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 are 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 (%)
Municipal ALT-1	0.89	230	8.8
Municipal ALT-2	0.86	366	9.2
Intermedia	1.37	- 538	4.6
San Cancio	1.40	- 491	4.6

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

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 2002, with a projected aggregate profit of US$2,714,000 at the end of service life.

Table - 10.2 PROJECTED FINANCIAL STATEMENTS

(1) PROJECTED REVENUE AND EXPENDITURE STATEMENT (at 1989 Price)
== Municipal : ALT-2 ==

Year	Year in Order	(A) Total Operating Revenue	(B) Operating Expenditure (US$:1000) O/M Cost	Depreci-ation	Interest on Investment	Total	(C) Net Benefit (A)-(B)
1989	-6	83.5	5.6	0.0	0.0	5.6	77.9
1990	-5	83.5	5.6	0.0	0.0	5.6	77.9
1991	-4	83.5	5.6	0.0	0.0	5.6	77.9
1992	-3	83.5	5.6	0.0	11.8	17.4	66.1
1993	-2	83.5	5.6	0.0	23.6	29.2	54.2
1994	-1	83.5	5.6	0.0	29.6	35.2	48.3
1995	0	56.7	5.6	0.0	128.2	133.8	-77.1
1996	1	56.7	5.6	132.5	390.4	528.5	-471.8
1997	2	454.6	18.0	132.5	576.8	727.3	-272.7
1998	3	454.6	18.0	132.5	530.8	681.3	-226.7
1999	4	454.6	18.0	132.5	472.6	623.1	-168.5
2000	5	454.6	18.0	132.5	414.4	564.9	-110.3
2001	6	454.6	18.0	132.5	356.3	506.7	-52.1
2002	7	454.6	18.0	132.5	206.0	356.4	98.1
2003	8	454.6	18.0	132.5	193.9	344.3	110.3
2004	9	454.6	18.0	132.5	181.7	332.2	122.4
2005	10	454.6	18.0	132.5	169.6	320.1	134.5
2006	11	454.6	18.0	132.5	157.5	308.0	146.6
2007	12	454.6	18.0	132.5	145.4	295.9	158.7
2008	13	454.6	18.0	132.5	133.3	283.8	170.8
2009	14	454.6	18.0	132.5	121.2	271.6	183.0
2010	15	454.6	18.0	132.5	109.0	259.5	195.1
2011	16	454.6	18.0	132.5	96.9	247.4	207.2
2012	17	454.6	18.0	132.5	84.8	235.3	219.3
2013	18	454.6	18.0	132.5	72.7	223.2	231.4
2014	19	454.6	18.0	132.5	60.6	211.1	243.5
2015	20	454.6	18.0	132.5	48.5	198.9	255.7
2016	21	454.6	18.0	132.5	36.3	186.8	267.8
2017	22	454.6	18.0	132.5	24.2	174.7	279.9
2018	23	454.6	18.0	132.5	12.1	162.6	292.0
2019	24	454.6	18.0	132.5	0.0	150.5	304.1
2020	25	454.6	18.0	132.5	0.0	150.5	304.1
TOTAL		11274.1				8560.2	2713.9
						C/B:	0.76

(2) PROJECTED FUNDS FLOW STATEMENT (Constant Price at 1989)
== Municipal : ALT-2 ==

Year	Year in Order	(A) Source: Benefit before Interest	Depreci-ation	Balance Brought Forward	Long/Short Term Borrowing	Total	(B) Application (US$:1000): Construc-tion Progress	Debt Service: Interest	Debt Service: Principal	Total	Cash Balance (A)-(B)
1989	-6	77.9	0.0		0.0	77.9	0.0	0.0	0.0	0.0	77.9
1990	-5	77.9	0.0		0.0	77.9	0.0	0.0	0.0	0.0	77.9
1991	-4	77.9	0.0		118.2	196.1	118.2	0.0	0.0	118.2	77.9
1992	-3	77.9	0.0		118.2	196.1	118.2	11.8	0.0	130.1	66.1
1993	-2	77.9	0.0		59.1	137.0	59.1	23.6	0.0	82.8	54.2
1994	-1	77.9	0.0		587.3	665.2	587.3	29.6	0.0	616.8	48.3
1995	0	51.1	0.0		1778.7	1829.8	1778.7	128.2	0.0	1906.9	-77.1
1996	1	-81.4	132.5		1418.0	1469.0	1418.0	390.4	219.3	2027.6	-558.6
1997	2	304.1	132.5			436.6		576.8	219.3	796.2	-359.6
1998	3	304.1	132.5			436.6		530.8	340.5	871.3	-434.7
1999	4	304.1	132.5			436.6		472.6	340.5	813.1	-376.5
2000	5	304.1	132.5			436.6		414.4	340.5	754.9	-318.3
2001	6	304.1	132.5			436.6		356.3	340.5	696.7	-260.1
2002	7	304.1	132.5			436.6		206.0	340.5	546.4	-109.9
2003	8	304.1	132.5			436.6		193.9	121.2	315.0	121.6
2004	9	304.1	132.5	121.6		558.2		181.7	121.2	302.9	255.3
2005	10	304.1	132.5	255.3		691.9		169.6	121.2	290.8	401.1
2006	11	304.1	132.5	401.1		837.7		157.5	121.2	278.7	559.0
2007	12	304.1	132.5	559.0		995.6		145.4	121.2	266.6	729.0
2008	13	304.1	132.5	729.0		1165.6		133.3	121.2	254.4	911.2
2009	14	304.1	132.5	911.2		1347.8		121.2	121.2	242.3	1105.5
2010	15	304.1	132.5	1105.5		1542.1		109.0	121.2	230.2	1311.9
2011	16	304.1	132.5	1311.9		1748.5		96.9	121.2	218.1	1530.4
2012	17	304.1	132.5	1530.4		1967.0		84.8	121.2	206.0	1761.0
2013	18	304.1	132.5	1761.0		2197.6		72.7	121.2	193.9	2003.7
2014	19	304.1	132.5	2003.7		2440.3		60.6	121.2	181.7	2258.6
2015	20	304.1	132.5	2258.6		2695.2		48.5	121.2	169.6	2525.6
2016	21	304.1	132.5	2525.6		2962.1		36.3	121.2	157.5	2804.6
2017	22	304.1	132.5	2804.6		3241.2		24.2	121.2	145.4	3095.8
2018	23	304.1	132.5	3095.8		3532.4		12.1	121.2	133.3	3399.2
2019	24	304.1	132.5	3399.2		3835.7		0.0	0.0	0.0	3835.7
2020	25	304.1	132.5	3835.7		4272.3		0.0	0.0	0.0	4272.3

CHAPTER 11 BASIC DESIGN

11.1 Facilities Design

11.1.1 Design Standards of Civil Structures

The following standards shall apply to the design of facilities.

(1) The diversion weir, less than 15 m wide, is at the concrete gravity dam. The design flood discharge, with no gate, can safely flow over the overflow crest.

(2) A sandtrap will be constructed between the intake and the diversion weir. The width of the sandtrap water channels is in line with the need to remove all sediment. As such, a CAT D4C bulldozer (width 1.83 m and weight 6.85 tons) could enter and leave the channel.

(3) The intake will be designed to take water at a right angle from the river and a screen will be installed at the entrance. The flow rate at the screen is 0.6 - 1.0 m/s.

(4) The desilting basin has a capacity to remove all particles greater than 0.075 mm in size.

(5) The free board of the water channels (open channels) is 0.3 m.

(6) The size of the head tank is designed to be equivalent to a 2-minute capacity of the designed flow.

11.1.2 Design of Improvement for the Main Structure

(1) San Cancio Power Plant

(a) Intake equipment

The specifications for the new intake facilities to be built downstream from the existing ones are shown below.

Weir type	Gravity type concrete dam
Height of overflowing crest	1,912.1 m
Height of weir	4.9 m
Length of overflowing crest	20.0 m
Design flood	230 m^3/s
Height of head water (when design flood rate flows)	3.4 m
Width of sand trap	2.5 m
Dimensions of entrance at the intake	3.0 x 2.5 m
Intake water level	1,912.06 m

(b) Conduction channels

An investigation will be conducted into the through capacity of the water channels in irregular flows, which depends on channel cross-section and the gradient.

i) Equation

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

$$i.\Delta x - \Delta H = \alpha . Q^2/2.g \times (1/A_1^2 - 1/A_2^2 + n^2.Q^2/2 \times (1/R_1^{4/3} A_1^2 + 1/R_2^{4/3} A_2^2)\ \Delta x \qquad (2)$$

where:

α = correction coefficient for velocity distribution

i = bed gradient

H = depth of flow (m)

A = cross-sectional area (m^2)

(1) : top end cross-section

(2) : bottom end cross-section

R = hydraulic radius

(1) : top end cross-section

(2) : bottom end cross-section

Q = discharge (m^3/s)

n = coefficient of roughness

Assuming 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.

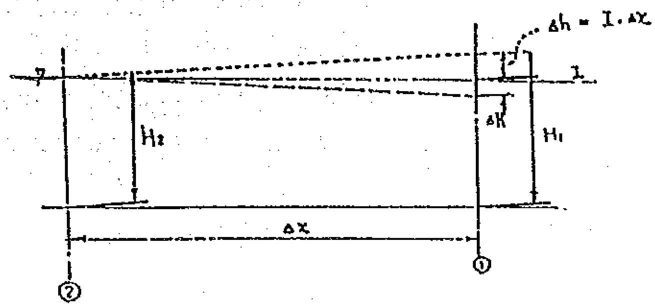


Fig. 11.1 Non-uniform Flow

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.

In the case of angled flow the calculation proceeds from the top end to the bottom end.

ii) 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.

iii) 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.

iv) Height of spare capacity

Since the water is constantly varying, the water channels will be constructed with spare height for safety reasons. The initial height of this is 0.30 m.

v) Result of calculation

Fig. 11.2 shows the relation of water level and channel, based on the vertical and cross section of the conduction channel measured by CHEC.

According to the result of calculation, the design discharge (5.6 m^3/s) of water cannot flow through the 900 m-long part of about 2,400 m-long conduction channel. Judging from the condition of field reconnaissance survey, however, the values measured in the 900 m-long part are considered false.

vi) Conclusion

Covers are placed on the places where covers have not been provided yet.

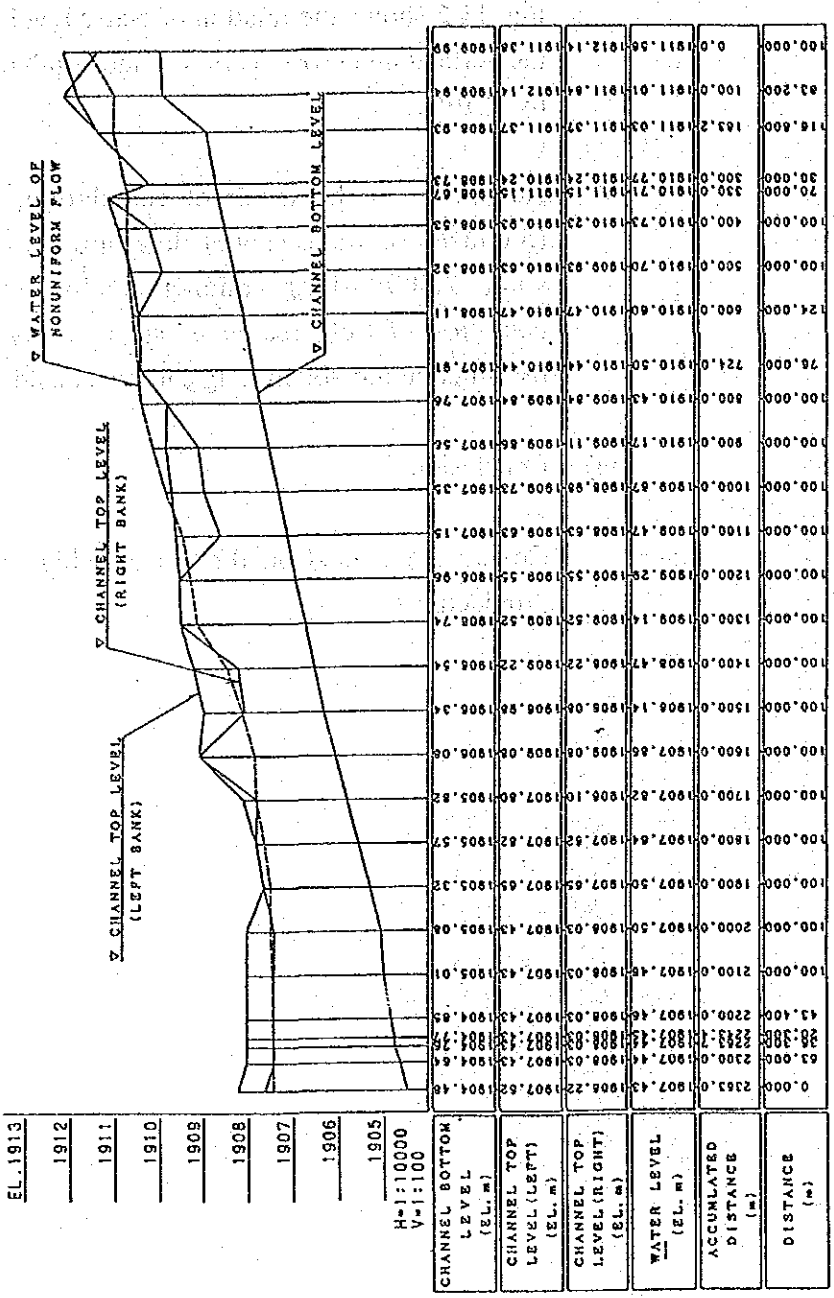


Fig. 11.2 Relation of Water Level and Channel

(c) Desilting basin

i) 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^2/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.

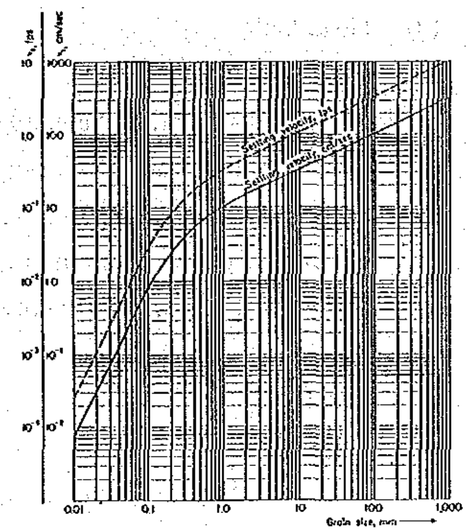


Fig. 11.3 Grain Diameter and Settling Velocity

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

ii) Shape

The shape of the desilting basin is calculated from the following:

$$L = h/V \times B \times C$$

where:

L = length of desilting basin (m)
h = settling depth in desilting basin (m)
V = sediment settling velocity (m/s)
B = average flow speed in desilting basin (m/s)
C = coefficient

The desilting basin No. 1 is divided into two sections, which are used in turn. The basin No. 1 will be improved to allow both sections to be simultaneously used. The basin No. 2 will be used without any rehabilitation.

(d) Head tank

The effective storage capacity of the existing head tank corresponds to the discharge for about 60 seconds. This indicates the current capacity does not satisfy the requirement. Accordingly, the head tank will be expanded horizontally toward the mountain side and will be partially reconstructed to ensure the required capacity.

(e) Penstock

The existing penstock is in good condition and will be used without any rehabilitation.

(f) Powerhouse

The foundation for the turbine and generator will be partially removed and reconstructed to replace it. The existing powerhouse will be used without any rehabilitation.

(2) Intermedia power plant

(a) Conduction channel

The conduction channel (3,400 m in length) was constructed only by excavating the ground, except the box culvert area near the Pan American Highway.

The channel except the box culvert area will be lined with concrete and concrete covers will be placed there.

A conduction channel which may maintain the water levels at the intake (at the San Cancio tailrace), at the existing culvert area and at the head tank should have the longitudinal gradient and the cross section shown below.

Section	Length (m)	Longitudinal gradient (‰)	Cross section (W x H)
San Cancio to box culvert start point	1,800	1.9	2.1 x 1.5 m
Box culvert area	117	4.5	Already installed
Box culvert end point to head tank	1,223	1.3	2.2 x 1.6 m

(b) Head tank and desilting basin

The head tank and the desilting basin were constructed in series, and the capacity of the head tank does not meet the requirement completely.

In the rehabilitation plan, the function of the desilting basin in the San Cancio P/P will be improved, and covers will be placed on its conduction channel. This will prevent earth and sand from flowing into the water channel in the Intermedia P/P, located downstream from the San Cancio desilting basin. As a result, a desilting basin basically does not need to be provided in the Intermedia P/P. Accordingly, the desilting basin will be only partially reconstructed to increase the head tank capacity.

(c) Penstock

Since the existing penstock is in good condition because of adequate maintenance, it will be used as it is, except that it will be constructed to branch off near the powerhouse because this power plant will have two generating equipment after the rehabilitation.

(d) Powerhouse

The existing powerhouse was built to contain one unit of generating equipment, and has been in good condition. However, two generating equipment will be provided after the rehabilitation and the powerhouse does not have space enough to contain two units. Accordingly, it is necessary to build the battery and utility rooms on the west of the powerhouse to clear the above problem.

In addition, the foundation for the generating equipment must be reconstructed to replace it.

(3) Municipal power plant

(a) Intake facilities

Sand trap facilities (2.5 m in width) will be built on the right bank of the diversion weir (25.3 m in crest length), and the top of the crest will be raised from 1,780.635 m to 1,780.95 m.

The intake will be used without any rehabilitation, but the gate and the screen will be replaced.

(b) Desilting basin

As the intake water level is raised, the water level on the side wall of the head tank will be raised by 50 cm. Four obsolete gates will be replaced.

(c) Conduction channel

Judging from the relation of water level and channel obtained in the same manner as in the San Cancio, the height of the whole channel wall must be raised by 50 cm to enable 7.0 m^3/s of water to flow. (Refer to Fig. 11.4.)

Concrete covers will be placed on the full length of channel.

(d) Head tank

As mentioned before, the effective storage capacity of the head tank corresponds to the discharge for about 20 seconds, which is much smaller than the targeted value, 120 seconds. And this value is not enough especially after the water level of the head tank is raised because of increase of the intake water level. Accordingly an overall reconstruction is required.

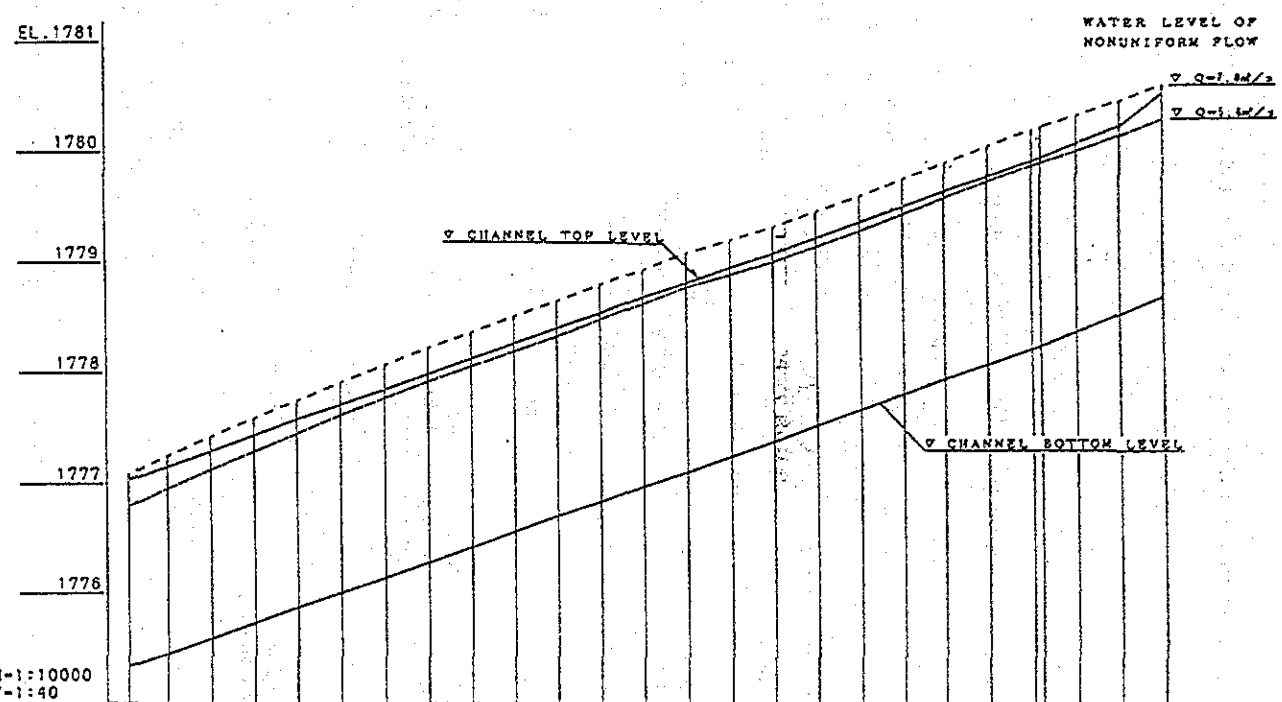
Since it is difficult to horizontally enlarge the head tank because of the geological restrictions, the head tank will be reconstructed to increase its depth.

(e) Penstock

The existing penstock is in good condition because of adequate maintenance and it will be used without any rehabilitation.

(f) Powerhouse building

Since the powerhouse has enough space and remains in good condition, it will be used without any rehabilitation, except that the foundation for the generating equipment will be reconstructed for the equipment replacement.



CHANNEL BOTTOM LEVEL (EL. m)	CHANNEL TOP LEVEL (LEFT) (EL. m)	CHANNEL TOP LEVEL (RIGHT) (EL. m)	WATER LEVEL Q=5.5m³/s (EL. m)	WATER LEVEL Q=7.8m³/s (EL. m)	ACCUMLATED DISTANCE (m)	DISTANCE (m)
1775.34	1777.04	1777.04	1776.79	1777.09	2390.0	0.000
1775.46	1777.16	1777.16	1776.96	1777.26	2300.0	90.000
1775.60	1777.30	1777.30	1777.13	1777.43	2200.0	100.000
1775.74	1777.44	1777.44	1777.30	1777.59	2100.0	100.000
1775.88	1777.58	1777.58	1777.45	1777.75	2000.0	100.000
1776.01	1777.71	1777.71	1777.62	1777.91	1900.0	100.000
1776.15	1777.85	1777.85	1777.77	1778.07	1800.0	100.000
1776.29	1777.99	1777.99	1777.92	1778.23	1700.0	100.000
1776.43	1778.13	1778.13	1778.06	1778.37	1600.0	100.000
1776.57	1778.27	1778.27	1778.20	1778.51	1500.0	100.000
1776.71	1778.41	1778.41	1778.33	1778.64	1400.0	100.000
1776.84	1778.54	1778.54	1778.46	1778.80	1300.0	100.000
1776.99	1778.69	1778.69	1778.63	1778.94	1200.0	100.000
1777.12	1778.82	1778.82	1778.76	1779.10	1100.0	100.000
1777.26	1778.96	1778.96	1778.90	1779.21	1000.0	100.000
1777.39	1779.09	1779.09	1779.01	1779.33	900.0	100.000
1777.53	1779.23	1779.23	1779.15	1779.47	800.0	100.000
1777.67	1779.37	1779.37	1779.29	1779.61	700.0	100.000
1777.81	1779.51	1779.51	1779.44	1779.75	600.0	100.000
1777.95	1779.65	1779.65	1779.59	1779.90	500.0	100.000
1778.08	1779.78	1779.78	1779.73	1780.05	400.0	100.000
1778.22	1779.92	1779.92	1779.88	1780.20	300.0	100.000
1778.36	1780.06	1780.06	1780.01	1780.33	200.0	80.000
1778.53	1780.23	1780.23	1780.15	1780.47	100.0	100.000
1778.69	1780.54	1780.54	1780.30	1780.62	0.0	100.000

Fig. 11.4 Relation of Water Level and Channel

11.1.3 Gate and Valve Specifications and Types

The gates and valves used in the three power plants are described in Table 11.2 through Table 11.4.

(1) San Cancio

Table 11.2 Summary of Gate and Valve Types

	Regulating gate	Sand-flush gate	Screen	Sand-flush gate	Regulating gate	Screen	Sand-flush gate
Use	Water intake	Sand trap sand removal	Silt removal	Desilting basin sand removal	Penstock	Head tank sand removal	Head tank
Type	Steel, sluice gate	Wooden, sluice gate	Fixed type	Steel, sluice gate	Steel, sluice gate	Fixed type	Wooden, sluice gate
Width x height	1.9x2.3m	2.9x2.3m	3.0x3.0m	1.4x1.4m	1.4x1.4m	2x1.5m	1.0x1.0m
Design depth	10 m	11 m	-	5 m	5 m	-	5 m
Stopwater method	Reverse 4 direct.	Reverse 4 direct.	Rack spacing: 100 mm	Reverse 4 direct.	Reverse 4 direct.	Rack spacing: 100 mm	Reverse 4 direct.
Starting method	Spindle	Spindle		Spindle	Spindle		Spindle
*Hoisting device	Engine or manual	Engine or manual		Manual	Engine or manual		Manual
Lifting speed	0.1 m/min.	-	Gradient 1:0.3	-	0.1 m/min.	Gradient 1:0.3	-
Lifting torque	10 kg	-		-	10kg		-

* The hoisting device shall also be used as the sand-flush gate.

(2) Intermedia

Table 11.3 Summary of Gate and Valve Types

	Sand-flush gate	Regulating gate	Screen	Sand-flush gate
Use	Desilting basin sand removal	Head tank	Head tank sand removal	Head tank
Type	Steel, sluice gate	Steel, sluice gate	Fixed type	Wooden, sluice gate
Width x height	1.6 x 1.6m	1.6 x 1.6m	4 x 4.5m	1.4 x 1.4m
Design depth	5 m	5 m	-	5 m
Stopwater method	Reverse 4 direct.	Reverse 4 direct.	Rack spacing; 100 mm	Reverse 4 direct.
Starting method	Spindle	Spindle		Spindle
Hoisting device*	Manual	Engine or manual		Manual
Lifting speed	0.1 m/min.	0.1 m/min.	Gradient 1:0.3	-
Lifting torque	10 kg	10 kg		-

* The hoisting device shall also be used as the sand-flush gate.

(3) Municipal

Table 11.4 Summary of Gate and Valve Types

	Regulating gate	Sand-flush gate	Screen	Sand-flush gate	Regulating gate	Screen	Sand-flush gate
Use	Water intake (2 gates)	Sand trap sand removal	Silt removal (2 gates)	Desilting basin sand removal	Penstock	Head tank sand removal	Head tank
Type	Steel, sluice gate	Wooden, sluice gate	Fixed type	Steel, sluice gate	Steel, sluice gate	Fixed type	Wooden, sluice gate
Width x height	2.0x1.5m	2.9x2.3m	5.4x2.8m	1.2x1.2m	2.5x2.5m	10x4.0m	3.0x2.5m
Design depth	10 m	11 m	-	5 m	5 m	-	5 m
Stopwater method	Reverse 4 direct.	Reverse 4 direct.	Rack spacing	Reverse 4 direct.	Reverse 4 direct.	Rack spacing	Reverse 4 direct.
Starting method	Spindle	Spindle		Spindle	Spindle		Spindle
Hoisting device *	Engine or manual	Engine or manual		Manual	Engine or manual		Manual
Lifting speed	0.1 m/min.	-	Gradient 1:0.3	-	0.1 m/min.	Gradient 1:0.3	-
Lifting torque	10 kg	-		-	10kg		-

* The hoisting device shall also be used as the sand-flush gate.

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

There are two water turbines and generators since water turbines and generators can be inspected and repaired alternately and since the generating equipment is stopped revenue is reduced.

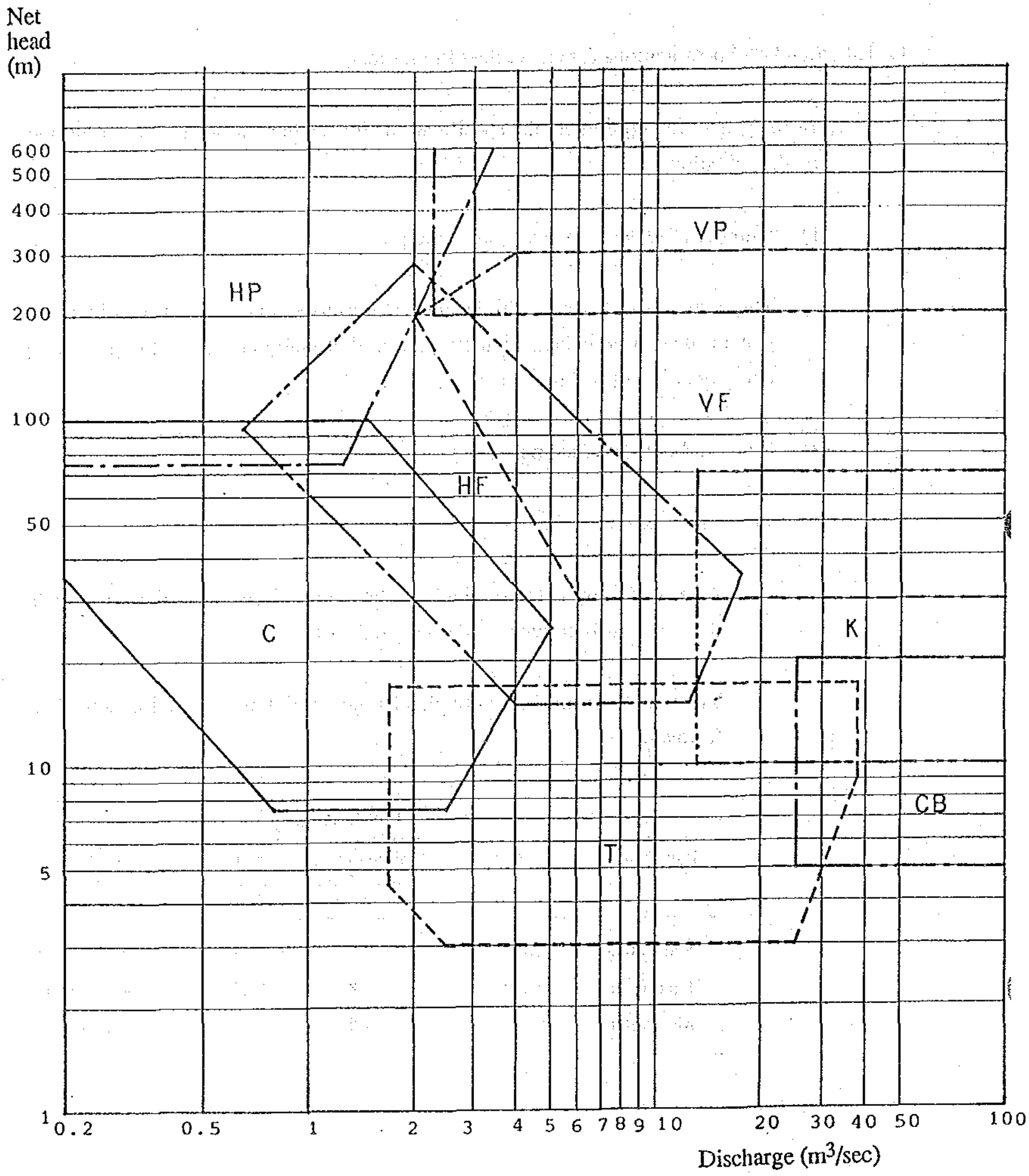
(2) Water turbine specifications

1) Machine type

After deciding on the turbine's net head and discharge at the project site, the water turbine type can be selected from Fig. 11.5.

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

Power plant	Plan	Rehabilitation plan		Chosen machine type
		Discharge per water turb. (m^3/s)	Net head (m)	
San Cancio	REH	2.8	53.8	horiz. Francis
Intermedia	REH	2.8	56.8	horiz. Francis
Municipal	ALT- 2	3.5	*79.6*	*horiz. Francis*



KEY

Fig. 11.5 Turbine Type Selection Table

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)

2) Output

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

Power plant	Plan	Rehabilitation plan		Water turb. estimated efficiency η_T	Water turb. output P_T (kW)
		Discharge per water turb. Q (m^3/s)	Net head H (m)		
San Cancio	REH	2.8	56.8	0.874	1,360
Intermedia	REH	2.8	56.8	0.874	1,360
Municipal	ALT-2	3.5	79.6	0.879	2,400

The water turbine output (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 determined from the following.

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

$$Ns \leqq \frac{20,000}{He+20} + 30 \text{ (m-kW)} \quad \text{.............................} \quad (1)$$

where H is the net head (m).

The number of revolutions N is shown in the following equation.

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

where N_S is the specific speed taken from eq. (1)
H is the net head (m)
P_T is the water turbine output (kW)

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

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

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 less than 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 of rehabilitation generating plan are shown in the following table.

Power plant	Plan	Net head, H (m)	Turbine output, P (kW)	Number of poles	Specific speed, Ns (m-kW)	Number of revolution N (rpm)
San Cancio	REH	56.8	1,360	6	284	1,200
Intermedia	REH	56.8	1,360	6	284	1,200
Municipal	ALT-2	79.6	2,400	8	185	900

(3) Generator specifications

1) Cooling system

The generator cooling system will be designed to evacuate air from the powerhouse and blow it into the powerhouse.

2) Rated voltage

It shall be standardized to be 4.16 kV.

3) 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 as important in small-capacity generators, an economical power factor of 0.9 is available.

4) Number of poles

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.

5) Generator capacity

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

Power plant	Plan	Rehabilitation plan		Estimated turbine effic. η_T	Estimated generator effic. η_G	Generator capacity P_G (kW)	Power factor	Generator capacity (kVA)
		Discharge per turbine Q (m^3/s)	Net head He (m)					
San Cancio	REH	2.8	56.8	0.874	0.95	1,250	0.9	1,400
Intermedia	REH	2.8	56.8	0.874	0.95	1,250	0.9	1,400
Municipal	ALT-2	3.5	79.6	0.879	0.95	2,250	0.9	2,500

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

(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 the 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 panel

(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 activated and the water turbine and generator stop simultaneously as a buzzer and flickering light warn the operator.

(6) Substation

In the San Cancio and Intermedia substations, considering that it will become the distributed voltage of 13.2 kV in the future, one 4.16/13.2 kV main transformer will be installed outdoor. New 13.2 kV switchgear should be installed inside powerhouse building.

Furthermore, in the Municipal Substation, existing main transformer should replaced with new one which is suitable for the capacity of generating equipment rehabilitated. New 13.2 kV switchgear should be installed inside the powerhouse building.

(7) Power distribution lines

In the San Cancio and Intermedia P/Ps, the present distribution voltage is 4.16 kV, but it will be changed to 13.2 kV in the future.

Therefore, in this stage of the study, the costs for rehabilitation or new installation of the distribution lines shall not be considered.

Furthermore, in the Municipal P/P, the costs for rehabilitation or expansion of existing 13.2 kV distribution lines shall not be considered.

11.2 Construction Execution Plan

11.2.1 Investigation into Construction Conditions

The period of power generation stoppage caused by the rehabilitation construction must be shortened because the three P/Ps are presently in operation. Care must be taken not to affect the operation of the power plant located downstream.

There are no conditions for restricting the execution of construction.

11.2.2 Preparatory Work

Before installing the intake equipment in the San Cancio and Intermedia P/Ps, a river diversion work will be undertaken in the river, the main channel will be diverted to the left bank and the right bank will be closed off. Sediment will be heaped up to close off the area, and gabions and sand bags will be used to prevent erosion of the surface. Within the closed off area of the right bank the intake, a sand trap and one part of the diversion weir will be constructed. After the right bank work is completed, the completed sand trap will be used and river flow will be diverted to the right bank. The left bank area will then be closed off and the remainder of the diversion weir will be finished.

Further management of the river flow includes a one year construction period for a low concrete dam and using the probability discharge 1 ~ 3 times per year of 15 m^3/s.

11.2.3 Construction Access Road Work

The construction access roads to each power plant are described below.

In San Cancio, vehicles can enter near all facilities except No. 2 desilting basin.

In Intermedia and Municipal, vehicles can enter near the powerhouse building, but the bridges crossing over the river cannot endure heavy loads to transport generating equipment. Accordingly, temporary facilities will be required to transport the generating equipment.

In the Intermedia P/P, only the first 1/3 of the road to the conduction channel is vehicle-accessible. The head tank is not accessible by car or truck, but the routes along the conduction channel or along the penstock may be accessible by vehicles which are smaller than cars, because the scale of the head tank construction is not large. The construction of new access road is not required.

In the Municipal P/P, the vehicles are accessible to the area near the diversion weir or the desilting basin, but inaccessible to the area near the conduction channel or the head tank. The scale of the head tank reconstruction is rather large, and an access road must be built to transport materials, equipment and personnel. There is no access road route near the right-bank side. Thus, concrete covers of the conduction channel should be used as a passage of light cars.

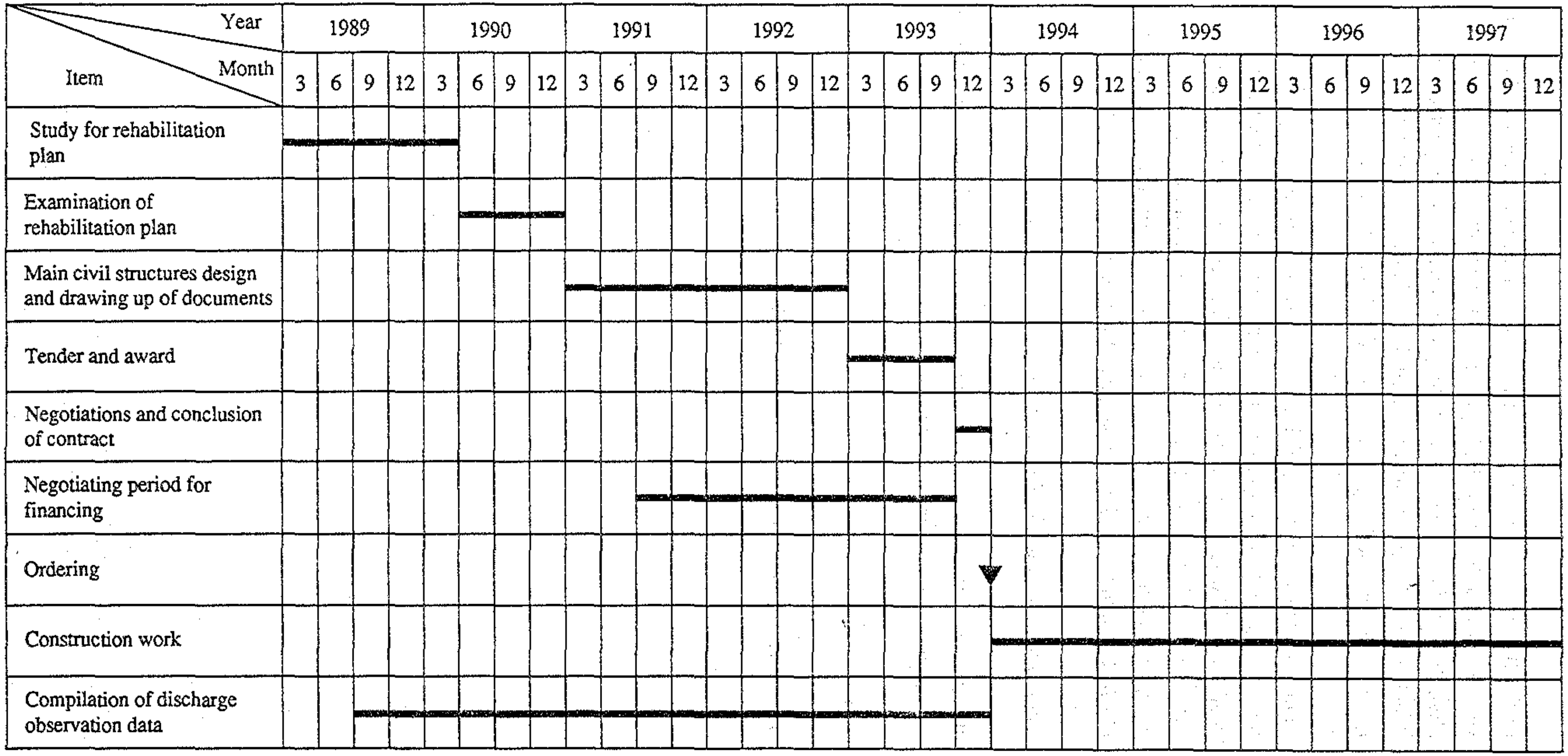
11.2.4 Temporary Facilities for Construction

It is necessary to construct general temporary facilities instead of temporary facilities for construction because it is not a full-scale construction.

11.2.5 Work Schedule

The work schedule is shown in Table 11.5.

Table 11.5 San Cancio/Intermedia/Municipal Hydroelectric Power Plants Rehabilitation Plan Work Schedule



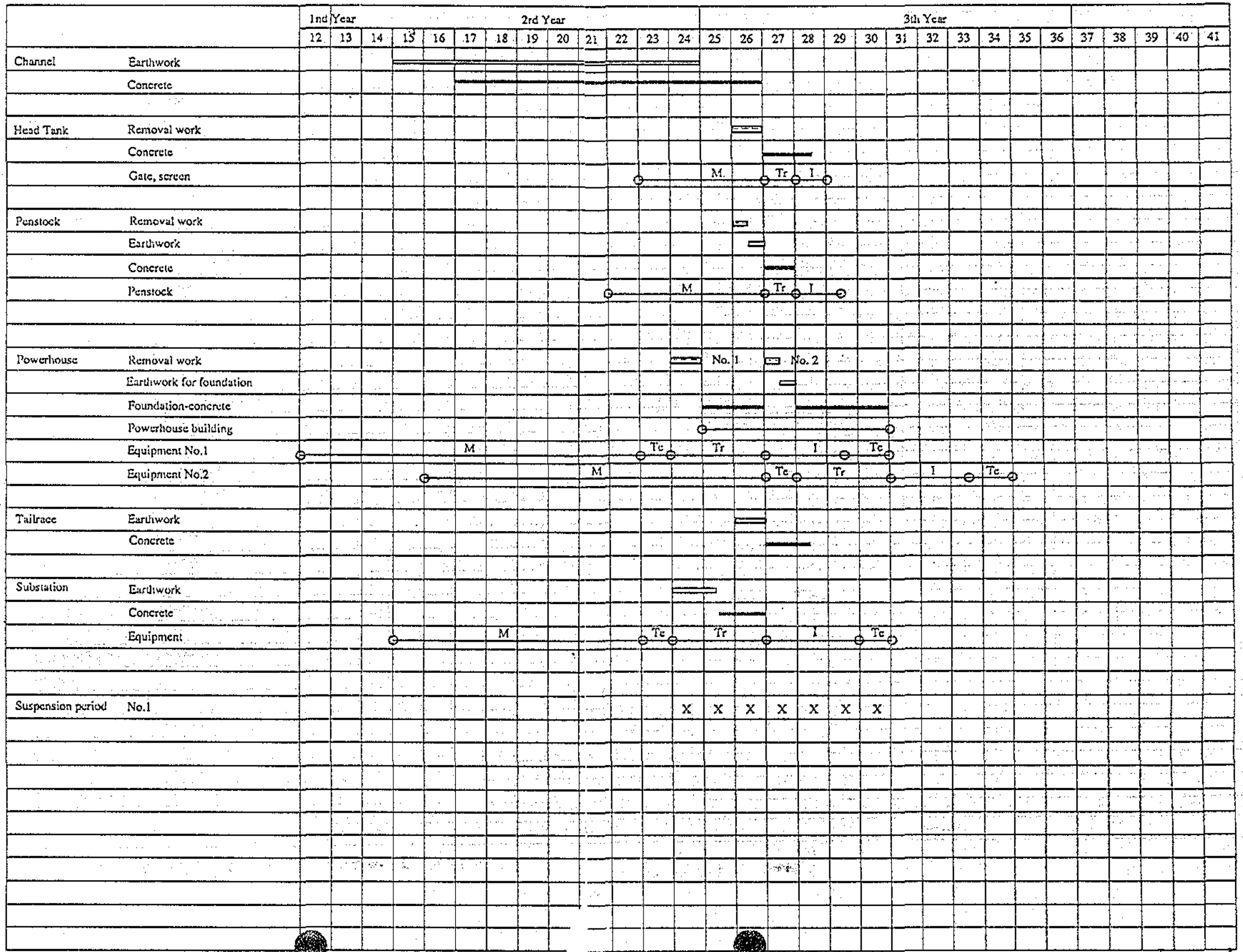
Note) The details of the construction period are in Table 11.6(1) ~ (3)

Table 11.6(1) San Cancio

		2nd Year		3rd Year												4th Year													
		23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Intake Facilities	Removal work																														
	Earthwork							Left Bank				Right Bank																			
	Concrete																														
	Gate, screen															M	Tr	I													
Desilting Basin	Removal work																														
	Concrete																														
	Gate, screen													M			Tr	I													
Channel	Earthwork																														
	Concrete																														
Head Tank	Removal work																														
	Earthwork																														
	Concrete																														
	Gate, screen													M			Tr	I													
	Slope protection work																														
Powerhouse	Removal work																														
	Foundation-concrete																														
	Powerhouse building																														
	Equipment No.1							M					Te		Tr			I		Te											
	Equipment No.2													M			Te		Tr			I		Te							
Tailrace	Earthwork																														
	Concrete																														
Substation	Earthwork																														
	Concrete																														
	Equipment								M				Te		Tr			I		Te											
Suspension period	No.1													X	X	X	X	X	X	X											
	No.2																X	X	X	X	X	X	X	X							

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

Table 11.6(2) Intermedia



Note) M = Manufacturing, Tc = Testing, Tr = Transportation, I = Installation

Table 11.6(3) Municipal

		1st Year												2nd Year												3rd Year					
		1	2	3	41	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Intake Facilities	Removal work																														
	Earthwork																														
	Concrete																														
	Gate, screen								M			Tr	I																		
Desilting Basin	Earthwork																														
	Concrete																														
	Gate, screen									M		Tr		I																	
Channel	Earthwork																														
	Concrete																														
Head Tank	Removal work																														
	Earthwork																														
	Concrete																														
	Gate, screen													M				Tr	I												
	Slope protection work																														
Powerhouse	Removal work														No.				No. 2												
	Foundation-concrete																														
	Powerhouse building																														
	Equipment No.1						M						Te		Tr			I		Te											
	Equipment No.2									M							Te		Tr			I		Te							
Tailrace	Earthwork																														
	Concrete																														
	Equipment																														
Substation	Earthwork																														
	Concrete																														
	Equipment								M				Te		Tr			I		Te											
Suspension period	Equipment No.1													X	X	X	X	X	X	X											
	Equipment No.2																X	X	X	X	X	X	X	X							

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

11.3 *Construction Costs*

11.3.1 Basic Conditions of Estimates

(1) Estimate method

(a) Estimate of work content

Project-related approximate construction costs include the following items:

Civil construction costs
Direct construction costs + contingency + engineering fees

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

(b) Civil construction cost calculation

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

- The work quantity is estimated based on attached Dwg. No. SC-C-01 ~ SC-C-04, IN-C-01, IN-C-02 and MU-C-01 ~ MU-C-05.

- Within the unit direct temporary work costs (AIU) are taken as 20% in Colombia.

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

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

(c) Estimate of equipment and construction costs

Using the FOB and the ISA hydroelectric power plant project direct construction costs, equipment and construction costs 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 fees	FOB x 14.9%	8% of (direct construction costs + contingency)

(d) Division of work type

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

Intake dam/intake : earthwork, removal of existing concrete, concrete, cobble concrete, reinforcing bars, gate, screen, gabions

Desilting basin : earthwork, concrete, reinforcing bars, gate, screen

Headrace : earthwork, concrete, reinforcing bars, masonry

Head tank	:	earthwork, removal of existing concrete, concrete, reinforcing bars, gate, screen
Penstock	:	earthwork, concrete, reinforcing bars, pipework
Powerhouse	:	earthwork, concrete, reinforcing bars, removal of existing concrete, building (new/repair)
Substation	:	earthwork, concrete, reinforcing bars

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
main transformer
13.2 kV switchgear

(e) Annual estimate

Estimation rate was used as of September 1989 according to the meeting with ICEL.

(2) Civil construction units

As shown in 5.4 the units prepared by CHEC in September 1989 were used. The cost of temporary work camps, electricity sources, communication facilities etc., were included within the present units.

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 three power plants is shown on the following pages.

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
	San Cancio (REH-1)					
1.	Diversion Weir & Intake					
1.1	Earthwork	m^3	1,700	3,965	6,740,500	
1.2	Concrete Work	"	700	27,625	19,337,500	
1.3	Reinforcing Bar	ton	28	454,000	12,712,000	
1.4	Gate	"	6.9	500,000	3,450,000	
1.5	Screen	"	3.3	500,000	1,650,000	
1.6	Cyclopean Concrete	m^3	500	14,000	7,000,000	
	Sub Total	-	-	-	50,890,000	
2.	Settling Basin					
2.1	Concrete Work	m^3	60	27,625	1,657,500	
2.2	Reinforcing Bar	ton	3.0	454,000	1,362,000	
2.3	Gate	ton	11.9	500,000	5,950,000	
2.4	Concrete Removal	m^3	100	14,000	1,400,000	
	Sub Total	-	-	-	10,369,500	
3.	Conduction Channel					
3.1	Earthwork	m^3	700	2,925	2,047,500	
3.2	Concrete Work	m^3	600	27,625	16,575,000	
3.3	Reinforcing Bar	ton	36.0	454,000	16,344,000	
3.4	Concrete Removal	m^3	100	14,000	1,400,000	
	Sub Total	-	-	-	36,366,500	

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
4.	Head Tank					
4.1	Earthwork	m^3	2,100	2,925	6,142,500	
4.2	Concrete Work	"	270	27,625	7,458,750	
4.3	Reinforcing Bar	ton	7.6	454,000	3,450,400	
4.4	Gate	ton	4.1	500,000	2,050,000	
4.5	Screen	ton	3.0	500,000	1,500,000	
4.6	Concrete Removal	m^3	50	14,000	700,000	
	Sub Total				21,301,650	
5.	Foundation of Equip.					
5.1	Concrete	m^3	190	27,625	5,248,750	
5.2	Reinforcing Bar	ton	10	454,000	4,540,000	
5.3	Concrete Removal	m^3	90	14,000	1,260,000	
	Sub Total	-	-	-	11,048,750	
6.	Powerhouse					
6.1	Building (Modification)	m^2	100	10,000	1,000,000	
	Sub Total	-	-	-	1,000,000	
7.	Substation					
7.1	Excavation	m^3	88	2,925	257,000	
7.2	Concrete	"	44	27,625	1,216,000	
7.3	Reinforcing Bar	ton	2.2	454,000	999,000	
	Sub Total	-	-	-	2,470,000	
8.	Grand Total				132,596,400	

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
	Intermedia (REH-1)					
1.	Conduction Channel					
1.1	Earthwork	m^3	14,400	2,925	42,120,000	
1.2	Concrete Work	"	3,500	27,625	96,687,500	
1.3	Reinforcing Bar	ton	75	454,000	9,450,000	
1.4	Concrete Removal	m^3	10	14,000	140,000	
	Sub Total	-	-	-	218,397,500	
2.	Head Tank					
2.1	Concrete Work	m^3	10	27,625	276,250	
2.2	Reinforcing Bar	ton	1	454,000	454,000	
2.3	Gate	ton	7	500,000	3,500,000	
2.4	Screen	ton	5	500,000	2,500,000	
2.5	Concrete Removal	m^3	70	14,000	980,000	
	Sub Total				7,710,250	
3.	Penstock					
3.1	Earthwork	m^3	50	2,925	146,250	
3.2	Concrete Work	m^3	30	27,625	828,750	
3.3	Reinforcing Bar	ton	2	454,000	908,000	
3.4	Penstock	ton	3	1,000,000	3,000,000	
3.5	Concrete Removal	m^3	20	14,000	280,000	
	Sub Total				5,163,000	

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
4.	Foundation of Equip.					
4.1	Excavation	m^3	400	2,925	1,170,000	
4.2	Concrete Work	"	200	27,625	5,525,000	
4.3	Reinforcing Bar	ton	10	454,000	4,540,000	
4.4	Concrete Removal	m^3	70	14,000	980,000	
	Sub Total				12,215,000	
5.	Powerhouse					
5.1	Building (New)	m^2	17	50,000	850,000	
5.2	Building (Modification)	m^3	100	10,000	1,000,000	
	Sub Total				1,850,000	
6.	Substation					
6.1	Excavation	m^3	88	2,925	257,000	
6.2	Concrete	"	44	27,625	1,216,000	
6.3	Reinforcing Bar	ton	2.2	454,000	994,000	
	Sub Total				2,470,000	
7.	Grand Total				247,805,750	

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
	Municipal (ALT-2)					
1.	Diversion Weir & Intake					
1.1	Earthwork	m^3	300	3,965	1,189,500	
1.2	Concrete Work	"	400	27,625	1,050,000	
1.3	Reinforcing Bar	ton	16	454,000	7,264,000	
1.4	Gate	"	6.9	500,000	3,450,000	
1.5	Screen	"	1.6	500,000	800,000	
1.6	Concrete Removal	m^3	200	14,000	2,800,000	
	Sub Total	-	-	-	26,553,500	
2.	Settling Basin					
2.1	Concrete Work	m^3	50	27,625	1,381,250	
2.2	Reinforcing Bar	ton	2.5	454,000	1,135,000	
2.3	Gate	ton	10.8	500,000	5,400,000	
2.4	Concrete Removal	m^3	20	14,000	280,000	
	Sub Total				8,196,250	
3.	Conduction Channel					
3.1	Earthwork	m^3	700	2,925	2,047,500	
3.2	Concrete Work	"	1,100	27,625	30,387,500	
3.3	Reinforcing Bar	ton	66.0	454,000	29,964,000	
3.4	Concrete Removal	m^3	100	14,000	1,400,000	
	Sub Total				63,799,000	

No.	Description	Unit	Quantity	Rate	Estimated Amount	Remarks
4.	Head Tank					
4.1	Earthwork	m^3	2,400	2,925	7,020,000	
4.2	Concrete Work	"	850	27,625	23,481,250	
4.3	Reinforcing Bar	ton	24.0	454,000	10,896,000	
4.4	Gate	ton	6.0	500,000	3,000,000	
4.5	Screen	ton	5.5	500,000	2,750,000	
4.6	Concrete Removal	m^3	400	14,000	5,600,000	
	Sub Total				52,747,250	
5.	Foundation of Equip.					
5.1	Concrete	m^3	280	27,625	7,735,000	
5.2	Reinforcing Bar	ton	14.0	454,000	6,356,000	
5.3	Concrete Removal	m^3	150	14,000	2,100,000	
	Sub Total				16,191,000	
6.	Powerhouse					
6.1	Building (Modification)	m^2	100	10,000	1,000,000	
	Sub Total				1,000,000	
7.	Substation	m^3	94	2,925		
7.1	Excavation	m^3	47	27,625	275,000	
7.2	Concrete	ton	2.4	454,000	1,298,000	
7.3	Reinforcing Bar				1,090,000	
	Sub Total				2,663,000	
8.	Grand Total				171,150,000	

11.3.3 Breakdown of Generating Equipment Costs

The breakdown of generating equipment costs for three power plans is shown below.

(US$1,000)

FOB Price of Electric & Mechanical Equipment				
No.	Description	San Cancio	Intermedia	Municipal (ALT-2)
1	Water Turbine and Auxiliary Equipment	741.4	741.4	995.7
2	Generator and Auxiliary Equipment	304.3	304.3	401.4
3	Turbine and Generator Control Panel	97.1	97.1	97.1
4	Switchgear for Generator	72.9	72.9	72.9
5	Auxiliary Service Trans. Distribution Board Battery and charger	25.0	25.0	25.0
6	Main Transformer	37.1	37.1	71.4
7	33 kV Substation	35.7	35.7	35.7
	Total	1,313.5	1,313.5	1,699.2

11.3.4 Annual Construction Costs

The annual construction costs are calculated in two cases. One is the individual cost for each power plant, and the other is the overall cost for the three power plants.

Annual Estimation of Civil Construction Cost
(San Cancio Power Plant)

(Units: 10^6 pesos)

Item	Alternative Plans			
	Rehabilitation of the existing facilities			
	REH-1			
	1st year	2nd year	3rd year	4th year
Diversion weir and intake construction	0	0	36.7	24.4
Desilting basin construction	0	0	0	12.4
Conduction channel construction	0	0	43.6	0
Head tank construction	0	0	7.7	17.0
Penstock construction	0	0	0	0
Equipment foundation construction	0	0	0.75	
Powerhouse building construction	0	0	0.6	0.6
Temporary facilities construction	0	0	0	0
Other construction	0	0	3.0	0
① Total	0	0	94.9	65.3
② Contingency (① x 0.15)	0	0	14.2	9.8
③ Engineering fees (① + ②) x 0.10	0	0	10.9	7.5
④ Total ① + ② +③	0	0	120.0	82.6
⑤ Output loss	0	0	3.7	24.3
Grand total ④ + ⑤	0	0	123.7	106.9

Annual Estimation of Civil Construction Cost
(Intermedia Power Plant)

(Units: 10^6 pesos)

Item	Alternative Plans			
	Rehabilitation of the existing facilities			
	REH-1			
	1st year	2nd year	3rd year	4th year
Diversion weir and intake construction	0	0	0	0
Desilting basin construction	0	0	0	0
Conduction channel construction	0	209.7	52.4	0
Head tank construction	0	0	9.3	0
Penstock construction	0	0	6.2	0
Equipment foundation construction	0	1.5	13.1	0
Powerhouse building construction	0	0	2.2	0
Temporary facilities construction	0	0	0	0
Other work	0	0.6	2.4	0
① Total	0	211.8	85.6	0
② Contingency (① x 0.15)	0	31.8	12.8	0
③ Engineering fee (① + ②) x 0.10	0	24.4	9.8	0
④ Total ① + ② +③	0	268.0	108.2	0
⑤ Output loss	0	1.5	9.1	0
Grand total ④ + ⑤	0	269.5	117.3	0

Annual Estimation of Civil Construction Cost
(Municipal Power Plant)

(Units: 10^6 pesos)

	Alternative Plans							
	Rehabilitation of the existing facilities							
	ALT-1				ALT-2			
	1st year	2nd year	3rd year	4th year	1st year	2nd year	3rd year	4th year
Diversion weir and intake construction	0	0	0	0	31.9	0		
Desilting basin construction	8.8	1.0			8.8	1.0		
Conduction channel construction	46.9	0			76.6	0		
Head tank construction	16.7	38.9			19.0	44.3		
Penstock construction	0	0			0	0		
Equipment foundation construction	0	17.9			0	19.4		
Powerhouse building construction	0	1.2			0	1.2		
Temporary facilities construction	0	0			0	0		
Other work	0.6				0.6	2.6		
① Total	73.0	61.6			136.9	68.5		
② Contingency (① x 0.15)	11.0	9.2			20.5	10.3		
③ Engineering fees (① + ②) x 0.10	8.4	7.1			15.7	7.9		
④ Total ① + ② +③	92.4	77.9			173.1	86.7		
⑤ Output loss	0	19.8			0	19.8		
Grand total ④ + ⑤	92.4	97.7			173.1	106.5		

Annual Estimation of Civil Construction Cost

(Three Power Plants)

(Units: 10^6 pesos)

	Alternative Plans							
	Rehabilitation of the existing facilities							
	ALT-1				ALT-2			
	1st year	2nd year	3rd year	4th year	1st year	2nd year	3rd year	4th year
Diversion weir and intake construction	0	0	36.7	24.4	31.9	0	36.7	24.4
Desilting basin construction	8.8	1.0	0	12.4	8.8	1.0	0	12.4
Conduction channel construction	46.9	209.7	96.0	0	76.6	209.7	96.0	0
Head tank construction	16.7	38.9	17.0	17.9	19.0	44.3	17.0	17.9
Penstock construction	0	0	6.2	0	0	0	6.2	0
Equipment foundation construction	0	19.4	16.4	10.0	0	20.9	16.4	10.0
Powerhouse building construction	0	1.2	2.8	0.6	0	1.2	2.8	0.6
Temporary facilities construction	0	0	0	0	0	0	0	0
Other work	0.6	3.2	5.4	0	0.6	3.2	5.4	0
① Total	73.0	273.4	180.5	65.3	136.9	280.3	180.5	65.3
② Contingency (① x 0.15)	11.0	41.0	27.0	9.8	20.5	42.1	27.0	9.8
③ Engineering fees (① + ②) x 0.10	8.4	31.5	20.7	7.5	15.7	32.3	20.7	7.5
④ Total ① + ② +③	92.4	345.9	228.2	82.6	173.1	354.7	228.2	82.6
⑤ Output loss	0	21.3	12.8	24.3	0	21.3	12.8	24.3
Grand total ④ +⑤	92.4	367.2	241.0	106.9	173.1	376.0	241.0	106.9

11.3.5 Loss by Power Supply Stoppage

The operation of the power plants will be suspended during the rehabilitation construction, and this suspension will cause electricity-selling loss.

(1) San Cancio Power Plant

Stoppage period	15 months (total)
No. 1 Unit	7 months
No. 2 Unit	8 months
Output drop	1.75 MW
Generated energy drop	8.44 GWh x 15/24 = 5.28 GWh
Loss caused by electricity-selling	
Unit price	4,936.18 P/MWh 1,086,909.69 P/MW
	1.75 MW x 1,086,909.69 P/MW + 5.28 x 10^3 MWh x 4,936.18 P/MWh = 27,965,000 pesos
Breakdown of annual loss	
3rd year	3,719,000 pesos
4th year	24,246,000 pesos

(2) Intermedia Power Plant

Stoppage period	7 months
Output drop	0.9 MW
Generated energy drop	3.33 GWh x 7/12 = 1.94 GWh
Loss caused by electricity-selling	0.9 MW x 1,0896,909.69 P/MW + 1.94 x 10^3 MWh x 4,936.18 P/MWh = 10,554,000 pesos
Breakdown of annual loss	
2nd year	1,508,000 pesos
3rd year	9,046,000 pesos

(3) Municipal Power Plant

Stoppage period	15 months (total)
No. 1 Unit No. 2 Unit	7 months 8 months
Output drop	1.4 MW
Generated energy drop	5.94 GWh x 15/24 = 3.71 GWh
Loss caused by power electricity-selling	1.4 MW x 1,086,909.69 P/MW + 3.71 x 10^3 MWh x 4,936.18 P/MWh = 19,835,000 pesos
Breakdown of annual loss	2nd year only

CHAPTER 12 CONCLUSION AND RECOMMENDATIONS

This chapter describes JICA study team's conclusion of the feasibility study for the rehabilitation of the San Cancio, Intermedia and Municipal hydroelectric P/Ps located along the Chinchina River (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

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

(1) San Cancio Power Plant

Item				Unit	Content
(1) Generation plan requirements	Max. available discharge		Q	m^3/s	5.6
	Standard net head		H	m	53.8
	Theoretical output			kW	2,952
	Max. output		P	kW	2,400
	No. of generating equipment				2
	Annual potential generated energy		E_1	GWh	18.5
	Plant utilization factor			%	88
(2) Civil structure specification	Diversion weir	Type			Linear gravity type concrete dam
		Dimensions		m	4.9 (height), 20.0 (crest length)
	Sand flush gate	Type			Wooden sluice gate
		No. of gates			1
		Dimensions		m	2.9 (width), 4.0 (height)
	Intake	Type			Non-pressure type, rectangular
		Dimensions		m	3.00 (width), 2.50 (height)
	Intake gate	Type			Steel sluice gate
		Dimensions		m	1.90 (width), 2.50 (height)
	Desilting basin	Type			Sand trap in open channel floor, rectangular open channel (2 sections) (Existing basin will be used).
		Dimensions		m	9.90 (width), 2.00 (average depth), 2.00 (length)
	Sand trap gate	Type			Steel sluice gate
		No. of gates			2
		Dimensions		m	1.40 (width), 1.40 (height)
	Conduction channel	Type			RC U-shape (with covers)
		Length		m	2.30
		Dimensions		m	2
	Head tank	Shape			Rectangular
		Dimensions		m	9.5 (average width), 3.5 (average depth), 24.8 (length)
	Head tank gate	Type			Steel sluice gate
		Dimensions		m	1.40 (width), 1.40 (height)
	Penstock	No. of penstocks			1
		Diameter		m	ø1.24
		Length		m	231.1 (Existing penstock will be used.)

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

Item			Unit	Content
	Powerhouse	Shape Dimensions	 m	Exposed type, RC structure (present powerhouse building will be used.) 12.5 (width), 40.0 (length), 7.0 (height)
	Tailrace	Shape Dimensions	 m	Rectangular 2.00 (width), 1.8 (height)
(3) Generating equipment specifications	Turbine	Type No. of turbines Output Revolution	 kW rpm	Horizontal Francis 2 1, 360 1,200
	Generator	Type No. of generators Output No. of poles Revolution	 kVA rpm	Synchronous 2 1,400 6 1,200
	Main transformer	Type No.of transformer Voltage Capacity	 kV kVA	ONAN 1 4.16/13.2 2,800
(4) Rehabilitation work cost	Generating equipment	Foreign currency portion Local currency portion	US$ US$	1,900,000 750,000
	Civil and building work cost	Foreign currency portion Local currency portion	US$ US$	0 600,000
	Project cost		US$	3,250,000
	Construction cost	per kW per kWh	US$/kW mills/kWh	1,350 175.7

Table 12.2 Summary of Post-rehabilitation Optimum Generating Facilities

(2) Intermedia Power Plant

Item			Unit	Content
(1) Generation plan requirements	Max. available discharge Q		m^3/s	5.6
	Standard net head H		m	56.8
	Theoretical output		kW	3,117
	Max. output P		kW	2,500
	No. of generating equipment			2
	Annual potential generated energy E_1		GWh	19.7
	Plant utilization factor		%	88
(2) Civil structure specification	Diversion weir	Type		
		Dimensions	m	N/A
	Sand flush gate	Type		
		No. of gates		
		Dimensions	m	N/A
	Intake	Type		
		Dimensions		N/A
	Intake gate	Type		
		Dimensions		N/A
	Desilting basin	Type		
		Dimensions	m	N/A
	Sand trap gate	Type		Steel sluice gate
		No. of gates		2
		Dimensions	m	1.40 (width), 1.40 (height)
	Conduction channel	Type		RC U-shape (with cover)
		Length	m	1,800 1,223
		Dimensions	m	width: 2.1 depth: 1.6 depth: 1.5 width: 2.2
	Head tank	Shape		Rectangular (2 sections, in series)
		Dimensions	m	7.9 (average width), 4.5 (average depth), 29.00 (length)
	Head tank gate	Type		Steel sluice gate
		Dimensions	m	1.40 (width), 1.40 (height)
	Penstock	No. of penstocks		1
		Diameter	m	ø1.24
		Length	m	153.5 (Existing penstock will be used.)

Table 12.2 Summary of Post-rehabilitation Optimum Generating Facilities (cont'd)

Item			Unit	Content
	Tailrace	Shape		Rectangular
		Dimensions	m	2.00 (width), 1.80 (height)
	Powerhouse	Shape		Exposed type, RC structure (partial expansion of the building)
		Dimensions	m	12.40 (width), 16.20 (length), 8.75 (height)
(3) Generating equipment specifications	Turbine	Type		Horizontal Francis
		No. of turbines		2
		Output	kW	1,360
		Revolution	rpm	1,200
	Generator	Type		Synchronous
		No. of generators		2
		Output	kVA	1,400
		No. of poles		6
		Revolution	rpm	1,200
	Main transformer	Type		ONAN
		No.of transformer		1
		Voltage	kV	4.16/13.2
		Capacity	kVA	2,800
(4) Rehabilitation work cost	Generating equipment	Foreign currency portion	US$	1,900,000
		Local currency portion	US$	750,000
	Civil and building work cost	Foreign currency portion	US$	0
		Local currency portion	US$	1,050,000
	Project cost		US$	3,700,000
	Construction cost	per kW	US$/kW	1,500
		per kWh	mills/kWh	187.8

Table 12.3 Summary of Post-rehabilitation Optimum Generating Facilities

(3) *Municipal Power Plant (ALT-2)*

Item			Unit	Content
(1) Generation plan requirements	Max. available discharge Q		m^3/s	7.0
	Standard net head H		m	79.6
	Theoretical output		kW	5,460
	Max. output P		kW	4,500
	No. of generating equipment			2
	Annual potential generated energy E_1		GWh	34.8
	Plant utilization factor		%	88
(2) Civil structure specification	Diversion weir	Type		Steel gravity type concrete dam (Existing weir will be used.)
		Dimensions	m	2.5 (height), 21 (crest length)
	Sand flush gate	Type		Steel sluice gate
		No. of gates		1
		Dimensions	m	2.9 (width), 2.3 (height)
	Intake	Type		Rectangular
		Dimensions	m	2.00 (width), 1.5 (height)
	Intake gate	Type		Steel sluice gate
		Dimensions	m	2.0 (width), 1.5 (height)
	Desilting basin	Type		Sand trap in open channel floor, rectangular open channel
		Dimensions	m	15.00 (width), 4.20 (average depth), 27.00 (length)
	Sand trap gate	Type		Steel sluice gate
		No. of gates		
		Dimensions	m	1.20 (width), 1.20 (height)
	Conduction channel	Type		RC U-shape
		Length	m	2.4
		Dimensions	m	2.3 (average width), 2.2 (average height)
	Head tank	Shape		Rectangular
		Dimensions	m	9.00 (average width), 2.8 (average depth), 30.00 (length)
	Head tank gate	Type		Steel sluice gate
		Dimensions	m	1.40 (width), 1.40 (height)
	Penstock	No. of penstocks		1
		Diameter	m	ø1.52
		Length	m	157.8 (Existing penstock will be used.)

Table 12.3 Summary of Post-rehabilitation Optimum Generating Facilities (cont'd)

Item			Unit	Content
	Powerhouse	Shape		Exposed type, RC structure
		Dimensions	m	12.00 (width), 55.00 (length), 8.75 (height)
	Tailrace	Shape		Rectangular
		Dimensions	m	2.00 (width), 1.80 (height)
(3) Generating equipment specifications	Turbine	Type		Horizontal Francis
		No. of turbines		2
		Output	kW	2,400
		Revolution	rpm	900
	Generator	Type		Synchronous
		No. of generators		2
		Output	kVA	2,500
		No. of poles		8
		Revolution	rpm	900
	Main transformer	Type		ONAN
		No.of transformer		1
		Voltage	kV	4.16/13.2
		Capacity	kVA	5,000
(4) Rehabilitation work cost	Generating equipment	Foreign currency portion	US$	2,450,000
		Local currency portion	US$	1,000,000
	Civil and building work cost	Foreign currency portion	US$	0
		Local currency portion	US$	750,000
	Project cost		US$	4,200,000
	Construction cost	per kW	US$/kW	950
		per kWh	mills/kWh	120.7

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 ~ 12.3 are as follows:

	San Cancio	Intermedia	Municipal (ALT-2)
Construction cost per kw (US$/kW)	1,350	1,500	950
Average generating cost for annual supplied electric power (mills/kWh)	18	19	13

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 three hydroelectric P/Ps, 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 Main Report contains the general management manual for the maintenance and inspection of the main civil structures and generating equipment.

12.4 Technical Recommendations on the Rehabilitation Plan

When the rehabilitation plan of three 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.

(2) Topographic map of the area around each power plant's facilities

In this FS, the surveying was roughly performed for civil structures. To formulate the rehabilitation plan in more detail a topographic survey should be conducted in the area around each power plant.

(3) Topographic relationship among three power plants

From the results of the surveying conducted in the FS, it is possible to recognize the configurations of respective structures, but it is impossible to recognize the interconnection of facilities which are continuously installed.

The topographic relationship among three power plants was created by referring to the as-built drawings. (refer to the following figure.) This figure needs to be checked using other references.

PROFILE OF CASCADE FOR RIO CHINCHINA