CHAPTER 7

TECHNICAL STUDY OF THE PLAN OF BRIDGE IMPROVEMENT

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7-1 Summary of Survey Findings

A field survey was made of the bridges on the section of No.8 State Highway between its intersection with the Pan American Highway and Cajamarca, as shown in Table 7-1. Of the 24 existing bridges, the Yonan Bridge, the La Muyuna Bridge and the Chetilla Bridge are relatively large bridges built over the Jequetepeque river. Other bridges are built over the tributaries of the Jequetepeque river or dales. The standard and width differ from one bridge to the other. The bridges with a span of 30 to 60 m are built with the steel truss structure, but all but the Yonan bridge are so old that trucks must slow down when crossing them. The bridges with a short span are built with the concrete or wooden simple girder structure. Concrete bridges are generally in good condition, but wooden ones are so worn that they need reconstruction. When reconstructing or improving the bridges, it is desirable that the bridges should be so designed as to conform to the standard of the second class state road and support the motor traffic resulting from the development of the Michiquillay mine. The plan of bridge improvement has been formulated in consideration of not only the technical complexities but also benefits of users, safety, acceptable riding qualities and so forth.

7-2 Basic Concept of the Plan Bridge Inmprovement

The wear, corrosion and life of the bridges have been studied on the basis of the field survey findings and other relevant information collected, and the basic concept of the plan of bridge improvement has been formulated, as will be summarized below.

A) Bridges needing improvement for lack of enough strength to bear design load H-20.
B) Bridges which are strong enough to support the traffic of heavy vehicles for use in the transportation of mining machinery and materials but are too narrow for their passage.
C) Of the bridges of category (B), those which will permit vehicles to bypass them during the dry season.

To transport mining machinery and equipment, trailers of a capacity of 60 to 80 tons are expected to be employed. Their load can be considered to be about equal to design load H-20. This means that the bridges will present no problem in terms of load and strength, if so improved as to conform to the standard of the second class state road. The vehicle gauge required to transport the mining machinery and equipment is 5.1 m. There are 4 bridges which do not meet this requirement. However, since such heavy gauge vehicles will be used for a brief period in early course of mine development, it is desirable to bypass the narrow bridges where possible during the dry season to avoid their reconstruction which is needed for no other reason than width insufficiency. There are as many as 12 bridges which are not wide enough, but it is bad economy to reconstruct them only for this reason in the light of expected traffic.

The 24 surveyed bridges are classified into categories (A), (B) and (C) in Table 7-1.

Table 7-1. Results of bridge survey

No.	Distance from Pan Am.	Name	Length	Width	Design Load	Structure	Remarks	Comment	A	B	C
1	50.5 km	Yonan	68.4 m	4.4 m	H-20	Steel truss Floor: conc.		Generally in good condition but strength partially inadequate.		0	0
2	53.7	Pampa Large	9.0	8.0	"	RC slab		Generally in good condition.			
3	55.3	Chuqui Mango	19.2	3.8	H-15	Steel truss Floor: wood		Strength inadequate dur to wear.	0		
4	80.7	La Monica	25.0	3.6	"	Steel truss RC slab		Same as described above.	0		
5	88.6	Huertas	46.8	6.6	H-20	RC slab Cont. (14.5 + 17.4 + 14.5)		Generally in good condition.			
6	95.0	La Muyuna	51.8	4.7	"	Steel truss Floor: wood		Strength of floor and members partially inadequate.		0	0
7	100.2	Chetilla	31.4	3.7	"	Steel truss Floor: wood		Members excessively deformed.	0		
8	106.2	La Viffa	5.3	8.5	"	RC slab		Generally in good condition.			
9	110.5	Amillas	12.0	10.0	"	Conc. arch		"			
10	112.2	Chilango	18.4	7.4	"	Composite pier		"			
11	116.4	El Mirme	26.8	8.6	"	RC cantilever (7.3 +11.7 + 7.3)		"			
12	118.0	El Mirmechico	5.9	8.0	"	RC arch	Erected Nov. 24, 1972	"			
13	120.0	Huana Huana	44.0	9.3	"	RC slab (Curved: 18.0 + 26.0)		"			
14	123.4	Lla Gaden	9.0	5.0	H-15	I-beam Floor: wood		Strength of floor and members partially inadequate.	0		0
15	128.6	Les Naranjes	9.7	11.8	H-20	RC slab (Curved)		Generally in good condition.			
16	130.8	Bay Lle	36.8	4.4	H-15	Baily bridge		Abutment on Cajamarca side worn and cannot be widened.	0		

(Continued)

No.	Distance from Pan Am.	Name	Length	Width	Design Load	Structure	Remarks	Comment	A	B	C
17	131.2	El Tingo	12.0	10.6	H-20	RC slab (Curved)		Generally in good condition.			
18	150.4	Yu Magual	4.6	4.5	H-15	Timber structure		Girders dangerously worn and stone abutment also dangerous.	0		
19	152.2	Choten	6.5	4.0	H-20	RC T-beam		Strength partially inadeauate.		0	0
20	157.9		5.0	4.5	H-15	Timber structure		Temporary bridge erected due to damaged culvert.			
21	162.6	Shingolcaga	4.5	4.0	H-20	RC slab	Can be widened by corrugated pipes.	Strength partially inadequate.		0	0
22	167.6	Luinua Mayo	5.0	5.4	"	"		Generally in good condition.			
23	173.3	Cruz Blanca	8.7	9.4	"	"	"	"			
24	175.2	Carita	6.5	8.5	"	"		"			

Table 7-2. Bridges needing improvement or reconstruction

No.	Name	Strength		Width (m)	Construction Gauge (Mine trucks)	Remarks
		Structure	Floor			
1	Yonan	Adequate	Adequate	3.2	Too narrow	Bypassing possible.
3	Chuqui Mango	Inadequate	Inadequate (wood)	2.8	Too narrow	To be reconstructed.
4	La Monica	Inadequate	Adequate	3.6	Too narrow	To be reconstructed.
6	La Muyuna	Adequate	Inadequate (wood)	3.7	Too narrow	Bypassing possible.
7	Chetille	Inadequate	Inadequate (wood)	2.7	Too narrow	To be reconstructed.
14	Llagaden	Adequate	Inadequate (wood)	4.0	Adequate	Bypassing possible.
16	Baylle	Inadequate	Inadequate (wood)	2.6	Too narrow	To be reconstructed.
18	Yamagual	Inadequate	Inadequate (wood)	3.5	Too narrow	To be reconstructed
19	Choten	Adequate	Adequate	4.0	Adequate	Bypassing impossible.
21	Shingalcaga	Adequate	Adequate	4.0	Adequate	Bypassing impossible.

The Government of Peru has a plan to reconstruct (3) Chiqui Mango, (4) La Monica, (7) Chetille and (14) Llagaden bridges.

7-3 Plan of Bridge Improvement

As shown in Table 7-1, the following six bridges do not meet the load condition (H-20) of the second class state road of Peru: Chugal Mango Bridge, La Monica Bridge, Chetilla Bridge, Bay Lle Bridge, Yu Magual Bridge, and Lla Gaden Bridge (Group A).

a) Chuqui Mango Bridge

(1) Findings

This bridge is built with the steel deck truss structure, having a capacity of supporting design load H-15 of the third class state road. Its specifications are as follows.

Design load	H-15
Deck material	Wood
Bridge structure	Pratt truss bridge
Span	19.2 m

(2) Plan of Reconstruction

As the upper structural members are so worn that the bridge will not be capable of supporting expected motor traffic, no matter how reinforced. In other words, this bridge must be reconstructed. As a new bridge must be about 30 m long, it is planned to be built with steel composite girders in consideration of the period, ease and economy of construction and other factors. The specifications of the new bridge are as follows.

Design load	H-20
Bridge structure	Simple live load composite girder bridge
Span	28.0 m
Abutment	Gravity type

New abutments will be built behind the old ones so as to maintain motor traffic during bridge construction. As the upper structure will be built with four main girders, two girders for each side will be assembled at the site and erected by a crane.

b) La Monica Bridge

(1) Findings

This is a deck bridge built with the truss structure, having a capacity of supporting design load H-15. Its specifications are as follows.

Design load	H-15
Deck material	Concrete
Bridge structure	Pratt truss bridge
Span	25.0 m

(2) Plan of Reconstruction

As the upper structural members are so worn that the bridge will not be capable of supporting expected motor traffic, no matter how reinforced. In other words, this bridge must be reconstructed. It is recommended that a new bridge be built with live load composite steel girders.

The specifications of a new bridge are as follows.

Design load	H-20
Bridge structure	Simple live load composite girder bridge
Span	27.7 m
Abutment	Gravity type

The construction method is the same as that for the Chuqui Mango Bridge.

c) Bay Lle Bridge

(1) Findings

This is a through truss bridge with a wooden deck, having a capacity of supporting design load H-20. This bridge is neither a permanent structure nor strong enough. As it is located over a precipitous cliff, it is practically impossible to build a bypass. Although the abutment is secured to the exposed bed-rock on the side of Pacasmayo, the abutment on the side of Cajamarca is not firmly secured to the bedrock and is very unstable. Its specifications are as follows.

Design load	H-15
Deck material	Wood
Bridge structure	Poney truss bridge
Span	27.64 m

(2) Plan of Reconstruction

This bridge is considered a temporary installation. Its structural members are extremely thin and not suitable for a permanent installation. As it is impossible to bypass this bridge during its reconstruction, it is necessary to reduce the construction period to a minimum. To meet this requirement, the new bridge is planned to be built with live load composite girders which can be assembled at the site of construction. The specifications of the new bridge are as follows.

Design load	H-20
Bridge structure	Simple live load composite girder bridge
Span	34.0 m

To maintain motor traffic during reconstruction, new abutments will be built on the valley side and the old girders will be moved to the same side to provide a passageway. After the new girders are in place, the abutments will be secured to the bedrock to the dimension of the old bridge. The method of upper structure construction is the same as that for the Chuqui Mango and La Monica bridges.

d) Chetille Bridge

(1) Findings

This is a Poney Warren truss bridge. As it is very narrow, many of its structural members are damaged due to contact with passing vehicles. Generally speaking, deformed compression members of the truss bridge are very dangerous. Furthermore, the wooden deck is rotten. Its specifications are as follows.

Design load	H-15
Deck material	Wood
Bridge structure	Poney Warren truss bridge
Span	27.4 m

(2) Plan of Reconstruction

Judging from the extent of damage, the bridge will not serve the purpose, no matter how reinforced. It is desirable, therefore, that the bridge should be reconstructed, preferably with live load composite girders. The specifications of the new bridge are as follows.

Design load	H-20
Bridge structure	Simple live load composite girder bridge
Span	32.0 m

Abutment	Gravity type

e) Yamagual Bridge

(1) Findings

This bridge is a temporary wooden installation. A new bridge is being built in parallel with this bridge by the Government of Peru. Its abutments have been completed but the upper structure remains to be erected. The specifications of the old bridge are as follows.

Design load	H-15
Bridge structure	Simple bridge built with logs
Abutment	Rubble mound

(2) Plan of Reconstruction

Judging by the present condition of the bridge, it seems necessary to reconstruct it. The specifications of the new bridge are as follows.

Design load	H-20
Bridge structure	Concrete slab bridge
Span	7.5 m
Abutment	Already built as mentioned above

f) Lla Gaden Bridge

(1) Findings

This bridge is a temporary installation made up of logs and square timer laid on I-steel girders and used rails, having a capacity of supporting design load H-15.

are as follows.

Design load	H-15
Bridge structure	I-steel simple girder bridge
Span	8.0 m
Abutment	Rubble mound

(2) Plan of Reconstruction

To maintain traffic during reconstruction, one lane will be first be built on the downstream side of the old bridge and then the old bridge will be replaced with another lane. The specifications of the new bridge are as follows.

Design load	H-20
Bridge structure	Reinforced concrete slab bridge

Span	7.6 m
Abutment	Gravity type

The bridges which are not wide enough to permit the passage of heavy gauge trucks are as follows (group B).

a) Yonan Bridge

This is a railway bridge designed with KS load. It is strong enough, but is as narrow as 4.4 m, presenting a problem to the passage of heavy gauge trucks. However, as it seems possible to bypass this bridge during the dry season, it may not be necessary to reconstruct it.

b) La Muyuna Bridge

(1) Findings

This is a steel truss bridge, having a capacity of supporting design load H-20. Its specifications are as follows.

Design load	H-20
Deck material	Wood
Bridge structure	Warren arched truss through bridge
Span	49.4 m

(2) Plan of Reconstruction

Some of the upper structural members are damaged, and the wooden deck is not strong enough. If it is replaced with a reinforced concrete deck, there is danger that the main structural members are overloaded. In the light of its insufficient width, it seems better to reconstruct this bridge rather than to reinforce it. When it is to be reconstructed, another pier should be erected at the center of the river for an economic reason. The specifications of the new bridge are as follows.

Design load	H-20
Bridge structure	Simple live load composite girder bridge
Span	27.7 m x 2

As it is bad economy to build a new bridge for the sole purpose of carrying building materials and mining equipment only, the existing bridge had better be used for the time being in the light of expected traffic, although it has only one lane and is not wide enough as a bridge of the second class state road.

c) Choten and Shingolcaga Bridges

The Choten and Shingolcaga bridges are strong enough to support design load H-20 or load of motor traffic resulting from mine development, but are not wide enough. Although it is desirable to reconstruct them if possible, their improvement should be considered from the standpoint of traffic growth for an economic reason.

7-4 Plan of Construction Work

7-4-1 Quantities of Materials

The quantities of materials required for the improvement or reconstruction of the bridges mentioned in the foregoing section are shown in Table 7-3.

Table 7-3 Estimated quantities of building materials

No.		Steel t	Foundation concrete m3	Retaining wall concrete m3	Approach	Remarks
No. 1	Yonan Bridge	180	320		As usual	
No. 3	Chuqui Mango Bridge	45	200	100	"	
No. 4	La Monica Bridge	45	150	80	"	
No. 6	La Muguna Bridge	86	350	120	"	
No. 7	Chetille Bridge	55	200	100	"	
No.14	Llagaden Bridge	1.6 (30 m3)	200		"	
No.16	Baylle Bridge	116	100	150	"	
No.18	Yamagual Bridge	1.6 (30 m3)	20		"	
No.19	Choten Bridge	1.6 (30 m3)	250		"	
No.21	Shingalcaga Bridge	(10 m3)	60		"	

Figures in parentheses indicate quantities of slab concrete.

Total 531.8 ≒ 540t
100 m3 1850 m3 550 m3

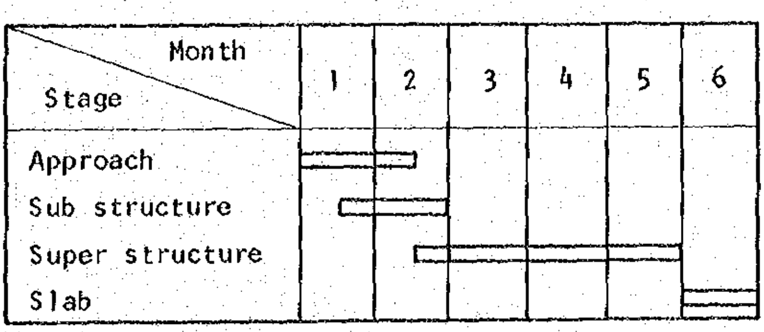
7-4-2 Conditions of Construction Work

The improvement or reconstruction of bridges should be completed in the shortest possible period so as to avoid traffic disturbance. To this end, the construction work should be efficiently carried out by the use of construction machinery. With these considerations in mind, the steel structure has been adopted for bridge improvement or reconstruction in this feasibility study.

7-4-3 Construction Schedule

As mentioned above, the plan of bridge improvement or reconstruction has been worked out in such a way as to minimize the construction period. The construction period of each bridge ranges from 4 to 6 months. A construction schedule is shown below by way of example.

Construction Schedule



CHAPTER 8

CONSTRUCTION COST

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8-1 Conditions of Construction Cost Estimation

1) Unit Prices

The unit prices have been calculated with reference to the unit prices used in the construction of the route projected by the Ministory of Transportation (MOT), allowing for inflation at a rate of about 30%. The estimation of required labor is based on the design of the Government of Peru. Unit prices of labor and materials and machinery depreciation are shown in Tables 8-1, 8-2, and 8-3.

Table 8-1 Unit labor cost

	(MOT) project (1972)		This project (MOT)Price x 1.3)	
	Soles	Yen	Soles	Yen
Skilled worker	246.67	1,677	320.00	2,176
Semi-skilled worker	216.70	1,474	281.00	1,911
Worker	186.63	1,269	243.00	1,652
Foreman	374.00	2,543	486.00	3,305

[1 soles = 6.8 yen]

Table 8-2 Unit material cost

Material	Unit	MOT project		This project (MOT) price x 1.3)	
		Soles	Yen	Soles	Yen
Dynamite	kg	45	306	59	401
Cobble stone	m3			650	4,420
Crushed stone	m3	250	1,700	325	2,210
Sand	m3	150	1,020	195	1,326
Reinforcing bar	t			20,000	136,000
PC steel bar	t			140,000	952,000
Cement	Bag	60	408	78	530

[1 soles = 6.8 yen]

2) Unit Cost of Construction Work

The construction cost of this project has been estimated on the basis of the unit costs of the MOT project. The items which differ in unit cost from those of the MOT project are as follows.

1. In the MOT project grading was carried out by motor grader and the embankment was compressed by roller, whereas it seems impossible to use the motor grader in this project, since much of the filling material is soft rock. This makes it necessary to use the bulldozer (DC6) instead of the motor grader and roller; thus a higher unit cost of earthwork. The same thing can be said of the embankment which needs transportation of earth over a distance of 1 km or less.

Table 8-3 Unit cost of earthwork

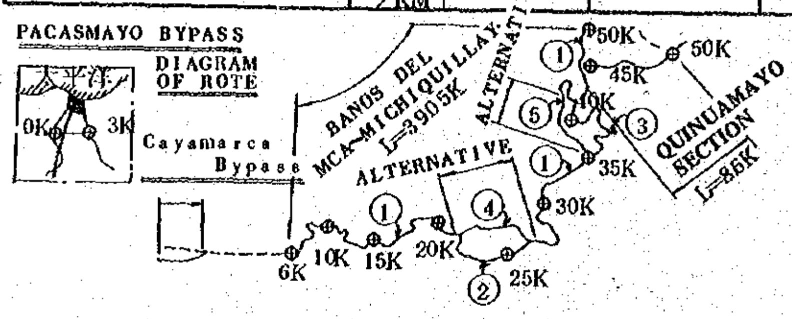
		MOT project (1972)	This project
Embankment without imported earth	Amount of daily work	2,000 m^3	350 m^3
	Unit cost (soles)	1972years x 1.3= 7.8	27
Embankment needing imported earth (within 1 km)	Amount of daily work	2,000 m^3	400 m^3
	Unit cost (soles)	1972years x 1.3=33.8	81

2. The unit cost of laying the subgrade does not differ from this project to the MOT project, because the soil found on site is used, but the unit cost of laying the subbase is higher in this project, because the subbase material is broken stone crushed in a crusher.

3. The surfacing material is mixed in an asphalt plant and laid on the road base by a finisher. The unit cost of surfacing is higher in this project, in large part because of a difference in distance of transportation. Since one asphalt plant is planned to be used over the whole distance of 39 km in this project, the average distance of asphalt transportation is 10 km. On the other hand, the correspond-

8 – 2 NET COSTS OF ROAD CONSTRUCTION

SECTON / ITEM	UNIT	UNIT PRICE (1,000S)	PACASMAYO BYPASS QUANTITY	PACASMAYO BYPASS AMOUNT (1,000S)	CAJAMARCA BYPASS QUANTITY	CAJAMARCA BYPASS AMOUNT (1,000S)	BANOS DEL INCA～MICHIQUILLAY ①+②+③ QUANTITY	①+②+③ AMOUNT (1,000S)	①+④+⑤ QUANTITY	①+④+⑤ AMOUNT (1,000S)	①+②+⑥ QUANTITY	①+②+⑥ AMOUNT (1,000S)	①+④+③ QUANTITY	①+④+③ AMOUNT (1,000S)	QUINUAMAYO AREA QUANTITY	QUINUAMAYO AREA AMOUNT (1,000S)
EARTH WORK: EARTH WORK				3,773		7,098		68,761		95,310		56,995		76,402		24,098
CUT				2,721		5,207		59,102		74,813		49,272		59,859		22,303
COMMON	M³	30	10,895	326	9,788	293	62,706	1,881	89,281	2,678	67,392	2,020	67,397	2,021	10,978	329
SOFT ROCK	〃	71	30,506	2,165	57,977	4,116	559,039	39,691	735,414	52,214	522,147	37,072	567,723	40,308	170,174	12,082
HARD ROCK	〃	106	2,179	230	7,530	798	165,385	17,530	187,935	19,921	96,091	10,180	165,379	17,530	93,322	9,892
BANK				1,052		1,891		9,659		20,497		7,723		16,543		1,795
EMBANKMENT Trunfer Length Within 1KM	M³	81	10,000	810	20,000	1,620	59,000	4,779	173,000	14,013	83,000	6,723	149,000	12,069	5,000	405
EMBANKMENT Tranfer Length Within 0.3KM	〃	27	8,972	242	10,051	271	180,774	4,880	240,174	6,484	37,049	1,000	165,721	4,474	51,514	1,390
PAVE MENT: PAVE MENT				4,252		4,673		55,516		72,195		57,307		54,364		11,975
SUBBASE COURSE	M²	37	28,600	1,058	31,400	1,161	369,600	13,675	481,414	17,812	381,734	14,124	361,867	13,389	80,000	2,960
BASE COURSE	〃	49	27,400	1,342	30,100	1,474	354,900	17,390	462,146	22,645	366,516	17,959	347,485	17,026	76,800	3,763
SURFACE COURSE	〃	98	18,700	1,852	20,800	2,038	249,500	24,451	323,860	31,738	257,390	25,224	244,380	23,949	53,600	5,252
STRUCTURE: STRUCTURE				1,507		0		12,319		12,972		10,169		11,630		331
PC BRIDGE	M²	13,730	97.5	1,340	0	0	423.0	5,807	423.0	5,807	423.0	5,807	423.0	5,807	0	0
RC BRIDGE	〃	7,200	0	0	0	0	462.0	3,326	462.0	3,326	182.0	1,310	462.0	3,326	0	0
CORRUGA TED METAL PIPEØ1.00	M	3,737	43.5	162	0	0	190.5	711	272.5	1,018	188.5	704	218.5	816	34.0	127
〃 Ø1.50	〃	10,241	0	0	0	0	55.0	563	55.0	563	55.0	563	30.0	307	20.0	204
〃 Ø1.80	〃	14,542	0	0	0	0	131.5	1,912	131.5	1,912	99.0	1,439	94.5	1,374	0	0
MASONRY	M²	350	0	0	0	0	0	0	990.0	346	990.0	346	0	0	0	0
ROAD SIGN: ROAD SING				6		6		137		136		134		138		48
KM SING		1,300	4	5	3	3	40	52	41.0	53	42	54	39	50	10	13
WARNING SING	〃	650	2	1	6	3	132	85	128	83	124	80	136	88	54	35
CONSTRACTON OF DUM	M³	152	0	0	0	0	0	0	767,000	(116,584)	0	0	767,000	(116,584)	0	0
SUB TOTAL				9,534		11,777		136,733		180,613 (297,197)		124,605		142,534 (259,118)		36,452
TRANSPORTATON COST OF EQUIPMENT		5%		477		588		6,836		9,030 (14,859)		6,230		7,126 (12,955)		1,822
TOTAL	1,000 Soles			10,011		12,365		143,569		189,643 (312,056)		130,835		149,660 (272,073)		38,274
LENGTH	KM			K 3.17		K 3.665		K 39.05		K 39.58		K 40.43		K 38.2		K 8.6
COST PER 1KM	1000 Soles/KM			3,158		3,374		3,676		4,791 (7,884)		3,236		3,917 (7,122)		4,450
					ALTERNATIVE ROUTE		①+②+③		①+④+⑤		①+②+⑥		①+④+③		QUINUAMAYO ROUTE	



Note;

①; 6.0K～20.8K, 26.45K～35.10K, 41.10K～45.05K

②; 20.80K～26.45K (ROUTE A)

③; 35.10K～41.10K (〃 〃)

④; 20.80K～25.60K (〃 B)

⑥; 35.10K～42.48K (〃 〃)

NOTE; ( ) in cluding lar thwork of the dun

FOREIGN COMPONENT OF ROAD COSTS

	SECTION / ITEM	UNIT	UNIT PRICE	PACASMAYO BYPASS		CAJAMARCA BYPASS		BANOS DEL INCA~MICHIQUILLAY								QUINUAMAYO AREA	
								①+②+③		①+④+⑥		①+②+⑥		①+④+③			
				QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT
EARTH WORK	EARTH WORK				(1,000S) 1,693		(1,000S) 3,146		(1,000S) 29,380		(1,000S) 41,472		(1,000S) 24,494		(1,000S) 33,186		(1,000S) 10,011
	CUT				1,157		2,185		24,430		31,017		20,572		24,757		9,085
	COMMON	M³	14	10,895	153	9,788	137	62,706	878	89,281	1,250	69,392	971	67,397	944	10,978	154
	SOFT ROCK	〃	30	30,506	915	57,977	1,739	559,039	16,771	735,414	22,062	522,147	15,664	567,723	17,032	170,174	5,105
	HARD ROCK	〃	41	2,179	89	7,530	309	165,385	6,781	187,935	7,705	96,014	3,937	165,379	6,781	93,322	3,826
	BANK				536		961		4,950		10,455		3,922		8,429.		926
	EMBANKMENT Trunfer Length Within 1KM	M³	41	10,000	410	20,000	820	59,000	2,419	173,000	7,093	83,000	3,403	149,000	6,109	5,000	205
	EMBANKMENT Trunfer Length Within 0.3KM	〃	14	8,972	126	10,051	141	180,774	2,531	240,174	3,362	37,049	519	165,721	2,320	51,514	721
PAVE MENT	PAVE MENT				1,779		1,954		23,203		30,178		23,952		22,721		5,007
	SUBBASE COURSE	M²	16	28,600	458	31,400	502	369,600	5,914	481,414	7,703	381,734	6,108	361,867	5,790	80,000	1,280
	BASE COURSE	〃	22	27,400	603	30,100	662	354,900	7,808	462,146	10,168	366,516	8,063	347,486	7,645	76,800	1,690
	SURFACE COURSE	〃	38	18,900	718	20,800	790	249,500	9,481	823,860	12,307	257,390	9,781	244,380	9,286	53,600	2,037
STRUCTURE	STRUCTURE				291		0		1,841		1,907		1,626		1,773		33
	PC BRIDGE	M²	2,814	97.5	274	0	0	423.0	1,190	423.0	1,190	423.0	1,190	423.0	1,190	0	0
	RC BRIDGE	〃	720	0	0	0	0	462.0	333	462.0	333	182.0	131	462.0	333	0	0
	CORRUGATED METAL PIPEφ100	M	374	43.5	16	0	0	190.5	71	272.5	102	188.5	70	218.5	82	34.0	13
	〃 φ1.50	〃	1,024	0	0	0	0	55.0	56	55.0	56	55.0	56	30.0	31	20.0	20
	〃 φ1.80	〃	1,454	0	0	0	0	131.5	191	131.5	191	99.0	144	94.5	137	0	0
	MASONRY	M²	35	0	0	0	0	0	0	990.0	35	990.0	35	0	0	0	0
ROAD SIGN	ROAD SING				1		2		22		22		21		23		8
	KM SING		130	4	1	3	1	40	5	41.0	5	42	5	39	5	10	1
	WARNING SING	〃	130	2	0	6	1	132	17	128	17	124	16	136	18	54	7
	CONSTRACTON OF DAM	M³	69	0	0	0	0	0	0	767,000	(52,923)	0	0	267,000	(52,923)	0	0
	SUB TOTAL				3,763	(39.5%)	5,100	(43.3%)	54,446	(39.8%)	73,579 (126,502)	(40.7%) (42.6%)	50,093	(39.3%)	57,703 (110,626)	40.5% (42.7%)	15,059 (41.3%)
	TRANSPORTATON COST OF EQUIPMEMT				0		0		0		0		0		0		0
	TOTAL	1,000 so les			3,763	(37.6%)	5,100	(41.2%)	54,446	(37.9%)	73,579 (126,502)	(38.8%) (40.5%)	50,093	(37.5%)	57,703 (110,626)	38.6% (40.7%)	15,059 (39.3%)
	LENGTH	KM			K 3.17		K 3.665		K 39.05		K 39.58		K 40.43		K 38.2		K 8.6
	COST PER IKM	1,000 so les /KM			1,187		1,392		1,394		1,859 (3,196)		1,239		1,510 (2,896)		1,751

LOCAL COMPONENT OF ROAD COSTS

	SECTION / ITEM	UNIT	UNIT PRICE	PACASMAYO BYPASS		CAJAMARCA BYPASS		BANOS DEL INCA~MICHIQUILLAY								QUINUAMAYO AREA	
								① + ② + ③		① + ④ + ⑤		① + ② + ⑤		① + ④ + ③			
				QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT	QUANTITY	AMOUNT
EARTH WORK	EARTH WORK				(1,000S) 2,080		(1,000S) 3,952		(1,000S) 39,381		(1,000S) 53,838		(1,000S) 32,501		(1,000S) 43,216		(1,000S) 14,087
	CUT				1,564		3,022		34,672		43,796		28,700		35,102		13,218
	COMMON	M^3	17	10,895	173	9,788	156	62,706	1,003	89,281	1,428	69,342	1,049	67,397	1,077	10,978	175
	SOFT ROCK	〃	43	30,506	1,250	57,977	2,377	559,039	22,920	735,414	30,152	552,147	21,408	567,723	23,276	170,174	6,977
	HARD ROCK	〃	67	2,179	141	7,530	489	165,385	10,749	187,935	12,216	96,014	6,243	165,379	10,749	93,322	6,066
	BANK				516		930		4,709		10,042		3,801		8,114		869
	EMBANKMENT Trun fer Length Within 1KM	M^3	40	10,000	400	20,000	800	59,000	2,360	173,000	6,920	83,000	3,320	149,000	5,960	5,000	200
	EMBANKMENT Trun fer Length Within 0.3KM	〃	13	8,972	116	10,051	130	180,774	2,349	240,174	3,122	37,049	481	165,721	2,154	51,514	669
PAVEMENT	PAVEMENT				2,473		2,719		32,313		42,017		33,355		31,643		6,968
	SUBBASE COURSE	M^2	21	28,600	600	31,400	659	369,600	7,761	481,414	10,109	381,734	8,016	361,867	7,599	80,000	1,680
	BASE COURSE	〃	27	27,400	739	30,100	812	354,900	9,582	462,146	12,477	366,516	9,896	347,485	9,381	76,800	2,073
	SURFACE COURSE	〃	64	18,900	1,134	20,800	1,248	249,500	14,970	323,860	19,431	257,390	15,443	244,380	14,663	53,600	3,215
STRUCTURE	STRUCTURE				1,212		0		10,478		11,065		8,543		9,857		298
	PC BRIDGE	M^2	10,916	97.5	1,066	0	0	423.0	4,617	423.0	4,617	423.0	4,617	423.0	4,617	0	0
	RC BRIDGE	〃	6,885	0	0	0	0	462.0	2,993	462.0	2,993	182.0	1,179	462.0	2,993	0	0
	CORRUGATED METALPIPE φ1.00	M	3,363	43.5	146	0	0	190.5	640	272.5	916	188.5	634	218.5	734	34.0	114
	〃 φ1.50	〃	9,217	0	0	0	0	55.0	507	55.0	507	55.0	507	30.0	276	20.0	184
	〃 φ1.80	〃	13,088	0	0	0	0	131.5	1,721	131.5	1,721	99.0	1,295	94.5	1,237	0	0
	MASONRY	M^2	315	0	0	0	0	0	0	990.0	311	990.0	311	0	0	0	0
ROAD SIGN	ROAD SIGN				5		7		115		114		113		115		40
	KM SIGN		1,170	4	4	3	2	40	47	41.0	48	42	49	39	45	10	12
	WARNING SIGN	M^2	520	2	1	6	5	132	68	128	66	124	64	136	7.0	54	28
CONSTRACTON OF DAM		M^3	83	0	0	0	0	0	0	767,000	(63,661)	0	0	767,000	(63,661)	0	0
SUB TOTAL					5,771	(60.5%)	6,677	(56.7%)	82,287	(60.2%)	107,034 (170,695)	59.3% (57.4%)	74,512	(60.7%)	84,831 (148,492)	59.5% (57.3%)	21,393 (58.7%)
TRANSPORTATON COST OF EQUIPMEMT					477		588		6,836		9,030 (14,859)		6,349		7,126 (12,955)		1,822
TOTAL		1,000 Soles			6,248	(62.4%)	7,265	(58.8%)	89,123	(62.1%)	116,064 (185,554)	61.2% (59.5%)	80,742	(62.5%)	91,957 (161,447)	61.4% (59.3%)	23,215 (60.7%)
LENGTH		KM			K 3.17		K 3.665		K 39.05		K 39.58		K 40.43		K 38.2		K 8.6
COST PER 1KM		1,000 Soles /KM			1,971		1,982		2,282		2,932 (4,688)		1,997		2,407 (4,226)		2,699

ing distances are 33. 6 km and 5 km, respectively, in the MOT project. Furthermore, stone crushing is another factor which boosts the unit cost of earthwork and surfacing in this project.

The construction cost is divided into the domestic currency portion (for equipment and materials which can be locally procured in Peru) and the foreign currency portion (equipment and materials which have to be imported from abroad), as shown in Table 8-7.

8-2 Road

The estimated cost of road improvement and reconstruction is shown in the table to follow.

Table 8-4

	Net costs	Engineering fee	Contingency	Sub-total
Pacasmayo Bypass	10,011	1,000	1,500	12,511
Cajamarca Bypass	12,365	1,200	1,800	15,365
Banos Del Inca - Michiquillay	130,835	13,100	19,600	163,535
Quinuamayo Bypass	38,274	3,800	5,700	47,774
Total	191,485	19,100	28,600	239,185

Note: Engineering fee is 10% of net costs of construction.
Contingency is 15% of net costs of construction.

8-3 Bridges

The estimated cost of bridge improvement and reconstruction is shown in the table to follow.

Table 8-5 Estimated cost of bridge

Unit: 1000 Soles

	Net costs	Engineering fee	Contingency	Sub-total
Yonan	24,660	2,400	3,700	30,760
Chuqui Mango	7,330	700	1,100	9,130
La Monica	8,460	800	1,300	10,560
La Muyuna	15,620	1,500	2,300	19,420
Chetilla	11,250	1,100	1,700	14,050
Lla Gaden	4,450	400	700	5,550
Bay Lle	15,280	1,500	2,300	19,080
Yu Magual	2,450	200	400	3,050
Choten	5,250	500	800	6,550
Shingolcaga	2,640	300	400	3,340
Total	97,390	9,400	14,700	121,490

Note: Engineering fee is 10% of net costs of construction
Contingency is 15% of net costs of construction

Table 8-6 Estimated construction net cost of bridge

Unit: 1000 Soles

	Superstructure	Substructure	Approach	Net costs
Yonan	18,300	3,360	3,000	24,660
Chuqui Mango	3,900	3,430	0	7,330
La Monica	3,800	4,660	0	8,460
La Muyuna	7,300	6,800	1,520	15,620
Chetilla	5,100	4,400	1,750	11,250
Lla Gaden	1,360	2,600	490	4,450
Bay Lle	10,000	5,280	0	15,280
Yu Magual	1,000	200	1,250	2,450
Choten	960	3,500	790	5,250
Shingolcaga	400	1,760	480	2,640
Total	52,120	35,990	9,280	97,390

CHAPTER 9

ECONOMIC EVALUATION OF THE PROJECT

CHAPTER 9

ECONOMIC EVALUATION OF THE PROJECT

9-1 Method of Evaluation

This section deals with the method of estimation of costs and benefits of this projects. The costs and benefits of this project are determined by discounting the value of the costs and benefits for a certain period to the level of the year when the road comes into service.

The cost benefit ratio is obtained by dividing the discounted benefits by the discounted expenses, and the internal rate-of-return is determined by the discount rate which makes the benefit equal the costs.

In case cost-benefit ratio is more than 1.0 under the rate-of-return approach which is adopted in this study, this project is enough to justify the investment. In like manner, prospective rate of return is more than opportunity cost of this country on this investment, the investment of this project is evaluate to be reasonable.

The flow chart of this analytical procedure is shown in Fig. 9-1.

At the same time, sensitivity analysis was made so as to determine the stability of this project. The factors used in sensitivity analysis are as follows.

a) Construction costs: In case estimated construction cost increases 10% and 20%.

b) Benefits: With and without time saving benefits.

c) Discount rate: 10%, 12%, 15%

9-2 Data as Conditions of Analysis

Mention will now be made of the conditions which have been not studied in the foregoing sections. Traffic growth has already been discussed in detail in Section 5-2-2 and 5-2-3.

9-2-1 Transportation

As sufficient information has not been collected concerning the transportation cost, it has been estimated, using the data of transportation cost per km between Pacasmayo and Michiquillay obtained from the Department of Transportation of Peru and other relevant materials.

Since the transportation cost does not greatly differ from the heavy truck to the bus, the vehicles are divided into light and heavy vehicles. The transportation cost per km for a flat, paved road (gradient, 1-3%) is shown in Table 9-1. The transportation cost is purely economic expenses excluding customs duty and taxes.

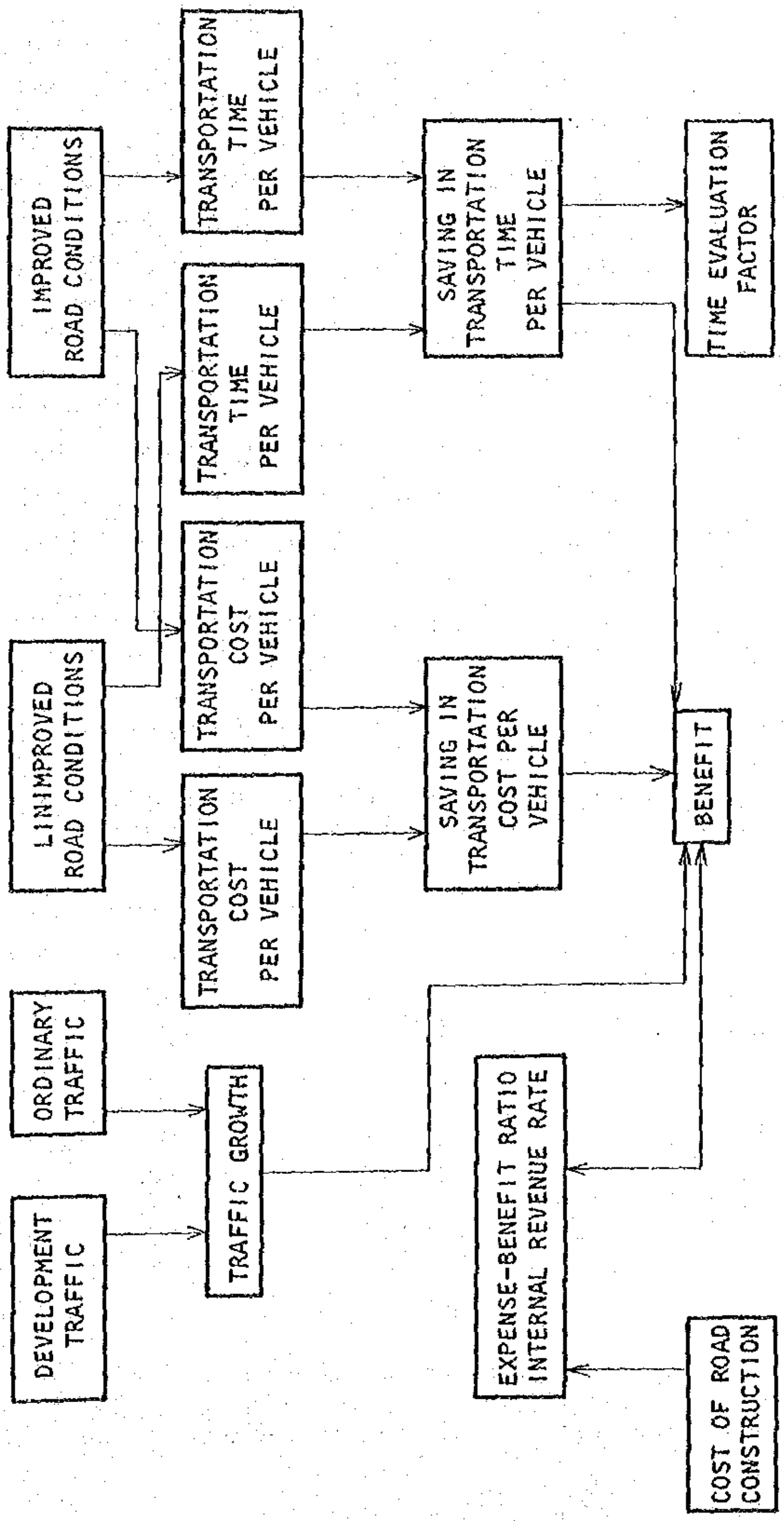


Figure 9-1 Flow chart of cost-benefit analysis

9-1 Vehicle operating cost

[Soles/km]

	Light vehicle	Heavy vehicle
1. Running cost		
1) Depreciation & interest	0.44	1.12
2) Fuel	0.27	0.78
3) Oil and lubricants	0.05	0.09
4) Tires and tubes	0.08	0.51
5) Maintenance	0.48	0.67
Subtotal	1.32	3.17
2. Fixed cost		
1) Depreciation & interest	0.44	1.12
2) Insurance	0.30	0.32
3) Driver and assistant	1.64	2.25
4) Overhead	1.06	0.88
Subtotal	3.44	4.57
3. Total operating cost	4.76	7.74

Table 9-2 Correction coefficients for estimation of transportation cost by road conditions and vehicles

Type	Condition	Light vehicles	Buses/Trucks
Paved	Good	100	100
	Fair	115	125
	Bad	140	170
Gravel	Good	115	125
	Fair	130	150
	Bad	150	180
Earth	Good	130	150
	Fair	(130)	(150)
	Bad	200	280

* Good : no potholes or corrugation
Fair : some potholes
Bad : corrugated surface or rutted surface

Terrain	Light vehicles	Buses/Trucks
Flat	100	100
Rolling	110	120
Mountainous	130	140

Flat : gradient = 0 ~ 3%
Rolling : gradient = 3 ~ 5%
Mountainous: gradient = over 5%

** These figures were cited from IBRD report

9-2-2 Road Conditions

The road conditions which are considered to produce a direct effect on transportation cost are listed in Tables 9-3 and 9-4, assuming two cases where the road is either improved or not.

Table 9-3 Road conditions (Unimproved)

Key point	Distance (km)	Surfacing	Surface condition	Distance by gradients(km) 0-3%	3-5%	5% up
Cajamarca						
	5	Paved	Good	5.0	0	0
Banos de Inca						
	2	Gravel	Fair Bad	11.4	2.4	6.2
Banos del Inca + 2 km						
	3	Gravel	Fair Bad	2.2	0.6	0.2
Polloc						
	5	Gravel	Fair Bad	3.0	0.6	1.4
Encanada						
	8	Gravel	Fair Bad	3.7	1.6	2.7
Michiquillay						

Table 9-4 Road conditions (Improved)

Key point	Distance (km)	Surfacing	Surface condition	Distance by gradients(km) 0-3%	3-5%	5% up
Cajamarca						
	5	Paved	Good	5.0	0	0
Banos del Inca						
	2	Paved	Good	11.4	8.6	0
Banos del Inca + 2 km						
	3	Paved	Good	2.2	0.8	0
Polloc						
	5	Paved	Good	3.0	2.0	0
Encanada						
	8	Paved	Good	3.7	4.3	0
Michiquillay						

9-2-3 Benefit Derived from Saving in Transportation Time

There are many arguments against the inclusion of the saving in transportation time into the benefits of road improvement, in large part because it is extremely difficult to estimate the time evaluation factor. However, since it is beyond doubt that the saving in transportation time brings about a benefit it one form or another, the benefit of this sort has been estimated on the basis of several assumptions.

The time evaluation factor used in this feasibility study is the observed value which is used in Japan, and it has been corrected by the ratio of Japan-Peru income ratio, as shown below.

$$A = B \times \frac{\text{Per capita income in Peru}}{\text{Per capita income in Japan}}$$

where,

A = time evaluation factor in Peru

B = time evaluation factor in Japan

$$A \text{ (light vehicles)} = 8.41 \text{ yen/min} \times \frac{US\$435}{US\$2,400} = 1.52 \text{ yen/min}$$
$$= 0.224 \text{ soles/min}$$

$$B \text{ (heavy vehicles)} = 16.41 \text{ yen/min} \times \frac{US\$435}{US\$2,400} = 2.97 \text{ yen/min}$$
$$= 0.437 \text{ soles/min}$$

Assuming that the average vehicle speed on the unimproved road is 35-40 km/hr and the average vehicle speed on the improved road is 60 km/hr, a saving of about 20 min can be achieved by improving the project road over a distance of 41 km. Accordingly, the benefit derived from the time saving can be calculated as follows.

Light vehicle

$$\text{Benefit} = 0.224 \text{ soles/min} \times 20 \text{ min} \times \frac{1}{41 \text{ km}} = 0.109 \text{ soles/km/vehicle}$$

Heavy vehicle

$$\text{Benefit} = 0.437 \text{ soles/min} \times 20 \text{ min} \times \frac{1}{41 \text{ km}} = 0.213 \text{ soles/km/vehicle}$$

9-2-4 Other Conditions

1) Road Construction Cost

The cost of construction of the road using costs and benefits analysis includes direct construction cost and engineering fee and excludes contingency. The cost of construction of the road including the Cajamarca bypass and the section between Banos del Inca and Michiquillay is placed at 157,000,000 soles. The assumption is made that the entire cost is defrayed in 1978 when the road comes into service.

2) Observation Period and Life of the Road

The observation period and life of the road is 20 years, and the assumption is made that the residual value of the road is zero after the lapse of 20 years.

9-3 Results of Cost-benefit Analysis

The results obtained by analyzing the costs and benefits of this projects under the conditions set forth in the foregoing sections are shown below.

1) Cost-benefit ratio

The real value of the benefits discounted at different rates to the level of the year of road service inauguration is as follows.

Benefit [in million sales]

Discount rate	Ordinay traffic		Development traffic (direct)		Development traffic (indirect)		Indirect traffic		Total	
	A(1)	B(2)	A(1)	B(2)	A(1)	B(2)	A(1)	B(2)	A(1)	B(2)
10%	123.4	112.6	93.8	90.3	52.0	49.9	12.3	11.2	281.5	264.0
12%	104.5	95.5	80.4	77.4	43.3	41.5	10.4	9.6	238.6	224.0
15%	83.5	76.3	65.2	62.8	33.6	32.3	8.3	7.6	190.6	179.0

A = Benefit
B = Time-saving benefit excluded

The expense-benefit ratio is as follows.

Discount rate	Construction cost C (1)	C (2)	C x 1.10 (1)	C x 1.10 (2)	C x 1.20 (1)	C x 1.20 (2)
10%	1.79	1.67	1.62	1.52	1.49	1.39
12%	1.51	1.42	1.37	1.29	1.26	1.18
15%	1.21	1.13	1.16	1.03	1.01	0.94

2) Internal rate of return

The internal rate-of-return obtained by analyzing the costs and benefits including running cost and time saving cost are as follows.

The Internal rate-of-return is:

16.8%, if the construction cost is 157,500,000 soles;

15.3%, if the construction cost increases at a rate of 10%;

14.3%, if the construction cost increases at a rate of 20%;

3) Consideration of the results

The results of cost-benefit ratio shows Table 9-6. According to this list, in case discount rate is 15% and construction cost increases 10% of prospective cost, cost-benefit ratio comes less than 1.0. When discount rate is less than 12%, if construction cost comes 20% expensive of the estimated cost, .ost-benefit ratio is more than 1.0.

It is very hard to forecast suitable discount rate accurately, however discount rate, which is applied in the rate-of-return methods of economic analysis by an international agency. In same manner, rate-of-return is 14.3%, more than 10 - 20%, if construction cost comes up 20%. Therefore, this project is high enough to justify the investment.

9-4 Other Qualitative Economic Effects

In addition to the above-mentioned economic effects which can be quantitatively determined, qualitative effects which are hard to treat as economic parameters are as follows.

- Improvement of road will promote comfort of travelling, decrease of traffic accidents and decrease of damage of loadings.
- Up grade of pavement structure will produce effects in order to increase carrying capacity by using heavy vehicles.
- Improvement of road will induce generated traffic to stimulate the flow of community people, communications and administrative activities.
- Furthermore, road construction itself will give the benefit of employment to the community where there are a number of latent jobless people.
- According to improvement of pavement, maintenance costs of improvement road will be more reduced than of existing road.

The benefits as mentioned above will produce effects of the investment in this project.

APPENDIX

DEVELOPMENT OF A WATER RESOURCE FOR THE MICHIQUILLAY MINE

DEVELOPMENT OF A WATER RESOURCE FOR THE MICHIQUILLAY MINE

1. Objectives of the Water Resource Survey

To promote the project of mining at Michiquillay it requires to build an electric power station, a water supply system, roads, a port, houses, and other related facilities. In this study the plans of the Peruvian government to tap a water source in the proposed area, the surveys already made in the proposed area and topographic and geological characteristics of the proposed dam sites have been reviewed in order to make recommendations for a preliminary survey necessary to accumulate more detailed information.

2. Various Plans of Water Resource Development

(1) Plans to Build a Single-purpose Reservoir

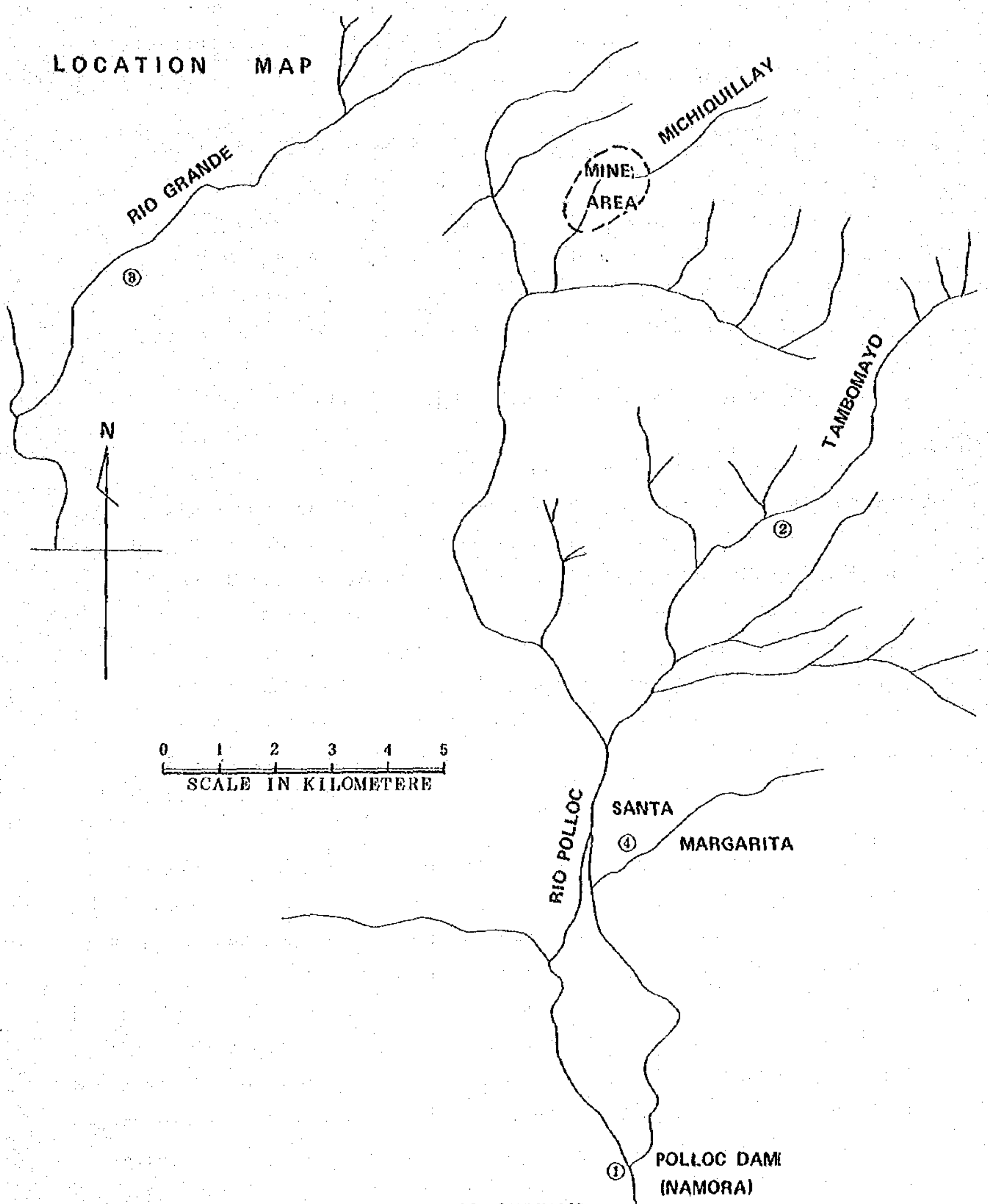
The Mining Corporation of Peru has the following plans of water resource development:

1) Plan to build a single-purpose reservoir in the Namora gorge of the Polloc river (Namora plan)
2) Plan to build a pondage in the Namora gorge to store water of the Polloc river in the single-purpose reservoir to be built in its upstream tributary Tampomayo (Polloc-Tampomayo plan)
3) Plan to build a single-purpose reservoir in the Rio Grande river, a tributary of the Cajamarca river (Rio Grande plan)
4) Plan to utilize ground water in the district of Santa Margarita (plan of ground water utilization)

Of the four plans the Namora plan seems to be the best choice from the standpoint of construction cost and volume of available water.

(2) Plans to Build a Multiple-purpose Reservoir

The Irrigation Committee of the Department of Agriculture of Peru has a plan, called "Jequetepeque-Sanya plan," to build a multi-purpose dam which will serve to irrigate the coastal district and generate electric power for regional industrial development. The first phase of this plan has already been put into action with the aid of West Germany, and the Irrigation Committee is now working on the second phase of this plan with



MICHIQUILLAY WATER SUPPLY MAJOR STREAMS

a view to utilizing the water of the Cajamarca and Namora rivers (tributaries of the Polloc river) in the Atlantic coastal district. To promote this project of regional development, the Irrigation Committee worked out two alternative plans to build a multi-purpose dam which would serve to generate electric power, irrigate the coastal district and supply water to the Michiquillay mine.

1) To convert Lake St. Nicolas located about 7 km southwest of the Namora gorge into a multi-purpose water storage reservoir and build a dam in the Polloc gorge to conduct water from the Polloc river through a tunnel and a siphon (Lake St. Nicolas plan)
2) To build a multi-purpose dam in the Namora gorge (Polloc dam plan)

A geological survey was conducted in the proposed dam site to study the feasibility of the Lake St. Nicolas plan. At the survey revealed that the soil condition of the proposed dam site was not favorable, the plan was given up (in 1974). On the other hand, topographical and geological maps were prepared, and test boring was performed at three locations to study the feasibility of the Polloc dam plan, but its study was not completed. Later this project was transferred from the Department of Agriculture to the Development of Energy and Mining, but the survey has not been resumed to date.

3. Promotion of the Project of Water Resource Development

The development of the Michiquillay mine is one of Peru's urgent programs of economic and industrial development, but the plan to supply water to the mine has been making little progress. This is probably because the Mining Corporation can do nothing but receive water as far as the development and utilization of water resources are concerned, whereas the Department of Agriculture with which the right to plan and decide the development of water resources rests attaches priority to the Jequetepe-Sanya plan of regional development.

As recent news has it, a committee of Michiquillay mine development was established some time ago, and it has been decided that officials from related government departments would study the project of regional development from various angles. With this decision made, it is expected that the committee will also go in for scrutiny of the plan of water resource development in the near future.

The Lake St. Nicolas plan was given up in large part because high permeability of the soil of the dam site, but the survey made to date shows that the soil of the proposed dam site of the Polloc river may also be so permeable as to present a problem. If a more detailed survey showed that this dam site is as permeable as the dam site of the Lake St. Nicolas plan, it would be difficult to promote the Jequetepe-Sanya plan beyond its first phase. In case of such an unfavorable outcome, therefore, it is of prime importance to study the feasibility of multi-purpose dam construction in the Namora gorge. In conclusion it is recommended that a survey be started at an early date to collect accurate information necessary to study the feasibility of the Namora plan.

4. Recommended Survey Policy

It is necessary to use far more care in the survey of proposed dam sites. The survey to be resumed to select an optimum dam site and plan boring tests should consist of geologic survey and seismic prospecting in a wider area including the proposed dam site. The area with impermeable marshy deposits up the proposed dam site may provide a solution to the problem of permeability.

The problem with the proposed dam site is the high permeability of its soil. Unless the outcome of seismic prospecting is most unfavorable, tunnel driving would also be necessary in addition to boring test so as to obtain sufficient geological data. It is also desirable that specialists in dam construction should also survey the proposed dam site to collect information necessary for dam construction.

The estimated construction periods for the plans to build multipurpose dams for regional development including the Michiquillay mine and a single-purpose dam and pumping wells dedicated to the development of Michiquillay mine are compared in the table below. If the multipurpose dam is chosen in preference to the small single purpose dam or utilization of ground water, there is danger that it may not serve the Michiquillay mine (expected to come into operation in 1981 or 1982) in time, unless its construction is started at an early date.

It should be noted that some allowance is made in the computation of the construction periods shown below in consideration of the local situation with the supply of construction machinery.

Comparison of Estimated Construction Periods

Stage			Multi-purpose Dams: Proposed Site	Multi-purpose Dams: Upstream Site	Single-purpose Dam and Pumping Wells: Small Dam	Single-purpose Dam and Pumping Wells: Pumping Wells
Basic Survey Period (1 2 years)	1st stage	Seismic prospecting (including ground reconnaissance)	Survey staff: 6 persons (Field survey: 50 days) (Analysis in Japan: 40 days) Total length of measuring line: Approx. 15 km			Number of wells: 55 Well depth: 300 m
	2nd stage	Boring test (including permeability test)	3 locations Total length: 400 m		3 locations Total length: 200m	
		Tunneling	2 locations Total length: 60 m			
		Boring test (including permeability test)		6 locations Total length: 600 m		
Detailed survey and design			2 years	2 years	0.5 year	
Preparations			1 year	1 year	0.5 year	
Construction			3 years	3 years	1 year	
Expected time of completion			7th year	8th year	3rd year	(2nd year)
Notes			If the outcome of seismic prospecting is not favorable, boring test will be performed but no tunnel will be driven.	If the basic survey in the second stage is performed concurrently with the survey of the proposed dam site, the construction period can be further reduced.		The construction period depends on the number of drilling machines used.

5. Reference (Polloc dam)

(1) Topography

Above the level of 3,100 m east and north of the Polloc basin (stretching about 8 km south and north and about 4 km east and west) up the Namora gorge rise steep slopes with spares surface soil and exposed rock and the river bed shows a steep gradient. Below the level of 3,100 m a rolling terrain tends down to an altitude of 3,000 m. West of the Polloc basin the terrain is also rolling, but is higher than the piedmont which lies east and north of the basin. South of the basin there is a mass of mountains which forms the Namora gorge. Laterite is widely distributed east, north and west of the basin, with gully erosions everywhere. Collapses due to well-developed gully erosions on either bank of the river are not rare. The center of the basin forms a vast expanse of land looking like a dish, and the Polloc river flows south through the center of the basin. Both banks of the river forms a terrace. Polloc is a name given the lower reaches of the Michiquillay river which originates in the Michiquillay mine district about 3,800 m above sea level. The drainage area of the Namora gorge is 241 sq.km.

The area is generally above timber line. There is relatively little soil cover and rock is exposed over much of the terrain. Vegetation is sparse, consisting principally of grassy growth, thus runoff rates are rapid, with the stream responding almost immediately to beginning and cessation of precipitation and flash floods readily ensuring on rainfalls.

The Namora gorge where the dam is planned to be built forms a narrow passage of water (about 10 m wide at the narrowest point) where the river bed is at an altitude of about 2,800m. Both banks dip at an angle of 60-70°, forming a precipitous cliff about 130 m high. This is a typical V-shaped valley.

(2) Geology

The bedrocks of the Polloc basin are made up of Cretaceous sediments as in the neighboring highlands. Laterite which is residual soil is thickly distributed over the east and north downlands, with highly weathered bedrocks exposed in places. On the west downland there were weathered bedrocks exposed and much laterite. Laterite is also found in the recesses in the uplands to a considerable altitude. At the center of the Polloc basin sediments looking like a marshy deposit are deposited to a thickness of 170 m or more over a vast expanse.

The area where the bedrocks are exposed near the bed of the Polloc river is located about 1 km up the proposed dam site and down the observatory of river discharge efficiency. This site has the following geological features.

The soil of this site is chiefly composed of white firm quartz sandstone which is regarded as the constituent of the lowest formation in this area. In the Namora gorge is a large anticline structure which has an axis with a west-northwest strike and gradually sinks. It is assumed that there exists a huge fault with a north-northeast strike called "Namora fault" on the left bank of the proposed dam site. This fault is believed to be discontinuous with the geologic formation on both banks, judging from the topography of this site. The proposed dam site is located at the north wing of the anticline, having a nearly east-west strike and dipping north at an angle of 20 to 30°.

There are innumerable well-developed fissures, large and small, in the rock forming the precipitous cliff of the V-shaped Polloc gorge. Some of these fissures are parallel with the bedding of the rock and some are at right angles with it. As will be discussed later, these fissures can be considered responsible for the high permeability of the bedrocks. It is also of great importance to elucidate the properties of the Namora fault which is believed to exist on the left bank of the river.

(3) Permeability of Bedrocks

According to the report of the geological survey of the Polloc dam site, the boring hole was not advanced beyond the pervious layer at three locations except PIV, and the existence of an aquiclude or an impervious layer was not confirmed. At some depths Lugeon coefficient read 70.0 or more, and in the PIV boring test Lugeon coefficient was below 1 near the hole bottom (depth, 65.00 m). In the light of these wide variations in measurements, it is necessary to make further boring tests to obtain more accurate data.

Boring was carried out in the pumping test wells in the left platform (2,985-2,990 above sea level) 5-6 km up the proposed dam site. The data obtained in this boring test show that the main aquifer is made up of a bedrock which differs from that of the dam site. The deepest test well reached a depth of 200 m or more under the unsolidified layer. This fact means that fissures in the bedrocks reach a depth of 200 m or more.
As it is desirable that Lugeon coefficient of the bedrock of the dam should be held below 1, it may be necessary to provide curtain grouting at a considerable depth when building a dam at the proposed site.
It is a large question that permeability of bedrocks are remarkably pervious to water at the proposed dam site. According to results of future investigation, the proposed dam site would be necessary to relocate to the area, which impervious sediments are widely distributed over the upstream of the proposed dam site.

(4) Inferiority of Bedrocks

Within the bedrocks in the test wells as mentioned above, limestone and sandstone were not appreciably affected but shale is argillized into 294 meters in depth.
The argillization of bedrocks has been studied using the boring data obtained in the pumping test wells dug in the area of Santa Margarita. The results are as follows.
The bedrocks in the test wells were all under ground water level, and shales was argillized to a considerable depth, but limestone and quartz sandstone were not appreciably affected. The bedrocks of the Namora gorge are believed to be composed of quartz sandstone of the lowest formation of this area, but it is possible that shales exists at a great depth and is argillized. In this respect the proposed dam site needs a more detailed survey.
Care must also be exercised, since the survey results so far obtained do not rule out the possibility that the bedrocks have been adversely affected by the probable fault of the Namora gorge.

(5) Sedimentation in the Reservoir

As has been discussed in the sections on "Topography" and "Geology," it is expected that a substantial amount of sedimentary materials derived from the disintegration of the surface layers of the upper parts of the valley by rain will be brought into the reservoir. This can be easily inferred from the fact that the boring test in the pumping test well revealed the existence of marshy deposits at a depth as great as 170 m or more. However, there are no data available to calculate the rate of sedimentation for the proposed dam site.

In the previous report, the dead storage of the reservoir was placed at 2,000,000 m^3 on the assumption that the annual rate of sedimentation was 150 m^3/km^2 and the life of the reservoir was 50 years. Judging from the topographic and geologic features of the proposed dam site and the conditions of the river, these values seem to be too small. Data available in Japan suggest that the annual rate of sedimentation exceeds 600 m^3/km^2. Accordingly, it seems necessary to assume a high rate of sedimentation when determining the scale of the dam.

LIST OF DATA

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