CHAPTER 10 FINANCIAL ANALYSIS

To evaluate the profitability of rehabilitation plans, a cost-benefit analysis is adopted. The difference between revenue after the existing facilities are rehabilitated and the revenue when the existing facilities are not rehabilitated is regarded as the profitability of the investment. Then the financial analysis of the selected rehabilitation plan is made for the planning of the balance of revenue and expenditure in accordance with the cash balance. For the evaluation of the investment propriety within the national economy, refer to the economic analysis described in the main report.

10.1 Preconditions for the Financial Analysis

Preconditions set up for the financial analysis are summarized below:

(1) Residual life of existing power plant

In case of unchanging the existing facilities with new ones, residual life of the existing power plant is tentatively set at five years after the installation of new equipment.

(2) Estimation of construction cost

The construction cost is estimated in both foreign and local currency portion according to the market price as of September, 1989. Currency exchange rate between foreign currency (US$) and local currency (Col.$) is set at US$1.00 = Col.$369.4, as determined by DNP.

The construction cost includes the contingency and technical management expense. The land acquisition cost is not accounted because the plan is for rehabilitating the existing power plant. The FOB price of the generating facilities is taken from Japanese market price. The CIF price is calculated in the ratio of CIF price to FOB price which ISA usually applies to a hydroelectric power generation project. The ratio of CIF price to FOB price is 1.00 : 1.12.

(3) Service life

The service life of the project is set at 25 years after rehabilitation for evaluating the profitability.

The annual depreciation of facilities will be based on the fixed amount method adopted by ICEL. The service life, as described below, is determined according to the facility. The residual price will be set at zero.

1) Service life of civil structure : 50 years
2) Service life of generating facilities : 25 years

(4) Operation and maintenance costs

Operation and maintenance costs consist of the fixed cost which depends upon the scale invested in the facilities, and the variable cost which fluctuates in proportion to generated electric power. This study adopts the average cost, i.e., US$4.0 per installed capacity (kW) per year, which ISA usually applies to make an estimate of operation and maintenance costs of a hydroelectric power plant.

(5) Estimation of revenue

ICEL's electricity-selling unit price of US$13.36/MWh (Col $4,936.18/MWh) and US$2,942.36/MW (Col$1,086,909.69/MW) in December, 1988 is adopted as the financial unit price. The estimation of annual revenue can be made by multiplying the rated capacity and the annual supplied power at generating terminal.

(6) Discount rate

The discount rate which is used to calculate the net present value (NPV) and the cost-benefit ratio (C/B Ratio) is set at 7.6% per year. It is determined by the real interest rate in Colombia.

(7) Conditions for borrowing capital on investment

The loan conditions for borrowing capital in foreign and local currency are as follows:

1) Loan conditions of foreign currency

- Annual interest	:	10%
- Period for principal repayment	:	25 years (including a 4-year grace period)
- Terms of payment	:	Repayment of the principle in equal, annual amounts

2) Loan conditions of local currency

- Annual interest	:	21%
- Period for principal repayment	:	8 years (including a 1-year grace period)
- Terms of payment	:	Repayment of the principal in equal, annual amounts

(8) Constant price

The annual inflation rate in Colombia varied from 24 to 30%, but the prices used in the cost and benefit stream are set at the constant price in 1989.

(9) Evaluation index

For evaluating profitability, the following three indices, which are commonly used, are adopted.

(1) Cost-benefit ratio (C/B ratio)
(2) Net present value (NPV)
(3) Internal rate of return (IRR)

These indices are calculated by using "with" and "without" the project.

10.2 Comparison of Profitability

The profitability of the generating plans is calculated using the cash flow for each alternative plan, as shown in Table 10.1.

Table 10.1 Profitability Index of Alternative Plans

Alternative	C/B	NPV (US$1,000)	IRR (%)
REH-1	4.24	- 3,227	- 3.1
ALT-1	2.71	- 3,664	- 0.6
ALT-2	2.29	- 6,398	0.5

From the results of the financial analysis according to cash generation of the project, ALT-2 is determined to be the most profitable plan.

The rehabilitation plan, ALT-1 is selected as the optimum plan, which is described in Section 9.3.3, since it has a high profitability amongst the alternatives.

10.3 Financial Planning

The cash balance of the selected rehabilitation plan is prepared as a projected financial statement. The projected Profit-Loss Statement and Fund Flows Statement are shown in Table 10.2. According to the financial plan, the selected rehabilitation plan will show a profit from the year 2013, though there will be a projected aggregate deficit of US$16,873,000 at the end of service life.

Table - 10.2 PROJECTED FINANCIAL STATEMENTS

(1) PROJECTED REVENUE AND EXPENDITURE STATEMENT (at 1989 Price)

== La Vuelta : ALT-2 ==

Year	Year in Order	(A) Total Operating Revenue	(B) Operating Expenditure (US$:1000) O/M Cost	Depreciation	Interest on Investment	Total	(C) Net Benefit (A)-(B)
1989	-6	85.0	2.0	0.0	0.0	2.0	83.0
1990	-5	85.0	2.0	0.0	0.0	2.0	83.0
1991	-4	85.0	2.0	0.0	0.0	2.0	83.0
1992	-3	85.0	2.0	0.0	65.9	67.9	17.1
1993	-2	85.0	2.0	0.0	131.8	133.8	-48.9
1994	-1	85.0	2.0	0.0	164.8	166.8	-81.8
1995	0	33.7	2.0	0.0	1075.6	1077.6	-1043.9
1996	1	33.7	2.0	566.7	2680.7	3249.4	-3215.7
1997	2	856.4	30.8	566.7	3244.8	3842.3	-2985.9
1998	3	856.4	30.8	566.7	2902.0	3499.5	-2643.1
1999	4	856.4	30.8	566.7	2519.0	3116.5	-2260.1
2000	5	856.4	30.8	566.7	2136.0	2733.4	-1877.0
2001	6	856.4	30.8	566.7	1752.9	2350.4	-1494.0
2002	7	856.4	30.8	566.7	684.3	1281.8	-425.4
2003	8	856.4	30.8	566.7	644.1	1241.5	-385.2
2004	9	856.4	30.8	566.7	603.8	1201.3	-344.9
2005	10	856.4	30.8	566.7	563.6	1161.0	-304.6
2006	11	856.4	30.8	566.7	523.3	1120.8	-264.4
2007	12	856.4	30.8	566.7	483.1	1080.5	-224.1
2008	13	856.4	30.8	566.7	442.8	1040.3	-183.9
2009	14	856.4	30.8	566.7	402.5	1000.0	-143.6
2010	15	856.4	30.8	566.7	362.3	959.8	-103.4
2011	16	856.4	30.8	566.7	322.0	919.5	-63.1
2012	17	856.4	30.8	566.7	281.8	879.2	-22.9
2013	18	856.4	30.8	566.7	241.5	839.0	17.4
2014	19	856.4	30.8	566.7	201.3	798.7	57.7
2015	20	856.4	30.8	566.7	161.0	758.5	97.9
2016	21	856.4	30.8	566.7	120.8	718.2	138.2
2017	22	856.4	30.8	566.7	80.5	678.0	178.4
2018	23	856.4	30.8	566.7	40.3	637.7	218.7
2019	24	856.4	30.8	566.7	0.0	597.5	258.9
2020	25	856.4	30.8	566.7	0.0	597.5	258.9
TOTAL		20875.6				37748.3	-16872.3
						C/B:	1.31

(2) PROJECTED FUNDS FLOW STATEMENT (Constant Price at 1989)

== La Vuelta : ALT-2 ==

Year	Year in Order	(A) Source Benefit before Interest	Depreciation	Balance Brought Forward	Long/Short Term Borrowing	Total	(B) Application (US$:1000) Construction Progress	Debt Service Interest	Debt Service Principal	Total	Cash Balance (A)-(B)
1989	-6	83.0	0.0		0.0	83.0	0.0	0.0	0.0	0.0	83.0
1990	-5	83.0	0.0		0.0	83.0	0.0	0.0	0.0	0.0	83.0
1991	-4	83.0	0.0		659.2	742.2	659.2	0.0	0.0	659.2	83.0
1992	-3	83.0	0.0		659.2	742.2	659.2	65.9	0.0	725.2	17.1
1993	-2	83.0	0.0		329.6	412.6	329.6	131.8	0.0	461.5	-48.9
1994	-1	83.0	0.0		4693.4	4776.4	4693.4	164.8	0.0	4858.2	-81.8
1995	0	31.7	0.0		9247.9	9279.6	9247.9	1075.6	0.0	10323.4	-1043.9
1996	1	-535.0	566.7		4290.2	4321.9	4290.2	2680.7	1632.3	8603.3	-4281.4
1997	2	258.9	566.7			825.6		3244.8	1632.3	4877.1	-4051.5
1998	3	258.9	566.7			825.6		2902.0	2034.8	4936.9	-4111.3
1999	4	258.9	566.7			825.6		2519.0	2034.8	4553.9	-3728.3
2000	5	258.9	566.7			825.6		2136.0	2034.8	4170.8	-3345.2
2001	6	258.9	566.7			825.6		1752.9	2034.8	3787.8	-2962.2
2002	7	258.9	566.7			825.6		684.3	2034.8	2719.2	-1893.6
2003	8	258.9	566.7			825.6		644.1	402.5	1046.6	-221.0
2004	9	258.9	566.7			825.6		603.8	402.5	1006.4	-180.8
2005	10	258.9	566.7			825.6		563.6	402.5	966.1	-140.5
2006	11	258.9	566.7			825.6		523.3	402.5	925.9	-100.3
2007	12	258.9	566.7			825.6		483.1	402.5	885.6	-60.0
2008	13	258.9	566.7			825.6		442.8	402.5	845.3	-19.8
2009	14	258.9	566.7			825.6		402.5	402.5	805.1	20.5
2010	15	258.9	566.7	20.5		846.1		362.3	402.5	764.8	81.2
2011	16	258.9	566.7	81.2		906.8		322.0	402.5	724.6	182.2
2012	17	258.9	566.7	182.2		1007.8		281.8	402.5	684.3	323.5
2013	18	258.9	566.7	323.5		1149.1		241.5	402.5	644.1	505.0
2014	19	258.9	566.7	505.0		1330.6		201.3	402.5	603.8	726.8
2015	20	258.9	566.7	726.8		1552.4		161.0	402.5	563.6	988.8
2016	21	258.9	566.7	988.8		1814.4		120.8	402.5	523.3	1291.1
2017	22	258.9	566.7	1291.1		2116.7		80.5	402.5	483.1	1633.6
2018	23	258.9	566.7	1633.6		2459.2		40.3	402.5	442.8	2016.4
2019	24	258.9	566.7	2016.4		2842.0		0.0	0.0	0.0	2842.0
2020	25	258.9	566.7	2842.0		3667.5		0.0	0.0	0.0	3667.5

CHAPTER 11 BASIC DESIGN

The basic design for ALT-1 selected as the optimum rehabilitation plan is described below.

11.1 Facilities Design

11.1.1 Design Standards of Civil Structures

The following design criteria shall apply to the structures in designing the facilities.

(1) So far as the diversion weir is concerned, only rehabilitation of the existing facilities and the crest elevation shall be remained as it is and no sand trap shall be necessitated.

(2) Sedimentary sand between the forebay entrance and diversion weir shall be dredged by the dragline.

(3) The velocity of water at the entrance to the turbine shall be 1.0~1.5 m/s while that at the outlet of discharge shall be 1.5~1.8 m/s.

(4) Forebay shall be designed to take water at a right angle from the river and a screen to prevent entry of sand and gravel shall be provided. The flow rate at the screen for the forebay shall be designed so that particles more than 1 mm in diameter can be screened.

11.1.2 Design of Improvement for the Main Structure

(1) Intake equipment

The repaired diversion weir has an overflow crest at elevation 79.7 m, a length of 120 m and a design flood discharge of 1,700 m^3/s at the HWL (85.00 m). The depth at the overflow is 4.30 m.

An estimated 50 m^3/day silt accumulates in front of the diversion weir, and is removed and collected by a dragline located at the left hand side bank of river and used as construction material.

(2) Navigation lock

The existing Canoe lock will be remained unchanged. As the power plant is going to be discontinued, the present forebay shall be reclaimed leaving the width of space necessary for canoe navigation and the reclaimed land is to be utilized as a site for cargo unloading and other purposes. The water channel has a width of 5 m and a length of 45.3 m.

(3) Forebay

- Water level of flood

The forebay has a width of 18 m, a height of 11 m, a water channel length of 45.3 m and the elevation of the water channel bed is 75.00 m. The provided at the entrance to prevent entry of sand and gravel has a height of 2 m and a length of 18 m, and its elevation of crest is 77.00 m. Firm water level of the forebay is 79.70 m. The water level of flood at the forebay is calculated considering the stream of the river 193 m downstream of the diversion weir as non-uniform flow.

(a) Equation

The flow in the water channel can be calculated from the following equation for any random cross-section.

$$i.\Delta x - \Delta H$$
$$= \alpha.Q^2/2.g \text{ x } (1/A_1^2 - 1/A_2^2 + n^2.Q^2/2 \text{ x } (1/R_2^{4/3} A_1^2 + 1/R_2^{4/3} A_2^2 \Delta \text{ x} \quad (2)$$

where:

- α = correction coefficient for velocity distribution (generally about 1.1)
- i = bed gradient
- H = depth of flow (m)

A = cross-sectional area (m^2)

(1) : bottom end cross-section

(2) : top end cross-section

R = hydraulic radius

(1) : bottom end cross-section

(2) : top end cross-section

Q = discharge (m^3/s)

n = coefficient of roughness

Assuming that a suitable length, ΔX, to separate the two cross sections with water level difference ΔH, the top end section is shown in Figure 11.1.

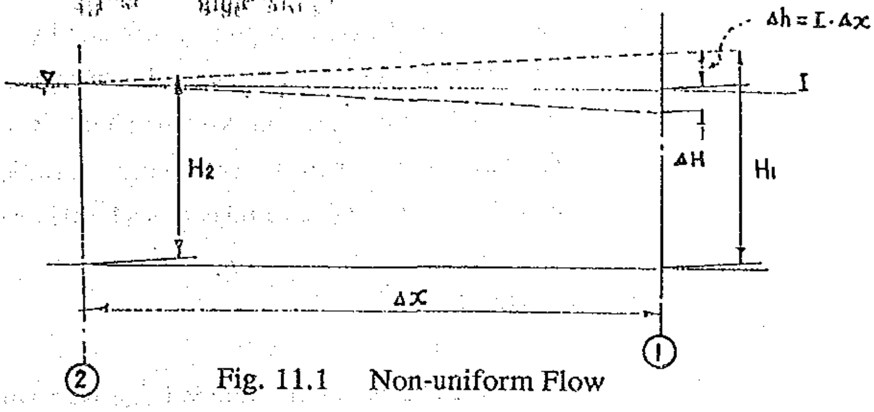


Fig. 11.1 Non-uniform Flow

A_1, R_1, A_2, R_2 are calculated for the two values of H_1 and H_2 and inserted into the right hand side of equation (2) and compared with the values on the left hand side. The value of ΔH is then adjusted accordingly and the process repeated.

(b) Factors affecting the coefficient of roughness

By referring to the following items, which show the main factors affecting the coefficient of roughness for recent and existing water channel material, a value of n can be estimated.

1. Surface roughness

In a fine grained surface the value of n is small and changes in the water level have comparatively small effects. However, in medium grained or coarse surfaces n is generally big and varies greatly between low water and high water periods.

2. Biological incrustation

Where there is much incrustation the capacity of the water channels becomes small and flow becomes difficult. The height of the incrustation, the amount, distribution and type are the main factors causing variation in the value.

3. Cross-section parameters

The coefficient's value is greatly affected by varying cross sections, sizes and shapes in irregular sided water channels. Where the variation in cross-section, size or shape is small n is not greatly affected. However in the case where variation between large and small is great the value of n becomes 0.005 or greater.

4. Curving channels

Where the radius of curvature is large with smooth transitions from straight to curve the value of n is comparatively small but in the case of rapidly changing curves the value of n increases.

5. Silting and removal

There are cases where silting (sedimentation) in non-uniform shaped channel creates a more uniform shaped channel and n becomes small. Removal of this sediment then causes an increase in n. The effects of this sediment are controlled by the materials properties.

6. Water level and discharge

Where water level or discharge increases the value of n is reduced.

7. Floating material and material suspended in the flow

The head loss caused by the energy consumed by floating and suspended materials appears to increase the channel roughness.

(c) Coefficient of roughness

The coefficient of roughness for various kinds of material is as shown in Table 11.1.

Table 11.1 Manning's Coefficient of Roughness

	Least	Average	Most
Steel			
1. Rock bar and welding	0.010	0.012	0.014
2. Rivet or screw	0.013	0.016	0.017
Cast iron			
1. Coated	0.010	0.013	0.014
2. Non-coated	0.011	0.014	0.016
Concrete			
1. Culvert - straight no impediments	0.010	0.011	0.013
2. Culvert - curved, jointed and impediment	0.011	0.013	0.014
3. Well finished	0.011	0.012	0.014
4. Not finished, unsmooth wood form	0.012	0.014	0.016
5. Aggregate visible in the surface	0.015	0.016	0.018
Smooth concrete base with sidewalls as;			
1. Regular surface	0.015	0.017	0.020
2. Irregular surface	0.017	0.020	0.024
3. Rough, missing stones in surface	0.020	0.030	0.035

Where there is sphagnum in the water channel +0.002 is added.

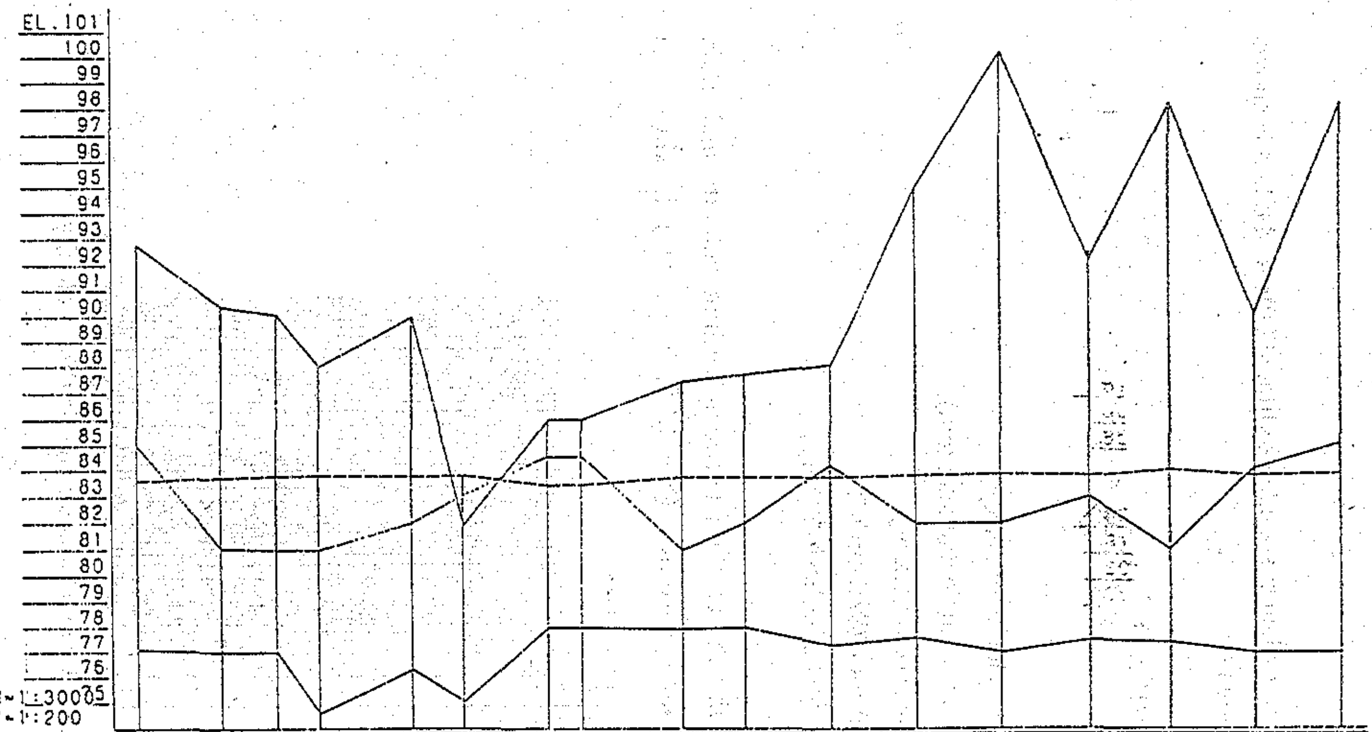
	Least	Average	Most
Natural river			
Regular in both linear and cross section, deep water with sand bed	0.025	0.030	0.033
Same as above but riverbed is gravel and both banks have vegetation	0.030	0.036	0.040
Meandering and has deeps and shallows	0.033	0.040	0.045
Meandering and has some gravels and weeds	0.035	0.042	0.050
Same as above and shallow	0.040	0.050	0.055
Same as above and has gravel bed with shallow water	0.045	0.055	0.060
Sharp meandering and heavy irregularity in the deeps shallows with a lot of seeds	0.050	0.070	0.080
Same as above with dense growth of seeds, rapid stream	0.075	0.080	0.150

(d) Results of calculation

Results of calculation are as shown in Fig. 11.2. The results indicate that the water level at the elevation of U-0* at the entrance to the forebay is 83.75 m, but as the topography at the left bank side has not been confirmed, the water level of flood at the power plant is determined to be 85.00 m.

* As per the topographic survey map (5.1(2))

$Q = 1.700\ m^3/s$



Mark Simbole	River Bed Level	Ground Surface Level (L)	Ground Surface Level (R)	Water Surface Level	Distance
0-8	77.100	65.000	92.750	63.600	0.000
0-7	77.000	61.050	90.400	63.731	50.000
0-6	77.000	61.000	90.100	63.769	33.000
0-5	74.600	61.000	68.000	63.606	25.000
0-4	76.300	62.000	90.050	63.773	55.000
0-3	75.050	63.060	61.900	63.607	30.000
0+M	75.600	64.560	65.000	63.435 63.336	50.000
0-2	76.000	64.560	66.000	63.462	20.000
0-1	77.950	61.000	67.450	63.746	59.000
0-0	78.000	62.000	67.700	53.744	37.000
U-0	77.300	64.200	66.050	63.741	50.000
U-1	77.500	62.000	95.000	63.606	50.000
U-2	77.000	62.000	100.200	63.660	50.000
U-3	77.510	63.010	92.160	63.796	53.000
U-4	77.420	61.020	98.220	64.026	47.000
U-5	77.000	64.100	90.100	63.616	50.000
U-6	77.000	65.100	96.200	63.669	50.000

Fig. 11.2 Water Level of Flood

(3) Desilting basin

(a) Settling velocity

The settling velocity when suspended sediment falls to the bed is shown in the following equation.

$$V_s = (S - 1)g/18\nu \times D^2$$

where:

V_s = settling velocity (cm/sec)
D = settlement particle diameter (cm)
S = particle specific gravity
g = acceleration (980 cm/s^2)
ν = coefficient of cohesion (cm/s)

According to Ruby the relation between settling velocity and grain diameter for quartz particles (S = 2.65, T = 16°C) is shown in Fig. 11.3.

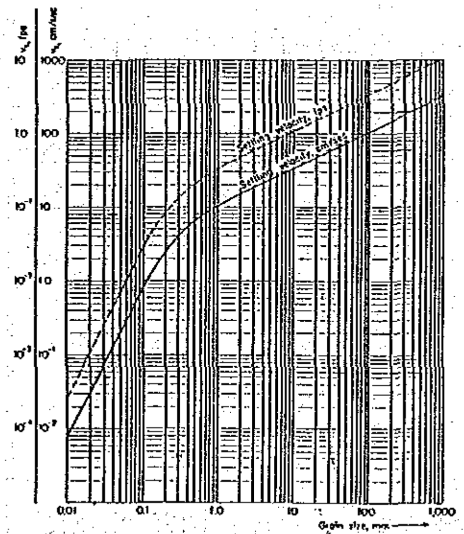


Fig. 11.3 Grain Diameter and Settling Velocity

The investigation into the settling velocity for suspended sediment removal from forebay will be based on the relationship between particle diameter and settling velocity as shown in Fig. 11.3.

(b) Particle diameter

The particle diameter of sediment which can be removed from the forebay is calculated by the following equation.

$$V = \frac{h \times B \times C}{L}$$

where:

L = length of forebay (m)
h = settling depth in forebay (4.70 m)
V = sediment settling velocity (m/s)
B = average flow speed in forebay (1.18 m/s)
C = coefficient.

From the settling velocity the diameter of the particle is calculated to be about 1 mm.

(c) Removal of silt

The forebay sediment, with an average 6 m^3/day sedimentation per year, can be emptied into the river together with the water through the sand pipe and there is the potential to flush sediment through the existing desilting basin into the river.

(4) Powerhouse

The new powerhouse is to be located upstream of the existing powerhouse roughly in parallel with the existing powerhouse. The location has the bedrocks suitable for the foundation for the generating equipment.

(5) Tailrace

The present water lever of tailrace is about 75.60 m and the available discharge is estimated to be about 40 m^3/s according to the hydrological calculation. If the water flows at the rate of Q=54 m^3/s in the present tailrace, the water level becomes 75.70 m. If the water is flown at Q=100 m^3/s, the water level would be increased by approximately 0.50 m and become 76.26 m. The difference in the riverbed elevation between the tailrace and the main stream of the river at the point of cross section D-17 is about 1.0 m. The gradients of the riverbeds are 1:1100 and 1:360 respectively and the water level of 75.20 m at the draft outlet should be maintained by dredging the riverbed as much as 1.0 m.

11.1.3 Gate and Valve Specifications and Types

A summary of the equipment such as gates and valves for the facility is shown in Table 11.2.

Table 11.2 Summary of Gate and Valve Types

	Regulating gate	Sand-flush gate	Screen	Regulating gate
Use	Water intake	Forebay sand removal	Silt removal	Tailrace
Type	Steel, sluice gate	Steel, sluice valve	Fixed type	Steel, sluice gate
Width x height	8.60 x 7.00m 2 gates	Ø500mm	8 x 13m 2 gates	7.60 x 5.50m 2 gates
Design depth	10 m	15 m	-	6 m
Stopwater method	Reverse 4 direct. Water tight	Reverse 4 direct. Water tight	Rack spacing 100 mm	Reverse 4 direct. Water tight
Operating method	Wire drum	Spindle		Wire drum
Hoisting device		Manual		
Lifting speed	0.03 m/min.		Gradient 1:0.3	
Lift	7 m	7 m	-	6 m
Material weight	60 ton Hoist 27 t	Gate 1 t	37 t	Gate 42 t Hoist 16 t

11.1.4 Standard Specifications for Generating Equipment

For the generating equipment the specifications for the generators and water turbines are shown below.

(1) Number of water turbines and generators

Two water turbines and generators are designed to be installed so that they can be inspected and repaired alternately and profit loss due to down time can be reduced.

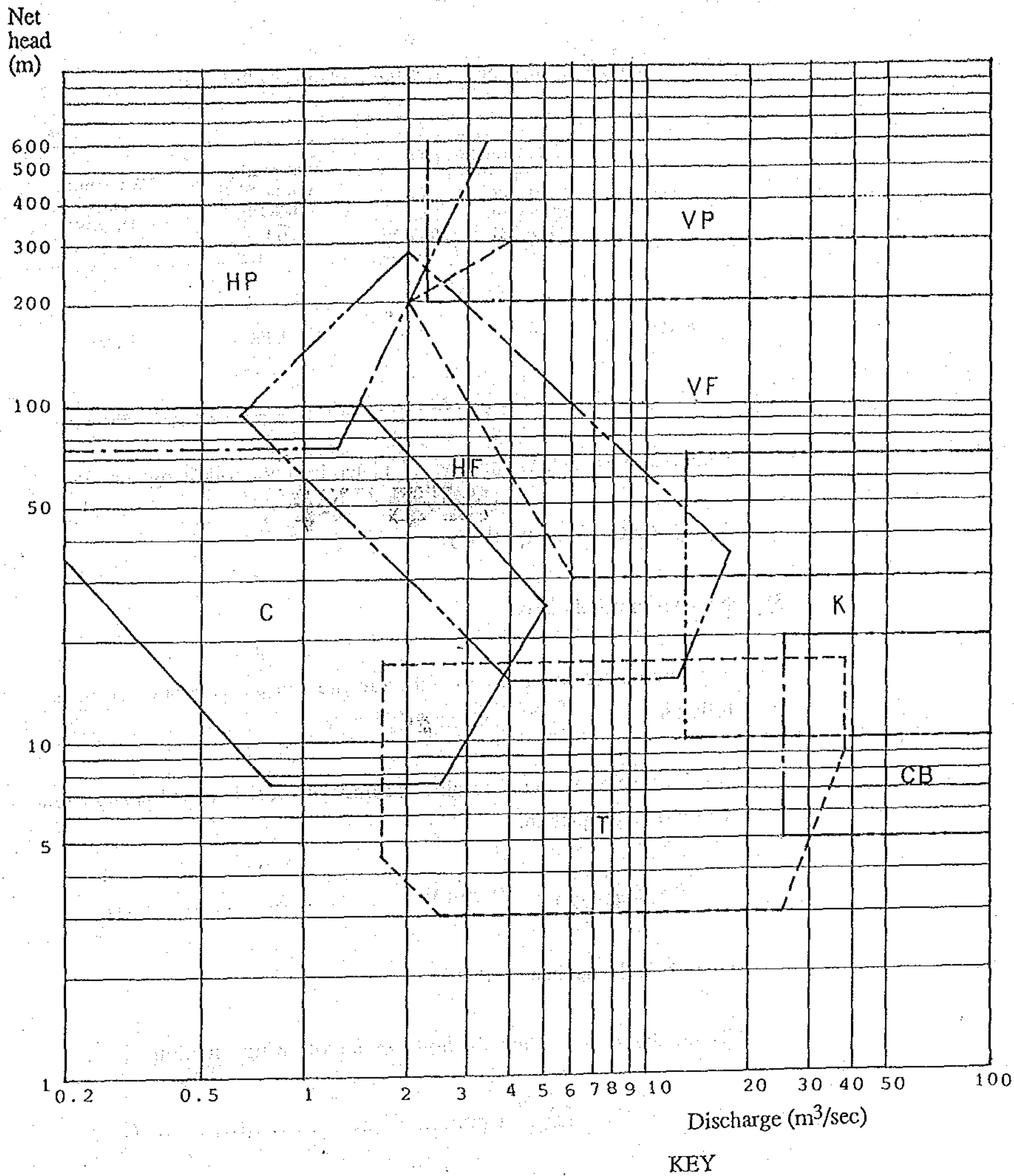
(2) Water turbine specifications

1) Machine type

After deciding on the turbine's net head and flow the water turbine type can be chosen from Fig. 11.4.

The choice of machines for the optimum generation rehabilitation plan is made as follows:

Plan	Rehabilitation plan		Machine type chosen
	Flow per water turb. (m^3/s)	Net head (m)	
ALT - 1	50	4.4	Conduit type bulb turbine



KEY

H = horizontal shaft type
V = vertical shaft type
P = Pelton turbine
F = Francis turbine
K = Kaplan turbine
C = cross flow turbine
T = tubular turbine
CB = conduit type bulb turbine

(Source: Enterprise Bureau, Gunma Prefectural Government)

Fig. 11.4 Turbine Type Selection Table

2) Output

The output per turbine for the optimum plan is as follows:

Plan	Rehabilitation plan: Flow per water turb. Q (m^3/s)	Rehabilitation plan: Net head He (m)	Water turb. estimated efficiency η_T	Water turb. output P_T (kW)
ALT - 1	50	4.4	0.866	1,860

The water turbine (kW) may be calculated from the following equation.

$P_T = 9.8 \times Q \times He \times \eta_T$ (kW)

3) Number of revolutions

The number of revolutions of the turbine can be calculated from the following.

For the case of a tubular turbine the limit of specific speed is shown in the following equation.

$$Ns \leqq \frac{20{,}000}{He+20} + 50 \text{ (m-kW)} \quad \ldots\ldots (1)$$

where H is the net head (m).

The number of revolutions is shown in the following equation.

$$N = Ns \times \frac{He^{5/4}}{P^{1/2}} \text{ (rpm)} \quad \ldots\ldots (2)$$

where N_s is the specific speed taken from eq. (1)
He is the net head (m)
P is the water turbine output (kW)

The generator's synchronous speed (N) is shown in the following equation:

$$N = \frac{120f}{pole} = \frac{120 \times 60}{pole} = \frac{7200}{pole} \text{ (rpm)} \quad \dots\dots\dots\dots\dots\dots \quad (3)$$

where f is the frequency
and pole is the number of pole.

A value for the pole is chosen such that the value of N in eq. (3) is smaller but close to the value of N in eq. (2).

The value of N from eq. (3) is then substituted into eq. (2) to obtain a value for Ns.

The results for the optimum plan are shown in the following table.

Plan	Net head, H_e (m)	Turbine output, P (kW)	Number of poles	Specific speed, Ns (m-kW)	Number of revolution N (rpm)
ALT - 1	4.4	1,860	56	865	128.5

(3) Generator specifications

1) Rated voltage

Standardized to be 4.16 kV.

2) Power factor

Large-capacity generators, aiming to supply reactive power to the power system network, have a power factor of 0.8-0.85. However, since this factor is not so important in small-capacity generators, an economical power factor of 0.9 is available.

3) Pole

In deciding the turbine speed, the number of poles for the generator pole is decided and reference is made to the previous water turbine specifications.

4) Generator capacity

The capacity per generator for the optimum plan is as follows:

Plan	Rehabilitation plan: Discharge per turbine Q (m^3/s)	Rehabilitation plan: Net head H_e(m)	Estimated turbine effic. η_T	Estimated generator effic. η_G	Generator capacity P_G (kW)	Power factor	Generator capacity (kVA)
ALT - 1	50	4.4	0.866	0.95	1,780	0.9	2,000

The generator capacity (kW) may be calculated from the following equation:

$$P_G = 9.8 \times Q \times He \times \eta_T \times \eta_G \text{ (kW)}$$

11.1.5 Standard Specifications for Electrical Equipment

The machine specifications are explained in the following for the electrical equipment attached to the generator and the substation electrical equipment.

(1) Excitation equipment

A brushless excitation method is used for the generator excitation method so that maintenance inspection is quick and easy.

(2) Grounding method

In order to protect the generator when the value of the generator's current flow to ground is small, the transformer uses a high resistance grounding method.

(3) Switchgear

With the generator circuit the switchgear contains the following electrical items.

- circuit breaker
- lightning arrester
- current transformer and voltage transformer
- excitation transformer
- auxiliary transformer
- low-voltage distribution board

(4) Direct current equipment

The direct current supply for the initial excitation for the generator's excitation circuit and the control panel is supplied by a charger and lead batteries.

(5) Control and protective relay panels

The simultaneous start, stop and generator circuit breakers, for the water turbine and generators, emergency and all essential controls are contained in a water turbine/generator control board. Thus, one operator can control the system.

Furthermore, the protective relay for the generator circuit is contained in the protective relay board. If an accident occurs the relay is put into action, stopping the water turbine and generator stops simultaneously as a buzzer and flickering light warn the operator.

(6) Substation equipment

The substation has been designed to be consisted for the normal outdoor type equipment in order to simplify the arrangement and to reduce the construction cost. The rated voltage of the substation equipment is designed to be 34.5 kV so that it can correspond to the voltage for the existing equipment to which the new equipment is to be connected. The specifications of the major equipment are shown in Table 11.3.

Table 11.3 Major Equipment Specifications

Item		Specifications
1. Main transformer		
	1) Number of units	1
	2) Type	Oil immersed, self-cooled, three-phase
	3) Voltage	4.16/34.5 kV
	4) Capacity	4,000 kVA
	5) Connection	Δ/Δ
2. Breaker		
	1) Number of units	2
	2) Type	ABB
	3) Voltage	36 kV
	4) Current	600 A
	5) Short-time current	25 KA
3. Disconnecting switch		
	1) Number of units	4
	2) Type	Three-phase throwing-in at a time trip
	3) Voltage	36 kV
	4) Current	600 A
4. Current transformer		
	1) Number of units	One-phase x 6 units
	2) Current	100/5 A
5. Transformer		
	1) Number of units	One-phase x 6 units
	2) Voltage	34.5 kV/110 V

Fig. 11.5 shows main circuits connection diagrams. Fig. 11.6 shows the layout of the equipment.

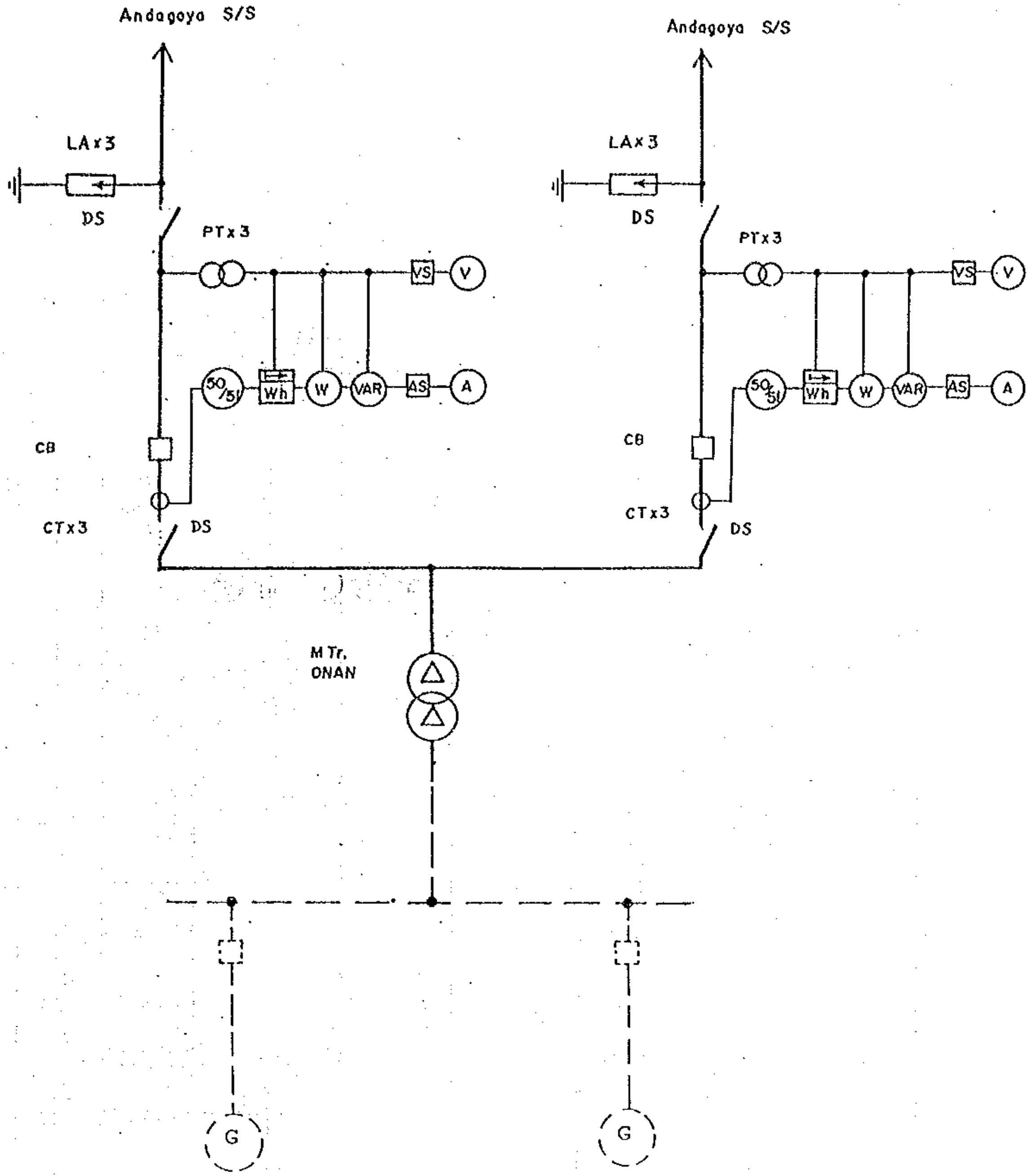


Fig. 11.5 Substation Main Circuits Connection Diagram

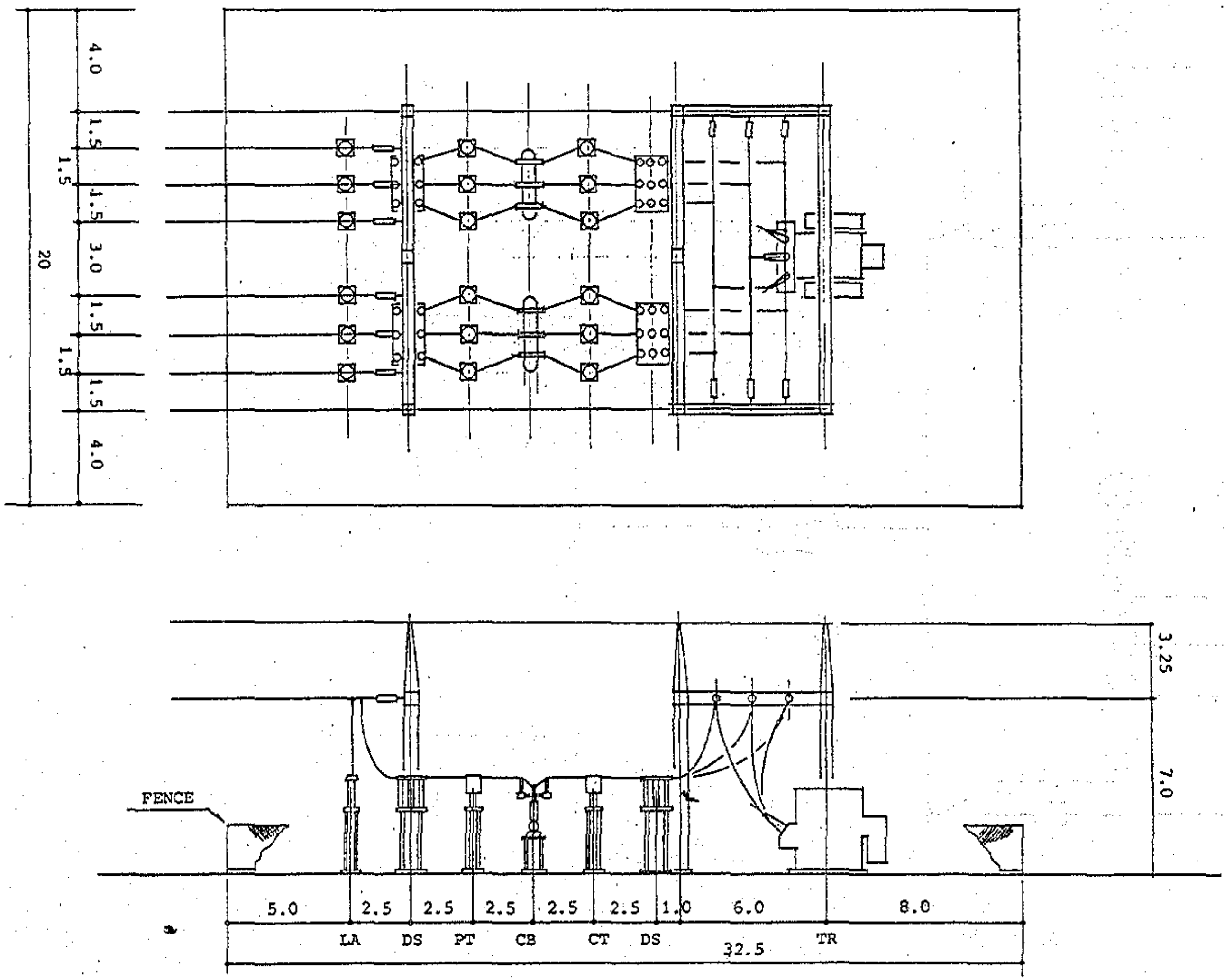


Fig. 11.6 Substation Equipment Layout Plan

(7) Transmission line

Transmission line is a line which connects a new power plant and the existing transmission line. Construction costs for pylons, transmission lines etc. are not included in the estimation. The power generated by the new power plant is shown in Fig. 11.7 and is to be supplied to the consumers scattered in the area between the power plant and the Andayoya substation station.

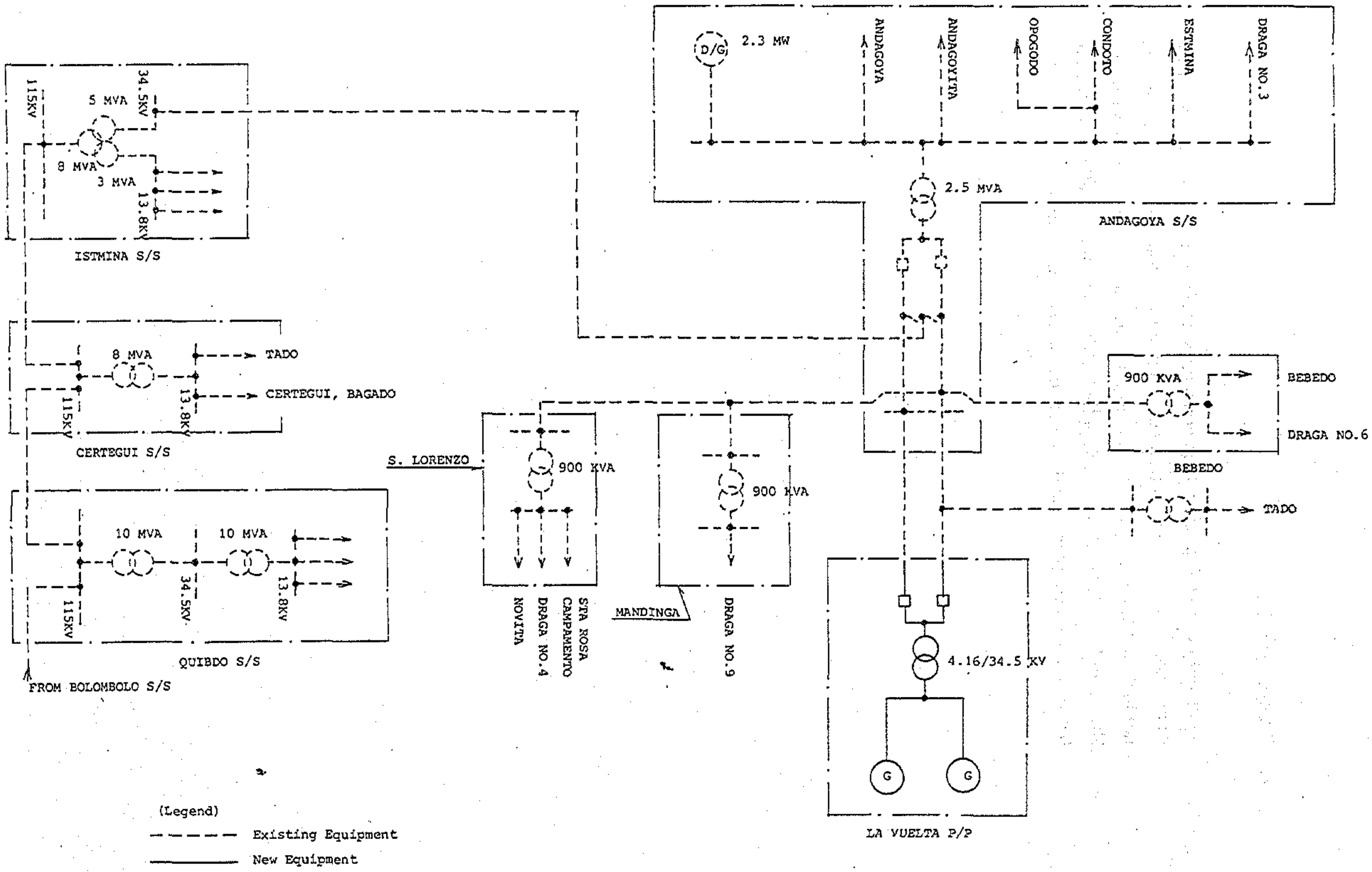


Fig. 11.7 Power Schematic Diagram

11.2 Construction Execution Plan

11.2.1 Study on Construction Execution Conditions

Two 1,000 kW generators are running in the existing power plant. In the new power plant and forebay sites, there are the existing substation and pylons for transmission lines. It is possible that these existing facilities are temporarily moved or that they will be relocated upstream from the existing location to have the existing generators operated during the construction of the new plant. However, since the construction period for the new plant is relatively short, and an increase in the construction cost would be expected if the location of new power plant is changed from the location where the existing P/P is situated, the shut down of the existing P/P is to be considered. Accordingly, a measure must be taken so that the power supply to La Vuelta village and its vicinity should be assured from the temporary substation during the shut down of the existing P/P. Besides the canoe navigation, there is no right already acquired for fisheries.

11.2.2 Preparatory Work

(1) Cofferdam and well point

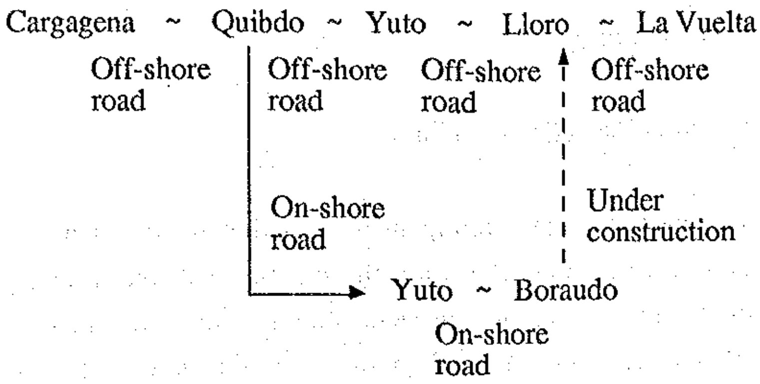
Prior to construction of the powerhouse, the cofferdam should be constructed around the outlet of the draft. Care should be exercised so that the navigation of canoes will no be interrupted due to the cofferdam.

(2) Dismantling of existing power generating facilities

The existing generating facilities which can be reused shall be dismantled.

11.2.3 Access Road for Construction

As an access road for construction, the existing on-shore road and the belowmentioned off-shore road have been considered.



The conduction channel section between Lloro and La Vuelta on the existing route has a water depth of more than 2 meters at the flood season of April through November, but water depth decreases to about 0.3 meter during the drought season of December through March. Although some parts of the on-shore section of the route between Yuto and La Vuelta are still under construction, it would be completed before the project is started, so that the on-shore transportation between Quibdo and La Vuelta is possible. (There is a ferry service which crosses the river available at Yuto.)

Either route between Quibdo and Lloro, on-shore or off-shore has its own problems when considering it as an access road to the construction and as there is no sufficient information on the route, detailed studies are necessary to select the appropriate route before starting the construction.

11.2.4 Temporary Works Equipment

The main temporary works equipment are as follows:

1. Excavation equipment
2. Concrete
3. Ropeway
4. Power source for construction

(1) Excavation equipment

Major excavation sites are those for powerhouse and forebay. The thin layer of sand and gravel existing at the surface of the earth shall be excavated by a bulldozer. The bedrock underneath the surface layer shall be excavated from the surface down to the subsoil with the combination of 4 units of shinka (air consumption: 2.0 m^3/min., weight: 14 kg) and 2 units of compressors (portable type, capacity: 5 m^3/min., delivery pressure: 7 kg/cm^2, weight: 1 ton). Excess excavated soil shall be dumped into the disposal site located downstream through the route of the construction road.

(2) Equipment for placing concrete

Concrete shall be placed using 2 x 0.5 m^3 mixers. The aggregates (sand and gravel) bin and cement storage sheds shall be located at the right bank of the forebay, and the gravels deposited at the riverbed in the vicinity of La Vuelta shall be used as the aggregates for concrete after sieving them. Cement and reinforcing bars shall be procured in Medellin.

(3) Ropeway

A ropeway crossing the Rio Andagueda shall be provided upstream at the right bank of the forebay to transport the aggregates and other construction materials.

(4) Power source for construction

Power source for construction shall be supplied from the temporary substation (capacity: 900 kVA) which is provided at the location opposite bank of the forebay as a substation receiving point through the existing transmission line after transforming the voltage of 34.5 kV into 4.4 kV.

The capacity of power for the construction shall include the power needed for the consumers in the vicinity of the power plant besides those for the power facilities for construction.

11.2.5 Construction Schedule

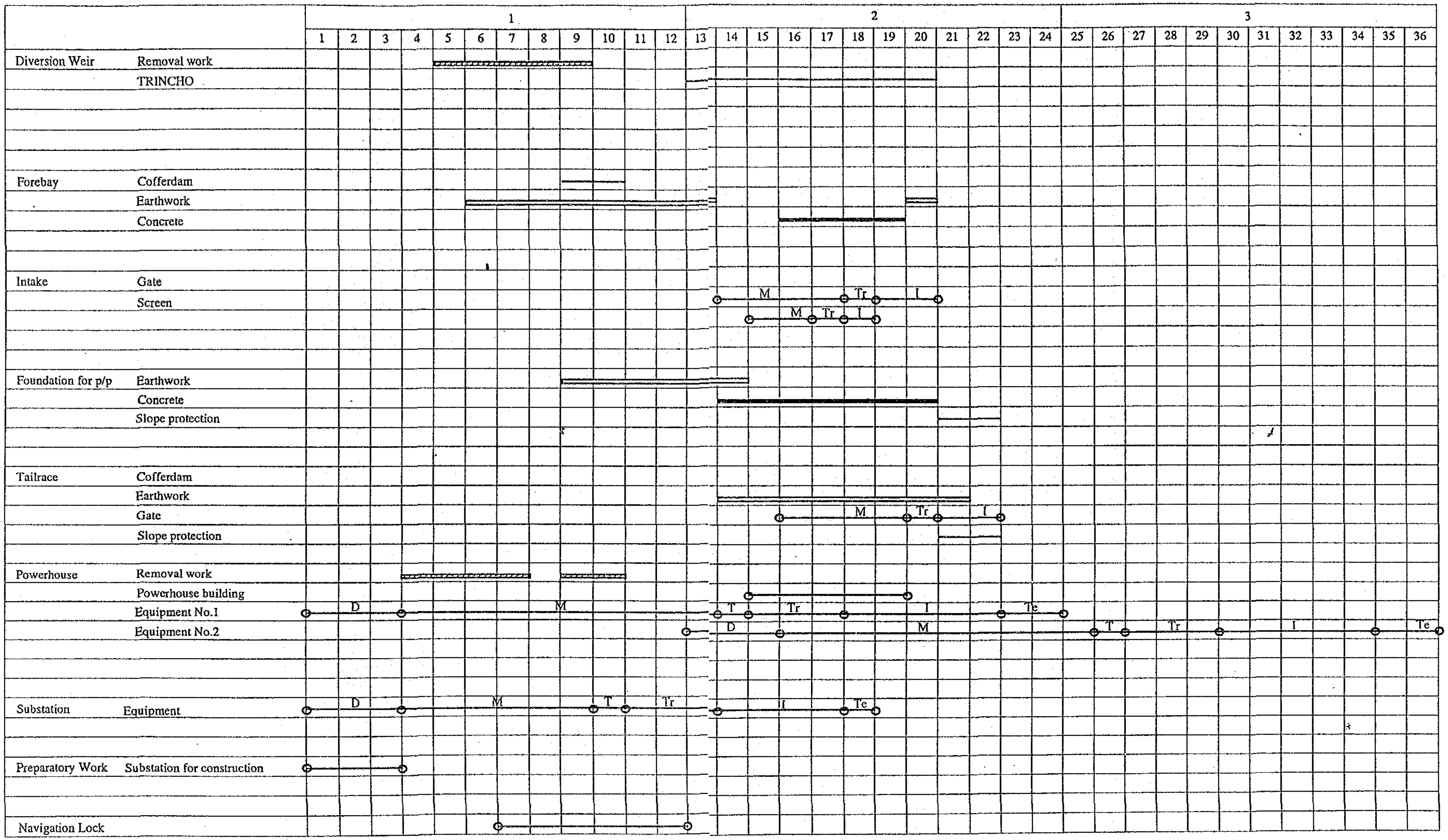
The construction schedule is shown in Table 11.4.

Table 11.4 La Vuelta Hydroelectric Power Plant Rehabilitation Plan Work Schedule

Year	1989				1990				1991				1992				1993				1994				1995				1996			
Item / Month	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12
Study for rehabilitation plan	━	━	━	━	━																											
Examination of rehabilitation plan						━	━	━																								
Main civil structures design and drawing up of documents									━	━	━	━	━	━	━	━																
Tender and award																	━	━	━													
Negotiations and conclusion of contract																				━												
Negotiating period for financing											━	━	━	━	━	━	━	━	━													
Ordering																					▼											
Construction work																					━	━	━	━	━	━	━	━	━	━	━	━
Compilation of discharge observation data			━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━	━												

Note) The details of the construction period are in Table 11.5.

Table 11.5 Construction Period



Note: M = Manufacturing, Te = Testing, Tr = Transportation, I = Installation

11.3 Construction Costs

11.3.1 Basic Conditions for Estimates

(1) Estimate method

(a) Estimate of work content

Project-related approximate construction costs include the following items:

Civil works costs
Direct work costs + contingency + engineering costs

Equipment costs
FOB + sea transport costs (inc. insurance) + land transport costs (inc. insurance) + various taxes + installation costs + testing costs + contingency + engineering costs

(b) Civil work cost calculation

- Direct costs are calculated as the work quantity x unit price

- The work quantity is estimated based on attached Dwg. No. LV-C-01 ~No. LV - C - 05.

- Within the unit direct temporary work costs (AIU) are taken as 30% in Colombia.

- The contingency and engineering costs are based on the ISA hydro-electric power project's construction costs as follows:

Contingency	direct construction costs x 15%
Engineering costs	(direct cost + contingency) x 10%

(c) Estimate of equipment work costs

Using the FOB and the ISA hydroelectric power plant project direct construction costs the work cost of equipment may be calculated as follows:

- FOB	100%	
- sea transport costs	FOB x 10%	
- sea transport insurance	FOB x 2%	
- taxes	FOB x 22.3%	3.15 x 1.105
- law 68		2.0 x 1.105
- law 50		8.0 x 1.105
- proexpo		5.0 x 1.105
- value-added tax	FOB x 13.4%	10% of above
- land transport/insurance	FOB x 6%	
- installation	FOB x 10%	
- test, connection	FOB x 6%	
- direct construction costs	FOB x 169.7%	
- contingency	FOB x 17%	10% of direct costs
- engineering costs	FOB x 14.9%	8% of (direct construction costs + contingency)

(d) Division of work type

The cost estimate for the La Vuelta hydroelectric power plant is divided as follows:

Intake dam : earthwork, removal of existing concrete, concrete, cobble concrete

Forebay : earthwork, concrete, rebars, masonry

Intake : earthwork, removal of existing concrete, concrete, rebars, gate, screen, slope protection

Powerhouse : earthwork, concrete, rebars, removal of existing concrete, building (new/repair)

Substation : earthwork, concrete, rebars

Furthermore, the generating equipment is divided as follows:

turbine and ancillary equipment
generator and ancillary equipment
turbine/generator control panel
generator switchgear
auxiliary transformer, distribution board, battery, charger
substation

(e) Annual estimate

An estimated rate was used as of September, 1989, according to the meeting with ICEL.

(2) Civil work units

As shown in 5.4 the units prepared by E. CHOCO in September, 1989 were used. The costs of temporary work camps, electricity sources, communication facilities etc., have been included within the present units. The standard unit for access road construction of 7.0 m width is US$350/m.

(3) Equipment FOB costs

Quotes were taken from two domestic Japanese companies and 90% of the lowest cost is determined as FOB cost.

11.3.2 Breakdown of Civil Construction Costs

The breakdown of the costs of civil construction for ALT-1 is shown on the following pages.

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
	La Vuelta (ALT-1)					
1.	Diversion Weir					
1.1	Trincho	L.S.			14,000,000	
	Sub Total				14,000,000	
2.	Forebay					
2.1	Earthwork	m^3	19,000	2,950	56,050,000	
2.2	Concrete Work	"	1,100	26,800	29,480,000	
2.3	Reinforcing Bar	ton	33	447,500	14,767,500	
	Sub Total				100,297,500	
3.	Intake					
3.1	Gate	ton	60	1,100,000	66,000,000	
3.2	Hoist	ton	24	1,000,000	26,400,000	
3.3	Screen	ton	37	1,000,000	37,000,000	
	Sub Total				129,400,000	
4.	Foundation of Equip.					
4.1	Earthwork	m^3	10,000	2,950	29,500,000	
4.2	Concrete	m^3	4,000	26,800	107,200,000	
4.3	Reinforcing Bar		320	447,500	143,200,000	
	Sub Total				279,900,000	

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
5.	Powerhouse					
5.1	Building	m^2	560	50,000	28,000,000	
	Sub Total				28,000,000	
6.	Tail Race					
6.1	Dredge Work	m^3	13,000	2,950	38,350,000	
6.2	Gabion	"	200	8,800	1,760,000	
6.3	Gate	ton	42	1,100,000	46,200,000	
6.4	Hoist	ton	16	1,100,000	17,600,000	
	Sub Total				103,910,000	
7.	Temporary facilities					
7.1	Power facility for construction	L.S.			23,000,000	
7.2	Ropeway	L.S.			4,000,000	
	Sub Total				27,000,000	
8.	Others					
8.1	Navigation Lock	L.S.			40,000,000	
	Sub Total				40,000,000	
9.	Grand Total				722,507,500	

11.3.3 Breakdown of Generating Equipment Costs

The breakdown of generating equipment costs for ALT-1 is shown below.

FOB COST OF ELECTRIC & MECHANICAL EQUIPMENT (ALT - 1)		
No.	Description	FOB Cost (US$1,000)
1	Water Turbine and Auxiliary Equipment	2,234.3
2	Generator and Auxiliary Equipment	984.3
3	Turbine and Generator Control Panel	97.1
4	Switchgear for Generator	121.4
5	Auxiliary Service Transformer, Distribution Board, Battery and Charger	25.0
6	Main Transformer	65.7
7	33 kV Substation	210.0
	Total	3,737.8

11.3.4 Annual Construction Work Costs

The annual construction work costs calculated according to the total work cost and the construction work schedule are shown in the following table.

Table Estimation of Annual Civil Construction Cost

(Units: 10^6 pesos)

Item	Alternative Plans			
	REH - 1		ALT - 1	
	Ist year	2nd year	1st year	2nd year
Diversion weir construction	-	18.2	-	18.2
Forebay construction	44.9	55.3	65.6	64.8
Intake construction	12.4	80.6	24.0	144.2
Equipment foundation construction	8.8	278.2	11.5	352.4
Powerhouse building construction	-	31.9	-	36.4
Tailrace construction	-	46.7	-	135.1
Temporary facilities construction	35.1	-	35.1	-
Other construction	52.0	-	52.0	-
① Subtotal	153.2	519.9	188.2	751.1
② Contingency (① x 0.15)	23.0	78.0	28.2	112.7
③ Engineering fees (①+②) x 0.10	17.6	59.8	21.6	86.4
④ Total ① + ② + ③	193.8	657.7	238.0	950.2
⑤ Output loss	16.5	21.4	16.5	21.4
Grand total (④ + ⑤)	210.3	679.1	254.5	971.6

CHAPTER 12 CONCLUSION AND RECOMMENDATIONS

This chapter describes the JICA study team's conclusion of the feasibility study for the rehabilitation of the La Vuelta hydroelectric P/P (for 17 months from November 1988 to March 1990), which was conducted following the pre-feasibility study (for 8 months from November 1987 to June 1988).

12.1 Most Feasible Rehabilitation Plan

La Vuelta P/P has been in operation on the maximum output of 500 kW, because of damage to TRINCHO and conduction channel and decreased efficiency of generating equipment. to rehabilitate this power plant, the rehabilitation plan which is most likely to be implemented from the technical and financial point of view is summarized below.

Table 12.1 Summary of Post-rehabilitation Optimum Generating Facilities

Item				Unit	Content
(1) Generation plan requirements	Max. available discharge		Q	m^3/s	100
	Standard net head		H	m	4.4
	Theoretical output			kW	4,312
	Max. output		P	kW	3,500
	No. of generating equipment				2
	Annual potential generated energy		E_1	GWh	29.9
	Plant utilization factor			%	96
(2) Civil structure specification	Diversion weir	Type			wooden-made
		Dimensions		m	2 (height), 200, 240 (crest length)
	Intake	Type			Non-pressure type, rectangular
		Dimensions		m	18.00 (width), 5.50 (height)
	Intake gate	Type			Steel sluice gate, two gates
		Dimensions		m	8.60 (width), 7.0 (height)
	Forebay	Type			Rectangular open channel
		Dimensions		m	18.00 (width), 11.00 (length)
	Sand trap valve	Type			Sluice valve
		No. of gates			One gate
		Dimensions		m	ϕ0.50
	Powerhouse	Shape			Rectangular, RC structure
		Dimensions		m	29.90 (width), 16.50 (depth)
	Tailrace	Shape			Rectangular
		Dimensions		m	7.00 (width), 4.80 (height)
	Tailrace gate	Type			Steel sluice gate
		No. of gates			2
		Dimensions		m	7.60 (width), 5.50 (hegith)

Table 12.1 Summary of Post-rehabilitation Optimum Generating Facilities (cont'd)

Item			Unit	Content
(3) Generating equipment specifications	Turbine	Type		Conduit bulb
		No. of turbines		2
		Output	kW	1,860
		Revolution	rpm	128.5
	Generator	Type		Synchronous
		No. of generators		2
		Output	kVA	2,000
		No. of poles		56
		Revolution	rpm	128.5
	Main transformer	Type		ONAN, 3φ
		No.of transformer		1
		Voltage	kV	4.16/34.5 kV
		Capacity	kVA	4,000
(4) Rehabilitation work cost	Generating equipment	Foreign currency portion	US$	5,400,000
		Local currency portion	US$	2,150,000
	Civil and building work cost	Foreign currency portion	US$	0
		Local currency portion	US$	3,320,000
	Project cost		US$	10,870,000
	Construction cost	per kW	US$/kW	3,100
		per kWh	mills/kWh	364

12.2 Economic Indices

As general indices to evaluate the feasibility, the construction cost per kW and the average generating cost per kWh are explained in the General Criteria Vol.1 issued by ISA in June, 1987. The study result of these economic indices is described in Section 9. Economic indices in the case of the optimum rehabilitation plan shown in Table 12.1 are as follows:

Construction cost per kw: US$3,100/kW
Average generating cost for annual supplied electric power: 36 mills/kWh

12.3 Operation and Maintenance Manual

The maintenance manual contains the regulations to secure stable power supply and to maintain the installed facilities in the normal condition. Each electric power company shall establish such regulations based on its managerial policy.

In the rehabilitation of the La Vuelta hydroelectric P/P, the generating equipment such as the turbines, generators and main transformers will be replaced with new ones. Therefore the maker of each equipment shall provide the operation and maintenance manual which conforms to the specification.

Accordingly the attached data in the Summary of this report contains the general management manual for the maintenance and inspection of the main civil structures and generating equipment.

12.4 Technical Recommendations for the Rehabilitation Plan

When the rehabilitation plan of the La Vuelta hydroelectric P/P is realized, the following points should be carefully considered at the stage shifting from the feasibility study to the basic design and detailed design.

(1) Topographic, geologic and biological incrustation survey of the watershed

The topographic map will be drawn on a scale of 1:10,000 ~ 1:5,000 from the aerial photograph. It is desirable to conduct the present condition survey of topography, geology, biological incrustation of the watershed. The catchment area of the intake area and the Aguasal hydrological gauging station will be confirmed.

a) A geological survey will be conducted for foundation for diversion weir (including abutment on right and left banks), powerhouse building, and tailrace structures to confirm the bedrock condition and water leakage from a pond.

b) Backwater effect by the increased intake water level will be examined, and a study of compensation cases by subsidence will be made.

(2) Works to conform river hydrological regime

It is desirable to actually measure river hydrological regime according to the rating curve used by the Aguasal hydrological gauging station managed by HIMAT which offers the discharge data. In addition, it is also desirable to periodically conduct the water quality test to check the characteristics of river sediment water quality. The catchment area at the intake site and the hydrological gauging station will be confirmed by using the topographic map on a scale of 1:10,000 ~ 1:5,000.

(3) Conduction channel protection

The inflow of sand to the forebay needs to be restricted, otherwise it will accumulate between TRINCHO and the forebay entrance, wearing out the water turbine. The amount of sedimentation shall be estimated from characteristic of river sedimentation. A plan for removing such sedimentation shall be formulated.

CONTENTS OF APPENDICES

§1. Generation Plan

Study is made on the case when the intake water level is increased.

The present divrsion weir is of the wooden structure type dam and is said to have poor efficiency of water intake and needs annual repair.

To meet the requirements of the project, the diversion weir is going to have a concrete dam at the river section and the right bank abutment, and a fill-type dam at the left bank abutment since there is no data available on the topography and baserock in that area. Forebay and generating plant are to be built upstream of the existing powerhouse parallel to it.

(1) Maximum available discharge

As shown in the flow-duration curves in the intake point, the discharge which can be assured for 95% of a year is 72.2 m^3/s and 80% can be assured by 100 m^3/s. Taking the study results of the maximum available discharge shown in Fig. 8.1 into consideration, the maximum available discharge is designed to be 100 m^3/s.

(2) Standard net head

As a result of studying how far the maximum water level can be increased in the water intake point from the present topographical maps and the field reconnaissance survey, water level at the intake and tailrace is determined to be 85.00 m and 75.20 m respectively.

Assuming that the net head for determining the turbine output and calculating annual generated energy is constant, the standard net head calculated under the following standard is used.

Effective head (He) can be obtained by calculating the loss of head between forebay and tailrace in the following equation.

$$He = Hg - \Delta H + \frac{Vg^2}{2g} - \frac{Vf^2}{2g}$$

$$\Delta H = V_2^2 / 2g \left(f_e + \frac{V_2^2 - V_1^2}{V_2^2} + f_p + f_n\right) + \Delta h$$

where:

Hg	=	gross head
		Forebay water level (85.00 m) - tailrace water level (75.20 mm)= 9.80 m
ΔH	=	total loss of head (m)
V_1	=	velocity at forebay (m/s)
V_2	=	velocity at the entrance of the intake (m/s)
f_e	=	coefficient of inflow loss; 0.1
f_p	=	coefficient of frictional loss due to pier at regulating gate; 0.095
f_n	=	loss of head due to silt grid; 0.353
$V_g^2 2g$	=	velocity head at entrance of turbine (Vg = 1.0 m/s)
$V_f^2 2g$	=	velocity head at tailrace (Vf = 1.5 m/s)
Δh	=	margin (m)
n	=	Coefficient of roughness, 0.015

Calculated Result of Standard Net Head

Q (m^3/s)	Hg (m)	$V_2^2/2g\Sigma f$ (m)	Δh (m)	ΔH (m)	$V_g^2/2g$ (m)	$V_f^2/2g$ (m)	He (m)
100	9.80	0.039	0.015	0.054	0.047	0.113	9.68

Accordingly, the standard net head is calculated to be 9.65 m.

(3) Generated output

The calculation results of generated output are shown in the following table.

Calculation of Generated Output

Item / Alternative plan	①	②	③	④	⑤
	Available discharge Q (m^3/s)	Standard net head H (m)	9.8 x ① x ② Theoretical output (kW)	Resultant efficiency η	③ x ④ Generated output ρ (kW)
ALT-2 (Tentative)	100	9.65	9,457	0.823	7,783

(4) Annual potential generated energy

1) The calculation results of annual potential generated energy are shown in the following table.

New layout plan at adjacent location, ALT-2 (tentative)

Max. available discharge Q = 50 m^3/s x 2 units
Standard net head H = 9.65 m
Turbine type: Condit type bulb turbine

Day	Number of days	Available discharge (m^3/s)	Burden ratio Available discharge / Max. available discharge	Resultant efficiency η	Generating power (kW)	Average power (kW)	Generated energy (MWh)
Max.	289	100	1.000	0.823	7,783	7,783	53,982
295	6	97.8	0.978	0.825	7,630	7,706	1,109
300	5	95.5	0.955	0.826	7,459	7,544	905
305	5	93.9	0.939	0.827	7,343	7,401	888
310	5	91.1	0.911	0.830	7,150	7,246	869
315	5	88.9	0.889	0.830	6,978	7,064	847
320	5	85.3	0.853	0.833	6,719	6,848	821
325	5	83.2	0.832	0.835	6,569	6,644	797
330	5	81.1	0.811	0.837	6,419	6,494	779
335	5	78.7	0.787	0.837	6,229	6,324	758
340	5	76.1	0.701	0.837	6,023	6,126	735
345	5	73.5	0.735	0.837	5,817	5,920	710
350	5	70.2	0.702	0.837	5,556	5,686	682
355	5	66.0	0.660	0.830	5,180	5,368	644
360	5	62.3	0.623	0.827	4,872	5,026	603
365	5	55.4	0.554	0.812	4,254	4,563	547
Total	365					(6,483)	65,676

§2. Rehabilitation Work Cost (draft)

For the overflow section of the diversion weir, a sand trap and a spillway will be constructed on the concrete dam in the present river stream section, a concrete dam at the right bank abutment of the river and a non-overflow section or the fill-type dam will be built at the left bank abutment.

For the overflow section, a sand trap gate (EL: 77.00 m) will be provided at the right bank of the river, and rubber dam (which allows overflow and has an EL of 82.00 m) and spillway gate (EL: 79.00 m) will be provided as an emergency spillway and will be designed to discharge the flood at EL of 86.00 m.

A bridge will be constructed at the weir column to allow the traffics between right and left blanks.

(1) Civil construction cost

The total cost for the civil construction is as follow, and its breakdown is shown in the following table.

Estimation of Civil Construction Cost

(unit: 10^6 pesos)

Item	Alternative
	ALT-2 (Tentative)
Diversion weir construction	1,699.5
Forebay construction	152.4
Intake construction	168.2
Foundation of equipment construction	435.5
Powerhouse building construction	42.9
Tailrace construction	135.1
Temporary facility construction	35.1
Other construction	153.4
① Subtotal	2,822.1
② Contingency (① x 0.15)	423.3
③ Engineering fees ((① + ②) x 0.10)	324.5
④ Total (① + ② + ③)	3,569.9
⑤ Output loss	37.9
Total (④ + ⑤)	3,607.8

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
	La Vuelta (ALT-2) (Tentative)					
1.	Diversion Weir					
1.1	Earthwork	m^2	23,000	2,950	67,850,000	
1.2	Concrete Work	"	12,000	26,800	321,600,000	
1.3	Cyclopean Concrete Work	"	5,000	24,000	120,000,000	
1.4	Reinforcing Bar	ton	450	447,500	201,375,000	
1.5	Gate	"	185	1,100,000	203,500,000	
1.6	Screen	"	110	1,100,000	121,000,000	
1.7	Fabric Dam	L.S.			242,000,000	
1.8	Fill Dam	L.S.			30,000,000	
	Sub Total				1,307,325,000	
2.	Forebay Channel					
2.1	Earthwork	m^3	22,000	2,950	64,900,000	
2.2	Concrete Work	"	1,300	26,800	34,840,000	
2.3	Hoist	ton	39	447,500	17,452,500	
	Sub Total				117,192,500	
3.	Intake					
3.1	Gate	ton	60	1,100,000	66,000,000	
3.2	Screen	ton	37	1,000,000	37,000,000	
3.3	Hoist	ton	24	1,100,000	26,400,000	
	Sub Total				129,400,000	
4.	Foundation of Equip.					
4.1	Earthwork	m^3	12,000	2,950	35,400,000	
4.2	Concrete Work	m^3	5,000	26,800	134,000,000	
4.3	Reinforcing Bar	ton	370	447,500	165,575,000	
	Sub Total				334,975,000	

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
5.	Powerhouse					
5.1	Building	m^2	660	50,000	33,000,000	
	Sub Total				33,000,000	
6.	Tailrace					
6.1	Earthwork	m^3	13,000	2,950	38,350,000	
6.2	Gate	ton	42	1,100,000	46,200,000	
6.3	Hoist	ton	16	1,100,000	17,600,000	
6.4	Gabion	m^3	200	8,800	1,760,000	
	Sub Total				103,910,000	
7.	Temporary Facilities					
7.1	Power facility for Construction	L.S.			23,000,000	
7.2	Ropeway	L.S.			4,000,000	
	Sub Total				27,000,000	
8.	Others					
8.1	Bridge	L.S.			78,000,000	
8.2	Lock	L.S.			40,000,000	
	Sub Total				118,000,000	
	Grand Total				2,170,802,500	

(2) Estimation of generating equipment cost

Specifications for generating equipment and their FOB and CIF prices are shown in the following table.

Item	Alternative
	ALT-2 (Tentative)
1. Specifications	
Design discharge (m^3/s)	50
Net head (m)	9.65
Theoretical output (kW)	4,728
Turbine type	Conduit bulb
Turbine output (kW)	4,100
Generator power factor	0.9
Generator output (kVA)	4,300
Main transformer capacity (kVA)	8,600
2. FOB costs (US$1,000)	
Generating equipment	
(1) Turbine and ancillary equipment	1,581.45
(2) Generator and ancillary equipment	747.85
(3) = (1) + (2) Subtotal:	2,329.3
(4) Number of units	2
(5) = (3) x (4) Subtotal:	4,658.6
(6) 4.16 kV switchgear etc.	146.4
(7) Substation	335.7
(8) = (5) + (6) + (7) Total:	5,140.7

Implementation Cost of Generating Equipment

(units: US$1,000)

Item			Alternative ALT-2 (Tentative) A	Alternative ALT-2 (Tentative) B
1)	FOB cost		5,140.7	-
2)	Transportation costs, insurance	1) x 0.12	616.9	-
3)	Tax	1) x 0.223	-	1,146.4
4)	Value-added tax	1) x 0.134	-	688.9
5)	Others	1) x 0.22	-	1,131
6)	Total		5,757.6	2,966.3
7)	Contingency	1) x 0.17	873.6	-
8)	Eng. Fee	1) x 0.149	765.7	-
9)	Total	6) + 7) + 8)	7,396.9	2,966.3
10)	Grand Total		10,363.2	

Note: A = foreign currency portion
B = local currency portion

(3) Annual construction costs

Annual construction costs calculated from the tables of Total Construction Costs and Construction Schedule are shown in the following table.

Estimation of Civil Construction Cost

(unit: 10^6 pesos)

Item	Alternative	
	ALT-2 (Tentative)	
	1st year	2nd year
Diversion weir construction	499.0	1,200.5
Forebay construction	76.0	76.4
Intake construction	24.0	144.2
Foundation of equipment construction	13.8	421.7
Powerhouse building construction	-	42.9
Tailrace construction	-	135.1
Temporary facility construction	35.1	-
Other construction	52.0	101.4
① Subtotal	699.9	2,122.2
② Contingency (① x 0.15)	105.0	318.3
③ Engineering fees ((① + ②) x 0.10)	80.5	244.0
④ Total (① + ② + ③)	885.4	2,684.5
⑤ Output loss	16.5	21.4
Total (④ + ⑤)	901.9	2,705.9

§3. Economic Indices (draft)

(1) Construction cost per kW

The construction cost per increased-output is US$2,800/kW, as shown in the following table.

Construction Cost per kW

Item		Alternative: ALT-2 (Tentative)
Existing equipment output (kW)		
Rated output	Po	2,000
Available output	Pe	500
Post-rehabilitation output	P_1 (kW)	7,700
Recovered/increased output $\Delta P = P_1 - Pe$ (kW)		7,200
Rehabilitation work cost	(US$1,000)	
Foreign currency portion Cf		7,400
Local currency portion C		12,720
Total C = Cf + C		20,120
Construction cost per kW	(US$/kW)	
C/P_1		2,600
$C/\Delta P$		2,800

(2) Generating cost per kWh

The calculation results of generating costs per kWh are shown in the following table. The generating cost per annual supplied power is 29 mills/kWh.

Comparison of Generating Cost per kWh

Item		Alternative ALT-2 (Tentative)
Existing equipment capacity:		
Power output	Pe (kW)	500
Energy	Ee (GWh)	6.25
Rehabilitation plan:		
Power output	P_1 (kW)	7,700
Generated energy	E_1 (GWh)	65.7
Recovered/increased power		
Output	$\Delta P = P_1 - Pe$ (kW)	7,200
Energy	$\Delta E = E_1 - Ee$ (GWh)	59.4
Total of expenses at generating terminal: (US$1,000)		
Construction work cost		
Foreign currency portion Cf_1		7,400
Local currency portion $C\ell_1$		12,720
Construction cost total $C_1 = Cf_1 + C\ell_1$		20,120
Interest payment C_2		
Foreign currency portion Cf_2		11,914
Local currency portion $C\ell_2$		12,923
Total $C_2 = Cf_2 + C\ell_2$		24,837
AOM C_3 = US$4 x P_1 x 25 years		770
Total $\Sigma Ci = C_1 + C_2 + C_3$		45,727
Average annual cost $C = \Sigma Ci/25$		1,829
Generating cost per annually supplied energy (mills/kWh)		
Per E1	$C/(E_1 \times 0.95)$	29
Per ΔE	$C/(\Delta E \times 0.95)$	32

Table Comparison of Rehabilitation Plan for the La Vuelta Power Plant

Alternative Plan	(1) Specifications for Existing Generating Facilities: (10) Max. available discharge Qo (m³/s)	(11) Net head Ho (m)	(12) Rated output Po (kW)	(13) Present facility capacity: (14) Output Pe (kW)	(15) Generated energy Ee (GWh)	(2) Rehabilitation Plan: (20) Max. available discharge Ql (m³/s)	(21) Standard net head Hl (m)	(22) Theoretical output =9.8x(20) x(21) (kW)	(23) Resultant efficiency η	(24) Output =(22)x(23) Pl (kW)	(25) Annual probable generated energy El (GWh)	(26) Facility utilization factor ε (%)	(3) Recovered or Increased Energy: (30) Output =(24)-(14) ΔP (kW)	(31) Annual probable generated energy (25)-(15) ΔE (GWh)
ALT-2	54.0	4.8	2,000	500	6.25	100.0	9.65	9,457	0.823	7,700	65.7	96	7,200	59.4

Alternative Plan	(4) Rehabilitation Work Cost (US$1000): (40) Generating Equipment Cost: (41) Foreign currency portion Cif	(42) Local currency portion Clℓ	(43) (41)+(42) C1	(44) Civil work cost C2	(45) (43)+(44) C	(5) Construction Cost per kW (US$/kW): (50) Cost per ΔP =(45)/(30) C/ΔP	(51) Cost per Pl =(45)/(24) C/Pl	(6) Total of Annual Cost at Generating Terminal (US$1000): (60) Operation and maintenance costs AOM	(61) Principal repayment amount for construction cost (25-year average): (62) Foreign currency portion 2.610 x (41) ÷ 25	(63) Local currency portion 2.016 x [(42)+(44)] ÷ 25	(64) (62)+(63)	(65) (60)+(64)	(7) Average Generating Cost per kWh (mills/kWh): (70) per El =(65)/(25) ÷0.95	(71) per ΔE =(65)/(31) ÷0.95	(8) Cost/Benefit C/B	(9) Priority order
ALT-2	7,400	2,950	10,350	9,700	20,120	2,800	2,600	30.8	772	1,026	1,798	1,829	29	32	2.29	—

(Notes)

(1) : For the existing generating equipment specifications, refer to the facility register record attached to the pre-FS report.

(7) : Generating cost = $\frac{\text{Total of annual average cost at generating terminal}}{\text{Annual average supplied electric power}}$

(8) : C/B is the value of cost and benefit ratio calculated according to the financial analysis.

(15) : Ee is computed according to the average annual operation record for years from 19 to 19 .

(23) : η is the resultant efficiency of turbine and generator.

(25) : El(Energia Media)

(26) : $\varepsilon = \frac{\text{Annual water amount for turbine } (m^3/s \cdot hr)}{Q_l \times 365 \times 24} \times 100(\%)$

(60) : The annual AOM is the amount which is equivalent to US$4 per kW.

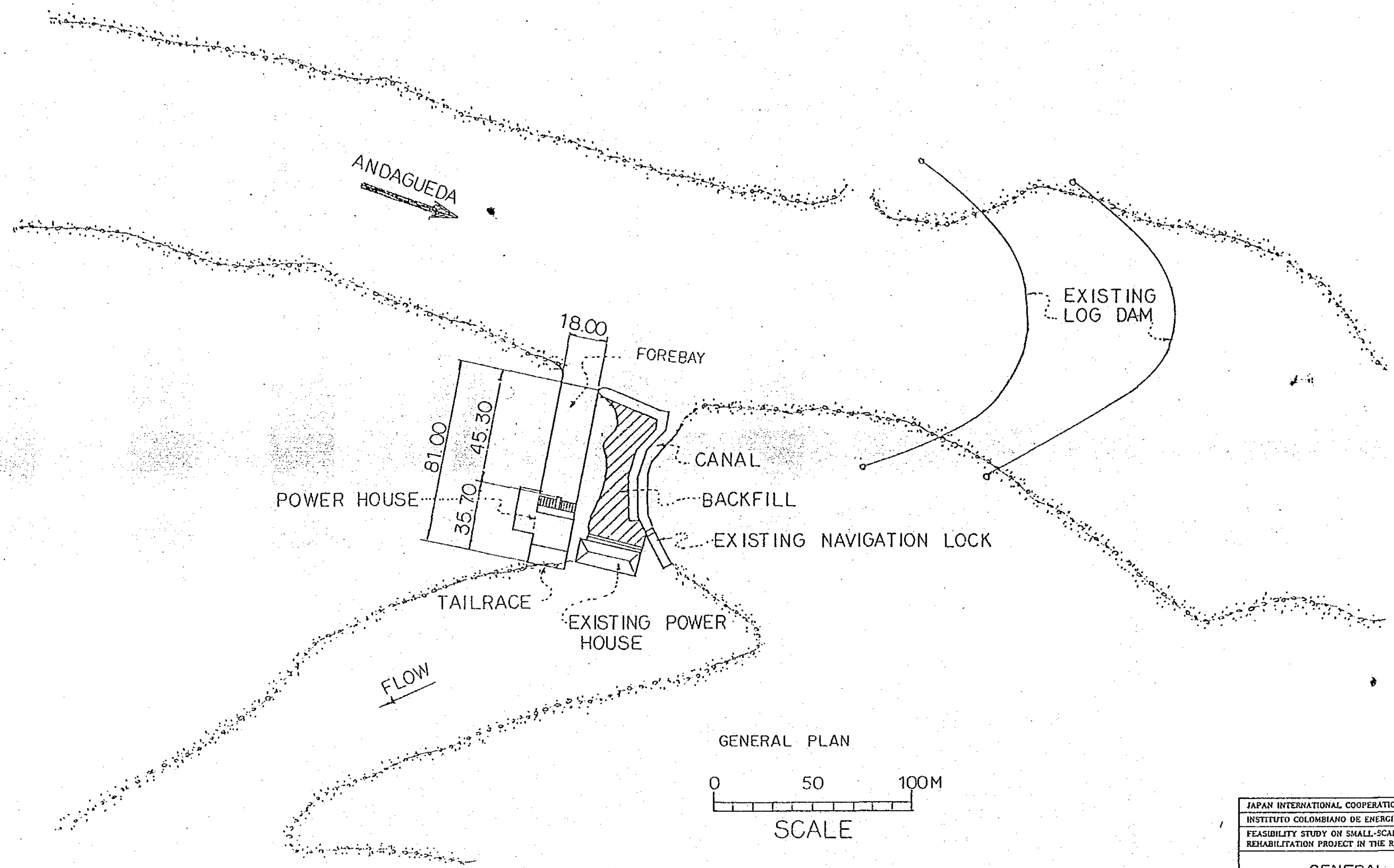
(61) : Interest is calculated by a repayment of principal in equal annual amounts under the following conditions.

Foreign currency portion: Annual interest rate of 10%, unredeemable for 4 years, repayment over 25 years

Local currency portion : Annual interest rate of 21%, unredeemable for 1 year, repayment over 8 years

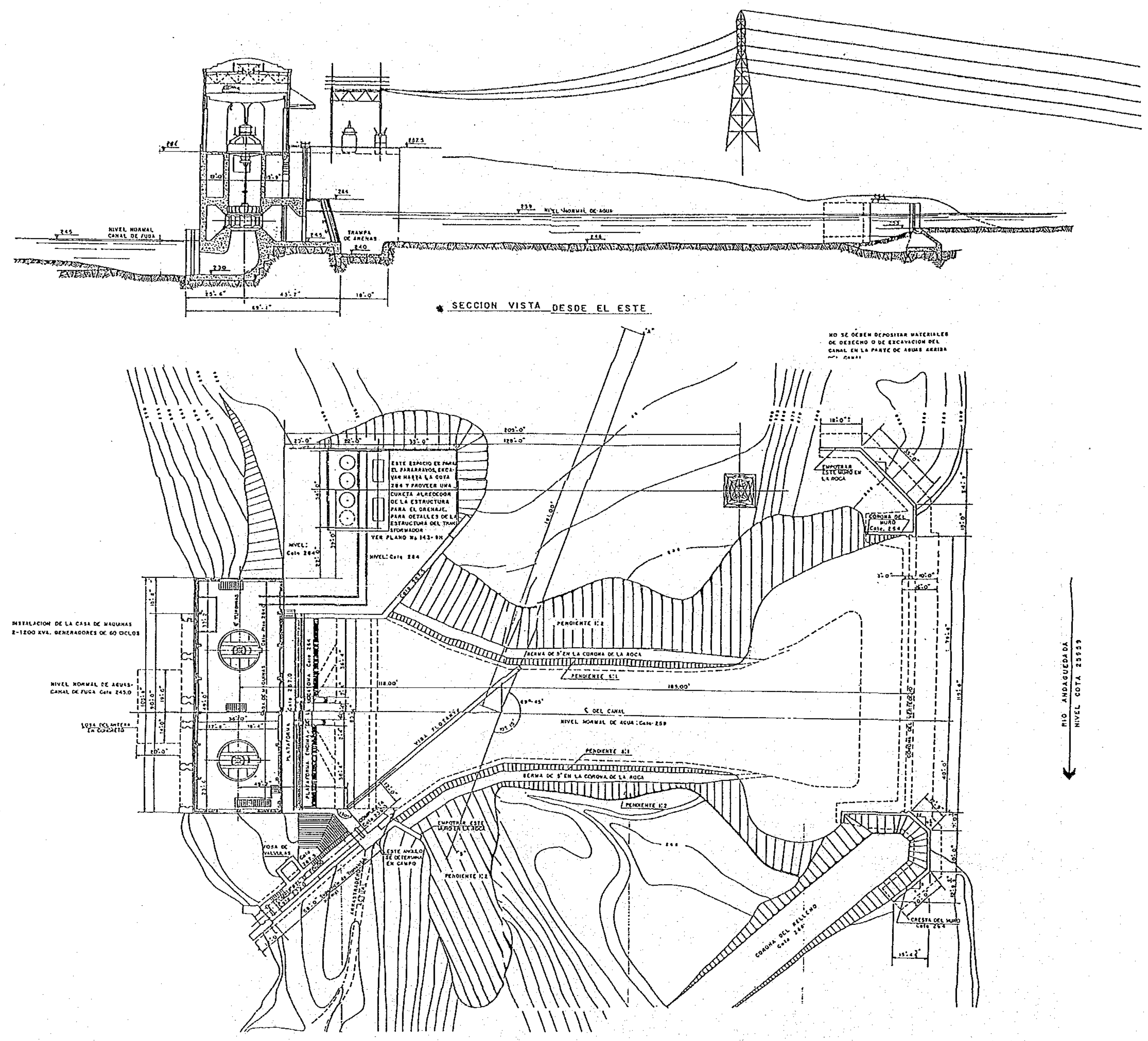
Drawings

Title	Drawing No.
ALT-1	
General Plan	LV-C-01
General Plan and Section of Existing Plant	LV-C-02
General Plan of Powerhouse	LV-C-03
Powerhouse Typical Section	LV-C-04
Powerhouse Profile and Cross Sections	LV-C-05
Duration Curves	LV-H-01
Geological Plan and Profile	LV-G-01
One Line Diagram	LV-E-01
ALT-2	
General Plan	LV-C-06
Profile and Sections of Diversion Weir	LV-C-07
Plan and Sections of Diversion Weir	LV-C-08



GENERAL PLAN

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
GENERAL PLAN (ALT — 1)	
DRAWING NO.	LV-C-01
SCALE	DATE



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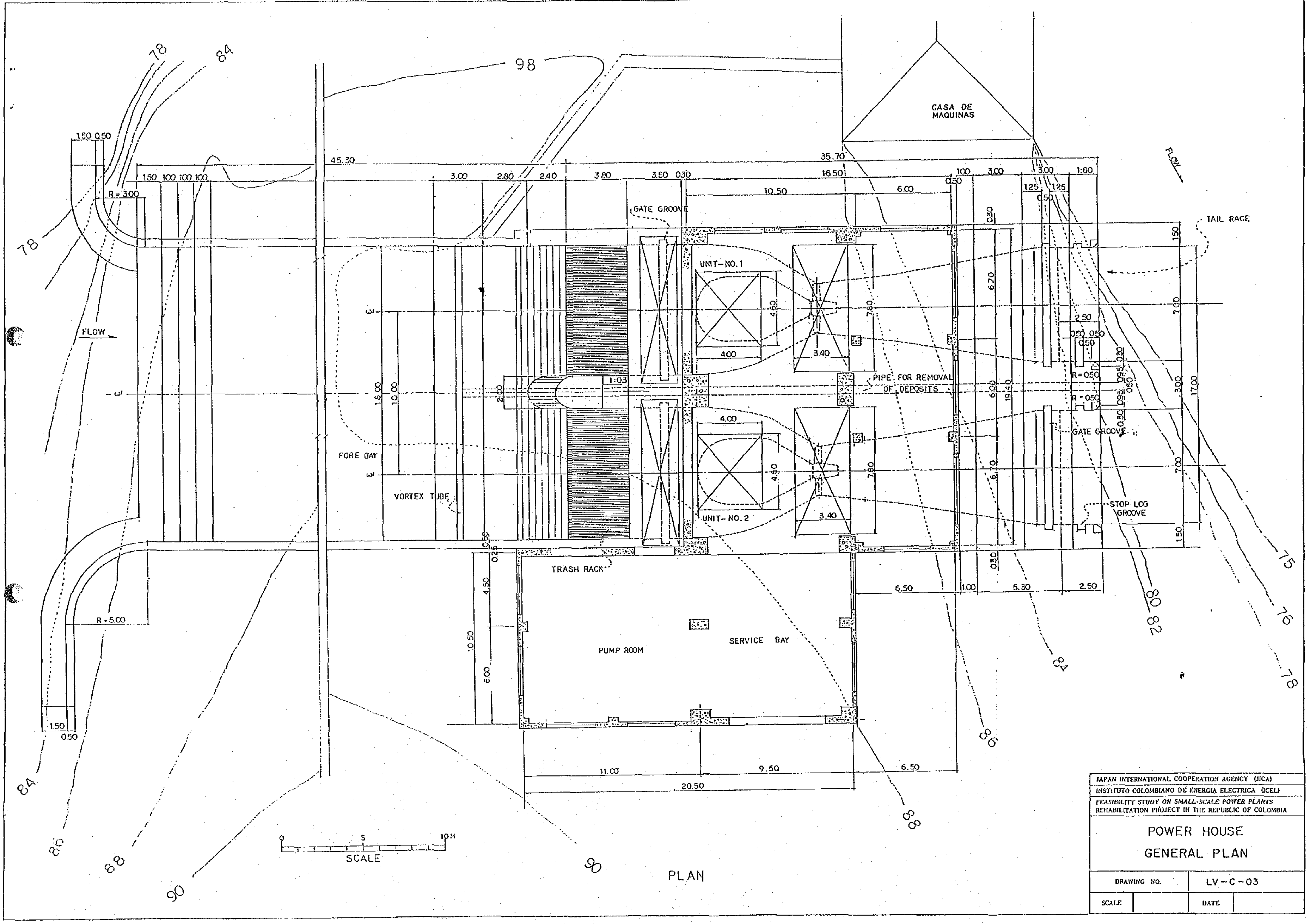
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA

EXISTING PLANT
GENERAL PLAN AND SECTION

DRAWING NO.	LV-C-02
SCALE	DATE



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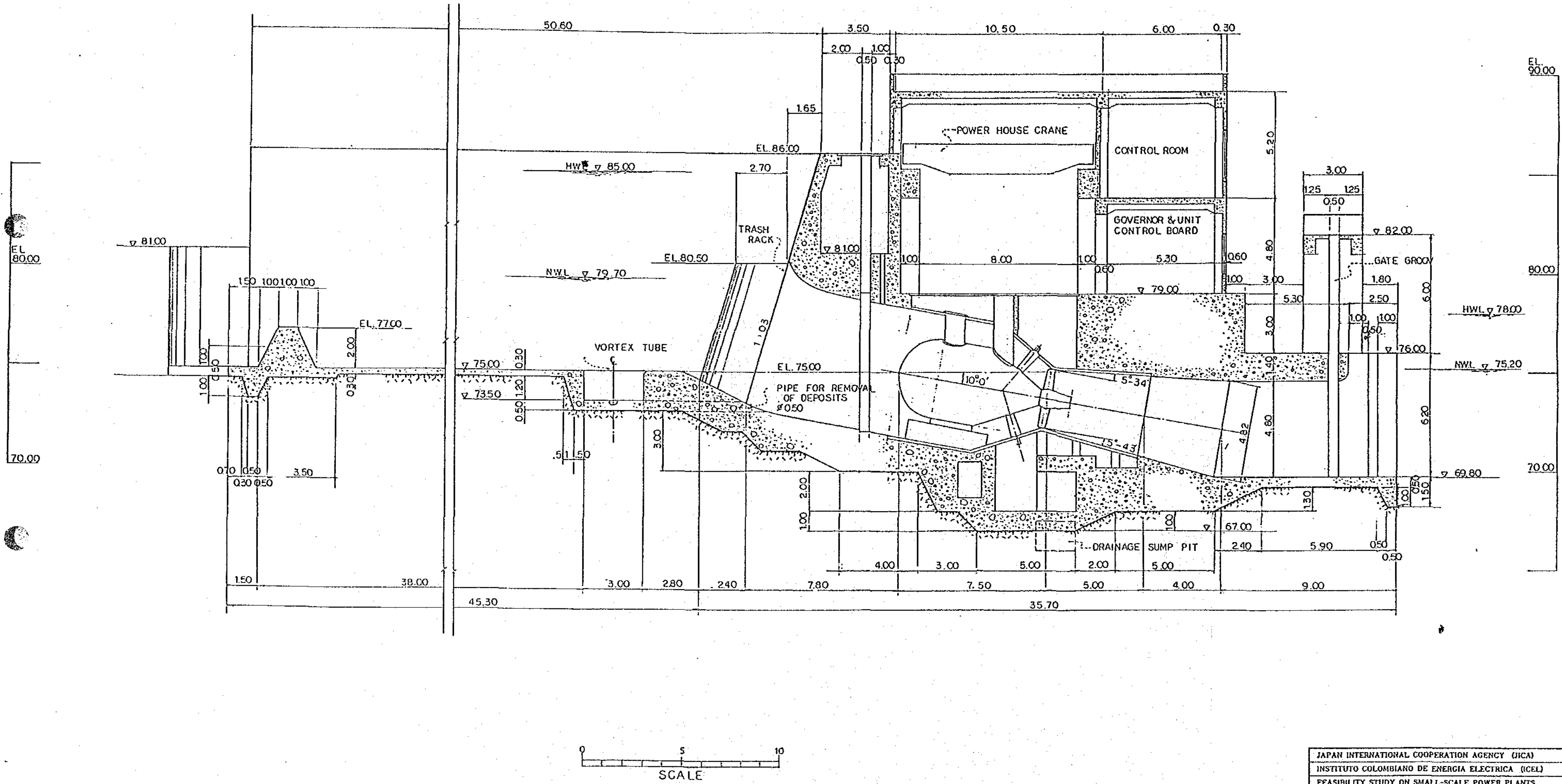
POWER HOUSE
GENERAL PLAN

DRAWING NO.		LV-C-03	
SCALE		DATE	

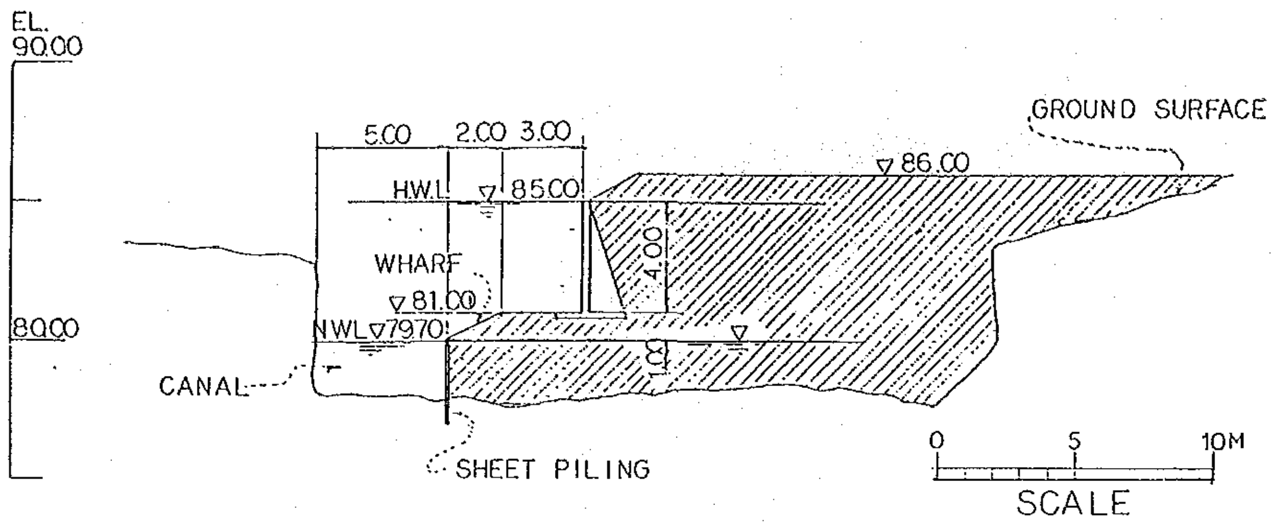


PROFILE ON CENTERLINE OF POWER HOUSE

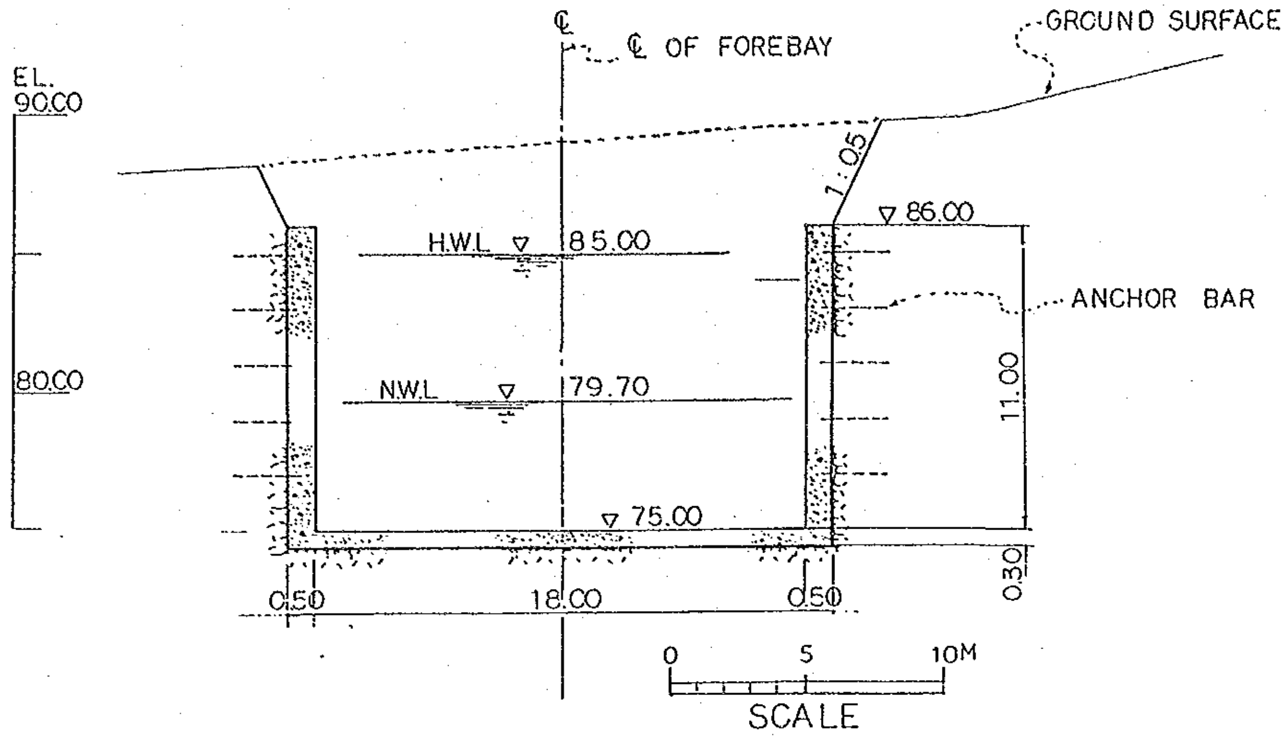
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA

POWER HOUSE
TYPICAL SECTION

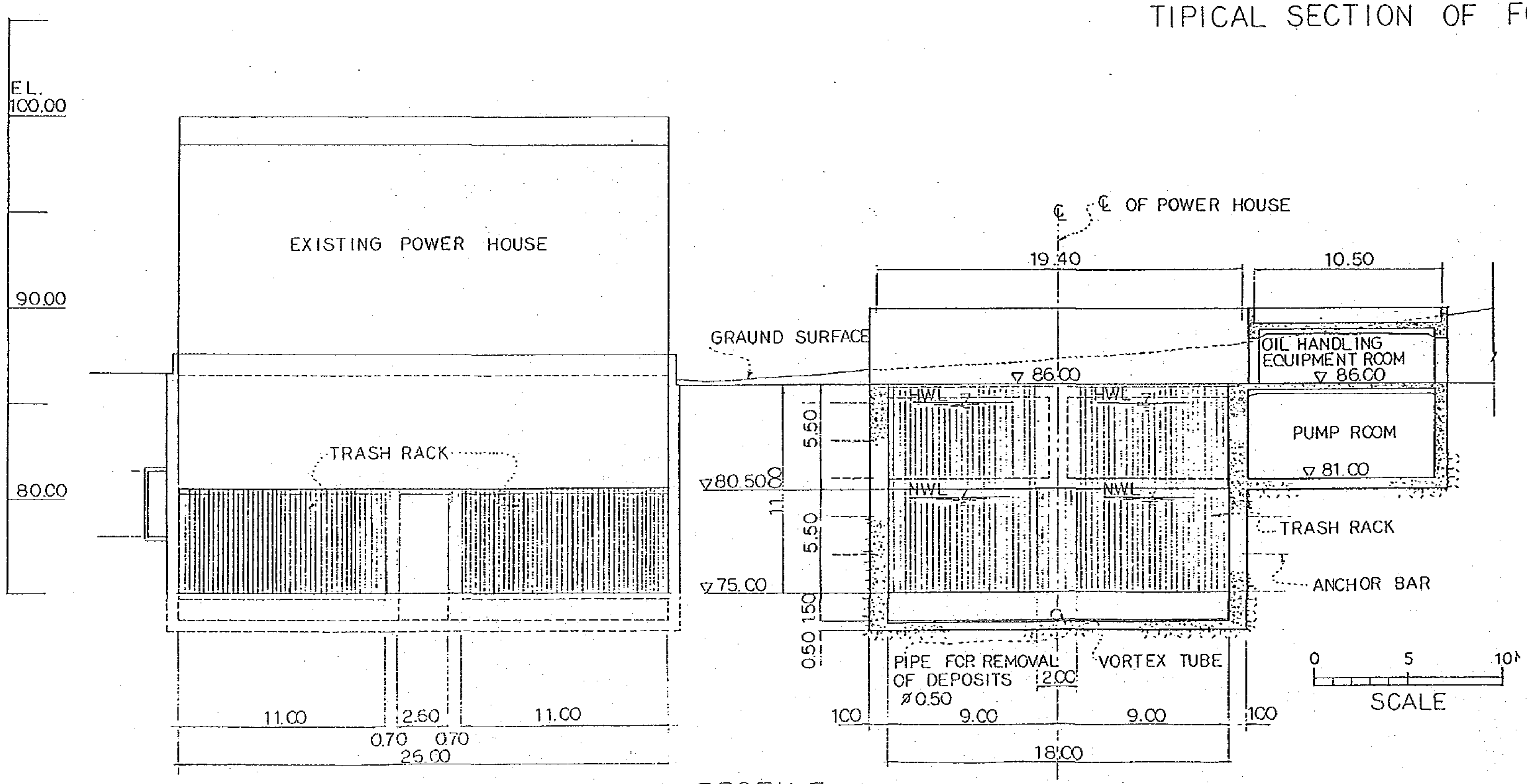
DRAWING NO.	LV-C-04
SCALE	DATE



TIPICAL SECTION OF CANAL



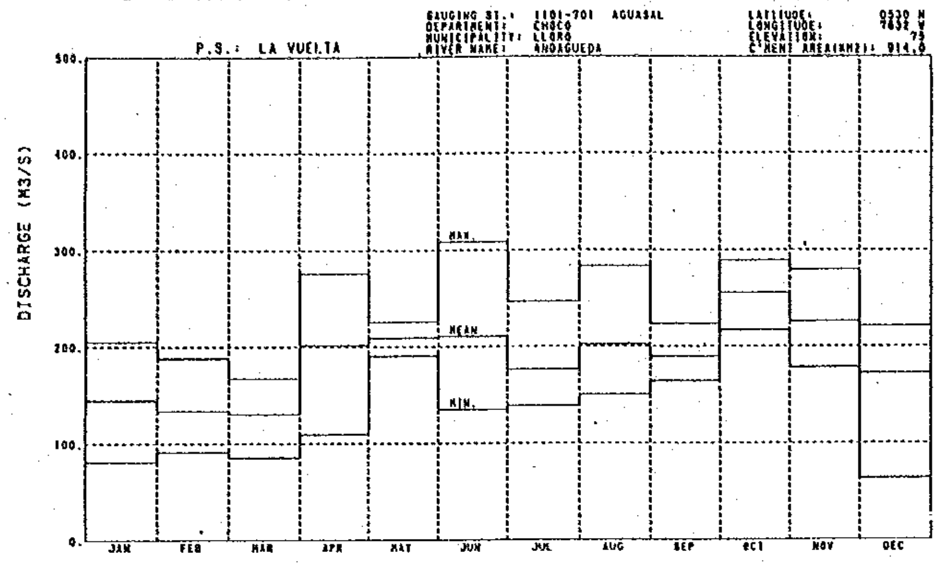
TIPICAL SECTION OF FOREBAY



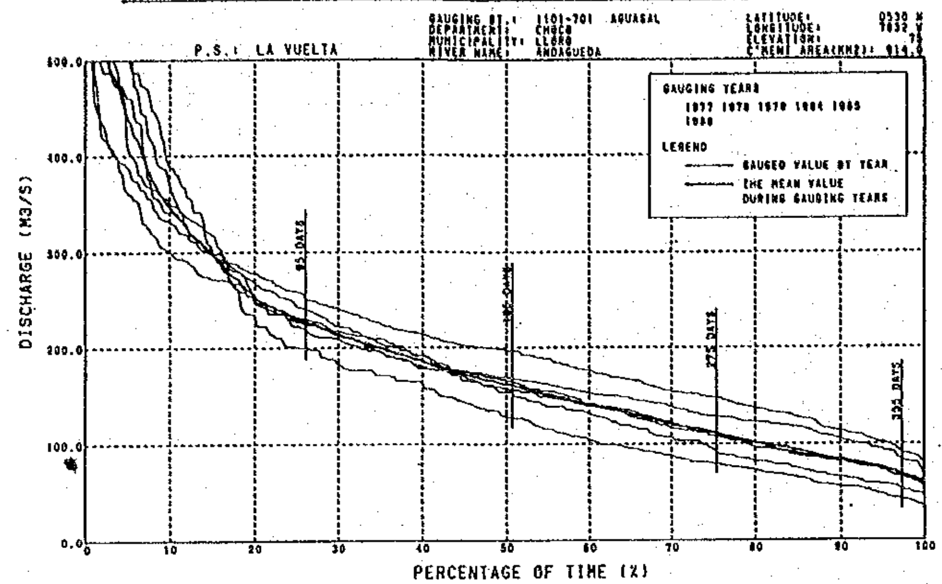
PROFILE

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
POWER HOUSE PROFILE AND CROSS SECTIONS	
DRAWING NO.	LV-C-05
SCALE	DATE

(1)
MONTHLY MEAN VALUE OF DAILY AVERAGE FLOW AT G.S. SITE



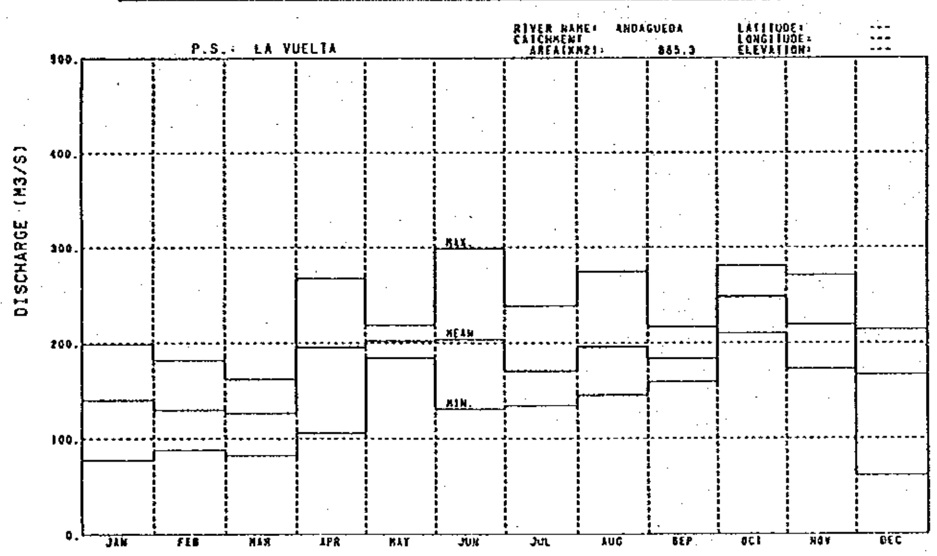
(3)
FLOW DURATION CURVE AT GAUGING STATION SITE



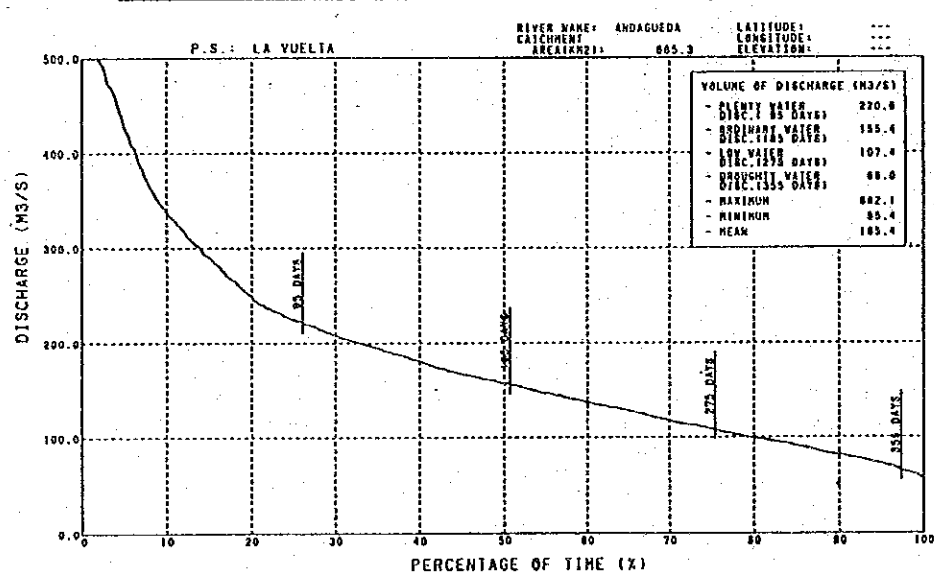
Data of Hydrological Gauging Station

No. of Station	1101 – 701
Name of Station	Aguasal
River	Andagueda
Management	HIMAT
Installation Year – Month	1976 05
Coordinates (Deg. – Min.)	
Latitude	0530
Longitude	7632
Above Sea Level s.n.m. (m)	75
Long River (km)	76
Catchment Area (km²)	1030.0
Water Shed (m)	1148
Observation Period	1977 – 1986

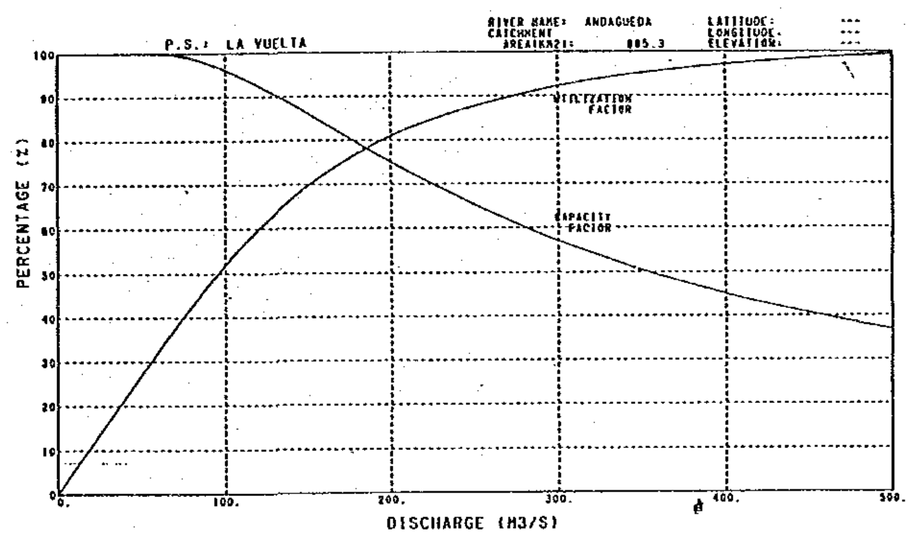
(2)
MONTHLY MEAN VALUE OF DAILY AVERAGE FLOW AT INTAKE SITE



(4)
TYPICAL FLOW DURATION CURVE AT INTAKE SITE



(5)
UTILIZATION & CAPACITY FACTOR



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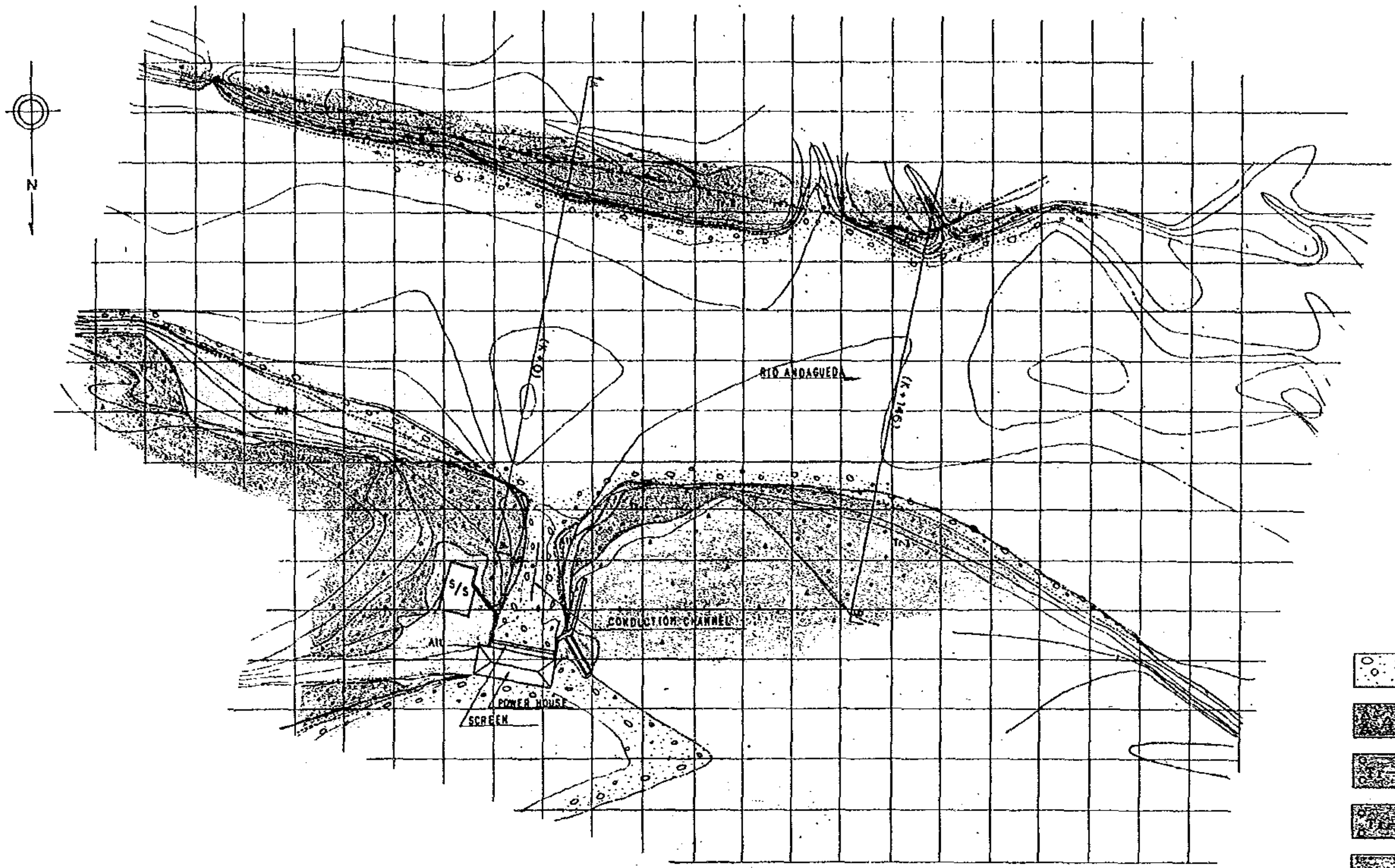
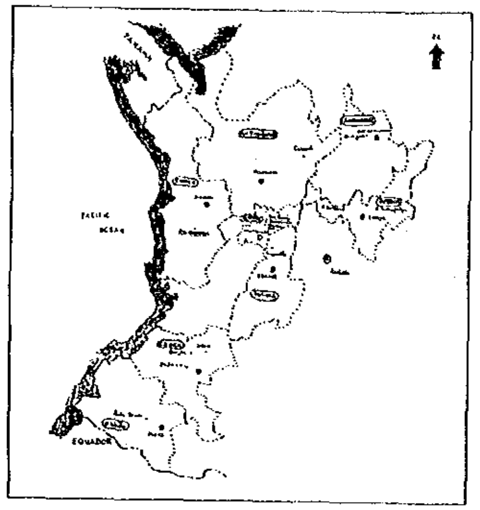
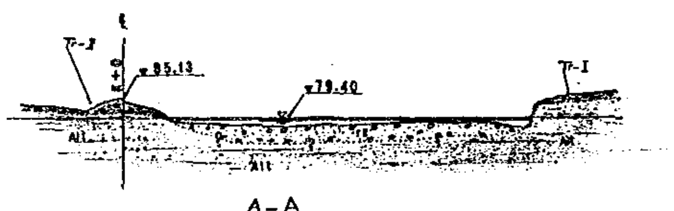
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
DURATION CURVES	
DRAWING NO.	LV – H – 01
SCALE ——	DATE



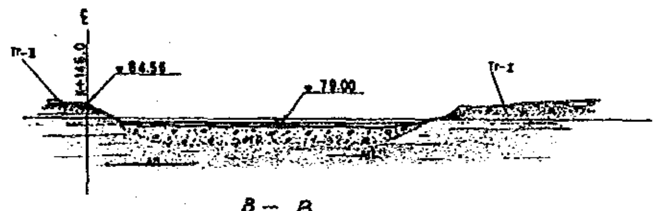


LEGEND

- River bed deposits
- Talus deposits
- Low terrace deposits
- High terrace deposits
- Alternation of sandstone and mudstone
- Geological boundary



A-A
(K + 0)



B - B
(K + 146.0)

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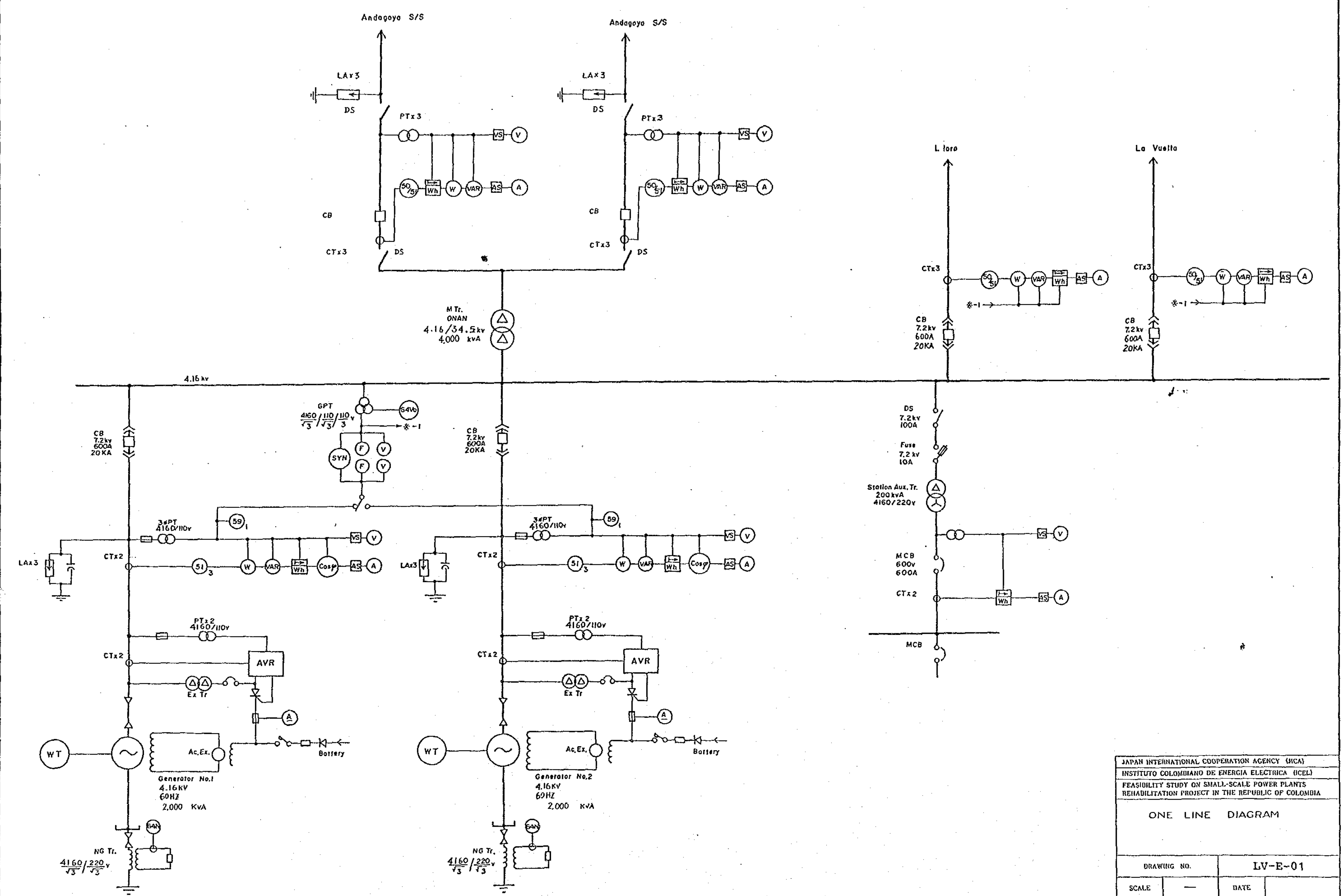
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA

Geological Plan and Profile
La Vuelta

DRAWING NO.		LV-G-01	
SCALE	1/2, 330	DATE	



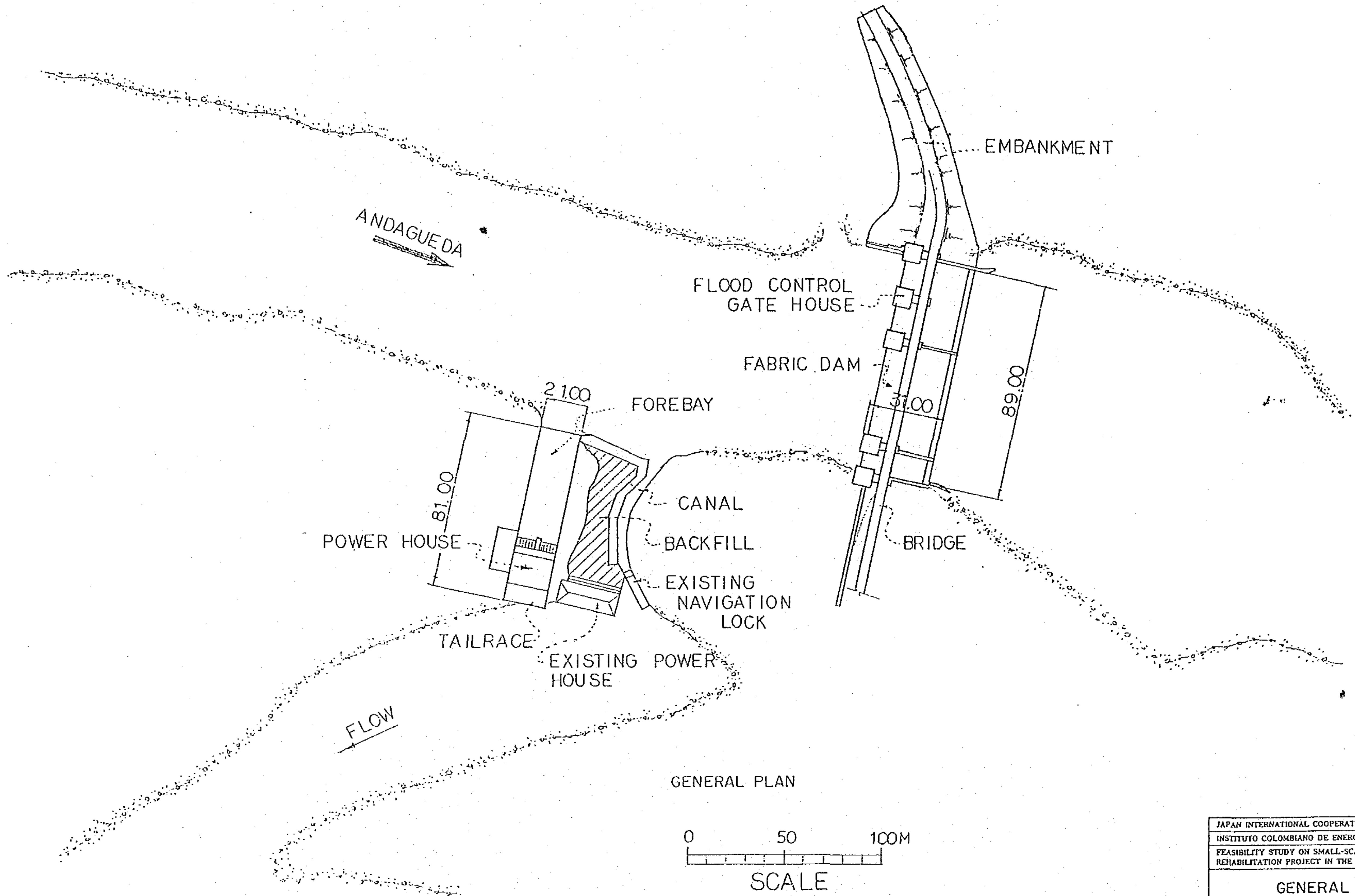
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)

FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA

ONE LINE DIAGRAM

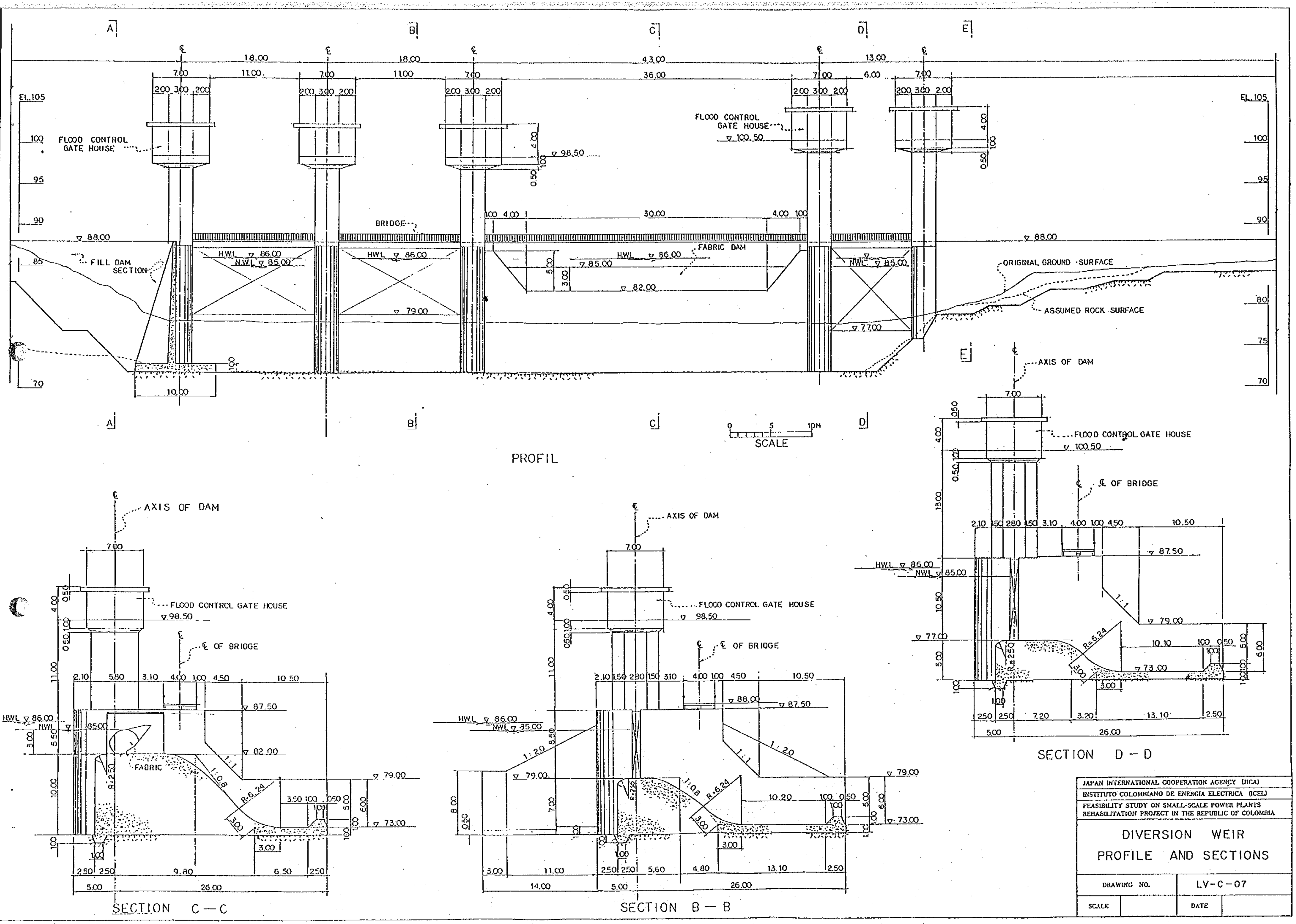
DRAWING NO.	LV-E-01		
SCALE	—	DATE	



GENERAL PLAN

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA
GENERAL PLAN (ALT-2)

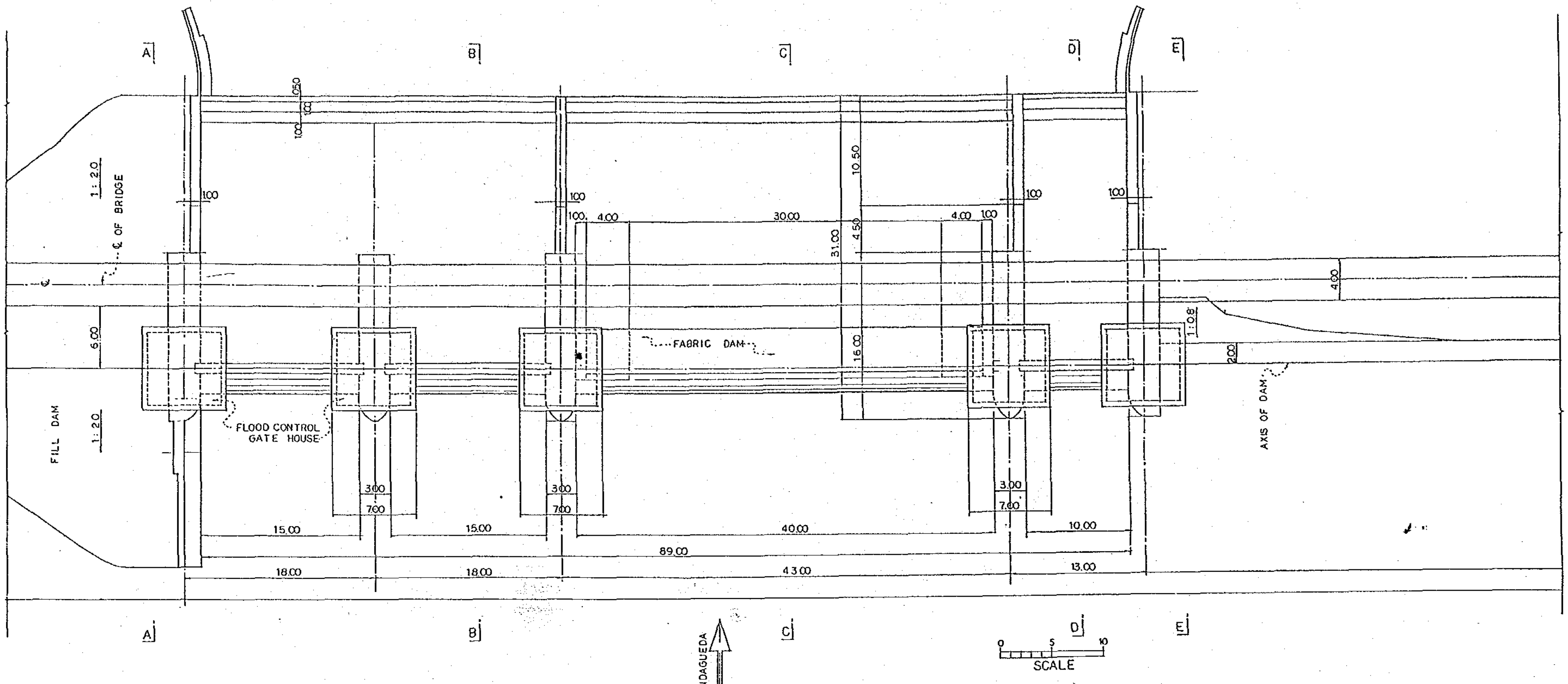
DRAWING NO.		LV-C-06	
SCALE		DATE	



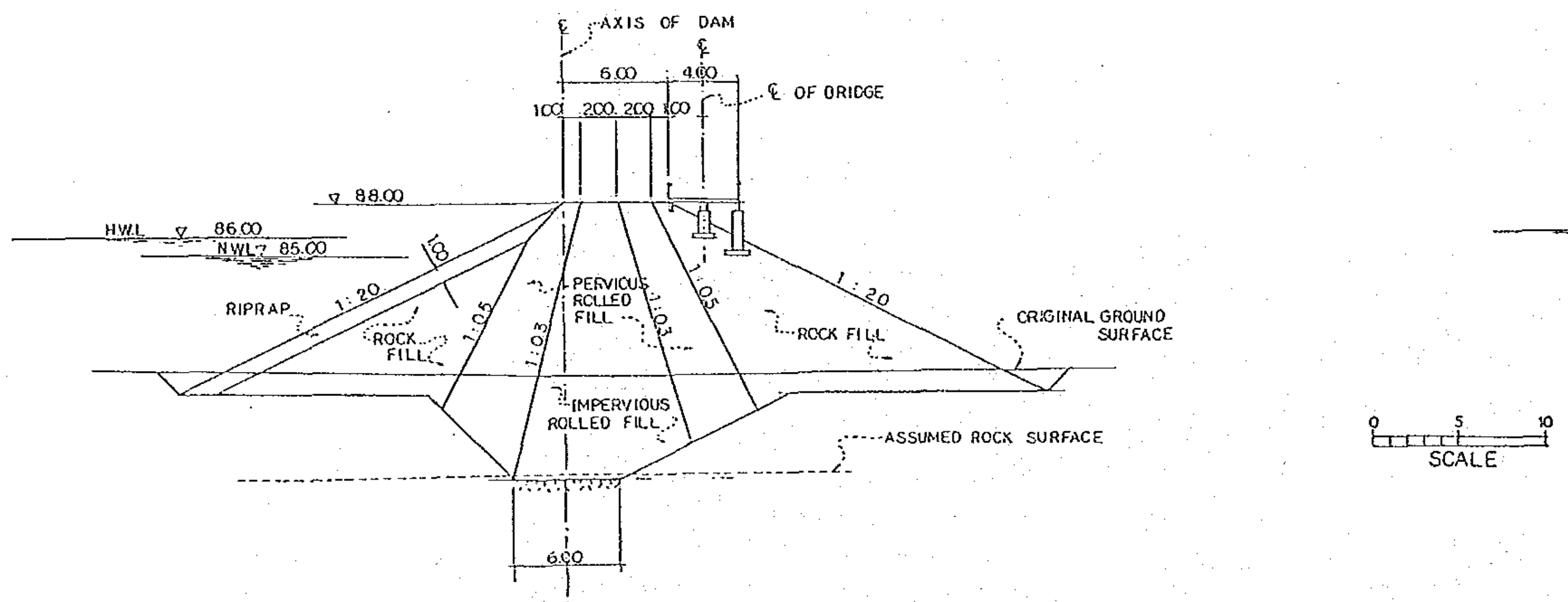
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA

DIVERSION WEIR
PROFILE AND SECTIONS

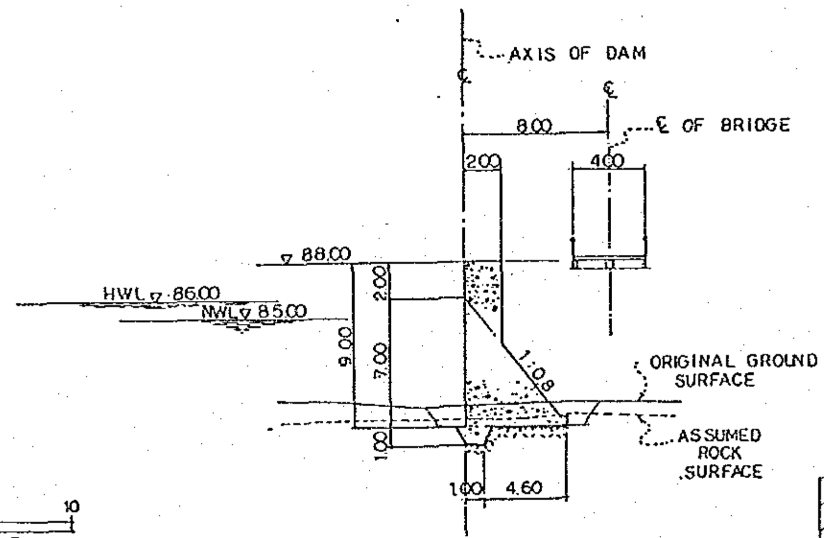
DRAWING NO.		LV-C-07	
SCALE		DATE	



PLAN



SECTION A – A



SECTION E – E

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)	
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA	
DIVERSION WEIR PLAN AND SECTIONS	
DRAWING NO.	LV-C-08
SCALE	DATE

Attached Data

1. Facility Register for the Existing Power Plant

2. Survey Record

①

Facility Register for the Existing Power Plant

Power Plant	La Vuelta
Electric Power Company	E. CHOCO
Location	La Vuelta/CHOCO
River	Andagueda
Generating Method	Run-of-River
Year Installed	1916
Years in Service	
Installed Capacity	2,000 kW
Available Capacity	500 kW

Civil	
Item	**Data**
1. Dam	
1) Type	Wooden
2) Height (m)	4.8
3) Crest length (m)	120
4) Height of overflowing crest (m)	no data available
5) Width of overflowing crest (m)	120
6) Depth of overflowing crest (m)	no data available
2. Intake Gate	
1) Type	Sluice
2) Number of gates	6
3) Dimensions (W x H)(m)	3.0 × 6.0
3. Intake	
1) Intake sill height (m)	no data available
2) Number of intake	2
3) Dimensions (W x H)(m)	12.0 × 6.0
4. Desilting Basin	
1) Dimensions (W x L x H)(m)	N/A
5. Sand Trap Gate	
1) Type	〃
2) Number of gates	〃
3) Dimensions (W x H)(m)	〃
6. Headrace	
1) Type	open channel
2) Dimensions (W x H)(m)	13.0 × 12.0
3) Length (m)	37

Civil	
Item	**Data**
7. Reservoir Tank 1) Dimensions (W x L x H)(m)	N/A
8. Forebay 1) Dimensions (W x H)(m)	no data available
9. Penstock 1) Number of lines	N/A
2) Penstock diameter (d)(m)	〃
3) Penstock length (L)(m)	〃
10. Tailrace 1) Dimensions (W x H)(m)	〃

Equipment		
Item	Data	
	#1	#2
1. Water Turbine		
1) Manufacturer's name		
2) Year manufactured	1915	1930
3) Type	Francis (v.axis)	Francis (v.axis)
4) Output (kW)	895.2	895.2
5) Revolution (rpm)	72	72
6) Ancillary equipment		
a) Type of governor	Woodward	Woodward
b) Inlet valve	Not existing	Not existing
- Type		
- Diameter (mm)		
2. Generator and Exciter		
1) Manufacturer's name	GE	GE
2) Year manufactured	1895	1895
3) Type	Synchro.	Synchro.
4) Capacity (kVA)	1,250	1,250
5) Power factor (%)	80	80
6) Voltage (V)	4,400	4,400
7) Frequency (Hz)	60	60
8) Revolution (rpm)	72	72
9) Method of neutral earthing	no data available	
10) Type of exciter		

Equipment		
Item	**Data**	
3. Transformer		
1) Manufacturer's name	GE	
2) Year manufactured	1895	
3) Type	Outdoor, ONAN	
4) Capacity (kVA)	833 x 3	
5) Primary voltage (kV)	4.4	
6) Secondary voltage (kV)	34.5	
7) Number of unit	1	
8) Vector-group symbol	Δ — Δ	
9) Impedance (%)	no data available	
10) Purpose for use	Step-up	
4. Circuit Breaker		
1) Manufacturer's name	no data available	
2) Year manufactured	〃	
3) Type	OCB	
4) Voltage (kV)	no data available	
5) Rated current (A)	〃	
6) Rupturing capacity (kA)	〃	
7) Purpose for use	〃	
5. Transmission Line		
1) Destination	Andagoya	Lloro
2) Length (m)	51,500	4,440
3) Voltage (kV)	3 3	4.4
4) Number of circuit	2	no data available
5) Number of pylons	218	〃
6) Size of conductors	2 AWG	#6
7) Materials of conductors	Copper	Copper

Equipment	
Item	**Data**
6. Battery	
1) Manufacturer's name	GE
2) Year manufactured	no data available
3) Capacity (AH/HR)	66 units x 40 Ah
4) DC voltage (V)	120
5) Type	no data available
7. Battery Charger	
1) Manufacturer's name	GE
2) Year manufactured	no data available
3) Capacity	0.95 kVA
4) Incoming voltage (V)	115
8. Overhead Crane	
1) Weight (ton)	35
2) Method of operation	motor
3) Span (m)	no data available

②

Survey Records

La Vuelta Hydroelectric Power Plant

(9)

I. RECORDS BY VISUAL INSPECTION AND HEARING SURVEY

Unit No.: 1

Type of Turbine: Francis

	Generating Facilities	Check item by visual inspection and hearing	Results
Francis Turbine	Casing	1) Existence of corrosion 2) Wear in thickness	1) No 2) There is no visible diminution.
		3) Presence of vibration	3) No vibration
	Runner	1) Existence of corrosion 2) Occurrence of porosity by sand pitting	1) No existence 2) No existence
	Shaft	1) Shaking of shaft axis	1) Yes, it presents shaking:
	Bearing	1) Oil shortage on bearing surface	1) with good condition
		2) Lack of oil viscosity	2) Yes, it exists by friction between surface
	Governor control	1) Control by belt-driven type 2) Speed detection device 3) Speed regulation system	1) No, hydraulic and manual control 2) Electric control 3) Electric control
		4) Installation of load limiter	4) Yes, manual
		5) Aoouracy of governor speed regulation	5) Regular

	Generating Facilities	Check item by visual inspection and hearing	Results
Francis Turbine	Oil pressure equipment	1) Existence of oil leakage 2) Application of oil pressure pumping system	1) Yes, regular (little) 2) Yes, it functions adequately.
	Inlet valve	1) Operation method 2) Locking condition 3) Smoothness of pressurized oil operation	1) 2) 3) There is no inlet valve. It is controlled by flood-gate.
	Guide vanes	1) Smoothness of control 2) Presence of water leakage from casing when guide vanes are closed 3) Break frequency of shear pins	1) Regular 2) Yes, there is water loss. The guide vanes are not closed. 3) It breaks very few.
	Sealing device	1) Sufficiency of water sealing for shaft 2) Sufficiency of packing for shaft seal	1) Regular 2) They are sufficient. (It functions without any problem.)

(11)

Unit No. 1

	Generating Facilities	Check item by visual inspection and hearing	Results
Generator	Rotor	1) Discoloration of winding surface due to heat 2) Existence of erosion for core 3) Fitness of between rotor and shaft	1) Yes, it has been discolored. 2) No existence 3) Normal
	Stator winding	1) Frequency of burning trouble or repair 2) Reduction of insulation resistance 3) Rust and erosion of core	1) It isn't frequent. 2) Yes, it has reduced. 3) No existence
	Bearing	1) Occurrence of deformation on metal surface 2) Lack of oil lubrication 3) Occurrence of temperature rise	1) Yes, the deformation exists. 2) Yes, it exists. 3) No.
	Exciter	1) Exchange frequency of brushes worn out 2) Sufficient stock of spare brush	1) 8 months 2) Yes, it is sufficient.
	Voltage regulator	1) Operation method of voltage regulator 2) Response of voltage detection for load variation	1) Electric (rheostat) 2) It responds slowly.

Unit No.: 2

Type of Turbine: Francis

	Generating Facilities	Check item by visual inspection and hearing	Results
Francis Turbine	Casing	1) Existence of corrosion	1) It doesn't present.
		2) Wear in thickness	2) There is no visible diminution.
		3) Presence of vibration	3) Yes, there is vibration
	Runner	1) Existence of corrosion	1) Yes
		2) Occurrence of porosity by sand pitting	2) It is not by sand. Friction of axle bearing.
	Shaft	1) Shaking of shaft axis	1) Sufficient stressed with bad axle bearing.
	Bearing	1) Oil shortage on bearing surface	1) The problems don't exist in the upper axle bearing. There is in below part.
		2) Lack of oil viscosity	2) Yes, it exists. The oil is changed each 15 days.
	Governor control	1) Control by belt-driven type	1) No, hydraulic and manual control
		2) Speed detection device	2) Electric motor
		3) Speed regulation system	3) Electric motor
		4) Installation of load limiter	4) Manual
		5) Aocuracy of governor speed regulation	5) Regular

(3)

Generating Facilities		Check item by visual inspection and hearing	Results
Francis Turbine	Oil pressure equipment	1) Existence of oil leakage 2) Application of oil pressure pumping system	1) Yes, it exists. 2) Yes, it functions adequately.
	Inlet valve	1) Operation method 2) Locking condition 3) Smoothness of pressurized oil operation	1) 2) 3) } There is no inlet valve. It is adjusted with flood-gate.
	Guide vanes	1) Smoothness of control 2) Presence of water leakage from casing when guide vanes are closed 3) Break frequency of shear pins	1) Regular 2) Yes, it exists. 3) Very little
	Sealing device	1) Sufficiency of water sealing for shaft 2) Sufficiency of packing for shaft seal	1) It is sufficient. 2) It is sufficient.

Unit No. 2

	Generating Facilities	Check item by visual inspection and hearing	Results
Generator	Rotor	1) Discoloration of winding surface due to heat	1) Yes, it is discolored.
		2) Existence of erosion for core	2) Yes, it is moderate.
		3) Fitness of between rotor and shaft	3) Normal
	Stator winding	1) Frequency of burning trouble or repair	1) It is not frequent (only one time)
		2) Reduction of insulation resistance	2) Yes, it is reduced.
		3) Rust and erosion of core	3) Normal
	Bearing	1) Occurrence of deformation on metal surface	1) Yes, it exists.
		2) Lack of oil lubrication	2) Yes, it exists.
		3) Occurrence of temperature rise	3) No
	Exciter	1) Exchange frequency of brushes worn out	1) 8 months
		2) Sufficient stock of spare brush	2) Yes, it is sufficient.
	Voltage regulator	1) Operation method of voltage regulator	1) Electric (rheostat)
		2) Response of voltage detection for load variation	2) Slowly

(15)

Generating Facilities		Check item by visual inspection and hearing	Results
Control Board	Metering equipment	1) Sufficiency of accuracy for instruments 2) Lack of necessary instruments 3) Items constantly recorded	1) No, it is bad accuracy. 2) It is completed, but it is regular condition. 3) MW, VAR, A, F, PF, Temp.
	Pretection equipment	1) Lack of relays to be installed 2) Operation method in case of accident in transmission lines	1) No 2) Electric and manual
	Remote control equipment	1) Control method for turbine and generator operation 2) Control method for voltage and speed control 3) Operation method of synchronized switching	1) Automatic 2) Automatic hydraulic governor and electric for exciter 3) Manual with synchroscope
	Power system	1) Power supply voltage (kV) after rehabilitation work	1) ——

Generating Facilities		Check item by visual inspection and hearing	Results
Indoor Switchgear	Insulation level	1) Sufficiency of insulation level 2) Unification of insulation level 3) Reduction of insulation registance	1) Yes 2) Yes 3) Yes, it is sufficient.
	Accessibility and Safety	1) Accessibility to high voltage devices 2) Sufficiency of protection for high voltage cable terminals 3) Method and reliability of operation for synchronizing circuit breaker	1) All are closed and screened. 2) Sufficient 3) Good and trustworthy

(2)

Generating Facilities		Check item by visual inspection and hearing	Results
Outdoor Equipment	Transformer	1) Presence of over load operation	1) No
	Circuit breaker	1) Situation of tripfor outgoing feeder breaker in case of accident on transmission line 2) Fitness of maintenance in case of oil circuit breaker	1) Electric with batteries and manual, in bad condition. 2) Annual
	Line switch	1) Operation method 2) Reliability of operation	1) Electric and manual 2) Regular
	Insulator	1) Presence of damage and dusts	1) Yes, the dust exists, no damage
	Structural steel	1) Occurence of erosion due to rust 2) Presence of injury	1) No 2) No
	Line protection	1) Existence of adequate protection relays to connect to RED	1) No, it doesn't useful.

(19)

Unit No.: 1 and 2

Installed Capacity of Generator: ________ KVA

Type of Turbine: ________

YEAR		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL TOTAL	REMARKS
1983	MWH														
	OPE. TIME														
1984	MWH														
	OPE. TIME														
1985	MWH	464.804	469.025	531.814	541.551	512.835	434.678	526.773	*565.006	*565.006	555.561	*565.006	565.006	6,297.065	
	OPE. TIME	720	672	720	720	720	720	744	*744	*744	744	*744	744	8,736	
1986	MWH	495.412								676.589	673.445	518.793			
	OPE. TIME	744								720	744	720			
1987	MWH														
	OPE. TIME														
1988	MWH														
	OPE. TIME														

(Note) 1. MWH : Gross

2. OPE. TIME : Hour

3. * : These data are estimated by JICA F/S Team, because these data were not given.

III. REPAIR RECORDS

No.	Study Item	Results
	The past records concerning the following items shall be obtained to evaluate reliability of generating facilities.	*Without available information*
	1) Repaired locations and method for repairing	
	2) Causes for damage/defect	
	3) Duration of repairing and power supply stoppage	
	4) Repaired by;	
	a) staff in Power Plant	
	b) manufacturer	
	c) other	
	5) Repair cost	
	6) Operation life after the completion of repairing work	

IV. SITUATION OF STOCK SPARE PARTS

No.	Study Item	Results
	Data on the situation of stock spare parts shall be obtained to evaluate maintainability of generating facilities.	without available information

V. E. CHOCO's INTENTION FOR REHABILITATION

No.	Study Item	Leaving as it is	Repair work	Replacement	Notes
	Mark with √ in pertinent columns.				
	- Inlet valve	√			1
	- Turbine, governor, auxiliary equipment			√	2
	- Generator, exciter			√	2
	- Control panel			√	2
	- Switchgear			√	2
	- Transformer			√	2
	- Substation equipment (Circuit breaker, Isolator, etc.)			√	2
	- Transmission tower, conductor and insulator	√			3
	- Power House			√	4

(Notes)
1. The system doesn't exist.
2. Old equipment
3. In good condition
4. Completely old construction