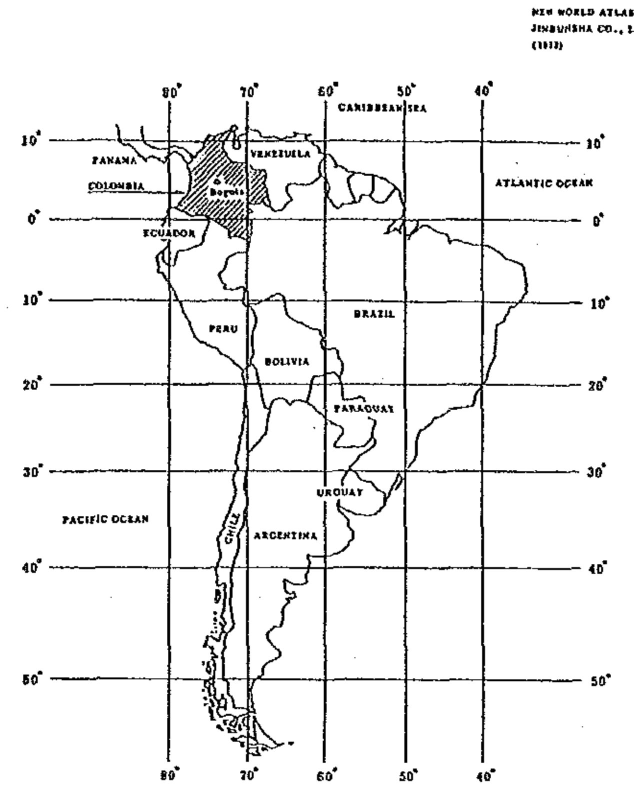
FEASIBILITY STUDY
ON
SMALL-SCALE POWER PLANTS
REHABILITATION PROJECT
IN
THE REPUBLIC OF COLOMBIA

PUENTE GUILLERMO HYDROELECTRIC POWER PLANT

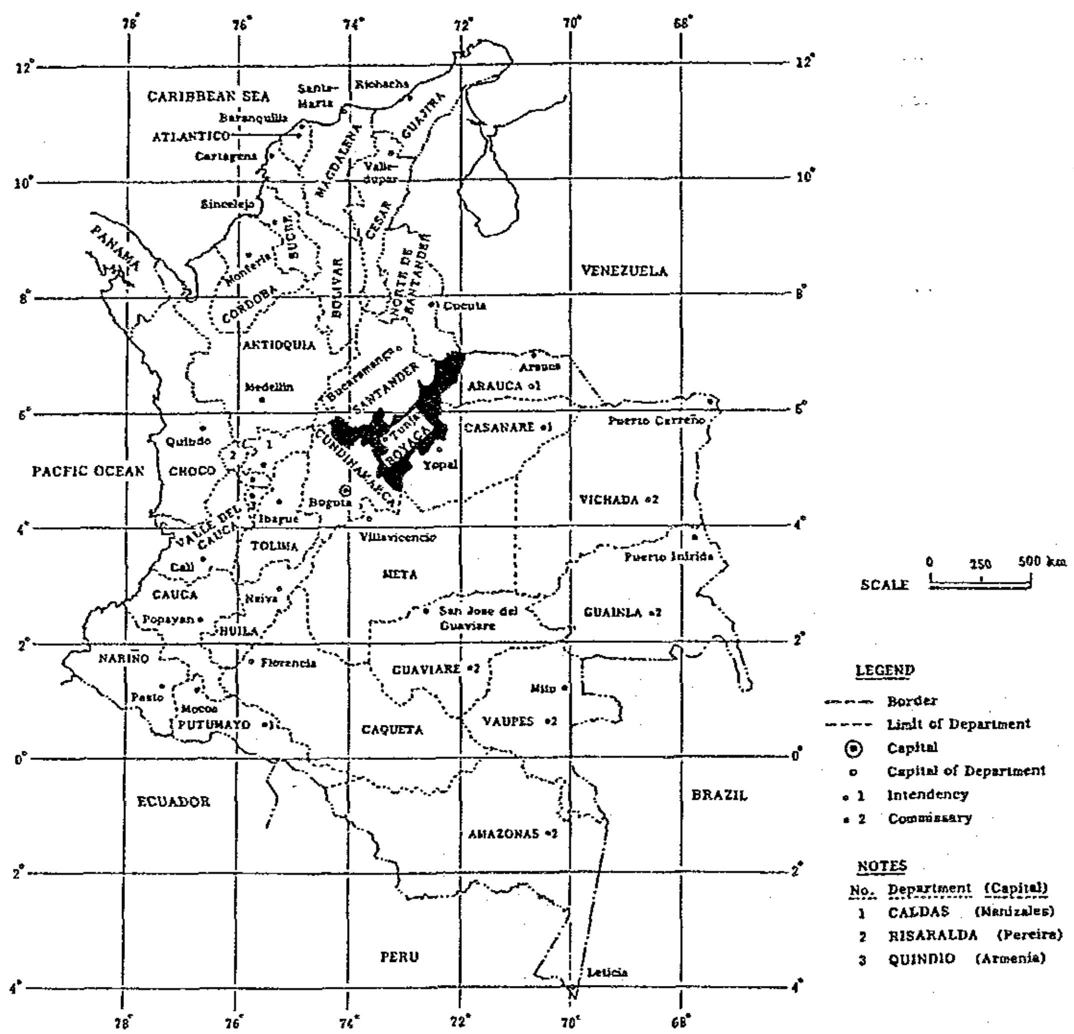
MARCH 1990

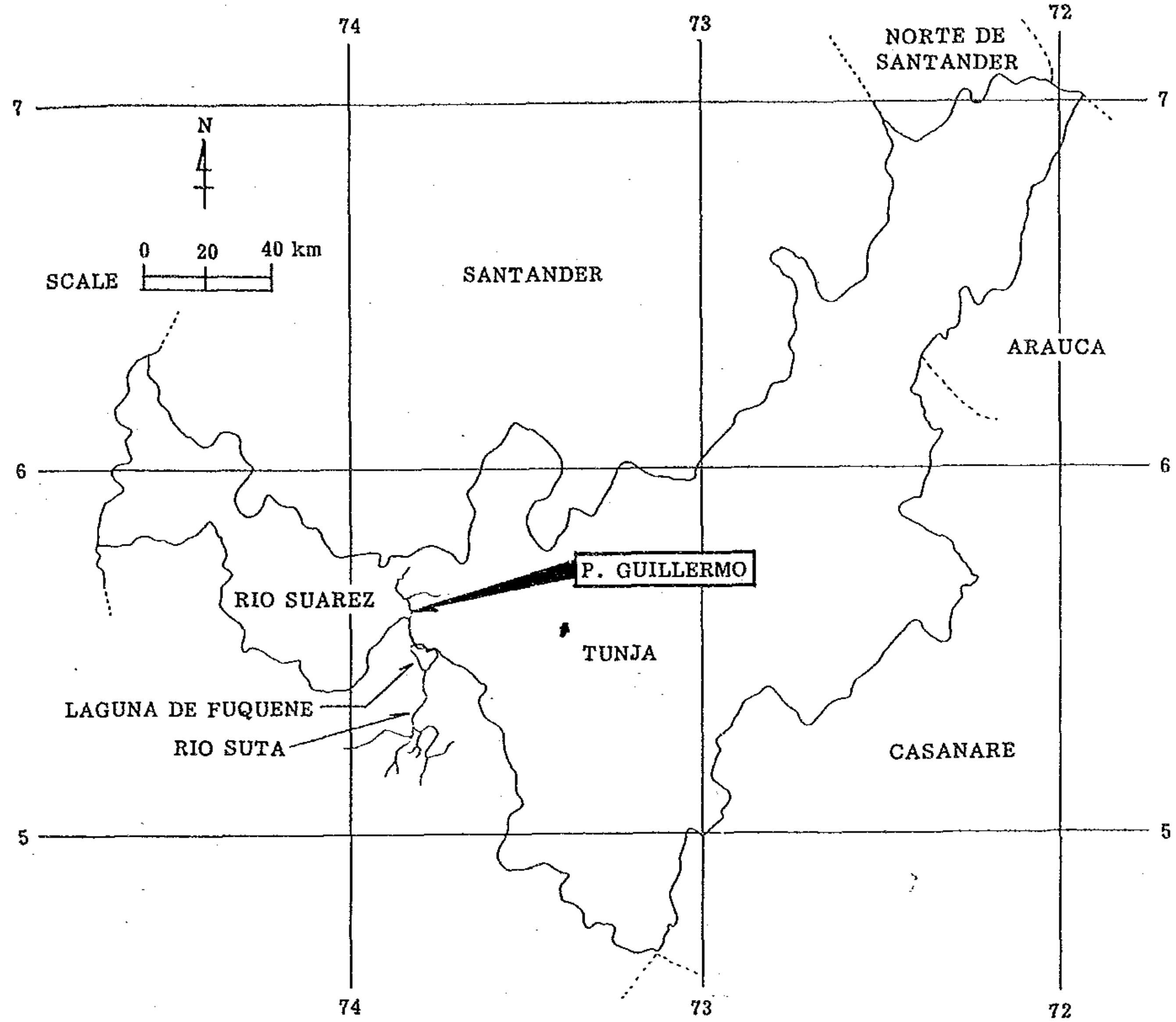
Japan International Cooperation Agency

MAP OF SOUTH AMERICA

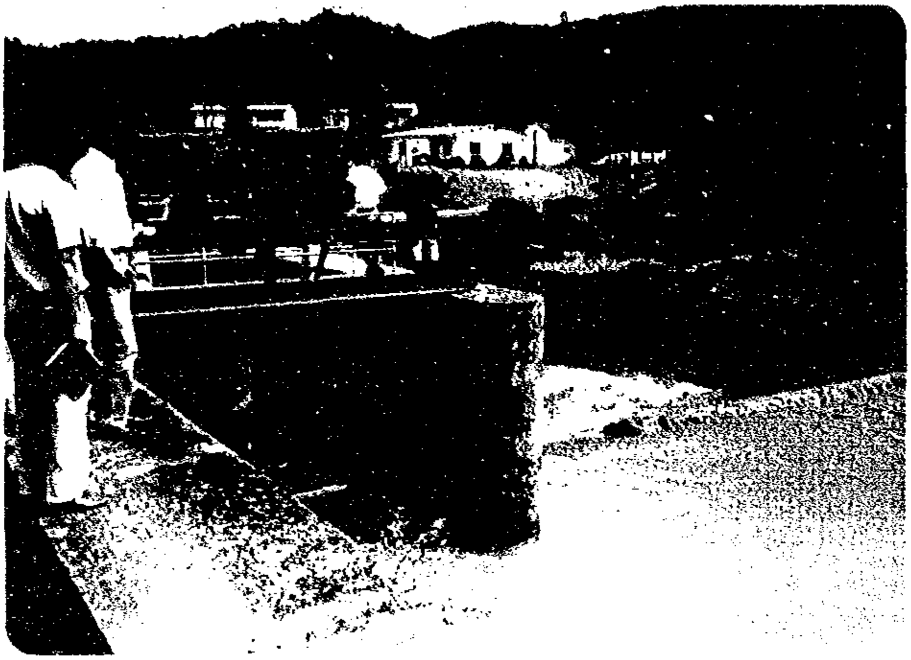


POLITICAL DIVISION IN THE REPUBLIC OF COLOMBIA

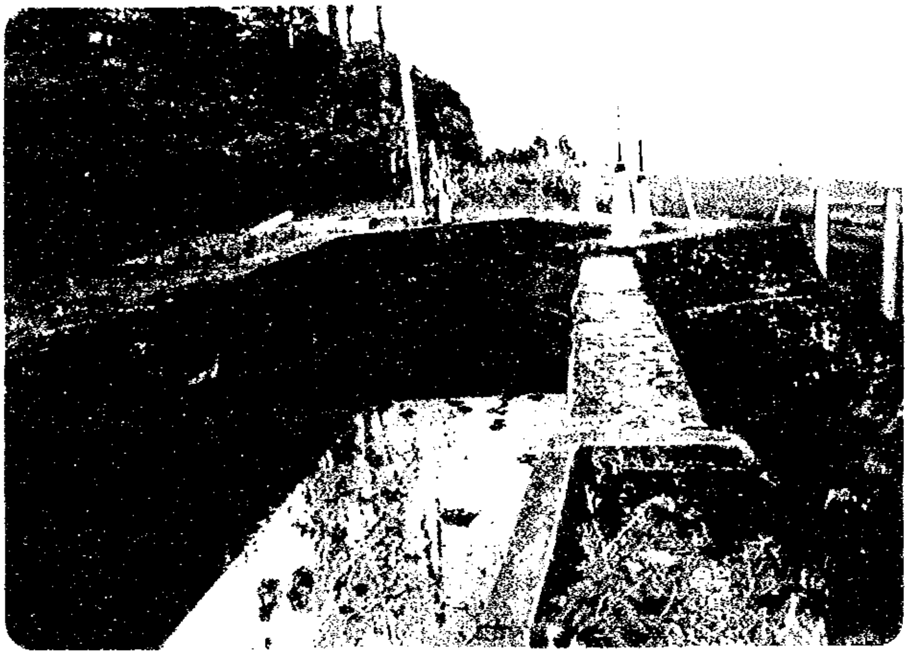




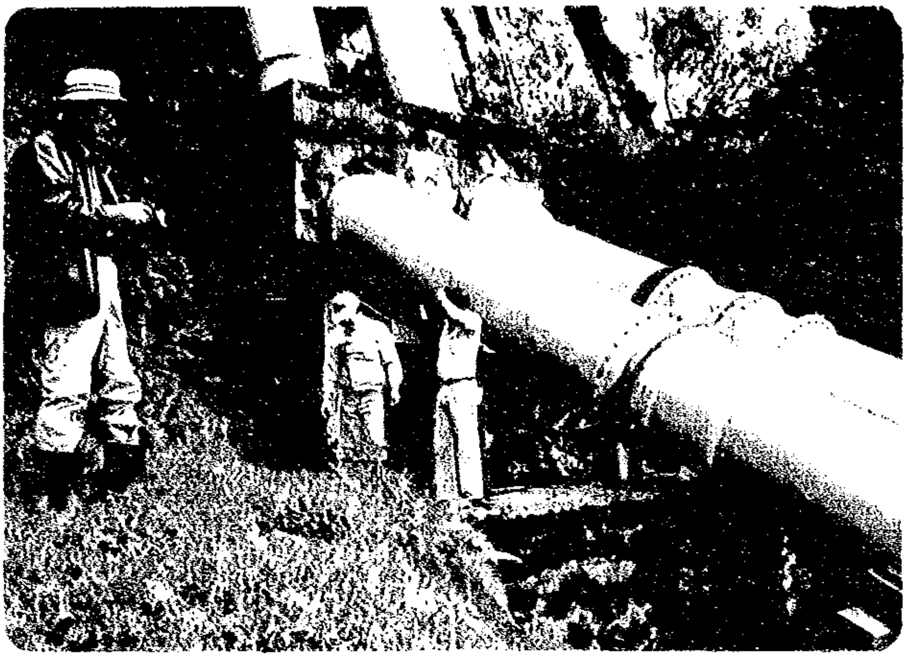
Location Map of Study Area



Rio Suarez and Intake



Head Tank



Penstock

CONTENTS

CHAPTER 1 INTRODUCTION

This power plant, owned by EBSA, is a run-of-the-river type (rated output: 1,280 kW) located along the Suarez River in Boyaca Department. Operation of this plant stopped in 1985 for rehabilitation of damage to the penstock caused when the anchoring block foundation of the penstock began to sink. Accordingly, the rehabilitation plan of this power plant calls for the recovering of the existing penstock.

Two Francis turbine units, with rated outputs of 640 kW each, were manufactured in 1950 and 1960. After 30 years of operation followed by five years of idleness since the penstock accident, inspection is deemed necessary.

The quality of the diversion weir, intake, 372-meter-long open channel and head tank structures is in good condition. However, the gate, valves, screens, and particularly the installed head tank have deteriorated and cannot be recovered.

CHAPTER 2 FIELD SURVEY

2.1 Organization of Study Team and Field Survey Schedule

Two field surveys were conducted at P. Guillermo P/P, as shown in Table 2.1.

In the first site reconnaissance, two civil engineers conducted the present-condition study of the existing facilities (mainly civil structures) and collected necessary data.

In the second field survey, a geologist and hydroelectric power generation planner gathered data relating to the geological survey.

Table 2.1 Field Survey Schedule

The first site reconnaissance

Date	Schedule	Detail of Study Item	Member	
			ICEL	JICA
Jan. 17	Bogota → Tunja	Discussion at EBSA, and data collection	R. Torres	Murao Toyama Yoshio Kawasaki
Jan. 18	Tunja → Chiquinquira	Field survey at P. Guillermo P/P		
Jan. 19		Discussion at CAR		
Jan. 20		Discussion at EBSA		

The second field survey

Date	Schedule	Detail of Study Item	Member	
			ICEL	JICA
July 6	Bogota → Tunja → Chiquinquira	Discussion at EBSA, and data collection	R. Torres	Yoshio Kawasaki Takashi Inoue
July 7		Field survey at P. Guillermo P/P		

2.2 Field Survey Work

The field survey work planned upon consultation between JICA Study Team and ICEL counterpart staff according to the results of the site reconnaissance includes topographic surveying and boring survey as described below.

(1) Scope of Topographic Surveying

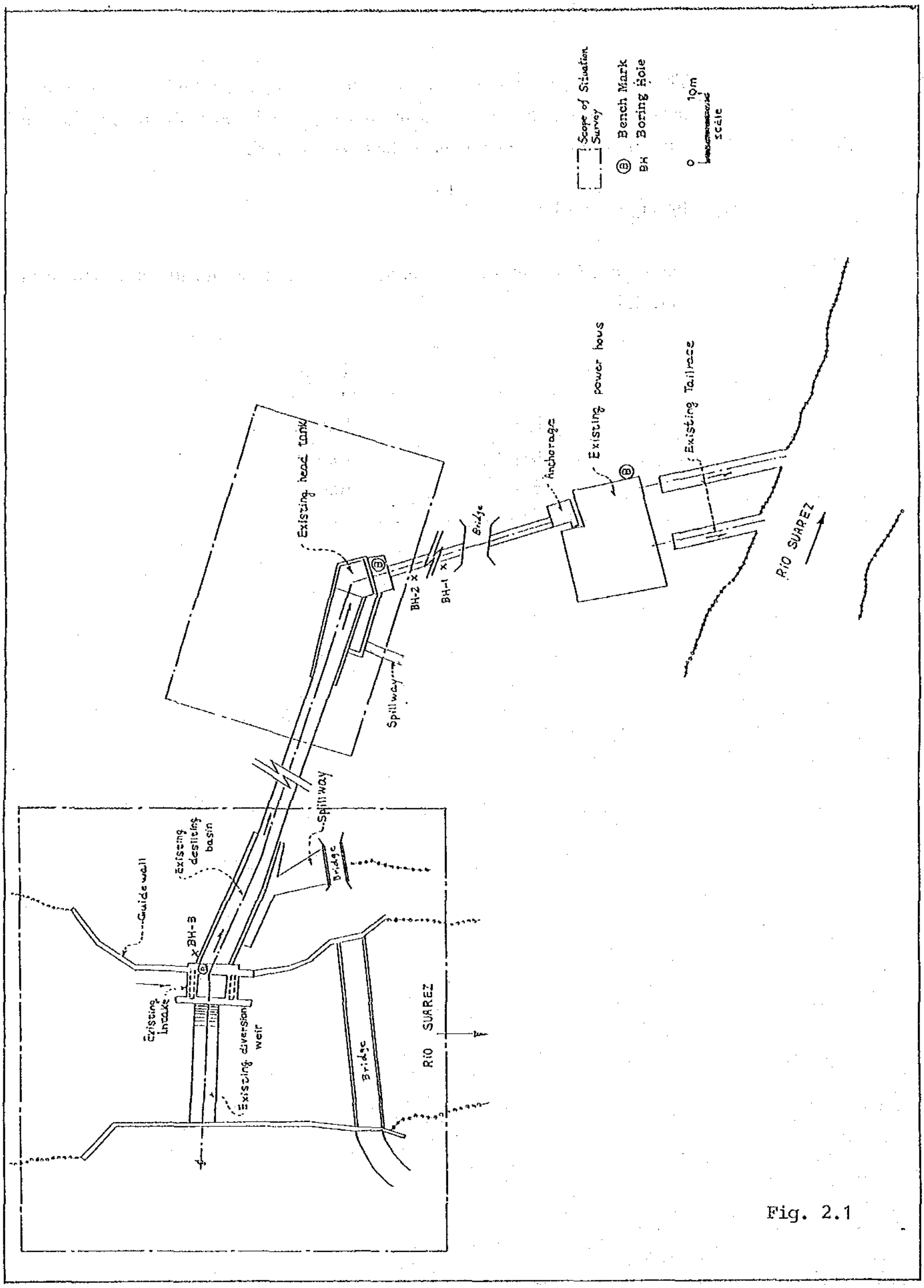
The scope of topographic surveying is shown in Figure 2.1. The scales for the topographic maps are as follows:

The existing diversion weir, desilting basin, head tank, penstock and powerhouse building were drawn on a scale of 1:200 with contour lines of 2 m. Bench marks were set up at the three locations.

(2) Boring Survey Plan

The core boring survey was conducted at the three locations as shown in Fig. 2.1.

	Depth
BH-1	12.5 m
BH-2	16.0 m
BH-3	10.0 m



Scope of Situation Survey
Ⓑ Bench Mark
BH Boring Hole
0
10m
scale
Existing power hous
Existing Tailrace
Anchorage
Bridge
Existing head tank
BH-2
BH-1
Spillway
RIO SUAREZ
Spillway
Existing desilting basin
Bridge
Guide wall
BH-3
Existing Intake
Existing diversion weir
Existing
Bridge
RIO SUAREZ

Fig. 2.1

2.3 Data Collection

The Study Team collected the following data during the field survey.

2.3.1 Topographic Maps

JICA Study Team collected the following topographic data.

- Topographic maps (scale: 1/25,000 - 1/400,000) published by IGAC
- Topographic survey maps that were actually measured by EBSA for the study of this power plant
- As-built drawings

(1) Topographic maps published by IGAC

Scale	Drawing No.	Description
1/400,000	-	the whole area of Boyaca Department
1/100,000	170	Power plant and vicinity
"	190	the upstream area of the power plant
1/ 25,000	170-N-A,B,C,D	Power plant and vicinity

(2) Topographic maps actually measured by EBSA

Scale	Drawing No.	Description
Variable	1	Plan and profile of conduction channel, detail of intake facilities
"	2	Plan and profile of penstock, plan of powerhouse building
1/50; 1/100	3	Sectional view of desilting basin, head tank and powerhouse building

(3) As-built drawings

Scale	Drawing No.	Description	
1/1000	610	General plan of generating facilities	
1/200	611	Longitudinal section of conduction channel	
H = 1/20 V = 1/20	612	Detailed longitudinal section of conduction channel	(1/2)
"	613	"	(2/2)
1/100	614	Transverse cross section of conduction channel	(1/2)
"	615	"	(2/2)
1/20, 1/100	616	Detail of intake facilities	
1/5 - 1/50	617	Detail of intake	
1/40	619	Detail of desilting basin	
1/50	620	Plan and cross section of aqueduct	
1/50	622	Structural drawing of head tank	
1/100	683	Plan and longitudinal section of penstock	(1/3)
1/100	684	"	(2/3)
1/100	685	"	(3/3)
1/50, 1/100	686	Penstock foundation drawing	
1/50	688	Powerhouse building structural drawing	
1/40	948	Detail of desilting basin	

2.3.2 Geologic Survey Data

Geologic survey data that was collected for this survey is as follows:

- Aerial photographs of this power plant and vicinity
- Estudio de Suelos Microcentral Hidroelectrica Puenta Guillermo, 1989, Lopez de Hermanos Ltda.

CHAPTER 3 OUTLINE OF THE STUDY AREA

The existing generating facilities, civil structures and topographical and geological conditions at P. Guillermo power plant site are summarized below:

3.1 Present Condition of Generating Facilities

Two horizontal shaft type Francis turbines, with rated output of 640 kW each, were installed. Operation of this plant stopped for more than 5 years because of damage to the penstock. According to a survey conducted by EBSA (as shown in the Survey Record in the attached appendix), no defects in the generating facilities were found. Accordingly, EBSA does not desire the rehabilitation of the generating facilities.

3.2 Present Condition of Civil Structures

(1) Intake facilities

The diversion weir is constructed of cobble-mixed concrete. Its length of overflowing crest, crest elevation and height are 18 m, 102 m and 7.50 m respectively. The foundation of the diversion weir is built on the bedrock. Piers are built at intervals of 1 m at the crest portion on the left bank. Water level at the intake can be adjusted by means of the wooden boards inserted between the piers.

The intake (4 m wide, 8 m long) are constructed on the left bank of the Suares River at a right angle to the river, which is connected to the desilting basin and the conduction channel for sand trap.

The dimensions of the intake entrance are 1.50 m wide and 1.50 m height. Two intakes are constructed in parallel with the river. Sill height of the intake entrance is 100 m. Two gates are installed in the intake. Two gates are installed in the sand trap located at the downstream edge of the intake. The dimensions of the sand trap are 1.50 m wide and 1.50 m high. Concrete quality of the intake facilities is in fairly good condition.

(2) Desilting basin

The desilting basin (3.50 m wide, 13.50 m long and 2.40 m deep) is built adjacent to the intake. Four sand trap gates for sand removal (0.50 m x 0.40 m) are installed on the right bank of the desilting basin.

The spillway is built adjacent to the sand trap at the downstream side. Its length of overflowing crest and crest elevation are 7.50 m and 101.10 m respectively. This spillway joins the channel for sand trap, and water is discharged into the river. Concrete quality of the desilting basin is in a fairly good condition.

(3) Conduction channel

The coduction channel is the open culvert type, and the total length, width, height and crest width of the conduction channel are 373 m, 1.10 m, 1.50 m and 3.10 m respectively. Its typical section is trapezoid. The conduction channel crosses over two streams via the aqueducts. Their length, width and height are 20 m, 1.90 m and 1.45 m respectively. The aqueduct has a rectangular section. Although cracks in some part of concrete structure of the aqueducts were visible, the aqueducts are in good condition.

(4) Head tank

The head tank has a rectangular section. Its width, length and depth are 4 m, approx. 10 m and 2.50 m respectively. The head tank is built at right angles to the conduction channel. Oe sand trap gate (1.00 x 1.00 m) is isntalled at the wall of the river side. A bend angle between the center line of the conduction channel and that of tunnel entrance to the penstock is 120 degrees.

The structure is built of cobble-mixed concrete. Although some part of the concrete peels off, the structure is in good condition.

(5) Penstock

Steel conduit pipes (diameter: 0.80 m) are laid to construct the penstocks in two rows, with a total length of 180 m. The penstocks are supported by five concrete blocks, concrete and saddles. The penstocks built upstream were damaged due to the deformed bedrock.

(6) Powerhouse building and tailrace

The dimensions of the powerhouse building are 16.5 x 13.5 m. Its floor elevation is 36.45 m. There are two tailraces. Section of the tailrace is 2.50 (W) x 1.10 (H) m. Channel length is 15 m and 22 m respectively. The channel is the cascade-type. Foundation of equipment and tailrace is in good condition. Although the building was built 30 years ago, it is in good condition.

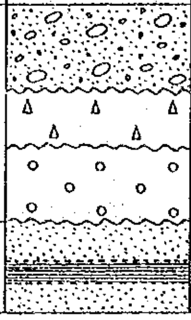
3.3 Present Condition of Topography and Geology

3.3.1 Topography and Geology in the Area

The Suarez River originates from the east mountain range, located 50 km north-east of Bogota City and flows north-east, joining the Sogamoso River, the right tributary of the Magdanera River 40 km southwest of Bucaramanga, the capital of Santander Department. The project site is located upstream of the Suarez River and the surrounding topography includes a wide valley with a gentle slope to the summit, with 20 to 50 m high cliffs visible.

The bedrock consists of alternating layers (sandstone-rich layers) of cretaceous sandstone and mudstone, topped with debris flow and riverbed deposits. The stratigraphy of the project site is detailed in Table 6.1.

Table 6.1 Stratigraphy of Project Site Area

Age	Schematic column	Strata	Remarks
Quaternary period		Debris flow deposits	
		Talus deposits	
		Terrace deposits	
Cretaceous period		Fine-grained sandstone Mudstone	

The bedding consists of slightly rolling layers, and runs to the northwest, gently sloping southward by 3 - 8 degrees. No significant scale faults are detected. From aerial photographs, the contour extends northwest along the cliffs beneath the head tank, while upstream from the contour, another cliff, runs east to west with no observable faults.

3.3.2 Geology of the Project Site

The geology of the foundation of the structures at the project site is explained below.

1) Diversion weir and desilting basin

No outcrops are visible around the diversion weir or desilting basin, and debris flow deposits (riverbed deposit), including clumps of sandstone are distributed over the area.

2) Headrace and penstock

Excluding two marshes, the headrace is built on the bedrock. The penstock is grounded in the talus deposits formed in the foundation of the marsh, except under the cliff section beneath the head tank.

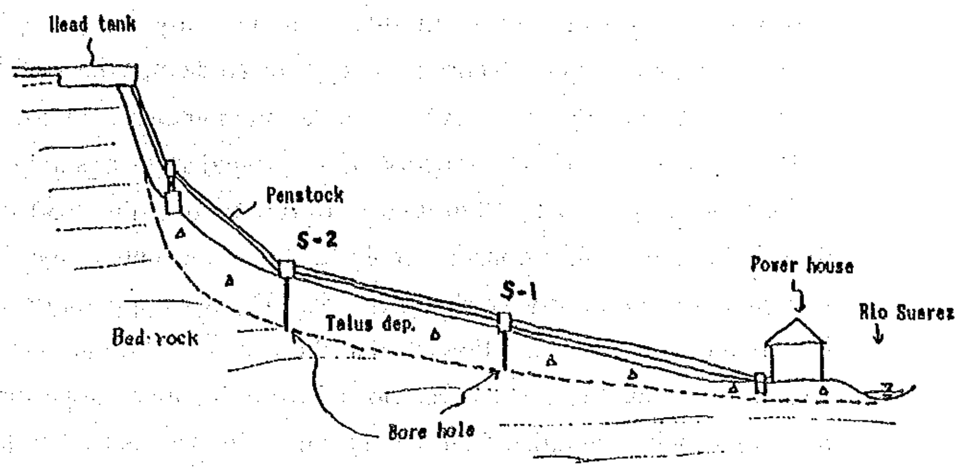


Fig. 3.1 Schematic Geological Profile

3) Head tank

The head tank is located on the cliff directly on sandstone-rich layers.

4) Powerhouse

No exposed bedrock has been observed in proximity to the powerhouse building, and debris flow deposit, including clumps of sandstone and talus deposits are distributed over the area. It is presumed from outcrop condition in that area the powerhouse building is not located on the bedrock.

3.3.3 Geotechnical Evaluation

1) The new layers of the project site bedrock, consisting of cretaceous sandstone and mudstone, are extremely dense, and thus has sufficient bearing capacity and impermeability for constructing the foundations of a concrete dam, not exceeding 10 m in height, and other related structures.

2) Although talus deposits, including clumps of sandstone, are widely distributed in the lower section of the cliff, the loose matrix reduces the bearing capacity, making it unsuitable for constructing a foundation.

3) Part of the talus deposit of the penstock foundation has slipped. There are no observable "landslide scars" in this area, nor any history of landslide occurrences for this area. A boring survey showed the thickness of debris to be over 30 m, with many stones over one meter in diameter. The location of the slide surface is unclear. Deformation of the ground surface is only visible in a vicinity of the penstock, 10 m wide and 100 m from the head of the talus deposit through the third foundation block. Thus, the depth of the slide surface is assumed to be relatively shallow. The slide was apparently a localized landslide caused by debris flowing into the penstock through the conduction channel and tank. The water was flowed from the upper slope through talus deposits which accumulated on the bottom of the penstock, and the resulting rise of the groundwater level caused an increase in water pressure against the talus deposits, resulting in the landslide.

4) Although large-scale landslides have not been observed in the vicinity of the project site, one relatively new cave-in was noted on the cliff in the east to west direction upstream from the project site. An overhung section is visible in part of the site, and measurements need to be implemented to ensure long-term stability.

3.3.4 Geological Problems

Proper countermeasures for protecting the penstock foundation against landslide include building the penstock foundation on the bedrock using piles, and lowering the groundwater level as far as possible.

CHAPTER 4 CAUSE ANALYSIS OF PENSTOCK DAMAGE

To resolve the cause of damage to the penstock and its foundation, the results of the bedrock survey and the forces exerted on the anchor blocks were examined.

4.1 Present Condition

If the locations of the damaged penstock were marked on the as-built drawing prepared in 1955, and the cause of damage was investigated according to the geological survey data, there were problems explained below:

(1) All of the foundation of the pipeline between No. 2 anchor block and power plant is built on talus.

(2) Talus is distributed at deeper places (where the bedrock is not discovered). The characteristics of the bedrock deformation (the amount of deformation to the compressive force) are not resolved.

(3) Fluctuations in the underground level are not confirmed. If the underground level fluctuates, the compressive force also fluctuates, influencing the deformation of the bedrock where the pipeline are laid. If the underground level drops by 1 m, the effective stress of 1 ton/m^2 increases at the bedrock.

(4) No.1 anchor block at the entrance of the penstock is not erected on the bedrock, and is not sufficient for the structure foundation.

(5) The depth of footing base for the anchor block is not sufficient.

4.2 Soil Properties of the Bedrock

According to the results of soil test results of core boring samplings collected at BH-1 and BH-2, properties of the bedrock can be obtained as follows:

(1) Natural water content, consistency index and silt fraction 0.075 mm content

The relationship among the core boring depth, natural water content, consistency index and silt fraction 0.075 mm content is shown in Fig. 4.1. From this figure, the following can be understood.

- Natural water content from the ground surface to a depth of 4.0 m greatly fluctuates, but is gradually close to 20% (16-24%) at deeper places.

- Elevation difference at boreholes of BH-1 and BH-2 is approximately 16 m. Difference in water content of the same depth at a depth of 8 m from the ground surface is 4-10%. The value of water content at BH-1 (lower elevation) is small.

- Natural water content is close to plastic limit or has a lower value.

- The value of consistency index at the ground surface is small, but is greater than 1.0. According to Terzaghi* formula, unconfined compression strength (qu) of undisturbed sample ranges from 1 to 5 kg/cm^2.

  * Terzaghi, K. and Peck, R. B. "Soil Mechanics in Engineering Practice" John Wiley & Sons Inc.

- Grain-size distribution of the bedrock is silt fraction 0.075 mm content, and on average 70%. It ranges from 60 to 80%. Grain size of No.1 at a depth of more than 4.0 m at BH-1 and BH-2 is coarse.

(2) N value

Fig. 4.2 shows the relationship between the depth and N value. From this figure, the relationship between the bedrock depth and N value can be obtained below:

Depth (m)	N value
4-9	10
9-16	20

(3) Unconfined compression strength

Fig. 4.3 shows the relationship between the depth and unconfined compression strength. From this figure, the relationship between the bedrock depth and unconfined compression strength can be found below:

Depth (m)	Unconfined compression strength*, qu (kg/cm^2)
4-9	1.0
9-16	1.5

* The value of Pocket Penetrometer was not used.

As compared with the estimated value of consistency index (Ic), the above values are in near agreement.

From the above, the properties of the bedrock are summarized below:

Table 4.1 Soil Properties at the Bedrock of Penstock

Depth (m)		4 - 9	9 - 16
Unit volume weight (ton/m^3) Wet		2.0	2.0
Dry	No.1	1.75	1.80
	No.2	1.60	1.60
Unconfined compression strength, qu (kg/cm^2)		1.0	1.50
C = qu/2		0.50	0.75
ø		0	0

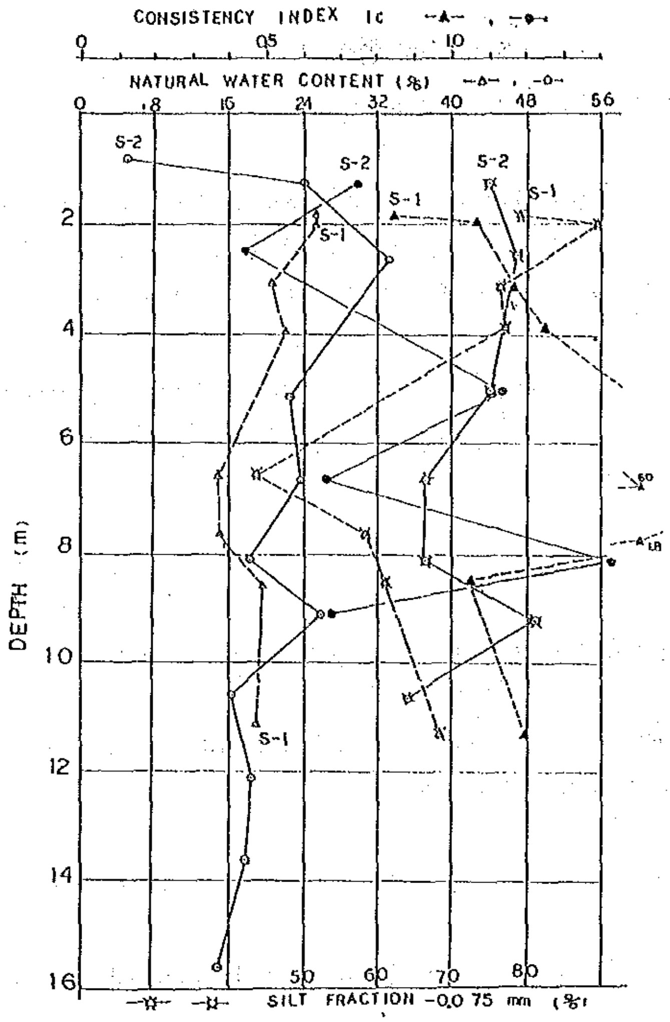


Fig. 4.1 Depth, Natural Water Content, Consistency Index and Silt Fraction 0.075 mm Content

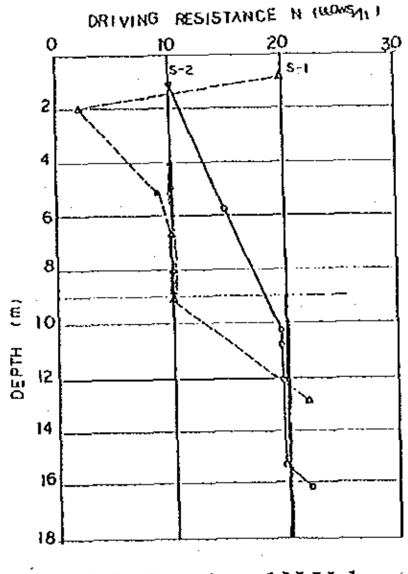


Fig. 4.2 Depth and N Value

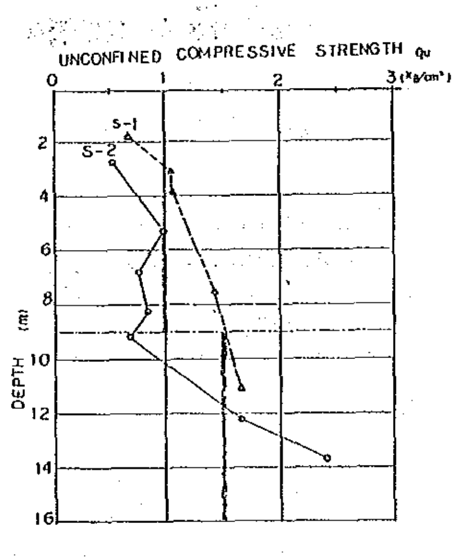


Fig. 4.3 Depth and Unconfined Compression Strength

4.3 Ultimate Bearing Capacity

There are a variety of methods for obtaining ultimate bearing capacity. N value which is determined from the experience and Terzaghi's formula (using the solid test results) are used.

$$QD = B\,(CNc + \gamma DfNq + \frac{1}{2}\gamma.B.Nr)$$

$$qa = QD/FS$$

where:

QD	=	ultimate bearing capacity (per unit length) (t/m)
B	=	footing base width (m)
Df	=	depth from ground surface (m)
C	=	cohesion (t/m^2)
γ	=	unit weight of bedrock (t/m^3)
F.S	=	safety factor, 3
Nc , Nq, Nr	=	bearing capacity factors (determined according to angle of shearing resistance, ϕ)
qa	=	allowable pressure (t/m^2)

Assuming a footing base is placed on the layer at a depth of 4 m below the ground surface, the values of the bearing capacity of No.2 and No.3 anchor blocks according to Terzaghi's formula are given below:

	No.2 anchor block	No.3 anchor block
QD (t/m)	53	53
$qa = \frac{QD}{3}$ (t/m)	18	18

4.4 Study of Forces Acting on Anchor Block

Forces such as resultant forces, pipe's own weight, weight of water inside the pipe act on the bent penstock. External forces exerted on the anchor block of the penstock are as follows:

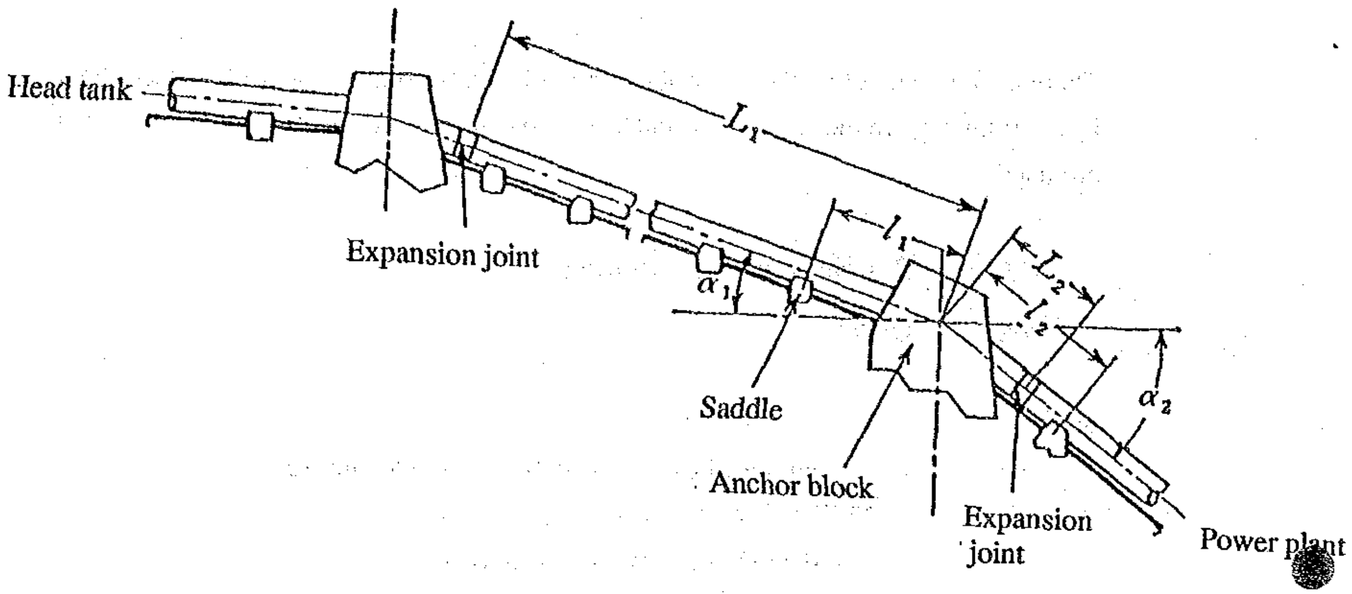


Fig. 4.4 Longitudinal Section of Penstock

(1) Formulas

Formulas are given below:

(a) Thrust generated by the inclined pipe

- Resultant force in the vertical direction to the pipe axis

Force due to dead weight of pipe on the upstream side

$$W_1 = \frac{1}{2}(W_1 + S_1)\ell_1 \cos \alpha_1$$

Force due to dead weight of pipe on the downstream side

$$W_2 = \frac{1}{2}(W_2 + S_2)\ell_2 \cos \alpha_2$$

- Resultant force in the direction of the pipe axis

Force due to dead weight of pipe on the upstream side

$$T_1 = S_1 L_1 \sin\alpha_1 \pm C(W_1 + S_1)(L_1 - \frac{\ell_1}{2}) \cos\alpha_1$$

Force due to dead weight of pipe on the downstream side

$$T_2 = S_2 L_2 \sin\alpha_2 \mp C(W_2 + S_2)(L_2 - \frac{\ell_2}{2}) \cos\alpha_2$$

(b) Thrust generated by friction of water flowing through the pipe

Force due to dead weight of pipe on the upstream side

$$P_1 = \frac{2fQ^2}{g\pi D_1^3} L_1$$

Force due to dead weight of pipe on the downstream side

$$P_2 = \frac{2fQ^2}{g\pi D_2^3} L_2$$

(c) Centrifugal force acting on the bet pipe

$$P_3 = \frac{2V^2}{g} A \sin\frac{\varphi}{2}$$

(d) Resultant force due to bend in pipe with water flowing

$$P_4 = 2HA \sin\frac{\varphi}{2}$$

(e) Thrust by internal pressure in the direction of pipe axis acting on the gradual contraction pipe

$$P_5 = H (A_1 - A_2)$$

Where:

α_1 = angle of intersection between the center line and horizontal line of pipe on the upstream side

α_2 = angle of intersection between the center line and horizontal line of pipe on the downstream side

ℓ_1 = distance between the anchor block and anchor block on the upstream side (m)

ℓ_2 = distance between the anchor block and anchorblock on the downstream side (m)

L_1 = distance between the anchor block and expansion joint on the upstream side (m)

L_2 = distance between the anchor block and expansion joint on the downstream side (m)

S_1 = weight per 1 m of penstock on the upstream side = $\pi D_1 \cdot t \cdot \gamma$ (t)

S_2 = weight per 2 m of penstock on the upstream side = $\pi D_2 \cdot t \cdot \gamma$ (t)

W_1 = weight of water inside the pipe per 1 m of penstock on the upstream side = $\frac{\pi}{4} \cdot D_1^2$ (t)

W_2 = weight of water inside the pipe per 1 m of penstock on the downstream side = $\frac{\pi}{4} \cdot D_2^2$ (t)

D = inside diameter of the pipe (m)

t = wall thickness of the pipe (m)

γ = specific gravity of steel (= 7.85)

C = friction coefficient of anchor block

φ = central angle of bent pipe (degree)

A = cross section area of the pipe (m^2)

Q = rate of discharge inside the pipe (m^3/sec)

f = friction coefficient of water flow inside the pipe (0.02)

(2) Calculation results

The results of the overturning, sliding and vertical normal stress at No.2 and No.3 anchor blocks caused by forces exerted by the penstock are given below:

		No.2 anchor block	No.3 anchor block
Overturning		in the middle third one	in the middle third one
Sliding (horizontal force) (t)	Normal condition	1.0	4.9
	During earthquake	2.3	7.7
Vertical normal stress (t/m)	Normal condition	10	12
	During earthquake	13	14

4.5 General Consideration

Assuming the soil at a depth of 4 m below the ground surface is used as a supporting layer, the bearing capacity of the bedrock for No.2 and No.3 anchor blocks and sliding coefficient are safe, as explained below:

(1) A line of action of the resultant forces on the anchor blocks lies at the middle third.

(2) Frictional forces to the sliding between the anchor block and the bedrock are expected to be approximately 12 tons, assuming the sliding coefficient is 0.35. Horizontal forces acting on No.2 and No.3 anchor blocks at the time of earthquake are 2 tons and 8 tons respectively; the sliding is satisfactory.

(3) Allowable pressure is 18 tons/m. Vertical normal stresses acting on No.2 and No.3 anchor blocks at the time of earthquake are 13 tons/m and 14 tons/m respectively. These are almost satisfactory.

Even if it is stable in terms of mechanics, the influence of non-uniform settlement by displacement is considered. However, since the survey data and information on displacement are not available, the Study Team does not make mention of the influence by displacement. Since the anchor blocks of the penstocks are built on talus deposit, water leaks from the penstock, the rainwater enters the pipe and the underground water level lying at talus deposit (which forms the bedrock) increases. As a result, small-scale landsliding occurs, which is considered to be the cause of damage to the penstock.

CHAPTER 5 REHABILITATION DESIGN OF HEAD TANK AND PENSTOCK

In conducting the rehabilitation design of the head tank and penstock, the following design standards were established for respective civil structures.

(1) The maximum available discharge shall be Q = 2.6 0 m^3/s, which is the same as the existing one.

(2) The head tank shall be reconstructed to match the layout of the penstocks, and the storage capacity of the reconstructed head tank shall be equivalent to a 2-minute capacity of the maximum available discharge.

(3) Penstocks in two rows (diameter: 800 mm), which are the same as the existing ones, shall be laid.

5.1 Design of the Head Tank

Dimensions of the head tank are 11.00 m (W), 6.00 m (L) and 6.10 m (D). Spillways shall be constructed at two places. Their effective length of crest, crest elevation and crest depth are 6.00 m, 95.00 m and 0.25 m respectively. Discharge at crest (2.60 m^3/s) flows into the existing two spillways (0.8 m), and the overflowing water is discharged into the river. The sand removal channel is connected from the sand removal pipe (diameter: 0.50 m) to the existing spillways.

The angle between the center line of the entrance to the penstock at the head tank and that of the channel shall be 120 degrees. Design drawings for the head tank rehabilitation are included in Drawing PG-C-02 and PG-C-03.

5.2 Design of Penstock

Steel conduit pipelines (diameter: 800 mm, length: 183 m) in two rows will be laid at the places which are the same as the existing. Design drawings of the penstocks are included in Drawing PG-C-03 and PG-C-04.

Damage to the penstocks is caused by non-uniform settlement at the anchor blocks or insufficient depth of footing base up to the bedrock of the anchor blocks. Judging from the existing survey data, the relationship between the compression stress and displacement is not clear, but if the footing bases for the anchor blocks are placed in the ground at a depth of 4 m below the present ground surface, these bases will be stable.

The structure of No.1 and No.2 anchor blocks is changed so that the steel conduit pipes are built on the place where is dug and concrete-lined at the front side of cliff. The remaining three anchor blocks installed downstream will be built on talus, which is the same as the existing ones. Excavation depth of the footing bases shall be 4 m from the ground surface. Saddle-type shall be applied to support the pipes. Two gates, screen (width: 3.5 m, height: 6.8 m) will be constructed at the entrance of the penstock.

5.3 Specifications for Gates and Valves

A summary of new gates and valves, which will be installed in connection with the rehabilitation fo head tank and penstock, is shown in the following table.

	Regulating gate	Screen	Sand-flush gate
Use	Water intake for penstock	Dust removal at head tank	Head tank sand removal
Type	Steel, sluice gate	Fixed type	Steel, sluice gate
Width x height	1.1 x 1.1 m, 2 gates	3.5 x 6.8 m	1.0 x 1.0 m
Design depth	10 m	-	10 m
Stopwater method	Reverse 4 direct	Rack spacing: 100 mm	Reverse 4 direct
Starting method	Spindle	-	Spindle
Hoisting device	Engine or manual	-	Manual
Lifting speed	0.1 m/min.	Gradient 1:0.3	-
Lifting torque	10 kg	-	-
Life	2 m	-	2 m
Material weight	Gates 0.7 ton Hoist 0.7 ton	4.3 ton	Gate 1.0 ton

5.4 Estimation of Rehabilitation Work Cost

The unit prices for construction work decided by EADE and other five companies were multiplied by the quantities of work for improvement or reconstruction of civil structures, and the civil construction costs were estimated on the local currency base.

(1) Head tank improvement work

Description	Unit	Quantity	Rate (pesos)	Estimated Amount (pesos)	Remarks
Earthwork	m^3	800	2,400	1,920,000	
Concrete Work	m^3	270	27,000	7,290,000	
Reinforcing Bar	t	22	350,000	7,700,000	80 kg/m^3
Gate	t	1.4	1,100,000	1,540,000	
Screen	t	4.3	1,000,000	4,300,000	180 kg/m^2
Concrete Demolition	m^3	170	10,000	1,700,000	
Shotcreat t = 110	m^2	-			
Sub Total				24,450,000	x 1.30 = 31,785,000

(2) Penstock rehabilitation work

Description	Unit	Quantity	Rate (pesos)	Estimated Amount (pesos)	Remarks
Earthwork	m^3	500	2,400	1,200,000	
Concrete Work	m^3	360	27,000	9,720,000	
Reinforcing Bar	t	22	350,000	7,700,000	60 kg/m^3
Penstock	t	43	1,000,000	43,000,000	
Concrete Demolition	m^3	70	10,000	700,000	
Sub Total				62,320,000	x 1.3 = 81,016,000

(3) Other related construction

Description	Unit	Quantity	Rate (pesos)	Estimated Amount (pesos)	Remarks
Incline				7,000,000	
Cable Way				4,000,000	
Access Road				5,000,000	
Sub Total				16,000,000	x 1.3 = 20,800,000

(4) Total rehabilitation work cost (10,000 pesos)

①	Direct construction cost	
	Head tank construction	31,785
	Penstock construction	81,016
	Other construction	20,800
	Subtotal	133,601
②	Contingency (① x 15%)	20,040
③	Engineering fees (①+ ②) x 10%	15,364
	Total	169,005

5.5 Execution Plan

5.5.1 Study of Conditions for Execution of Work

Operation of P. Guillermo P/P has stopped, and there are no restrctions affecting the progress of the rehabilitation plan. Water rights will not been acquired for other purposes or fisheries. Site for construction of the head tank has been acquired.

5.5.2 Access Road for Construction

The existing road can be used as an access road necessary for the rehabilitation work.

There is a road branching from Bogota-Barbosa Road and leading from the intake to P. Guillermo P/P. There is a flat site along the conduction channel which can be used as a road leading to the head tank construction site. However, people must make a detour of a valley at the aqueduct, or a bridge must be constructe.d

5.5.3 Temporary Facilities for Construction

Main temporary facilities for construction are as follows:

- Excavation equipment
- Concrete equipment
- Cable way equipment
- Incline equipment

(1) Excavation equipment

Excavation will be performed at the places between the head tank construction site and No.2 anchor block for the penstock. The presence of conglomerate will be estimated at the excavation section between No.2 anchor block and the power plant site.

Rocks will be excavated using two sinkas (air consumption: 2.0 m^3/min., weight: 14 kg) and one compressor (portable type, 5 m^3/min., delivery pressure: 7 kg/cm^2, weight: 1 ton).

(2) Concrete equipment

Concrete will be placed using one mixer (0.5 m^3). Concrete aggregates will be produced using terrace deposits. Cement and reinforcing bars will be available from Chiquinquira City.

(3) Cable way equipment

Cable way will be provided in parallel with the penstocks, the working efficiency will be improved by simultaneous operation of the incline equipment.

(4) Incline equipment

Incline equipment will be provided at the sloped face of the penstocks to place concrete for the penstocks, transport and lay the steel conduit pipes. Trolleys shall be run on the rail.

Construction Period

		1st Year												2nd Year												3rd Year											
		1	2	3	4	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	31	32	33	34	35	36
Intake Facilities	Removal work																																				
	Earthwork																																				
	Concrete																																				
	Gate, screen																																				
	Slope protection work																																				
Desilting Basin	Removal work																																				
	Earthwork																																				
	Concrete																																				
	Gate, screen																																				
Channel	Removal work																																				
	Earthwork																																				
	Concrete																																				
Head Tank	Removal work																																				
	Earthwork																																				
	Concrete																																				
	Gate, screen										M		Tr	I																							
	Slope protection work																																				
	Concrete demolition																																				
Penstock	Removal work																																				
	Earthwork																																				
	Concrete																																				
	Piping												M		Tr			I		T																	
	Concrete demolition																																				
Powerhouse	Removal work																																				
	Site grading work																																				
	Foundation-earthwork																																				
	Foundation-concrete																																				
	Building																																				
	Equipment																																				
Tailrace	Earthwork																																				
	Concrete																																				
Substation	Earthwork																																				
	Concrete																																				
	Equipment																																				
Preparatory work	Access road																																				
	Incline facilities																																				
	Cableway equipment																																				

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

CHAPTER 6 RECOMMENDATIONS TOWARD IMPLEMENTATION OF THE REHABILITATION PLAN

For the implementation of the rehabilitation plan, the following items should be considered at the stage from the feasibility study stage to the basic design and detailed design.

(1) In addition to the boring survey (BH-1 and BH -2) conducted, two boreholes (BH-4 and BH-5), as shown in Fig. 7.1, will be provided.

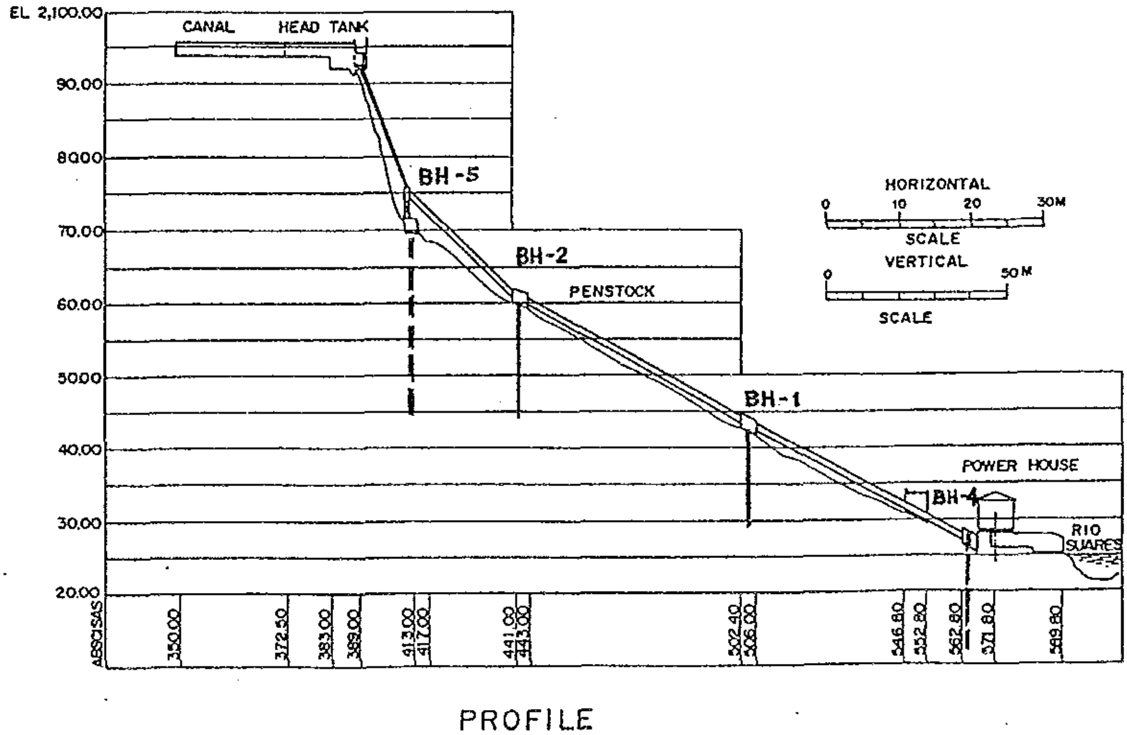


Fig. 7.1 Additional Boring Survey Plan

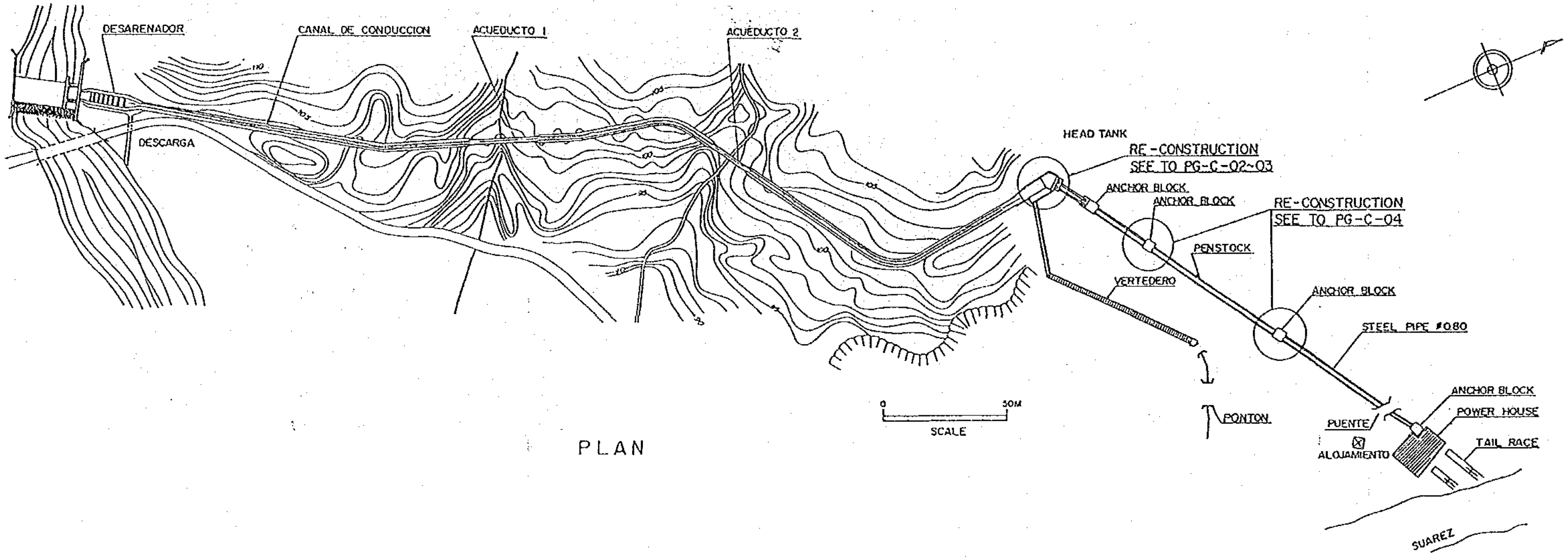
(2) Physical properties (using undisturbed samples), unconfined compression, triaxial shear, consolidation tests will be conducted using the boring core to obtain the design properties for the bearing capacity, stability and consolidation settlement.

(3) Fluctuations in underground water level will be continuously observed through the boreholes.

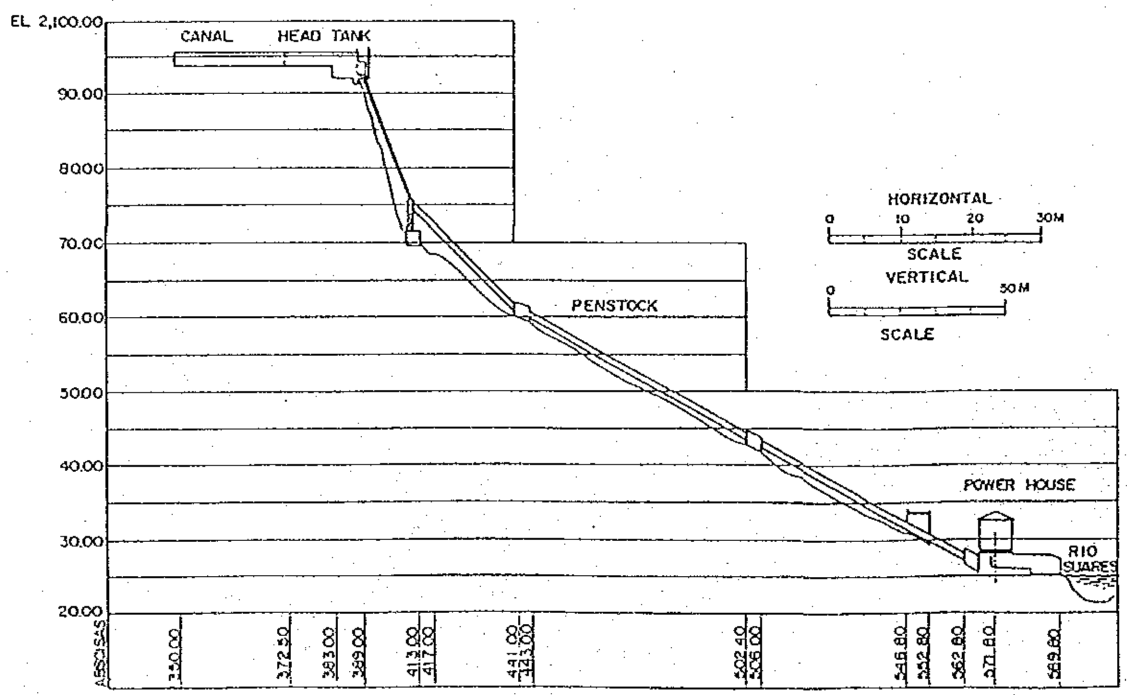
(4) Flexible expansion joints which absorb expansion, bend, eccentricity and twist will be used to prevent any displacement of the steel conduit pipes.

Drawings

Title	Drawing No.
General Plan and Profile of Existing Plant	PG-C-01
Head Tank, Plan	PG-C-02
Head Tank, Sections	PG-C-03
Penstock Plan and Sections	PG-C-04
Geological Plan and Profile	PG-G-01



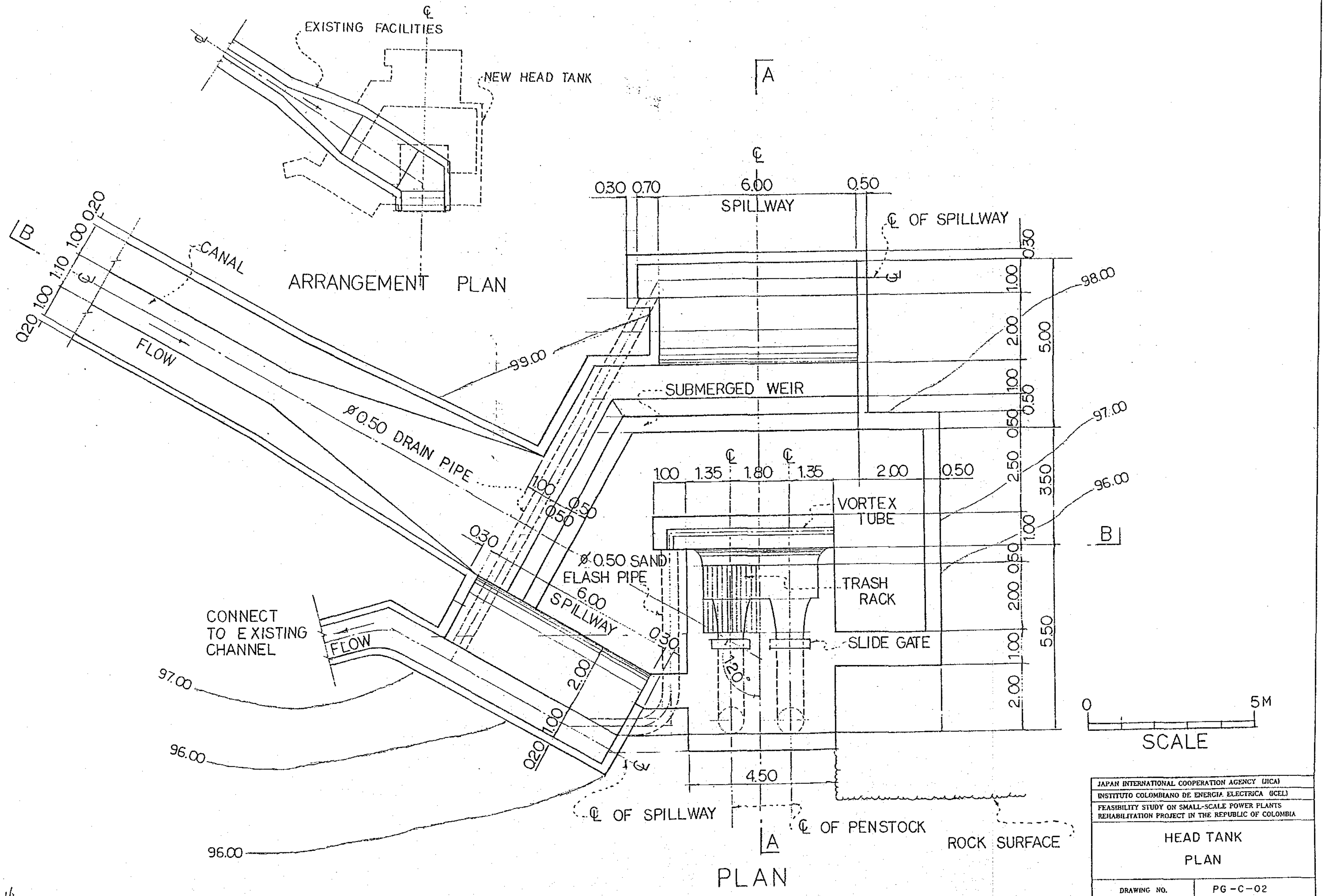
PLAN



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
EXISTING PLANT GENERAL PLAN, AND PROFILE
DRAWING NO. PG-C-01
SCALE   DATE

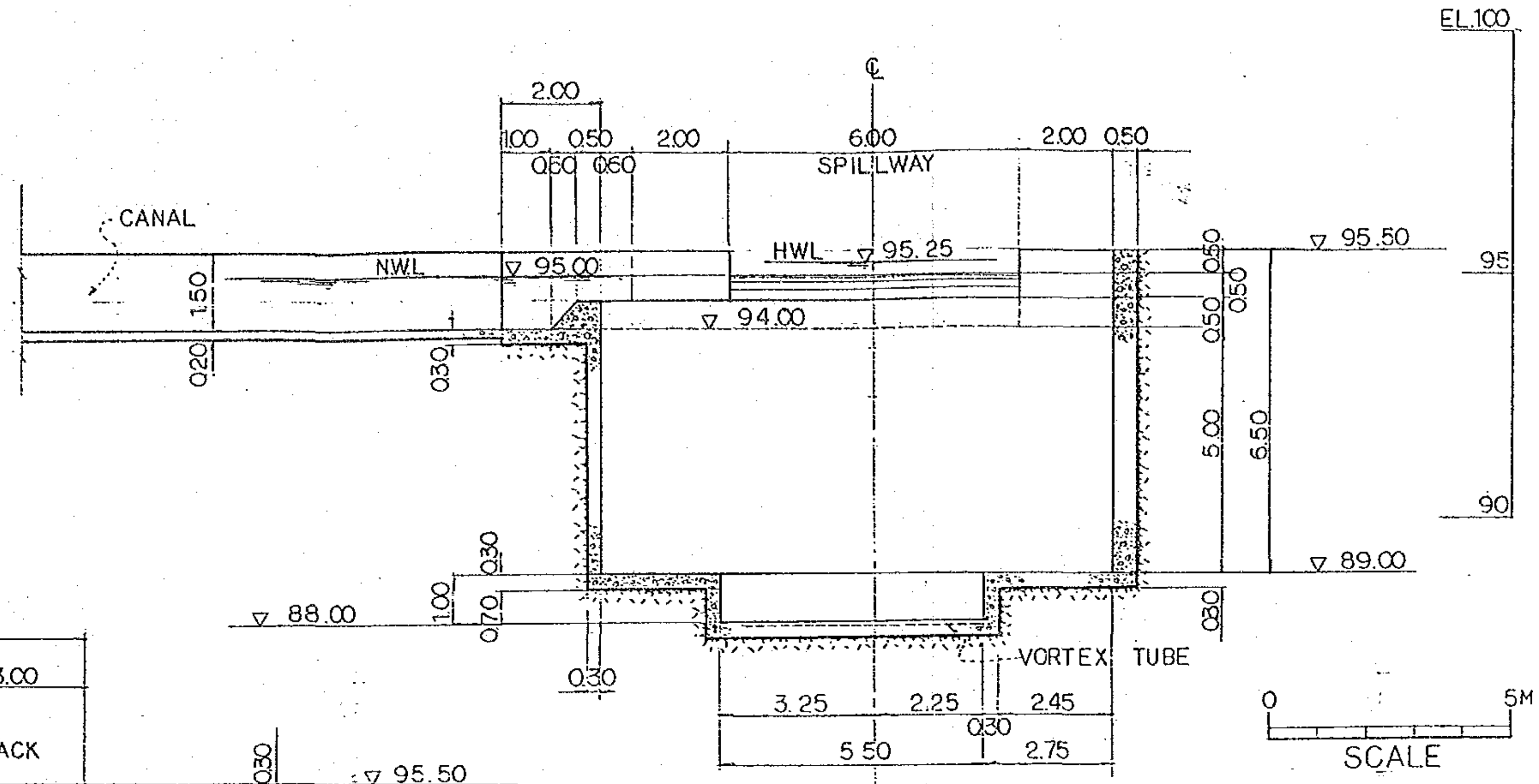
5-2-3



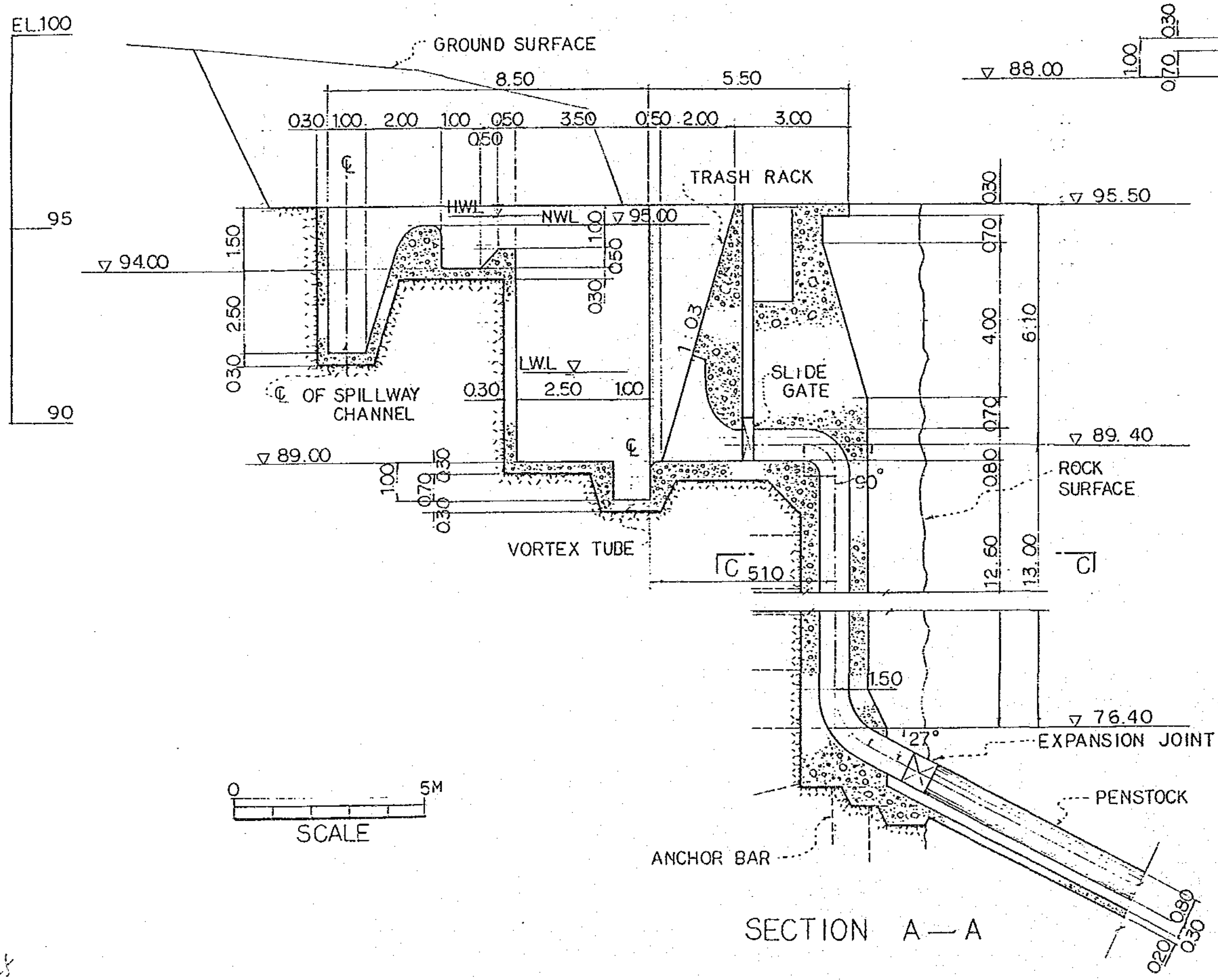
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA

HEAD TANK
PLAN

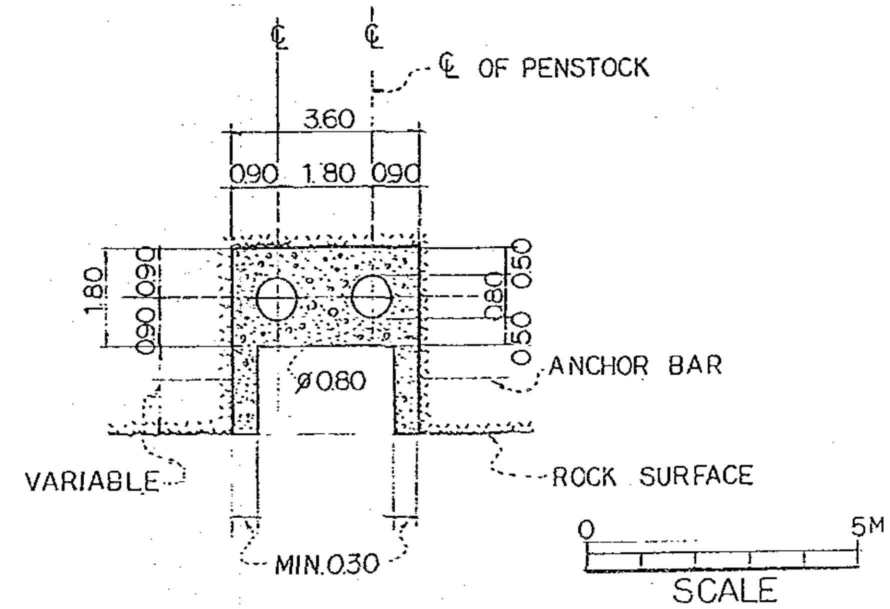
DRAWING NO.	PG-C-02
SCALE	DATE



SECTION B — B



SECTION A — A

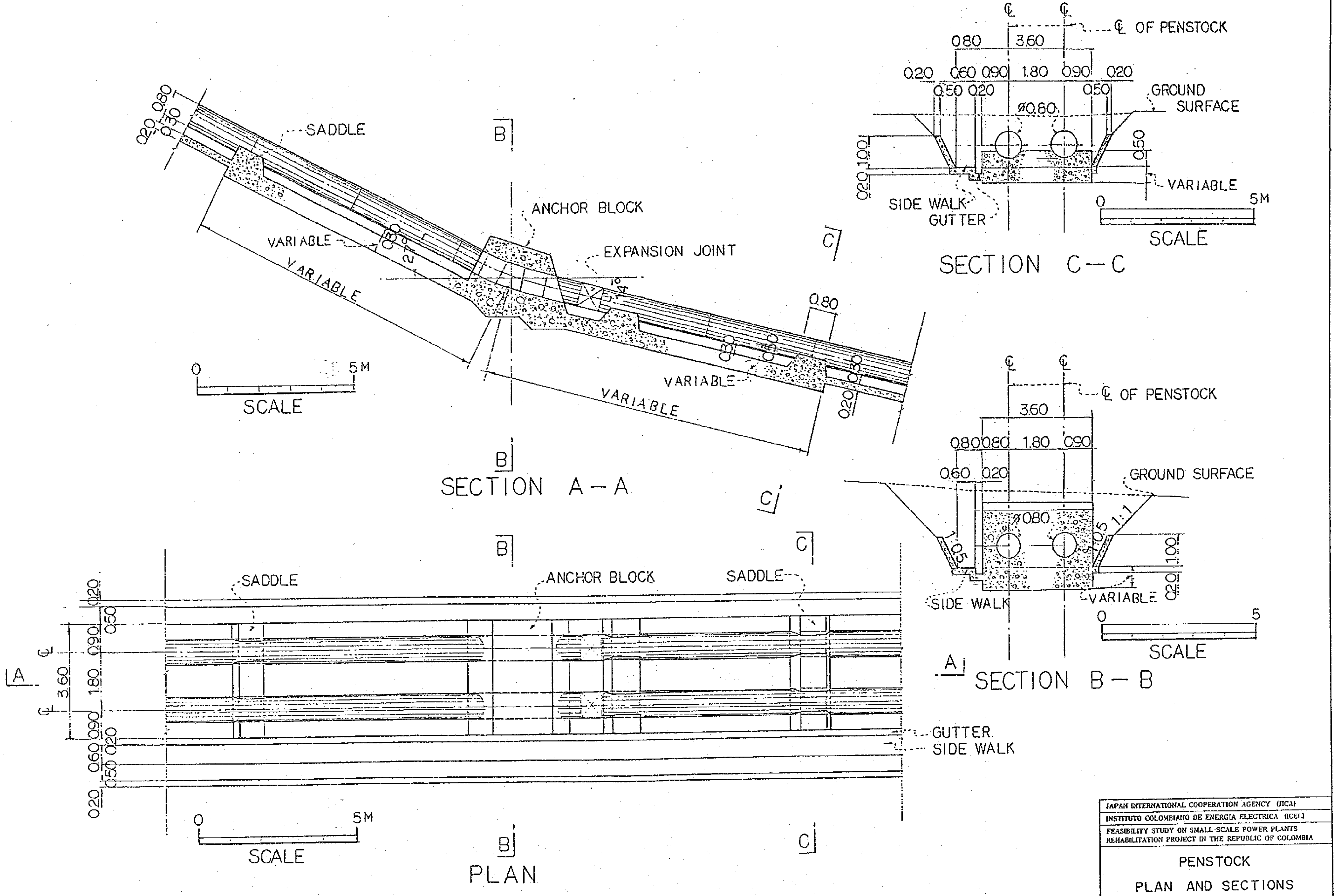


SECTION C — C

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

HEAD TANK
SECTIONS

DRAWING NO.	PG—C—03
SCALE	DATE

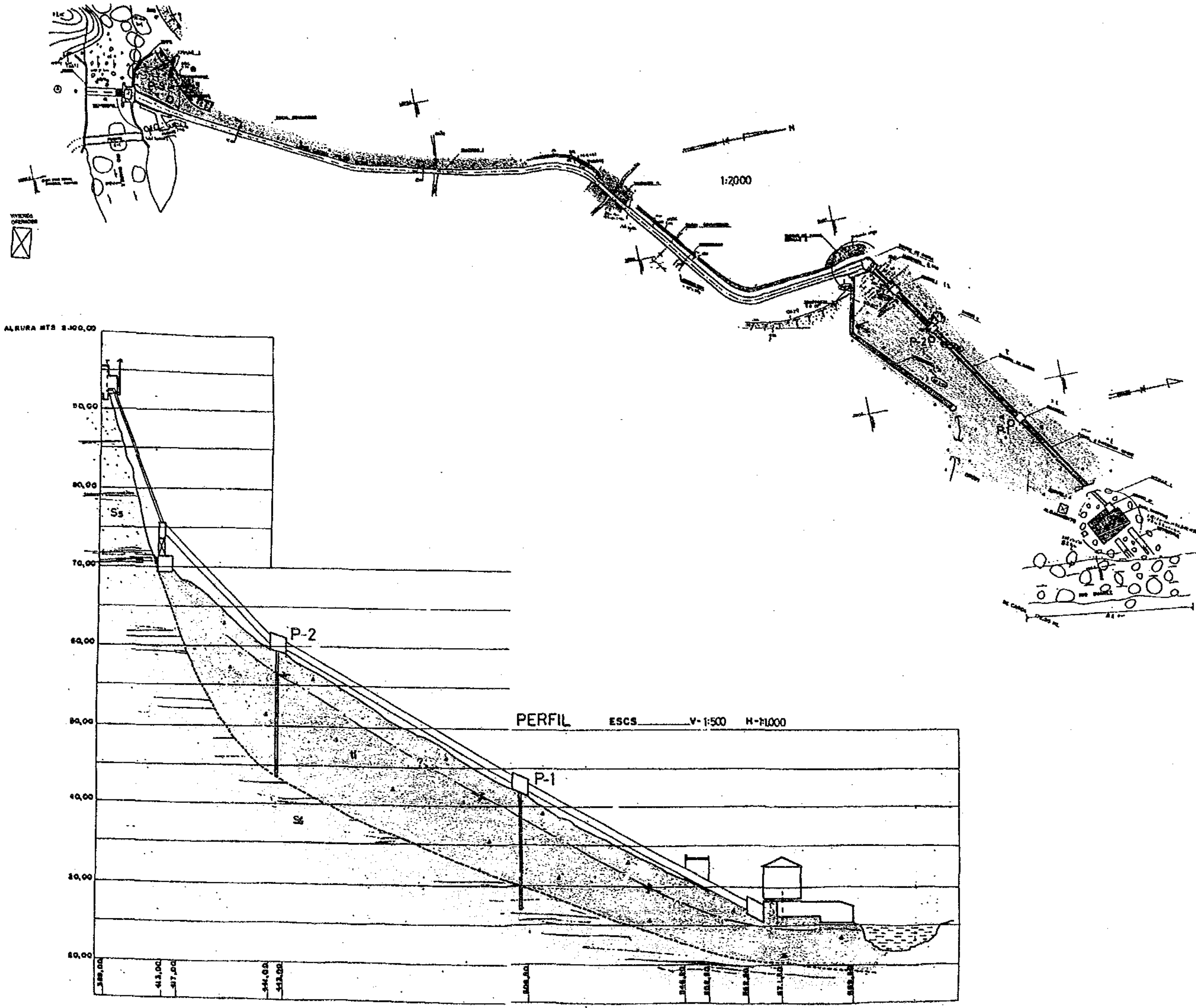


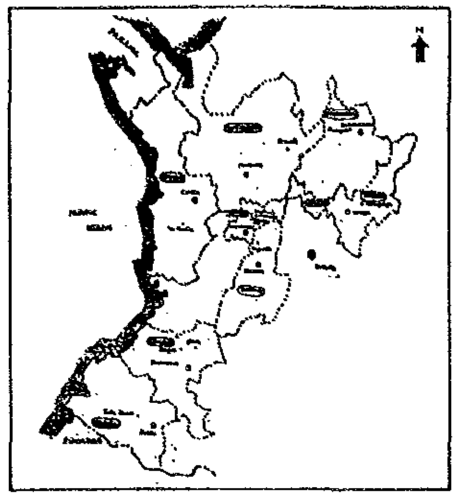
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)
INSTITUTO COLOMBIANO DE ENERGIA ELECTRICA (ICEL)
FEASIBILITY STUDY ON SMALL-SCALE POWER PLANTS REHABILITATION PROJECT IN THE REPUBLIC OF COLOMBIA

PENSTOCK

PLAN AND SECTIONS

DRAWING NO.	PG — C — 04
SCALE	DATE





LEGEND

- River bed deposits
- Talus deposits
- Sandstone
- Mudstone
- Geological boundary
- Borehole

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	
Geological Plan and Profile Puente Guillermo	
DRAWING NO.	PG-G-01
SCALE 1/2,330	DATE

Attached Data

1. Facility Register for the Existing Power Plant

2. Survey Record

Facility Register for the Existing Power Plant

Power Plant	P. Guillermo
Electric Power Company	EBSA
Location	P. Guillermo/Boyaca
River	Suarez
Generating Method	Run-of-River
Year Installed	1963
Years in Service	1963
Installed Capacity	1,280 kW
Available Capacity	0

Civil	
Item	Data
1. Dam	
1) Type	no data available
2) Height (m)	〃
3) Crest length (m)	〃
4) Height of overflowing crest (m)	〃
5) Width of overflowing crest (m)	〃
6) Depth of overflowing crest (m)	〃
2. Intake Gate	
1) Type	〃
2) Number of gates	2
3) Dimensions (W x H)(m)	no data available
3. Intake	
1) Intake sill height (m)	〃
2) Number of intake	2
3) Dimensions (W x H)(m)	no data available
4. Desilting Basin	
1) Dimensions (W x L x H)(m)	W x L x H 4.0 x x 4.0
5. Sand Trap Gate	
1) Type	no data available
2) Number of gates	2
3) Dimensions (W x H)(m)	no data available
6. Headrace	
1) Type	channel
2) Dimensions (W x H)(m)	3.0 x 2.0
3) Length (m)	380

Civil

Item	Data
7. Reservoir Tank	
1) Dimensions (W x L x H)(m)	no data available
8. Forebay	
1) Dimensions (W x H)(m)	N/A
9. Penstock	
1) Number of lines	2
2) Penstock diameter (d)(m)	1.0
3) Penstock length (L)(m)	no data available
10. Tailrace	
1) Dimensions (W x H)(m)	〃

Equipment		
Item	Data	
	#1	#2
1. Water Turbine		
1) Manufacturer's name		
2) Year manufactured	1960	1950
3) Type	Francis	Francis
4) Output (kW)	800	750
5) Revolution (rpm)	900	900
6) Ancillary equipment		
a) Type of governor		
b) Inlet valve		
- Type	Geared manual	Geared manual
- Diameter (mm)	500	500
2. Generator andf Exciter		
1) Manufacturer's name	Siemens	Siemens
2) Year manufactured		
3) Type	Synchro.	Synchro.
4) Capacity (kVA)	800	800
5) Power factor (%)	80	80
6) Voltage (V)	240	240
7) Frequency (Hz)	60	60
8) Revolution (rpm)	900	900
9) Method of neutral earthing	no data available	
10) Type of exciter	〃	

Equipment		
Item	**Data**	
3. Transformer		
1) Manufacturer's name	Siemens	
2) Year manufactured	1961	
3) Type	ONAN	
4) Capacity (kVA)	800	
5) Primary voltage (kV)	0.24	
6) Secondary voltage (kV)	22	
7) Number of unit	2	
8) Vector-group symbol	Y/D	
9) Impedance (%)	no data available	
10) Purpose for use	Step-up	
4. Circuit Breaker		
1) Manufacturer's name	Siemens Schuckert	Siemens Schuckert
2) Year manufactured	no data available	
3) Type	R 913 DM	H626.20
4) Voltage (kV)	0,24	20
5) Rated current (A)	2000	400
6) Rupturing capacity (kA)	12	15
7) Purpose for use	Generator and interconnection	Outgoing
5. Transmission Line		
1) Destination	no data available	
2) Length (m)	〃	
3) Voltage (kV)	〃	
4) Number of circuit	〃	
5) Number of pylons	〃	
6) Size of conductors	〃	
7) Materials of conductors	〃	

Equipment		
Item	**Data**	
6. Battery		
1) Manufacturer's name	Magna	Magna
2) Year manufactured	1987	1987
3) Capacity (AH/HR)	180	180
4) DC voltage (V)	24	24
5) Type	Lead acid	Lead acid
7. Battery Charger		
1) Manufacturer's name	Siemens	
2) Year manufactured	no data available	
3) Capacity	E4x16	
4) Incoming voltage (V)	24	
8. Overhead Crane		
1) Weight (ton)	5	
2) Method of operation	no data available	
3) Span (m)	"	

Survey Records

P. Guillermo Hydroelectric Power Plant

I. RECORDS BY VISUAL INSPECTION AND HEARING SURVEY

Unit No.: 1

Type of Turbine: Francis (1963)

	Generating Facilities	Check item by visual inspection and hearing	Results
Francis Turbine	Casing	1) Existence of corrosion	1) Minim.
		2) Wear in thickness	2) Corrected new shield and reconstructed with welding.
		3) Presence of vibration	3) No
	Runner	1) Existence of corrosion	1) No
		2) Occurrence of porosity by sand pitting	2) Minim.
	Shaft	1) Shaking of shaft axis	1) No
	Bearing	1) Oil shortage on bearing surface	1) No
		2) Lack of oil viscosity	2) No
	Governor control	1) Control by belt-driven type	1) Yes
		2) Speed detection device	2) Yes
		3) Speed regulation system	3) Yes
		4) Installation of load limiter	4) Yes
		5) Accuracy of governor speed regulation	5) Yes

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) No 2) Yes
	Inlet valve	1) Operation method 2) Locking condition 3) Smoothness of pressurized oil operation	1) Manual 2) No 3) No
	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) Yes 2) Minim. 3) No
	Sealing device	1) Sufficiency of water sealing for shaft 2) Sufficiency of packing for shaft seal	1) Yes 2) Yes

Unit No. 1

	Generating Facilities	Check item by visual inspection and hearing	Results
Generator	Rotor	1) Discoloration of winding surface due to heat	1) No
		2) Existence of erosion for core	2) No
		3) Fitness of between rotor and shaft	3) Yes
	Stator winding	1) Frequency of burning trouble or repair	1) No
		2) Reduction of insulation resistance	2) 5 MΩ
		3) Rust and erosion of core	3) No
	Bearing	1) Occurrence of deformation on metal surface	1) No
		2) Lack of oil lubrication	2) Sufficient
		3) Occurrence of temperature rise	3) No
	Exciter	1) Exchange frequency of brushes worn out	1) 3 months
		2) Sufficient stock of spare brush	2) Yes
	Voltage regulator	1) Operation method of voltage regulator	1) Manual, remote
		2) Response of voltage detection for load variation	2) Constant

Unit No.: 2

Type of Turbine: Francis (1955)

	Generating Facilities	Check item by visual inspection and hearing	Results
Francis Turbine	Casing	1) Existence of corrosion	1) Minim.
		2) Wear in thickness	2) Corrected new shield and reconstructed with welding.
		3) Presence of vibration	3) No
	Runner	1) Existence of corrosion	1) No
		2) Occurrence of porosity by sand pitting	2) Minim.
	Shaft	1) Shaking of shaft axis	1) No
	Bearing	1) Oil shortage on bearing surface	1) No
		2) Lack of oil viscosity	2) No
	Governor control	1) Control by belt-driven type	1) Yes
		2) Speed detection device	2) Yes
		3) Speed regulation system	3) Yes
		4) Installation of load limiter	4) Yes
		5) Accuracy of governor speed regulation	5) Yes

	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) No 2) Yes
	Inlet valve	1) Operation method 2) Locking condition 3) Smoothness of pressurized oil operation	1) Manual 2) No 3) No
	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) Yes 2) Minim. 3) No
	Sealing device	1) Sufficiency of water sealing for shaft 2) Sufficiency of packing for shaft seal	1) Yes 2) Yes

Unit No. 2

Generating Facilities		Check item by visual inspection and hearing	Results
Generator	Rotor	1) Discoloration of winding surface due to heat	1) No
		2) Existence of erosion for core	2) No
		3) Fitness of between rotor and shaft	3) Yes
	Stator winding	1) Frequency of burning trouble or repair	1) No
		2) Reduction of insulation resistance	2) 5MΩ
		3) Rust and erosion of core	3) No
	Bearing	1) Occurrence of deformation on metal surface	1) No
		2) Lack of oil lubrication	2) Sufficient
		3) Occurrence of temperature rise	3) No
	Exciter	1) Exchange frequency of brushes worn out	1) 3 months
		2) Sufficient stock of spare brush	2) Yes
	Voltage regulator	1) Operation method of voltage regulator	1) Manual, remote
		2) Response of voltage detection for load variation	2) Constant

Generating Facilities		Check item by visual inspection and hearing	Results
Control Board	Metering equipment	1) Sufficiency of accuracy for instruments	1) OK
		2) Lack of necessary instruments	2) Sufficient
		3) Items constantly recorded	3) No
	Protection equipment	1) Lack of relays to be installed	1) Sufficient
		2) Operation method in case of accident in transmission lines	2) Existing methods
	Remote control equipment	1) Control method for turbine and generator operation	1) Manual and electrical
		2) Control method for voltage and speed control	2) ditto
		3) Operation method of synchronized switching	3) ditto
	Power system	1) Power supply voltage (kV) after rehabilitation work	1) Existing zz kv

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) Sufficient 2) Sufficient 3) No reduction
	Accessi-bility 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) No 2) Sufficient 3) Trustworthy

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) 2) Yes (maintenance is regular)
	Line switch	1) Operation method 2) Reliability of operation	1) Manual and remote 2) Yes
	Insulator	1) Presence of damage and dusts	1) No
	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) Yes

II. ACTUAL GENERATED ENERGY AND OPERATION TIME

The records during the past five years are not available due to power plant's stoppage.

III. REPAIR RECORDS

No.	Study Item	Results
	The past records concerning the following items shall be obtained to evaluate reliability of generating facilities.	
	1) Repaired locations and method for repairing	1) Repair : Stator's coil of two groups in 1984.
	2) Causes for damage/defect	2) Condensation of water and humidity
	3) Duration of repairing and power supply stoppage	3) 10 months
	4) Repaired by; a) staff in Power Plant b) manufacturer c) other	4) Staff in Termopaipa
	5) Repair cost	5) No data
	6) Operation life after the completion of repairing work	6) Since Aug. 20 1985 this plant did'nt operate. After the date formely mentioned, general maintenance of civil structures, hydraulic equipment and electrical equipment have been realized.

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.	- 3 sets of generator's coil and 1 set of brush - circuit breaker 240V , 1200A, 12KA - bearing - various spare parts

V. EBSA's INTENTION FOR REHABILITATION

No.	Study Item	Leaving as it is	Repair work	Replacement
	Mark with ✓ in pertinent columns			
	– Inlet valve			✓ (see Note)
	– Turbine, governor, auxiliary equipment	✓		
	– Generator, exciter	✓		
	– Control panel	✓		
	– Switchgear	✓		
	– Transformer	✓		
	– Substation equipment (Circuit breaker, Isolator, etc.)	✓		
	– Transmission tower, conductor and insulator	✓		
	– Power House	✓		

(Note) Inlet valves are in operating condition, but the purpose is to change them to automatic driving valves by remote operation with safety control.