Appendix I-6 Construction Cost for Quellouno Power Station

I. Summary of Construction Cost for Quellouno Power Station

Unit: US$

Work Item	*Construction Cost*	*Remarks*
1. Preliminary Works	**32,286**	
(1) Access Road	24,687	
(2) Facilities for Construction Office	2,170	Cost of Civil Works x 0.05
(3) Transportation cost	5,429	392.6ton x $13.83/ton
2. Cost for Environmental Mesures	**434**	Cost of Civil Works x 0.01
3. Civil Works	**43,414**	
(1) Weir	1,282	
(2) Intake	1,650	
(3) Settling Basin	980	
(4) Headrace	1,456	
(5) Head Tank	2,881	
(6) Penstock & Spillway Channel	29,355	
(7) Power House	5,140	
(8) Outlet	670	
(9) Miscellaneous Work	0	
4. Hydraulic Equipment	**28,400**	
(1) Gate & Screen	946	
(2) Penstock	8,461	
(3) PVC (φ300)	10,449	
(4) PVC (φ150)	3,889	
(5) Others	4,655	
5. Electrical Equipment	**24,800**	
6. Direct Cost	**129,334**	1.+2.+3.+4.+5.
7. Engineering Cost	**12,933**	6. x 0.1: Detailed Design and Supervision
8. Contingent Budget	**12,733**	6. x 0.098
9. IGV	**29,450**	19.00%
10. Total Cost	**184,450**	

II. Detailed Statement of Transportation Cost for Quellouno Power Station

Items	*Unit*	*Quantity*	*Remarks*
(1) Wier	ton	**9.48**	
a. Cements		1.98	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		7.35	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.14	
(2) Intake	ton	**15.84**	
a. Gate		0.08	
b. Screen		0.03	
c. Cements		3.29	Cement: 0.27ton per concrete $1m^3$
d. Coarse aggregate		12.19	Coarse aggregate: 1ton per concrete $1m^3$
e. Reinforcement Bars		0.26	
(3) Settling Basin	ton	**5.93**	
a. Cements		1.17	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		4.34	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.42	
(4) Headrace	ton	**3.14**	
a. PVC (φ300)		3.14	Weight: 610m x 30.918kg/6m
(5) Head Tank	ton	**15.81**	
a. Cements		3.23	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		11.97	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.61	
(6) Penstock & Spillway Channel	ton	**309.97**	
a. Penstock Steel (φ150)		2.73	
b. Penstock PVC (φ150)		0.68	Weight: 128m x 32.000kg/6m
c. Cements		65.11	Cement: 0.27ton per concrete $1m^3$
d. Coarse aggregate		241.14	Coarse aggregate: 1ton per concrete $1m^3$
e. Reinforcement Bars		0.31	
(7) Power House	ton	**30.77**	
a. Cements		6.27	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		23.24	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		1.25	
(8) Outlet	ton	**1.66**	
a. Cements		0.29	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		1.08	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.29	
(9) Subtotal		**392.60**	
(10) Transportation Cost		**5,430**	(9) x $13.83/ton

III. Detailed Statement of Civil Works Cost for Quellouno Power Station

Unit: US$

Work Items	*Unit*	*Unit Price*	*Quantity*	*Cost*	*Remarks*
(1) Wier				**1,282**	
a. Excavation	m^3	5.53	42.2	233	
b. Concrete	m^3	93.05	7.3	683	
c. Reinforcement Bars	ton	1,070.00	0.1	153	
d. Others	-			213	(a+b+c) x 0.2 (including coffer dam construction, etc.)
(2) Intake				**1,650**	
a. Excavation	m^3	5.53	5.0	27	
b. Concrete	m^3	93.05	12.2	1,133	
c. Reinforcement Bars	ton	1,070.00	0.3	275	
d. Others	-			215	(a+b+c) x 0.15 (including coffer work, etc.)
(3) Settling Basin				**980**	
a. Excavation	m^3	5.53	7.8	43	
b. Concrete	m^3	93.05	4.3	403	
c. Reinforcement Bars	ton	1,070.00	0.4	445	
d. Others	-			89	(a+b+c) x 0.10 (including other works)
(4) Headrace				**1,456**	
a. Excavation	m^3	5.53	219.6	1,214	
b. Concrete	m^3	93.05	0.0	0	
c. Reinforcement Bars	ton	1,070.00	0.0	0	
d. Others	-			242	(a+b+c) x 0.20 (including filling works)
(5) Head Tank				**2,881**	
a. Excavation	m^3	5.53	52.9	292	
b. Concrete	m^3	93.05	12.0	1,113	
c. Reinforcement Bars	ton	1,070.00	0.6	653	
d. Others	-			823	(a+b+c) x 0.40 (including gate, screen)
(6) Penstock & Spillway Channel				**29,355**	
a. Excavation	m^3	5.53	709.5	3,923	
b. Concrete	m^3	93.05	241.1	22,438	
c. Reinforcement Bars	ton	1,070.00	0.3	326	
d. Others	-			2,668	(a+b+c) x 0.10 (including filling works)
(7) Power House				**5,140**	
a. Excavation	m^3	5.53	82.2	454	
b. Concrete	m^3	93.05	23.2	2,162	
c. Reinforcement Bars	ton	1,070.00	1.3	1,338	
d. Others	-			1,186	(a+b+c) x 0.30 (including drainage work, wooden
(8) Outlet				**670**	
a. Excavation	m^3	5.53	31.2	172	
b. Concrete	m^3	93.05	1.1	100	
c. Reinforcement Bars	ton	1,070.00	0.3	311	
d. Others	-			87	(a+b+c) x 0.15 (including coffer work, etc.)
(9) Miscellaneous Work	-			**0**	Σ(1)-(8) x 0.05 not consider
(10) Subtotal				**43,414**	

IV. Detailed Statement of Hydraulic Equipment Cost for Quellouno Power Station

Unit: US$

Work Items	*Unit*	*Unit Price*	*Quantity*	*Cost*	*Remarks*
(1) Weir & Spillway				**0**	
a. Gate	ton	8,811.04	0.00	0	
(2) Intake				**946**	
a. Gate	ton	8,811.04	0.08	664	
b. Screen	ton	8,811.04	0.03	282	
(3) Penstock Steel (φ150)	ton	3,100.00	2.73	**8,461**	
(4) PVC (φ300) for headrace	m	17.13	610	**10,449**	
(5) Penstock PVC (φ150) C-10	m	30.39	128	**3,889**	
(6) Subtotal				**23,745**	
(7) Others				**4,655**	19.60%
(8) Total				**28,400**	

V. Quantity

(1) Weir

Excavation:	V_e =	$8.69 \times (H_d \times L)^{1.14}$	=	**42.21**	(m^3)	
Concrete:	V_c =	$8.64 \times (H_d^2 \times L)^{0.726}$	=	**7.35**	(m^3)	
Reinforcement Bars	W_r =	$0.0274 \times V_c^{0.830}$	=	**0.14**	(ton)	
Weight of Gate:	W_g =	$0.145 \times Q_f^{0.692}$	=	**0.00**	(ton)	(unconsidered)

Where,

H_d:	Height of Dam =	**0.20**	(m)
L:	Length of Dam =	**20.00**	(m)

(2) Intake

Excavation:	V_e =	$171 \times (R \times Q)^{0.666}$	=	**5.02**	(m^3)
Concrete:	V_c =	$147 \times (R \times Q)^{0.470}$	=	**12.19**	(m^3)
Reinforcement Bars	W_r =	$0.0145 \times V_c^{1.15}$	=	**0.26**	(ton)
Weight of Gate:	W_g =	$1.27 \times (R \times Q)^{0.533}$	=	**0.08**	(ton)
Weight of Screen:	W_s =	$0.701 \times (R \times Q)^{0.582}$	=	**0.03**	(ton)

Where,

D:	Diameter of Waterway =	**0.50**	(m)		
R:	Radius of Waterway =	0.25	(m)	D/2	Assumption; Waterway Gradient = 1/1,000
Q:	Maximum Discharge =	**0.020**	(m^3/s)		

(3) Settling Basin

Excavation:	V_e =	$515 \times Q^{1.07}$	=	**7.83**	(m^3)
Concrete:	V_c =	$169 \times Q^{0.936}$	=	**4.34**	(m^3)
Reinforcement Bars	W_r =	$0.120 \times V_c^{0.847}$	=	**0.42**	(ton)
Weight of Gate:	W_g =	$0.910 \times Q^{0.613}$	=	**0.08**	(ton)
Weight of Screen:	W_s =	$0.879 \times Q^{0.785}$	=	**0.04**	(ton)

Where,

Q:	Maximum Discharge =	0.020	(m^3/s)

(4) Headrace

In the case of PVCφ300:

Excavation:	$V_e = B \times H \times L$	=	**219.60**	(m^3)
Concrete:	$V_c = ((H \times t \times 2) + (B + 2t) \times t) \times L$	=	**-**	(m^3)
Reinforcement Bars	$W_r = 0.577 \times (V_c/L)^{0.888} \times L$	=	**-**	(ton)

Where,

Q:	Maximum Discharge =	0.020	(m^3/s)	
L:	Length of Channel =	**610.00**	(m)	
B:	Width of Channel =	**0.60**	(m)	for excavation (2D from RIBLOC Brochure)
H:	Height of Channel =	**0.60**	(m)	for excavation (2D from RIBLOC Brochure)
t:	Thickness of Concrete =	-	(m)	

(5) Head Tank

Excavation:	V_e =	$808 \times Q^{0.697}$	=	**52.87**	(m^3)
Concrete:	V_c =	$197 \times Q^{0.716}$	=	**11.97**	(m^3)
Reinforcement Bars	W_r =	$0.051 \times V_c$	=	**0.61**	(ton)

Where,

Q:	Maximum Discharge =	0.020	(m^3/s)

(6) Penstock & Spillway Channel

Penstock (Steel)φ150:

Excavation:	V_{e1} =	$10.9 \times D_m^{1.33} \times L$	=	167.85	(m^3)
Concrete:	V_{c1} =	$2.14 \times D_m^{1.68} \times L$	=	16.96	(m^3)
Reinforcement Bars	W_{r1} =	$0.018 \times V_c$	=	0.31	(ton)

Where,

D_m:	vg. Diameter of Penstock =	**0.15**	(m)
L:	Length of Penstock =	**192.00**	(m)

Weight of Penstock	$W_{p1} = 7.85 \times \pi \times D_m \times t_m \times 10^{-3} \times 1.15 \times L$	=	2.73	(ton)
Thickness of Penstock:	$t_m = 0.0362 \times H \times D_m + 2$	=	3.34	(mm)

Where,

W_{p1}:	Weight of Penstock	2.73	(ton)	(Tensil allowable Stress: 1,150 kgf/cm^2)
tm:	Thickness of Penstock	3.34	(mm)	
D_m:	vg. Diameter of Penstock =	0.15	(m)	
H:	Design Head =	**247.10**	(m)	(Intake Water Level - Tailrace Water Level)
L:	Length of Penstock =	192.00	(m)	

Penstock (PVC)φ150:

Excavation:	$V_e = B \times H \times L$	=	75.89	(m^3)

Where,

Q:	Maximum Discharge =	0.020	(m^3/s)	
L:	Length of Channel =	**128.00**	(m)	
B:	Width of Channel =	**0.77**	(m)	from TUBOPLAST Brochure
H:	Height of Channel =	**0.77**	(m)	from TUBOPLAST Brochure

Spillway Channel:

	$(B \times H)^{0.5} = 1.09 \times Q^{0.379}$	=	0.25	
Excavation:	$V_e = 6.22 \times ((B \times H)^{0.5})^{1.04} \times L$	=	465.80	(m^3)
Concrete:	$V_c = H \times t \times 2 + (B + 2t) \times L$	=	224.18	(m^3)
Reinforcement Bars	$W_r = 0.577 \times (V_c/L)^{0.888} \times L$	=	0.00	(ton)

Where,

Q:	Maximum Discharge =	0.020	(m^3/s)
L:	Length of Channel =	**320.00**	(m)
B:	Width of Channel =	**0.40**	(m)
H:	Height of Channel =	**0.60**	(m)
t:	Thickness of Concrete =	**0.15**	(m)

Total Quantity of Penstock and Spillway Channel:

Excavation:	V_e =	$V_{e1} + V_{e2}$	=	**709.54**	(m^3)
Concrete:	V_c =	$V_{c1} + V_{c2}$	=	**241.14**	(m^3)
Reinforcement Bars	W_r =	$W_{r1} + W_{r2}$	=	**0.31**	(ton)
Weight of Penstock	W_p =	W_{p1}	=	**2.73**	(ton)

(7) Power House

Excavation:	$V_e = 97.8 \times (Q \times He^{2/3} \times n^{1/2})^{0.727}$	=	**82.21**	(m^3)
Concrete:	$V_c = 28.1 \times (Q \times He^{2/3} \times n^{1/2})^{0.795}$	=	**23.24**	(m^3)
Reinforcement Bars	$W_r = 0.046 \times V_c^{1.05}$	=	**1.25**	(ton)

Where,

Q:	Maximum Discharge =	0.020	(m^3/s)
He:	Effective Head =	247.10	(m)
n:	uantity Unit of Turbine =	**1.00**	

(8) Outlet

Excavation:	V_e =	$395 \times (R \times Q)^{0.479}$	=	31.22	(m^3)
Concrete:	V_c =	$40.4 \times (R \times Q)^{0.684}$	=	1.08	(m^3)
Reinforcement Bars	W_r =	$0.278 \times V_c^{0.610}$	=	0.29	(ton)

Where,

D:	Diameter of Waterway =	0.50	(m)	
R:	Radius of Waterway =	0.25	(m)	D/2
Q:	Maximum Discharge =	0.020	(m^3/s)	

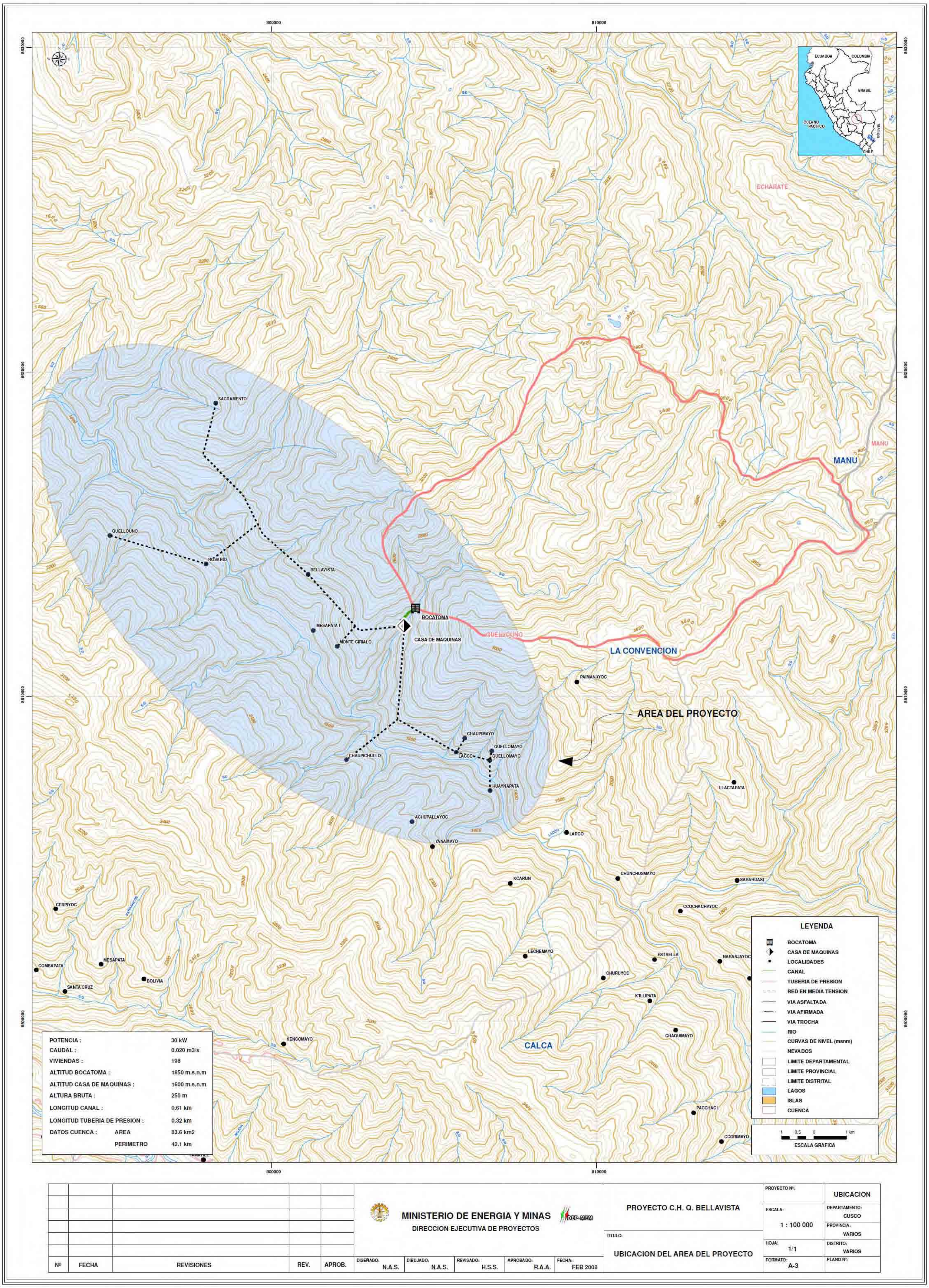
: Input Cell
: Calculation Cell
: Reference Cell

VI. Unit Price

1USD = 3.00 S/. (as of November, 2007)

(1) Civil Works				
Excavation				
Open	:	**5.53**	($\text{US\$/m}^3$)	* (8.70+2.35) x 0.5 = $\$5.53/\text{m}^3$, from CAPAECO and Fainal study on Omia <Human power and Machine excavation>
Tunnel	:	**-**	($\text{US\$/m}^3$)	
Concrete				
Open	:	**93.05**	($\text{US\$/m}^3$)	* from CAPAECO (average of foundation, wall and structure concrete)
Tunnel	:	**-**	($\text{US\$/m}^3$)	
Reinforcement Bar	:	**1,070.00**	(US$/ton)	*$1.07/kg, from CAPAECO
(2) Hydraulic Equipment				
Gate & Screen	:	**8,811.04**	(US$/ton)	* from final study on Omia
Steel Penstock	:	**3,100.00**	(US$/ton)	including installation
PVC (φ300)		**17.13**	(US$/m)	RIB LOC for Headrace
PVC (φ150)	:	**30.39**	(US$/m)	80% of TUBOPLAST(φ315) for Penstock (C-10) = 43.42 x 0.7 = 30.39
(3) Others				
Access Road	:	**5,877.89**	(US$/m)	Constrruction of Unpaved Road (3.0m Width)
(4) Transportation Cost				
Cusco to the site	:	**13.83**	(US$/ton)	156km

Quellouno Map



Appendix I-7 Construction Cost for Sarapampa Power Station

I. Summary of Construction Cost for Sarapampa Power Station

Unit: US$

Work Item	*Construction Cost*	*Remarks*
1. Preliminary Works	**8,186**	
(1) Access Road	0	
(2) Facilities for Construction Office	2,636	Cost of Civil Works x 0.05
(3) Transportation cost	5,550	345.41ton x $16.07/ton
2. Cost for Environmental Mesures	**527**	Cost of Civil Works x 0.01
3. Civil Works	**52,727**	
(1) Weir	2,221	
(2) Intake	4,835	
(3) Settling Basin	3,667	
(4) Headrace	7,299	
(5) Head Tank	8,428	
(6) Penstock & Spillway Channel	13,857	
(7) Power House	10,440	
(8) Outlet	1,980	
(9) Miscellaneous Work	0	
4. Hydraulic Equipment	**65,000**	
(1) Gate & Screen	3,158	
(2) Penstock	0	
(3) PVC (φ500)	45,837	
(4) PVC (φ200)	5,211	
(5) Others	10,794	
5. Electrical Equipment	**41,100**	
6. Direct Cost	**167,540**	1.+2.+3.+4.+5.
7. Engineering Cost	**16,754**	6. x 0.1: Detailed Design and Supervision
8. Contingent Budget	**16,706**	6. x 0.100
9. IGV	**38,190**	19.00%
10. Total Cost	**239,190**	

II. Detailed Statement of Transportation Cost for Sarapampa Power Station

Items	Unit	Quantity	Remarks
(1) Wier	ton	**17.05**	
a. Cements		3.57	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		13.24	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.23	
(2) Intake	ton	**44.67**	
a. Gate		0.24	
b. Screen		0.12	
c. Cements		9.24	Cement: 0.27ton per concrete $1m^3$
d. Coarse aggregate		34.22	Coarse aggregate: 1ton per concrete $1m^3$
e. Reinforcement Bars		0.84	
(3) Settling Basin	ton	**23.91**	
a. Cements		4.79	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		17.74	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		1.37	
(4) Headrace	ton	**9.45**	
a. PVC (φ500)		9.45	Weight: 1,100m x 51.522kg/6m
(5) Head Tank	ton	**46.41**	
a. Cements		9.49	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		35.13	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		1.79	
(6) Penstock & Spillway Channel	ton	**134.83**	
a. Penstock Steel (φ200)		0.00	
b. Penstock PVC (φ200)		1.25	Weight: 150m x 50.000kg/6m
c. Cements		28.40	Cement: 0.27ton per concrete $1m^3$
d. Coarse aggregate		105.18	Coarse aggregate: 1ton per concrete $1m^3$
e. Reinforcement Bars		0.00	
(7) Power House	ton	**62.23**	
a. Cements		12.67	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		46.94	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		2.62	
(8) Outlet	ton	**6.88**	
a. Cements		1.31	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		4.84	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.73	
(9) Subtotal		**345.41**	
(10) Transportation Cost		**5,551**	(9) x $16.07/ton

III. Detailed Statement of Civil Works Cost for Sarapampa Power Station

Unit: US$

Work Items	Unit	Unit Price	Quantity	Cost	Remarks
(1) Wier				**2,221**	
a. Excavation	m^3	5.53	67.0	370	
b. Concrete	m^3	93.05	13.2	1,231	
c. Reinforcement Bars	ton	1,070.00	0.2	250	
d. Others	-			370	(a+b+c) x 0.2 (including coffer dam construction, etc.)
(2) Intake				**4,835**	
a. Excavation	m^3	5.53	21.7	119	
b. Concrete	m^3	93.05	34.2	3,184	
c. Reinforcement Bars	ton	1,070.00	0.8	902	
d. Others	-			630	(a+b+c) x 0.15 (including coffer work, etc.)
(3) Settling Basin				**3,667**	
a. Excavation	m^3	5.53	39.2	216	
b. Concrete	m^3	93.05	17.7	1,651	
c. Reinforcement Bars	ton	1,070.00	1.4	1,467	
d. Others	-			333	(a+b+c) x 0.10 (including other works)
(4) Headrace				**7,299**	
a. Excavation	m^3	5.53	1100.0	6,083	
b. Concrete	m^3	93.05	0.0	0	
c. Reinforcement Bars	ton	1,070.00	0.0	0	
d. Others	-			1,216	(a+b+c) x 0.20 (including filling works)
(5) Head Tank				**8,428**	
a. Excavation	m^3	5.53	150.8	834	
b. Concrete	m^3	93.05	35.1	3,269	
c. Reinforcement Bars	ton	1,070.00	1.8	1,917	
d. Others	-			2,408	(a+b+c) x 0.40 (including gate, screen)
(6) Penstock & Spillway Channel				**13,857**	
a. Excavation	m^3	5.53	508.5	2,812	
b. Concrete	m^3	93.05	105.2	9,786	
c. Reinforcement Bars	ton	1,070.00	0.0	0	
d. Others	-			1,259	(a+b+c) x 0.10 (including filling works)
(7) Power House				**10,440**	
a. Excavation	m^3	5.53	156.3	864	
b. Concrete	m^3	93.05	46.9	4,367	
c. Reinforcement Bars	ton	1,070.00	2.6	2,800	
d. Others	-			2,409	(a+b+c) x 0.30 (including drainage work, wooden
(8) Outlet				**1,980**	
a. Excavation	m^3	5.53	89.4	494	
b. Concrete	m^3	93.05	4.8	450	
c. Reinforcement Bars	ton	1,070.00	0.7	778	
d. Others	-			258	(a+b+c) x 0.15 (including coffer work, etc.)
(9) Miscellaneous Work	-			**0**	Σ(1)-(8) x 0.05 not consider
(10) Subtotal				**52,727**	

IV. Detailed Statement of Hydraulic Equipment Cost for Sarapampa Power Station

Unit: US$

Work Items	*Unit*	*Unit Price*	*Quantity*	*Cost*	*Remarks*
(1) Weir & Spillway				**0**	
a. Gate	ton	8,811.04	0.00	0	
(2) Intake				**3,158**	
a. Gate	ton	8,811.04	0.24	2,142	
b. Screen	ton	8,811.04	0.12	1,016	
(3) Penstock Steel (φ200)	ton	3,100.00	0.00	**0**	
(4) PVC (φ500) for headrace	m	41.67	1,100	**45,837**	
(5) Penstock PVC (φ200) C-10	m	34.74	150	**5,211**	
(6) Subtotal				**54,206**	
(7) Others				**10,794**	19.91%
(8) Total				**65,000**	

V. Quantity

(1) Weir

Excavation:	V_e =	$8.69 \times (H_d \times L)^{1.14}$	=	**67.01**	(m^3)	
Concrete:	V_c =	$8.64 \times (H_d^2 \times L)^{0.726}$	=	**13.24**	(m^3)	
Reinforcement Bars	W_r =	$0.0274 \times V_c^{0.830}$	=	**0.23**	(ton)	
Weight of Gate:	W_g =	$0.145 \times Q_f^{0.692}$	=	**0.00**	(ton)	(unconsidered)

Where,

H_d:	Height of Dam =	**0.30**	(m)
L:	Length of Dam =	**20.00**	(m)

(2) Intake

Excavation:	V_e =	$171 \times (R \times Q)^{0.666}$	=	**21.68**	(m^3)
Concrete:	V_c =	$147 \times (R \times Q)^{0.470}$	=	**34.22**	(m^3)
Reinforcement Bars	W_r =	$0.0145 \times V_c^{1.15}$	=	**0.84**	(ton)
Weight of Gate:	W_g =	$1.27 \times (R \times Q)^{0.533}$	=	**0.24**	(ton)
Weight of Screen:	W_s =	$0.701 \times (R \times Q)^{0.582}$	=	**0.12**	(ton)

Where,

D:	Diameter of Waterway =	**1.00**	(m)		
R:	Radius of Waterway =	0.50	(m)	D/2	Assumption; Waterway Gradient = 1/1,000
Q:	Maximum Discharge =	**0.090**	(m^3/s)		

(3) Settling Basin

Excavation:	V_e =	$515 \times Q^{1.07}$	=	**39.16**	(m^3)
Concrete:	V_c =	$169 \times Q^{0.936}$	=	**17.74**	(m^3)
Reinforcement Bars	W_r =	$0.120 \times V_c^{0.847}$	=	**1.37**	(ton)
Weight of Gate:	W_g =	$0.910 \times Q^{0.613}$	=	**0.21**	(ton)
Weight of Screen:	W_s =	$0.879 \times Q^{0.785}$	=	**0.13**	(ton)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)

(4) Headrace

In the case of PVCφ500:

Excavation:	$V_e = B \times H \times L$	=	**1,100.00**	(m^3)
Concrete:	$V_c = ((H \times t \times 2) + (B + 2t) \times t) \times L$	=	**-**	(m^3)
Reinforcement Bars	$W_r = 0.577 \times (V_c/L)^{0.888} \times L$	=	**-**	(ton)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)	
L:	Length of Channel =	**1,100.00**	(m)	
B:	Width of Channel =	**1.00**	(m)	for excavation (2D from RIBLOC Brochure)
H:	Height of Channel =	**1.00**	(m)	for excavation (2D from RIBLOC Brochure)
t:	Thickness of Concrete =	**-**	(m)	

(5) Head Tank

Excavation:	V_e =	$808 \times Q^{0.697}$	=	**150.84**	(m^3)
Concrete:	V_c =	$197 \times Q^{0.716}$	=	**35.13**	(m^3)
Reinforcement Bars	W_r =	$0.051 \times V_c$	=	**1.79**	(ton)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)

(6) Penstock & Spillway Channel

Penstock (Steel)φ200:

Excavation:	V_{e1} =	$10.9 \times D_m^{1.33} \times L$	=	0.00	(m^3)
Concrete:	V_{c1} =	$2.14 \times D_m^{1.68} \times L$	=	0.00	(m^3)
Reinforcement Bars	W_{r1} =	$0.018 \times V_c$	=	0.00	(ton)

Where,

D_m:	Avg. Diameter of Penstock =	**0.00**	(m)
L:	Length of Penstock =	**0.00**	(m)

Weight of Penstock	W_{p1} =	$7.85 \times \pi \times D_m \times t_m \times 10^{-3} \times 1.15 \times L$	=	0.00	(ton)
Thickness of Penstock:	t_m =	$0.0362 \times H \times D_m + 2$	=	2.00	(mm)

Where,

W_{p1}:	Weight of Penstock	0.00	(ton)	(Tensil allowable Stress: 1,150 kgf/cm²)
tm:	Thickness of Penstock	2.00	(mm)	
D_m:	Avg. Diameter of Penstock =	0.00	(m)	
H:	Design Head =	**97.50**	(m)	(Intake Water Level - Tailrace Water Level)
L:	Length of Penstock =	0.00	(m)	

Penstock (PVC)φ200:

Excavation:	V_e =	$B \times H \times L$	=	113.54	(m^3)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)	
L:	Length of Channel =	**150.00**	(m)	
B:	Width of Channel =	**0.87**	(m)	from TUBOPLAST Brochure
H:	Height of Channel =	**0.87**	(m)	from TUBOPLAST Brochure

Spillway Channel:

	(B x H)^0.5 =	$1.09 \times Q^{0.379}$	=	0.44	
Excavation:	V_e =	$6.22 \times ((B \times H)^{0.5})^{1.04} \times L$	=	395.01	(m^3)
Concrete:	V_c =	$H \times t \times 2 + (B + 2t) \times L$	=	105.18	(m^3)
Reinforcement Bars	W_r =	$0.577 \times (V_c/L)^{0.888} \times L$	=	0.00	(ton)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)
L:	Length of Channel =	**150.00**	(m)
B:	Width of Channel =	**0.40**	(m)
H:	Height of Channel =	**0.60**	(m)
t:	Thickness of Concrete =	**0.15**	(m)

Total Quantity of Penstock and Spillway Channel:

Excavation:	V_e =	$V_{e1} + V_{e2}$	=	**508.55**	(m^3)
Concrete:	V_c =	$V_{c1} + V_{c2}$	=	**105.18**	(m^3)
Reinforcement Bars	W_r =	$W_{r1} + W_{r2}$	=	**0.00**	(ton)
Weight of Penstock	W_p =	W_{p1}	=	**0.00**	(ton)

(7) Power House

Excavation:	V_e =	$97.8 \times (Q \times He^{2/3} \times n^{1/2})^{0.727}$	=	**156.34**	(m^3)
Concrete:	V_c =	$28.1 \times (Q \times He^{2/3} \times n^{1/2})^{0.795}$	=	**46.94**	(m^3)
Reinforcement Bars	W_r =	$0.046 \times V_c^{1.05}$	=	**2.62**	(ton)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)
He:	Effective Head =	97.50	(m)
n:	Quantity Unit of Turbine =	**1.00**	

(8) Outlet

Excavation:	V_e =	$395 \times (R \times Q)^{0.479}$	=	89.43	(m^3)
Concrete:	V_c =	$40.4 \times (R \times Q)^{0.684}$	=	4.84	(m^3)
Reinforcement Bars	W_r =	$0.278 \times V_c^{0.610}$	=	0.73	(ton)

Where,

D:	Diameter of Waterway =	1.00	(m)	
R:	Radius of Waterway =	0.50	(m)	D/2
Q:	Maximum Discharge =	0.090	(m^3/s)	

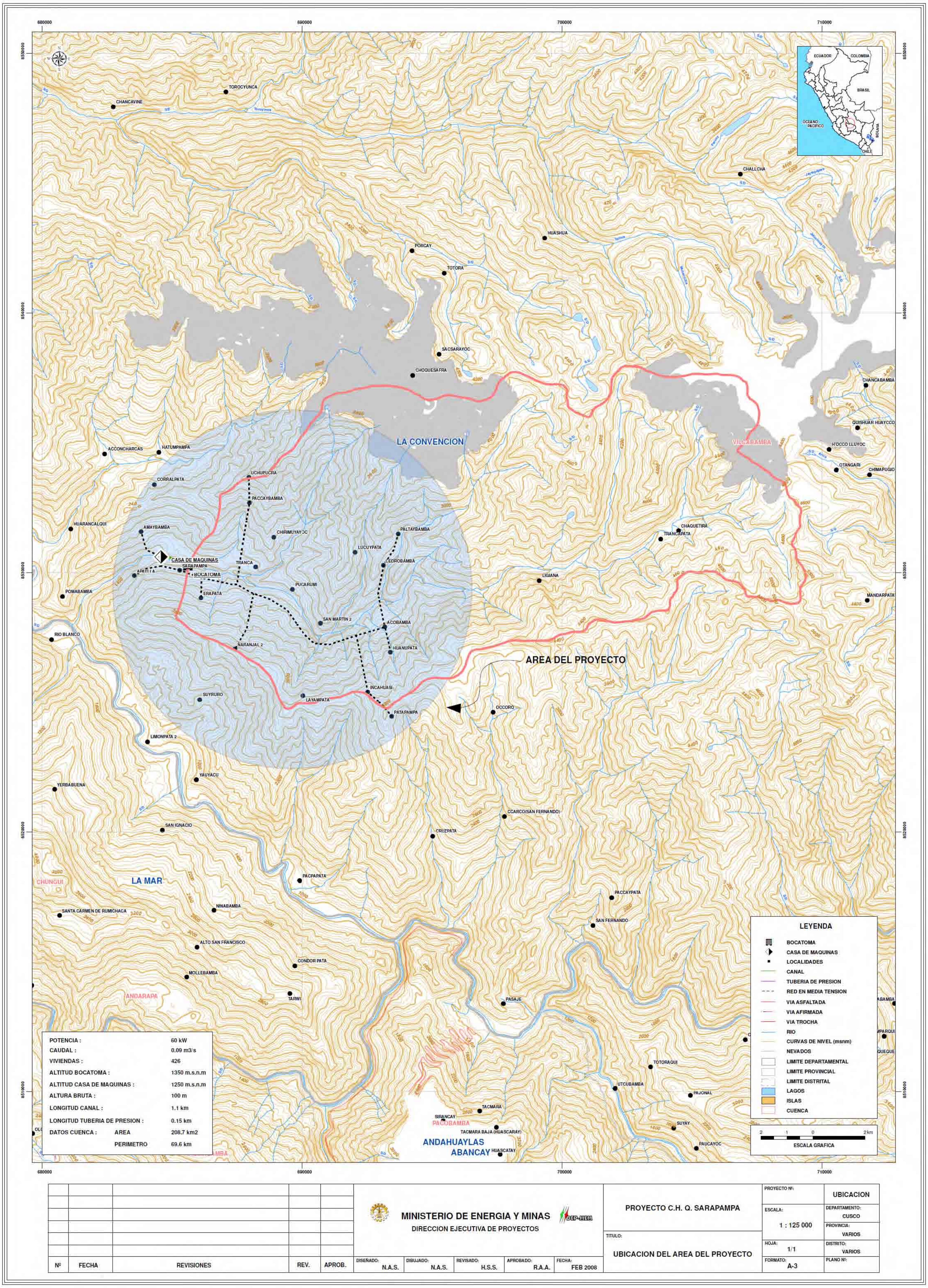
: Input Cell
: Calculation Cell
: Reference Cell

VI. Unit Price

1USD = 3.00 S/. (as of November, 2007)

(1) Civil Works				
Excavation				
Open	:	**5.53**	(US$/m^3)	* (8.70+2.35) x 0.5 = $5.53/m^3, from CAPAECO and Fainal study on Omia <Human power and Machine excavation>
Tunnel	:	**-**	(US$/m^3)	
Concrete				
Open	:	**93.05**	(US$/m^3)	* from CAPAECO (average of foundation, wall and structure concrete)
Tunnel	:	**-**	(US$/m^3)	
Reinforcement Bar	:	**1,070.00**	(US$/ton)	*$1.07/kg, from CAPAECO
(2) Hydraulic Equipment				
Gate & Screen	:	**8,811.04**	(US$/ton)	* from final study on Omia
Steel Penstock	:	**3,100.00**	(US$/ton)	including installation
PVC (φ500)		**41.67**	(US$/m)	RIB LOC for Headrace
PVC (φ200)	:	**34.74**	(US$/m)	80% of TUBOPLAST(φ315) for Penstock (C-10) = 43.42 x 0.8 = 34.74
(3) Others				
Access Road	:	**-**	(US$/m)	-
(4) Transportation Cost				
Cusco to the site	:	**16.07**	(US$/ton)	221km (road)

Sarapampa Map



Appendix I-8 Construction Cost for Yanama Power Station

I. Summary of Construction Cost for Yanama Power Station

Unit: US$

Work Item	*Construction Cost*	*Remarks*
1. Preliminary Works	**5,197**	
(1) Access Road	0	
(2) Facilities for Construction Office	1,597	Cost of Civil Works x 0.05
(3) Transportation cost	3,600	224.02ton x $16.07/ton
2. Cost for Environmental Mesures	**319**	Cost of Civil Works x 0.01
3. Civil Works	**31,948**	
(1) Weir	1,282	
(2) Intake	2,582	
(3) Settling Basin	2,185	
(4) Headrace	2,972	
(5) Head Tank	5,539	
(6) Penstock & Spillway Channel	9,803	
(7) Power House	6,539	
(8) Outlet	1,046	
(9) Miscellaneous Work	0	
4. Hydraulic Equipment	**28,500**	
(1) Gate & Screen	1,564	
(2) Penstock	0	
(3) PVC (φ400)	18,431	
(4) PVC (φ200)	3,821	
(5) Others	4,684	
5. Electrical Equipment	**24,800**	
6. Direct Cost	**90,764**	1.+2.+3.+4.+5.
7. Engineering Cost	**9,076**	6. x 0.1: Detailed Design and Supervision
8. Contingent Budget	**8,160**	6. x 0.090
9. IGV	**20,520**	19.00%
10. Total Cost	**128,520**	

II. Detailed Statement of Transportation Cost for Yanama Power Station

Items	Unit	Quantity	Remarks
(1) Wier	ton	**9.48**	
a. Cements		1.98	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		7.35	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.14	
(2) Intake	ton	**24.40**	
a. Gate		0.12	
b. Screen		0.05	
c. Cements		5.06	Cement: 0.27ton per concrete $1m^3$
d. Coarse aggregate		18.74	Coarse aggregate: 1ton per concrete $1m^3$
e. Reinforcement Bars		0.42	
(3) Settling Basin	ton	**13.86**	
a. Cements		2.76	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		10.24	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.86	
(4) Headrace	ton	**4.81**	
a. PVC (φ400)		4.81	Weight: 700m x 41.214kg/6m = 4.81ton
(5) Head Tank	ton	**30.47**	
a. Cements		6.23	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		23.06	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		1.18	
(6) Penstock & Spillway Channel	ton	**98.94**	
a. Penstock Steel (φ200)		0.00	
b. Penstock PVC (φ200)		0.92	Weight: 110m x 50.000kg/6m =0.92ton
c. Cements		20.84	Cement: 0.27ton per concrete $1m^3$
d. Coarse aggregate		77.18	Coarse aggregate: 1ton per concrete $1m^3$
e. Reinforcement Bars		0.00	
(7) Power House	ton	**39.09**	
a. Cements		7.97	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		29.51	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		1.61	
(8) Outlet	ton	**2.99**	
a. Cements		0.54	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		2.02	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.43	
(9) Subtotal		**224.02**	
(10) Transportation Cost		**3,600**	(9) x $16.07/ton

III. Detailed Statement of Civil Works Cost for Yanama Power Station

Unit: US$

Work Items	*Unit*	*Unit Price*	*Quantity*	*Cost*	*Remarks*
(1) Wier				**1,282**	
a. Excavation	m^3	5.53	42.2	233	
b. Concrete	m^3	93.05	7.3	683	
c. Reinforcement Bars	ton	1,070.00	0.1	153	
d. Others	-			213	(a+b+c) x 0.2 (including coffer dam construction, etc.)
(2) Intake				**2,582**	
a. Excavation	m^3	5.53	9.2	51	
b. Concrete	m^3	93.05	18.7	1,744	
c. Reinforcement Bars	ton	1,070.00	0.4	451	
d. Others	-			336	(a+b+c) x 0.15 (including coffer work, etc.)
(3) Settling Basin				**2,185**	
a. Excavation	m^3	5.53	20.9	115	
b. Concrete	m^3	93.05	10.2	952	
c. Reinforcement Bars	ton	1,070.00	0.9	920	
d. Others	-			198	(a+b+c) x 0.10 (including other works)
(4) Headrace				**2,972**	
a. Excavation	m^3	5.53	448.0	2,477	
b. Concrete	m^3	93.05	0.0	0	
c. Reinforcement Bars	ton	1,070.00	0.0	0	
d. Others	-			495	(a+b+c) x 0.20 (including filling works)
(5) Head Tank				**5,539**	
a. Excavation	m^3	5.53	100.1	553	
b. Concrete	m^3	93.05	23.1	2,146	
c. Reinforcement Bars	ton	1,070.00	1.2	1,258	
d. Others	-			1,582	(a+b+c) x 0.40 (including gate, screen)
(6) Penstock & Spillway Channel				**9,803**	
a. Excavation	m^3	5.53	313.0	1,731	
b. Concrete	m^3	93.05	77.2	7,181	
c. Reinforcement Bars	ton	1,070.00	0.0	0	
d. Others	-			891	(a+b+c) x 0.10 (including filling works)
(7) Power House				**6,539**	
a. Excavation	m^3	5.53	102.3	565	
b. Concrete	m^3	93.05	29.5	2,745	
c. Reinforcement Bars	ton	1,070.00	1.6	1,720	
d. Others	-			1,509	(a+b+c) x 0.30 (including drainage work, wooden
(8) Outlet				**1,046**	
a. Excavation	m^3	5.53	48.4	267	
b. Concrete	m^3	93.05	2.0	187	
c. Reinforcement Bars	ton	1,070.00	0.4	456	
d. Others	-			136	(a+b+c) x 0.15 (including coffer work, etc.)
(9) Miscellaneous Work	-			**0**	Σ(1)-(8) x 0.05 not consider
(10) Subtotal				**31,948**	

IV. Detailed Statement of Hydraulic Equipment Cost for Yanama Power Station

Unit: US$

Work Items	*Unit*	*Unit Price*	*Quantity*	*Cost*	*Remarks*
(1) Weir & Spillway				**0**	
a. Gate	ton	8,811.04	0.00	0	
(2) Intake				**1,564**	
a. Gate	ton	8,811.04	0.12	1,082	
b. Screen	ton	8,811.04	0.05	482	
(3) Penstock Steel (φ200)	ton	3,100.00	0.00	**0**	
(4) PVC (φ400) for headrace	m	26.33	700	**18,431**	
(5) Penstock PVC (φ200) C-10	m	34.74	110	**3,821**	
(6) Subtotal				**23,816**	
(7) Others				**4,684**	19.67%
(8) Total				**28,500**	

V. Quantity

(1) Weir

Excavation:	V_e =	$8.69 \times (H_d \times L)^{1.14}$	=	**42.21**	(m^3)
Concrete:	V_c =	$8.64 \times (H_d^2 \times L)^{0.726}$	=	**7.35**	(m^3)
Reinforcement Bars	W_r =	$0.0274 \times V_c^{0.830}$	=	**0.14**	(ton)
Weight of Gate:	W_g =	$0.145 \times Q_f^{0.692}$	=	**0.00**	(ton) (unconsidered)

Where,

H_d:	Height of Dam =	**0.20**	(m)
L:	Length of Dam =	**20.00**	(m)

(2) Intake

Excavation:	V_e =	$171 \times (R \times Q)^{0.666}$	=	**9.24**	(m^3)
Concrete:	V_c =	$147 \times (R \times Q)^{0.470}$	=	**18.74**	(m^3)
Reinforcement Bars	W_r =	$0.0145 \times V_c^{1.15}$	=	**0.42**	(ton)
Weight of Gate:	W_g =	$1.27 \times (R \times Q)^{0.533}$	=	**0.12**	(ton)
Weight of Screen:	W_s =	$0.701 \times (R \times Q)^{0.582}$	=	**0.05**	(ton)

Where,

D:	Diameter of Waterway =	**0.50**	(m)	
R:	Radius of Waterway =	0.25	(m)	D/2 Assumption; Waterway Gradient = 1/1,000
Q:	Maximum Discharge =	**0.050**	(m^3/s)	

(3) Settling Basin

Excavation:	V_e =	$515 \times Q^{1.07}$	=	**20.88**	(m^3)
Concrete:	V_c =	$169 \times Q^{0.936}$	=	**10.24**	(m^3)
Reinforcement Bars	W_r =	$0.120 \times V_c^{0.847}$	=	**0.86**	(ton)
Weight of Gate:	W_g =	$0.910 \times Q^{0.613}$	=	**0.15**	(ton)
Weight of Screen:	W_s =	$0.879 \times Q^{0.785}$	=	**0.08**	(ton)

Where,

Q: Maximum Discharge = 0.050 (m^3/s)

(4) Headrace

In the case of PVCφ400:

Excavation:	$V_e = B \times H \times L$	=	**448.00**	(m^3)
Concrete:	$V_c = ((H \times t \times 2) + (B + 2t) \times t) \times L$	=	**-**	(m^3)
Reinforcement Bars	$W_r = 0.577 \times (V_c/L)^{0.888} \times L$	=	**-**	(ton)

Where,

Q:	Maximum Discharge =	0.050	(m^3/s)	
L:	Length of Channel =	**700.00**	(m)	
B:	Width of Channel =	**0.80**	(m)	for excavation (2D from RIBLOC Brochure)
H:	Height of Channel =	**0.80**	(m)	for excavation (2D from RIBLOC Brochure)
t:	Thickness of Concrete =	-	(m)	

(5) Head Tank

Excavation:	V_e =	$808 \times Q^{0.697}$	=	**100.14**	(m^3)
Concrete:	V_c =	$197 \times Q^{0.716}$	=	**23.06**	(m^3)
Reinforcement Bars	W_r =	$0.051 \times V_c$	=	**1.18**	(ton)

Where,

Q: Maximum Discharge = 0.050 (m^3/s)

(6) Penstock & Spillway Channel

Penstock (Steel)φ200:

Excavation:	V_{e1} =	$10.9 \times D_m^{1.33} \times L$	=	0.00	(m^3)
Concrete:	V_{c1} =	$2.14 \times D_m^{1.68} \times L$	=	0.00	(m^3)
Reinforcement Bars	W_{r1} =	$0.018 \times V_c$	=	0.00	(ton)

Where,

D_m:	Avg. Diameter of Penstock =	**0.00**	(m)
L:	Length of Penstock =	**0.00**	(m)

Weight of Penstock	W_{p1} =	$7.85 \times \pi \times D_m \times t_m \times 10^{-3} \times 1.15 \times L$	=	0.00	(ton)
Thickness of Penstock:	t_m =	$0.0362 \times H \times D_m + 2$	=	2.00	(mm)

Where,

W_{p1}:	Weight of Penstock	0.00	(ton)	(Tensil allowable Stress: 1,150 kgf/cm²)
tm:	Thickness of Penstock	2.00	(mm)	
D_m:	Avg. Diameter of Penstock =	0.00	(m)	
H:	Design Head =	**98.10**	(m)	(Intake Water Level - Tailrace Water Level)
L:	Length of Penstock =	0.00	(m)	

Penstock (PVC)φ200:

Excavation:	V_e =	$B \times H \times L$	=	83.26	(m^3)

Where,

Q:	Maximum Discharge =	0.050	(m^3/s)	
L:	Length of Channel =	**110.00**	(m)	
B:	Width of Channel =	**0.87**	(m)	from TUBOPLAST Brochure
H:	Height of Channel =	**0.87**	(m)	from TUBOPLAST Brochure

Spillway Channel:

	$(B \times H)^{0.5}$ =	$1.09 \times Q^{0.379}$	=	0.35	
Excavation:	V_e =	$6.22 \times ((B \times H)^{0.5})^{1.04} \times L$	=	229.77	(m^3)
Concrete:	V_c =	$H \times t \times 2 + (B + 2t) \times L$	=	77.18	(m^3)
Reinforcement Bars	W_r =	$0.577 \times (V_c/L)^{0.888} \times L$	=	0.00	(ton)

Where,

Q:	Maximum Discharge =	0.050	(m^3/s)
L:	Length of Channel =	**110.00**	(m)
B:	Width of Channel =	**0.40**	(m)
H:	Height of Channel =	**0.60**	(m)
t:	Thickness of Concrete =	**0.15**	(m)

Total Quantity of Penstock and Spillway Channel:

Excavation:	V_e =	$V_{e1} + V_{e2}$	=	**313.03**	(m^3)
Concrete:	V_c =	$V_{c1} + V_{c2}$	=	**77.18**	(m^3)
Reinforcement Bars	W_r =	$W_{r1} + W_{r2}$	=	**0.00**	(ton)
Weight of Penstock	W_p =	W_{p1}	=	**0.00**	(ton)

(7) Power House

Excavation:	V_e =	$97.8 \times (Q \times He^{2/3} \times n^{1/2})^{0.727}$	=	**102.28**	(m^3)
Concrete:	V_c =	$28.1 \times (Q \times He^{2/3} \times n^{1/2})^{0.795}$	=	**29.51**	(m^3)
Reinforcement Bars	W_r =	$0.046 \times V_c^{1.05}$	=	**1.61**	(ton)

Where,

Q:	Maximum Discharge =	0.050	(m^3/s)
He:	Effective Head =	98.10	(m)
n:	Quantity Unit of Turbine =	**1.00**	

(8) Outlet

Excavation:	V_e =	$395 \times (R \times Q)^{0.479}$	=	48.42	(m^3)
Concrete:	V_c =	$40.4 \times (R \times Q)^{0.684}$	=	2.02	(m^3)
Reinforcement Bars	W_r =	$0.278 \times V_c^{0.610}$	=	0.43	(ton)

Where,

D:	Diameter of Waterway =	0.50	(m)	
R:	Radius of Waterway =	0.25	(m)	D/2
Q:	Maximum Discharge =	0.050	(m^3/s)	

: Input Cell
: Calculation Cell
: Reference Cell

VI. Unit Price

1USD = 3.00 S/. (as of November, 2007)

(1) Civil Works

Excavation				
Open	:	**5.53**	(US$/m^3)	* (8.70+2.35) x 0.5 = $5.53/m^3, from CAPAECO and Fainal study on Omia <Human power and Machine excavation>
Tunnel	:	-	(US$/m^3)	
Concrete				
Open	:	**93.05**	(US$/m^3)	* from CAPAECO (average of foundation, wall and structure concrete)
Tunnel	:	-	(US$/m^3)	
Reinforcement Bar	:	**1,070.00**	(US$/ton)	*$1.07/kg, from CAPAECO

(2) Hydraulic Equipment

Gate & Screen	:	**8,811.04**	(US$/ton)	* from final study on Omia
Steel Penstock	:	**3,100.00**	(US$/ton)	including installation
PVC (φ400)		**26.33**	(US$/m)	RIB LOC for Headrace
PVC (φ200)	:	**34.74**	(US$/m)	80% of TUBOPLAST(φ315) for Penstock (C-10) = 43.42 x 0.8 = 34.74

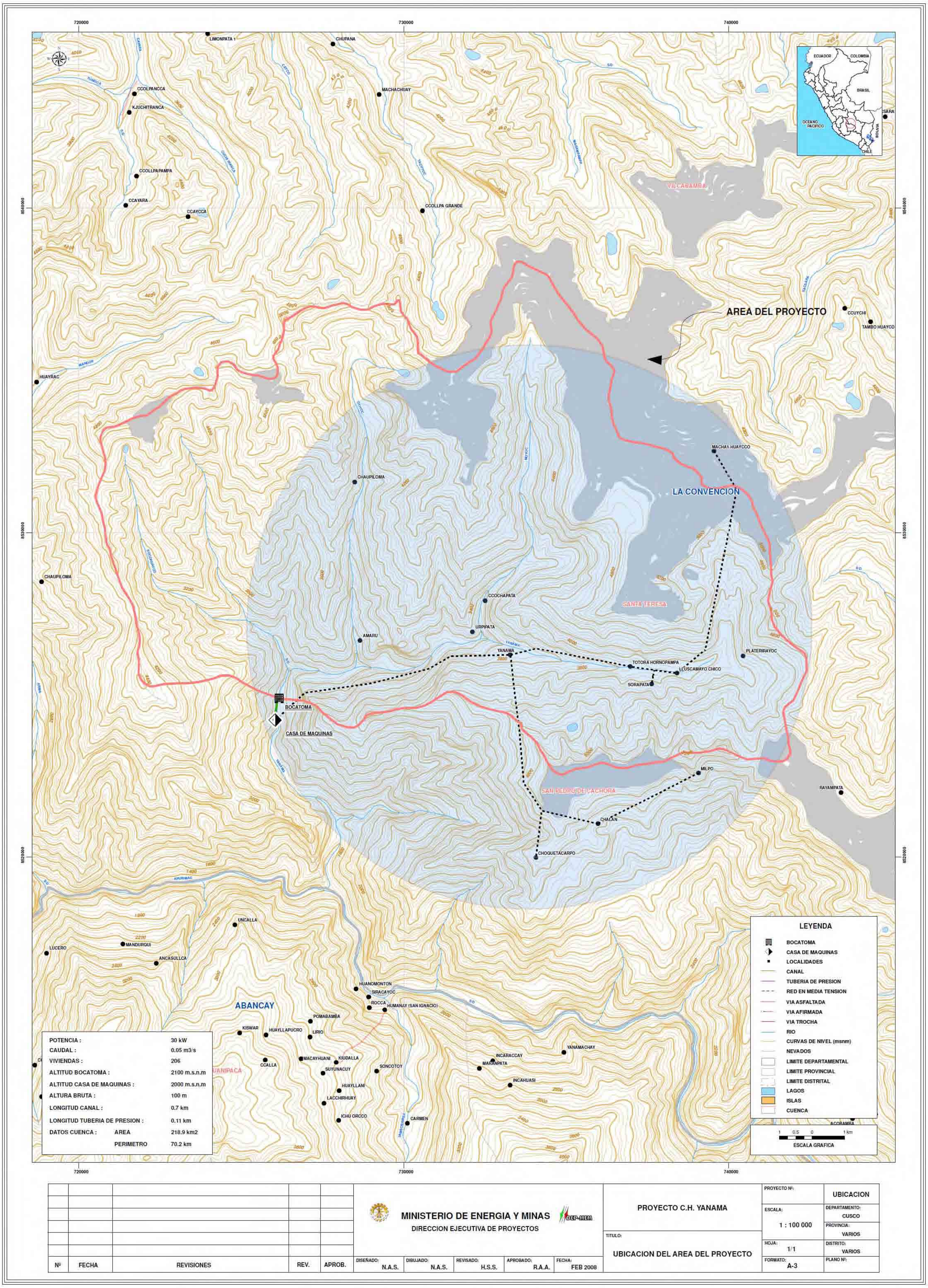
(3) Others

Access Road	:	-	(US$/m)	

(4) Transportation Cost

to the site	:	**16.07**	(US$/ton)	221km (same as the Sarapampa case)

Yanama Map



AREA DEL PROYECTO
VILCABAMBA
LA CONVENCION
SANTA TERESA
SAN PEDRO DE CACHORA
ABANCAY
LIMONPATA 1
CHUPANA
MACHACHUAY
CCOLPANCCA
KJUCHITRANCA
CCOLLPAPAMPA
CCAYARA
CCAYCCA
CCOLLPA GRANDE
HUAYRAC
CCUYCHI
TAMBO HUAYCO
MACHAY-HUAYCCO
CHAUPILOMA
CCOCHAPATA
URPIPATA
AMARU
YANAMA
TOTORA HORNOPAMPA
LLUSCAMAYO CHICO
SORAPATA
PLATERIRAYOC
BOCATOMA
CASA DE MAQUINAS
MILPO
RAYAMPATA
CHALAN
CHOQUETACARPO
UNCALLA
LUCERO
MANDURQUI
ANCASULLCA
HUANOMONTON
SIRACAYOC
ROCCA
HUMANAY (SAN IGNACIO)
POMABAMBA
KISWAR
HUAYLLAPUCRO
LIRIO
CCALLA
MACAYHUANI
KIUDALLA
SUYUNACUY
SONCOTOY
HUAYLLANI
LACCHIRHUAY
ICHU ORCCO
CARMEN
INCARACCAY
MARANPATA
INCAHUASI
YANAMACHAY
ACOBAMBA
ECUADOR
COLOMBIA
BRASIL
OCEANO PACIFICO
BOLIVIA
CHILE
720000
730000
740000
POTENCIA : 30 kW
CAUDAL : 0.05 m3/s
VIVIENDAS : 206
ALTITUD BOCATOMA : 2100 m.s.n.m
ALTITUD CASA DE MAQUINAS : 2000 m.s.n.m
ALTURA BRUTA : 100 m
LONGITUD CANAL : 0.7 km
LONGITUD TUBERIA DE PRESION : 0.11 km
DATOS CUENCA : AREA 218.9 km2
PERIMETRO 70.2 km
LEYENDA
BOCATOMA
CASA DE MAQUINAS
LOCALIDADES
CANAL
TUBERIA DE PRESION
RED EN MEDIA TENSION
VIA ASFALTADA
VIA AFIRMADA
VIA TROCHA
RIO
CURVAS DE NIVEL (msnm)
NEVADOS
LIMITE DEPARTAMENTAL
LIMITE PROVINCIAL
LIMITE DISTRITAL
LAGOS
ISLAS
CUENCA
1 0.5 0 1 km
ESCALA GRAFICA
Nº FECHA REVISIONES REV. APROB.
MINISTERIO DE ENERGIA Y MINAS
DIRECCION EJECUTIVA DE PROYECTOS
DEP-MEM
DISEÑADO: N.A.S.
DIBUJADO: N.A.S.
REVISADO: H.S.S.
APROBADO: R.A.A.
FECHA: FEB 2008
PROYECTO C.H. YANAMA
TITULO: UBICACION DEL AREA DEL PROYECTO
PROYECTO Nº:
ESCALA: 1 : 100 000
HOJA: 1/1
FORMATO: A-3
UBICACION
DEPARTAMENTO: CUSCO
PROVINCIA: VARIOS
DISTRITO: VARIOS
PLANO Nº:

Appendix I-9 Construction Cost for Cayay Power Station

I. Summary of Construction Cost for Cayay Power Station

Unit: US$

Work Item	*Construction Cost*	*Remarks*
1. Preliminary Works	**7,662**	
(1) Access Road	0	
(2) Facilities for Construction Office	2,670	Cost of Civil Works x 0.05
(3) Transportation cost	4,992	347.18ton x $14.38/ton
2. Cost for Environmental Mesures	**534**	Cost of Civil Works x 0.01
3. Civil Works	**53,411**	
(1) Weir	2,221	
(2) Intake	5,569	
(3) Settling Basin	4,727	
(4) Headrace	6,019	
(5) Head Tank	10,346	
(6) Penstock & Spillway Channel	11,386	
(7) Power House	10,852	
(8) Outlet	2,291	
(9) Miscellaneous Work	0	
4. Hydraulic Equipment	**55,800**	
(1) Gate & Screen	3,698	
(2) Penstock	0	
(3) PVC (φ600)	37,592	
(4) PVC (φ315)	5,210	
(5) Others	9,300	
5. Electrical Equipment	**41,100**	
6. Direct Cost	**158,507**	1.+2.+3.+4.+5.
7. Engineering Cost	**15,851**	6. x 0.1: Detailed Design and Supervision
8. Contingent Budget	**15,642**	6. x 0.099
9. IGV	**36,100**	19.00%
10. Total Cost	**226,100**	

II. Detailed Statement of Transportation Cost for Cayay Power Station

Items	Unit	Quantity	Remarks
(1) Wier	ton	**17.05**	
a. Cements		3.57	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		13.24	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.23	
(2) Intake	ton	**51.16**	
a. Gate		0.28	
b. Screen		0.14	
c. Cements		10.58	Cement: 0.27ton per concrete $1m^3$
d. Coarse aggregate		39.18	Coarse aggregate: 1ton per concrete $1m^3$
e. Reinforcement Bars		0.98	
(3) Settling Basin	ton	**31.22**	
a. Cements		6.27	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		23.23	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		1.72	
(4) Headrace	ton	**8.38**	
a. PVC (φ600)		8.38	Weight: 630m x 79.8kg/6m
(5) Head Tank	ton	**57.02**	
a. Cements		11.66	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		43.17	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		2.20	
(6) Penstock & Spillway Channel	ton	**109.37**	
a. Penstock Steel (φ300)		0.00	
b. Penstock PVC (φ315)		2.46	Weight: 120m x 122.833kg/6m
c. Cements		22.73	Cement: 0.27ton per concrete $1m^3$
d. Coarse aggregate		84.18	Coarse aggregate: 1ton per concrete $1m^3$
e. Reinforcement Bars		0.00	
(7) Power House	ton	**64.67**	
a. Cements		13.17	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		48.78	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		2.73	
(8) Outlet	ton	**8.31**	
a. Cements		1.59	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		5.90	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.82	
(9) Subtotal		**347.18**	
(10) Transportation Cost		**4,992**	(9) x $14.38/ton

III. Detailed Statement of Civil Works Cost for Cayay Power Station

Unit: US$

Work Items	Unit	Unit Price	Quantity	Cost	Remarks
(1) Wier				**2,221**	
a. Excavation	m^3	5.53	67.0	370	
b. Concrete	m^3	93.05	13.2	1,231	
c. Reinforcement Bars	ton	1,070.00	0.2	250	
d. Others	-			**370**	(a+b+c) x 0.2 (including coffer dam construction, etc.)
(2) Intake				**5,569**	
a. Excavation	m^3	5.53	26.3	145	
b. Concrete	m^3	93.05	39.2	3,645	
c. Reinforcement Bars	ton	1,070.00	1.0	1,053	
d. Others	-			726	(a+b+c) x 0.15 (including coffer work, etc.)
(3) Settling Basin				**4,727**	
a. Excavation	m^3	5.53	53.3	294	
b. Concrete	m^3	93.05	23.2	2,161	
c. Reinforcement Bars	ton	1,070.00	1.7	1,843	
d. Others	-			429	(a+b+c) x 0.10 (including other works)
(4) Headrace				**6,019**	
a. Excavation	m^3	5.53	907.2	5,016	
b. Concrete	m^3	93.05	0.0	0	
c. Reinforcement Bars	ton	1,070.00	0.0	0	
d. Others	-			1,003	(a+b+c) x 0.20 (including filling works)
(5) Head Tank				**10,346**	
a. Excavation	m^3	5.53	184.3	1,019	
b. Concrete	m^3	93.05	43.2	4,016	
c. Reinforcement Bars	ton	1,070.00	2.2	2,355	
d. Others	-			2,956	(a+b+c) x 0.40 (including gate, screen)
(6) Penstock & Spillway Channel				**11,386**	
a. Excavation	m^3	5.53	455.5	2,519	
b. Concrete	m^3	93.05	84.2	7,832	
c. Reinforcement Bars	ton	1,070.00	0.0	0	
d. Others	-			1,035	(a+b+c) x 0.10 (including filling works)
(7) Power House				**10,852**	
a. Excavation	m^3	5.53	161.9	895	
b. Concrete	m^3	93.05	48.8	4,538	
c. Reinforcement Bars	ton	1,070.00	2.7	2,915	
d. Others	-			2,504	(a+b+c) x 0.30 (including drainage work, wooden
(8) Outlet				**2,291**	
a. Excavation	m^3	5.53	102.6	567	
b. Concrete	m^3	93.05	5.9	548	
c. Reinforcement Bars	ton	1,070.00	0.8	878	
d. Others	-			298	(a+b+c) x 0.15 (including coffer work, etc.)
(9) Miscellaneous Work	-			**0**	Σ(1)-(8) x 0.05 not consider
(10) Subtotal				**53,411**	

IV. Detailed Statement of Hydraulic Equipment Cost for Cayay Power Station

Unit: US$

Work Items	*Unit*	*Unit Price*	*Quantity*	*Cost*	*Remarks*
(1) Weir & Spillway				**0**	
a. Gate	ton	8,811.04	0.00	0	
(2) Intake				**3,698**	
a. Gate	ton	8,811.04	0.28	2,497	
b. Screen	ton	8,811.04	0.14	1,201	
(3) Penstock Steel (φ315)	ton	3,100.00	0.00	**0**	
(4) PVC (φ600) for headrace	m	59.67	630	**37,592**	
(5) Penstock PVC (φ315) C-10	m	43.42	120	**5,210**	
(6) Subtotal				**46,500**	
(7) Others				**9,300**	20.00%
(8) Total				**55,800**	

V. Quantity

(1) Weir

Excavation:	V_e =	$8.69 \times (H_d \times L)^{1.14}$	=	**67.01**	(m^3)
Concrete:	V_c =	$8.64 \times (H_d^2 \times L)^{0.726}$	=	**13.24**	(m^3)
Reinforcement Bars	W_r =	$0.0274 \times V_c^{0.830}$	=	**0.23**	(ton)
Weight of Gate:	W_g =	$0.145 \times Q_f^{0.692}$	=	**0.00**	(ton) (unconsidered)

Where,

H_d:	Height of Dam =	**0.30**	(m)
L:	Length of Dam =	**20.00**	(m)

(2) Intake

Excavation:	V_e =	$171 \times (R \times Q)^{0.666}$	=	**26.26**	(m^3)
Concrete:	V_c =	$147 \times (R \times Q)^{0.470}$	=	**39.18**	(m^3)
Reinforcement Bars	W_r =	$0.0145 \times V_c^{1.15}$	=	**0.98**	(ton)
Weight of Gate:	W_g =	$1.27 \times (R \times Q)^{0.533}$	=	**0.28**	(ton)
Weight of Screen:	W_s =	$0.701 \times (R \times Q)^{0.582}$	=	**0.14**	(ton)

Where,

D:	Diameter of Waterway =	**1.00**	(m)	
R:	Radius of Waterway =	0.50	(m)	D/2 Assumption; Waterway Gradient = 1/1,000
Q:	Maximum Discharge =	**0.120**	(m^3/s)	

(3) Settling Basin

Excavation:	V_e =	$515 \times Q^{1.07}$	=	**53.28**	(m^3)
Concrete:	V_c =	$169 \times Q^{0.936}$	=	**23.23**	(m^3)
Reinforcement Bars	W_r =	$0.120 \times V_c^{0.847}$	=	**1.72**	(ton)
Weight of Gate:	W_g =	$0.910 \times Q^{0.613}$	=	**0.25**	(ton)
Weight of Screen:	W_s =	$0.879 \times Q^{0.785}$	=	**0.17**	(ton)

Where,

Q: Maximum Discharge = 0.120 (m^3/s)

(4) Headrace

In the case of PVCφ600:

Excavation:	$V_e = B \times H \times L$	=	**907.20**	(m^3)
Concrete:	$V_c = ((H \times t \times 2) + (B + 2t) \times t) \times L$	=	**-**	(m^3)
Reinforcement Bars	$W_r = 0.577 \times (V_c/L)^{0.888} \times L$	=	**-**	(ton)

Where,

Q:	Maximum Discharge =	0.120	(m^3/s)	
L:	Length of Channel =	**630.00**	(m)	
B:	Width of Channel =	**1.20**	(m)	for excavation (2D from RIBLOC Brochure)
H:	Height of Channel =	**1.20**	(m)	for excavation (2D from RIBLOC Brochure)
t:	Thickness of Concrete =	-	(m)	

(5) Head Tank

Excavation:	V_e =	$808 \times Q^{0.697}$	=	**184.33**	(m^3)
Concrete:	V_c =	$197 \times Q^{0.716}$	=	**43.17**	(m^3)
Reinforcement Bars	W_r =	$0.051 \times V_c$	=	**2.20**	(ton)

Where,

Q: Maximum Discharge = 0.120 (m^3/s)

(6) Penstock & Spillway Channel

Penstock (Steel)φ315:

Excavation:	V_{e1} =	$10.9 \times D_m^{1.33} \times L$	=	0.00	(m^3)
Concrete:	V_{c1} =	$2.14 \times D_m^{1.68} \times L$	=	0.00	(m^3)
Reinforcement Bars	W_{r1} =	$0.018 \times V_c$	=	0.00	(ton)

Where,

D_m:	Avg. Diameter of Penstock =	**0.00**	(m)
L:	Length of Penstock =	**0.00**	(m)

Weight of Penstock	$W_{p1} = 7.85 \times \pi \times D_m \times t_m \times 10^{-3} \times 1.15 \times L$	=	0.00	(ton)
Thickness of Penstock:	$t_m = 0.0362 \times H \times D_m + 2$	=	2.00	(mm)

Where,

W_{p1}:	Weight of Penstock	0.00	(ton)	(Tensil allowable Stress: 1,150 kgf/cm^2)
tm:	Thickness of Penstock	2.00	(mm)	
D_m:	Avg. Diameter of Penstock =	0.00	(m)	
H:	Design Head =	**68.10**	(m)	(Intake Water Level - Tailrace Water Level)
L:	Length of Penstock =	0.00	(m)	

Penstock (PVC)φ315:

Excavation:	$V_e = B \times H \times L$	=	101.57	(m^3)

Where,

Q:	Maximum Discharge =	0.120	(m^3/s)	
L:	Length of Channel =	**120.00**	(m)	
B:	Width of Channel =	**0.92**	(m)	from TUBOPLAST Brochure
H:	Height of Channel =	**0.92**	(m)	from TUBOPLAST Brochure

Spillway Channel:

	(B x H)^0.5 =	$1.09 \times Q^{0.379}$	=	0.49	
Excavation:	V_e =	$6.22 \times ((B \times H)^{0.5})^{1.04} \times L$	=	353.95	(m^3)
Concrete:	V_c =	$H \times t \times 2 + (B + 2t) \times L$	=	84.18	(m^3)
Reinforcement Bars	W_r =	$0.577 \times (V_c/L)^{0.888} \times L$	=	0.00	(ton)

Where,

Q:	Maximum Discharge =	0.120	(m^3/s)
L:	Length of Channel =	**120.00**	(m)
B:	Width of Channel =	**0.40**	(m)
H:	Height of Channel =	**0.60**	(m)
t:	Thickness of Concrete =	**0.15**	(m)

Total Quantity of Penstock and Spillway Channel:

Excavation:	V_e =	$V_{e1} + V_{e2}$	=	**455.52**	(m^3)
Concrete:	V_c =	$V_{c1} + V_{c2}$	=	**84.18**	(m^3)
Reinforcement Bars	W_r =	$W_{r1} + W_{r2}$	=	**0.00**	(ton)
Weight of Penstock	W_p =	W_{p1}	=	**0.00**	(ton)

(7) Power House

Excavation:	$V_e = 97.8 \times (Q \times He^{2/3} \times n^{1/2})^{0.727}$	=	**161.95**	(m^3)
Concrete:	$V_c = 28.1 \times (Q \times He^{2/3} \times n^{1/2})^{0.795}$	=	**48.78**	(m^3)
Reinforcement Bars	$W_r = 0.046 \times V_c^{1.05}$	=	**2.73**	(ton)

Where,

Q:	Maximum Discharge =	0.120	(m^3/s)
He:	Effective Head =	68.10	(m)
n:	Quantity Unit of Turbine =	**1.00**	

(8) Outlet

Excavation:	V_e =	$395 \times (R \times Q)^{0.479}$	=	102.64	(m^3)
Concrete:	V_c =	$40.4 \times (R \times Q)^{0.684}$	=	5.90	(m^3)
Reinforcement Bars	W_r =	$0.278 \times V_c^{0.610}$	=	0.82	(ton)

Where,

D:	Diameter of Waterway =	1.00	(m)	
R:	Radius of Waterway =	0.50	(m)	D/2
Q:	Maximum Discharge =	0.120	(m^3/s)	

: Input Cell
: Calculation Cell
: Reference Cell

VI. Unit Price

1USD = 3.00 S/. (as of November, 2007)

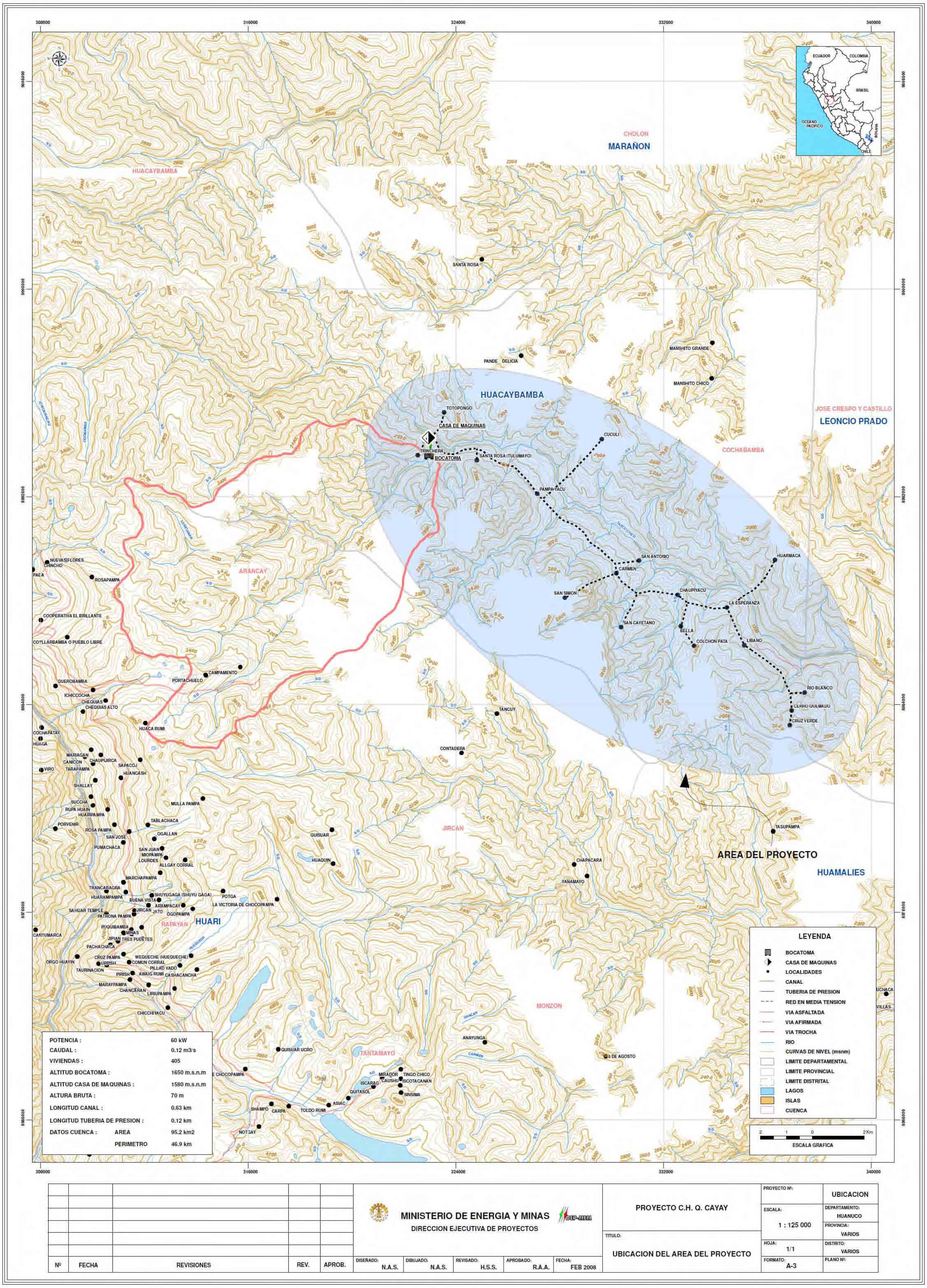
(1) Civil Works				
Excavation				
Open	:	**5.53**	(US$/m³)	* (8.70+2.35) x 0.5 = $5.53/m³, from CAPAECO and Fainal study on Omia <Human power and Machine excavation>
Tunnel	:	**-**	(US$/m³)	
Concrete				
Open	:	**93.05**	(US$/m³)	* from CAPAECO (average of foundation, wall and structure concrete)
Tunnel	:	**-**	(US$/m³)	
Reinforcement Bar	:	**1,070.00**	(US$/ton)	*$1.07/kg, from CAPAECO

(2) Hydraulic Equipment				
Gate & Screen	:	**8,811.04**	(US$/ton)	* from final study on Omia
Steel Penstock	:	**3,100.00**	(US$/ton)	including installation
PVC (φ600)		**59.67**	(US$/m)	RIB LOC for Headrace
PVC (φ315)	:	**43.42**	(US$/m)	TUBOPLAST for Penstock (C-10), The number of joints is 215. This price include joint price. 190m/6m =30 (joint), 30 x $2.7 =81$, 81$/190m =0.43$/m, 42.99$/m (PVC) + 0.43$/m (joint) = 43.42$/m

(3) Others				
Access Road	:	**-**	(US$/m)	

(4) Transportation Cost				
Huaraz to the site	:	**14.38**	(US$/ton)	172 km (road)

Cayay Map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CHOLON
MARAÑON
SANTA ROSA
PANDE DELICIA
MANSHITO GRANDE
MANSHITO CHICO
HUACAYBAMBA
TOTOPONGO
CASA DE MAQUINAS
TRINCHERA
BOCATOMA
SANTA ROSA (TULUMAYO)
CUCULI
JOSE CRESPO Y CASTILLO
LEONCIO PRADO
COCHABAMBA
PAMPAYACU
SAN ANTONIO
CARMEN
HUARMACA
SAN SIMON
CHAUPIYACU
LA ESPERANZA
SAN CAYETANO
BELLA
COLCHON PATA
LIBANO
RIO BLANCO
CERRO QUEMADO
CRUZ VERDE
ARANCAY
NUEVAS FLORES
ROSAPAMPA
COOPERATIVA EL BRILLANTE
CAMPAMENTO
PORTACHUELO
QUEROBAMBA
CHEQUIAS
CHEQUIAS ALTO
HUACA RUMI
TANCUY
CONTADERA
TASUPAMPA
AREA DEL PROYECTO
JIRCAN
HUAMALIES
CHAPACARA
YANAMAYO
MULLA PAMPA
QUISUAR
HUAQUIN
RAPAYAN
HUARI
POTGA
LA VICTORIA DE CHOCOPAMPA
MONZON
ANAYUNGA
TANTAMAYO
QUISUAR UCRO
TINGO CHICO
SINSIMA
TOLDO RUMI
NOTGAY
POTENCIA : 60 kW
CAUDAL : 0.12 m3/s
VIVIENDAS : 405
ALTITUD BOCATOMA : 1650 m.s.n.m
ALTITUD CASA DE MAQUINAS : 1580 m.s.n.m
ALTURA BRUTA : 70 m
LONGITUD CANAL : 0.63 km
LONGITUD TUBERIA DE PRESION : 0.12 km
DATOS CUENCA : AREA 95.2 km2
PERIMETRO 46.9 km
LEYENDA
BOCATOMA
CASA DE MAQUINAS
LOCALIDADES
CANAL
TUBERIA DE PRESION
RED EN MEDIA TENSION
VIA ASFALTADA
VIA AFIRMADA
VIA TROCHA
RIO
CURVAS DE NIVEL (msnm)
LIMITE DEPARTAMENTAL
LIMITE PROVINCIAL
LIMITE DISTRITAL
LAGOS
ISLAS
CUENCA
ESCALA GRAFICA
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APROB.
MINISTERIO DE ENERGIA Y MINAS
DIRECCION EJECUTIVA DE PROYECTOS
DEP-MEM
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DIBUJADO: N.A.S.
REVISADO: H.S.S.
APROBADO: R.A.A.
FECHA: FEB 2008
PROYECTO C.H. Q. CAYAY
TITULO:
UBICACION DEL AREA DEL PROYECTO
PROYECTO Nº:
ESCALA: 1 : 125 000
HOJA: 1/1
FORMATO: A-3
UBICACION
DEPARTAMENTO: HUANUCO
PROVINCIA: VARIOS
DISTRITO: VARIOS
PLANO Nº:

Appendix I-10 Construction Cost for Chontabamba Power Station

I. Summary of Construction Cost for Chontabamba Power Station

Unit: US$

Work Item	Construction Cost	Remarks
1. Preliminary Works	**19,131**	
(1) Access Road	12,931	
(2) Facilities for Construction Office	2,509	Cost of Civil Works x 0.05
(3) Transportation cost	3,691	358.41ton x $10.30/ton
2. Cost for Environmental Mesures	**501**	Cost of Civil Works x 0.01
3. Civil Works	**50,195**	
(1) Weir	2,221	
(2) Intake	3,443	
(3) Settling Basin	3,667	
(4) Headrace	3,051	
(5) Head Tank	8,428	
(6) Penstock & Spillway Channel	16,960	
(7) Power House	11,026	
(8) Outlet	1,399	
(9) Miscellaneous Work	0	
4. Hydraulic Equipment	**33,300**	
(1) Gate & Screen	2,158	
(2) Penstock	782	
(3) PVC (φ500)	19,168	
(4) PVC (φ200)	5,697	
(5) Others	5,495	
5. Electrical Equipment	**43,000**	
6. Direct Cost	**146,127**	1.+2.+3.+4.+5.
7. Engineering Cost	**14,613**	6. x 0.1: Detailed Design and Supervision
8. Contingent Budget	**14,260**	6. x 0.098
9. IGV	**33,250**	19.00%
10. Total Cost	**208,250**	

II. Detailed Statement of Transportation Cost for Chontabamba Power Station

Items	Unit	Quantity	Remarks
(1) Wier	ton	**17.05**	
a. Cements		3.57	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		13.24	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.23	
(2) Intake	ton	**32.20**	
a. Gate		0.17	
b. Screen		0.08	
c. Cements		6.67	Cement: 0.27ton per concrete $1m^3$
d. Coarse aggregate		24.71	Coarse aggregate: 1ton per concrete $1m^3$
e. Reinforcement Bars		0.58	
(3) Settling Basin	ton	**23.91**	
a. Cements		4.79	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		17.74	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		1.37	
(4) Headrace	ton	**3.95**	
a. PVC (φ500)		3.95	Weight: 460m x 51.522kg/6m
(5) Head Tank	ton	**46.41**	
a. Cements		9.49	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		35.13	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		1.79	
(6) Penstock & Spillway Channel	ton	**164.82**	
a. Penstock Steel (φ200)		0.25	
b. Penstock PVC (φ200)		1.37	Weight: 164m x 50.000kg/6m
c. Cements		34.69	Cement: 0.27ton per concrete $1m^3$
d. Coarse aggregate		128.47	Coarse aggregate: 1ton per concrete $1m^3$
e. Reinforcement Bars		0.04	
(7) Power House	ton	**65.70**	
a. Cements		13.38	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		49.55	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		2.77	
(8) Outlet	ton	**4.37**	
a. Cements		0.81	Cement: 0.27ton per concrete $1m^3$
b. Coarse aggregate		3.01	Coarse aggregate: 1ton per concrete $1m^3$
c. Reinforcement Bars		0.55	
(9) Subtotal		**358.41**	
(10) Transportation Cost		**3,692**	(9) x $10.30/ton

III. Detailed Statement of Civil Works Cost for Chontabamba Power Station

Unit: US$

Work Items	Unit	Unit Price	Quantity	Cost	Remarks
(1) Wier				**2,221**	
a. Excavation	m^3	5.53	67.0	370	
b. Concrete	m^3	93.05	13.2	1,231	
c. Reinforcement Bars	ton	1,070.00	0.2	250	
d. Others	-			370	(a+b+c) x 0.2 (including coffer dam construction, etc.)
(2) Intake				**3,443**	
a. Excavation	m^3	5.53	13.7	75	
b. Concrete	m^3	93.05	24.7	2,299	
c. Reinforcement Bars	ton	1,070.00	0.6	620	
d. Others	-			449	(a+b+c) x 0.15 (including coffer work, etc.)
(3) Settling Basin				**3,667**	
a. Excavation	m^3	5.53	39.2	216	
b. Concrete	m^3	93.05	17.7	1,651	
c. Reinforcement Bars	ton	1,070.00	1.4	1,467	
d. Others	-			333	(a+b+c) x 0.10 (including other works)
(4) Headrace				**3,051**	
a. Excavation	m^3	5.53	460.0	2,543	
b. Concrete	m^3	93.05	0.0	0	
c. Reinforcement Bars	ton	1,070.00	0.0	0	
d. Others	-			508	(a+b+c) x 0.20 (including filling works)
(5) Head Tank				**8,428**	
a. Excavation	m^3	5.53	150.8	834	
b. Concrete	m^3	93.05	35.1	3,269	
c. Reinforcement Bars	ton	1,070.00	1.8	1,917	
d. Others	-			2,408	(a+b+c) x 0.40 (including gate, screen)
(6) Penstock & Spillway Channel				**16,960**	
a. Excavation	m^3	5.53	618.7	3,421	
b. Concrete	m^3	93.05	128.5	11,954	
c. Reinforcement Bars	ton	1,070.00	0.0	44	
d. Others	-			1,541	(a+b+c) x 0.10 (including filling works)
(7) Power House				**11,026**	
a. Excavation	m^3	5.53	164.3	908	
b. Concrete	m^3	93.05	49.6	4,610	
c. Reinforcement Bars	ton	1,070.00	2.8	2,964	
d. Others	-			2,544	(a+b+c) x 0.30 (including drainage work, wooden
(8) Outlet				**1,399**	
a. Excavation	m^3	5.53	64.2	354	
b. Concrete	m^3	93.05	3.0	280	
c. Reinforcement Bars	ton	1,070.00	0.5	583	
d. Others	-			182	(a+b+c) x 0.15 (including coffer work, etc.)
(9) Miscellaneous Work	-			**0**	Σ(1)-(8) x 0.05 not consider
(10) Subtotal				**50,195**	

IV. Detailed Statement of Hydraulic Equipment Cost for Chontabamba Power Station

Unit: US$

Work Items	*Unit*	*Unit Price*	*Quantity*	*Cost*	*Remarks*
(1) Weir & Spillway				**0**	
a. Gate	ton	8,811.04	0.00	0	
(2) Intake				**2,158**	
a. Gate	ton	8,811.04	0.17	1,480	
b. Screen	ton	8,811.04	0.08	678	
(3) Penstock Steel (φ200）	ton	3,100.00	0.25	**782**	
(4) PVC (φ500）for headrace	m	41.67	460	**19,168**	
(5) Penstock PVC (φ200) C-10	m	34.74	164	**5,697**	
(6) Subtotal				**27,805**	
(7) Others				**5,495**	19.76%
(8) Total				**33,300**	

V. Quantity

(1) Weir

Excavation:	V_e =	$8.69 \times (H_d \times L)^{1.14}$	=	**67.01**	(m^3)	
Concrete:	V_c =	$8.64 \times (H_d^2 \times L)^{0.726}$	=	**13.24**	(m^3)	
Reinforcement Bars	W_r =	$0.0274 \times V_c^{0.830}$	=	**0.23**	(ton)	
Weight of Gate:	W_g =	$0.145 \times Q_f^{0.692}$	=	**0.00**	(ton)	(unconsidered)

Where,

H_d:	Height of Dam =	**0.30**	(m)
L:	Length of Dam =	**20.00**	(m)

(2) Intake

Excavation:	V_e =	$171 \times (R \times Q)^{0.666}$	=	**13.66**	(m^3)
Concrete:	V_c =	$147 \times (R \times Q)^{0.470}$	=	**24.71**	(m^3)
Reinforcement Bars	W_r =	$0.0145 \times V_c^{1.15}$	=	**0.58**	(ton)
Weight of Gate:	W_g =	$1.27 \times (R \times Q)^{0.533}$	=	**0.17**	(ton)
Weight of Screen:	W_s =	$0.701 \times (R \times Q)^{0.582}$	=	**0.08**	(ton)

Where,

D:	Diameter of Waterway =	**0.50**	(m)		
R:	Radius of Waterway =	0.25	(m)	D/2	Assumption; Waterway Gradient = 1/1,000
Q:	Maximum Discharge =	**0.090**	(m^3/s)		

(3) Settling Basin

Excavation:	V_e =	$515 \times Q^{1.07}$	=	**39.16**	(m^3)
Concrete:	V_c =	$169 \times Q^{0.936}$	=	**17.74**	(m^3)
Reinforcement Bars	W_r =	$0.120 \times V_c^{0.847}$	=	**1.37**	(ton)
Weight of Gate:	W_g =	$0.910 \times Q^{0.613}$	=	**0.21**	(ton)
Weight of Screen:	W_s =	$0.879 \times Q^{0.785}$	=	**0.13**	(ton)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)

(4) Headrace

In the case of PVCφ500:

Excavation:	$V_e = B \times H \times L$	=	**460.00**	(m^3)
Concrete:	$V_c = ((H \times t \times 2) + (B + 2t) \times t) \times L$	=	**-**	(m^3)
Reinforcement Bars	$W_r = 0.577 \times (V_c/L)^{0.888} \times L$	=	**-**	(ton)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)	
L:	Length of Channel =	**460.00**	(m)	
B:	Width of Channel =	**1.00**	(m)	for excavation (2D from RIBLOC Brochure)
H:	Height of Channel =	**1.00**	(m)	for excavation (2D from RIBLOC Brochure)
t:	Thickness of Concrete =	-	(m)	

(5) Head Tank

Excavation:	V_e =	$808 \times Q^{0.697}$	=	**150.84**	(m^3)
Concrete:	V_c =	$197 \times Q^{0.716}$	=	**35.13**	(m^3)
Reinforcement Bars	W_r =	$0.051 \times V_c$	=	**1.79**	(ton)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)

(6) Penstock & Spillway Channel

Penstock (Steel)φ200:

Excavation:	V_{e1} =	$10.9 \times D_m^{1.33} \times L$	=	20.51	(m^3)
Concrete:	V_{c1} =	$2.14 \times D_m^{1.68} \times L$	=	2.29	(m^3)
Reinforcement Bars	W_{r1} =	$0.018 \times V_c$	=	0.04	(ton)

Where,

D_m:	Avg. Diameter of Penstock =	**0.20**	(m)
L:	Length of Penstock =	**16.00**	(m)

Weight of Penstock	$W_{p1} = 7.85 \times \pi \times D_m \times t_m \times 10^{-3} \times 1.15 \times L$	=	0.25	(ton)
Thickness of Penstock:	$t_m = 0.0362 \times H \times D_m + 2$	=	2.78	(mm)

Where,

W_{p1}:	Weight of Penstock	0.25	(ton)	(Tensil allowable Stress: 1,150 kgf/cm^2)
tm:	Thickness of Penstock	2.78	(mm)	
D_m:	Avg. Diameter of Penstock =	0.20	(m)	
H:	Design Head =	**108.00**	(m)	(Intake Water Level - Tailrace Water Level)
L:	Length of Penstock =	16.00	(m)	

Penstock (PVC)φ200:

Excavation:	$V_e = B \times H \times L$	=	124.13	(m^3)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)	
L:	Length of Channel =	**164.00**	(m)	
B:	Width of Channel =	**0.87**	(m)	from TUBOPLAST Brochure
H:	Height of Channel =	**0.87**	(m)	from TUBOPLAST Brochure

Spillway Channel:

	$(B \times H)^{0.5} = 1.09 \times Q^{0.379}$	=	0.44	
Excavation:	$V_e = 6.22 \times ((B \times H)^{0.5})^{1.04} \times L$	=	474.01	(m^3)
Concrete:	$V_c = H \times t \times 2 + (B + 2t) \times L$	=	126.18	(m^3)
Reinforcement Bars	$W_r = 0.577 \times (V_c/L)^{0.888} \times L$	=	0.00	(ton)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)
L:	Length of Channel =	**180.00**	(m)
B:	Width of Channel =	**0.40**	(m)
H:	Height of Channel =	**0.60**	(m)
t:	Thickness of Concrete =	**0.15**	(m)

Total Quantity of Penstock and Spillway Channel:

Excavation:	V_e =	$V_{e1} + V_{e2}$	=	**618.65**	(m^3)
Concrete:	V_c =	$V_{c1} + V_{c2}$	=	**128.47**	(m^3)
Reinforcement Bars	W_r =	$W_{r1} + W_{r2}$	=	**0.04**	(ton)
Weight of Penstock	W_p =	W_{p1}	=	**0.25**	(ton)

(7) Power House

Excavation:	$V_e = 97.8 \times (Q \times He^{2/3} \times n^{1/2})^{0.727}$	=	**164.29**	(m^3)
Concrete:	$V_c = 28.1 \times (Q \times He^{2/3} \times n^{1/2})^{0.795}$	=	**49.55**	(m^3)
Reinforcement Bars	$W_r = 0.046 \times V_c^{1.05}$	=	**2.77**	(ton)

Where,

Q:	Maximum Discharge =	0.090	(m^3/s)
He:	Effective Head =	108.00	(m)
n:	Quantity Unit of Turbine =	**1.00**	

(8) Outlet

Excavation:	V_e =	$395 \times (R \times Q)^{0.479}$	=	64.16	(m^3)
Concrete:	V_c =	$40.4 \times (R \times Q)^{0.684}$	=	3.01	(m^3)
Reinforcement Bars	W_r =	$0.278 \times V_c^{0.610}$	=	0.55	(ton)

Where,

D:	Diameter of Waterway =	0.50	(m)	
R:	Radius of Waterway =	0.25	(m)	D/2
Q:	Maximum Discharge =	0.090	(m^3/s)	

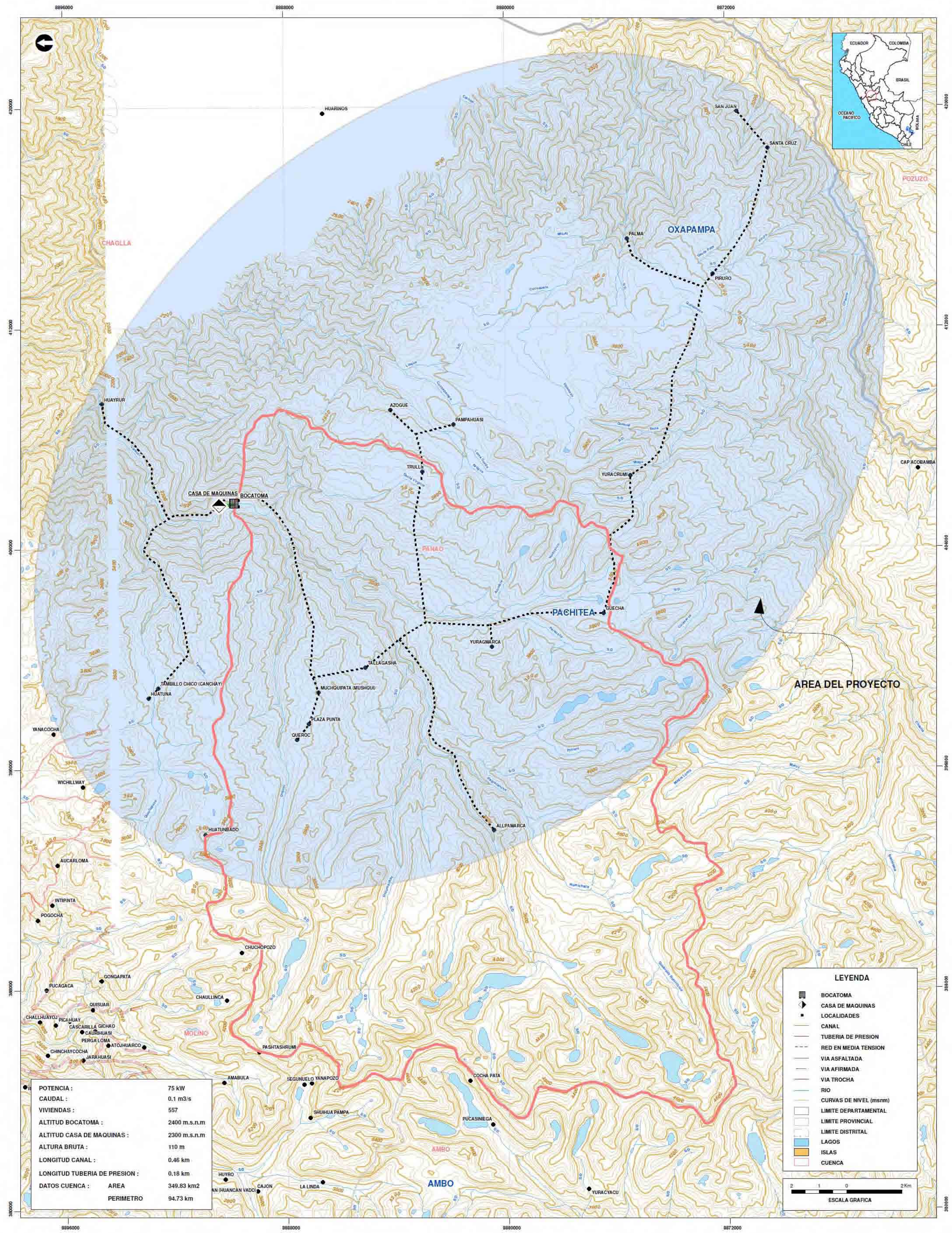
: Input Cell
: Calculation Cell
: Reference Cell

VI. Unit Price

1USD = 3.00 S/. (as of November, 2007)

(1) Civil Works				
Excavation				
Open	:	**5.53**	(US$/m^3)	* (8.70+2.35) x 0.5 = $5.53/m^3, from CAPAECO and Fainal study on Omia <Human power and Machine excavation>
Tunnel	:	-	(US$/m^3)	
Concrete				
Open	:	**93.05**	(US$/m^3)	* from CAPAECO (average of foundation, wall and structure concrete)
Tunnel	:	-	(US$/m^3)	
Reinforcement Bar	:	**1,070.00**	(US$/ton)	*$1.07/kg, from CAPAECO
(2) Hydraulic Equipment				
Gate & Screen	:	**8,811.04**	(US$/ton)	* from final study on Omia
Steel Penstock	:	**3,100.00**	(US$/ton)	including installation
PVC (φ500)		**41.67**	(US$/m)	RIB LOC for Headrace
PVC (φ200)	:	**34.74**	(US$/m)	80% of TUBOPLAST(φ315) for Penstock (C-10) = 43.42 x 0.8 = 34.74
(3) Others				
Access Road	:	**979.65**	(US$/m)	Repair Work for Existing Unpaved Road
(4) Transportation Cost				
Huanuco to the site	:	**10.30**	(US$/ton)	54km (road)

Chontabamba Map



Nº	FECHA	REVISIONES	REV.	APROB.

MINISTERIO DE ENERGIA Y MINAS
DIRECCION EJECUTIVA DE PROYECTOS
DEP-MEM

DISEÑADO:	DIBUJADO:	REVISADO:	APROBADO:	FECHA:
N.A.S.	N.A.S.	H.S.S.	R.A.A.	SET 2007

PROYECTO C.H. CHONTABAMBA

TITULO: UBICACION DEL AREA DEL PROYECTO

PROYECTO Nº:	UBICACION
ESCALA: 1 : 125 000	DEPARTAMENTO: HUANUCO
	PROVINCIA: VARIOS
HOJA: 1/1	DISTRITO: VARIOS
FORMATO: A-3	PLANO Nº:

Appendix I-11 Construction Cost for Quechuarpata Power Station

I. Summary of Construction Cost for Quechuarpata Power Station

Unit: US$

Work Item	*Construction Cost*	*Remarks*
1. Preliminary Works	**20,185**	
(1) Access Road	8,229	
(2) Facilities for Construction Office	4,749	Cost of Civil Works x 0.05
(3) Transportation cost	7,207	611.34ton x $11.79/ton
2. Cost for Environmental Mesures	**949**	Cost of Civil Works x 0.01
3. Civil Works	**94,991**	
(1) Weir	3,284	
(2) Intake	8,148	
(3) Settling Basin	9,384	
(4) Headrace	7,803	
(5) Head Tank	17,963	
(6) Penstock & Spillway Channel	19,201	
(7) Power House	25,799	
(8) Outlet	3,409	
(9) Miscellaneous Work	0	
4. Hydraulic Equipment	**71,400**	
(1) Gate & Screen	5,654	
(2) Penstock	1,657	
(3) PVC (φ700)	43,002	
(4) PVC (φ350)	9,257	
(5) Others	11,830	
5. Electrical Equipment	**107,800**	
6. Direct Cost	**295,325**	1.+2.+3.+4.+5.
7. Engineering Cost	**29,533**	6. x 0.1: Detailed Design and Supervision
8. Contingent Budget	**29,143**	6. x 0.099
9. IGV	**67,260**	19.00%
10. Total Cost	**421,260**	

II. Detailed Statement of Transportation Cost for Quechuarpata Power Station

Items	Unit	Quantity	Remarks
(1) Wier	ton	**25.86**	
a. Cements		5.43	Cement: 0.27ton per concrete 1m^3
b. Coarse aggregate		20.10	Coarse aggregate: 1ton per concrete 1m^3
c. Reinforcement Bars		0.33	
(2) Intake	ton	**73.70**	
a. Gate		0.43	
b. Screen		0.21	
c. Cements		15.21	Cement: 0.27ton per concrete 1m^3
d. Coarse aggregate		56.35	Coarse aggregate: 1ton per concrete 1m^3
e. Reinforcement Bars		1.50	
(3) Settling Basin	ton	**64.01**	
a. Cements		12.93	Cement: 0.27ton per concrete 1m^3
b. Coarse aggregate		47.90	Coarse aggregate: 1ton per concrete 1m^3
c. Reinforcement Bars		3.18	
(4) Headrace	ton	**9.31**	
a. PVC (φ700)		9.31	Weight: 600m x 93.102kg/6m
(5) Head Tank	ton	**99.20**	
a. Cements		20.27	Cement: 0.27ton per concrete 1m^3
b. Coarse aggregate		75.09	Coarse aggregate: 1ton per concrete 1m^3
c. Reinforcement Bars		3.83	
(6) Penstock & Spillway Channel	ton	**172.60**	
a. Penstock Steel (φ350)		0.53	
b. Penstock PVC (φ350)		4.26	Weight: 164m x 155.748kg/6m
c. Cements		35.65	Cement: 0.27ton per concrete 1m^3
d. Coarse aggregate		132.05	Coarse aggregate: 1ton per concrete 1m^3
e. Reinforcement Bars		0.11	
(7) Power House	ton	**152.83**	
a. Cements		31.06	Cement: 0.27ton per concrete 1m^3
b. Coarse aggregate		115.05	Coarse aggregate: 1ton per concrete 1m^3
c. Reinforcement Bars		6.71	
(8) Outlet	ton	**13.84**	
a. Cements		2.70	Cement: 0.27ton per concrete 1m^3
b. Coarse aggregate		10.01	Coarse aggregate: 1ton per concrete 1m^3
c. Reinforcement Bars		1.13	
(9) Subtotal		**611.34**	
(10) Transportation Cost		**7,208**	(9) x $11.79/ton

III. Detailed Statement of Civil Works Cost for Quechuarpata Power Station

Unit: US$

Work Items	Unit	Unit Price	Quantity	Cost	Remarks
(1) Wier				**3,284**	
a. Excavation	m^3	5.53	93.0	514	
b. Concrete	m^3	93.05	20.1	1,870	
c. Reinforcement Bars	ton	1,070.00	0.3	353	
d. Others	-			**547**	(a+b+c) x 0.2 (including coffer dam construction, etc.)
(2) Intake				**8,148**	
a. Excavation	m^3	5.53	43.9	243	
b. Concrete	m^3	93.05	56.3	5,243	
c. Reinforcement Bars	ton	1,070.00	1.5	1,600	
d. Others	-			1,062	(a+b+c) x 0.15 (including coffer work, etc.)
(3) Settling Basin				**9,384**	
a. Excavation	m^3	5.53	121.9	673	
b. Concrete	m^3	93.05	47.9	4,456	
c. Reinforcement Bars	ton	1,070.00	3.2	3,402	
d. Others	-			853	(a+b+c) x 0.10 (including other works)
(4) Headrace				**7,803**	
a. Excavation	m^3	5.53	1176.0	6,503	
b. Concrete	m^3	93.05	0.0	0	
c. Reinforcement Bars	ton	1,070.00	0.0	0	
d. Others	-			1,300	(a+b+c) x 0.20 (including filling works)
(5) Head Tank				**17,963**	
a. Excavation	m^3	5.53	316.0	1,747	
b. Concrete	m^3	93.05	75.1	6,987	
c. Reinforcement Bars	ton	1,070.00	3.8	4,097	
d. Others	-			5,132	(a+b+c) x 0.40 (including gate, screen)
(6) Penstock & Spillway Channel				**19,201**	
a. Excavation	m^3	5.53	914.4	5,056	
b. Concrete	m^3	93.05	132.0	12,287	
c. Reinforcement Bars	ton	1,070.00	0.1	113	
d. Others	-			1,745	(a+b+c) x 0.10 (including filling works)
(7) Power House				**25,799**	
a. Excavation	m^3	5.53	354.9	1,962	
b. Concrete	m^3	93.05	115.1	10,705	
c. Reinforcement Bars	ton	1,070.00	6.7	7,179	
d. Others	-			5,953	(a+b+c) x 0.30 (including drainage work, wooden
(8) Outlet				**3,409**	
a. Excavation	m^3	5.53	148.7	822	
b. Concrete	m^3	93.05	10.0	931	
c. Reinforcement Bars	ton	1,070.00	1.1	1,212	
d. Others	-			444	(a+b+c) x 0.15 (including coffer work, etc.)
(9) Miscellaneous Work	-			**0**	Σ(1)-(8) x 0.05 not consider
(10) Subtotal				**94,991**	

IV. Detailed Statement of Hydraulic Equipment Cost for Quechuarpata Power Station

Unit: US$

Work Items	*Unit*	*Unit Price*	*Quantity*	*Cost*	*Remarks*
(1) Weir & Spillway				**0**	
a. Gate	ton	8,811.04	0.00	0	
(2) Intake				**5,654**	
a. Gate	ton	8,811.04	0.43	3,771	
b. Screen	ton	8,811.04	0.21	1,883	
(3) Penstock Steel (φ350)	ton	3,100.00	0.53	**1,657**	
(4) PVC (φ700) for headrace	m	71.67	600	**43,002**	
(5) Penstock PVC (φ350) C-10	m	56.45	164	**9,257**	
(6) Subtotal				**59,570**	
(7) Others				**11,830**	19.86%
(8) Total				**71,400**	

V. Quantity

(1) Weir

Excavation:	V_e =	$8.69 \times (H_d \times L)^{1.14}$	=	**93.01**	(m^3)	
Concrete:	V_c =	$8.64 \times (H_d^2 \times L)^{0.726}$	=	**20.10**	(m^3)	
Reinforcement Bars	W_r =	$0.0274 \times V_c^{0.830}$	=	**0.33**	(ton)	
Weight of Gate:	W_g =	$0.145 \times Q_f^{0.692}$	=	**0.00**	(ton)	(unconsidered)

Where,

H_d:	Height of Dam =	**0.40**	(m)
L:	Length of Dam =	**20.00**	(m)

(2) Intake

Excavation:	V_e =	$171 \times (R \times Q)^{0.666}$	=	**43.94**	(m^3)
Concrete:	V_c =	$147 \times (R \times Q)^{0.470}$	=	**56.35**	(m^3)
Reinforcement Bars	W_r =	$0.0145 \times V_c^{1.15}$	=	**1.50**	(ton)
Weight of Gate:	W_g =	$1.27 \times (R \times Q)^{0.533}$	=	**0.43**	(ton)
Weight of Screen:	W_s =	$0.701 \times (R \times Q)^{0.582}$	=	**0.21**	(ton)

Where,

D:	Diameter of Waterway =	**1.00**	(m)		
R:	Radius of Waterway =	0.50	(m)	D/2	Assumption; Waterway Gradient = 1/1,000
Q:	Maximum Discharge =	**0.260**	(m^3/s)		

(3) Settling Basin

Excavation:	V_e =	$515 \times Q^{1.07}$	=	**121.85**	(m^3)
Concrete:	V_c =	$169 \times Q^{0.936}$	=	**47.90**	(m^3)
Reinforcement Bars	W_r =	$0.120 \times V_c^{0.847}$	=	**3.18**	(ton)
Weight of Gate:	W_g =	$0.910 \times Q^{0.613}$	=	**0.40**	(ton)
Weight of Screen:	W_s =	$0.879 \times Q^{0.785}$	=	**0.31**	(ton)

Where,

Q:	Maximum Discharge =	0.260	(m^3/s)

(4) Headrace

In the case of PVCφ700:

Excavation:	$V_e = B \times H \times L$	=	**1,176.00**	(m^3)
Concrete:	$V_c = ((H \times t \times 2) + (B + 2t) \times t) \times L$	=	**-**	(m^3)
Reinforcement Bars	$W_r = 0.577 \times (V_c/L)^{0.888} \times L$	=	**-**	(ton)

Where,

Q:	Maximum Discharge =	0.260	(m^3/s)	
L:	Length of Channel =	**600.00**	(m)	
B:	Width of Channel =	**1.40**	(m)	for excavation (2D from RIBLOC Brochure)
H:	Height of Channel =	**1.40**	(m)	for excavation (2D from RIBLOC Brochure)
t:	Thickness of Concrete =	**-**	(m)	

(5) Head Tank

Excavation:	V_e =	$808 \times Q^{0.697}$	=	**315.97**	(m^3)
Concrete:	V_c =	$197 \times Q^{0.716}$	=	**75.09**	(m^3)
Reinforcement Bars	W_r =	$0.051 \times V_c$	=	**3.83**	(ton)

Where,

Q:	Maximum Discharge =	0.260	(m^3/s)

(6) Penstock & Spillway Channel

Penstock (Steel)φ350:

Excavation:	V_{e1} =	10.9 x $D_m^{1.33}$ x L	=	43.17	(m^3)
Concrete:	V_{c1} =	2.14 x $D_m^{1.68}$ x L	=	5.87	(m^3)
Reinforcement Bars	W_{r1} =	0.018 x V_c	=	0.11	(ton)

Where,

D_m:	Avg. Diameter of Penstock =	**0.35**	(m)
L:	Length of Penstock =	**16.00**	(m)

Weight of Penstock	W_{p1} = 7.85x π x D_m x t_m x10^{-3}x1.15 x L	=	0.53	(ton)
Thickness of Penstock:	t_m = 0.0362 x H x D_m + 2	=	3.37	(mm)

Where,

W_{p1}:	Weight of Penstock	0.53	(ton)	(Tensil allowable Stress: 1,150 kgf/cm^2)
tm:	Thickness of Penstock	3.37	(mm)	
D_m:	Avg. Diameter of Penstock =	0.35	(m)	
H:	Design Head =	**107.80**	(m)	(Intake Water Level - Tailrace Water Level)
L:	Length of Penstock =	16.00	(m)	

Penstock (PVC)φ350:

Excavation:	V_e = B x H x L	=	151.14	(m^3)

Where,

Q:	Maximum Discharge =	0.260	(m^3/s)	
L:	Length of Channel =	**164.00**	(m)	
B:	Width of Channel =	**0.96**	(m)	from TUBOPLAST Brochure
H:	Height of Channel =	**0.96**	(m)	from TUBOPLAST Brochure

Spillway Channel:

	(B x H)^0.5 = 1.09 x $Q^{0.379}$	=	0.65	
Excavation:	V_e = 6.22 x $((B x H)^{0.5})^{1.04}$ x L	=	720.10	(m^3)
Concrete:	V_c = H x t x 2 + (B + 2t) x L	=	126.18	(m^3)
Reinforcement Bars	W_r = 0.577 x $(V_c/L)^{0.888}$ x L	=	0.00	(ton)

Where,

Q:	Maximum Discharge =	0.260	(m^3/s)
L:	Length of Channel =	**180.00**	(m)
B:	Width of Channel =	**0.40**	(m)
H:	Height of Channel =	**0.60**	(m)
t:	Thickness of Concrete =	**0.15**	(m)

Total Quantity of Penstock and Spillway Channel:

Excavation:	V_e =	V_{e1} + V_{e2}	=	**914.41**	(m^3)
Concrete:	V_c =	V_{c1} + V_{c2}	=	**132.05**	(m^3)
Reinforcement Bars	W_r =	W_{r1} + W_{r2}	=	**0.11**	(ton)
Weight of Penstock	W_p =	W_{p1}	=	**0.53**	(ton)

(7) Power House

Excavation:	V_e = 97.8 x $(Q x He^{2/3} x n^{1/2})^{0.727}$	=	**354.95**	(m^3)
Concrete:	V_c = 28.1 x $(Q x He^{2/3} x n^{1/2})^{0.795}$	=	**115.05**	(m^3)
Reinforcement Bars	W_r = 0.046 x $V_c^{1.05}$	=	**6.71**	(ton)

Where,

Q:	Maximum Discharge =	0.260	(m^3/s)
He:	Effective Head =	107.80	(m)
n:	Quantity Unit of Turbine =	**1.00**	

(8) Outlet

Excavation:	V_e =	395 x $(R x Q)^{0.479}$	=	148.65	(m^3)
Concrete:	V_c =	40.4 x $(R x Q)^{0.684}$	=	10.01	(m^3)
Reinforcement Bars	W_r =	0.278 x $V_c^{0.610}$	=	1.13	(ton)

Where,

D:	Diameter of Waterway =	1.00	(m)	
R:	Radius of Waterway =	0.50	(m)	D/2
Q:	Maximum Discharge =	0.260	(m^3/s)	

: Input Cell
: Calculation Cell
: Reference Cell

VI. Unit Price

1USD = 3.00 S/. (as of November, 2007)

(1) Civil Works

Excavation				
Open	:	**5.53**	(US$/m³)	* (8.70+2.35) x 0.5 = $5.53/m³, from CAPAECO and Fainal study on Omia <Human power and Machine excavation>
Tunnel	:	**-**	(US$/m³)	
Concrete				
Open	:	**93.05**	(US$/m³)	* from CAPAECO (average of foundation, wall and structure concrete)
Tunnel	:	**-**	(US$/m³)	
Reinforcement Bar	:	**1,070.00**	(US$/ton)	*$1.07/kg, from CAPAECO

(2) Hydraulic Equipment

Gate & Screen	:	**8,811.04**	(US$/ton)	* from final study on Omia
Steel Penstock	:	**3,100.00**	(US$/ton)	including installation
PVC (φ700)		**71.67**	(US$/m)	RIB LOC for Headrace
PVC (φ350)	:	**56.45**	(US$/m)	130% of TUBOPLAST(φ315) for Penstock (C-10) = 43.42 x 1.3 = 56.45

(3) Others

Access Road	:	**979.65**	(US$/m)	Repair Work for Existing Unpaved Road

(4) Transportation Cost

Huanuco to the site	:	**11.79**	(US$/ton)	97 km (road)

Quechuarpata Map