transportation, storage, service suspension and loss of quality and value.

These disposition categorization is made in accordance with the freight handling pattern by commodity in reference with the comments of exporters, importers and ENFE.

Although a part of freights have arrived at Santa Cruz via Yacuiba by shifting the transport route to the port of Buenos Aires in Argentina from the debarkation at the port of Santos in Brazil, such freight volume is quite little, so that this route is not included in the evaluation, while it is considered to include an emergency transport route between Taperas and Robore and the air freight transport required in a harry to be delivered.

As for the storage of freights, it is considered at such two classification as warehouse and open stockpile, as the held-up cargoes require somehow to be stored until any alternative transportation is opened or the railway traffic is resumed.

The shutdown includes such goods that the production activities are voluntarily held up to avoid any excessive production, to which wood making industry, butcher business and others are applicable.

The loss of quality and value includes such goods that the quality and value of such are lowered due to the halt of transport service, to which vegitables, fruits and other perishable goods are applicable.

Table 5.1.2 Commercial Sales Amount by Commodity

Goods	Export		Import		Domestic		Key goods
	No. of tons handled (ton)	Sales sum ($b)	No. of tons handled (ton)	Sales sum ($b)	No. of tons handled (ton)	Sales sum ($b)	
		× 10^3		× 10^3		× 10^3	
Agriculture & sea products	13,299	338,691	13,800	145,155	6,443	229,777	Wheat, fruits, cotton, beaf, mule, etc.
Forest products	3,824	36,999	475	1,663	3,919	17,290	Lumbers, cross-ties, etc.
Mining products	628	4,246	502	9,450	3,764	38,037	Lime, marble, gypsum, iron ore, etc.
Metal & machinery	219	28,280	45,028	2,991,817	2,164	359,775	Train, electric generator, automobile, agricultural machinery
Chemical products	7,290	22,210	61,402	977,876	6,118	14,408	Alcohol, chemical fibres, oil synthetic rubber, etc.
Light industrial products	1,591	52,414	6,372	295,104	39	312	Glass wares, textile, beers, papers, etc.
Industrial merchandise	1,029	102,900	6,148	883,390	272	168,040	Home furniture, chinawares, TV's music instruments, etc.
Special products	0	0	3,676	247,180	0	0	Animal feed
Others	410	-	2,205	862	295	6,450	Tobacco
Total goods	28,290	585,740	139,608	5,552,497	23,014	834,089	
$b/ton	14.8%	20,705	73.1%	39,772	12.1%	36,243	

(Note) The sales sum by goods are calculated to subtract various taxes from the survey results in cooperation with the exporters and importers.

Table 5.1.3 Ways of Freight Handling During Service Suspension

Unit : ton

		Alternative transport		Storage		Shut-down	Loss of quality & value
		Road	By air	Ware-house	Open stock-pile		
Export	Agriculture & sea products		20		12,510		769
	Forest products	1,512	249	236	907	920	
	Mining products			40	588		
	Metal & machinery	111	16	92			
	Chemical products			7,290			
	Light industrial products		796	795			
	Industrial merchandise		515	514			
	Special products						
	Others		205	205			
	Sum	1,623	1,801	9,172	14,005	920	769
	%	6	6	32	50	3	3
Import	Agriculture & sea products	6,644	448	6,700		30	1
	Forest products				238	237	
	Mining products	105			397		
	Metal & machinery	25,699	368	12,700	6,261		
	Chemical products	52,853	3,623	1,300	3,456	170	
	Light industrial products	2,678	1,855	1,809	30		
	Industrial merchandise	2,751	2,941	365	38	30	
	Special products	1,403	1,026	1,025	81		141
	Others	1,016		740	320		129
	Sum	93,149	10,261	24,639	10,821	467	271
	%	67	7	18	8	0	0
Domestic	Agriculture & sea products	6,397		23		23	
	Forest products	3,919					
	Mining products	3,260				504	
	Metal & machinery	2,148	16				
	Chemical products	5,801	66	251			
	Light industrial products	20		19			
	Industrial merchandise	144	128				
	Special products						
	Others	219		76			
	Sum	21,908	210	369		527	
	%	95	1	2	0	2	0

5-2 Benefits Incidental to the Project Execution

5-2-1 Evaluation of Non-transport Passenger

Among other ENFE railway lines, the passenger transport between Santa Cruz and Corumba counts the second heavy traffic after the line between Oruro and Cochabanba.

The actual use pattern in 1978 by the mode of transportation is recapitulated in Table 5.2.1, based on which the usage rate of ordinary train (including mixed trains with freight wagons) shows 67% of the total. It is said that approx. 70% of total passenger to use these trains are occupied by the private importers who buy general merchandise at Corumba on the boundary to Brazil and sell them within the country of Bolivia.

The average riding distance of ferrobus passengers is 502 km, a majority of which use throughout the route between Santa Cruz and Corumba and are occupied with the passengers of travelling and/or business purposes.

The railcar represents a train linking Santa Cruz station with El Pailon station (52 km with the original terminal at Santa Cruz) and San Jose station (266 km with the same at Santa Cruz), which are utilized by commuters and peddlers.

Table 5.2.1 Passenger Train Use Pattern by Mode of Transportation

Mode of transportation	No. of passengers	Ratio to total passenger (%)	Passenger - Km (x 1,000)	Average riding distance (km)
* Ordinary train	172,715	67	63,265	366
Ferrobus	77,249	30	38,799	502
Railcar	8,869	3	400	49
Total	258,833	100	102,504	-

(Note) * To include mixed trains with freight wagons.

Who is affected, if the route is suspended due to a calamity between Ipias (335 km with the original terminal at Santa Cruz) and Robore (401 km with the same), includes passengers of ordinary train and ferrobus, in view of the average riding distance of the passengers.

Such passengers of ordinary train and ferrobus are the object of benefits to be generated by the rehabilitation project, while it is assumed that the ferrobus passengers have no profit and loss in terms of economic cost, from the viewpoint that a majority of such passengers are occupied by those of inbound and outbound travelling and/or having important business purposes, and they can relatively freely choose an alternative mode of transportation like airplane even at such service suspension so as to minimize their own sacrifice.

It is also said that approx. 70% of the total ordinary train passenger are occupied by the private importers, while 30% of the rest by the ordinary passengers.

The time value loss incidental to the movement is determined for such ordinary passengers to be nil, in view of the passengers in subject to fall in a low income class, while it is estimated only for the private importers of majority percentage.

Figure 5.2.1 shows an benefit evaluation procedure.

(1) No. of private importers unmovable during train service suspension:

67% of the railway passengers are the one of ordinary train, of which the number of passengers to use all the line between Santa Cruz and Corumba is estimated at the pro rata basis of the average riding distance throughout the line between Santa Cruz and Corumba, because of no information and data concerned like OD table. Assuming that 70% of the total ordinary train passengers are the private importers, which make no change in the future, such passenger number is estimated, together with the service suspension term of 85 days as determined in para. 5.1.2.

Further, since it is possibly assumed that a part of such private importers may shift their way to Yacuiba toward Argentina, it is estimated to be about 40% of the total which is reduced from the above estimation.

(2) Loss amount of private importers:

The total purchase cost to be made by the private importers is said nearly to be $b6,000 to $b8,000, based on which an assumption of their loss is, therefore, resulted as follows.

$$\text{Loss of private importers} = 7{,}000 - (7{,}000 \times T + F)$$
$$= \$b5{,}268 \text{ per importer}$$

where: $T = 0.20$ (Import tax and other expenses)
$F = 332$ (Round-trip train fare between Santa Cruz and Corumba)

Calculating the total loss of private importers incurred during a period of train service suspension under the above condition, the result comes as shown in Table 5.2.2, leading into $b20,414 thousand in 1983 and an increase of about 10% or $b22,579 thousand at the last year of the project forecast.

Table 5.2.2 Loss Amount of Private Importers Incurred deu to Service Suspension

(1,000 $b)

Year	Forecasted volume of transport demand	*No. of private importers unmovable	Total loss of private importers
1983	289,461	3,875	20,414
84	295,627	3,958	20,851
85	301,746	4,040	21,282
86	307,871	4,122	21,715
87	313,998	4,204	22,147
88	320,121	4,286	22,579

(Note) * Since the figures of forecasted volume of transport demand represent cumulative ones of round-trip passengers, such figures are divided in half, based on which the numbers of private importers unmovable are calculated.

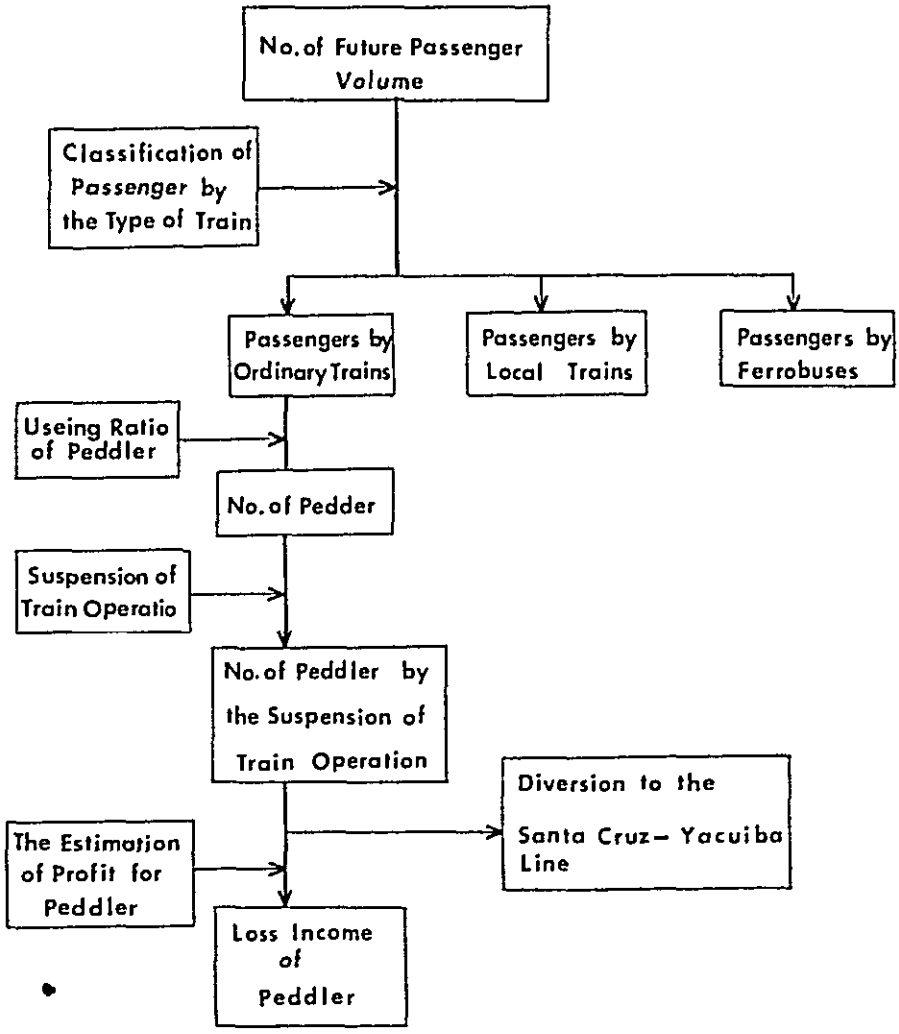


Fig. 5.2.1 Work Flow of Passenger Benefit

5-2-2 Non-transport Freight Evaluation

The route between Santa Cruz and Corumba ranks at the second heavy freight traffic volume after the line between Ollague and Uyuni linking to the port of Antofagasta.

The transportation to Brazil depends upon the railway between Santa Cruz and Corumba, so that the train service suspension due to a calamity may seemingly bring a critical influence upon the economy of Bolivia.

Evaluated hereunder are the economic losses in case of a suspension of freight transport service.

i) Prior consignment

Although a pattern of prior consignment has not been seen during 1979, this new pattern is determined to be adopted, based on the comments given by the exporters and importers, when the views are exchanged with them, that all the freights of expensive value shall be dealt with such pattern, because possible recurrence of transport suspension exist in a rainy season, if the current status of the railway is kept as it is.

Since such freights of prior consignment are deemed to be of high value, such volume is determined to be a half of those by air and the evaluation is made in terms of the storage cost and interest.

ii) Air freight

Air freights are determined to include those of high commercial value and of emergency necessity, but exclude the prior consignments.

Even though all the freights to be categorized under this mode of transportation should seemingly be assessed in terms of criterion of time value, they are determined not to be included in the evaluation, because they are assumed to have been choosing this mode of transportation for the purpose of minimizing the sacrifice of consigners.

iii) Warehousing and open stockpiling

This category includes freights to be stored until an alternative transport service is opened or the suspended railway service is resumed, assessing in terms of storage cost and interest. The storage cost of $b4.00 per ton is applied as being currently used by ENFE.

iv) Shutdown and loss of value

This category includes the lost products due to a shutdown of operation until resumption of transport service and the lost values of freights while being held up due to such occasion, which are assessed in terms of a sum subtracted various taxes and expenses to be accounted under a transfer cost from the market prices.

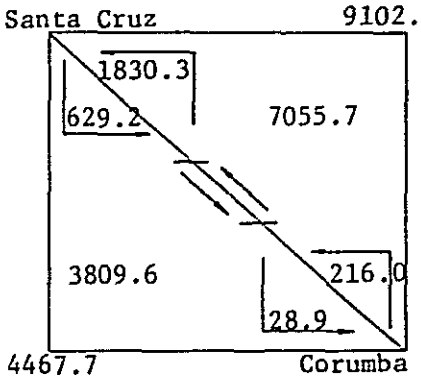
The cement factory at Yacuces is a good example to this category, although its operation may start in 1983 when this project execution commences, while a consideration is not given to a method of increasing an additive value likely as to store the produced cement in silo during a period of transport service suspension.

(1) Freight volume to be affected due to transport service suspension

The freight volume not transported shall be estimated, based on the train service suspension term set in para. 5.1.2 and the 1979 pattern of freight handling during such suspension (Figures 5.1.2 and 5.1.3).

Meanwhile, since the domestic freight transportation is available in every route other than the line between Ipias and Robore, if a per cent of freights passing through this route is estimated on the basis of OD Table as of June, 1978, the answer results in 80% of the total.

OD Table as of June, 1978



A per cent of Freights Passing Through the Route Between Ipias and Robore:

$$\frac{3809.6 + 7055.7}{4467.7 + 9102.0} = 0.80$$

. To Santa Cruz from Corumba:

$$\frac{7055.7}{3809.6 + 7055.7} = 0.65$$

. To Corumba from Santa Cruz:

$$\frac{3809.6}{3809.6 + 7055.7} = 0.35$$

(a) In case of 25-days suspension from 1 October to 25 October:

Total freight volume affected by such suspension is,

282,000 x 25/365 = 19,315 ton

Supposing the domestic freight traffic per centage to be 12.1%, then the freight volume between Ipias and Robore is,

19,315 - 19,315 x 0.121 x 0.20 = 18,848 ton

While, the cement volume unmovable is,

1200 x 25/365 = 8,219 ton

Now then, the total of such freight is broken down as follows.

	Freight ratio	Prior consign-ment	By air	Ware-house	Open stock-pile	* Shut-down	Lost value	Total
	(%)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)
Ex-port	14.8	86	86	1,085	1,430	86	86	2,859
Im-port	73.1	494	494	12,001	1,130	0	0	14,119
Do-mestic	12.1x 0.80	9	9	1,814	0	38	0	1,870
Total	-	589	589	14,900	2,560	124	86	18,848

*(Note) * Cement is not included.*

(b) In case of 45-days suspension from 15 December to 30 January:

Total freight volume affected by such suspension is,

282,000 x 45/365 = 34,767 ton

The same calculation method is applied as in case (a), above,

34,767 - 34,767 x 0.121 x 0.20 = 33,926 ton

While, the cement volume is,

1200 x 45/365 = 14,795 ton

Now then, the result is broken down in the same way as in case (a), above.

	Freight ratio	Prior consign-ment	By air	Ware-house	Open stock-pile	* Shut-down	Lost Value	Total
	(%)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)
Ex-port	14.8	154	154	1,957	2,573	154	154	5,146
Im-port	73.1	890	890	21,603	2,032	0	0	25,415
Do-mestic	12.1x 0.80	17	17	3,264	0	67	0	3,365
Total	-	1,061	1,061	26,824	4,605	221	154	33,926

(Note) * Cement is not included.

(c) In case of 15-days suspension from 15 March to 31 March:

To calculate hereunder in the same manner as in cases (a) and (b), above,

282,000 x 15/365 = 11,589 ton

11,589 - 11,589 x 0.121 x 0.20 = 11,308 ton

While, the cement volume is,

1200 x 15/365 = 14,795 ton

Now then, the result is broken down in the same way as in case (a) and (b), above,

	Freight ratio	Prior consign-ment	By air	Ware-house	Open stock-pile	* Shut-down	Lost value	Total
	(%)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)
Ex-port	14.8	51	51	652	859	51	51	1,715
Im-port	73.1	296	296	7,200	679	0	0	8,471
Do-mestic	12.1x 0.80	6	6	1,088	0	22	0	1,122
Total	-	353	353	8,940	1,538	73	51	11,308

(Note) * Cement is not included.

Since the rainfall volume is very little in this season and the freights held in the warehouses and stockpile are assumed to be shipped out in an alternative mode of transportation, few of freights are assumed to be held up.

An additional cost of transportation by the alternative mode of transportation is estimated by subtracting a sum cost calculated on the basis of an average train freight cost of $b0.90 per ton per km from a resultant sum calculated based on an average truck freight cost of $b2.58 per ton per km, supposing no such held freight to be transported by train between Taperas and Robore.

(2) *Mode and frequency of held-up freight transport*

The object in this category includes freights of export, import and domestic passing through the section between Ipias and Robore.

Although both the ordinary freights and the held-up freights can be delivered after the resumption of train operation, the number of days to complete delivery of freights held up shall be figured out

in accordance with the procedure illustrated in Figure 5.2.2, comparing to the current transportation capacity.

(a) Currently existing train transport capacity:

Supposing that a freight wagon has 15 tons in its self-weight and a loading capacity of 25 tons, and the hauling capacity between Santa Cruz and Corumba is 1,200 tons, a number of freight wagons to be composed of and the total loading capacity of freights per train result in as follows.

No. of freight wagons = 1200/40 = 30

Total loading capacity per train = 30 x 25 = 750 ton

If the forecasted volume of freight transport demand is divided into up-track and down-track, the result is tabulated as follows.

	1983	1988
Santa Cruz → Corumba	159 ton	194 ton
Corumba → Santa Cruz	613 ton	748 ton

(Note) Cement to be delivered from Yacuces is not included, as it uses an exclusive mode of transportation.

With the above, an another train of exclusive use is required for handling of freights held up to be delivered to Santa Cruz from Corumba, because of a lack of freight transport force at present.

Purchase cost per new train is,

Locomotive = 27,370,920$b (US$1,368,546)

$$\text{Freight wagon} = \frac{10,215,000\$b}{37,585,920} \text{ (US\$17,025 x 30 x 20.0\$b)}$$

If the numbers of days to be spent for clearing all the freight held up are calculated on the basis of the transport force with new purchase trains, the result in case of 1983 is as follows.

Term	Course of transport	Held freight by source of trade (ton)			No. of transport days = Freight vol./Transport Capacity
		Export	Import	Domestic	
From 1 Oct. to 25 Oct.	Corumba → Santa Cruz	-	13,131	1,179	14,310/750=20days
	Santa Cruz → Corumba	2,515	-	635	3,150/750 = 6 "
From 15 Dec. to 30 Jan.	Corumba → Santa Cruz	-	23,635	2,122	25,757/750=35 "
	Santa Cruz → Corumba	4,530	-	1,142	5,672/750 =10
From 15 Mar. to 31 Mar.	Corumba → Santa Cruz	-	7,879	707	8,586 Alternative mode
	Santa Cruz → Corumba	1,511	-	381	1,892 Alternative mode

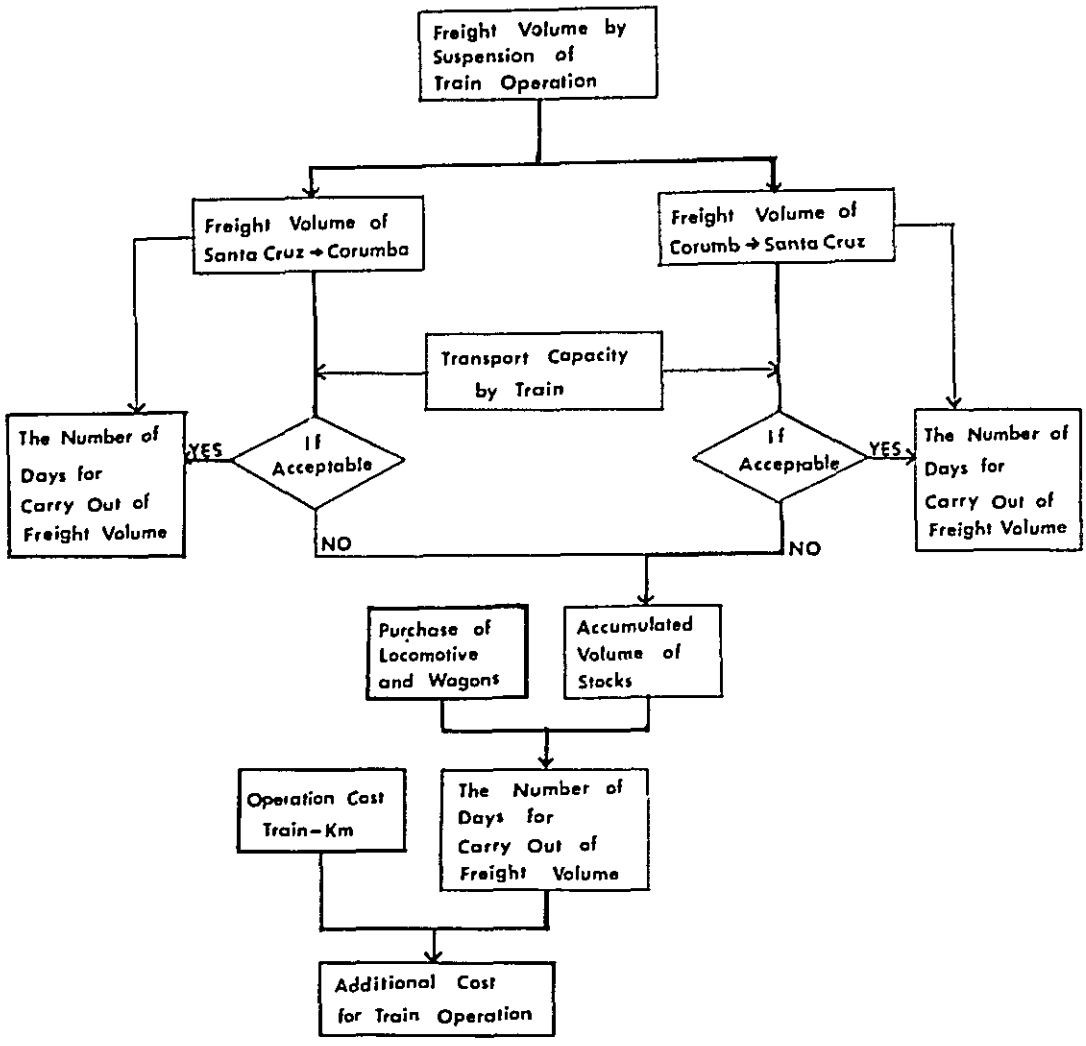


Fig. 5.2.2 Work Flow of Freight Transport Evaluation

(3) Lost value of non-transport freights

In assessing the lost value of non-transport freights in this economic analysis, a method is applied to estimate the interest rate as an additional cost to the capital goods as might ultimately be paid by the shippers for the stockpile of freight generated due to the transport service suspension, after they are classified by disposition.

The result is recapitulated in Table 5.2.3, below, which can be judged substantial in terms of the economic cost incidental to the operation suspension between Ipia and Robore.

(See Appendix-9 for calculation detail process.)

Table 5.2.3 Lost Value of Non-transport Freights

Unit : $b

Disposition \ Year	1983	1984	1985	1986	1987	1988
Prior consignment						
(storage cost)	271,060	282,996	294,932	306,868	318,804	330,740
(interest)	823,110	859,332	895,553	931,775	967,996	1,004,218
Warehouse						
(storage cost)	5,429,730	5,780,600	6,131,469	6,482,339	6,833,208	7,184,078
(interest)	17,129,450	18,240,528	19,351,606	20,462,684	21,513,762	22,684,842
Open sotckpile (interest)	2,027,776	2,154,549	2,281,322	2,408,095	2,534,868	2,661,641
Shutdown (loss)	10,628,016	11,150,882	11,673,748	12,196,614	12,719,480	13,242,346
Lost value (loss)	4,969,200	5,188,673	5,408,146	5,627,619	5,847,092	6,065,565
Alternative mode of transportation (expense)	2,300,969	2,401,941	2,502,913	2,603,885	2,704,857	2,805,829
*Cement (shut-down)	42,757,378	57,009,836	64,136,066	74,825,410	85,514,752	96,201,806
Total	86,336,689	103,069,337	112,675,765	125,845,289	139,014,819	152,132,065

(Note) * Since a selling price of cement to be delivered out of the cement factory at Yacuces is unknown, it is assumed to be 1,530$b per ton by making 10% discount of various taxes and delivery expenses from the current marketing price of 1,700$b per ton (seems to include imported cement) at Santa Cruz.

5-2-3 Rehabilitation Cost Assumption

If no execution of ultimate rehabilitation is made (if a current emergency repair is executed and left as it is), an annual requirement of rehabilitation cost by work criteria for the future is estimated on the basis of the actual cost spent for this calamity.

(1) Emergency restration cost at this calamity

It is reported to have spent $b30,749,000 for the emergency repair of the route between Ipias and Robore caused by this calamity.

Adding to this $b10,000,000 of countermeasure account whose expenditure is concluded for the subsequent emergency reinforcement, the total rehabilitation cost result in $b40,749,000 as shown in Table 5.2.4, below.

Should a break-down of this total by work criteria be available to obtain, it could be a very important key for the future assumption of such requirement, but it is estimated on a pro rata basis, as it is regretfully unknown.

Table 5.2.4 Emergency Restoration Cost (Financial Expense)

Unit : 1,000 $b

Major work	Range	Material cost			Labor cost			Total
		Domestic purchase	Foreign purchase	Sub-total	Skilled	Unskilled	Sub-total	
Embankment	3.1km	6,772	3,153	9,925	3,103	795	3,898	13,823
Soil & sand removal	3.8km	1,682	270	1,952	774	530	1,304	3,256
Track laying	4.1km	2,097	2,600	4,697	208	1,589	1,797	6,494
Temporary bridge erection	4 spots	810	1,255	2,065	99	1,059	1,158	3,223
Temporary bridge to BOX	4 spots	3,306	5,159	8,465	423	4,335	4,758	13,223
Other facilities	-	124	312	436	29	265	294	730
Grand total	-	14,791	12,749	27,540	4,636	8,573	13,209	40,749

(2) Future emergency restoration cost

The present conditions are left with an emergency repair made, and if such a state continues to stay as it is, such damages may probably occur at every rainy season that a lot of soil are required to be filled at the cross section of the rivers which have a lack of waterway cross section area, or the temporarily erected bridges may again be taken away resulting in the requirement of appropriate cost at such emergency repair.

An average ratio of such annually recurring emergency restoration cost as compared to the said cost spent at this calamity is assessed as follows.

For temporary bridge erection	1/2
For embankment & track laying	1/3
For BOX after completion of temporary repair	1/10
For other cost	1/10

Calculating based on these criteria, the result is recapitulated in Table 5.2.5, leading into 10,107,000$b in total or about one-fourth of the total rehabilitation cost required at this calamity, 40,749,000$b, and the economic cost reflecting shadow price of 9,545,000$b as shown in Table 5.2.6.

These requirements are assessed on the basis of the present conditions of the route, and if such calamity may occur every year, the ambient ground figure could be destroyed by soil collection to be used for emergency repair of the track and others, followed by expansion of incidental damages, thus leading into repeat of wrong circulation, with which it can easily be assumed that such restoration requirement is going to increasing every year.

Thus, a yearly increase of 10% is determined on the basis of an average restoration requirement of 9,545,000$b per annum.

Table 5.2.5 Forecasted Emergency Restoration Requirement (Market Price)

Unit : 1,000 $b

Major work	Reduction rate	Material cost			Labor cost			Total
		Domestic purchase	Foreign purchase	Sub-total	Skilled	Unskilled	Sub-total	
Embankment	1/3	2,258	1,051	3,309	1,034	265	1,299	4,608
Soil & sand removal	1/10	168	27	195	78	53	131	326
Track laying	1/3	699	867	1,566	69	530	599	2,165
Temporary bridge erection	1/2	405	627	1,032	50	530	580	1,612
Temporary bridge to BOX	1/10	331	516	847	42	434	476	1,323
Other facilities	1/10	12	31	43	3	27	30	73
Grand total	≒1/4	3,873	3,119	6,992	1,276	1,839	3,115	10,107

Table 5.2.6 Forecasted Emergency Restoration Requirement (Economic Cost)

Unit : 1,000 $b

Major work	Reduction rate	Material cost			Labor cost			Total
		Domestic purchase	Foreign purchase	Sub-total	Skilled	Unskilled	Sub-total	
Embankment	1/3	2,145	1,051	3,196	1,034	212	1,246	4,442
Soil & sand removal	1/10	160	27	187	78	42	120	307
Track laying	1/3	664	867	1,531	69	424	493	2,024
Temporary bridge erection	1/2	385	627	1,012	50	424	474	1,486
Temporary bridge to BOX	1/10	314	516	830	42	347	389	1,219
Other facilities	1/10	11	31	42	3	22	25	67
Grand total	≒1/4	3,679	3,119	6,798	1,276	1,471	2,747	9,545

5-2-4 Other Requirement

It is possibly considered to incur any unforeseenable requirement, if the train operation is carried out with the railway track which is temporarily repaired at every calamity.

A study is hereunder made on occurrence of train traffic accident among other requirement of this sort.

Statistics show 11 accidents including such occurrence with trains soly used for emergency restoration work during about 40-day period from 22 May to 30 June on the section between Taperas and Robore after completion of temporary rehabilitation, resulting in 91 accidents, if it is converted into annual basis, which represents nearly 5 times the occurrence in the last year (18 accidents in this route).

The rehabilitation requirements against train traffic accidents include chiefly the cost for repairing the locomotives, trains, tracks and others which have been damaged, and a comparison is made in terms only of the track rehabilitation requirement caused by train upset and removal with actual cost spent in the last year, as no concrete statistics is available for the cost of locomotive and train repairs, as follows.

	No. of accidents	Total rehabilitation cost	Emergency restoration cost per accident
1978	18	1,114,709 $b	61,928 $b
1979	91*	2,338,427 $b	25,697 $b

(Note) * Forecasted number of accidents for 1979 stands a conversion into the annual basis from the occurrence rate per day.

In regard to the requirement cost per accident in 1979, about 60% reduction from the 1978 average is assumingly attributed a limited inclusion of light traffic accidents like derailment and others with a view of no heavy accident due to the weakness of track structure.

On the other hand, the total rehabilitation cost in 1979 is more than doubled up over that in 1978, but it is determined to exclude this from the benefit evaluation in case of project execution (with project), because the figure reflects a record made at soon after completion of emergency repairs in 1979; an assumption is made to reduce occurrence of train traffic accident for the future, as the track rehabilitation goes on advance; and a variety of uncertain factors are feared to appear, if the number of train traffic accidents are forecasted on the basis of the present information and data.

5-3 Cost Incidental to the Project Execution

In regard to the construction plan for calamity rehabilitation, two plans of the existing line rehabilitation plan and the new detour line plan are ultimately selected, after various studies have been made in Chapter III.

Applying the shadow price on the domestic currency and the unskilled labor wage, a conversion of these requirements into the economic cost results in as shown in Figures 5.3.1 and 5.3.2.

Any other costs to be incurred incidental to execution of the Project have been determined with due consideration to the following conditions.

(1) Track renewal program

At present, there is a track renewal program for the route between Santa Cruz and Corumba, and 166 km of track is rehabilitated by the end of 1978. The area around Taperas to Robore which is included in the object of this plan is scheduled to complete during a period from 1981 to 1983.

In executing the rehabilitation plan as proposed, it should be noted that certain portions of the existing line will remain unchanged in either the existing line rehabilitation plan or the new detour line plan. Since such portions are also intended for improvement by track renewal it has been assumed that track maintenance conditions involved in those two alternatives would be same.

Meanwhile, in the case of "without project" where temporary measures would be taken for restoration on a case-by-case basis, everytime a future damage may occur, it is also assumed that the track would be improved by the similar renewal plan.

(2) Cost of operation and maintenance

Although it is assumed to require fairly more such cost in the new detour line plan than in the other plan, as the former track distance has longer extension by about 15 km than the existing route, the estimates of running hours and fuel consumption based on the planned plane and vertical curves and the train capacity resulted in as follows.

	Route distance	Running hour	Fuel consumption
Existing line rehabilitation plan	90.5 km	2°45'	430 ℓ
New detour plan	105.8 km	2°22'	588 ℓ

With this trial estimation, the running hour resulted in a reduction of 23 minutes in the new detour line plan, while the fuel consumption in a save of 158 litres in the existing line rehabilitation plan.

Since a very few sections of vertical grade and plane curve are planned in the new detour line plan, a reduction of its running hours is resulted, even though the plan has a longer distance than in the other plan.

Although it is quite difficult through the above results to assess the difference in cost of operation and maintenance between both plans, it is judged that the operational cost is less in the existing line rehabilitation plan, while the maintenance cost is less in the new detour line plan.

It is, therefore, concluded to offset each other, leading into a nearly negligible range of difference in between both plans.

Table 5.3.1 Capital Expenditure on Existing Line Rehabilitation Plan

Unit : 1,000 $b

Major work	Material cost			Labor cost			Grand total
	Domestic purchase	Foreign purchase	Sub-total	Skilled	Unskilled	Sub-total	
Earth work	38,112	87,400	125,512	2,866	10,316	13,182	138,694
Corrugated pipe setting	67	239	306	3	19	22	328
Open channel	65	46	111	6	26	32	143
L-type wall retaining	2,858	3,362	6,220	354	1,698	2,052	8,272
Lower sheathing	1,478	1,038	2,516	138	581	719	3,235
Box culvert	13,974	16,439	30,413	1,730	8,306	10,036	40,449
Bridge	24,249	102,102	126,351	3,003	15,616	18,619	144,970
Track	4,526	27,787	32,313	1,191	4,763	5,954	38,267
Sub-total ①	85,329	238,413	323,742	9,291	41,325	50,616	374,358
Engineering fee ②	4,252	11,870	16,122	584	2,023	2,607	18,729
Contingency ③	4,464	12,464	16,928	613	2,125	2,738	19,666
Sub-total ① - ③	94,045	262,747	356,792	10,488	45,473	55,961	412,753
Survey & design cost ④	-	25,305	25,305	-	-	-	25,305
Sub-total ① - ④	94,045	288,052	382,097	10,488	45,473	55,961	438,058
Track renewal ⑤	14,450	88,727	103,177	3,803	15,210	19,013	122,190
Engineering fee ⑥	722	4,437	5,159	190	761	951	6,110
Contingency ⑦	758	4,659	5,417	200	798	998	6,415
Sub-total ⑤ - ⑦	15,930	97,823	113,753	4,193	16,769	20,962	134,715
Grand total ① - ⑦	109,975	385,875	495,850	14,681	62,242	76,923	572,773

Table 5.3.2 Capital Expenditure on New Detour Line Plan

Unit : 1,000 $b

Major work	Material cost			Labor cost			Grand total
	Domestic purchase	Foreign purchase	Sub-total	Skilled	Unskilled	Sub-total	
Earth work	37,154	112,226	149,380	3,401	12,243	15,644	165,024
Open channel	11,543	8,100	19,643	1,080	4,536	5,616	25,259
Box culvert	3,628	4,268	7,896	449	2,156	2,605	10,501
Bridge	9,948	41,888	51,836	1,232	6,406	7,638	59,474
Track	19,400	119,124	138,524	5,105	20,422	25,527	164,051
Construction of station, maintenance facilities, etc.	1,279	5,386	6,665	158	824	982	7,647
Cost for land acquisition & road compensation	2,234	5,208	7,442	84	605	689	8,131
Sub-total ①	85,186	296,200	381,386	11,509	47,192	58,701	440,087
Engineering fee ②	2,601	8,899	11,500	411	1,424	1,835	13,335
Contingency ③	4,466	15,277	19,743	470	2,444	2,914	22,657
Sub-total ① - ③	92,253	320,376	412,629	12,390	51,060	63,450	476,079
Survey & design cost ④	-	31,345	31,345	-	-	-	31,345
Sub-total ① - ④	92,253	351,721	443,974	12,390	51,060	63,450	507,424
Track renewal ⑤	791	4,856	5,647	208	833	1,041	6,688
Engineering fee ⑥	40	243	283	10	42	52	335
Contingency ⑦	41	255	296	11	44	55	351
Sub-total ⑤ - ⑦	872	5,354	6,226	229	919	1,148	7,374
Grand total ① - ⑦	93,125	357,075	450,200	12,619	51,979	64,598	514,798

5-4 Economic Analysis

5-4-1 Benefit Cost Analysis

Having been variously studied on the economic benefits deemed to be brought into the national economy through the calamity rehabilitation project within a possible range of quantification, described hereunder are the analyses of economic effects.

Three kinds of allowance percentages, 10%, 12% and 15%, are used in this economic analysis to seek a percentage as an evaluation means in equalizing the internal rate of return of this project, by studying in each percentage as follows.

(1) Study by net present worth method, and
(2) Study by benefit cost ratio

The forecast of benefit and cost per annum is presented in Tables 5.4.1 and 5.4.2.

Plan / Analysis criteria / Discount ratio		Existing line rehabilitation plan	New detour line plan
10%	Net present worth	925,000 $b	974,000 $b
	Benefit cost ratio	2.87	3.18
12%	Net present worth	673,000 $b	720,000 $b
	Benefit cost ratio	2.39	2.65
15%	Net present worth	413,000 $b	458,000 $b
	Benefit cost ratio	1.89	2.09
Internal rate of return		26.02%	28.25%

Table 5.4.1 Cash Flow of Existing Line Rehabilitation Plan

Unit : 1,000 $b

Year	Costs				Benefits				
	Rehabilitation program		Track Renewal	Total	Passenger	Freight	Train Purchase	Emergency Restoration cost	Total
	Detailed design	Project cost							
1980	25,305			25,305					
81		167,482	51,505	218,987					
82		251,223	77,258	328,481					
83					20,414	86,337	37,586	13,363	157,700
84					20,851	103,069		14,318	138,238
85					21,282	112,676		15,272	149,230
86					21,715	125,845		16,227	163,787
87					22,147	139,015		17,181	178,343
88					22,579	152,132		18,136	192,847
89								19,090	193,801
1990								20,045	194,756
91								20,999	195,710
92								21,954	196,665
93								22,908	197,619
94								23,863	198,574
95								24,817	199,528
96								25,772	200,483
97								26,726	201,437
98								27,681	202,392
99								28,635	203,346
2000								29,590	204,301
01								30,544	205,255
02								31,499	206,210
03								32,453	207,164
04								33,408	208,119
05								34,362	209,073
06								35,317	210,028
07								36,271	210,982
08								37,226	211,937
09								38,180	212,891
2010								39,135	213,846
11								40,089	214,800
12								41,044	215,755

Table 5.4.2 Cash Flow of New Detour Line

Unit : 1,000 $b

Year	Costs				Benefits				
	Rehabilitation program		Track Renewal	Total	Passenger	Freight	Train Purchase	Emergency Restoration cost	Total
	Detailed design	Project cost							
1980	31,345			31,345					
81		190,611	2,770	193,381					
82		285,917	4,155	290,072					
83					20,414	86,337	37,586	13,363	157,700
84					20,851	103,069		14,318	138,238
85					21,282	112,676		15,272	149,230
86					21,715	125,845		16,227	163,787
87					22,147	139,015		17,181	178,343
88					22,579	152,132		18,136	192,847
89					↓	↓		19,090	193,801
1990								20,045	194,756
91								20,999	195,710
92								21,954	196,665
93								22,908	197,619
94								23,863	198,574
95								24,817	199,528
96								25,772	200,483
97								26,726	201,437
98								27,681	202,392
99								28,635	203,346
2000								29,590	204,301
01								30,544	205,255
02								31,499	206,210
03								32,453	207,164
04								33,408	208,119
05								34,362	209,073
06								35,317	210,028
07								36,271	210,982
08								37,226	211,937
09								38,180	212,891
2010								39,135	213,846
11								40,089	214,800
12								41,044	215,755

It can be judged through the economic analysis results that the project is feasible in either plan of the existing line rehabilitation or the new detour line.

Since there is no mode of land transportation in the hinterland of this project, it is notoriously featured that only a very few of passengers and freights can just possibly choose an alternative mode of transportation by air, while a majority of such must wait the resumption of train transport service, once it is suspended.

Further, the transport distance of this line is 396 km for passengers and 579 km for freights, having a typical nature of local transportation in distance, so that a service suspension in between Ipias and Robore situated nearly at the middle of the line may hit a death blow to the transport of passengers and freights.

If the section between Ipias and Robore is left for the future, as being at a current state of emergency repair, it is assumed to cause the route collapsed and the train operation suspended at every rainy season.

It is, therefore, advisable to complete an ultimate rehabilitation on an emergency basis, because the trunk artery linking the countries of Bolivia and Brazil may greatly be injured, thus leading into an interruption against the development of Bolivia, if such a condition is kept every year.

5-4-2 Sensitivity Analysis

All the information and data collected have been analysed in this economic analysis, but there are assumingly a variety of uncertainties on the estimations to measure the future benefits.

The project soundness is hereunder studied, by taking account of such variable factors of these estimates.

Case 1 : Supposing a period of train service suspension to be 85 days, the affects of such suspension are measured, if such a suspension period is reduced by 20%.

Case 2 : What occupy the largest percentage among the project benefits is cement to be delivered out of Yacuces. The production plan is now being carried out to correspond with the consumption within Bolivia, and this case study is made to the event when such production is reduced by 50%.

Case 3 : The study is made in combination of Case 1 and Case 2.

	Internal rate of return	
	Existing line rehabilitation plan	New detour line plan
Case 1	22.23%	24.20%
Case 2	21.18%	23.10%
Case 3	18.08%	19.79%

The sensitivity analysis was made for the above three cases, resulting in a judgement of the project to be sound in every case.

CHAPTER 6. FINANCIAL ANALYSIS

6-1 General

Although the financial standing till 1973 since 1964 when ENFE is organized has continued in stagnant way, except in 1969, it turned to a favorable way likely available to gain a net disposable operating profit of $b 6.7 million, leading into 79 in working ratio and 88 in operating ratio, because the government has afforded in 1973 and 1974 a subsidy to favor against the unsettled loans and the red figure caused due to the internal investment, and further, the government has allowed ENFE to raise substantial train fares in 1975 so as to make it possible for ENFE to operate voluntarily by himself.

Owing to a cause of a general strike of mines at the Western region during the first six (6) months of 1976, the traffic volume is greatly reduced, and the working and operating ratios are fairly lowered to 82 and 99, respectively, even though a certain amount of net disposable operating income is gained.

The traffic volume is consistently increasing during such period, even though the transport fare is raised, but the financial balance falls in a red figure in 1978, because the manpower cost occupying more than a half the total operating cost was raised by nearly 40% and the payable interest on a trend of slowly increasing pressed over the total management, thus leading into an operating ratio of 104 (see Table 6.1.1).

ENFE has raised the freight carriage charge by 68%, with further increase of another 52% to foods, since January, 1975. The transport fare may be higher at some routes than that of truck delivery fare, but the railway is a customary mode for a long distance transport of such freights as large size and low value. Further, the consigners to generally choose the railway of having security and certainty, even though the charge is higher than those by truck, or often use the railway for the purpose of avoiding from risks of pillage.

The passenger fare has not been raised since January, 1974, whose reason seems to be competing against the bus service at low fare. In the eastern region, the train riding efficiency is 100%, as there is no competition of bus service against the railway. However, the train fare is recently raised by 10% in February, 1977, because the total fare income can not cover the total operating expenses.

Table 6.1.1 Estimated Revenue and Expenditure

(Unit: Million Pesos)

Item	Western Line	Eastern Line	TOTAL ENFE 1975	Western Line	Eastern Line	TOTAL ENFE 1976	Western Line	Eastern Line	TOTAL ENFE 1977	Western Line	Eastern Line	TOTAL ENFE 1978
OPERATING REVENUES												
Passenger	36.6	19.3	55.9	46.6	22.7	69.3	49.6	28.3	77.9	48.8	34.2	81.2
Freight	290.6	165.0	455.6	289.0	189.7	478.7	341.9	196.8	538.7	405.9	203.7	609.6
Miscellaneous	31.2	27.2	58.4	38.4	16.6	55.0	36.3	22.3	58.6	42.8	28.8	71.6
Total Operating Revenues	358.4	211.5	569.9	374.0	229.0	603.0	427.8	247.4	675.2	497.5	264.9	762.4
OPERATING COSTS												
Administration and General	39.1	12.5	51.6	34.1	24.7	58.8	40.3	28.1	68.4	76.3	38.9	115.2
Maint. Roadway Telecom. & Signals	68.7	36.0	104.7	68.4	49.7	118.1	69.0	44.0	113.0	127.2	61.8	189.0
Maint. of Equipment	46.7	21.1	67.8	49.1	25.0	74.1	41.4	28.0	69.4	57.9	30.4	88.3
Traffic & Commercial	34.8	14.1	48.9	63.6	21.5	85.1	66.3	18.1	84.4	46.6	22.5	69.1
Traction	41.2	18.6	59.8	50.6	21.0	71.6	58.8	26.2	85.0	71.7	35.6	107.3
Freight Car Rental	13.7	62.8	76.5	13.2	30.4	43.6	18.8	12.8	31.6	15.9	7.5	23.4
Internal Transport Service	-	-	-	-	-	-	-	-	-	21.5	-	21.5
Loss on Subsidized Food	34.3	8.9	43.2	34.3	9.1	43.4	23.6	10.2	33.8	35.2	11.3	46.5
Total Working Costs	278.5	174.0	452.5	313.3	181.4	494.7	318.2	167.4	485.6	452.3	208.0	660.3
Depreciation	36.2	14.2	50.4	53.7	51.0	104.7	64.1	44.8	108.9	85.4	46.1	131.5
Total Operating Costs	314.7	188.2	502.9	367.0	232.4	599.4	382.3	212.2	594.5	537.7	254.1	792.3
Net Working Revenue	79.9	37.5	117.4	60.7	47.6	108.3	109.6	80.0	189.6	45.2	52.3	97.5
Net Operating Revenue	43.7	23.3	67.0	7.0	(3.4)	3.6	45.5	35.2	80.7	(40.2)	6.2	(34.0)
Non-Operating Receipts	0.3	0.8	1.1	20.7	17.4	38.2	15.7	7.5	23.2	3.5	7.7	11.2
Non-Operating Expenses	(0.5)	(1.2)	(1.7)	(2.2)	(1.5)	(3.7)	(25.0)	(13.8)	38.8	(1.2)	(2.0)	(3.2)
Net Revenue (Loss) before Interest	43.5	22.9	66.4	25.5	12.6	38.1	36.2	28.9	65.1	(37.9)	11.9	(26.0)
Loan Interest	(11.4)	-	(11.4)	(13.8)	(10.5)	(24.3)	(27.9)	(31.0)	(58.9)	(38.1)	(46.9)	(85.0)
Discount	-	-	-	-	-	-	-	-	-	(15.2)	-	(15.2)
Net Revenue	32.1	22.9	55.0	11.7	2.1	13.8	8.3	(2.1)	6.2	(91.2)	35.0	(126.2)
Coefficient: Working Ratio	0.77	0.82	0.79	84.0	79.0	82.0	74.0	68.0	72.0	91.0	80.0	87.0
Operating Ratio	0.87	0.88	0.88	98.0	101.0	99.0	89.0	86.0	88.0	108.0	78.0	104.0
OPERATING COSTS												
Labor	169.7	66.2	235.9	184.3	87.7	272.0	179.6	83.2	262.8	252.9	112.0	364.9
Fuel & Lubricant	23.0	9.4	32.4	40.7	14.3	55.0	40.8	9.8	50.6	42.8	12.0	54.8
Materials	17.5	18.3	35.8	39.8	29.3	69.1	26.0	21.3	47.3	34.0	28.1	62.1
Contractors	3.2	5.0	8.2	6.1	3.8	9.9	15.6	13.3	28.9	16.8	18.1	34.9
Freight Car Rental	15.1	38.6	53.7	5.5	28.2	33.7	17.4	12.1	29.5	15.9	7.5	23.4
Internal Transport Service	-	-	-	-	-	-	-	-	-	21.5	-	21.5
Loss on Subsidized Food	34.3	8.9	43.2	34.3	9.1	43.4	23.6	10.2	33.8	35.2	11.3	46.5
Miscellaneous	15.7	27.6	43.3	2.6	9.0	11.6	15.2	17.5	32.7	33.2	19.0	52.2
Total	278.5	174.0	452.5	313.3	181.4	494.7	318.2	167.4	485.6	452.3	208.0	660.3

LaPaz, August 1979

Source: Departmento De Finanzas

6-2 Financial Analysis

6-2-1 Purpose of the Analysis

The purpose of this financial analysis is to assess the total requirements for execution of this project and the total expenditure as may incur in case of no execution of the project, standing on the position of public utility organization required a self-supporting.

Since this project is not of nature available to increase the traffic volume of passengers and freights caused by implementation of this project through a transfer from other mode of transportation and/or a new induction, likely as in the other general development project, the revenue may not increase, even though the project is executed.

On the contrary, if the project is not executed, the revenue may reduce in accordance with a reduction in the traffic volume and an additional expenditure may incidentally be required for emergency rehabilitation and transportation or storage of freights held up.

6-2-2 Expenditures in Case of Project Execution

The total expenditure in case of project execution is estimated on the basis of the following studies.

(1) Organization

No increase of general administrative expense is considered, viewing that the project can possibly be carried out sufficiently with the currently composed ENFE organization and staffing, even if it is decided to be implemented.

(2) Subsidy

A certain amount of subsidy with no interest is assumed to be favored by the government for years foreseenable to account a red balance among the projected period.

On the contrary, a method is made to return such capital investment to the government at later years when the profit becomes available.

(3) Annual operating expenses

Although the operating expense is deemed to include costs for train, track, operation, repair and maintenance, no case is estimated as they are likely under the same condition. However, in case of no execution of the project, it is required to dispose of all the freights to be held up, so that a consideration includes such incidental operating expenses.

(4) Capital expenditure

As a result of technical studies, the existing track rehabilitation plan is selected, as it is deemed the optimum to this project, and

the capital expenditure is estimated, accordingly. The estimated capital expenditure is divided into the domestic currency and the foreign currency, and recapitulated in Tables 6.2.1 and 6.2.2.

Table 6.2.1 Existing Line Rehabilitation Plan

	Major Work	× 10^3 $b			× 10^3 US$		
		Domestic Currency	Foreign Currency	Total	Domestic Currency	Foreign Currency	Total
Rehabilitation expenditure	Earthwork	55,879	87,400	143,279	2,794	4,370	7,164
	Corrugated pipe	98	239	337	5	12	17
	Open channel	106	46	152	5	3	8
	L-type wall retaining	5,485	3,362	8,847	274	168	442
	Lower sheathing	2,420	1,038	3,458	121	52	173
	Box culvert	26,821	16,439	43,260	1,341	822	2,163
	Bridge	48,048	102,102	150,150	2,402	5,105	7,507
	Track	11,909	27,787	39,696	596	1,389	1,985
	Sub total ①	150,766	238,413	389,179	7,538	11,921	19,459
	Engineering fee ②	7,589	11,870	19,459	379	594	973
	Contingency (Physical) ③	7,968	12,464	20,432	399	623	1,022
	Sub total ①∿③	166,323	262,747	429,070	8,316	13,138	21,454
	Survey & design cost ④	-	25,305	25,305	-	1,265	1,265
	Sub total ①∿④	166,323	288,052	454,375	8,316	14,403	22,719
	Contingency (Price) ⑤	23,537	40,076	63,613	1,177	2,003	3,180
	Total ① ∿ ⑤	189,860	328,128	517,988	9,493	16,406	25,899
Track renewal expenditure	Track renewal ⑥	38,026	88,727	126,753	1,901	4,437	6,338
	Engineering fee ⑦	1,901	4,437	6,338	95	222	317
	Contingency (Physical) ⑧	1,996	4,659	6,655	100	232	332
	Sub total ⑥∿⑧	41,923	97,823	139,746	2,097	4,891	6,988
	Contingency (Price) ⑨	5,869	13,695	19,564	293	685	978
	Total ⑥ ∿ ⑨	47,792	111,518	159,310	2,390	5,576	7,966
Grand total ① ∿ ⑨		237,652	439,646	677,298	11,883	21,982	33,865

Table 6.2.2 New Detour Line Plan

Major Work		× 10^3 $b			× 10^3 US$		
		Domestic Currency	Foreign Currency	Total	Domestic Currency	Foreign Currency	Total
Rehabilitation expenditure	Earthwork	57,814	112,226	170,040	2,891	5,611	8,502
	Open channel	18,900	8,100	27,000	945	405	1,350
	Box culvert	6,963	4,268	11,231	348	213	561
	Bridge	19,712	41,888	61,600	985	2,095	3,080
	Track	51,053	119,124	170,177	2,552	5,957	8,509
	Construction of station, maintenance facilities, etc.	2,534	5,386	7,920	127	269	396
	Cost for land acquisition & road compensation	3,192	5,208	8,400	160	260	420
	Sub total ①	160,168	296,200	456,368	8,008	14,810	22,818
	Engineering fee ②	4,792	8,899	13,691	240	445	685
	Contingency (Physical) ③	8,226	15,277	23,503	411	764	1,175
	Sub total ①∿③	173,186	320,376	493,562	8,659	16,019	24,678
	Survey & design cost ④	-	31,345	31,345		1,567	1,567
	Sub total ①∿④	173,186	351,721	524,907	8,659	17,586	26,245
	Contingency (Price) ⑤	24,251	49,236	73,487	1,213	2,462	3,675
	Total ① ∿ ⑤	197,437	400,957	598,394	9,872	20,048	29,920
Track renewal expenditure	Track renewal ⑥	2,082	4,856	6,938	104	243	347
	Engineering fee ⑦	104	243	347	5	12	17
	Contingency (Physical) ⑧	109	255	364	6	12	18
	Sub total ⑥∿⑧	2,295	5,354	7,649	115	267	382
	Contingency (Price) ⑨	321	750	1,071	16	38	54
	Total ⑥ ∿ ⑨	2,616	6,104	8,720	131	305	436
Grand total ① ∿ ⑨		200,053	407,061	607,114	10,003	20,353	30,356

6-2-3 Expenditure and Revenue Reduction in Case of No-execution of Project

Since the train service suspension can possible be foreseen at every rainy season in case of no execution of this project, it is deemed to have an expenditure increase for both the emergency rehabilitation and the disposition of freights to be held up due to such suspension, and the revenue reduction due to the shutdown and the lost value.

If the estimate of such expenditure increase and revenue reduction is calculated in accordance with the 1979 pattern of train service suspension and freight handling, the result comes as follows.

(1) Freight fare income reduction due to lost value and shutdown

This account counts the cost of freights which become no longer requiring the railway transport due to the train service suspension, including a transfer to freight by air.

Therefore, if the freight fare income reduction is estimated on the basis of the current average fare of $b 0.90 per ton per km, the 1983 estimate results in as shown in Table 6.2.3, below.

Table 6.2.3 Estimated Freight Fare Income Reduction (1983)

Source of Trade	Freight Volume Affected During Suspension (F)			Average Transport Distance (K)	Freight Fare* (T)	Freight Fare Income Reduction =F×K×T $b
	Oct.1 ∿Oct.25	Dec.15 ∿Jan.30	Mar.15 ∿Mar.31			
Export	258	462	153	651	0.9	511,491
Import	494	890	296	645	0.9	975,240
Domestic	47	84	28	336	0.9	48,082
Cement	8,219	14,795	4,932	583	0.876	14,272,145
Total						15,806,958

Note: * The same rate is applied for the freight fare in this estimate, even though a discount fare is actually applied, depending upon the volume to be handled per consigner.

* The transport fare for cement is estimated to subtract the train operating cost to be incurred during the suspension.

(2) Additional expenditure required for transport of freights held up

All the freights held up are necessary to be transported by the freight wagon of exclusive use, as previously studied in the economic analysis.

Since a number of trains required are generally determined by taking account of a coefficient of busyness, operating efficiency and provisional ratio, it is concluded that there is no extra train to be used for transport of such held-up freights between Santa Cruz and Corumba, and thus such requirements shall be met with the newly purchased trains.

The purchasing time is determined on a convenience basis to be at the same years as the project commences.

Freight wagon purchase cost (at price of Aug., 1979):

Locomotive	27,370,920	(US$ 1,368,546 × 20.0 $b)
Freight wagon	10,215,000	(US$ 17,025 × 30 trains × 20.0 $b)
	37,585,920	

Meanwhile, calculating the train operating cost by dividing the total operating cost throughout the Eastern region with the total running distance (km), 9.05 $b per train per km (to use this value due to a possible division into passenger and freight) is resulted, based on which the total operating cost requirement in 1983 is estimated, together with the number of transport days required for the held-up freights as previously estimated in the economic analysis, as follows.

Distance between Santa Cruz and Robore: 401 km

Number of days in which the exclusive use train is used:
20 + 35 = 55 days

(Note: To exclude the number of days suspended in March, as an alternative mode of transportation is available.)

Thus, the total operating cost requirement is,
9.05 × 401 × 2 × 55 = 399,196 $b

(3) Passenger fare income reduction

Supposing that all the passengers passing between Ipias and Robore receive the influence throughout the train service suspension period, the total fare income reduction in this period is estimated.

Since a passenger OD Table is not available, a per cent of passengers passing between Ipias and Robore is estimated on the basis of the ratio between an average riding distance by class of train and the overall distance from Santa Cruz to Corumba, and additionally, a break-down into first and second classes is made on a pro rata basis by the number of seats in each class.

Calculating such in 1983 as an example, the result comes as shown in Table 6.2.4, below.

Table 6.2.4 Estimated Passenger Fare Income Reduction

Unit: Person

	Ordinary		Ferrobus		Total
	1st Class	2nd Class	1st Class	2nd Class	
No. of passengers	193,939 (67%)		86,838 (30%)		280,777
No. of passengers passing between Ipias and Robore (366/651 km)	109,035		66,964		175,999
No. of passengers by class of seat	40,888 (3/8)	68,147 (5/8)	33,482 (1/2)	33,482 (1/2)	175,999
No. of influenced passengers with suspension (85/365 days)	9,522	15,870	7,797	7,797	40,984
Passenger fare* ($b)	817,104	815,718	1,141,496	971,519	3,745,837

Note: * The fare is estimated with application of adult and children fares on the basis of 80% for adult and 20% for children.

(4) Additional expenditure and revenue reduction per annum

If an additional expenditure and revenue in case of no execution of this project is estimated for the future, as previously been studied, the result is as shown in Table 6.2.5, next page.

Table 6.2.5 Additional Expenditure and Revenue Reduction in Case of No-execution of This Project

Unit: 1,000 $b

	1983	1984	1985	1986	1987	1988
Freight fare income reduction*	2,155	2,250	2,345	2,440	2,535	2,631
Cement freight fare income reduction	14,272	19,030	21,408	24,976	28,544	32,112
New train purchase cost for held-up freights of exclusive use	37,586					
Train operating cost	399	415	431	447	463	479
Passenger fare income reduction	3,746	3,825	3,905	3,984	4,063	4,142
Total	58,158	25,520	28,089	31,847	35,605	39,364

Note: * Cement freight fare income reduction is separately estimated as below.

(5) Emergency restoration cost

In regard to the estimate of future emergency restoration cost as may incur at every calamity, the emergency restoration estimates calculated in the economic analysis in the previous Chapter are used after conversion into the financial expenditure.

6-2-4 Financial Internal Rate of Return

Assuming that the total fund requirement for execution of the calamity rehabilitation project can be supplied at a certain extent through a foreign aid loan, instead of a full supply of ENFE own fund, an estimate is made to find out up to how much of interest rate ENFE can sustain.

The expenditure in this estimate is determined to be the total construction cost estimated on the basis of currently marketing prices respectively by the existing line rehabilitation plan and the new detour line plan which have been ultimately selected as a result of various technical studies, while the revenue includes the additional expenditure for emergency rehabilitation and the revenue reduction of train fares as may incur in case of no execution of this project.

Meanwhile, there is a separate plan of track renewal program for the route between Santa Cruz and Corumba, 166 km of which has already been completed by the end of 1978, and the route from Taperas to Robore via

Ipias is also scheduled to be rehabilitated during 1981 ∿ 1983.

Therefore, if the track renewal program is considered as a separate project, such a case is also studied, as it is appreciable to reduce the construction cost in the calamity rehabilitation project.

	Existing line rehabilitation plan	New detour line plan
Financial internal rate of return	9.16%	10.23%
Financial internal rate of return (excluding track renewal program)	12.92%	14.77%

Judging from the calculation result, this project can possibly be said financially feasible (financially viable).

Owing to a fear of any unforeseenable occasion as may occur before the project execution, a verification of this project shall be made to prove whether or not this project can sustain against risks and uncertainties, likely as being made in the economic analysis.

A sensitivity analysis is made in the economic analysis on a variety of benefits as may be deemed to incur in the future, while in this financial analysis an estimate is made on how affects upon the financial internal rate of return, if the inflational effect which might incur in the future is applied on the estimated total construction cost in terms of 1979 price.

		Existing line rehabilitation plan	New detour line plan
Financial internal rate of return	7% 10%	7.86% 7.35%	8.87% 8.34%
Financial internal rate of return (excluding track renewal program)	7% 10%	11.36% 10.75%	13.08% 12.44%

With the above calculation result, it is clearly revealed that the existing line rehabilitation plan can sustain with an interest rate of 7.35%, while the new detour line plan with the same of 8.34%, if the inflational effect is assumed to be 10%.

It is advisable rather to borrow a foreign aid loan of low interest, because this project feature lies upon a saved loss of expenditure, instead of causing the revenue increased due to the project execution.

6-3 Financing and Repayment

A decision to make up a financing and repayment plan for the total fund requirement involved in this project is a complicate problem to require an abundance of experience and a high level of technology, which becomes available for the first time when a good cooperation is offered from any financing body related to the Republic of Bolivia.

As a prerequisite to develop a financing and repayment plan, it is assumed that the government shall bear both the capital expenditure and the interest of foreign loan.

The estimate is made on the basis of the following assumption of financial standing.

(1) Foreign currency

All the fund required as construction cost shall assumingly be financed with a foreign loan at an annual interest rate of 7.5%, whose repayment is under terms and conditions of 7-year deferment and 25-year equal-installment payment.

(2) Domestic currency

All the domestic currency required shall be provided from the government budget with no interest, which includes not only the capital expenditure, but also the subsidy for the payable interest.

A study is made on the financing and repayment plan to cover either case of the track renewal program work to be a separate project or the project execution on which an indexation is reflected.

In either case, the return to the capital expenditure shall become available from 1983 and the total amount of return to the government by the end of 2016 shall become as follows.

Tables 6.3.1 through 6.3.3 show the cash flow under the financing and repayment plan.

· In case of no consideration of any indexation

	Existing line rehabilitation plan (1,000 $b)	New detour line plan (1,000 $b)
Amount of return	953,275 (4.79)	1,052,488 (6.35)
Amount of return (excluding track renewal program)	1,299,291 (8.89)	1,392,788 (12.39)

· In case of price rising assumption at 7%

	Existing line rehabilitation plan (1,000 $b)	New detour line plan (1,000 $b)
Amount of return	782,442 (3.41)	898,646 (4.70)
Amount of return (excluding track renewal program)	1,181,723 (7.01)	1,291,397 (9.96)

· In case of price rising assumption at 10%

	Existing line rehabilitation plan (1,000 $b)	New detour line plan (1,000 $b)
Amount of return	704,467 (2.89)	828,439 (4.08)
Amount of return (excluding track renewal program)	1,128,057 (6.30)	1,245,080 (9.05)

Note: Figures in parentheses are percentages to the total investment made by the government.

Table 6.3.1 (1) In the Case of no Inflationary Effect (Existing Line Rehabilitation)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Govornment Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Ex-penditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Re-newal			
1980	25,305					25,305						0.000
1981	113,106	34,786		1,898	1,898	173,197	1,898	60,903	18,731	81.532		-81,532
1982	169,658	52,180		12,990	12,990	395,035	12,990	91,355	28,097	132.442		-132.442
1983				29,628	29,628	395,035	29,628			29,628	72,308	42,680
1984				29,628	29,628	395,035	29,628			29,628	40,681	11,053
1985				29,628	29,628	395,035	29,628			29,628	44,260	14,632
1986				29,628	29,628	395,035	29,628			29,628	49,029	19,401
1987			1,017	29,628	30,645	394,018	30,645			30,645	53,798	23,153
1988			6,944	29,551	36,495	387,074	36,495			36,495	58,567	22,072
1989			15,813	29,031	44,844	371,261	44,844			44,844	59,578	14,734
1990			15,800	27,845	43,645	355,461	43,645			43,645	60,589	16,944
1991			15,800	26,660	42,460	339,662	42,460			42,460	61,599	19,139
1992			15,800	25,475	41,275	323,862	41,275			41,275	62,610	21,335
1993			15,800	24,290	40,090	308,062	40,090			40,090	63,621	23,531
1994			15,800	23,105	38,905	292,262	38,905			38,905	64,632	25,727
1995			15,800	21,920	37,720	276,462	37,720			37,720	65,642	27,922
1996			15,800	20,735	36,535	260,663	36,535			36,535	66,653	30,118
1997			15,800	19,550	35,350	244,863	35,350			35,350	67,664	32,314
1998			15,800	18,365	34,165	229,063	34,165			34,165	68,674	34,509
1999			15,800	17,180	32,980	213,263	32,980			32,980	69,685	36,705
2000			15,800	15,995	31,795	197,463	31,795			31,795	70,696	38,901
2001			15,800	14,810	30,610	181,663	30,610			30,610	71,706	41,096
2002			15,800	13,625	29,425	165,863	29,425			29,425	72,717	43,292
2003			15,800	12,440	28,240	150,063	28,240			28,240	73,728	45,488
2004			15,800	11,255	27,055	134,263	27,055			27,055	74,739	47,684
2005			15,800	10,070	25,870	118,463	25,870			25,870	75,749	49,879
2006			15,800	8,885	24,685	102,663	24,685			24,685	76,760	52,075
2007			15,800	7,700	23,500	86,863	23,500			23,500	77,771	54,271
2008			15,800	6,515	22,315	71,063	22,315			22,315	78,781	56,466
2009			15,800	5,330	21,130	55,263	21,130			21,130	79,792	58,662
2010			15,800	4,145	19,945	39,463	19,945			19,945	80,803	60,858
2011			15,800	2,960	18,760	23,663	18,760			18,760	81,813	63,053
2012			14,788	1,775	16,563	8,875	16,563			16,563	82,824	66,261
2013			8,873	0,666	9,539	0.002	9,539			9,539	82,824	73,285
TOTAL	308,069	86,966	395.033	562,893	957,928	7505,238	957.928	152,258	46,828	1157,013	2110,289	953.275

Table 6.3.1 (2) In the Case of no Inflationary Effect
(Existing Line Excluded Whole Track Rehabilitation)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Govornment Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Ex-penditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Re-newal			
1980	25,305					25,305						0.000
1981	99,549			1.898	1.898	124,854	1.898	58,466		60.364		-60.364
1982	149,324			9.364	9.364	274.178	9.364	87,699		97.063		-97.063
1983				20.563	20.563	274,178	20,563			20.563	72.308	51.745
1984				20.563	20.563	274.178	20,563			20.563	40.681	20,118
1985				20.563	20.563	274.178	20.563			20.563	44.260	23,697
1986				20.563	20.563	274,178	20.563			20.563	49.029	28.466
1987			1,017	20.563	21.580	273,161	21.580			21.580	53.798	32.218
1988			5,017	20.487	25,504	268,144	25.504			25.504	58.567	33.063
1989			10,989	20,111	31,100	257.155	31.100			31.100	59.578	28.478
1990			10,965	19,287	30.252	246,190	30.252			30.252	60.589	30,337
1991			10,965	18,404	29,429	235,225	29,429			29.429	61,599	32,170
1992			10,965	17.642	28,607	224,260	28.607			28,607	62.610	34.003
1993			10,965	16,820	27,785	213,295	27.785			27,785	63,621	35.836
1994			10,965	15,997	26,962	202,330	26,962			26,962	64,632	37,670
1995			10,965	15,175	26,140	191,365	26,140			26,140	65,642	39,502
1996			10,965	14,352	25,317	180,400	25,317			25,317	66,653	41,336
1997			10,965	13,530	24,495	169,435	24,495			24,495	67,664	43,169
1998			10,965	12,708	23,673	158,470	23,673			23,673	68,674	45,001
1999			10,965	11,885	22,850	147,505	22,850			22,850	69,685	46,835
2000			10,965	11,063	22,028	136,540	22,028			22,028	70,696	48,668
2001			10,965	10,241	21,206	125,575	21,206			21,206	71,706	50,500
2002			10,965	9,418	20,383	114,610	20,383			20,383	72,717	52,334
2003			10,965	8,596	19,561	103,645	19,561			19,561	73,728	54,167
2004			10,965	7,773	18,738	92,680	18,738			18,738	74,739	56,001
2005			10,965	6,951	17,916	81,715	17,916			17,916	75,749	57,833
2006			10,965	6,129	17,094	70,750	17,094			17,094	76,760	59,666
2007			10,965	5,306	16,271	59,785	16,271			16,271	77,771	61,500
2008			10,965	4,484	15,449	48,820	15,449			15,449	78,781	63,332
2009			10,965	3,662	14,627	37,855	14,627			14,627	79,792	65,165
2010			10,965	2,839	13,804	26,891	13,804			13,804	80,803	66,999
2011			10,965	2,017	12,982	15,926	12,982			12,982	81,813	68,831
2012			9,953	1,194	11,147	5,973	11,147			11,147	82,824	71,677
2013			5,972	0.448	6,420	0.001	6,420			6,420	82,824	76,404
TOTAL	274,178		274,178	390,654	664,832	5208,734	664,832	146,165		810,996	2110.289	1299,291

Table 6.3.1 (3) In the Case of on Inflationary Effect
(New Detour Line)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Govornment Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Ex-penditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Re-newal			
1980	31,345					31,345						0.000
1981	132,412	2,200		2.351	2.351	165,957	2.351	65,218	1,083	68.652		-68.652
1982	198,617	3,300		12.447	12,447	367,874	12.447	97,827	1,625	111,899		-111.899
1983				27.590	27.590	367,874	27,590			27.590	72.308	44,717
1984				27.590	27.590	367,874	27,590			27.590	40.681	13,090
1985				27.590	27.590	367,874	27,590			27.590	44,260	16,669
1986				27.590	27.590	367,874	27,590			27.590	49.029	21,438
1987			1,273	27.590	28.863	366,601	28,863			28,863	53.798	24,934
1988			6,649	27,495	34.144	359,952	34.144			34.144	58.567	24,423
1989			14,730	26,996	41,726	345,222	41.726			41,726	59,578	17.852
1990			14,713	25.892	40.605	330,509	40.605			40,605	60.589	19.984
1991			14,713	24,788	39.501	315,796	39,501			39.501	61.599	22,098
1992			14,713	23,685	38,398	301,083	38,398			38.398	62.610	24.212
1993			14,713	22,58.	37.294	286,370	37.294			37.294	63.621	26,327
1994			14,713	21,478	36,191	271,657	36,191			36,191	64,632	28,441
1995			14,713	20,374	35,087	256,945	35,087			35,087	65.642	30,555
1996			14,713	19,271	33,984	242,232	33.984			33.984	66.653	32.669
1997			14,713	18,167	32,880	227,519	32,880			32.880	67,664	34,784
1998			14,713	17,064	31,777	212,806	31,777			31,777	68.674	36,897
1999			14,713	15,960	30,673	198,093	30,673			30.673	69,685	39.012
2000			14,713	14,857	29,570	183,380	29,570			29,570	70,696	41,126
2001			14,713	13,753	28,466	168,667	28,466			28,466	71.706	43,240
2002			14,713	12,650	27,363	153,954	27,363			27,363	72,717	45.354
2003			14,713	11,547	26,260	139,241	26,260			26.260	73,728	47,468
2004			14,713	10,443	25,156	124,528	25,156			25.156	74,739	49,583
2005			14,713	9,340	24,053	109,815	24,053			24,053	75,749	51,696
2006			14,713	8,236	22,949	95,102	22,949			22,949	76,760	53,811
2007			14,713	7,133	21,846	80,389	21,846			21,846	77,771	55,925
2008			14,713	6,029	20,742	65,676	20,742			20,742	78,781	58,039
2009			14,713	4,926	19,639	50,963	19,639			19,639	79,792	60,153
2010			14,713	3,822	18,535	36,250	18,535			18,535	80,803	62,268
2011			14,713	2,719	17,432	21,537	17,432			17,432	81,813	64,381
2012			13,460	1,615	15,075	8,077	15,075			15,075	82,824	67,749
2013			8,076	0,606	8,682	0,001	8,682			8,682	82,824	74,142
TOTAL	362,374	5,500	367,873	524,174	892,048	6988,992	892,048	163,045	2,708	1057,800	2110.289	1052,488

Table 6.3.1 (4) In the Case of no Inflationary Effect
(New Detour Line Excluded Whole Track Rehabilitation)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Government Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Expenditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Renewal			
1980	31,345					31,345						0.000
1981	87,278			2,351	2,351	118,623	2,351	44,962		47,313		-47,313
1982	130,917			8,897	8,897	249,540	8,897	67,442		76,339		-76,339
1983				18,715	18,715	249,540	18,715			18,715	72,308	53,593
1984				18,715	18,715	249,540	18,715			18,715	40,681	21,966
1985				18,715	18,715	249,540	18,715			18,715	44,260	25,545
1986				18,715	18,715	249,540	18,715			18,715	49,029	30,314
1987			1,273	18,715	19,988	248,267	19,988			19,988	53,798	33,810
1988			4,747	18,620	23,367	243,520	23,367			23,367	58,567	35,200
1989			9,997	18,264	28,261	233,523	28,261			28,261	59,578	31,317
1990			9,980	17,514	27,494	223,543	27,494			27,494	60,589	33,095
1991			9,980	16,766	26,746	213,563	26,746			26,746	61,599	34,853
1992			9,980	16,017	25,997	203,583	25,997			25,997	62,610	36,613
1993			9,980	15,269	25,249	193,603	25,249			25,249	63,621	38,372
1994			9,980	14,520	24,500	183,623	24,500			24,500	64,632	40,132
1995			9,980	13,772	23,752	173,643	23,752			23,752	65,642	41,890
1996			9,980	13,023	23,003	163,663	23,003			23,003	66,653	43,650
1997			9,980	12,275	22,255	153,683	22,255			22,255	67,664	45,409
1998			9,980	11,526	21,506	143,703	21,506			21,506	68,674	47,168
1999			9,980	10,778	20,758	133,723	20,758			20,758	69,685	48,927
2000			9,980	10,029	20,009	123,743	20,009			20,009	70,696	50,687
2001			9,980	9,281	19,261	113,763	19,261			19,261	71,706	52,445
2002			9,980	8,532	18,512	103,783	18,512			18,512	72,717	54,205
2003			9,980	7,784	17,764	93,803	17,764			17,764	73,728	55,964
2004			9,980	7,035	17,015	83,823	17,015			17,015	74,739	57,724
2005			9,980	6,287	16,267	73,843	16,267			16,267	75,749	59,482
2006			9,980	5,538	15,518	63,863	15,518			15,518	76,760	61,242
2007			9,980	4,790	14,770	53,883	14,770			14,770	77,771	63,001
2008			9,980	4,041	14,021	43,903	14,021			14,021	78,781	64,760
2009			9,980	3,293	13,273	33,923	13,273			13,273	79,792	66,519
2010			9,980	2,544	12,524	23,943	12,524			12,524	80,803	68,279
2011			9,980	1,796	11,776	13,963	11,776			11,776	81,813	70,037
2012			8,727	1,047	9,774	5,236	9,774			9,774	82,824	73,050
2013			5,236	0,393	5,629	0,000	5,629			5,629	82,824	77,195
TOTAL	249,540		249,540	355,556	605,096	4740,754	605,096	112,404		717,500	2110,289	1392,788

Table 6.3.2 (1) In the Case of 7% Inflationary Trend
(Existing Line Rehabilitation)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Govornment Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Ex-penditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Re-newal			
1980	26,191					26,191						0.000
1981	125,259	38,524		1.964	1.964	189.974	1.964	67,447	20,744	90.155		-90.155
1982	201,041	61,831		14.248	14.248	452.846	14.248	108,253	33,294	155.795		-155.795
1983				33.963	33.963	452.846	33.963			33.963	72.308	38.345
1984				33.963	33.963	452.846	33.963			33.963	40.681	6.718
1985				33.963	33.963	452.846	33.963			33.963	44.260	10.297
1986				33.963	33.963	452.846	33.963			33.963	49.029	15.066
1987			1.063	33.963	35.026	451.783	35.026			35.026	53.798	18.772
1988			7.606	33.884	41.490	444.177	41.490			41.490	58.567	17.077
1989			18.134	33.313	51.447	426.043	51.447			51.447	59.578	8.131
1990			18.112	31.953	50.065	407.931	50.065			50.065	60.589	10.524
1991			18.112	30.595	48.707	389.819	48.707			48.707	61.599	12.892
1992			18.112	29.236	47.348	371.708	47.348			47.348	62.610	15.262
1993			18.112	27.878	45.990	353.596	45.990			45.990	63.621	17.631
1994			18.112	26.520	44.632	335.484	44.632			44.632	64.632	20.000
1995			18.112	25.161	43.273	317.372	43.273			43.273	65.642	22.369
1996			18.112	23.803	41.915	299.260	41.915			41.915	66.653	24.738
1997			18.112	22.444	40.556	281.148	40.556			40.556	67.664	27.107
1998			18.112	21.086	39.198	263.037	39.198			39.198	68.674	29.476
1999			18.112	19.728	37.840	244.925	37.840			37.840	69.685	31.845
2000			18.112	18.369	36.481	226.813	36.481			36.481	70.696	34.215
2001			18.112	17.011	35.123	208.701	35.123			35.123	71.706	36.583
2002			18.112	15.653	33.765	190.589	33.765			33.765	72.717	38.952
2003			18.112	14.294	32.406	172.477	32.406			32.406	73.728	41.322
2004			18.112	12.936	31.048	154.365	31.048			31.048	74.739	43.691
2005			18.112	11.577	29.689	136.253	29.689			29.689	75.749	46.060
2006			18.112	10.219	28.331	118.141	28.331			28.331	76.760	48.429
2007			18.112	8.861	26.973	100.029	26.973			26.973	77.771	50.798
2008			18.112	7.502	25.614	81.917	25.614			25.614	78.781	53.167
2009			18.112	6.144	24.256	63.805	24.256			24.256	79.792	55.536
2010			18.112	4.785	22.897	45.693	22.897			22.897	80.803	57.906
2011			18.112	3.427	21.539	27.581	21.539			21.539	81.813	60.274
2012			17.065	2.069	19.134	10.516	19.134			19.134	82.824	63.690
2013			10.514	0.789	11.303	0.002	11.303			11.303	82.824	71.521
TOTAL	352,491	100,355	452.844	645.262	1098.109	8603.516	1098.109	175,700	54,038	1327.847	2110.289	782.442

Table 6.3.2 (2) In the Case of 7% Inflationary Trend
(Existing Line Excluded Whole Track Rehabilitation)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Government Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Expenditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Renewal			
1980	26,191					26,191						0.000
1981	110,246			1,964	1,964	136,437	1,964	64,748		66,712		-66.712
1982	176,945			10,233	10,233	313,382	10,233	103,920		114,153		-114.153
1983				23,504	23,504	313,382	23,504			23,504	72,308	48.804
1984				23,504	23,504	313,382	23,504			23,504	40,681	17.177
1985				23,504	23,504	313,382	23,504			23,504	44,260	20.756
1986				23,504	23,504	313,382	23,504			23,504	49,029	25.525
1987			1,063	23,504	24,567	312,319	24,567			24,567	53,798	29.231
1988			5,477	23,424	28,901	306,842	28,901			28,901	58,567	29.666
1989			12,553	23,013	35,566	294,289	35,566			35,566	59,578	24,012
1990			12,533	22,072	34,605	281,756	34,605			34,605	60,589	25.984
1991			12,533	21,132	33,665	269,223	33,665			33,665	61,599	27.934
1992			12,533	20,192	32,725	256,690	32,725			32,725	62,610	29.885
1993			12,533	19,252	31,785	244,157	31,785			31,785	63,621	31.836
1994			12,533	18,319	30,845	231,624	30,845			30,845	64,632	33.787
1995			12,533	17,372	29,905	219,091	29,905			29,905	65,642	35.737
1996			12,533	16,432	28,965	206,558	28,965			28,965	66,653	37.688
1997			12,533	15,492	28,025	194,025	28,025			28,025	67,664	39.639
1998			12,533	14,552	27,085	181,492	27,085			27,085	68,674	41.589
1999			12,533	13,612	26,145	168,959	26,145			26,145	69,685	43.540
2000			12,533	12,672	25,205	156,426	25,205			25,205	70,696	45,491
2001			12,533	11,732	24,265	143,893	24,265			24,265	71,706	47,441
2002			12,533	10,792	23,325	131,360	23,325			23,325	72,717	49,392
2003			12,533	9,852	22,385	118,827	22,385			22,385	73,728	51,343
2004			12,533	8,912	21,445	106,294	21,445			21,445	74,739	53,294
2005			12,533	7,972	20,505	93,761	20,505			20,505	75,749	55,244
2006			12,533	7,032	19,565	81,228	19,565			19,565	76,760	57,195
2007			12,533	6,092	18,625	68,695	18,625			18,625	77,771	59,146
2008			12,533	5,152	17,685	56,162	17,685			17,685	78,781	61,096
2009			12,533	4,212	16,745	43,629	16,745			16,745	79,792	63,047
2010			12,533	3,272	15,805	31,096	15,805			15,805	80,803	64,998
2011			12,533	2,332	14,865	18,563	14,865			14,865	81,813	66,948
2012			11,486	1,392	12,878	7,077	12,878			12,878	82,824	69,946
2013			7,077	0,531	7,608	0,000	7,608			7,608	82,824	75,216
TOTAL	313,382		313,381	446,515	759,897	5953,547	759,897	168,668		928,565	2110,289	1181,723

Table 6.3.2 (3) In the Case of 7% Inflationary Trend
(New Detour Line)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Government Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Expenditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Renewal			
1980	32,442					32,442						0.000
1981	146,640	2,436		2,433	2,433	181,518	2,433	72,225	1,200	75,858		-75,858
1982	235,356	3,910		13,614	13,614	420,784	13,614	115,922	1,926	131,462		-131,462
1983				31,559	31,559	420,784	31,559			31,559	72,308	40,749
1984				31,559	31,559	420,784	31,559			31,559	40,681	9,122
1985				31,559	31,559	420,784	31,559			31,559	44,260	12,701
1986				31,559	31,559	420,784	31,559			31,559	49,029	17,470
1987			1,314	31,559	32,873	419,470	32,873			32,873	53,798	20,925
1988			7,261	31,460	38,721	412,209	38,721			38,721	58,567	19,846
1989			16,846	30,916	47,762	395,363	47,762			47,762	59,578	11,816
1990			16,830	29,652	46,482	378,533	46,482			46,482	60,589	14,107
1991			16,830	28,390	45,220	361,703	45,220			45,220	61,599	16,379
1992			16,830	27,128	43,958	344,874	43,958			43,958	62,610	18,652
1993			16,830	25,865	42,695	328,044	42,695			42,695	63,621	20,926
1994			16,830	24,603	41,433	311,214	41,433			41,433	64,632	23,199
1995			16,830	23,341	40,171	294,384	40,171			40,171	65,642	25,471
1996			16,830	22,079	38,909	277,554	38,909			38,909	66,653	27,744
1997			16,830	20,817	37,647	260,724	37,647			37,647	67,664	30,017
1998			16,830	19,554	36,384	243,895	36,384			36,384	68,674	32,290
1999			16,830	18,292	35,122	227,065	35,122			35,122	69,685	34,563
2000			16,830	17,030	33,860	210,235	33,860			33,860	70,696	36,836
2001			16,830	15,768	32,598	193,405	32,598			32,598	71,706	39,108
2002			16,830	14,505	31,335	176,575	31,335			31,335	72,717	41,382
2003			16,830	13,243	30,073	159,745	30,073			30,073	73,728	43,655
2004			16,830	11,981	28,811	142,915	28,811			28,811	74,739	45,928
2005			16,830	10,719	27,549	126,085	27,549			27,549	75,749	48,200
2006			16,830	9,456	26,286	109,255	26,286			26,286	76,760	50,474
2007			16,830	8,194	25,024	92,425	25,024			25,024	77,771	52,747
2008			16,830	6,932	23,762	75,595	23,762			23,762	78,781	55,019
2009			16,830	5,670	22,500	58,765	22,500			22,500	79,792	57,292
2010			16,830	4,407	21,237	41,935	21,237			21,237	80,803	59,566
2011			16,830	3,145	19,975	25,105	19,975			19,975	81,813	61,838
2012			15,533	1,883	17,416	9,572	17,416			17,416	82,824	65,408
2013			9,570	0,718	10,288	0,002	10,288			10,288	82,824	72,536
TOTAL	414,438	6,346	420,782	599,585	1020,369	7994,480	1020,369	188,147	3,126	1211,641	2110,289	898,646

Table 6.3.2 (4) In the Case of 7% Inflationary Trend
(New Detour Line Excluded Whole Track Rehabilitation)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Government Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Expenditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Renewal			
1980	32,442					32,442						0.000
1981	96,656			2.433	2.433	129.098	2.433	49,793		52.226		-52.226
1982	155,120			9.682	9.682	284.218	9.682	79,910		89.592		-89.592
1983				21.316	21.316	284.218	21.316			21.316	72.308	50.992
1984				21.316	21.316	284.218	21.316			21.316	40.681	19,365
1985				21.316	21.316	284.218	21.316			21.316	44,260	22.944
1986				21.316	21.316	284.218	21.316			21.316	49.029	27.713
1987			1,314	21.316	22,630	282,904	22,630			22,630	53.798	31.168
1988			5.169	21.218	26.387	277.735	26.387			26.387	58.567	32.180
1989			11.387	20.830	32,217	266.348	32,217			32,217	59,578	27.361
1990			11,367	19.976	31,343	254,981	31,343			31,343	60.589	29.246
1991			11,367	19.124	30,491	243,614	30,491			30,491	61,599	31.108
1992			11,367	18.271	29,638	232,247	29,638			29,638	62,610	32.972
1993			11,367	17.419	28,785	220,880	28,785			28,785	63.621	34.835
1994			11,367	16,566	27,933	209,513	27,933			27,933	64,632	36.699
1995			11,367	15.713	27,080	198,146	27,080			27,080	65,642	38,562
1996			11,367	14,861	26,228	186,779	26,228			26,228	66,653	40.425
1997			11,367	14,008	25,375	175,412	25,375			25,375	67,664	42.289
1998			11,367	13,156	24,523	164,045	24,523			24,523	68,674	44,151
1999			11,367	12,303	23,670	152,678	23,670			23,670	69,685	46,015
2000			11,367	11,451	22,818	141,311	22,818			22,818	70,696	47,878
2001			11,367	10,598	21,965	129,944	21,965			21,965	71,706	49,741
2002			11,367	9,746	21,113	118,577	21,113			21,113	72,717	51,604
2003			11,367	8,893	20,260	107,210	20,260			20,260	73,728	53,468
2004			11,367	8,041	19,408	95,843	19,408			19,408	74,739	55,331
2005			11,367	7,188	18,555	84,476	18,555			18,555	75,749	57,194
2006			11,367	6,336	17,703	73,109	17,703			17,703	76,760	59,057
2007			11,367	5,483	16,850	61,742	16,850			16,850	77,771	60,921
2008			11,367	4,631	15,998	50,375	15,998			15,998	78,781	62,783
2009			11,367	3,778	15,145	39,008	15,145			15,145	79,792	64,647
2010			11,367	2,926	14,293	27,641	14,293			14,293	80,803	66,510
2011			11,367	2,073	13,440	16,274	13,440			13,440	81,813	68,373
2012			10,070	1,221	11,291	6,204	11,291			11,291	82,824	71,533
2013			6,204	0,465	6,669	0,000	6,669			6,669	82,824	76,155
TOTAL	284,218		284,217	404,969	689,187	5399,590	689,187	129,703		818,890	2110.289	1291,397

Table 6.3.3 (1) In the Case of 10% Inflationary Trend
(Existing Line Rehabilitation)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Government Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Expenditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Renewal			
1980	26,570					26,570						0.000
1981	130,637	40,178		1,993	1,993	197,385	1,993	70,343	21,635	93,971		-93.971
1982	215,552	66,294		14,804	14,804	479,231	14,804	116,066	35,697	166,567		-166.567
1983				35,942	35,942	479,231	35,942			35,942	72.308	36.366
1984				35,942	35,942	479,231	35,942			35,942	40.681	4.739
1985				35,942	35,942	479,231	35,942			35,942	44,260	8.318
1986				35,942	35,942	479,231	35,942			35,942	49.029	13.087
1987			1,082	35,942	37,024	478,149	37,024			37,024	53.798	16.774
1988			7,909	35,861	43,770	470,240	43,770			43,770	58,567	14,797
1989			19,188	35,268	54,456	451,052	54,456			54,456	59.578	5,122
1990			19,167	33,829	52,996	431,885	52,996			52,996	60.589	7.593
1991			19,167	32,391	51,558	412,718	51,558			51,558	61,599	10.041
1992			19,167	30,954	50,121	393,551	50,121			50,121	62,610	12.489
1993			19,167	29,516	48,683	374,384	48,683			48,683	63,621	14.938
1994			19,167	28,079	47,246	355,217	47,246			47,246	64,632	17.386
1995			19,167	26,641	45,808	336,050	45,808			45,808	65,642	19.834
1996			19,167	25,204	44,371	316,883	44,371			44,371	66,653	22.282
1997			19,167	23,766	42,933	297,716	42,933			42,933	67,664	24,731
1998			19,167	22,329	41,496	278,549	41,496			41,496	68,674	27,178
1999			19,167	20,891	40,058	259,382	40,058			40,058	69,685	29,627
2000			19,167	19,454	38,621	240,215	38,621			38,621	70,696	32,075
2001			19,167	18,016	37,183	221,048	37,183			37,183	71,706	34,523
2002			19,167	16,579	35,746	201,881	35,746			35,746	72,717	36,971
2003			19,167	15,141	34,308	182,714	34,308			34,308	73,728	39,420
2004			19,167	13,704	32,871	163,547	32,871			32,871	74,739	41,868
2005			19,167	12,266	31,433	144,380	31,433			31,433	75,749	44,316
2006			19,167	10,828	29,995	125,213	29,995			29,995	76,760	46,765
2007			19,167	9,391	28,558	106,046	28,558			28,558	77,771	49,213
2008			19,167	7,953	27,120	86,879	27,120			27,120	78,781	51,661
2009			19,167	6,516	25,683	67,712	25,683			25,683	79,792	54,109
2010			19,167	5,078	24,245	48,545	24,245			24,245	80,803	56,558
2011			19,167	3,641	22,808	29,378	22,808			22,808	81,813	59.005
2012			18,105	2,203	20,308	11,273	20,308			20,308	82,824	62,516
2013			11,273	0,845	12,118	0,000	12,118			12,118	82.824	70.706
TOTAL	372,759	106,472	479,231	682,850	1162,081	9104,676	1162,081	186,409	57,332	1405,821	2110,289	704,467

Table 6.3.3 (2) In the Case of 10% Inflationary Trend
(Existing Line Excluded Whole Track Rehabilitation)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Govornment Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Ex-penditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Re-newal			
1980	26,570					26.570						0.000
1981	114,979			1.993	1.993	141.549	1,993	67,528		69,521		-69.521
1982	189,717			10.616	10.616	331.266	10.616	111,421		122.037		-122.037
1983				24.845	24.845	331,266	24,845			24.845	72.308	47.463
1984				24.845	24.845	331,266	24,845			24.845	40,681	15.836
1985				24.845	24.845	331,266	24,845			24.845	44,260	19,415
1986				24.845	24.845	331,266	24.845			24.845	49,029	24.184
1987			1.082	24.845	25.927	330,184	25,927			25.927	53,798	27.871
1988			5,665	24,764	30,429	324,519	30,429			30.429	58.567	28,138
1989			13,266	24,339	37,605	311.253	37,605			37,605	59,578	21.973
1990			13,249	23,344	36,593	298,005	36,593			36.593	60,589	23,996
1991			13,249	22,350	35,599	284.756	35,599			35,599	61,599	26,000
1992			13,249	21.357	34,606	271,507	34,606			34,606	62,610	28.004
1993			13.249	20.363	33,612	258,258	33,612			33,612	63,621	30.009
1994			13.249	19.369	32.618	245,010	32,618			32.618	64.632	32.014
1995			13.249	18.376	31,625	231,761	31,625			31,625	65,642	34,017
1996			13.249	17.382	30.631	218.512	30.631			30.631	66,653	36.022
1997			13.249	16.388	29,637	205.263	29,637			29,637	67,664	38.027
1998			13.249	15.395	28,644	192.014	28,644			28,644	68.674	40.030
1999			13,249	14,401	27,650	178,765	27,650			27.650	69,685	42.035
2000			13.249	13.407	26,656	165,516	26,656			26.656	70,696	44,040
2001			13.249	12.414	25,663	152.267	25,663			25,663	71,706	46,043
2002			13.249	11.420	24,669	139,018	24,669			24,669	72,717	48,048
2003			13.249	10.426	23,675	125,769	23,675			23,675	73,728	50,053
2004			13.249	9.433	22,682	112,520	22,682			22,682	74,739	52,057
2005			13.249	8.439	21,688	99,271	21,688			21,688	75,749	54,061
2006			13.249	7.445	20,694	86,022	20,694			20,694	76,760	56,066
2007			13.249	6.452	19,701	72,773	19,701			19,701	77,771	58,070
2008			13.249	5.458	18,707	59,524	18,707			18,707	78,781	60,074
2009			13.249	4,464	17,713	46,275	17,713			17,713	79,792	62,079
2010			13.249	3,471	16,720	33.026	16,720			16.720	80.803	64.083
2011			13.249	2.477	15,726	19,777	15,726			15.726	81.813	66,087
2012			12.187	1.483	13,670	7.590	13,670			13.670	82.824	69.154
2013			7,588	0.569	8,157	0,002	8,157			8,157	82,824	74,667
TOTAL	331,266		331.265	472.016	803.282	6293.555	803.282	178,949		982.230	2110.289	1128,057

Table 6.3.3 (3) In the Case of 10% Inflationary Trend
(New Detour Line)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Government Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Ex-penditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Re-newal			
1980	32,912					32,912						0.000
1981	152,936	2,541		2.468	2,468	188,389	2.468	75,327	1,251	79.046		-79.046
1982	252,344	4,192		14.129	14.129	444.925	14.129	124,288	2,065	140.482		-140.482
1983				33.369	33.369	444.925	33.369			33.369	72.308	38.939
1984				33.369	33.369	444.925	33.369			33.369	40.681	7.312
1985				33.369	33.369	444.925	33.369			33.369	44.260	10.891
1986				33.369	33.369	444.925	33.369			33.369	49.029	15.660
1987			1.328	33.369	34.697	443.597	34.697			34.697	53.798	19.101
1988			7.537	33.270	40.807	436.060	40.807			40.807	58.567	17.760
1989			17.807	32.704	50.511	418.253	50.511			50.511	59.578	9.067
1990			17.796	31.369	49.165	400.457	49.165			49.165	60.589	11.424
1991			17.796	30.034	47.830	382.661	47.830			47.830	61.599	13.769
1992			17.796	28.700	46.496	364.865	46.496			46.496	62.610	16.114
1993			17.796	27.365	45.161	347.070	45.161			45.161	63.621	18.460
1994			17.796	26.030	43.826	329.274	43.826			43.826	64.632	20.806
1995			17.796	24.695	42.491	311.478	42.491			42.491	65.642	23.151
1996			17.796	23.361	41.157	293.682	41.157			41.157	66.653	25.496
1997			17.796	22.026	39.822	275.886	39.822			39.822	67.664	27.842
1998			17.796	20.691	38.487	258.090	38.487			38.487	68.674	30.187
1999			17.796	19.357	37.153	240.294	37.153			37.153	69.685	32.532
2000			17.796	18.022	35.818	222.498	35.818			35.818	70.696	34.878
2001			17.796	16.687	34.483	204.702	34.483			34.483	71.706	37.223
2002			17.796	15.353	33.149	186.906	33.149			33.149	72.717	39.568
2003			17.796	14.018	31.814	169.110	31.814			31.814	73.728	41.914
2004			17.796	12.683	30.479	151.314	30.479			30.479	74.739	44.260
2005			17.796	11.349	29.145	133.518	29.145			29.145	75.749	46.604
2006			17.796	10.014	27.810	115.722	27.810			27.810	76.760	48.950
2007			17.796	8.679	26.475	97.926	26.475			26.475	77.771	51.296
2008			17.796	7.344	25.140	80.130	25.140			25.140	78.781	53.641
2009			17.796	6.010	23.806	62.334	23.806			23.806	79.792	55.986
2010			17.796	4.675	22.471	44.538	22.471			22.471	80.803	58.332
2011			17.796	3.340	21.136	26.742	21.136			21.136	81.813	60.677
2012			16.480	2.006	18.486	10.262	18.486			18.486	82.824	64.338
2013			10.261	0.770	11.031	0.001	11.031			11.031	82.824	71.793
TOTAL	438,192	6,733	444.924	633.993	1078.918	8453.254	1078.918	199,615	3,316	1281.849	2110.289	828.439

Table 6.3.3 (4) In the Case of 10% Inflationary Trend
(New Detour Line Excluded Whole Track Rehabilitation)

Year	Foreign Currency Portion						Expenditure				Income	Total Annual Government Expenditure
	Foreign Currency Loan		Payment of Loan Capital	Payment of Loan Interest	Total Payment in Foreign Currency	Balance of Loan Outstanding	Total Payment in Foreign Currency	Investment on Local Currency Loan		Total Ex-penditure	Operational Saved/Loss Transferred	
	Project Cost	Track Renewal						Project Cost	Track Re-newal			
1980	32,912					32,912						0.000
1981	100,806			2,468	2,468	133,718	2,468	51,931		54,399		-54,399
1982	166,330			10,029	10,029	300,048	10,029	85,685		95,714		-95,714
1983				22,504	22,504	300,048	22,504			22,504	72,308	49,804
1984				22,504	22,504	300,048	22,504			22,504	40,681	18,177
1985				22,504	22,504	300,048	22,504			22,504	44,260	21,756
1986				22,504	22,504	300,048	22,504			22,504	49,029	26,525
1987			1,328	22,504	23,832	298,720	23,832			23,832	53,798	29,966
1988			5,354	22,404	27,758	293,366	27,758			27,758	58,567	30,809
1989			12,006	22,002	34,008	281,360	34,008			34,008	59,578	25,570
1990			12,001	21,102	33,103	269,359	33,103			33,103	60,589	27,486
1991			12,001	20,202	32,203	257,358	32,203			32,203	61,599	29,396
1992			12,001	19,302	31,303	245,357	31,303			31,303	62,610	31,307
1993			12,001	18,402	30,403	233,356	30,403			30,403	63,621	33,218
1994			12,001	17,502	29,503	221,355	29,503			29,503	64,632	35,129
1995			12,001	16,602	28,603	209,354	28,603			28,603	65,642	37,039
1996			12,001	15,702	27,703	197,353	27,703			27,703	66,653	38,950
1997			12,001	14,801	26,802	185,352	26,802			26,802	67,664	40,862
1998			12,001	13,901	25,902	173,351	25,902			25,902	68,674	42,772
1999			12,001	13,001	25,002	161,350	25,002			25,002	69,685	44,683
2000			12,001	12,101	24,102	149,349	24,102			24,102	70,696	46,594
2001			12,001	11,201	23,202	137,348	23,202			23,202	71,706	48,504
2002			12,001	10,301	22,302	125,347	22,302			22,302	72,717	50,415
2003			12,001	9,401	21,402	113,346	21,402			21,402	73,728	52,326
2004			12,001	8,501	20,502	101,345	20,502			20,502	74,739	54,237
2005			12,001	7,601	19,602	89,344	19,602			19,602	75,749	56,147
2006			12,001	6,701	18,702	77,343	18,702			18,702	76,760	58,058
2007			12,001	5,801	17,802	65,342	17,802			17,802	77,771	59,969
2008			12,001	4,901	16,902	53,341	16,902			16,902	78,781	61,879
2009			12,001	4,001	16,002	41,340	16,002			16,002	79,792	63,790
2010			12,001	3,101	15,102	29,339	15,102			15,102	80,803	65,701
2011			12,001	2,200	14,201	17,338	14,201			14,201	81,813	67,612
2012			10,685	1,300	11,985	6,653	11,985			11,985	82,824	70,839
2013			6,653	0,497	7,152	0,000	7,152			7,152	82,824	75,672
TOTAL	300,048		300,047	427,545	727,593	5700,605	727,593	137,616		865,208	2110,289	1245,080

APPENDIX

APPENDIX-1 Result of Soil Mechanical Analysis

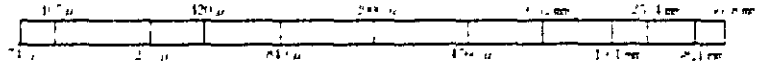
Title and Point of Study : Bolivia, Chochis - Robore
Date of Test : 7 June, 1979

A correlation table between the grain size used for plotting on a grain size accumulation curve and the weight percentage of soil particles smaller in diameter than the grain soil.

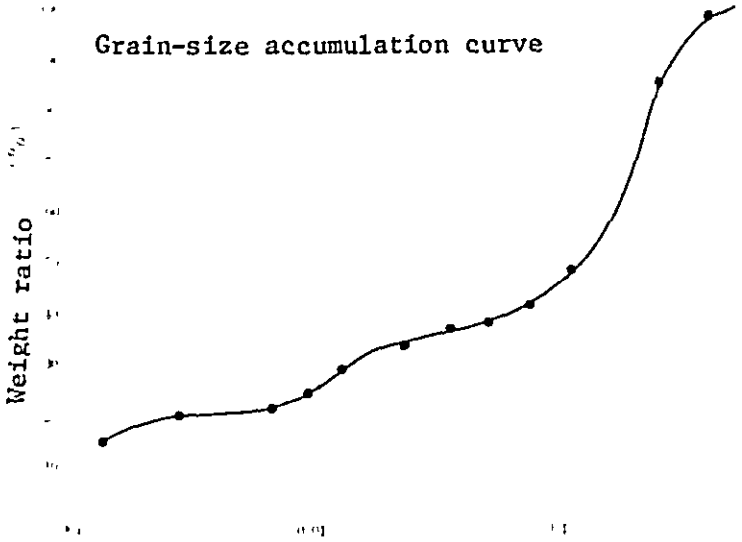
Test Number·Depth: No. B-1 (m∿ m) Hydrometer analysis:

Sieve analysis	Grain size (mm)	50.8	38.1	25.4	19.1	9.52	4.76	2.00	0.84	0.42	0.25	0.105	0.074
	Weight percentage (%)								100	99.9	87.4	48.0	40.7
Hydrometer analysis	Grain size (mm)	0.050	0.036	0.023	0.0134	0.0096	0.0068	0.0029	0.0014				
	Weight percentage (%)	37.9	36.8	33.3	28.6	24.0	21.6	19.8	14.0				

Sieve



Grain-size accumulation curve



Soil Classification SC

Liquid limit L.L.	23.95
Plastic limit P.L.	10.67
Plastic Index P.I.	13.28
Specific gravity of soil particle	2.60

Grain size (mm)

Colloid	Clay	silt	Sand	Gravel
	0.005	0.074	2.0	

Test Number Depth	No. m∿ m	Test Number Depth	No. m∿ m
Grain of more than 4.76mm in diameter (dia.)	100%	Maximum grain size	mm
Grain (4.76 ∿ 2.00mm)	100%	60% grain size	0.16mm
Grain (2.00 ∿ 0.42mm)	0.1%	30% grain size	0.014mm
Grain (0.42 ∿ 0.074mm)	59.2%	10% grain size	-
Silt particle between 0.074 ∿ 0.005mm in diameter	20.7%	Coefficient of uniformity	-
Clay of smaller than 0.005mm in diameter	20.0%	Coefficient of curveture	-
Coloid particle of smaller than 0.001mm in diameter	%	Spreadness of specimen passing through a sieve	Good
Weight percentage past through a sieve of 2,000μ	100%		
Weight percentage past through a sieve of 420μ	99.9%	Form and solidity of coarse soil grain	Squarely
Weight percentage past through a sieve of 74μ	40.7%		

APPENDIX-2 Datos Meteorologicos de Precipitacion Desde el Ano 1968 a 1979 de las Estaciones San Jose y Robore

A.A.S.A.N.A.

S A N J O S E	JAN.	FEB.	MAR.	APR.	MAY	JUN	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	ANNUAL AMOUNT
1968	162.0	253.0	70.0	53.0	5.0	10.0	0.0	16.0	20.0	95.2	125.0	259.0	1,068.2
1969	151.0	109.0	51.0	71.0	90.0	0.0	0.0	5.0	130.0	99.0	169.0	150.0	1,025.0
1970	107.0	170.3	64.0	73.0	27.0	15.0	4.0	0.0	18.0	127.0	14.0	54.0	673.3
1971	80.0	109.5	200.0	45.7	10.2	85.6	11.6	32.4	72.9	115.5	81.5	74.4	919.3
1972	124.5	177.6	52.0	34.4	19.5	14.1	17.0	96.0	34.0	50.8	14.1	165.3	799.3
1973	131.3	98.0	24.4	69.0	34.0	3.1	7.8	10.3	0.0	47.4	176.8	133.6	735.7
1974	243.7	177.0	42.5	138.7	16.4	34.5	15.1	18.3	16.3	107.8	129.7	130.9	1,070.9
1975	157.7	163.7	93.5	60.0	0.0	103.0	17.0	0.0	57.0	96.0	85.0	86.0	918.9
1976	59.0	103.0	169.0	32.0	130.0	15.0	0.0	8.0	73.0	45.0	60.0	82.0	776.0
1977	196.0	174.0	107.0	0.0	45.0	2.0	0.0	38.0	43.5	40.0	84.5	257.0	987.0
1978	82.5	88.0	60.5	85.0	18.0	50.0	0.0	0.0	43.0	51.0	118.0	55.0	651.0
1979	433.0	162.0	113.0										
MONTHLY AVERAGE	160.6	148.7	87.2	60.1	25.0	30.2	6.5	20.3	46.1	69.1	96.1	131.5	
R O B O R E													
1968	205.2	44.0	84.1	63.4	31.5	18.0	0.0	92.8	29.0	26.2	79.5	191.2	874.9
1969	184.0	228.4	43.6	63.3	104.2	18.7	13.6	40.7	41.8	86.1	219.3	126.2	1,169.9
1970	79.1	132.4	114.5	45.7	74.6	23.1	49.5	1.0	42.4	126.8	30.1	94.7	813.9
1971	116.0	111.4	91.9	60.4	137.0	34.6	11.6	16.0	121.0	128.9	44.3	82.1	955.1
1972	226.5	219.6	90.1	26.6	53.1	94.0	28.9	174.7	28.0	124.2	119.7	106.1	1,291.5
1973	98.6	105.8	67.0	5.2	6.4	90.8	11.4	11.8	0.0	121.7	234.7	156.4	1,017.2
1974	201.3	176.2	55.0	213.3	58.2	65.1	28.1	49.5	0.0	87.4	90.9	210.6	1,235.6
1975	98.4	108.7	120.6	44.1	63.0	113.8	28.3	1.9	70.7	126.2	201.2	159.7	1,136.6
1976	140.5	169.2	131.1	72.6	125.1	24.2	1.0	5.0	107.2	81.4	50.0	186.4	1,093.7
1977	183.2	41.3	186.3	131.7	55.0	61.5	12.0	57.0	109.9	73.9	67.9	167.4	1,147.1
1978	78.8	196.3	28.7	126.2	74.0	69.7	0.0	3.4	37.0	86.6	142.6	183.3	1,026.6
1979	741.1	162.0	248.7	115.3	42.3	2.9	33.0						

APPENDIX-3 Registro de Todaslas Observaciones del Tiempo de Superficie (Enero-1979)

JAN. 1979

DATE	2	3	4	5	6	7	8	9	10	11
19:00 - 8:00	3.1	0.0	0.0	0.4	31.0	28.0	0.0	0.0	0.0	7.0
8:00 - 14:00	0.0	0.0	14.0	10.0	5.0	1.7	0.0	0.0	0.0	3.0
14:00 - 19:00	2.2	17.0	0.0	1.0	3.6	2.4	0.0	0.0	0.0	0.0
TOTAL	5.3	17.0	14.0	11.4	39.6	32.1	0.0	0.0	0.0	10.0

DATE	12	13	14	15	1 6	17	18	19	20	21
19:00 - 8:00	14.0	0.0	8.0	27.0	170.0	240.0	12.0	4.6	0.0	14.0
8:00 - 14:00	0.0	0.0	7.0	2.0	—	10.0	0.0	0.0	0.0	0.0
14:00 - 19:00	0.0	0.0	7.0	15.0	—	0.0	2.0	0.0	0.0	0.0
TOTAL	14.0	0.0	22.0	44.0	170.0	250.0	14.0	4.6	0.0	14.0

DATE	22	23	24	25	26	27	28	29	30	31
19:00 - 8:00	0.0	0.0	0.0	3.6	0.0	0.0	0.0	1.0	3.0	0.0
8:00 - 14:00	26.0	0.0	0.0	0.0	0.0	0.0	0.0	9.3	0.6	0.0
14:00 - 19:00	0.9	0.0	26.0	0.0	0.0	0.0	8.0	0.0	0.0	0.0
TOTAL	26.9	0.0	26.0	3.6	0.0	0.0	8.0	10.3	3.6	0.0

APPENDIX-4 Estimation of Probable Precipitation

Estimation of probable precipitation probability calculation by use of the annual extremal value data

<Calculation method by logarithmic normal distribution>

1. Basic formula for the distribution

$$P(x) = 1 - F(x) = \frac{1}{\sqrt{2\pi}} \int_u^{\infty} e^{-\frac{u^2}{2}} du$$

$$u = a' \times \log\frac{x+b}{x_0+b} \qquad a' > 0,\ x_0 > -b,\ -b < x < \infty$$

Where, x: Probable value

u: Standard normal variable

$P(x)$: Probability of excess

$F(x)$: Probability of non-excess

x_0, a', b: Constant

2. Probable value (x) return period (T)

Table 1. Standard normal variable for various return periods (T)

T (Year)	$\frac{1}{T} = P(x)$ or $F(x)$	x
500	0.00200	2.8782
400	0.00250	2.8086
300	0.00333	2.7120
250	0.00400	2.6521
200	0.00500	2.5758
150	0.00667	2.4748
100	0.01000	2.3263
80	0.01250	2.2414
60	0.01667	2.1281
50	0.02000	2.0537
40	0.02500	1.9600
30	0.03333	1.8339
25	0.04000	1.7507
20	0.05000	1.6449
15	0.06667	1.5011
10	0.10000	1.2816
8	0.12500	1.1503
5	0.20000	0.8416
4	0.25000	0.8239
3	0.33333	0.4307
2	0.50000	0.

3. Estimation of constant by IWAI method

$$U = a' \cdot \log \frac{x + b}{x_0 + b}$$

Taking the geometrical mean as the first approximate value of x_0:

$$\log x_0 \doteqdot \log x_g, \quad \log x_g = \frac{1}{N} \sum_{i=1}^{N} \log x_i$$

The estimated value of b is obtained as follows;

(1) Arrange the values of x in sequential order of smallest to smaller.

(2) Compute the value of b_1, b_2, ... b_i, using the combinations of the largest and the smallest value, the second largest and the second smallest value ..., etc., and applying the following formula (*i is the order counting from the smallest x*).

(3) Determine the mean value of about N/10 samples of b_i and take this as $\hat{b}$.

$$\ell = N-i+1, \quad i = 1, 2, 3, \ldots, r, \quad r \doteqdot N/10$$

$$b_i = \frac{x_\ell \cdot x_i - x_g^2}{2x_g - (x_\ell + x_i)}, \quad \hat{b} = \frac{1}{r} \sum_{i=1}^{r} b_i$$

$$\log(x_0+b) = \frac{1}{N} \sum_{i=1}^{N} \log(x_i+b)$$

$$\frac{1}{a'} = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} \{\log(x_i+b) - \log(x_0+b)\}^2}$$

The T-year probable value x_T or the return period (T) is obtained by the use of the following formulae:

$$\frac{1}{T} = P(u) = 1 - F(u) \quad \ldots\ldots\ldots\ldots \text{(a)}$$

$$\log(x_T+b) = \log(X_0+b) + \frac{u}{a'}, \quad \ldots\ldots \text{(b)}$$

Either compute the value (u) corresponding to (a) and substitute it into formula (b) for formula (a) the value (x_T), or when the value (x_T) is given, substitute this into formula (b) for the value and then substitute the resulting value of (u) into formula (a) for the value of (T).

4. Calculation for probable volume of precipitation (Appendix-3)

(1) To calculate probable volume of precipitation in the area of Robore, analysis will be made on the basis of the data from the 12-year record of the '68 ∿ '79 period. After a site survey conducted by the Team to confirm the recorded 240mm per day in precipitation, it has been concluded that there was a heavy rainfall of 200mm per day at least. Therefore, the maximum record of rainfall to be used for analysis adopts the largest figure of 210mm including 10mm precipitation from 08:00 till 14:00 hours.

(2) Since the maximum record of precipitation on January 17th, 1979 shows a nearly abnormal figure when compared with the other record of actual measurement, calculation will be made for analysis from the 12-year data for the '68 ∿ '79 period (A) including the maximum record of precipitation and separately from the 11-year data for the '68 ∿ '78 period (B) excluding the maximum record of precipitation. Thus, the intermediate value (C) to be obtained from the calculated results as above will be used as the probable precipitation to be incorporated into the rehabilitation plan.

Fig. 1 Probable Precipitation

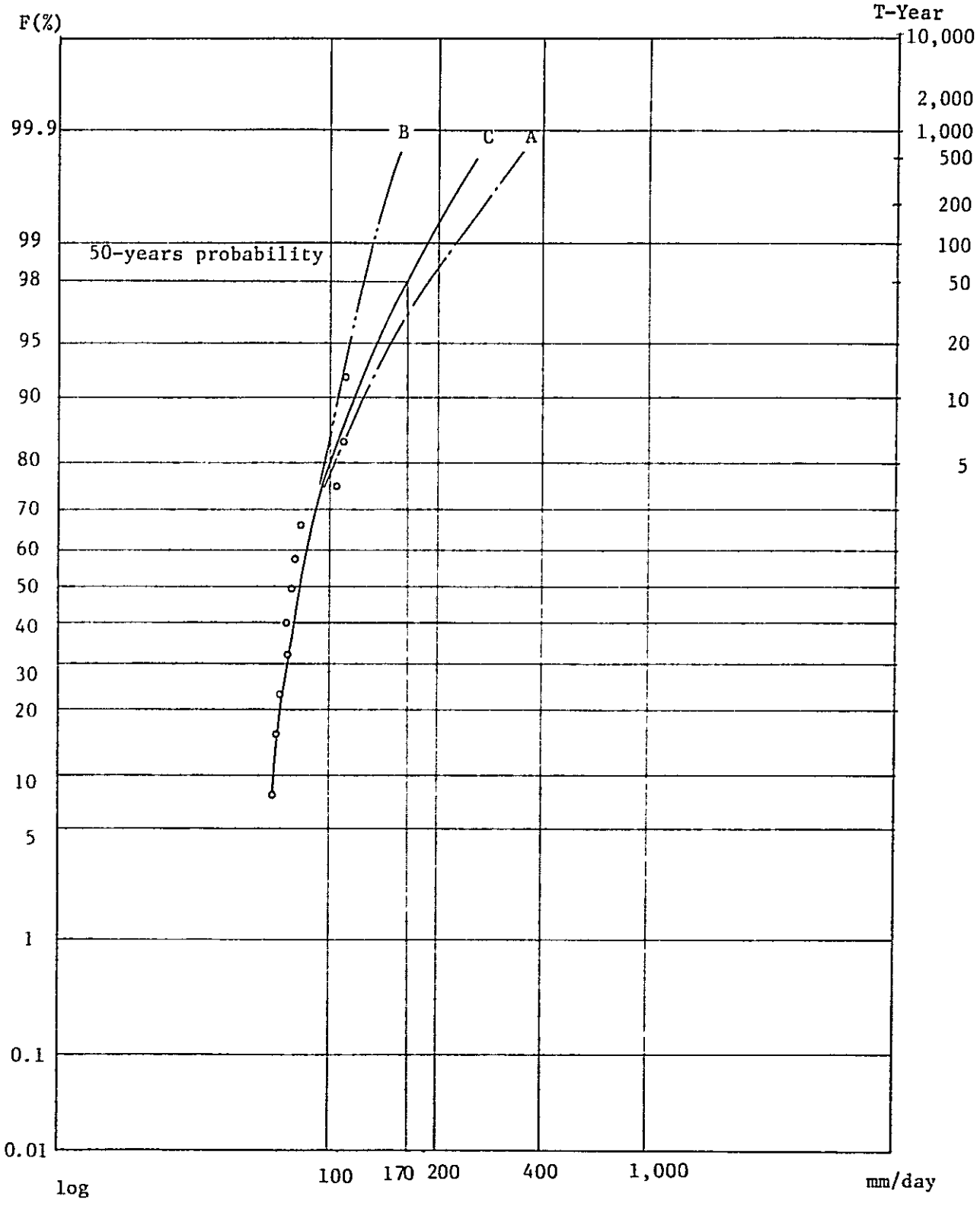


Table 1(a) Estimation from 12-year recording data for '68 ∿ '79 Period (Assuming the Max. Daily Precipitation to be 210 mm for 1979)

i	x_i	log x_i	$x_i + b$	$\log(x_i+b)$	$\{\log(x_i+b)-\log(x_0+b)\}^2$
1	210	2.322	150.2	2.177	0.789
2	110	2.041	49.2	1.692	0.162
3	109	2.037	48.2	1.683	0.155
4	106	2.025	45.2	1.655	0.134
5	86	1.934	25.2	1.401	0.013
6	76	1.881	15.2	1.182	0.011
7	75	1.875	14.2	1.152	0.019
8	74	1.869	13.2	1.121	0.028
9	70	1.845	9.2	0.964	0.106
10	70	1.845	9.2	0.964	0.106
11	68	1.833	7.2	0.857	0.187
12	65	1.813	4.2	0.623	0.444
N=12	Σ = 23.32		Σ = 15.471		Σ = 2.153
	$\log x_g = \frac{\Sigma}{N}$ = 1.943		$\log(x_0+b) = \frac{\Sigma}{N}$ = 1.289		$\frac{1}{a} = \sqrt{\frac{\Sigma}{N-1}}$ = 0.442
	x_g = 87.8		x_0+b = 19.46		
	b = -59.8		x_0 = 79.3		

Table 1(b) Estimation from 11-year recording data for '68 ∿ '78 period

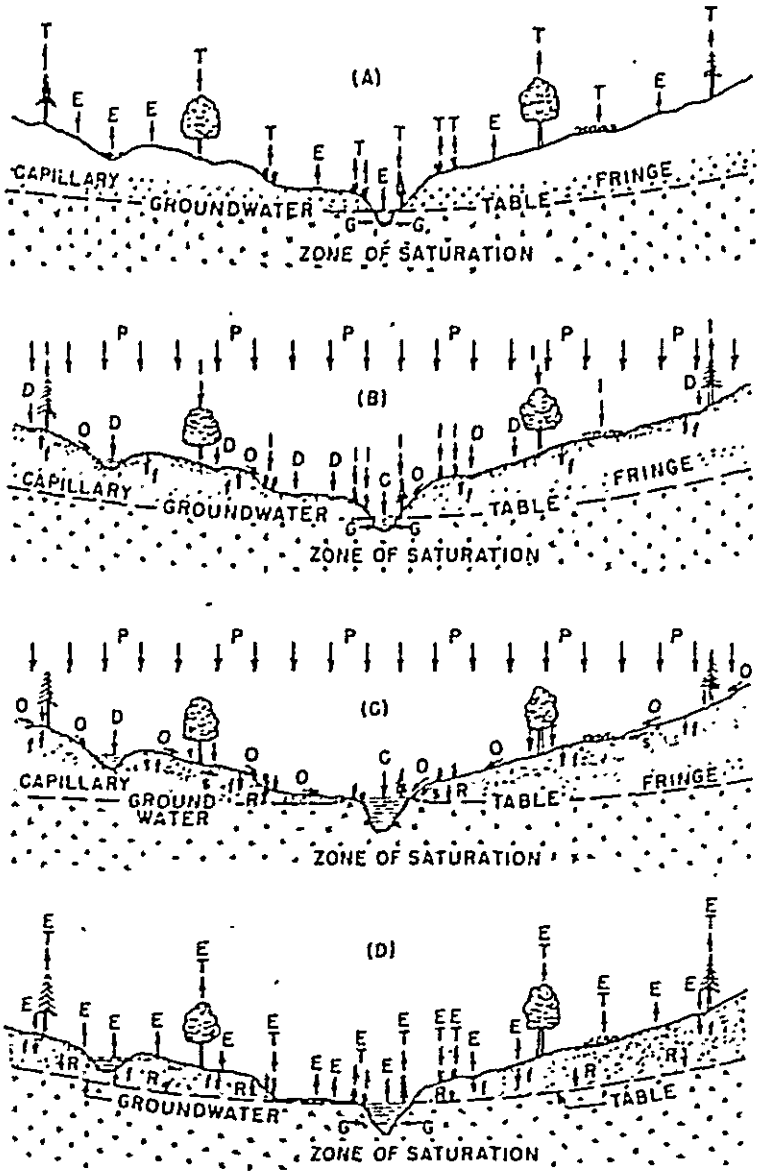
i	x_i	log x_i	$x_i + b$	$\log(x_i+b)$	$\{\log(x_i+b)-\log(x_0+b)\}^2$
1	110	2.041	65.3	1.815	0.075
2	109	2.037	64.3	1.808	0.071
3	106	2.025	61.3	1.787	0.061
4	86	1.934	41.3	1.616	0.006
5	76	1.881	31.3	1.500	0.002
6	75	1.875	30.3	1.481	0.004
7	74	1.869	29.3	1.467	0.005
8	70	1.845	25.3	1.403	0.019
9	70	1.845	25.3	1.403	0.019
10	68	1.833	23.3	1.367	0.030
11	65	1.813	20.3	1.307	0.055
N=11	Σ = 20.998		Σ = 16.954		Σ = 0.346
	$\log x_g = \frac{\Sigma}{N}$ = 1.909		$\log(x_0+b) = \frac{\Sigma}{N}$ = 1.541		$\frac{1}{a} = \sqrt{\frac{\Sigma}{N-1}}$ = 0.186
	x_g = 81.8		x_0+b = 34.8		
	b = -44.7		x_0 = 79.5		

Table (c) Design Rainfall Volumes for Various Return Period

Return period	u	(a) Estimated from '68 ∿ '79 data	(b) Estimated from '68 ∿ '78 data	Mean value $\frac{(a)+(b)}{2}$
		mm/day	mm/day	
500	2.878	423.9	164.1	294.0
300	2.712	367.3	155.9	261.6
250	2.652	349.1	153.1	251.1
200	2.576	327.6	149.6	238.6
100	2.326	267.4	138.7	203.2
50	2.054	217.2	128.6	172.9
25	1.751	175.4	118.4	146.9
10	1.282	131.5	105.0	118.3
5	0.842	105.6	94.6	100.1
3	0.431	90.0	86.6	88.3
2	0	79.3	79.5	79.4

APPENDIX-5 Run-off Coefficient

The run-off coefficient is may be expressed, as shown in Fig. 1, the ratio of the volume of concentration into the water course against that of precipitation (see Fig. 1). Behavior of precipitated rain water varies depending upon duration of rainfall. The longer the rainfall continues, the larger the run-off coefficient becomes. (See Fig. 2.)



Idealized cross sections representing specified limes throughout the runoff cycle (where T designates transpiration, E evaporation, G groundwater flow, P precipitation, I interception, D depression storage, O overland flow, f infiltration, C channel precipitation, S subsurface or interflow, and R groundwater recharge).

Fig. 1 Run-off Coefficient

It varies also depending upon soil conditions, and tends to be higher where the groundwater level is higher. (See Fig. 3.)

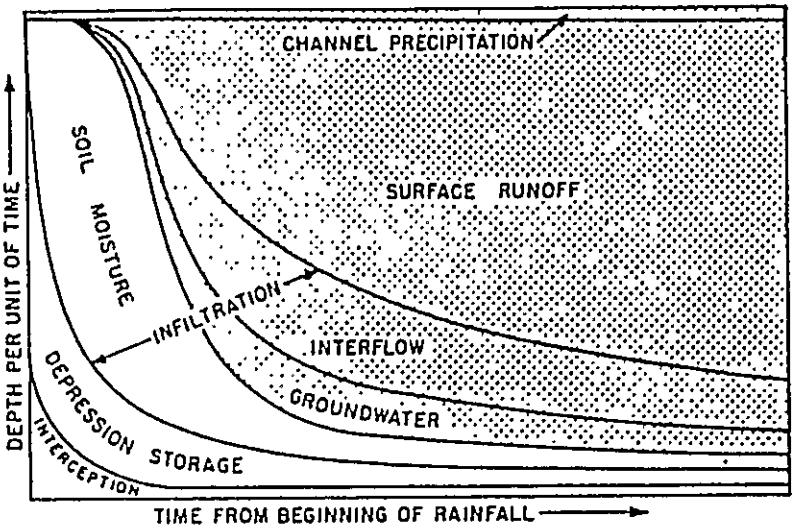


Fig. 2 Schematic Diagram of the Disposition of Storm Rainfall

Generally, when a large catchment area, beyond a certain size, is involved, the run-off coefficient approaches a constant when the rainfall is so heavy as to result in flooding. For such a mountainous area as the cost of the project site, the coefficient f_2 is normally 0.6 - 0.8.

Fig. 4 shows the monitored rainfall data for the White River in West Hartford, Vermont State. The run-off coefficient is seen to be constant at f = 0.6 for storm rainfall above 75mm (3 inches).

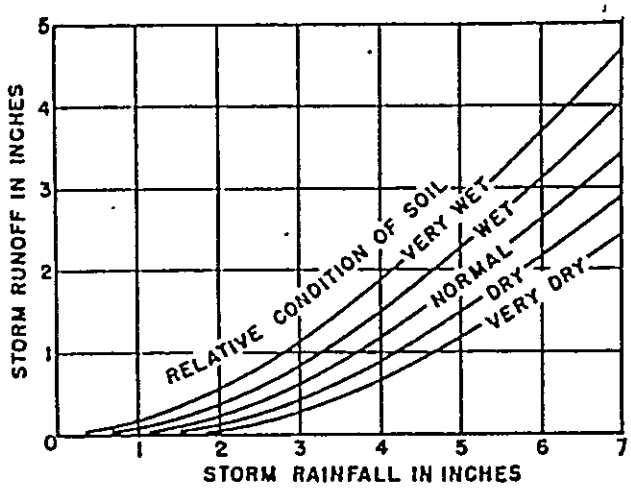


Fig. 3 Typical Rainfall-runoff Relation, Using Estimated Soil Condition as a Parameter

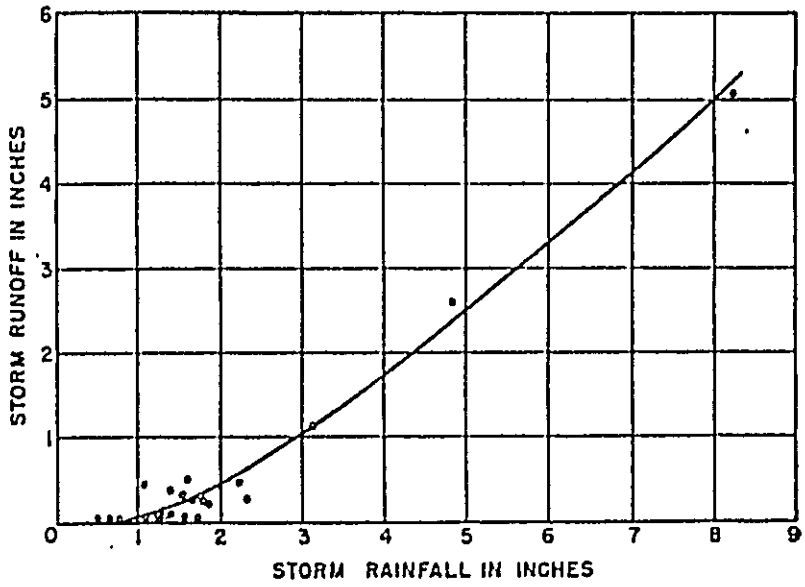


Fig. 4 Rainfall-runoff Relation for the White River at West Hartford, Vermont

The run-off coefficient figures used by the JNR are as shown in the following table.

Terrain/river	f	Terrain/river	f
Steep mountains	0.75 ∿ 0.90	Mountain river	0.75 ∿ 0.85
Tertiary hills	0.70 ∿ 0.80	Small river in plain	0.45 ∿ 0.75
Undulated land•woods	0.50 ∿ 0.75	River of which over half of its basin is constituted by area of flat terrain	0.50 ∿ 0.75
Flat farm land	0.45 ∿ 0.60		

APPENDIX-6 Calculation for Planned High Water Discharge

1. Catchment area in the existing line rehabilitation plan (Alternative-A)

   (1) Adequate flood control should be provided for the basin of relatively small catchment area in the steep mountains and of which estimated time of flood concentration is within half an hour. The run-off coefficient for such catchment area is assumed at 0.8.

   The average rainfall intensity can be obtained by using the MONONOBE Formula, assuming the time of concentration to be T = 0.5h, as follows.

$$r = \frac{R_{24}}{24}\left(\frac{24}{T}\right)^{2/3} = \frac{170}{24}\left(\frac{24}{0.5}\right)^{2/3} = 95.2 \text{ mm/hour}$$

   Therefore, the rational formula is to give the value of specific discharge.

$$Q = \frac{1}{3.6} \cdot f \cdot r \cdot A = \frac{1}{3.6} \times 0.8 \times 95.2 \times A = 21.2A \ (m^3/sec.)$$

   (2) For relatively large catchment areas where estimated time of concentration exceeds half an hour, the design flood discharge can be obtained through the following process.

      1) Obtain the speed of concentration by using the Bayern District Formula.

      2) Obtain the time of flow based on the above result.

      3) Compute the average rainfall intensity within the time of concentration by using the MONONOBE Formula.

      4) Determine the design flood discharge from ratinal formula. The applicable run-off coefficient is f = 0.6 for No. 35 and No. 36 with large catchment area and f = 0.8 for the rest.

For example, calculation of the design flood discharge at the proposed sites of No. 42 thru. 45 are made as in followings.

a) Taking the basin No. 35 as the representing point of the project site between No. 42 thru. 45;

Catchment area	$A = 321.8km^2$
Run-off coefficient	$f = 0.6$
Horizontal distance from utmost upstream point	$L = 31.5km$
Head	$H = 0.59km$

The speed of concentration according to Bayern District Formula is as follows;

$$W = 72(H/L)^{0.6} = 72(^{0.59}/_{31.5})^{0.6} = 6.6 \text{ km/hour}$$

The time of concentration (T) is,

$$T = L/W = {}^{31.5}/_{6.6} = 4.8\text{hour}$$

The average rainfall intensity r during the above time of concentration is calculated as follows by applying the MONONOBE Formula as:

$$r = \frac{R_{24}}{24}\left(\frac{24}{T}\right)^{2/3} = \frac{170}{24}\left(\frac{24}{4.8}\right)^{2/3} = 21.1 \text{ mm/hour}$$

The design flood discharge Q is obtained as follows:

$$Q = \frac{1}{3.6} \cdot f \cdot r \cdot A = \frac{1}{3.6} \times 0.6 \times 21.1 \times 321.8 = 1132 \text{ m}^3/\text{sec}.$$

b) The catchment area for design project site No. 46 is the sum of Basins No. 35 and 36.

Catchment area	$A = 527km^2$
Run-off coefficient	$f = 0.6$
Horizontal distance from utmost upstream point	$L = 38km$
Head	$H = 0.62km$

2. Catchment area in detour type alternative (Alternative-B)

As an example of how the design highwater discharge for the detour type alternative in determined, calculation for the case of Basin No. 10 is made as follows:

Catchment area	$A = 29.35 km^2$
Run-off coefficient	$f = 0.6$
Horizontal distance from utmost upstream point	$L = 10.4 km$
Head	$H = 0.21 km$

The speed of concentration according to Bayern District Formula is;

$$W = 72(H/L)^{0.6} = 72(^{0.21}/_{10.4})^{0.6} = 6.925 \text{ km/hour}$$

Time of flow (T_1) is;

$$T_1 = L/W = {}^{10.4}/_{6.925} = 1.502 \text{hour}$$

Assuming the time of inlet (T_2) to be 50% of the time of flow (T_1), its volume is;

$$T_2 = 0.5 \times 1.502 = 0.751 \text{hour}$$

The time of flood concentration (T) is therefore,

$$T = T_1 + T_2 = 1.502 + 0.751 = 2.253 \text{hour}$$

The average rainfall intensity (r) during the above time of concentration is obtained by applying the MONONOBE Formula as follows;

$$r = \frac{R_{24}}{24} \left(\frac{24}{T}\right)^{2/3} = \frac{170}{24} \left(\frac{24}{2.253}\right)^{2/3} = 34.9 \text{ mm/hour}$$

The design flood discharge Q is obtained as follows;

$$Q = \frac{1}{3.6} \times f \times r \times A = \frac{1}{3.6} \times 0.6 \times 34.9 \times 29.35 = 170.7 \text{ m}^3/\text{sec.}$$

Velocity of flow according to the Bayern District Formula is as follows;

$$W = 72(H/L)^{0.6} = 72(^{0.62}/_{38})^{0.6} = 6.1 \text{ km/hour}$$

Time of flood concentration (T) is;

$$T = L/W = {}^{38}/_{6.1} = 6.2\text{hour}$$

The average rainfall intensity (r) is calculated as follows by applying MONONOBE Formula:

$$r = \frac{R_{24}}{24}\left(\frac{24}{T}\right)^{2/3} = \frac{170}{24}\left(\frac{24}{6.2}\right)^{2/3} = 17.8 \text{ mm/hour}$$

The design flood discharges is obtained as;

$$Q = \frac{1}{3.6} \cdot f \cdot r \cdot A = \frac{1}{3.6} \times 0.6 \times 17.8 \times 527 = 1564 \text{ m}^3/\text{sec.}$$

APPENDIX-7 Ensayo de Sgaste "Los Angeles" para Balasto de Via (Piococa)

Santa Cruz, 20 de Abril de 1.976

INFORME

DE : Tec. Jorge Aspiazu A.,
JEFE LAB. DE SUELOS CORP. REGIONAL DE DESARROLLO

A : Ing. Luis Bravo
GERENTE RED ORIENTAL ENFE

REF : Ensayo desgaste "Los Angeles" para Balasto de vía.

==========

Señor Gerente:

Ejecutados los ensayos para determinar el porcentaje de - desgaste mediante el ensayo de Los Angeles, en las muestras de balasto de vía procedentes de la cantera de Piococa, se obtuvo 72.5% de resistencia a la abración y 27.5% de desgaste.

Aclaramos que para ejecutar el ensayo en concordancia a - normas establecidas, se redujo el tamaño de las partículas hasta pasarlo por tamiz de 1½" de acuerdo a la granulometría."A".

Es todo cuanto informo para los fines consiguientes.

Sin otro particular saludo a Ud. muy atentamente.

Tec. Jorge Aspiazu A.,
JEFE LABO DE SUELOS CORP.
REGIONAL DE DESARROLLO

Laboratorio de Suelos
y Hormigones

APPENDIX-8 Imforme Ensayo "Los Angeles" para Balasto (Yacuce)

COMITE DEPARTAMENTAL DE OBRAS PUBLICAS
SANTA CRUZ DE LA SIERRA
BOLIVIA

Santa Cruz, 24 de Agosto de 1.978

INFORME

DE : Tec. Jorge Aspiazu A.
JEFE LAB. DE SUELOS CORP. REGIONAL DE DESARROLLO.

A : Ing. Luis Bravo
GERENTE RED ORIENTAL ENFE

REF : Informe ensayo "Los Angeles" para balasto.

Señor Gerente:

Ejecutados los ensayos para determinar el porcentaje de desgaste mediante el ensayo de Los Angeles, en las muestras de balasto de vía procedentes de la cantera de Yacuse, se obtuvo 65% de resistencia a la abresión y 35% de desgaste.

El ensayo fué realizado con la gradación "A", conforme a mormas establecidas.

Es cuanto informo para los fines consiguientes

Sin otro particular, saludo a Ud. muy atentamente.

Téc. Jorge Aspiazu A.
JEFE LAB. SUELOS CORP.
REGIONAL DE DESARROLLO.

APPENDIX-9 The Methodology for the Evaluation of Non-Transport Freight (in 1983)

1. In case of 25-days suspension from 1 October to 25 October

	Freight ratio	Prior consign-ment	By air	Ware-house	Open stock-pile	* Shut-down	Lost value	Total
	(%)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)
Export	14.8	86	86	1,085	1,430	86	86	2,859
Import	73.1	494	494	12,001	1,130	0	0	14,119
Do-mestic	12.1× 0.80	9	9	1,814	0	38	0	1,870
Total	-	589	589	14,900	2,560	124	86	18,848

(Note) * Cement is not included.

(1) Warehouse
4 $b × 14,900 ton × 25 days × 1/2 = 745,000 $b

(2) Interest for warehouse
(1,085 ton × 20,705 $b + 12,001 ton × 39,722 $b + 1,814 ton × 36,243 $b) × 0.12 × 25/365 days × 1/2 = 2,324,022 $b

(3) Interest for open stockpile
(1,430 ton × 20,705 $b + 1,130 ton × 39,772 $b) × 0.12 × 25/365 days × 1/2 = 306,372 $b

(4) Shutdown
86 ton × 20,705 $b + 38 ton × 36,243 $b = 3,157,864 $b

(5) Lost value
86 ton × 20,705 $b = 1,780,630 $b

(6) Number of days to be spent for clearing all to Freight

In bound 12,001 ton + 1,179 ton + 1,130 ton = 14,310 ton 14,310/750 ≒ 20 days

Out bound 1,085 ton + 635 ton + 1,430 = 3,150 ton 3,150/750 ≒ 6 days

(7) Warehouse for clearing all the Freight

In bound 4 $b × (12,001 ton + 1,179 ton) × 20 days × 1/2 = 527,200 $b

Out bound 4 $b × (1,085 ton + 635 ton) × 6 days × 1/2 = 20,640 $b

(8) Interest for clearing all the Freight

In bound {(12,001 ton + 1,130 ton) × 39,772 $b
+ 1,179 ton × 36,243 $b} × 0.12
× 20/365 days × 1/2 = 1,857,455 $b

Out bound {(1,085 ton + 1,430 ton) × 20,705 $b
+ 635 ton × 36,243 ton} × 0.12
× 6/365 × 1/2 = 74,059 $b

(9) Prior consignment

Warehouse 4 $b × 589 ton × 25 days = 58,900 $b

Interest (86 ton × 20,705 $b + 484 ton
× 39,772 $b + 9 ton × 36,243 $b)
× 0.12 × 25/365 days = 178,802 $b

(10) Cement

8,219 ton × 1,530 $b = 12,575,070 $b

2. In case of 45-days suspension from 15 December to 30 January

	Freight ratio	Prior consign-ment	By air	Ware-house	Open stock-pile	* Shut-down	Lost value	Total
	(%)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)
Export	14.8	154	154	1,957	2,573	154	154	5,146
Import	73.1	890	890	21,603	2,032	0	0	25,415
Do-mestic	12.1× 0.80	17	17	3,264	0	67	0	3,365
Total	-	1,061	1,061	26,824	4,605	221	154	33,926

(Note) * Cement is not included.

(1) Warehouse

4 $b × 26,824 ton × 45 days × 1/2 = 2,414,160 $b

(2) Interest for warehouse

(1,957 ton × 20,705 $b + 21,603 ton
× 39,772 $b + 3,264 ton × 36,243 $b)
× 0.12 × 45/365 days × 1/2 = 7,530,485 $b

(3) Interest for open stockpile

(2,573 ton × 20,705 $b + 2,032 ton
× 39,772 $b) × 0.12 × 45/365 days
× 1/2 = 991,899 $b

(4) Shutdown

154 ton × 20,705 $b + 67 ton × 36,243 $b = 5,616,851 $b

(5) Lost value
154 ton × 20,705 $b = 3,188,570 $b

(6) Number of days to be spent for clearing all the Freight

In bound 21,603 ton + 2,122 ton + 2,032 ton = 25,757 ton 25,757/750 ≒ 35 days

Out bound 1,957 ton + 1,142 ton + 2,573 ton = 5,672 5,672/750 ≒ 10 days

(7) Warehouse for clearing all the Freight

In bound 4 $b × (21,603 ton + 2,122 ton) × 35 days × 1/2 = 1,660,750 $b

Out bound 4 $b × (1,957 ton + 1,142 ton) × 10 days × 1/2 = 61,980 $b

(8) Interest for clearing all the Freight

In bound {(21,603 ton + 2,032 ton) × 39,772 $b + 2,122 ton × 36,243 $b} × 0.12 × 35/365 days × 1/2 = 5,850,715 $b

Out bound {(1,957 ton + 2,573 ton) × 20,705 $b + 1,142 ton × 36,243} × 0.12 × 10/365 days × 1/2 = 222,219 $b

(9) Prior consignment

Warehouse 4 $b × 1,061 ton × 45 days = 190,980 $b

Interest (154 ton × 20,705 $b + 890 ton × 39,772 $b + 17 ton × 36,243 $b) × 0.12 × 45/365 days = 579,972 $b

(10) Cement
14,795 ton × 1,530 $b = 22,636,350 $b

3. In case of 15-days suspension from 15 March to 31 March

	Freight ration	Prior consign-ment	By air	Ware-house	Open stock-pile	* Shut-down	Lost value	Total
	(%)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)	(ton)
Export	14.8	51	51	652	859	51	51	1,715
Import	73.1	296	296	7,200	679	0	0	8,471
Do-mestic	12.1× 0.80	6	6	1,088	0	22	0	1,122
Total	-	353	353	8,940	1,538	73	51	11,308

(Note) * Cement is not included.

(1) Alternative mode

In bound	7,200 ton + 707 ton + 679 ton	= 8,586 ton
Out bound	652 ton + 381 ton + 859 ton	= 1,892 ton

(2) Transport cost for alternative mode
(2.58 $b × 1.20 - 0.9 $b)
× (8,586 ton + 1,892 ton) × 100 km = 2,300,969 $b

(3) Shutdown
51 ton × 20,705 $b + 22 ton × 36,243 $b = 1,853,301 $b

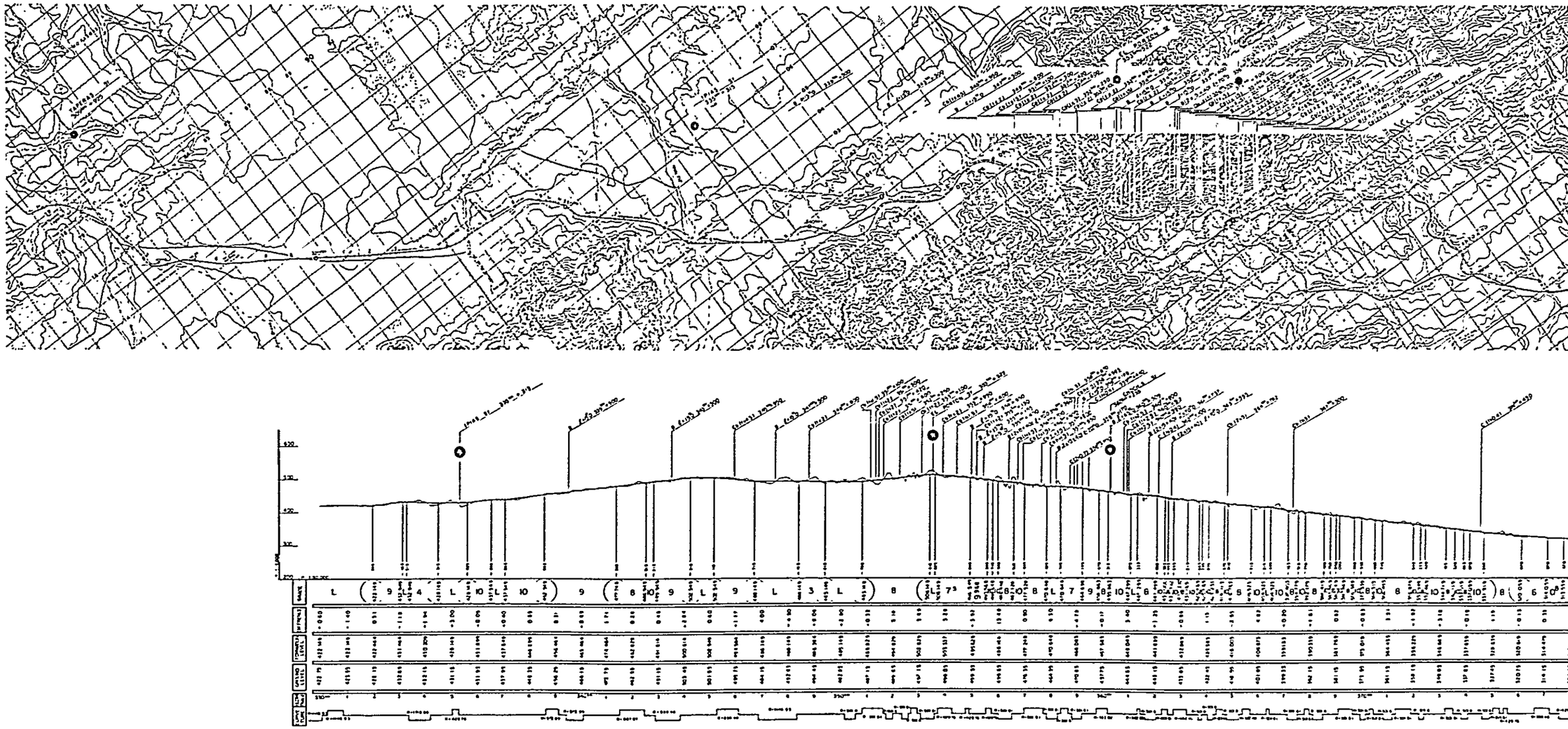
(4) Cement
4,932 ton × 1,530 $b = 7,545,960 $b

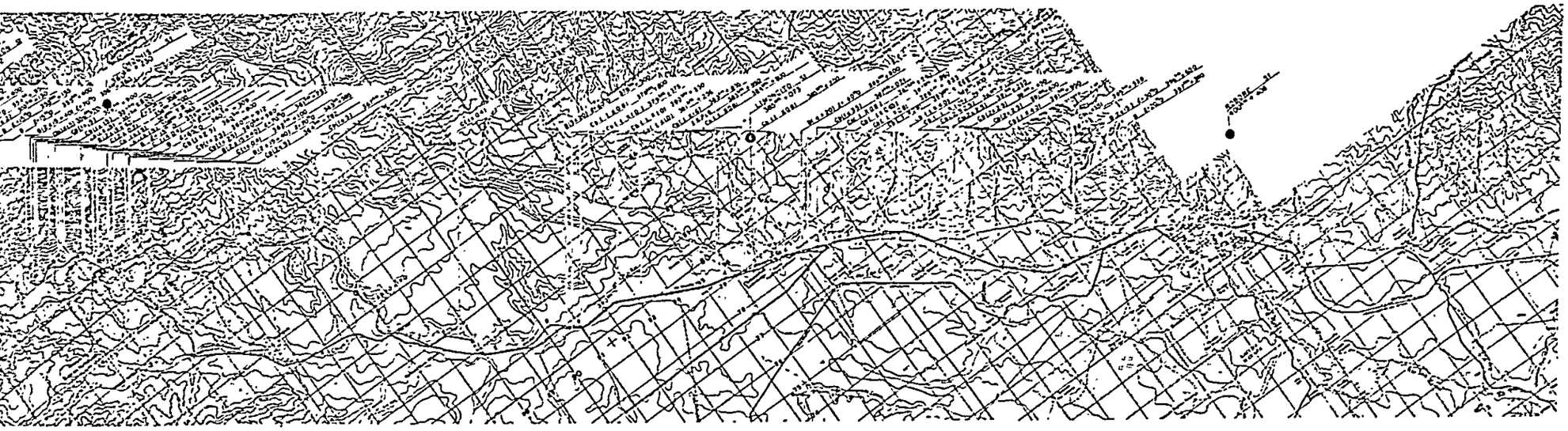
(5) Prior consignment

Warehouse	4 $b × 353 ton × 15 days	= 21,180 $b
Interest	(51 ton × 20,705 $b + 296 ton × 39,772 $b + 6 ton × 36,243 $b) × 0.12 × 15/365 days	= 64,336 $b

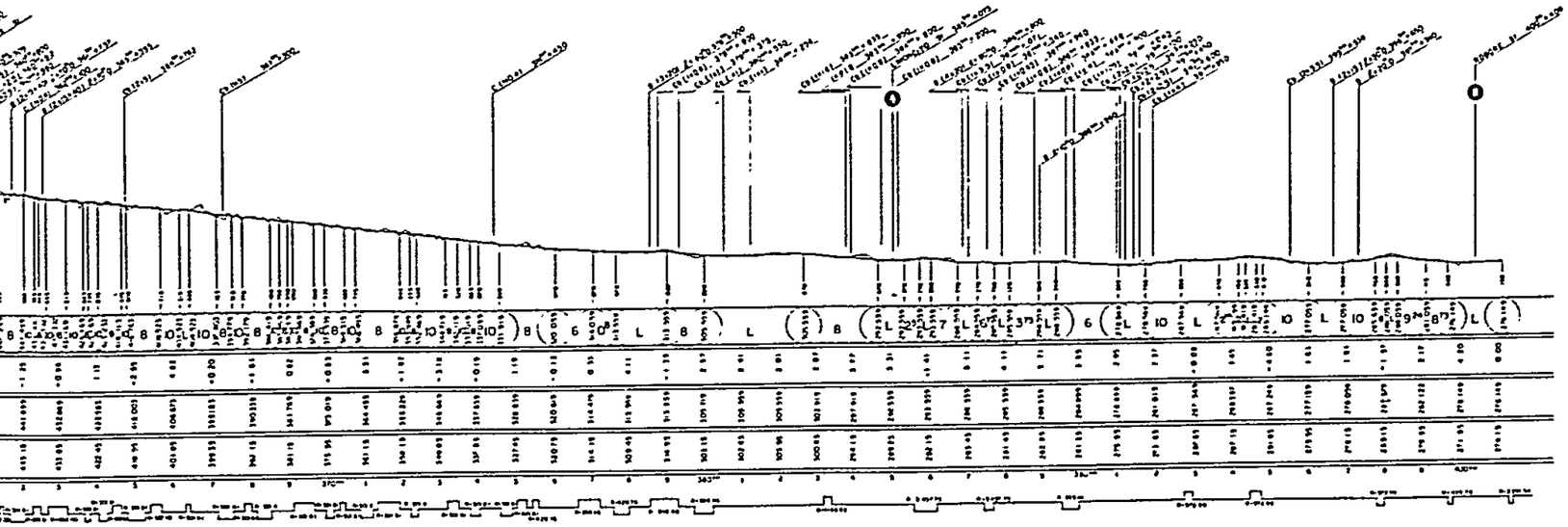
DRAWINGS

Drawing-1	Alternative-A Railway Plan
Drawing-2	Alternative-A Railway Longitudinal Profile
Drawing-3	Alternative-B Railway Plan
Drawing-4	Alternative-B Railway Longitudinal Profile
Drawing-5	Alternative-C Railway Plan
Drawing-6	Alternative-C Railway Longitudinal Profile
Drawing-7	Alternative-D Railway Plan
Drawing-8	Alternative-D Railway Longitduinal Profile
Drawing-9	Alternative-E Railway Plan
Drawing-10	Alternative-E Railway Longitidunal Profile
Drawing-11	Typical Design of Corrugated Steel Pipe
Drawing-12	Typical Design of Open Culvert
Drawing-13	Typical Design of Double Open Culvert
Drawing-14	Typical Design of Box Culvert
Drawing-15	Typical Design of Deck Steel Girder Bridge
Drawing-16	Typical Design of Through Steel Truss Bridge

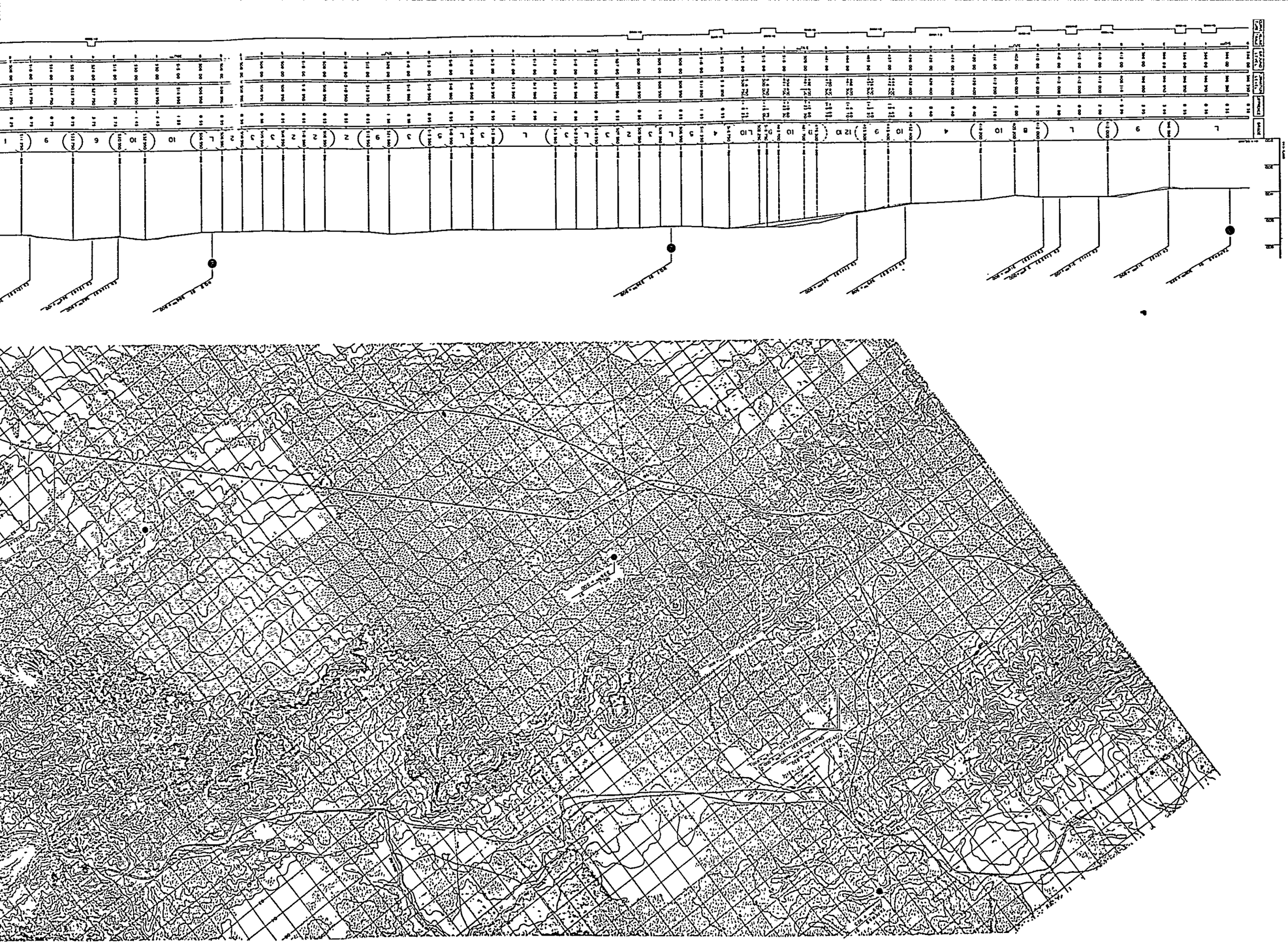




Drawing-1 Alternative-A
Railway Plan

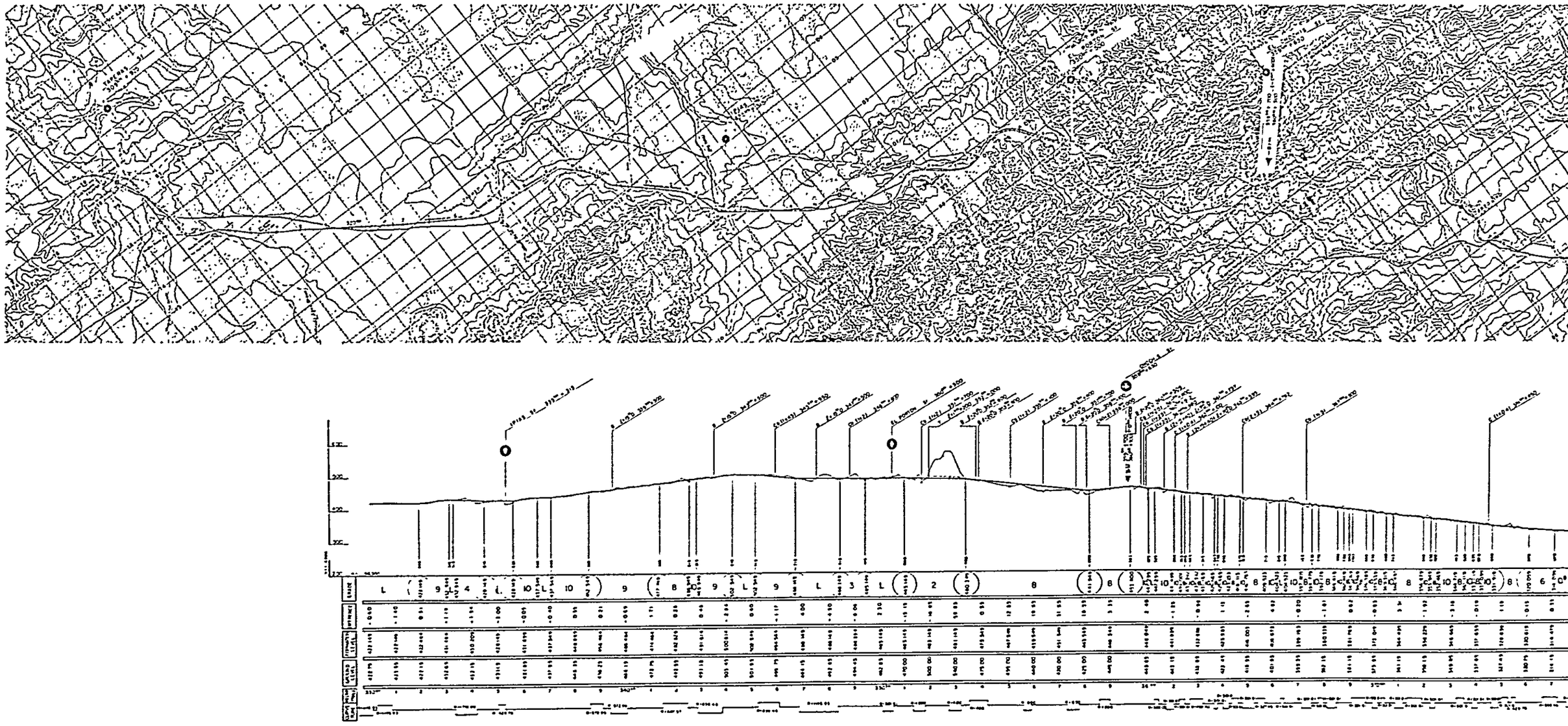


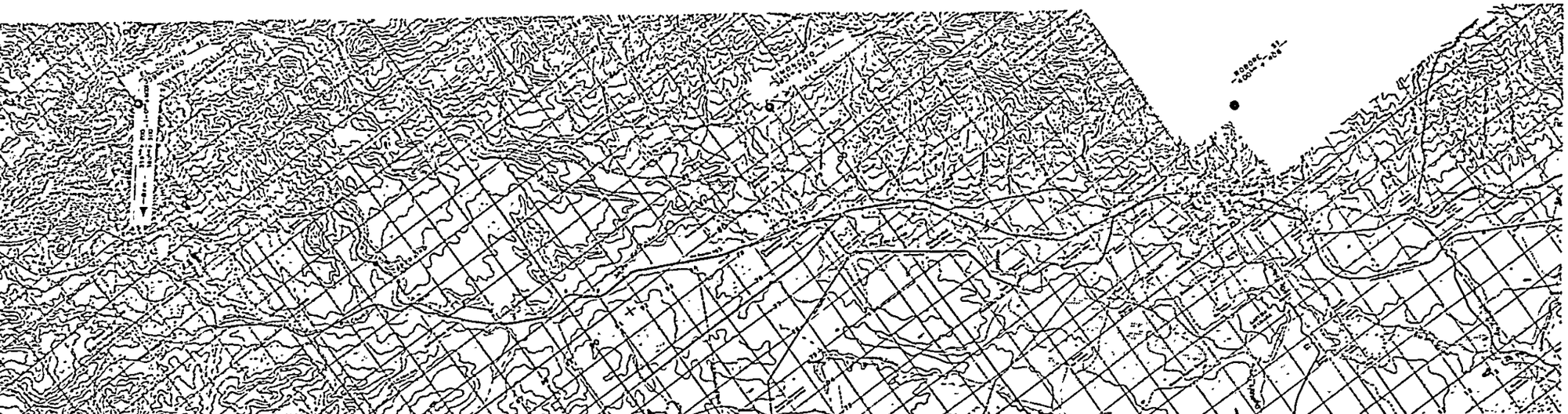
Drawing-2 Alternative-A
Longitudinal Profile



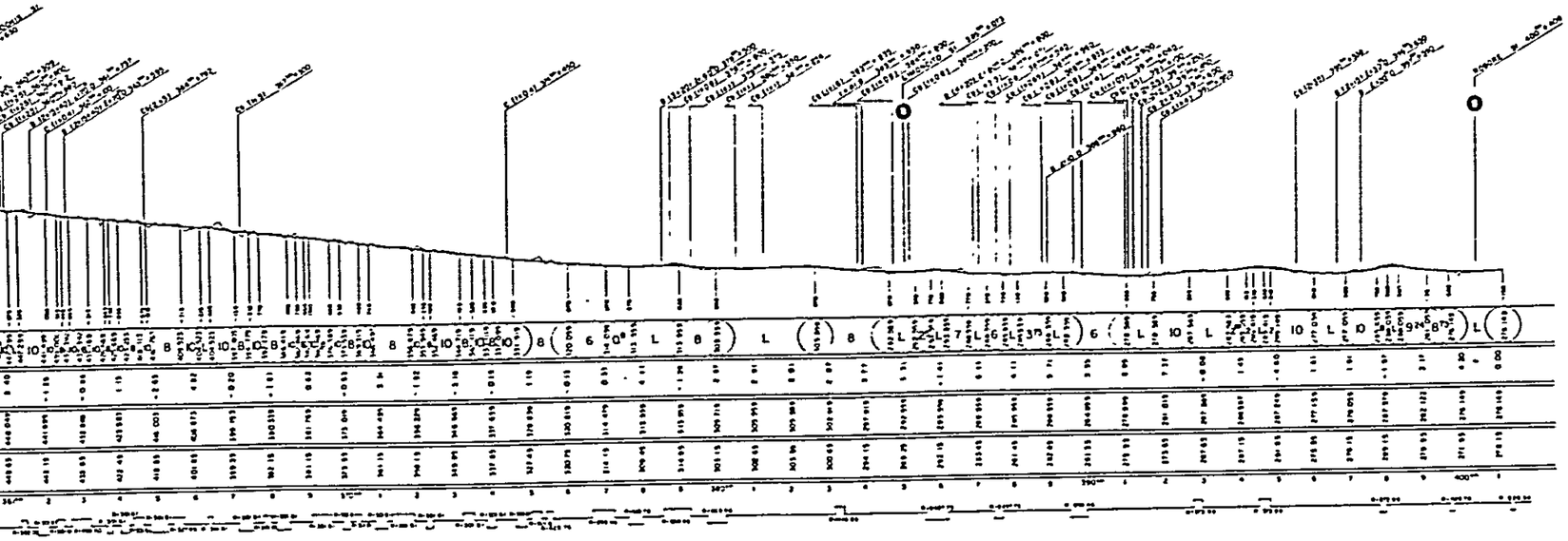
Drawing-3 Alternative-B
Railway Plan

Drawing-4 Alternative-B
Longitudinal Profile
D-3~4

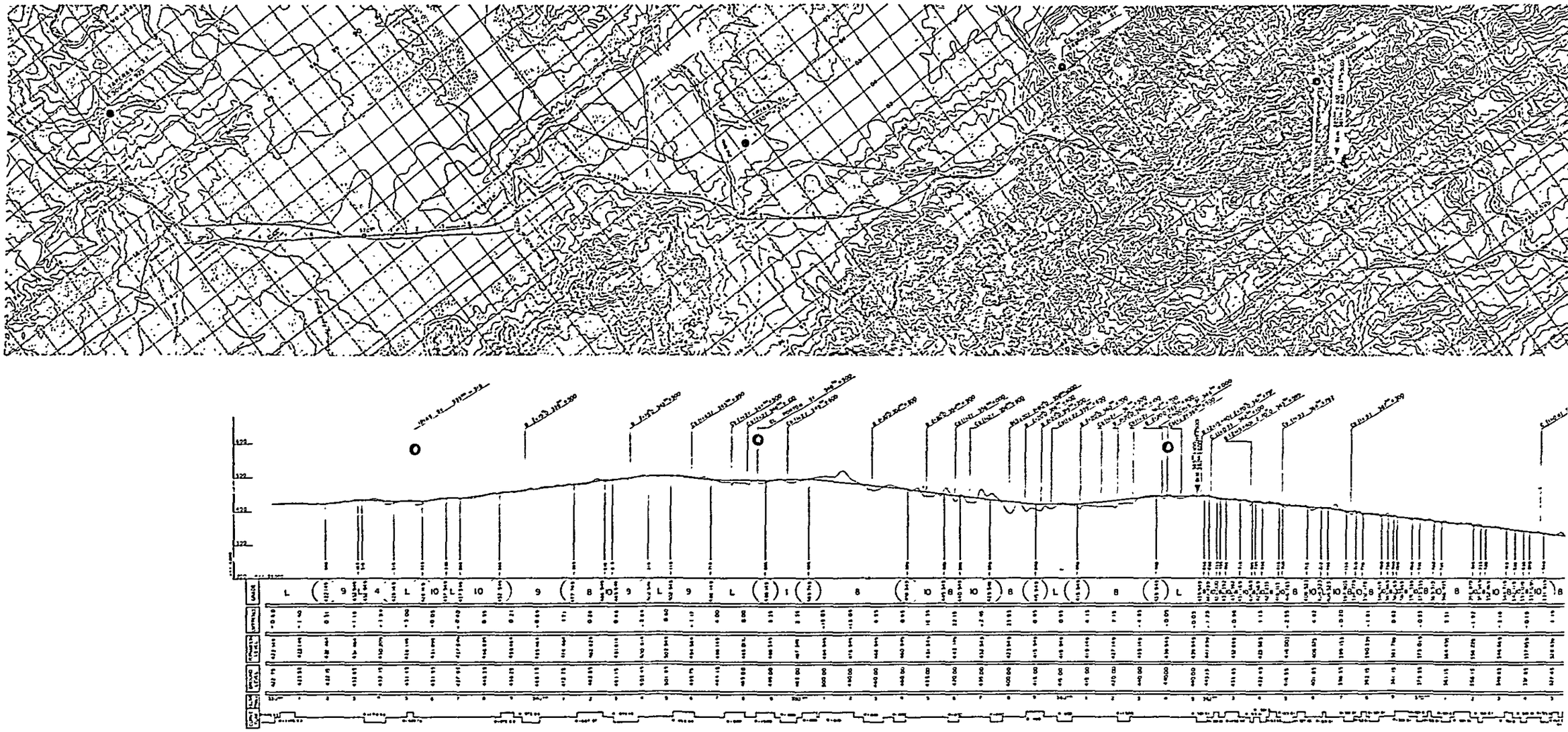


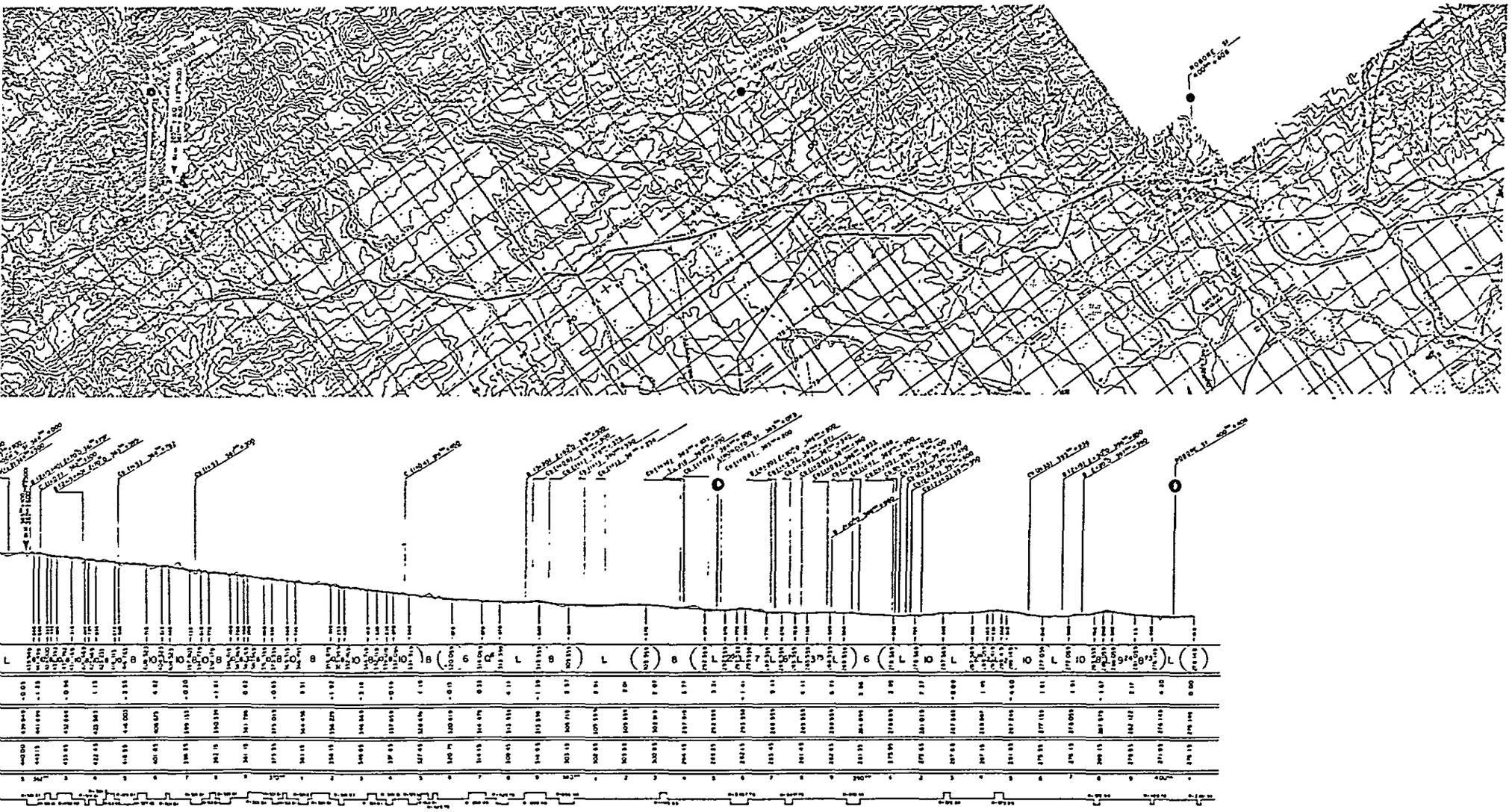


Drawing-5 Alternative-C
Railway Plan



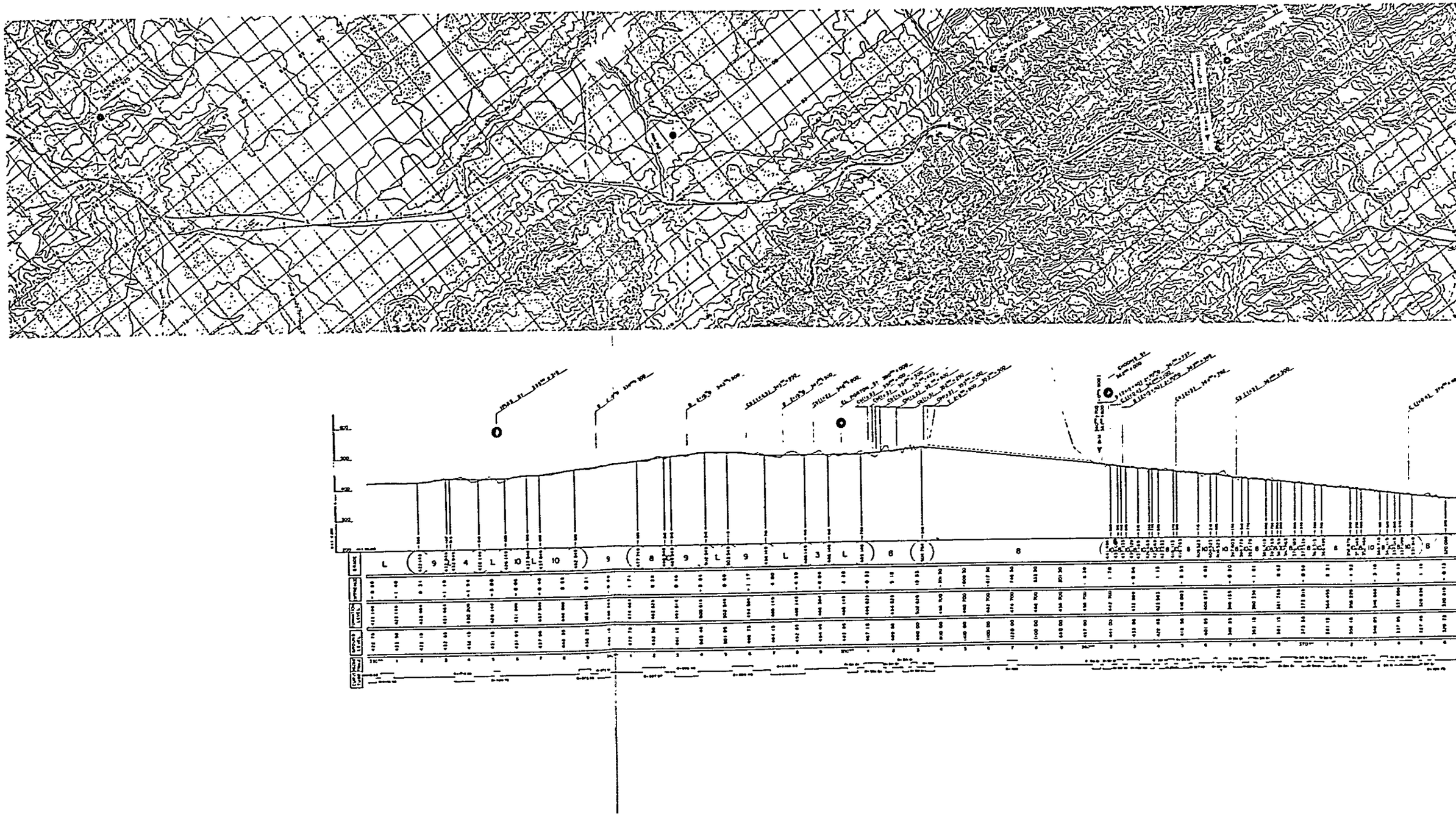
Drawing-6 Alternative-C
Longitudinal Profile

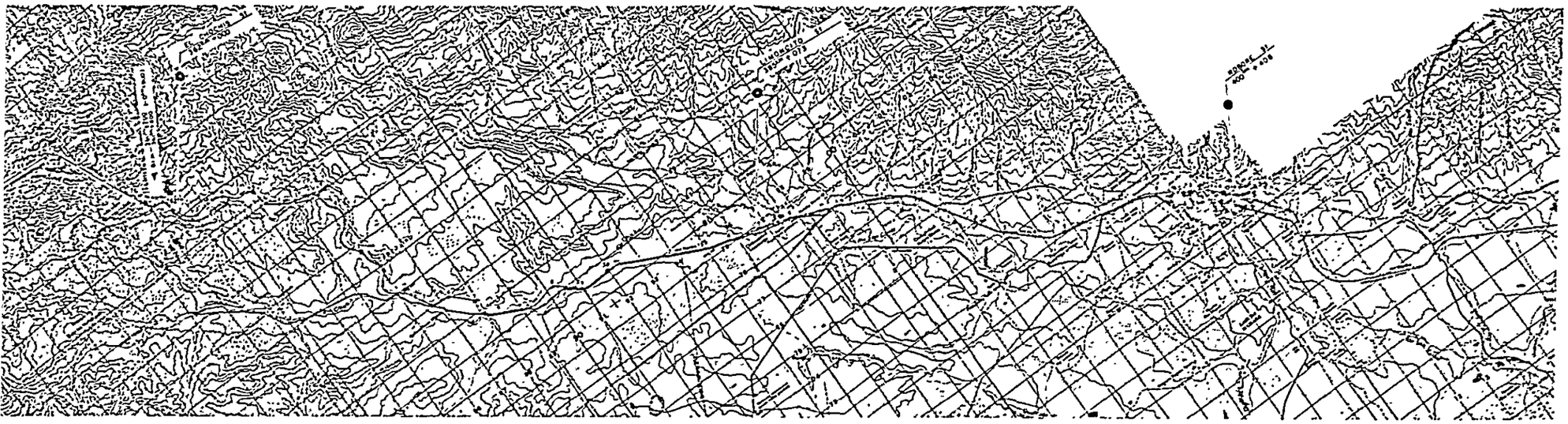




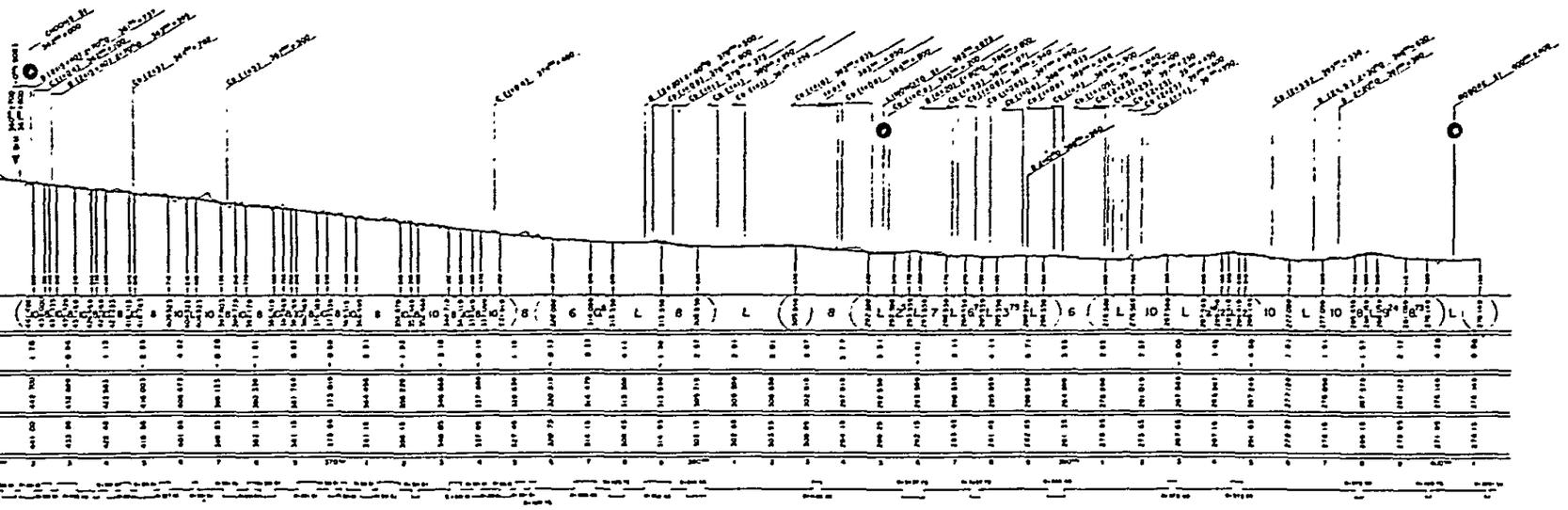
Drawing-7 Alternative-D
Railway Plan

Drawing-8 Alternative-D
Longitudinal Profile

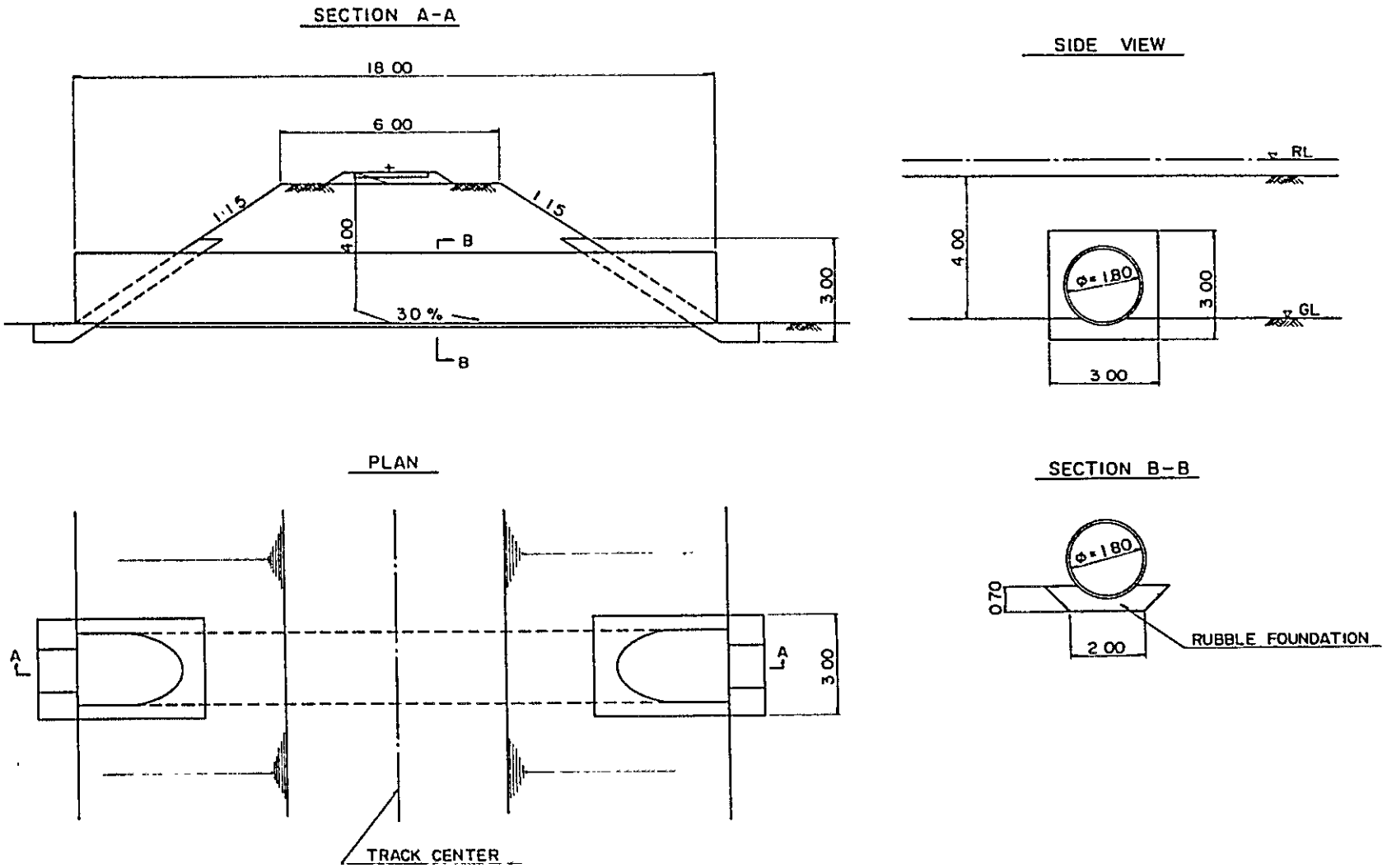




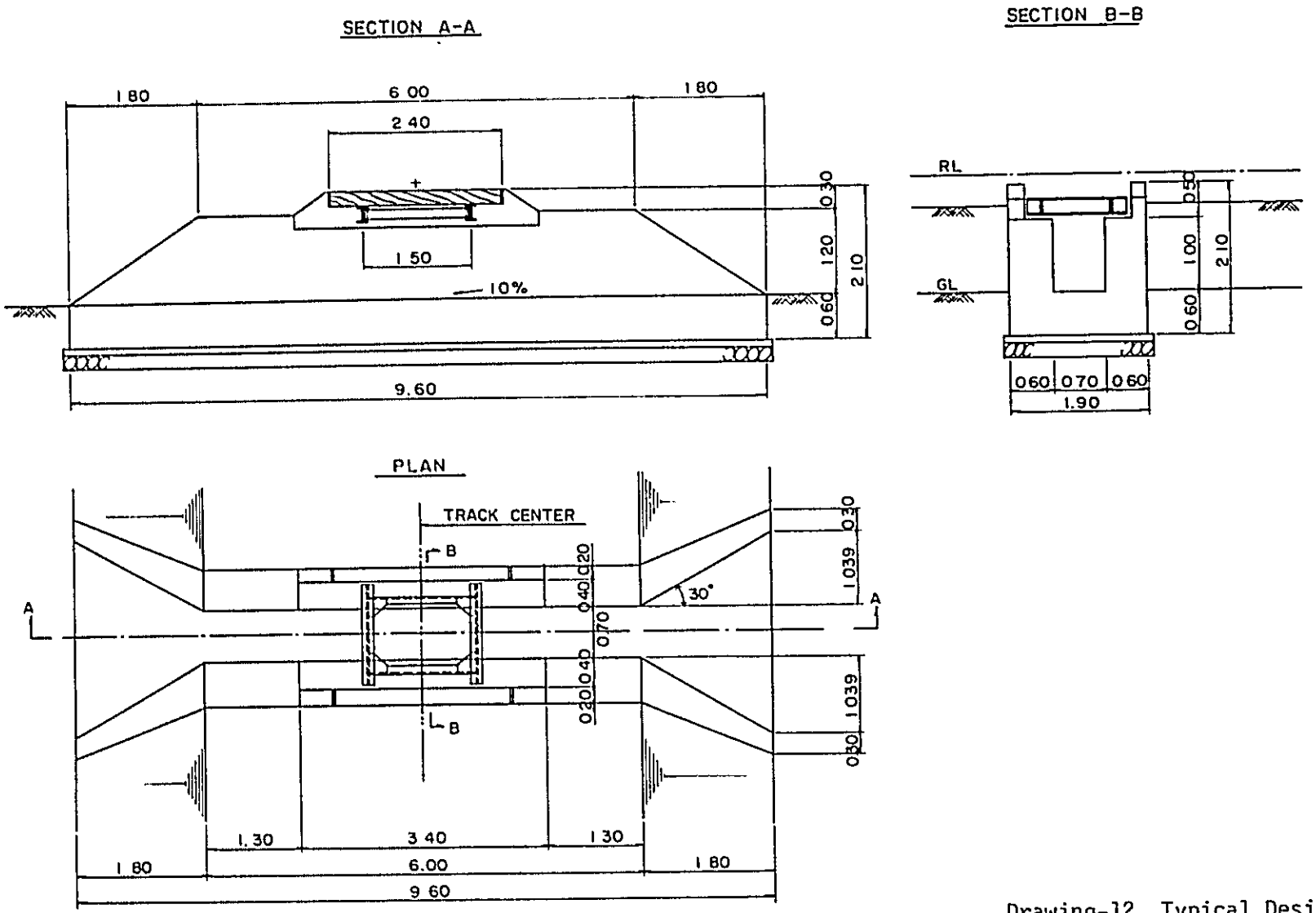
Drawing-9 Alternative-E
Railway Plan



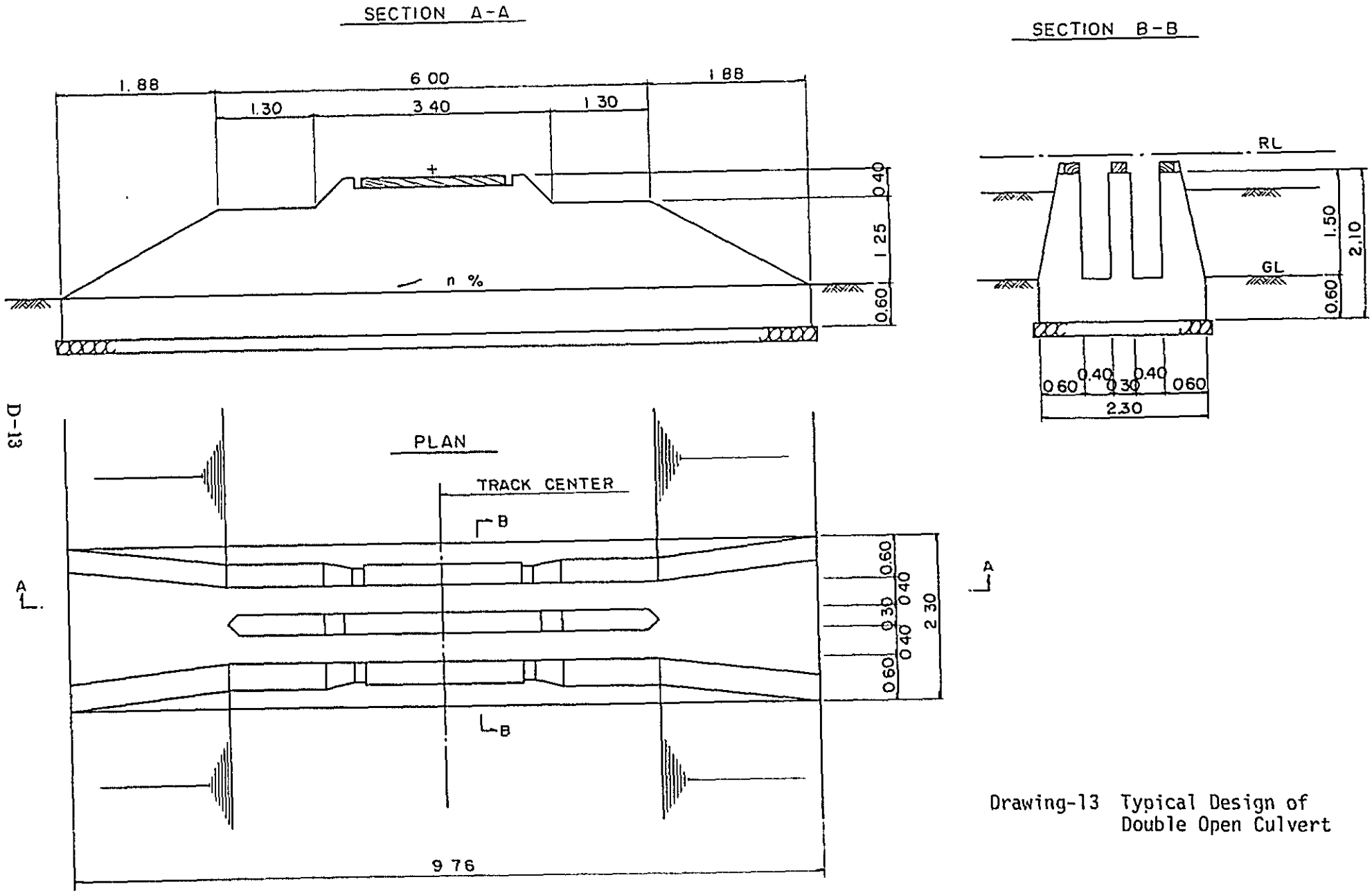
Drawing-10 Alternative-E
Longitudinal Profile



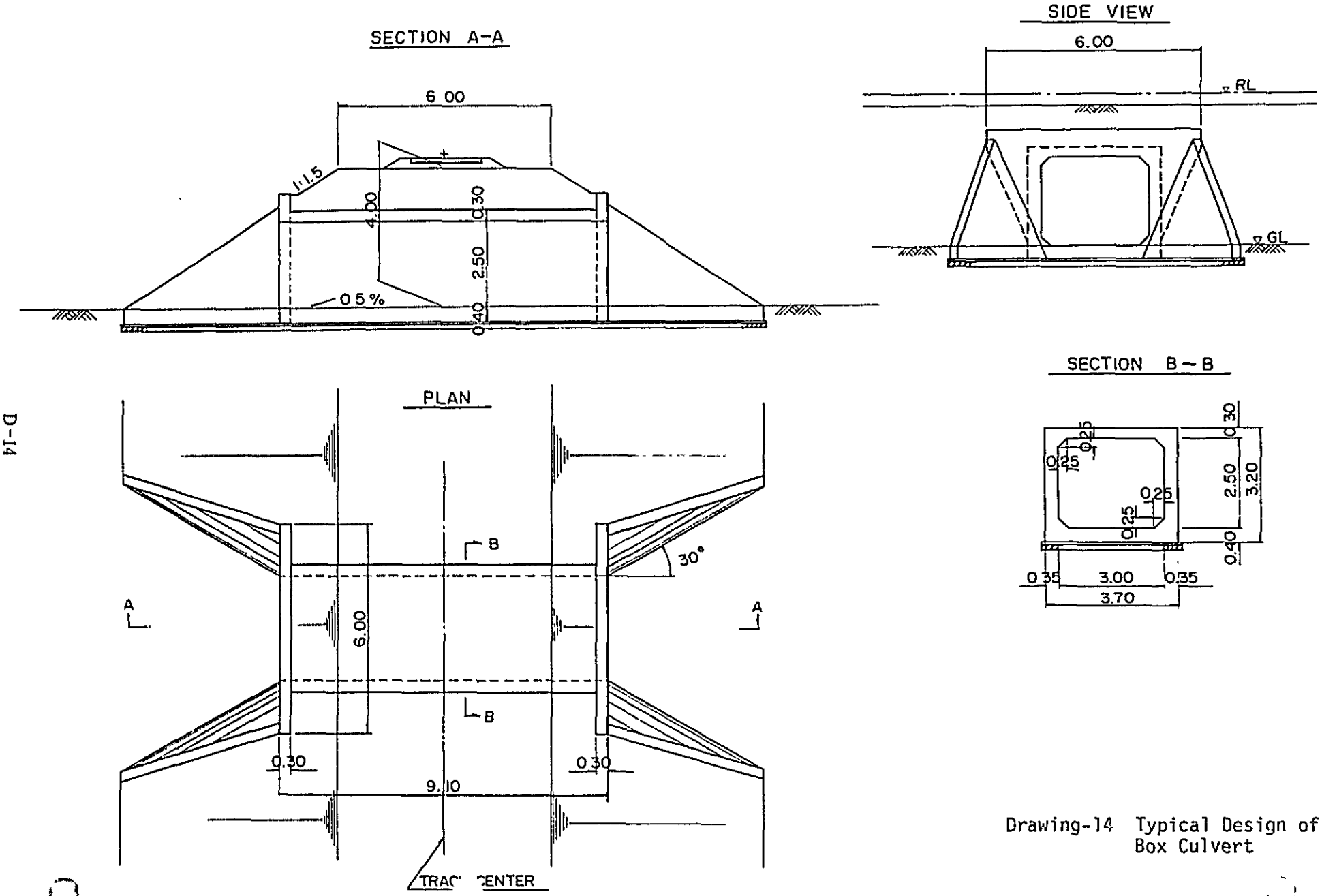
Drawing-11 Typical Design of
Corrugated Steel Pipe



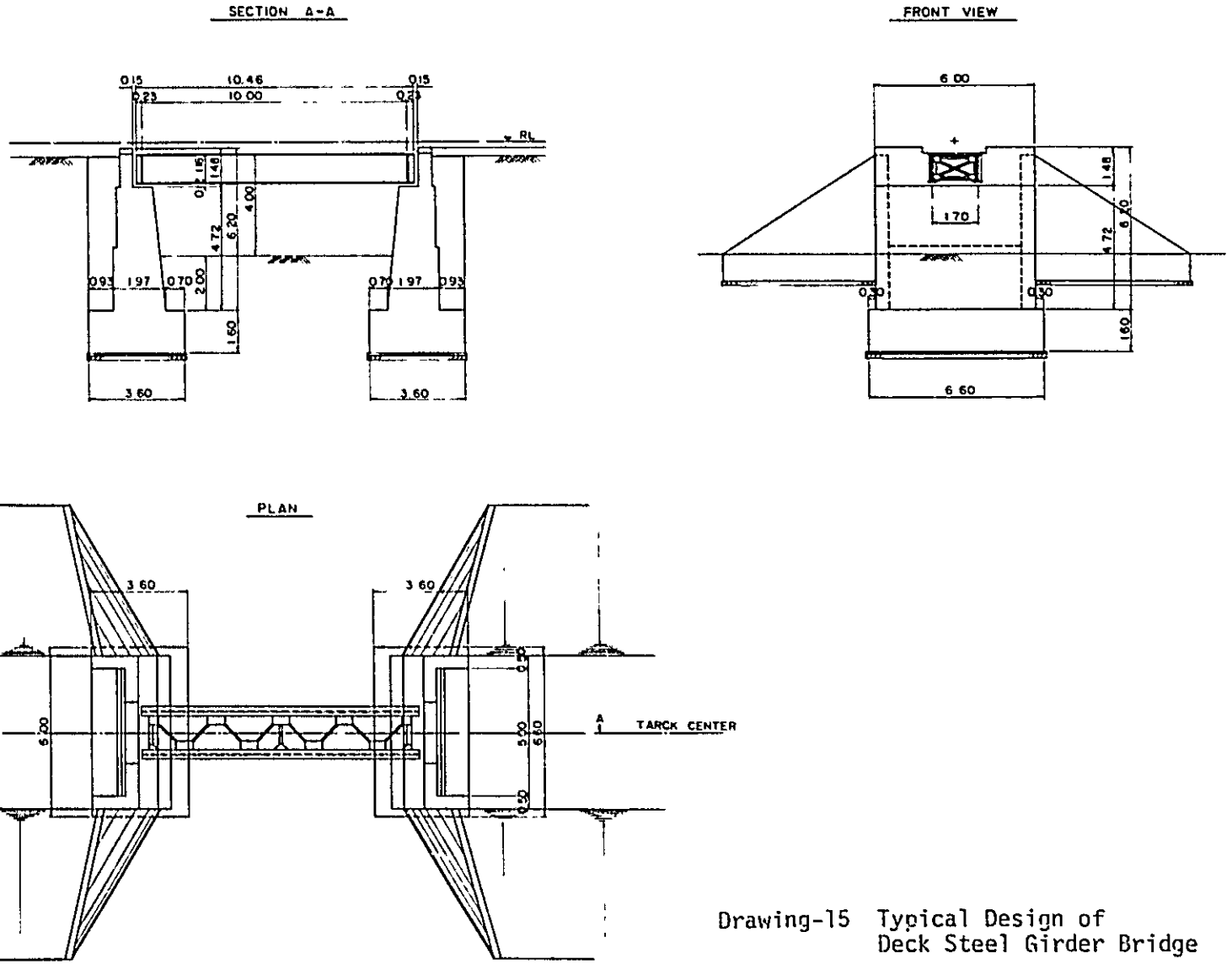
Drawing-12 Typical Design of Open Culvert



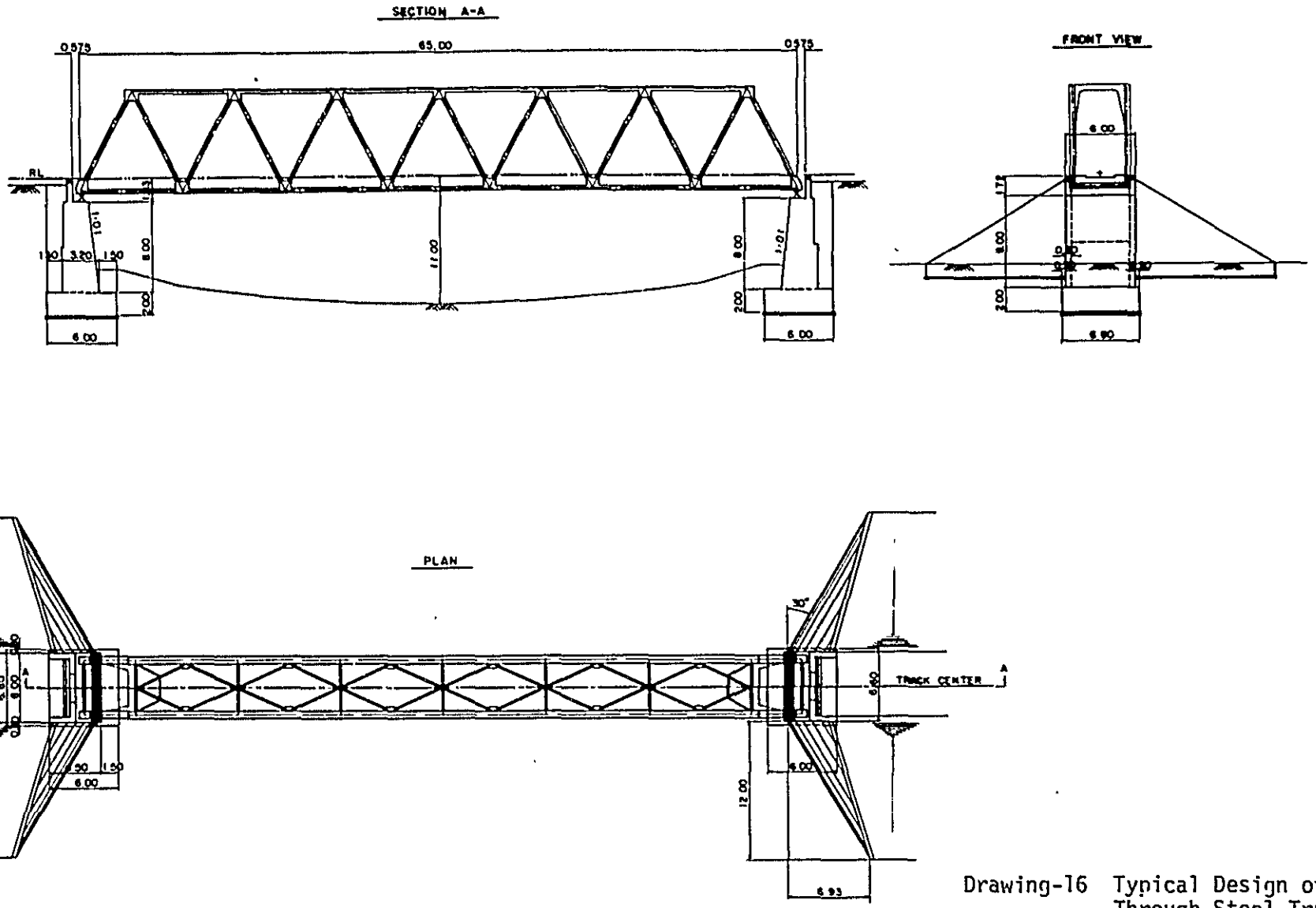
Drawing-13 Typical Design of Double Open Culvert



Drawing-14 Typical Design of Box Culvert



Drawing-15 Typical Design of
Deck Steel Girder Bridge



Drawing-16 Typical Design of
Through Steel Truss Bridge