FINAL REPORT

VOLUME III SUPPORTING REPORT

I. FACILITIES DESIGN AND COST ESTIMATES

STUDY
ON
INTEGRATED WATER RESOURCES DEVELOPMENT
IN THE CAÑETE RIVER BASIN
IN
THE REPUBLIC OF PERU

FINAL REPORT
VOLUME III
SUPPORTING REPORT

I: Facilities Design

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Chapter 1 Facilities Design

1.1 Preliminary Design

Preliminary design was prepared for the engineering works including dams and water conveyance facilities. Location of the works is shown in Figure 1.1. For comparison with project cost of alternative D/I water conveyance scheme (the Mantaro - Carispaccha scheme) to the Cañete scheme, the Study team reviewed the Mantaro - Carispaccha scheme of the SEDAPAL M/P. Location of the schemes is shown in Figure 1.2.

1.1.1 Dam

In the Cañete River basin, a private cement company, Cemantos Lima S.A. has already conducted some design works for dam and hydroelectric power, which are called “El Platanal Project”. In this project, it is planned to construct one earth fill dam (Paucarcocha dam), one RCC dam with hydroelectric power plant (Morro de Arica dam, recently the dam type was changed to CFRD) and one intake dam with hydroelectric power plant (Capillucas intake dam, concrete gravity type). Typical features are shown in Figures 1.3, 1.4 and 1.6. On the other hand, the Study team assumed additional dam sites (Auco and San Jeromino dams, both RCC type) for the purpose to enhance regulation capacity of the river runoff and carried out preliminary design as shown in Figures 1.5 and 1.7. Location of the dams is seen in Figure 1.1.

1.1.2 Cañete D/I Water Conveyance

Preliminary design for the facilities of the Cañete D/I water conveyance scheme (Mountain Route-1, total length: 206 km) was carried out for the purpose to review the existing design and preliminary cost estimate in a pre-feasibility study by SEDAPAL in 1995. Zuñiga intake dam is shown in Figure 1.8. Figure 1.9 illustrates main facilities of the water conveyance system to be composed of the following elements:

i)	Open channel	:	125 km
ii)	Pipe line (D=1.6m)	:	53 km
iii)	Siphons (D=1.6m)	:	8 km
iv)	Tunnels	:	18 km
v)	Drop	:	2 km
	Total		206 km

Two alternative mountain and coastal routes of the conveyance system were examined as shown in Figures 1.1 and 1.10, and the original Mountain Route-1 was selected for the study in this stage (see Chapter 2, numeral 2.1.2 (2)).

1.1.3 Mantaro - Carispaccha Water Conveyance

Location of facilities for Mantaro - Carispaccha scheme in Stage-1 and Stage-2 are shown in Figure 1.11. System diagram for Mantaro - Carispaccha scheme in Stage-1 is shown in Figure 1.12. Main structures of the scheme are shown in Figures 1.13 and 1.14.

Chapter 2 Cost Estimate

2.1 Preliminary Cost Estimate

2.1.1 Methodology

Existing reports related to the Study listed below were collected for the purpose to review the design, cost data and information including engineer's cost estimates and unit prices:

a) Pre-Feasibility Study on Cañete River Basin for Water Supply to Lima City 1995, SEDAPAL

b) Pomacocha – Rio Balanco Water Transfer Detailed Study (MARCA-II) 1998, SEDAPAL

c) Marcapomacocha Water Transfer Detailed Study (MARCA-III) 1997, SEDAPAL

d) Feasibility Study on Optimization of Rimac River Basin, between Moyopampa and La Atarjea, and the Environmental Impact Study, 1997, SEDAPAL

e) Feasibility Study on Cañete River Hydroelectric Power Project "EL PLATANAL" 1998, Cementos Lima S.A.

f) Feasibility Study on EL PLATANAL Hydroelectric Power Plant 1987, Electroperu S.A.

Cost estimate in this study was made in consideration of the following findings summarized from the collected reports:

a) Unit prices of major component of works were assumed with reference to the records of international bids for schemes of hydroelectric power and water supply development.

b) For dam and/or hydroelectric power scheme, simple conventional cost estimate equations were adopted to estimate project component cost including direct and indirect costs with input of principal dimensions of the project facilities and assumed unit prices.

c) For water conveyance schemes, work quantities were reviewed by a design method of the Study Team based on the preliminary design by SEDAPAL Pre-F/S, 1995.

d) For irrigation scheme, project component cost was worked out as a product of command area and unit price per irrigation area that was gauged with reference to the current cost data of similar schemes in Peru and other countries.

e) Costs of mobilization works and unmeasured factor were assumed as follows.(see Figure-2-1)
- Mobilization works: 10% of total amount of civil works
- Unmeasured factor: 5% of total amount of civil works

f) In-direct Costs are assumed as follows. (see Figure 2.1)
- Administration & Engineering Services: 10% of total direct cost
- Physical Contingency: 10% of total direct cost
- Price Contingency 3% of total direct cost

g) Annual operation and maintenance cost for this study is adopted as follows.
- Open channel: 1.0% of direct cost
- Pumping station: 2.0% of direct cost
- Tunnel: 0.1% of direct cost
- Access road: 0.5% of direct cost
- Pipeline & Siphon: 0.2% of direct cost
- Dam 0.5% of direct cost
- other Facilities 0.5% of direct cost

2.1.2 Project Cost of CANETE Scheme

Main project features and corresponding total project cost are set out below.

(1) Dam and hydroelectric power

For preliminary cost estimate of the dams and hydroelectric power schemes, preliminary design was prepared for each dam (Paucarcocha dam, Morro de Arica dam, Auco dam, Capillucas dam, San Jerónimo dam), as shown in Figures 1.3, 1.4, 1.5, 1.6 and 1.7 by reviewing the existing data and information given by SEDAPAL and Cementos Lima. The total project cost is summarized as follows. The cost-breakdowns are shown in Table-2.1 including of operation & maintenance cost.

Name of Dam	Paucarcocha	Morro de Arica		Auco	Capillucas	San Jerónimo
		High Dam	Low Dam			
Dam Type	Center Core Earthfill Dam	RCC Dam	RCC Dam	RCC Dam	Concrete Gravity Dam	RCC Dam
Dam Vol (m^3)	405,000m^3	2,499,400m^3	1,805,000m^3	6,934,500m^3	76,500m^3	6,635,500m^3
Dam Height from the Bottom (m)	30m	259m	232m	230m	37m	235m
Active Storage Vol.(mcm)	55mcm	245mcm	205mcm	300mcm	-	250mcm
Total Cost (US$ Million)						
Only Dam Construction	16	196	143	535	-	513
Dam & Hydro electric power (Install Capa. MW)	-	239 (50MW)	184 (46MW)	591 (47MW)	164 (200MW)	555 (42MW)

(2) D/I water conveyance

Route	Mountain Route			Coastal Route *	
	Proposed (Route-1)	Alternative (Route-2)	Proposed		
Length of Water Conveyance (km)	206km	172km	206km	165km	
Water Supply to Lima (m^3/sec)	5.0 m^3/sec	5.0 m^3/sec	10.0 m^3/sec	5.0 m^3/sec	10.0 m^3/sec
Diameter & Line of Steel Pipe	D=1.6m x 1line	D=2.0m x 1line D=1.6m x 1line	D=1.6m x 2lines	D=1.8m x 1line D=1.6m x 1line	D=1.8m x 2lines D=1.6m x 2lines
Total Cost (US$ million)	295	365	453	436	739

* 1 Pumping station will be installed on Coastal route.

For preliminary cost estimate, preliminary design was prepared for each water conveyance route as shown in Figures 1.8 and 1.9 by reviewing the design of SEDAPAL Pre-F/S.

It is noted that comparison of alternatives of water conveyance system, the 206 km long mountain route with gravity conveyance (Mountain Route-1) and the 165 km long coastal route with combination of gravity and pumping up, showed the mountain route to be in advantage in cost and operation reliability. The total project cost is summarized as above. The both cost-breakdowns for mountain and Coastal routes in case of water supply to Lima 5.0 & 10.0 m3/sec are shown in Table 2.2 and Table 2.3.

Mountain Route-2 (Figure 1.10) is more costly compared with the proposed Mountain Route-1, though Route-2 is safer against natural disasters such as land sliding because the main component is pipelines and tunnels instead of open channels. The elements of the alternative conveyance line (Route-2) are as follows:

i)	Open channel	:	70.5 km
ii)	Tunnels	:	29.3 km
iii)	Siphons (D=1.6m)	:	19.5 km
iv)	Pipeline(D=2.0m)	:	30.4 km
v)	Pipeline(D=1.6m)	:	19.5 km
vi)	Drop (D=1.6m)	:	2.8 km
	Total		172.0 km

Total project cost for the mountain routes (Route-1 & 2) are summarized as above table. The cost-breakdown of Alternative mountain route (Route 1) are shown in Table 2.4. Unit cost analysis (US$ mill./km) for the Canete Water Conveyance Mountain & Coastal routes are summarized in Table 2.5.

(3) Irrigation

Region	Valle de Cañete	Pampas Altas de Imperial	Pampas de Concón-Topará & Chincha Alta	Total
Irrigation Area (ha)	24,052 ha	2,475 ha	27,000 ha	53,527 ha
Irrigation Water (m^3/sec)	22.3 m^3/sec	1.7 m^3/sec	19.5 m^3/sec	43.5 m^3/sec
Total Cost (US$ million)	13	5	147	164

The cost-breakdowns for Irrigation & Agriculture are shown in Table 2.6.

(4) Operation & Maintenance Costs

The Operation & Maintenance costs for water conveyance mountain route (Route-1) in case of water supply to Lima 5.0 & 10.0 m3/sec are shown in Table 2.7. In Table 2.1 are shown O&M costs for dams.

2.1.3 Project Cost of Mantaro - Carispaccha Scheme

Review result indicated that the cost estimate for the Mantaro-Carispacha D/I water conveyance scheme of the SEDAPAL M/P is overestimated reason is because they considered cost as final stage let say for Q=10m^3/s instead of Q=5m^3/s. The estimate is now 218 million US$ for construction (6.2 million US$ for O/M cost) in the case of water supply of 5.0m^3/s to Lima. The cost-breakdowns and O&M costs for Mantaro Water Conveyance (5.0m^3/s) are shown in Table 2.8. Summary of construction cost is shown in Table 2.9 and unit cost analysis in Tables 2.10 (1/3) to (3/3).

2.1.4 Unit Development Cost of Water

Unit development cost of water is estimated as summarized below in terms of unit dam facilities cost (per 1 m^3 of active storage) and unit conveyance facilities cost (per 1 m^3 of water conveyance) to compare investment efficiency of prospective alternative dams and water conveyance systems.

(1) Unit development cost of dam and hydroelectric power

Name of Dam	Paucarcocha	Morro dde Arca		Auco	Capillucas	San Jerónimo
		High Dam	Low Dam			
Dam Type	Center Core Earthfill Dam	RCC Dam	RCC Dam	RCC Dam	Concrete Gravity Dam	RCC Dam
Active Storage Vol.(mcm)	55 mcm	245 mcm	205 mcm	300 mcm	-	250 mcm
Unit Dam Facilities Cost (US$ / Active Storage Vol. 1.0 m^3)						
Only Dam Constriction	0.3	0.8	0.7	1.8	-	2.1
Dam & Hydro-electric power (Install Capa. MW)	-	1.0 (50 MW)	0.9 (46 MW)	2.0 (47 MW)	- (200 MW)	2.2 (42 MW)

(2) Unit development cost of Cañete water conveyance system

(US$ Million)

Route	Mountain Route			Coastal Route *	
	Route-1 (A)	Route-2	Route-1 (B)		
Length of Water Conveyance (km)	206 km	172 km	206 km	165 km	
Water Supply to Lima (m^3/sec)	5.0 m^3/sec	5.0 m^3/sec	10.0 m^3/sec	5.0 m^3/sec	10.0 m^3/sec
Unit Conveyance Facilities Cost (US$ million/ Water Supply to Lima 1.0 m^3/sec)					
Unit Cost of Water Development	59.0	73.1	45.3	87.2	73.2

TABLES

Table 2.1 Cost Breakdown of Dam & Hydropower (1/3)

CANETE Scheme

Project Cost for Dam & Hydropower

Description	with Hydropower		without Hydropower	
	Construction Cost Amount	Operation & Maintenance Cost per Year	Construction Cost Amount	Operation & Maintenance Cost per Year
Paucarcocha Dam (Rockfill Dam, H=30m, without Hydropower)				
Earth fill Dam			5.383	0.027
Access Road			0.129	0.001
Diversion Works			6.106	
Hydropower Structures, Install Capacity - MW			0.000	
Mobilization for Civil Works (10%)			1.162	
Generating Equipment & Transmission Line			0.000	
Sub-total			12.779	
Administration & Engineering Service (10%)			1.278	
Physical Contingency (10%)			1.278	
Price Contingency (3%)			0.383	
Total			**15.718**	**0.028**
Morro de Arica Dam (RCC, H=259m, High dam)				
Dam RCC	143.544	0.718	143.544	0.718
Access Road	0.857	0.004	0.857	0.004
Diversion Works	0.524		0.524	
Hydropower Structures, Install Capacity 50 MW	13.557	0.068		
Mobilization for Civil Works (10%)	14.493		14.493	
Generating Equipment & Transmission Line	19.643	0.020		
Sub-total	193.974		159.418	
Administration & Engineering Service (10%)	19.397		15.942	
Physical Contingency (10%)	19.397		15.942	
Price Contingency (3%)	5.819		4.783	
Total	**238.588**	**0.809**	**196.084**	**0.722**

Table 2.1 Cost Breakdown of Dam & Hydropower (2/3)

CANETE Scheme
Project Cost for Dam & Hydropower

Description	with Hydropower		without Hydropower	
	Construction Cost Amount	Operation & Maintenance Cost per Year	Construction Cost Amount	Operation & Maintenance Cost per Year
Morro de Arica Dam (RCC, H=232m, Low dam)				
Dam RCC	104.247	0.521	104.247	0.521
Access Road	0.857	0.004	0.857	0.004
Diversion Works	0.524		0.524	
Hydropower structures, Install Capacity 46 MW	12.838	0.064	0.000	
Mobilization for Civil Works (10%)	11.847		10.563	
Generating Equipment & Transmission Line	19.002	0.019	0.000	
Sub-Total	149.314		116.190	
Administration & Engineering Service (10%)	14.931		11.619	
Physical Contingency (10%)	14.931		11.619	
Price Contingency (3%)	4.479		3.486	
Total	**183.656**	**0.609**	**142.914**	**0.526**
Auco Dam (RCC, H=216m)				
Dam RCC	392.927	1.965	392.927	1.965
Access Road	0.857	0.004	0.857	0.004
Diversion Works	1.654		1.654	
Hydropower structures, Install Capacity 50 MW	23.635	0.118	0.000	
Mobilization for Civil Works (10%)	41.907		39.544	
Generating Equipment & Transmission Line	19.790	0.020	0.000	
Sub-Total	480.770		434.981	
Administration & Engineering Service (10%)	48.077		43.498	
Physical Contingency (10%)	48.077		43.498	
Price Contingency (3%)	14.423		13.049	
Total	**591.347**	**2.107**	**535.027**	**1.969**

Table 2.1 Cost Breakdown of Dam & Hydropower (3/3)

CANETE Scheme
Project Cost for Dam & Hydropower

Description	with Hydropower		without Hydropower	
	Construction Cost Amount	Operation & Maintenance Cost per Year	Construction Cost Amount	Operation & Maintenance Cost per Year
Cpillucas Dam / EL Platanal HEPP (Concrete Gravity, H=37m)				
Dam RCC	8.562	0.043		
Access Road	0.159	0.001		
Diversion Works	1.272			
Hydropower structures, Install Capacity 205 MW	76.773	0.384		
Mobilization for Civil Works (10%)	8.677			
Generating Equipment & Transmission Line	37.920	0.038		
Sub-Total	133.362			
Administration & Engineering Service (10%)	13.336			
Physical Contingency (10%)	13.336			
Price Contingency (3%)	4.001			
Total	**164.035**	**0.465**		
San Jeronimo High Dam (High RCC, H=200, with Hydropower)				
Dam RCC	376.774	1.884	376.774	1.884
Access Road	0.857	0.004	0.857	0.004
Diversion Works	1.621		1.621	
Hydropower structures, Install Capacity 72 MW	14.627	0.073		
Mobilization for Civil Works (10%)	39.388		37.925	
Generating Equipment & Transmission Line	17.735	0.018		0.000
Sub-Total	451.002		417.177	
Administration & Engineering Service (10%)	45.100		41.718	
Physical Contingency (10%)	45.100		41.718	
Price Contingency (3%)	13.530		12.515	
Total	**554.732**	**1.979**	**513.128**	**1.888**

Table 2.2 Cost Breakdown of CAÑETE Water Conveyance (Mountain Route)

Preliminary Cost Estimate
for CAÑETE Water Conveyance

Route: Mountain Route
Water Supply: 5.0m3/sec to Lima (US$ million)

	Description	Unit Cost		Quantity		Amount	Remarks
Water Conveyance (5.0m3/sec to Lima)							
1	Intake & Desanding Basin (Zuniga)	-	-	-	-	5.200	
2	Open Channel	0.399	US$ mill./km	124.31	km	49.600	Rectangular Channel
3	Pipe Line	1.473	US$ mill./km	53.24	km	78.423	D=1.6m x 1 line
4	Tunnel	2.517	US$ mill./km	18.10	km	45.558	
5	Siphon & Chamber	2.387	US$ mill./km	8.15	km	19.454	D=1.6m x 1 line
6	Access Road	0.050	US$ mill./km	206.00	km	10.300	
	sub-total					**208.534**	
7	Mobilization (10.0%)					20.853	
8	Unmeasured (5.0%)					10.427	
	sub-total					**239.814**	
9	Administration & Engineering Service (10%)					23.981	
10	Physical Contingency (10%)					23.981	
11	Price Contingency (3%)					7.194	
	Total					**294.971**	

Preliminary Cost Estimate
for CAÑETE Water Conveyance

Route: Mountain Route
Water Supply: 10.0m3/sec to Lima (US$ million)

	Description	Unit Cost		Quantity		Amount	Remarks
Water Conveyance (10.0m3/sec to Lima)							
1	Intake & Desanding Basin (Zuniga)	-	-	-	-	5.200	
2	Open Channel	0.538	US$ mill./km	124.31	km	66.879	Rectangular Channel
3	Pipe Line	2.913	US$ mill./km	53.24	km	155.088	D=1.6m x 2 line
4	Tunnel	2.517	US$ mill./km	18.10	km	45.558	
5	Siphon & Chamber	4.600	US$ mill./km	8.15	km	37.490	D=1.6m x 2 line
6	Access Road	0.050	US$ mill./km	206.00	km	10.300	
	sub-total					**320.515**	
7	Mobilization (10.0%)					32.051	
8	Unmeasured (5.0%)					16.026	
	sub-total					**368.592**	
9	Administration & Engineering Service (10%)					36.859	
10	Physical Contingency (10%)					36.859	
11	Price Contingency (3%)					11.058	
	Total					**453.368**	

Table 2.3 Cost Breakdown of CAÑETE Water Conveyance (CoastalRoute)

Preliminary Cost Estimate
for CAÑETE Water Conveyance

Route: Coastal Route
Water Supply: 5.0m3/sec to Lima (US$ million)

Description	Unit Cost		Quantity		Amount	Remarks
Water Conveyance (5.0m3/sec to Lima)						
1 Intake & Desanding Basin (Zuniga)	-	-	-	-	6.050	
2 Open Channel	0.399	US$ mill./km	28.00	km	11.172	Rectangular Channel
3 Pipe Line						
- D = 1.6m x 1 lines	1.473	US$ mill./km	25.00	km	36.825	
- D = 1.8m x 1 lines	2.025	US$ mill./km	94.50	km	191.363	
4 Tunnel	2.517	US$ mill./km	10.70	km	26.932	
5 Siphon & Chamber	4.600	US$ mill./km	2.00	km	9.200	Qmax = 5.0m3/sec, Head = 112m
7 Pumping Station	-	-	-	-	11.230	
8 Transmission Line	0.130	US$ mill./km	10.00	km	1.300	
9 Substation and Communication	-	-	-	-	1.500	Based on MANTARO scheme
10 Penstock	-	-	-	-	4.500	Based on MANTARO scheme
11 Access Road	0.050	US$ mill./km	165.00	km	8.250	
sub-total					**308.321**	
12 Mobilization (10.0%)					30.832	
13 Unmeasured (5.0%)					15.416	
sub-total					**354.570**	
14 Administration & Engineering Service (10%)					35.457	
15 Physical Contingency (10%)					35.457	
16 Price Contingency (3%)					10.637	
Total					**436.121**	

Preliminary Cost Estimate
for CAÑETE Water Conveyance

Route: CoastalRoute
Water Supply: 10.0m3/sec to Lima (US$ million)

Description	Unit Cost		Quantity		Amount	Remarks
Water Conveyance (10.0m3/sec to Lima)						
1 Intake & Desanding Basin (Zuniga)	-	-	-	-	6.050	
2 Open Channel	0.538	US$ mill./km	28.00	km	15.064	Rectangular Channel
3 Pipe Line						
- D = 1.6m x 2 lines	2.913	US$ mill./km	25.00	km	72.825	
- D = 1.8m x 2 lines	3.813	US$ mill./km	94.50	km	360.329	
4 Tunnel	2.517	US$ mill./km	10.70	km	26.932	
5 Siphon & Chamber	4.600	US$ mill./km	2.00	km	9.200	Qmax = 5.0m3/sec, Head = 112m
7 Pumping Station	-	-	-	-	16.699	
8 Transmission Line	0.130	US$ mill./km	10.00	km	1.300	
9 Substation and Communication	-	-	-	-	1.500	Based on MANTARO scheme
10 Penstock	-	-	-	-	4.500	Based on MANTARO scheme
11 Access Road	0.050	US$ mill./km	165.00	km	8.250	
sub-total					**522.648**	
12 Mobilization (10.0%)					52.265	
13 Unmeasured (5.0%)					26.132	
sub-total					**601.046**	
14 Administration & Engineering Service (10%)					60.105	
15 Physical Contingency (10%)					60.105	
16 Price Contingency (3%)					18.031	
Total					**739.286**	

Table 2.4 Cost Breakdown of CAÑETE Water Conveyance (Alternative Mountain Route)

Preliminary Cost Estimate

Route: Mountain Route

Project Cost for CAÑETE Water Conveyance / Mountain route Alternative (Route-2) (US$ million)

	Description	Unit Cost		Quantity		Amount	Remarks
Water Conveyance (5.0m3/sec to Lima)							
1	Intake & Desanding Basin (Zuniga)	-	-	-	-	5.200	
2	Open Channel	0.399	US$ mill./km	70.50	km	28.130	Rectangular Channel
3	Pipe Line D=2.0m	2.082	US$ mill./km	30.40	km	63.293	
	Pipe Line D=1.6m	1.473	US$ mill./km	22.30	km	32.848	
4	Tunnel	2.517	US$ mill./km	29.30	km	73.748	
5	Siphon & Chamber	2.387	US$ mill./km	19.50	km	46.547	
6	Access Road	0.050	US$ mill./km	172.00	km	8.600	
	sub-total					**258.365**	
7	Mobilization (10.0%)					25.836	
8	Unmeasured (5.0%)					12.918	
	sub-total					**297.120**	
9	Administration & Engineering Service (10%)					29.712	
10	Physical Contingency (10%)					29.712	
11	Price Contingency (3%)					8.914	
	Total					**365.457**	

Table 2.5 Unit Price / Construction Cost Analysis for CAÑETE Water Conveyance (1/5)

Unit Price / Construction Cost Analysis for CAÑETE Water Conveyance Scheme

Description	Unit	Quantity	Construction Unit Cost	Unit Cost (US$ million) Amount	
1. Open Channel (Rectangular Type)					
1-1 Case-1					
Route:	Mountain & Coastal route				
Length of Channel:	Mountain : 124.31km, Coastal route: 28.0km				
Discharge:	Q = 5.0 m3/sec				
Gradient (m/m):	0.0008				
1) Excavation of Platform (Weathered/Rock)	m3/m	21.20	7.0	148.40	
2) Excavation of Trench (Rock)	m3/m	5.40	15.0	81.00	
3) Concrete	m3/m	0.95	110.0	104.50	
4) Reinforcing bar	ton/m	0.05	1,000.0	50.00	
5) Formwork	m2/m	0.05	20.0	1.00	
6) others (5%)				16.70	
Total		Unit Cost for Construction (US$/m):		399.05	
			US$ million	**0.399**	**/km**
1-2 Case-2					
Route:	Moutain route				
Length of Channel:	124.31km				
Discharge:	Q = 10.0 m3/sec				
Gradient (m/m):	0.0008				
1) Excavation of Platform (Weathered/Rock)	m3/m	26.90	7.0	188.30	
2) Excavation of Trench (Rock)	m3/m	8.90	15.0	133.50	
3) Concrete	m3/m	1.20	110.0	132.00	
4) Reinforcing bar	ton/m	0.06	1,000.0	60.00	
5) Formwork	m2/m	0.06	20.0	1.20	
6) others (5%)				22.69	
Total		Unit Cost for Construction (US$/m):		537.69	
			US$ million	**0.538**	**/km**
2. tunnel					
Route:	Mountain & Coastal route				
Total Tunnel Length:	Mountain : 18.1km, Coastal route: 10.7km				
Discharge:	Q = 5.00 m3/sec				
Diameter of Tunnel:	3.0m				
Gradient (m/m):	0.0007				
1) Tunnel Excavation (Rock)	m3	12.90	70.0	903.00	
2) Concrete	m3	4.87	160.0	779.20	
3) Reinforcing bar	ton	0.24	1,100.0	264.00	
4) Straight Formwork	m2	3.00	30.0	90.00	
5) Curved Formwork	m2	4.70	40.0	188.00	
6) Grouting	m	0.50	210.0	105.00	
7) others (10%)				228.81	
		Unit Cost for Construction (US$/m):		2,516.86	
			US$ million	**2.517**	**/km**

Table 2.5 Unit Price / Construction Cost Analysis for CAÑETE Water Conveyance (2/5)

Unit Price / Construction Cost Analysis for
CAÑETE Water Conveyance Scheme

Description	Unit	Quantity	Construction Unit Cost	Unit Cost (US$ million) Amount	
3. Pumping Station (Coastal route)					
3-1 Case-1					
Route:	Coastal route				
Pumping Head H:	112.1 m				
Pump-up Capacity Q:	7.50 m3/sec		Total 3unit / 1unit (2.5m3/sec) for Stand-by		
Install Capacity P:	10.09 MW (3 units)		P = 0.012 x Qmax H (MW)		
1) Civil works	*Total Cost (civil) = 0.34 + 0.53 x (Qmax)$^{0.79}$* =			2.94	
2) Equipment	*Total Cost (Equipment) = 1.22 x P$^{0.80}$* =			7.75	
3) others (5%)				0.53	
	Total Construction Cost for Pumping station (US mill.):			**11.231**	*
*: Total Construction Cost					
3-2 Case-2					
Route:	Coastal route				
Pumping Head H:	112.1 m				
Pump-up Capacity Q:	12.50 m3/sec		Total 5unit / 1unit (2.5m3/sec) for Stand-by		
Install Capacity P:	16.82 MW (3 units)		P = 0.012 x Qmax H (MW)		
1) Civil works	*Total Cost (civil) = 0.34 + 0.53 x (Qmax)$^{0.79}$* =			4.24	
2) Equipment	*Total Cost (Equipment) = 1.22 x P$^{0.80}$* =			11.67	
3) others (5%)				0.80	
	Total Construction Cost for Pumping station (US mill.):			**16.699**	*
*: Total Construction Cost					
4. Steel Pipe					
4-1 Case-1					
Route:	Mountain & Coastal route				
Pipe Diameter D:	1.6 m x 1 line				
Discharge:	5.00 m3/sec				
Length of Steel Pipe	Mountain: 53.23km, Coastal: 25.00km				
Gradient (m/m):	0.0008				
1) Excavation of Platform (Weathered/Rock)	m3/m	8.00	4.0	32.00	
2) Excavation of Trench (Rock)	m3/m	8.50	10.0	85.00	
3) Backfill	m3/m	6.50	4.0	26.00	
4) Steel Pipe	-	-	*US$ 1,110/m*	1,110.00	
5) Installation of Pipe	-	-	*US$ 150/m*	150.00	
6) others (5%)				70.15	
Total		Unit Cost for Construction (US$/m):		1,473.15	
			US$ million	**1.473**	**/km**

Table 2.5 Unit Price / Construction Cost Analysis for CAÑETE Water Conveyance (3/5)

Unit Price / Construction Cost Analysis for CAÑETE Water Conveyance Scheme

Description	Unit	Quantity	Construction Unit Cost	Unit Cost (US$ million) Amount	
4. Steel Pipe					
4-2 Case-2					
Route:	Coastal route				
Pipe Diameter D:	1.8 m x 1 line				
Discharge:	5.00 m3/sec				
Total Length L:	94.5 km				
Gradient (m/m):	0.0008				
1) Excavation of Platform (Weathered/Rock)	m3/m	12.70	4.0	50.80	
2) Excavation of Trench (Rock)	m3/m	18.00	10.0	180.00	
3) Backfill	m3/m	7.00	4.0	28.00	
4) Steel Pipe	-	-	*US$ 1,500/m*	1,500.00	
5) Installation of Pipe	-	-	*US$ 170/m*	170.00	
6) others (5%)				96.44	
Total		Unit Cost for Construction (US$/m):		2,025.24	
			US$ million	**2.025**	**/km**
4-3 Case-3					
Route:	Mountain route (Alternative)				
Pipe Diameter D:	2.0 m x 1 line				
Discharge:	5.00 m3/sec				
Length of Steel Pipe	30.4 km				
Gradient (m/m):	0.0008				
1) Excavation of Platform (Weathered/Rock)	m3/m	8.00	4.0	32.00	
2) Excavation of Trench (Rock)	m3/m	8.50	10.0	85.00	
3) Backfill	m3/m	6.50	4.0	26.00	
4) Steel Pipe	-	-	*US$ 1,650/m*	1,650.00	
5) Installation of Pipe	-	-	*US$ 190/m*	190.00	
6) others (5%)				99.15	
Total		Unit Cost for Construction (US$/m):		2,082.15	
			US$ million	**2.082**	**/km**
4-4 Case-4					
Route:	Mountain route (Alternative)				
Pipe Diameter D:	1.8 m x 1 line				
Discharge:	5.00 m3/sec				
Length of Steel Pipe	94.5 km				
Gradient (m/m):	0.0008				
1) Excavation of Platform (Weathered/Rock)	m3/m	12.70	4.0	50.80	
2) Excavation of Trench (Rock)	m3/m	18.00	10.0	180.00	
3) Backfill	m3/m	7.00	4.0	28.00	
4) Steel Pipe	-	-	*US$ 1,500/m*	1,500.00	
5) Installation of Pipe	-	-	*US$ 170/m*	170.00	
6) others (5%)				96.44	
Total		Unit Cost for Construction (US$/m):		2,025.24	
			US$ million	**2.025**	**/km**

Table 2.5 Unit Price / Construction Cost Analysis for CAÑETE Water Conveyance (4/5)

Unit Price / Construction Cost Analysis for CAÑETE Water Conveyance Scheme

Description	Unit	Quantity	Construction Unit Cost	Unit Cost (US$ million) Amount	
4. Steel Pipe					
4-5 Case-5					
Route:	Mountain & Coastal route				
Pipe Diameter D:	1.6 m x 2 lines				
Discharge:	10.00 m3/sec				
Total Length L:	Mountain: 53.23km, Coastal: 25.00km				
Gradient (m/m):	0.0008				
1) Excavation of Platform (Weathered/Rock)	m3/m	12.00	4.0	48.00	
2) Excavation of Trench (Rock)	m3/m	17.00	10.0	170.00	
3) Backfill	m3/m	14.00	4.0	56.00	
4) Steel Pipe	-	*US$ 1,100/m x 2 pipes*		2,200.00	
5) Installation of Pipe	-	*US$ 150/m x 2 pipes*		300.00	
6) others (5%)				138.70	
Total		Unit Cost for Construction (US$/m):		2,912.70	
			US$ million	**2.913**	**/km**
4-6 Case-6					
Route:	Mountain route (Alternative)				
Pipe Diameter D:	1.8 m x 2 lines				
Discharge:	10.00 m3/sec				
Total Length L:	94.5 km				
Gradient (m/m):	0.0008				
1) Excavation of Platform (Weathered/Rock)	m3/m	12.70	4.0	50.80	
2) Excavation of Trench (Rock)	m3/m	18.00	10.0	180.00	
3) Backfill	m3/m	15.08	4.0	60.31	
4) Steel Pipe	-	*US$ 1,500/m x 2 pipes*		3,000.00	
5) Installation of Pipe	-	*US$ 170/m x 2 pipes*		340.00	
6) others (5%)				181.56	
Total		Unit Cost for Construction (US$/m):		3,812.66	
			US$ million	**3.813**	**/km**
5. Siphon					
5-1 Case-1					
Route:	Mountain & Coastal route				
Discharge:	5.00 m3/sec				
Length of Channel	Mountain (8.15km), Coastal (2.0km)				
1) Excavation Soil	m3/m	25.00	4.0	100.00	
2) Excavation of Rock	m3/m	2.50	10.0	25.00	
3) Blinding Conrete	m3/m	0.36	100.0	36.00	
4) Structural Concrete	m3/m	4.11	130.0	534.30	
5) Reinforcing bar	ton	0.22	1,100.0	245.85	
6) Formwork	m2/m	3.60	20.0	72.00	
7) Steel Pipe	-		*US$ 1,100/m*	1,100.00	
8) Installation of Pipe	-		*US$ 150/m*	150.00	
9) others (5%)				113.66	
Total				2,386.81	

Table 2.5 Unit Price / Construction Cost Analysis for CAÑETE Water Conveyance (5/5)

Unit Price / Construction Cost Analysis for
CAÑETE Water Conveyance Scheme

Description	Unit	Quantity	Construction Unit Cost	Unit Cost (US$ million) Amount	
	Total Construction Cost for Penstock (US$/mill.):			**2.387**	**/km**
5-2 Case-2					
Route:	Mountain & Coastal route				
Discharge:	10.00 m3/sec				
Length of Channel	Mountain (8.15km), Coastal (2.0km)				
1) Excavation Soil	m3/m	31.50	4.0	126.00	
2) Excavation of Rock	m3/m	3.15	10.0	31.50	
3) Blinding Conrete	m3/m	0.72	100.0	72.00	
4) Structural Concrete	m3/m	8.22	130.0	1,068.60	
5) Reinforcing bar	ton	0.45	1,100.0	491.70	
6) Formwork	m2/m	4.54	20.0	90.72	
7) Steel Pipe	-	*US$ 1,500/m x 2 pipes*		2,200.00	
8) Installation of Pipe	-	*US$ 170/m x 2 pipes*		300.00	
9) others (5%)				219.03	
Total				4,599.55	
	Total Construction Cost for Penstock (US$/mill.):			**4.600**	**/km**

Table 2.6 Cost Breakdown of Irrigation & Agriculture

Summary of Initial Investment Cost for Irrigation and Drainage Works

	Description	Cost: Million US$
1.	Improvement Works in the Valle de Cañete	
1.1	Improvement of the existing facilities	6.71
1.2	Construction of dams at three lagoons	0.58
1.3	Construction of drains to recover saline area	5.58
	Sub-total	12.87
2.	Construction of irrigation facilities for the Pampas de Altas de Imperial	
2.1	Construction of irrigation facilities	4.32
2.2	Construction of one dam at Mallococha logoon	0.39
	Sub-total	4.71
3.	Construction of irrigation facilities for the Pampas de Concon-Topara and Chincha Alta	
3.1	Construction of headworks including intake structure	10.13
3.2	Construction of main canal and tunnels	49.7
3.3	Construction of secondary canals	23.54
3.4	Installation of mechanical irrigation system including pumping statio	47.11
3.5	Soil improvement and land grading	8.02
3.6	Miscellaneous works	8.1
	Sub-total	146.6
	TOTAL	**164.18**

Table 2.7 Operation & Maintenance Cost for Water Conveyance (Mountain Route)

CAÑETE Scheme
Project Cost for Water Conveyance

	Description	Construction Cost Amount	O/M cost per Year
Water Conveyance (5.0 m3/sec to Lima)			
1	Intake & Desanding Basin (Zuniga)	5.200	0.052
2	Open Channel	49.600	0.496
3	Pipe Line	78.423	0.157
4	Tunnel	45.558	0.046
5	Siphon & Chamber	19.454	0.039
6	Access Road	10.300	0.052
	sub-total	**208.534**	
7	Mobilization (10.0%)	20.853	
8	Unmeasured (5.0%)	10.427	
	sub-total	**239.814**	
9	Administration & Engineering Service (10%)	23.981	
10	Physical Contingency (10%)	23.981	
11	Price Contingency (3%)	7.194	
	Total	**294.971**	**0.842**

CAÑETE Scheme
Project Cost for Water Conveyance

	Description	Construction Cost Amount	O/M cost per Year
Water Conveyance (10.0 m3/sec to Lima)			
1	Intake & Desanding Basin (Zuniga)	5.200	0.052
2	Open Channel	66.879	0.669
3	Pipe Line	155.088	0.31
4	Tunnel	45.558	0.046
5	Siphon & Chamber	37.490	0.075
6	Access Road	10.300	0.052
	sub-total	**320.515**	
7	Mobilization (10.0%)	32.051	
8	Unmeasured (5.0%)	16.026	
	sub-total	**368.592**	
9	Administration & Engineering Service (10%)	36.859	
10	Physical Contingency (10%)	36.859	
11	Price Contingency (3%)	11.058	
	Total	**453.368**	**1.203**

Table 2.8 Cost Breakdown and O&M Costs of Mantaro Wate Conveyance

MONTARO Scheme
Project Cost for Water Conveyance

(US$ million)

	Description	Construction Cost Amount	O/M cost per Year
Water Conveyance (50.0m3/sec to Lima)			
1	Intake	18.000	0.180
2	Open Channel		
	-Type-1	0.520	0.005
	-Type-2	2.401	0.024
	-Type-3	3.683	0.037
3	Tunnel	27.435	0.027
4	Pumping Station (Carispaccha to Marcapomacocha)	28.238	0.565
4-1	Maintenance Cost (Pumping Station Energy Cost)		5.020
5	Transmission Line	3.000	0.015
6	Substation and Communication	1.700	0.009
7	Penstock	9.486	0.019
8	Upper Aqueduct (Channel & Head Pond)	2.075	0.021
9	Dam		
	-Carispaccha Dam	20.600	0.103
	-Marcapomacocha Dam	25.700	0.129
10	Access Road	4.560	0.023
11	Relocation of Marcapomacocha Town	6.682	
	sub-total	154.08	
12	Mobilization (10.0%)	15.408	
13	Unmeasured (5.0%)	7.704	
	sub-total	177.192	
14	Administration & Engineering Service (10%)	17.719	
15	Physical Contingency (10%)	17.719	
16	Price Contingency (3%)	5.316	
	Total	**217.946**	6.176

Table 2.9 Summary of Construction Cost of Mantaro Water Conveyance

MANTARO Water Conveyance

(US$ million)

Description	Unit Cost	Quantity	Amount	Remarks
Water Conveyance (5.0m3/sec to Lima)				
1 Intake	3.000 US$ mill./Intake	6.000 nos.	18.000	
2 Open Channel				
-Type-1	0.113 US$ mill./km	4.600 km	0.520	
-Type-2	0.207 US$ mill./km	11.600 km	2.401	
-Type-3	0.186 US$ mill./km	19.800 km	3.683	
3 Tunnel	2.517 US$ mill./km	10.900 km	27.435	
4 Pumping Station (Carispaccha to Marcapomacocha	- -	- -	28.238	Qmax=10.0m3/sec
5 Transmission Line	0.200 US$ mill./km	15.000 km	3.000	
6 Substation and Communication	- -	- -	1.700	
7 Penstock	- -	- -	9.486	
8 Upper Aqueduct (Channel & Head Pond)	- -	- -	2.075	
9 Dam				
-Carispaccha Dam	- -	- -	20.600	by Simple Equation
-Marcapomacocha Dam	- -	- -	25.700	by Simple Equation
10 Access Road	0.050 US$ mill./km	91.200 km	4.560	
11 Relocation by Marcapomacocha Town			6.682	
sub-total			154.080	
12 Mobilization (10.0%			15.408	
13 Unmeasured (5.0%)			7.704	
sub-total			177.192	
14 Administration & Engineering Service (10%)			17.719	
15 Physical Contingency (10%)			17.719	
16 Price Contingency (3%)			5.316	
Total			217.946	

Table 2.10 Unit Price / Construction Cost Analysis for Mantaro Water Conveyance (1/3)

Construction Cost / Unit Cost for
MANTARO Water Conveyance Scheme

Description	Unit	Quantity	Construction Unit Cost (US$) Unit Cost	Amount	Remarks
1. Open Channel (Trapezoidal Type)					
1-1 Channel Type -1					
Section	Yanacancha Intake - Richis Intake (4.6 km)				
Discharge:	Qmax < 1.50 m3/sec				
Gradient (m/m)	0.0008				
1) Excavation of Platform (Soil / Weathered)	m3/m	6.00	4.0	24.00	
2) Excavation of Trench (Weathered / Rock)	m3/m	2.60	10.0	26.00	
3) Concrete	m3	0.45	110.0	49.50	
4) Reinforcing bar:	ton	0.009	1,000.0	9.00	
5) Others (5%)				4.98	
Total		Unit Cost for Construction (US$/m)		113.48	
			US$ million	0.113	/km
1-2 Channel Type -2					
Section	Shoclay Intake - Morada Intake - Carispaccha Dam (11.6 km)				
Discharge:	Qmax < 4.90 m3/sec				
Gradient (m/m)	0.0010				
1) Excavation of Platform (Soil / Weathered)	m3	11.70	4.0	46.80	
2) Excavation of Trench (Weathered / Rock)	m3	5.90	10.0	59.00	
3) Concrete	m3	0.71	110.0	78.10	
4) Reinforcing bar:	ton	0.014	1,000.0	14.20	
5) Others (5%)				9.20	
Total		Unit Cost for Construction (US$/m)		207.30	
			US$ million	0.207	/km
1-3 Channel Type -3					
Section	Taprasa - Atapa ー Macuri ー CarispacchaDam (19.8 km)				
Discharge:	Qmax < 3.20 m3/sec				
Gradient (m/m)	0.0004				
1) Excavation of Platform (Soil / Weathered)	m3	6.60	4.0	26.40	
2) Excavation of Trench (Weathered / Rock)	m3	5.90	10.0	59.00	
3) Concrete	m3	0.71	110.0	78.10	
4) Reinforcing bar:	ton	0.014	1,000.0	14.20	
5) Others (5%)				8.18	
Total		Unit Cost for Construction (US$/m)		185.88	
			US$ million	0.186	/km

Table 2.10 Unit Price / Construction Cost Analysis for Mantaro Water Conveyance (2/3)

Construction Cost / Unit Cost for
MANTARO Water Conveyance Scheme

Description	Unit	Quantity	Construction Unit Cost (US$) Unit Cost	Amount	Remarks
2. Tunnel					
Total Tunnel Length:	10.9 km				
Discharge:	Qmax = 5.00 m3/sec				
Diameter of Tunnel:	3.0 m				
Gradient (m/m):	0.0007				
1) Tunnel Excavation (Rock)	m3	12.90	70.0	903.00	
2) Concrete	m3	4.87	160.0	779.20	
3) Reinforcing bar	ton	0.24	1,100.0	267.85	
4) Straight Formwork	m2	3.00	30.0	90.00	
5) Curved Formwork	m2	4.70	40.0	188.00	
6) Grouting	m	0.50	120.0	60.00	
7) Others (10%)				228.81	
			Unit Cost for Construction (US$/m)	2,516.86	
			US$ million	2.517	/km
3. Pumping Station (Carispaccha to Marcapomacocha)					
Pumpimg Head H:	257 m				
Pump-up Capacity Qmax:	12.50 m3/sec				
Install Capacity P:	38.55 MW (5 Units) P=0.012 x Qmax x H (MW)				
1) Civil Works	*Total Cost (civil) = 0.34 + 0.53 x (Qmax)$^{0.79}$ =*			4.24	
2) Equipment	*Total Cost (Equipment) = 1.22 x P$^{0.80}$ =*			22.66	
3) Others (5%)				1.34	
	Total Construction Cost for Pumping Station (US$/mill.)			28.238	*
4. Penstock (Carispaccha to Marcapomacocha)					
Pipe Diameter D:	2.0 m				
Total Length L:	1.81 km				
Head H:	257 m				
1) Excavation of Soil / Weathered	m3	130,000.0	4.0	520,000.00	
2) Excavation of Rock	m3	160,000.0	10.0	1,600,000.00	
3) Backfill	m3	260,000.0	4.0	1,040,000.00	
4) Concrete	m3	5,500.0	110.0	605,000.00	
5) Formwork	m2	6,950.0	30.0	208,500.00	
6) Reinforcing bar	ton	110.0	1,100.0	121,000.00	
7) Steel Penstock	ton	1,235.0	4,000.0	4,940,000.00	
8) Others (5%)				451,725.00	
Total				9,486,225.00	
		Total Construction Cost for Penstock (US$/mill.)		9.486	*

*: Total Construction Cost

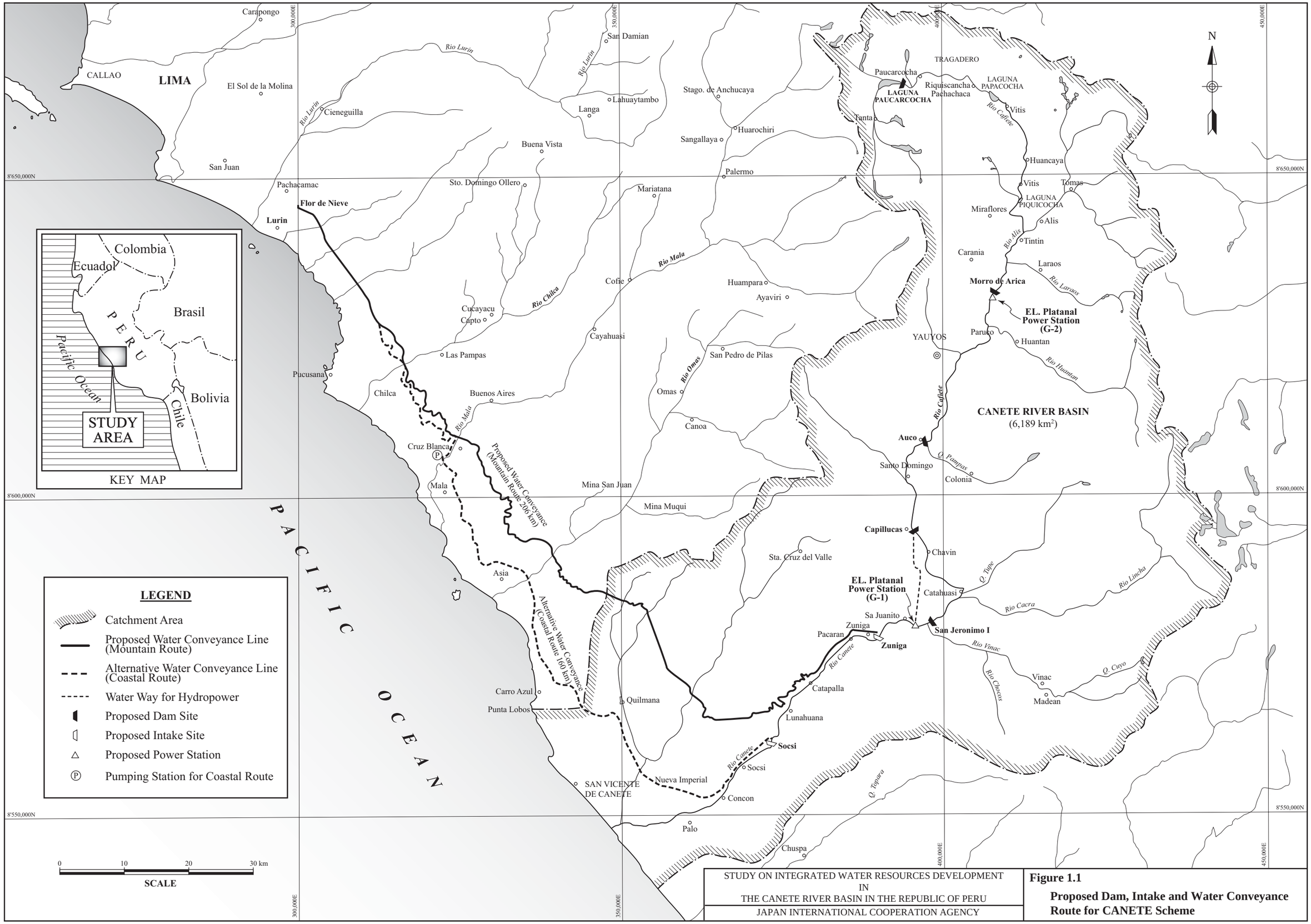
Table 2.10 Unit Price / Construction Cost Analysis for Mantaro Water Conveyance (3/3)

Construction Cost / Unit Cost for
MANTARO Water Conveyance Scheme

Description	Unit	Quantity	Construction Unit Cost (US$)		Remarks
			Unit Cost	Amount	
5. Upper Aqueduct (Channel & Headpond)					
Section:	Head pond to Marcapomacocha Dam				
Discharge:	10.0 m3/sec				
Type	Rectangular Channel				
Gradient (m/m):	0.0020				
1) Excavation of Soil	m3	57,000.0	4.0	228,000.00	
2) Excavation of Rock	m3	3,100.0	10.0	31,000.00	
3) Concrete	m3	5,700.0	130.0	741,000.00	
4) Reinforcing bar	ton	285.0	1,100.0	313,500.00	
5) Formwork	m2	19,100.0	30.0	573,000.00	
6) Others (10%)				118,650.00	
Total				2,075,150.00	
	Total Construction Cost for Upper Aqueduct (US$/mill.)			2.075	*

*: Total Construction Cost

FIGURES



STUDY ON INTEGRATED WATER RESOURCES DEVELOPMENT IN THE CANETE RIVER BASIN IN THE REPUBLIC OF PERU

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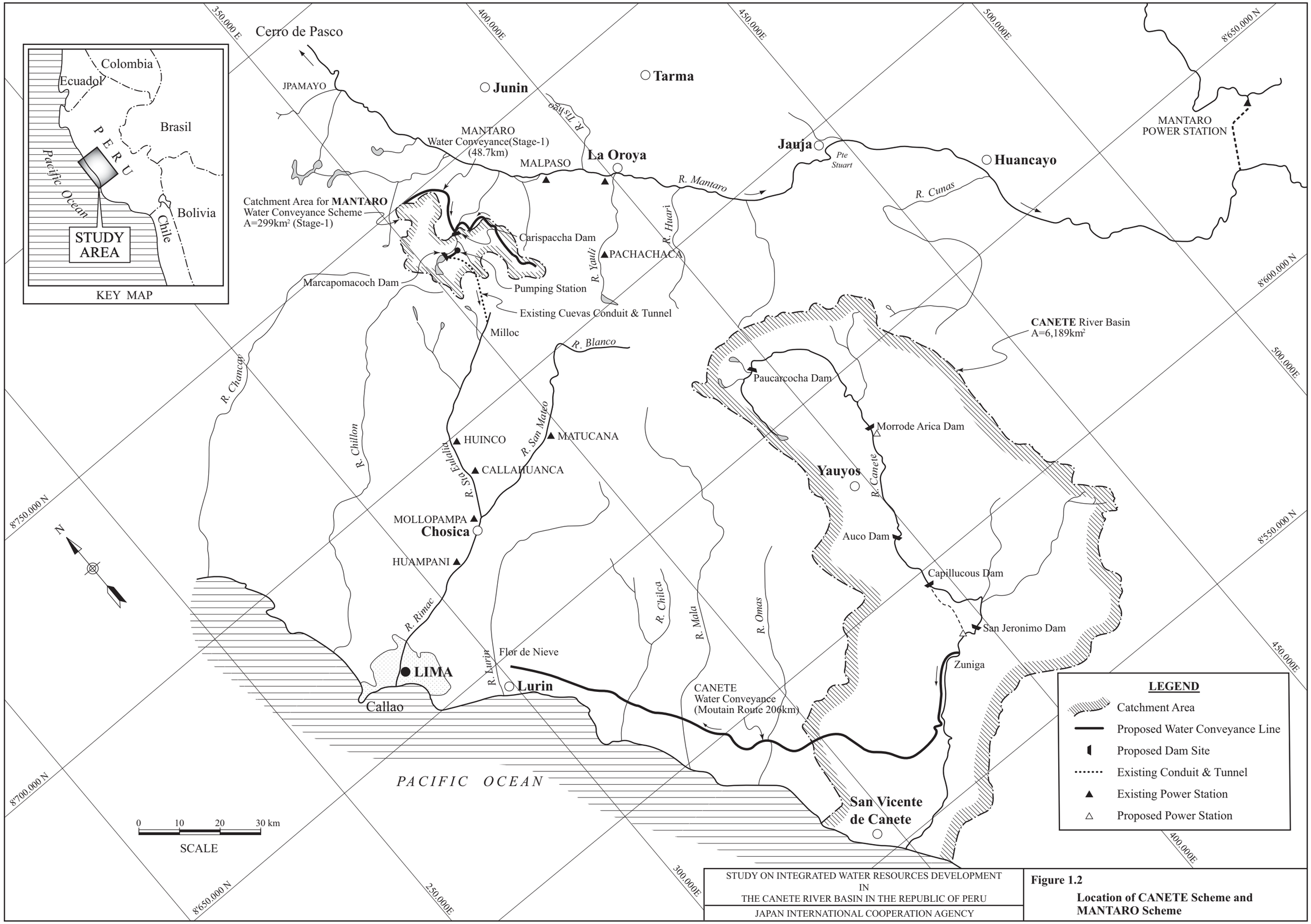
Figure 1.1

Proposed Dam, Intake and Water Conveyance Route for CANETE Scheme

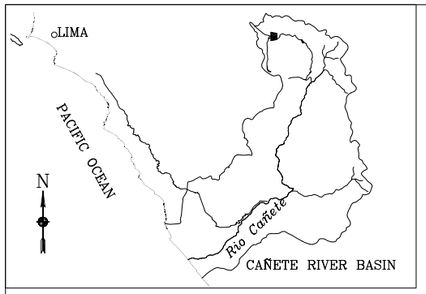


STUDY ON INTEGRATED WATER RESOURCES DEVELOPMENT
IN
THE CANETE RIVER BASIN IN THE REPUBLIC OF PERU

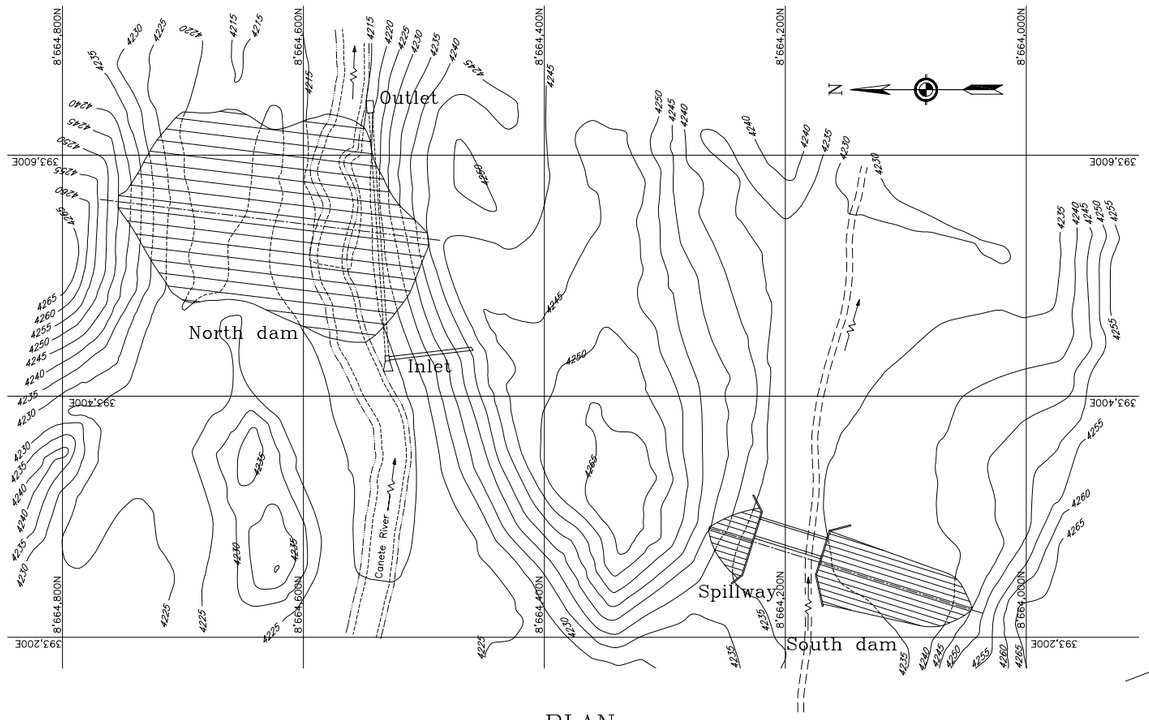
JAPAN INTERNATIONAL COOPERATION AGENCY

Figure 1.2

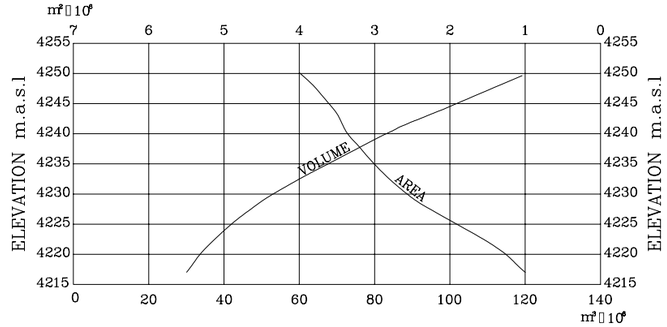
Location of CANETE Scheme and MANTARO Scheme



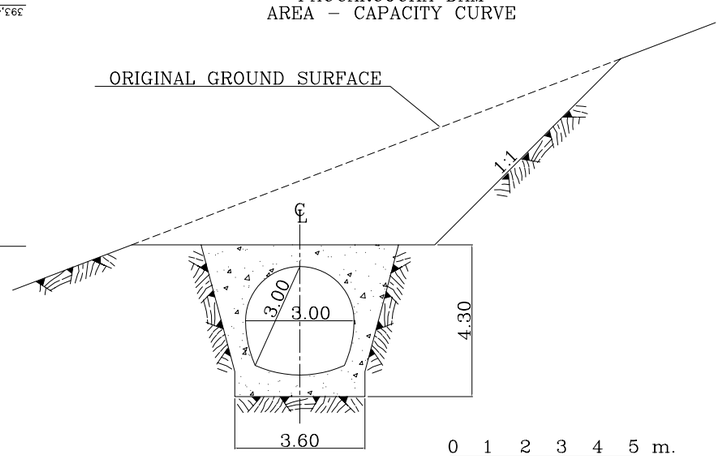
KEY MAP



PLAN



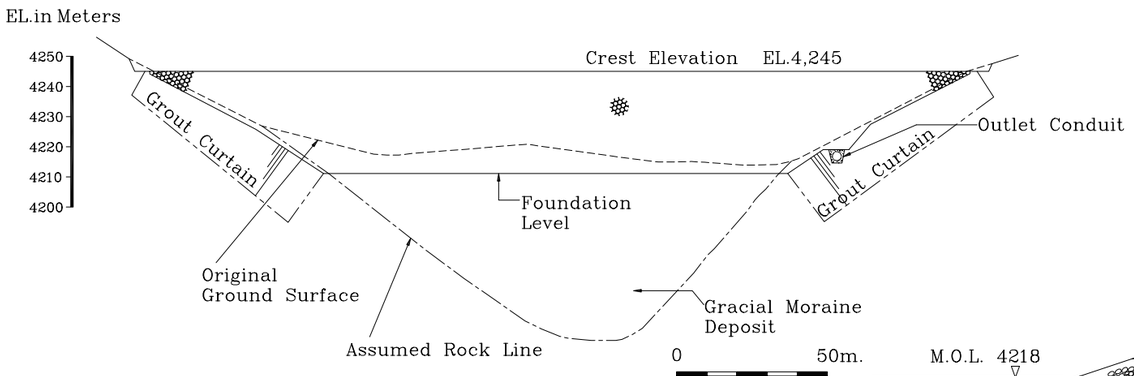
PAUCARCOCHA DAM
AREA – CAPACITY CURVE



0 1 2 3 4 5 m.
Scale

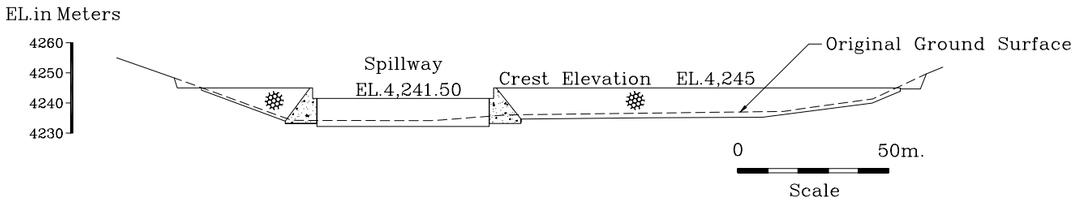
SECTION OF DIVERSION CONDUIT

0 35 70 105 140 175 m.
Scale



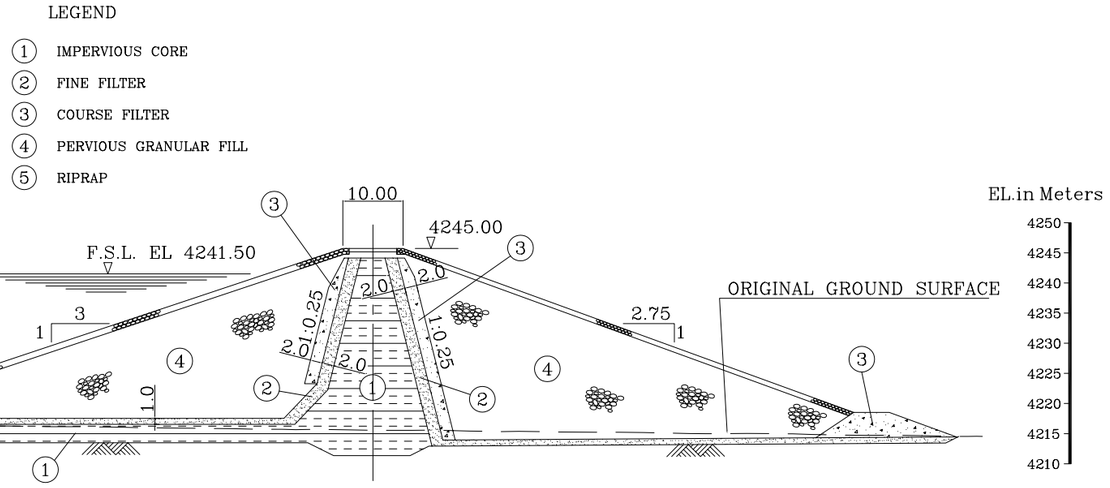
0 50m.
Scale

UPSTREAM ELEVATION OF NORTH DAM



0 50m.
Scale

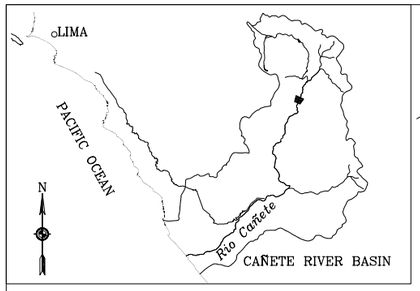
UPSTREAM ELEVATION OF SORTH DAM



TYPICAL SECTION OF NORTH DAM

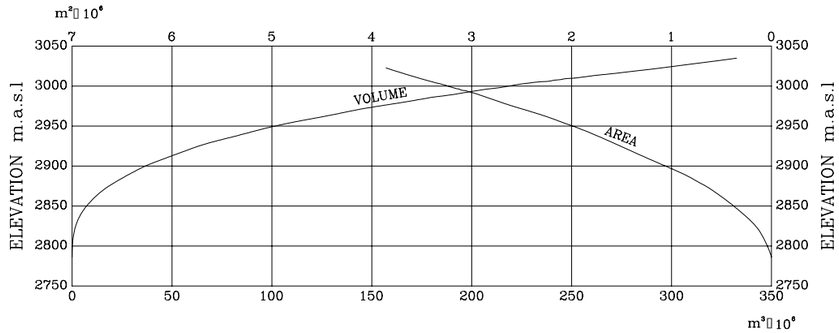
0 10 20 30 40 50 m.
Scale

STUDY ON INTEGRATED WATER RESOURCES DEVELOMENT THE CAÑETE RIVER BASIN IN THE REPUBLIC OF PERU JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 1.3 PAUCARCOCHA DAM (EARTHFILL DAM)

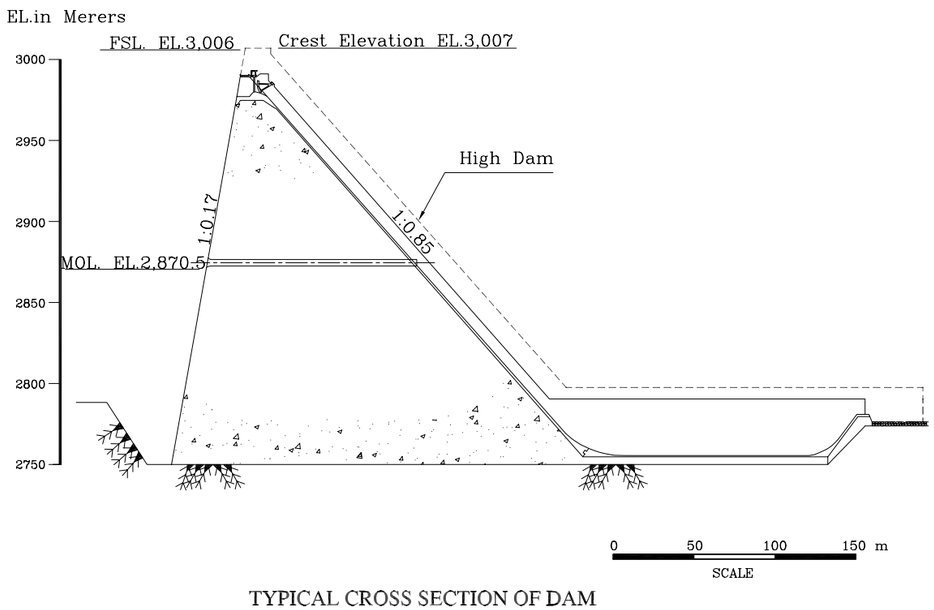


KEY MAP

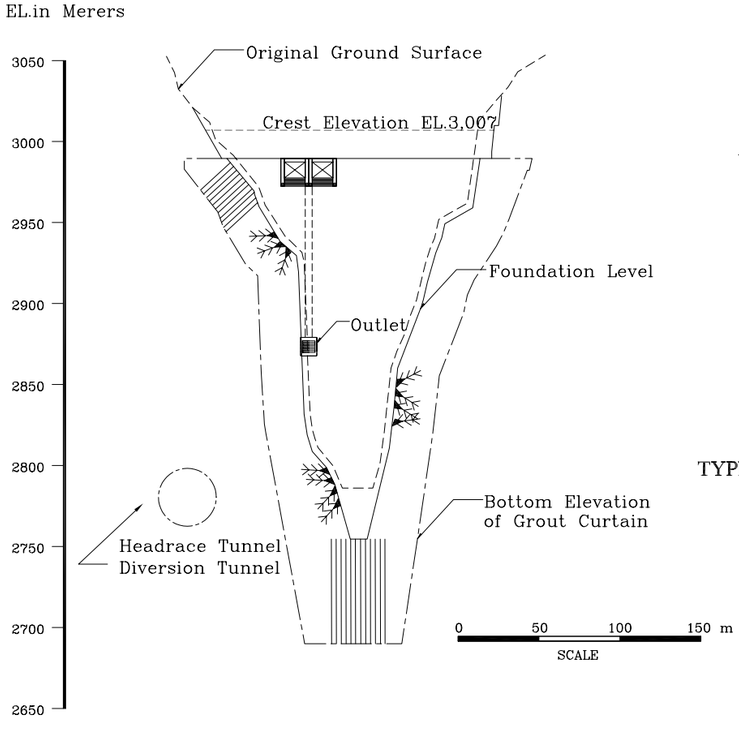
PLAN



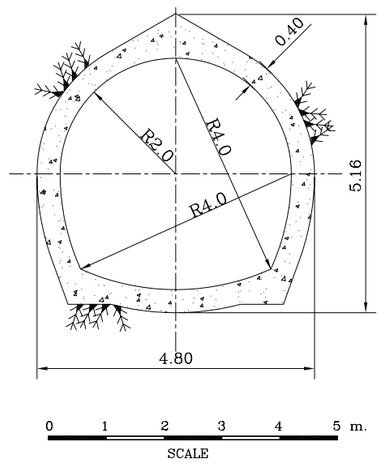
MORRO DE ARICA DAM
AREA-CAPACITY CURVE



TYPICAL CROSS SECTION OF DAM



UPSTREAM ELEVATION



TYPICAL SECTION OF HEADRACE TUNNEL

Notes:
1) Original design prepared by ARPL TECHNOLOGIA INDUSTRIAL S.A.
2) Crest Elevation(EL.3,007), FSL(EL.3,006), MOL(EL.2,870.5) for high dam are proposed by the JICA Study Team.

STUDY ON INTEGRATED WATER RESOURCES DEVELOMENT THE CAÑETE RIVER BASIN IN THE REPUBLIC OF PERU JAPAN INTERNATIONAL COOPERATION AGENCY	Figure 1.4 MORRO DE ARICA DAM (RCC DAM)