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REPUBLIC OF BOLIVIA

JAPAN INTERNATIONAL COOPERATION AGENCY

FEASIBILITY STUDY ON THE RAILWAY IMPROVEMENT BETWEEN ORURO AND COCHABAMBA IN THE REPUBLIC OF BOLIVIA

(SUMMARY)

FINAL

OCTOBER 1995

JAPAN RAILWAY TECHNICAL SERVICE
TONICHI ENGINEERING CONSULTANTS, INC.

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NOTE

US$ 1.00=Bs. 4.65(Bolivianos)

US$ 1.00=¥ 100(Yen)

PREFACE

In response to a request from the Government of the Republic of Bolivia, the Government of Japan decided to conduct a Feasibility Study on the Railway Improvement between Oruro and Cochabamba in the Republic of Bolivia and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Bolivia a study team headed by Mr. Tatsuya Ishihara, Japan Railway Technical Service (JARTS), 4 times between January 1994 and October 1995.

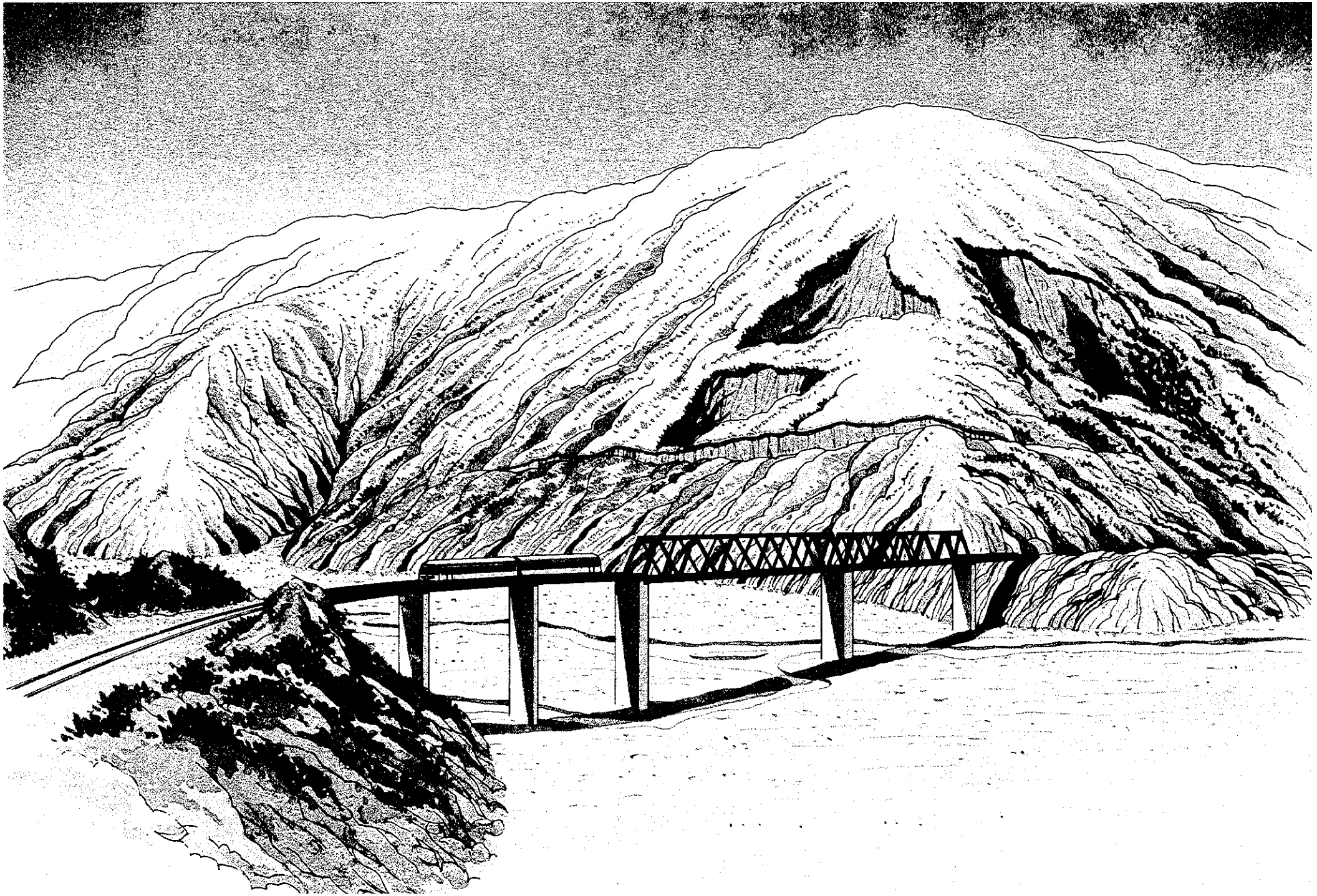
The team held discussions with the officials concerned of the Government of Bolivia, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

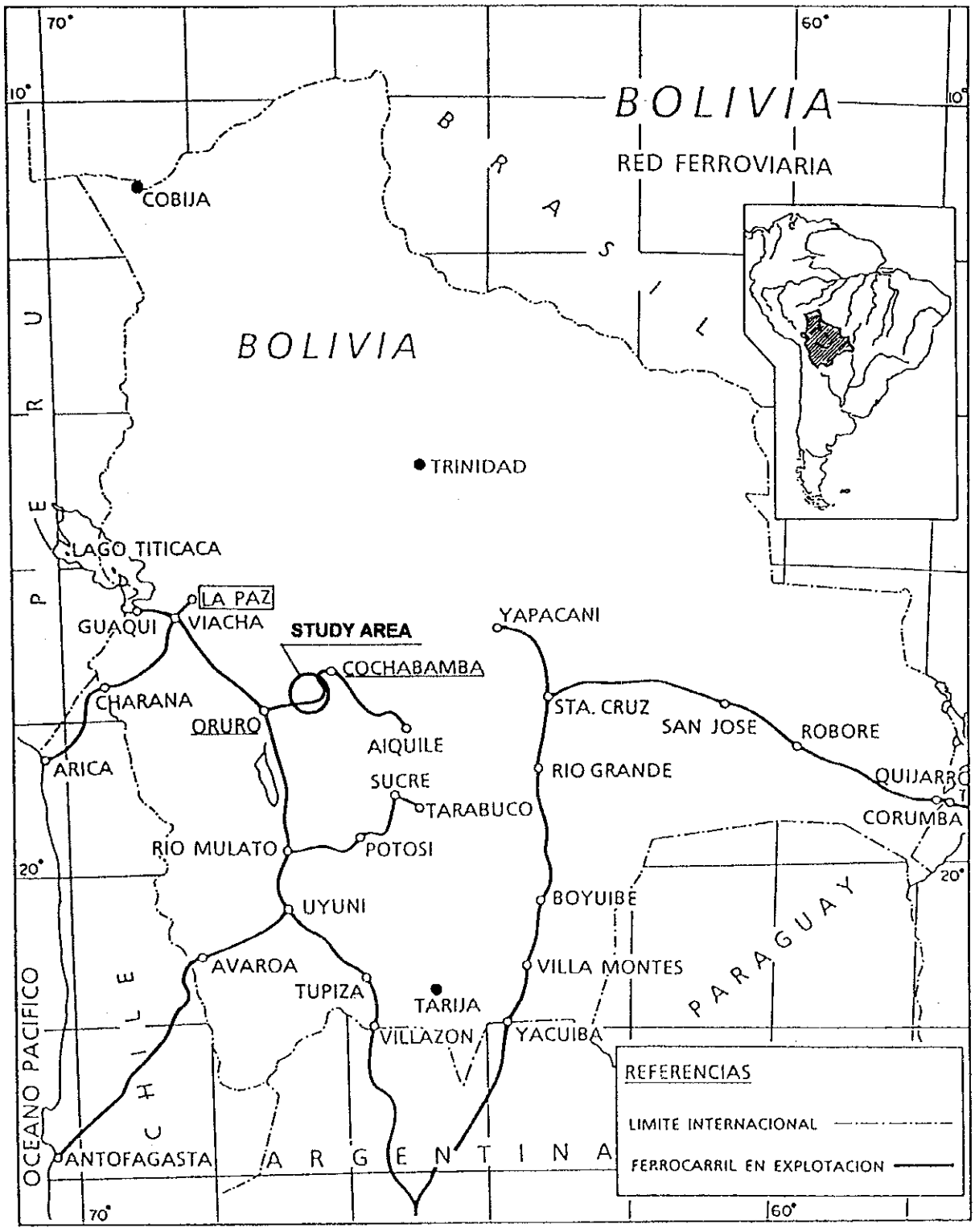
I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Bolivia for their close cooperation extended to the team.

October 1995

Kimio Fujita
President
Japan International Cooperation Agency

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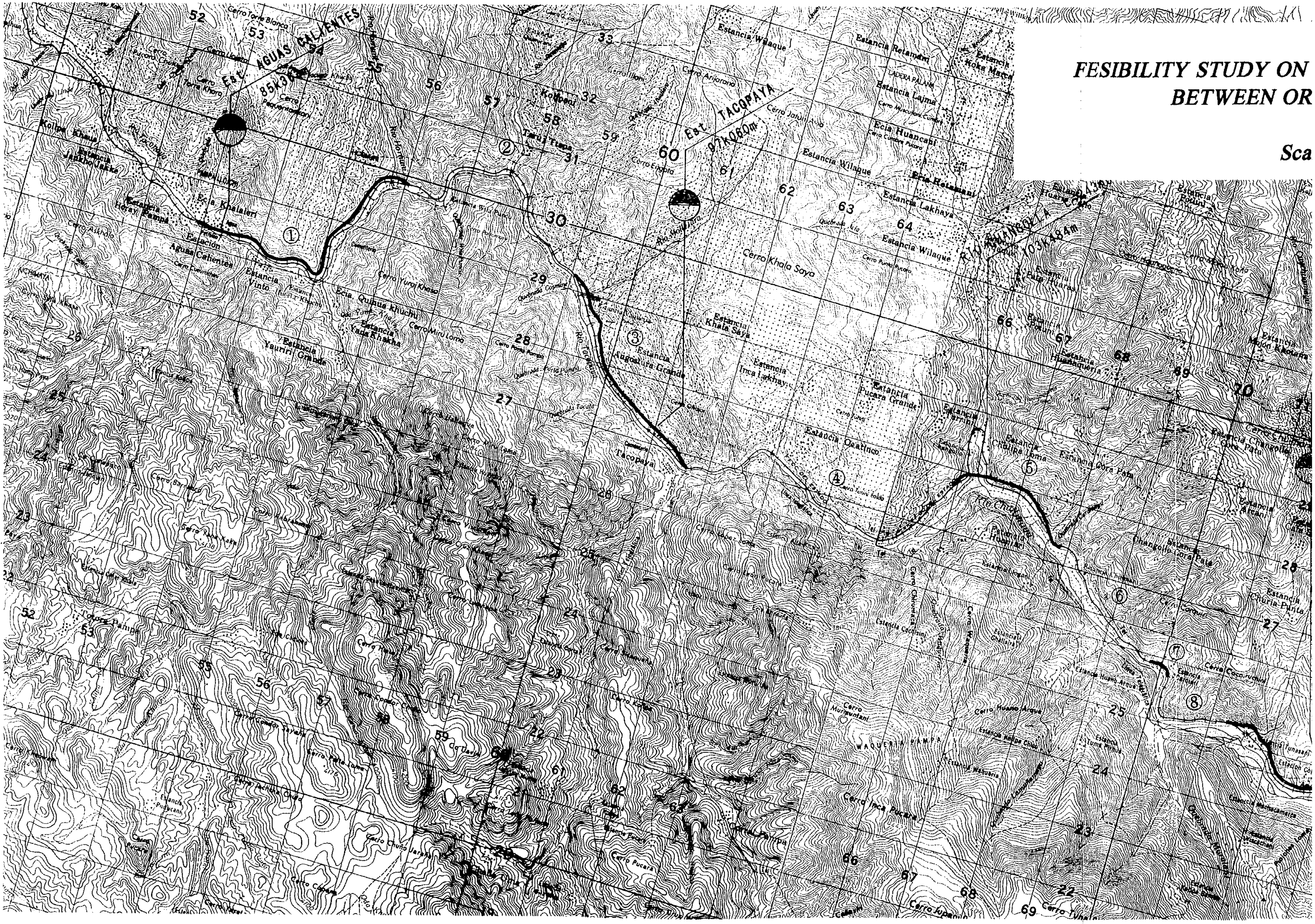

FESIBILITY STUDY ON THE RAILWAY IMPROVEMENT BETWEEN ORURO - COCHABAMBA

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TUDY ON THE RAILWAY IMPROVEMENT
WEEN ORURO - COCHABAMBA

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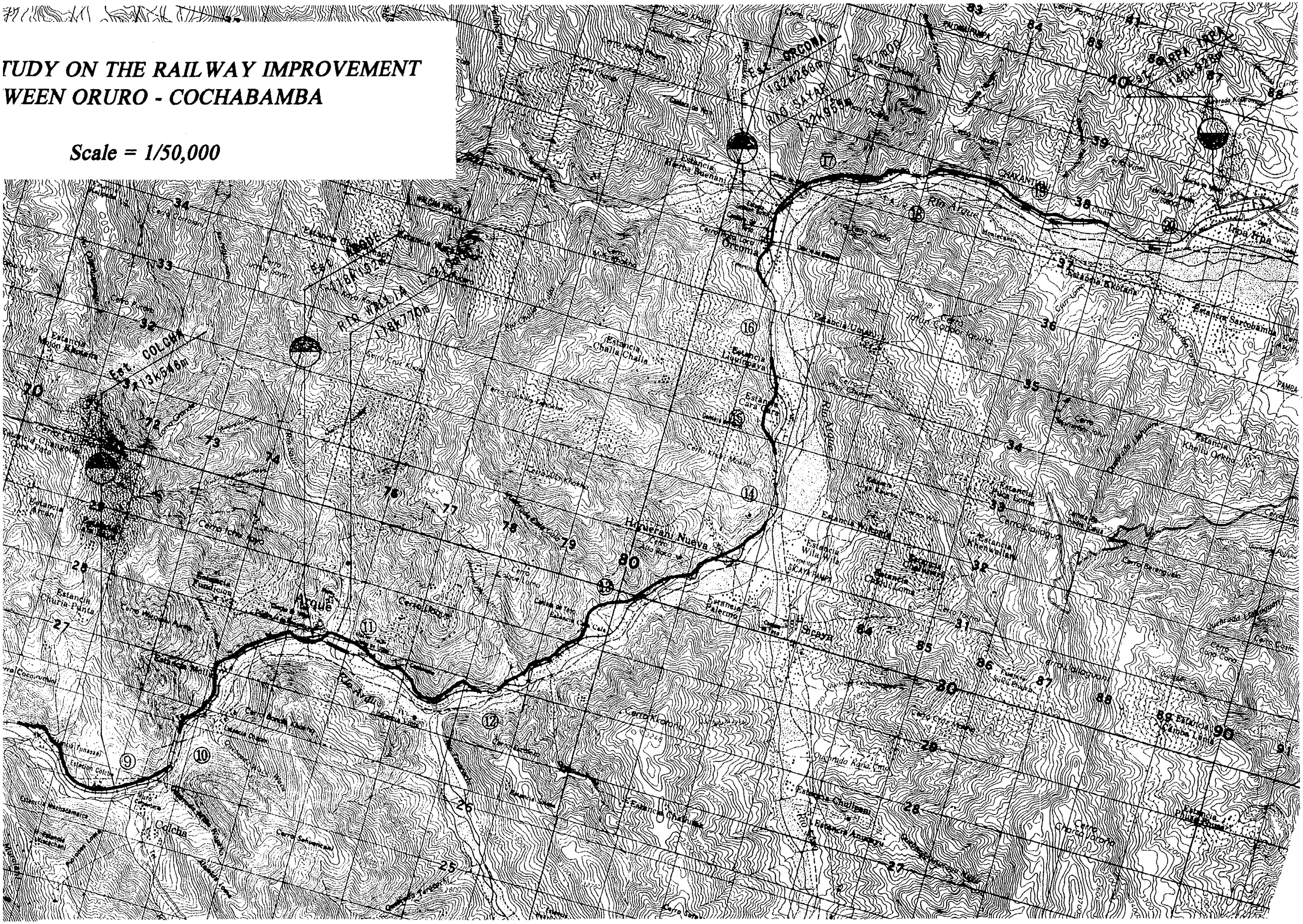

FEASIBILITY STUDY ON THE RAILWAY IMPROVEMENT BETWEEN ORURO AND COCHABAMBA IN THE REPUBLIC OF BOLIVIA

(ABSTRACT)

1. OBJECTIVE

The objective of this study is to determine the feasibility of the railway improvement project for the railway line between Oruro and Cochabamba in Bolivia, which has the aim of securing reliable transportation.

The Oruro - Cochabamba Line has a total length of 204km, and special attention is paid to the 55km Aguas Calientes - Irpa Irpa section where disasters frequently occur. Topographic maps have been prepared for the Aguas Calientes - Irpa Irpa section, and relocation of the section will be studied and an optimum route will be selected. A plan for structures will also be drawn up for the optimum route.

Comprehensive evaluation of the feasibility of the project will be conducted by taking into consideration on technical, environmental, economic and financial aspects.

2. OUTLINE OF THE PROJECT

(1) SUMMARY OF MAIN IMPROVEMENT PLANS

1) Aguas Calientes - Irpa Irpa section

1 The route will be relocated towards the mountains and the track will be improved. There are 10 sections approximately 33 km in length. In this area, there is little height difference between the track and bed of the river flowing parallel to it, which is the cause of frequent flooding.

2 Track that crosses over or is near the river will be protected against the debris flows of the river with bridges, box tunnels, etc.

3 As result of route relocation, it will be necessary to improve 5 stations: Aguas Calientes, Tacopaya, Colcha, Arque, and Orcoma. In addition, the Changolla and Higuerani side tracks will be closed taking into account track capacity.

4 Track, that will not be relocated and which consists of ten sections approximately 22 km in length, will be improved.

2) Oruro - Aguas Calientes section and Irpa Irpa-Cochabamba section

1 Track will be improved where accidents and derailments are most frequent (14 Km).

2 In Cona Cona, after considering the track capacity, a new side track will be introduced for train crossings.

3) In order to reduce construction costs, it is planned to re-utilize 21 existing steel bridges from the Yapacani Line. The following two cases will be studied.

1 Re-utilization of existing steel bridges from the Yapacani Line.
2 No re-utilization of existing steel bridges from the Yapacani Line.

Based on the results from studying these two cases, the Bolivian National Railways (ENFE) shall decide on the number of steel bridges to be re-utilized.

(2) APPROXIMATE TRACK LENGTH BY STRUCTURE TYPE ON THE RELOCATED SECTIONS

STRUCTURE TYPES	LENGTH (km)	PERCENTAGE (%)
Cut and embankment	29.9	90.9
Bridges	1.5	4.6
Box tunnels	1.4	4.2
Mountain tunnels	0.1	0.3
TOTAL	**32.9**	**100.0**

(3) PHASES OF IMPROVEMENT

The relocation of 10 sections about 33 km in length will be executed in two phases based on the level of urgency.

First phase : 5 sections requiring most urgent improvement (16 km)
Second phase : Remaining 5 sections (17 km)

	FIRST PHASE	SECOND PHASE
Preliminary work	Year 1996	Year 2001
Construction begins	Year 1998	Year 2003
Construction completed	Year 2000	Year 2005

(4) DEMAND FORECAST

Year	Passengers (1000 Per Year)	Cargo (1000 Tons/Year)
2000	114	742
2010	156	1,049
2020	185	1,389

(5) TRAIN OPERATION AND ROLLING STOCK

1) Scheduled speed : Express passenger trains : 42 km/h
Local passenger trains : 37 km/h
Freight trains : 35 km/h

2) Operational safety system : Train ticket system (system presently used)

3) Number of trains (round trips)

Year	Exp. Pass. Train	Local Pass. Train	Freight Train
2000	1 train/day	1 train/day	5 trains/day
2010	1 train/day	1 train/day	6 trains/day
2020	1 train/day	1 train/day	8 trains/day

4) Increase in number of rolling stock (total number for each year)

Year	Diesel Coaches (Passengers)	Diesel Locomotives	Freight Wagons
2000	1 Car	6 Engines	298 Wagons
2010	2 Cars	7 Engines	512 Wagons
2020	3 Cars	10 Engines	722 Wagons

Note : The increase in rolling stock is calculated from a transportation plan, based on a demand forecast for each year.

(6) ADMINISTRATION AND OPERATION COST

Unit : US$ Millions

Year	2000	2010	2020
Administration and operation costs	7.2	8.1	9.4

(7) INVESTMENT COST

Unit : US$ Millions

CASE	Total Investment Amount	Investment Cost for Fixed Facilities	
Steel Bridges from Yapacani Line are re-used	141 (local currency : 55, foreign currency : 86)	86 (local currency : 55, foreign currency : 31)	Phase I 50 (local currency : 29, foreign currency : 21) Phase II 36 (local currency : 26, foreign currency : 10)
Steel Bridges from Yapacani Line are not re-used	147 (local currency : 56, foreign currency : 91)	92 (local currency : 56, foreign currency :36)	Phase I 53 (local currency : 30, foreign currency : 23) Phase II 39 (local currency : 26, foreign currency : 13)

(8) ECONOMIC AND FINANCIAL EVALUATION

CASE	EIRR	FIRR
Steel bridges from Yapacani Line are re-used	13.24 %	3.31 %
Steel bridges from Yapacani Line are not re-used	12.69 %	3.09 %

3. COMPREHENSIVE EVALUATION (CONCLUSION)

(1) This project, which includes route relocation, is technically feasible and the impact to the environment is negligible.

(2) From a national economic viewpoint, the EIRR is 13.24% ~ 12.69% and, if indirect and uncountable benefits are considered, the implementation of this project is considered to be appropriate.

(3) Regarding the financial aspect of ENFE, the FIRR is 3.31% ~ 3.09%, which should pose no specific problem for project implementation as long as soft loans with low interest are available.

(4) From a comprehensive point of view, this project has adequately planned for the topography of the Los Andes Mountains, where the railway has been struck by disasters stopping traffic for long periods of time, and this project is judged to be feasible from the technical, environmental, economic and financial aspects as well.

(5) The execution of this project will provide reliable transportation between Oruro and Cochabamba, which will contribute to the social and economic development of the country.

(6) However, it is important for ENFE to obtain funding for this project at the lowest interest rate possible. To effectively execute this project, it is recommended to improve the software-related matters , such as transportation management, facility and equipment maintenance, and education and training, in addition to executing work efficiently, sufficient consideration of the environment and effective investment for facilities, equipment and rolling stock.

FEASIBILITY STUDY ON THE RAILWAY IMPROVEMENT BETWEEN ORURO AND COCHABAMBA IN THE REPUBLIC OF BOLIVIA

SUMMARY OF FINAL REPORT (ENGLISH)

CONTENTS

1. INTRODUCTION

The Bolivian National Railways (ENFE) operates its railway over track totalling about 3,460km in length, of which about 2,080km makes up the Western Railway Operation Division and about 1,380km the Eastern Railway Operation Division. ENFE plays an important socio-economic role as part of the Bolivian transportation system, and it carries more import/export products to and from Bolivia than any other mode of transportation.

However, most ENFE railway facilities are worn out and the quality of operation has deteriorated. Natural disasters have also seriously affected service and ENFE is unable to operate efficiently. From 1990 through 1991, under the assistance of the Japanese International Cooperation Agency (JICA), the "MASTER PLAN FOR THE MODERNIZATION AND REHABILITATION OF ENFE IN BOLIVIA" was initiated, which is the master plan of the total rehabilitation and improvement of ENFE.

A priority of the Master Plan is to improve the railway between Oruro and Cochabamba, which has been struck by many natural disasters over the years. ENFE operation has been affected so seriously that traffic on this route has had to be stopped for long periods of time.

Under these circumstances the Bolivian government requested the Japanese government to carry out a feasibility study to improve the railway line between Oruro and Cochabamba. In response, the Japanese government through JICA had a study team visit Bolivia. The study team initiated discusssions with Bolivian government officials and concluded a scope of work on October 19,1992. On the basis of the scope of work, JICA carried out as Phase I topographical mapping (1/2000) of the Aguas Calientes - Irpa Irpa section. At the present, a feasibility study is being carried out as Phase II.

The feasibility study covers the 204km Oruro-Cochabamba Line. A plan has been drawn up to improve this route by upgrading its resistance to disasters and by speeding up rehabilitation in the case of damage. The plan includes relocating parts of the 55km Aguas Calientes (85km364m) Irpa Irpa (140km928m)section, by applying the topographic map prepared in Phase I and studying the possible alternative routes.

Futhermore, during the course of the feasibility study, railway technology is to be transferred to ENFE counterparts.

The main criteria used for planning, which has been discussed with the Bolivian counterparts and include railway route selection, are as follows :

(1) To make the present plan compatible with previous work on the modernization and rehabilitation of ENFE and with other related ongoing or proposed work by ENFE and the World Bank.

(2) To consider the Bolivian economy and ENFE's financial situation and plan a realistic project with a proper magnitude of investment.

(3) To lower construction costs and improve investment efficiency by taking advantage of existing lines, local products, and materials available within ENFE.

(4) To emphasize safe and reliable transportation services instead of increasing speed.

(5) To consider ENFE's technical capacity and standards to help ENFE improve its work execution, management, and maintenance.

(6) To consider natural and environmental conditions on each section of the selected route in the preliminary structure and design plans.

With respect to Item (3), existing steel bridges will be re-utilized to reduce construction costs. However the planned re-utilization, which consists of 21 steel bridges on the Yapacani Line, has not been decided yet. Therefore,the following two cases are studied:

1) Re-utilization of existing steel bridges from the Yapacani Line
2) No re-utilization of existing steel bridges from the Yapacani Line (i. e., new steel bridges)

Based on the results of these two cases, ENFE shall decide on the number of steel bridges to be re-utilized from the Yapacani Line when the project is to be executed.

This report is a summary of the evaluation carried out on the improvement plan for the most appropriate route, which has been agreed on by both the Bolivian and Japanese sides.

2. PRESENT CONDITION OF THE RAILWAY

The Oruro-Cochabamba Line starts at Oruro Station in the highlands, which are known as the Altiplano and are 4,000 meters above sea level(a. s. l.). The line heads towards the eastern mountains and passes by La Cumbre Station (at 4,138m a.s.l.). It then descends along the tributaries of the Arque River at a steep gradient and reaches Buen Retiro Station at 2,379m a.s.l. Later, the line ascends to reach the Cochabamba Central Valley and stops at Cochabamba Station (at 2,556m a.s.l.), for a total route length of 210.8km.

On the section between La Cumbre and Buen Retiro along the Rio Arque, the track is laid to the river bed and is in bad condition, having a maximum gradient of 30‰ and a minimum curvature radius of 72 meters. During the rainy season (December ~ March), there are many problems with track including long term non operation due to the collapsing of slopes, avalanches of sand and stone, rises in the river bed, erosion of the river side, etc.

Table 2-1 shows the interruption of service caused by disasters, from the year 1984 through 1993.

TABLE 2-1 NUMBER OF DAYS OF INTERRUPTED SERVICE ON THE ORURO - COCHABAMBA DUE TO DERAILMENTS AND NATURAL DISASTERS

Item \ Year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Service interrupted by a disaster	86	46	108	68	89	15	39	45	28	16
Service interrupted by a derailment	22	21	12	10	10	8	11	18	17	10

Table 2-2 shows the number of disasters and train accidents that occurred in 1993 on the Andean Network and the Oruro-Cochabamba.

TABLE 2-2 NUMBER OF DISASTERS AND ACCIDENTS OCCURRED IN 1993

Item \ Lines	Oruro - Cochabamba	Other Lines	All Lines: Andean Network
Route Length in Operation	211 km	1.874 km	2,085 km
Train kilometers	168,219 km/year	859,536 km/year	1,027,775 km/year
Derailment with overturning	3	3	6
Derailment	490	328	818
Accident victims (no. killed and injured)	3	24	27
Accidents at level crossing and others	2	13	15
Train separation	0	2	2
Total	498	370	868
Number of disasters & accidents per km of route length	2.36	0.2	0.42
Number of disasters & accidents per million km of train operation	2,960	430	845

The total number of disasters and accidents on the Oruro - Cochabamba Line is large. Derailment on this line accounts for 60% of the total in the Andean Network. A summary of the disasters and accidents that occurred on the Oruro - Cochabamba Line from 1990 to 1993 is shown in Table 2-3.

The number of accidents due to the softening of the ground is the highest (394), or 85% of the total number (461)that occurred. The remaining accidents were caused by obstacles on the track, flooding, etc. As to track failures, were due to irregular track, which is the biggest cause out of a total of 1,006 failures, and almost all the rolling stock failures are due to wagons.

TABLE 2-3 NUMBER OF ACCIDENTS ON THE ORURO - COCHABAMBA LINE FROM 1990 TO 1993

Item	Disasters	Track failure	Rolling stock failure	Others	Total
1990	143	202	78	7	430
1991	98	338	99	10	545
1992	96	238	149	7	490
1993	124	228	138	8	498
Total	461	1,006	464	32	1,963

The Oruro - Cochabamba Line is located on the axis of the main railway network that connects the three major cities of Bolivia : La Paz, Cochabamba and Santa Cruz. Between Cochabamba and Santa Cruz, transportation is intermodal. If a new railway is constructed connecting the east and west networks of ENFE in the future, this line will become a very important route for crossing the South American continent. Transportation volumes are shown in Tables 2-4 and 2-5. Although passenger transportation shows a decrease, freight transportation is increasing (most of it consists of minerals, soja beans, wheat, wood, construction materials such as cement, etc.). The Oruro - Cochabamba Line account for 13% (42,181 Mton·km) of the total freight kilometerage in the Andean Network with 90% of this for exports and imports.

As of 1994, there are three express rail-buses making three round trips per week, while mixed trains and distribution trains operate once a week and freight trains make one round trip a day.

As facility maintenance is poor, recovery from a disaster is slow, and the railway is in an extremely bad state on this line. Because of this, a speed restriction of 22 km/hr has to be enforced on a section of about 40km in length. On this section alone 500 derailments in a year have been recorded. There is a 31 km section without interchange point, where the existing train operation of seven trains per day is not easy.

At present, the Oruro-Cochabamba Line does not operate efficiently. Urgent improvements have to be made if transportation is to be safe. It is expected that stable and efficient transportation will contribute to the development of the economy of Bolivia.

Table2 - 4 Volume of Passenger Tranceportation

Year	ENFE			Western Division			Oruro - Cochabamba Line			
	Passengers Transported (1,000 persons)	Passenger-kilometers (1,000 pers. km)	Average Trip Length (km)	Passengers Transported (1,000 persons)	Passenger-kilometers (1,000 pers. km)	Average Trip Length (km)	Passengers Transported (1,000 persons)	Passenger-kilometers (1,000 pers. km)	(%)	Average Trip Length (km)
1986	1,885	675,121	349	1,201	354,465	295	206	29,533	8.3	143
1987	1,393	500,388	359	769	233,916	304	111	15,110	6.5	136
1988	1,051	368,886	351	565	162,935	288	76	9,603	5.9	126
1989	1,092	385,831	353	600	174,178	290	103	12,947	7.4	126
1990	1,071	388,085	362	590	170,889	290	94	11,994	7.0	128
1991	901	350,043	389	445	136,983	308	39	4,703	3.4	121
1992	869	333,835	384	430	127,680	297	47	6,024	4.7	128
1993	747	288,476	386	377	114,344	303	43	5,756	5.0	134

Note : The (%) column for the Oruro - Cochabamba Line is the ratio of this line's passenger-km to that of the Western Division's.

Table 2 - 5 Volume of Freight Transportation

Year	ENFE			Western Division			Oruro - Cochabamba Line			
	Freight Transported (1,000 tons)	Ton-kilometers (1,000 ton km)	Average Trans. Length (km)	Freight Transported (1,000 tons)	Ton-kilometers (1,000 ton km)	Average Trans. Length (km)	Freight Transported (1,000 tons)	Ton-kilometers (1,000 ton km)	(%)	Average Trans. Length (km)
1986	923	463,617	502	535	271,781	508	102	20,868	7.7	205
1987	982	504,753	514	582	294,996	507	127	26,375	8.9	208
1988	872	423,850	486	534	254,071	476	102	21,287	8.4	209
1989	1,014	511,650	505	595	285,241	479	129	27,299	9.6	212
1990	1,082	540,923	500	676	326,105	482	175	36,574	11.2	209
1991	1,309	682,266	521	777	372,738	480	210	42,314	11.4	211
1992	1,409	710,411	504	825	373,688	453	194	41,001	11.0	211
1993	1,334	692,337	516	709	322,184	454	200	42,181	13.1	211

Note : The (%) column for the Oruro - Cochabamba Line is the ratio of this line's ton-km to that of the Western Division's.

3. NATURAL AND ENVIRONMENTAL CONDITIONS

3-1 NATURAL CONDITIONS

(1) Climate

Annual rainfall in the mountains, highlands and valleys of the area is relatively low, from 450mm to 1,100mm (Arque 1979).

The rainy season lasts four months, from December to March, and the dry season lasts eight months, from April to November.

Although the rainfall of the study area is relatively small, torrential rain concentrates in a short period, the disasters of avalanche of sand and stone and destruction of slope occur.

(2) Topography and Geology

The western part of Bolivia is formed by two mountain zones with an altitude of 6,000m a.s.l. The area between these zones constitutes a plateau called Altiplano with an altitude of about 4,000m a.s.l. The eastern part of Bolivia consists of alluvial plains around the Amazonas and La Plata tributaries.

The study area extends between the Altiplano and Los Andes Eastern zones.

1) Topography

The plateau between Oruro-San Pedro (0km000m)-Paria (16 km768m) (3,700m a.s.l.) is almost flat with very slight variations. The railway enters the eastern range of the Los Andes and runs along the Jachcha Uma River and then extends up to La Cumbre(54km632 m), the highest point of this line. Then, from La Cumbre, the railway passes Aguas Calientes (85km364m) and continues towards Buen Retiro (145km176m), where the river bed has a steep slope. It is on these sections that flooding frequently occurs. From Buen Retiro to Cochabamba (204km847m), the line then starts to gently ascend .

2) Fluvial system

The fluvial system in the study area, considered as a divide close to La Cumbre Station (4,138m a.s.l), is categorized into the Jachcha fluvial system flowing towards Oruro in the western Altiplano and the Arque fluvial system flowing towards eastern Cochabamba.
The Arque fluvial system flows near Buen Retiro Station and merges with the Rocha River flowing south from Cochabamba to later become the Caine River. The Arque fluvial system cuts the mountains deeply,