9. DEVELOPMENT PLAN

232 (2392)

CONTENTS

234 (2358)

9 DEVELOPMENT PLAN

9.1 Review of Existing Development Plan

9.1.1 Pre-FS (Phase 1A)

CEL has already finished a self-funded Pre-FS (by HARZA) for the hydroelectric complex over the Torola River, which was conducted from December 1997 to March 1999 for the purposes below.

1. To cope with the increasing electric demand by making use of competitive and sustainable water resources
2. To contribute to increased saving of oil products by hydro power
3. To make use of the present unused hydro power potential of the Torola River

The Pre-FS was divided into two stages, Phase 1A and Phase 1B, and the development scheme study for the whole river basin was executed, and individual projects that consist of development scheme were studied at the stage of Phase 1A.

(1) Site Characteristics of Candidate Project Sites

First, seven dam sites (El Chaparral, Carolina, La Honda, Las Marias, Cerro Pando, Las Mesas, Maroma) were selected and each site characteristic was examined by comparing their development plans. The selection of the seven potential dam sites was considered appropriate at the stage of the preliminary selection of the dam axis.

The generation type for each project is fundamentally the dam type and, in addition to the economic comparison study for different heights of a dam, the study on the dam and waterway type was made for certain sites.

Fig. 9.1 shows the location of the candidate project sites and Table 9.1 is the comparison table of generation features. It is fundamentally reasonable to set the HWL for each project based on the dam site's riverbed elevation so that no residual head arises. However in the case of the El Chaparral and Carolina sites, the reservoir areas would enter into the territory of Honduras with an HWL elevation of more than about 212 m, and it is not adequate to prepare a study case where the HWL is 255 m in the table.

236

It was judged that Cerro Pando does not offer good economy and also creates great environmental impact; therefore the elimination of this site from the candidate project sites was considered appropriate.

(2) Composition of Development Scheme

Two kinds of development schemes are conceivable for the survey reach (L=58 km, maximum difference of riverbed ΔH=327 m) of the Torola river. One development scheme has three dams (100 m height class) and the other one with four dams (80 m height class). A development scheme was composed of several individual projects after examining each characteristic of each project site. Technical points, which were considered for the composition of the development scheme, are as follows.

1) Compared with El Chaparral, the economy of Carolina is superior, and El Chaparral was eliminated from the development scheme. (at the stage of Phase 1B, El Chaparral was added back to the roster of candidates for development schemes because it was found that the head for El Chaparral was increased by 10m from the initial study.)
2) The high HWL case (El352 m) for La Honda was liminated from the development scheme, because this case would accompany a large-scale resettlement of inhabitant and require to relocated the existing road near Osicala.
3) The High HWL case (EL456 m) for Las Mesas was eliminated from the development scheme because this case was uneconomical.

Fig. 9.2 shows the location map of each development scheme, and Table 9.2 is the comparison table for each generation feature.

The dam and waterway type case for the Maroma project site was judged appropriate, as it is designed to eliminate the problems of location and environment in the upstream of the Las Mesas project site.

Thus, of the four schemes proposed in Phase 1A, only Scheme 1 and Scheme 2 fundamentally serve as the study results of that Phase, as the other two schemes involve the maximum HWL for Carolina, which is EL212m at the most.

9.1.2 Pre-FS (Phase 1B)

(1) Re-composition of Development Scheme

Following Phase 1A, the proposed development schemes were studied again at the stage of Phase 1B. The purpose of Phase 1B was to select the project sites that should be studied at the next step (FS stage).

In this case, the degree of the study level was increased through more accurate estimation of energy calculation and construction cost and through the incorporation of subsequent investigation results for topography, geology and socio-environment.

During this phase, Las Cruses was newly proposed as a project site. This site is located in the upstream of Maroma site and was selected in order to moderate the problems of location and environment.

The El Chaparral and Las Cruces sites were added to the last five sites (Carolina, La Honda, Las Marias, Las Mesas, Maroma), which were studied at the stage of Phase 1A.

Table 9.3 shows the generation features for each project. In this case, each generation feature is the individually planned one, and the influence from upstream project was not taken into account. Table 9.4 shows the comparison table of indexes showing environmental impact and socio-environment impact for each project site.

Table 9.5 lists the final candidate project sites selected for the development scheme based on the study results made so far. Technical points considered for setting the generation features are as follows.

1) The El Chaparral site has good economy and has less environmental impact compared with other projects. And it is appropriate to select it as one of the promising project sites.

2) The Carolina site also has good economy but there is a limit on the HWL, which cannot be raised above EL212m. Therefore, it would be difficult to secure the economy shown in Table 9.3. As a result, it was judged appropriate not to select it as a candidate for the development scheme.

3) The La Honda site has relatively good economy and has less environmental impact because it is unnecessary to relocate the existing road near Osicala. The selection of it as one of the promising project sites was considered appropriate.

4) The Las Marias site offers poor economy, and it is reasonable not to select it as candidate for development scheme.

5) The Las Mesas site creates great environmental impact for the high HWL case and its economy is less than desired. However, it is the promising project site in the upstream of the Torola River, and thus, it is acceptable to select it as the candidate site of the key project in the upstream basin.

6) The Maroma site offers poor economy and would not be improved even if the dam and waterway type was adopted to moderate the problems of location and environment in the downstream of the dam site. It also poses great impact on the location and environment by reservoir impounding. However, it is a very important project because its reservoir operation would strongly affect the downstream projects. Therefore, it is acceptable to select it as a candidate for the development schemes.

7) The Las Cruces site, on the other hand, was proposed in the upstream of the Maroma site in order to moderate the above-mentioned problems. But it offers poor economy and thus was eliminated.

   The development in the Torola River basin is divided into the upstream basin area (Las Mesas, Maroma, Las Cruses) and the downstream basin area (El Chaparral, Carolina, La Honda, Las Marias). as explained so far in Phase 1A and Phase 1B. Conclusions from both studies indicate that we should proceed with the development of the downstream basin. This conclusion is acceptable. Table 9.5 and Fig. 9.2 show the final development scheme as proposed.

9.2 Comparative Study of Alternative Development Plans

9.2.1 Preliminary Study of Development Plans

Based on the development scheme proposed at the stage of Pre FS, a development plan for the Torola River was restudied. As Table 9.5 shows, El Chaparral, La Honda, Las Mesas and Maroma were proposed. However, it was judged that the upstream development would accompany many difficulties in the near term from the view of the problems of locations and environment. Therefore, the object of the study was limited to the downstream development.

Therefore, in the FS, the El Chaparral and La Honda sites were selected for the development plans to be studied. First, the characteristics of economy for each development plan was clarified based on the single development scheme for each. Subsequently, the possibility of a joint development scheme for the two projects was studied

(1) Development Scheme

1) Single Development Scheme

a) It is reasonable to adopt the reservoir type, which allows the reservoir to regulate the river flow seasonally, and the dam type, which allows the powerhouse to be located at a point just downstream of the dam.

b) The Dam and waterway type, which uses the head given by waterway, was not studied because the riverbed gradient is moderate.

2) Joint Development Scheme

a) The joint development scheme is composed of the La Honda project (dam type • reservoir type) and the El Chaparral project (dam type • reservoir type).

b) The fundamental concept of the joint development scheme is that the El Chaparral dam in downstream can receive the regulated discharge from the La Honda dam in upstream, while the river flow in the remaining catchment between the two dams is regulated.

(2) Development plan site

1) El Chaparral Project

The El Chaparral dam is the most downstream project among the projects along the Torola River and is located at about 20 km upstream from the conjunction point with the Lempa River. That 20-km section is the border with Honduras and the construction of a concrete dam at about 300 m upstream from the border and a power house at just downstream of dam was proposed in the Pre-FS.

The valley at the dam site is a topographical gorge and the width of valley widens sharply. Therefore, the layout in the Pre-FS was respected to serve as a basis in FS. The width of the valley at the dam site is about 30 m, and the slopes at both abutments are steep in lower elevations and gentle in higher elevations. Therefore, the length of the dam crest with long wings at both sides will become long.

In setting the HWL for reservoir, it was considered that the reservoir area should not enter into the territory of Honduras and the upper HWL was set as EL212 m.

2) La Honda Project

La Honda project is located at the end of the reservoir, about 15 km from the El Chaparral dam. The construction of a concrete dam at that site and powerhouse at just downstream of dam was proposed in Pre-FS. The width of valley at the dam site is about 50 m and the slope at both abutments is gentle and has the gently-sloped form. Therefore, the length of the dam crest would be long and the dam volume large.

There is an alternative dam site at the relatively narrow valley point about 1.5 km upstream from the proposed dam site. In the FS, the upstream development plan was studied in addition to the dam site in the Pre-FS. The upstream dam site is a topographical gorge and has the steep slope especially at the right abutment. However, there is a topographical saddle part (around EL280m) on the left side of river and it is necessary to have a sub dam for a higher HWL case. Fig.9.3 shows the positions of the two dam axes including El Chaparral dam, and Fig. 9.4 presents a rough comparison of the La Honda project.

In selecting the development plan, a comparative study was made for both axes. Comparison in terms of economy was made for both plans, which have the same generation features (HWL=EL275m, Qmax=80m^3/s). Table 9.6 shows the study results, and the construction cost of the upstream axis plan was found to be decreased by approximately 3% as compared with the original one because the energy production would be down according to the reduction of effective head in spite of the reduction of the dam construction cost. The generation features used for this comparison are those that would give the most economical results to be elaborated in "9.2.2 Comparative Study of Development Plans".

Therefore, the El Chaparral and La Honda sites proposed in Pre-FS were selected for the development plans in FS.

9.2.2 Comparative Study of Development Plans

(1) Basic Matters for Study

1) Topographical Map

At the stage of Pre-FS, the study was made based on 1/50,000 and 1/10,000 maps. On the other hand, a new 1/25,000 map was collected in the first round of the site survey (June 2001) and a 1/5,000 map was completed based on the existing aerial photograph in August 2001. They was used for a comparative study of the development plans.

2) Geological Investigation Results

In the detailed investigation for the El Chaparral project, the geological investigation such as borings and others was executed by subcontractors together with the topographical survey.

241

In "11. Feasibility Design," feasibility design was made for the El Chaparral project based on the 1/1,000 map and river cross-section survey results, but the rough design for the La Honda project was based on the 1/5,000 map.

3) Catchment Area

Catchment areas for each dam site were newly measured based on the 1/50,000 map.

4) Area Capacity Curve of Reservoir

Reservoir capacity curve for each dam site was newly made. Figures 9.5 and 9.6 show the reservoir capacity curves for the La Honda and El Chaparral dam sites.

5) River Flow Discharge

a) Low River Flow

River flow discharge has been measured at Osicala GS and was used for the estimation of the river flow at the dam site. River flow discharge at the dam site was estimated based on the monthly data (1942~2000). Firm discharge with 95% probability was calculated by mass curve operation.

b) Flood Discharge

Design discharge for the care of the river was decided by the flood probability calculation (one-year probability for concrete gravity dam) and design discharge for the spillway by PMF

c) Evaporation

Evaporation from the surface of the reservoir was estimated by observed evaporation data of PAN and potential evapo-transpiration. It was considered in the energy calculation.

6) Reservoir Operation

a) Basic Idea of Reservoir Operation

Annual average inflow at Osicala GS is 30.0 m^3/s, with about 90% of the annual inflow occurring during the rainy season (May through October) and the fluctuation of river discharge is very large. Therefore, it is necessary to regulate the river discharge according to seasons, making use of the reservoir capacity. Reservoir operation rules were determined based on the items below.

- River water in the wet season is to be stored and released in the dry season to make the firm discharge as large as possible.
- Reservoir is to be operated so that the spill is as small as possible.

242

- Reservoir is to be operated so that a stable supply of power is assured for a long period and at the same time the energy production is large.

b) Operation Rules

Reservoir operation rules were prepared to maximize the energy production, using the Dynamic Programming Method, based on the basic ideas of operation. Dynamic programming is a mathematical technique to solve multi-decision processes, and it was applied to derive the reservoir operation rules. A multi-decision process is defined as a process to determine a series of control vectors (outflow from reservoir at some time) that make evaluation functions extreme (maximizing accumulated energy production from some reservoir water level to the water level at the end of calculation), based on "the principle of optimality" (Refer to Appendix 9.7).

c) Energy Calculation

Energy was obtained with the discharge for generation and reservoir water level that were given from the reservoir operation based on the above-mentioned rule curve. The procedure of energy calculation is shown in Fig.9.7 and the manner of reservoir operation by rule curve in Fig.9.8. Generation features are described below.

Peaking time:	Peaking time required in the balance of electric demand and supply, Tp=3 to 4hr was assumed.
Maximum discharge:	Maximum discharge is a peaked discharge used for a peak hour generation and was compared and examined in some different cases in the scale examination study.
Head loss:	It was counted as friction loss (penstock) +other loss.
Dependable capacity:	Dependable capacity is guaranteed within the peaking period (95% probability) except the period of accident.
Normal water level:	Normal water level was set at an elevation less 1/3 of the available drawdown depth. In this case, the maximum discharge is limited by the constant rated output when the water level is higher than the normal water level.

(2) Manner of Comparative Study

1) Scale Examination Study

a) Maximum discharge is a peaked discharge for the required peaking time (three to four hours) in the balance of electric demand and supply. In this scale examination study, various maximum discharges were set for a comparison and examination. If the amount of spilled water is large, it is increased to save the spilled water in order to improve the economy of development plan.

b) Comparative study of economy for different dam heights (HWL) in light of sedimentation capacity was made after different reservoir effective volumes were set.

c) Ecological minimum flow (2 m^3/s) would be constantly released from the dam. The way of discharge is to release the water through a small turbine equipped at the end of the penstock branching from the end part of the main penstock tube. Energy production by the small turbine would be counted as the energy at the power plant concerned.

d) Owing to the reservoir operation of El Chaparral and La Honda dams, the duration of inflow at existing 15 de Septiembre power plant would be improved and energy production increased. Increased energy would be counted as the energy at the power plant concerned.

Based on the above-mentioned conditions, some different combinations of maximum discharges and different dam heights (HWL) were prepared to make scale examination study.

2) Method of Economic Comparison

The method used for the evaluation of alternative development plans is "the benefit cost method (BC method)." The method uses an assumption that a standard thermal power plant would be built instead of the Torola project, and the assumed cost of the thermal power plant serves as the benefit of the project.

A diesel power plant (Motor) was selected as an alternative thermal power plant. B-C and B/C were used as the fundamental indexes for judging the economy of the project. C is the equalized annual cost for hydro power, and B is considered as the equalized cost of alternative thermal power that has the same power ability as hydro power.

In addition to the indexes (B/C, B−C), the energy cost per kWh was used as another index.

a) Annual cost (C)

The equalized annual cost of the Torola project consists of depreciation, interest, operation and maintenance costs. This is estimated by multiplying the annual cost factor by the investment cost.

244

Equalized cost (C)	=	Depreciation + Interest + Operation & Maintenance Costs
	=	Annual cost factor×Investment cost
Depreciation + Interest		Investment cost ×Capital recovery factor
Capital recovery factor	=	$i\,(1+i)^n/((1+i)^n - 1)$
n : service life		Civil facility: 50 years 0.1009
		Hydro mechanical equipment: 35 years 0.1037
		Electric equipment: 35 years 0.1037
		i: discount rate 10%

Operation and Maintenance costs (rate to investment cost):

n : service life 50 years	Civil facility: 0.5 %
	Hydro mechanical equipment: 1.5 %
	Electric equipment: 1.5 %
Annual cost factor	Civil facility : 10.6 %
	Hydro mechanical equipment : 11.9 %
	Electric equipment : 11.9 %

Assuming the rate of (hydro mechanical & electric equipment cost) / (total investment cost) as 25%, annual cost factor will be 10.9 %.

Annual cost (C) = 10.9 % × Investment cost

b) Benefit (B)

The benefit of the Torola project is summarized according to the fixed cost (Depreciation + Interest + Operation & Maintenance Cost) and Variable Cost (Fuel Cost + Operation & Maintenance Cost) of an alternative thermal power plant. And kW value and kWh value were calculated as shown in Table 9.7. Effective power output and effective energy production used in calculating the benefit are given according to the conditions below.

Effective power output:	Effective power output at the receiving end is expressed by the equation below. This equation reduces station service rate by 0.3%, forced outage rate by 0.3%, scheduled outage rate by 2.0% and transmission line loss rate by 3.3% from firm peak output.
Effective power output=	(1–0.003)×(1–0.003)×(1–0.02)× (1–0.033)×Dependable capacity
Effective energy:	Effective energy at the receiving end is expressed by the equation below.

245

This equation reduces station service rate by 0.3% and transmission line loss rate by 1.9% from the average annual energy.

Effective energy = (1–0.003) × (1–0.019) × Average annual energy

Benefit of hydro power would be calculated below.

B = Effective power output × kW value + Effective energy × kWh value

= Effective power output × 171.0 $/kW + Effective energy × 0.046 $/kWh

(3) Comparative Study Case

In the comparative study of generation layout and scale examination, alternative cases were prepared based on the above-mentioned method for the comparative study. Tables below show the list of alternatives.

(La Honda Project by Single Development Scheme)

	HWL=295 m			HWL= 285m			HWL= 275 m		
Type	Dam type /Reservoir type			Dam type /Reservoir type			Dam type /Reservoir type		
Ve (10^6m^3)	304	300	292	200	196	188	117	114	106
Hd (m)	102.5			92.5			82.5		
Qf (m^3/s)	18.5	18.3	17.8	14.1	13,9	13.4	8.8	8.6	8.1
Qmax (m^3/s)	90	120	150	70	100	130	50	80	110
He (m)	83.0	83.0	84.0	76.0	76.0	77.0	69.0	69.0	70.0
Pmax (MW)	66.1	88.1	111.5	47.1	67.2	88.5	30.5	48.8	68.1

(El Chaparral Project by Single Development Scheme)

	HWL=212 m			HWL=204 m			HWL=198 m		
Type	Dam type /Reservoir type			Dam type /Reservoir type			Dam type /Reservoir type		
Ve (10^6m^3)	111	106	96	54	50	40	31	23	19
Hd (m)	87.5			79.5			73.5		
Qf (m^3/s)	8.9	8.6	8.0	4.9	4.5	3.8	3.0	2.3	2.0
Qmax (m^3/s)	70	100	130	50	80	120	20	40	60
He (m)	71.8	72.8	72.8	66.8	66.8	67.8	61.8	61.8	62.8
Pmax (MW)	44.5	64.4	83.7	29.5	47.3	72.0	10.9	21.9	33.3

(La Honda－El Chaparral Project by Joint Development Scheme)

	La Honda	El Chaparral
	HWL=275 m	HWL=212 m
Type	Dam type /Reservoir type	Dam type /Reservoir type
Ve (10^6m^3)	114	106
Hd (m)	82.5	87.5
Qf (m^3/s)	8.6	11.3
Qmax (m^3/s)	80	100
He (m)	69.0	72.8
Pmax (MW)	48.8	64.4

(4) Comparative Study Results

Tables 9.8 through 9.10 and Figures 9.9 and 9.10 show the comparative study results that are summarized below.

(Single Development Scheme)

1) La Honda Project

- In the case of the La Honda dam site, the topographical condition at both abutments is gentle, and every study case revealed a large amount of mass concrete volume. Therefore, the investment cost will increase according to the dam height, attributing to the poor economy of the project.
- On the other hand, the benefit does not increase very much even if the dam height is raised. Energy cost for the low height of the dam (HWL275 m) is the most inexpensive (0.08 $/kWh level), but, if the target energy cost for the development is assumed to be US$ 0.06 ~0.07/kWh, investment cost needs to be reduced by about 20%, leading to a low likelihood of its development. The priority of the development is not high compared with the alternative thermal power plant because the values of B/C and B－C are low.

2) El Chaparral Project

- In the case of the El Chaparral dam site, the topographical condition at both abutments is relatively steep, and the dam cost does not increase so much even if the dam height is raised.
- On the other hand, reservoir effective capacity is not large compared with that of La Honda. Energy cost for the high height of the dam (HWL212 m) is inexpensive (US$ 0.065/kWh), and this value is competitive enough in the electric market, where

the actual wholesale energy price is in the range of US$ 0.06~0.07 /kWh. However, the priority of development is not especially high compared to the alternative thermal power plant with 1.01 (B/C) and US$ 0.16 × 10^6 (B − C).

- The reason is that a river discharge is very small in the dry season and the discharge in a required peaking time cannot be increased with additional water from the reservoir. As a result, the firm peak output is small and the kW benefit is also small.

(Joint Development Scheme)

- The joint development scheme is composed of La Honda (HWL=275 m) and El Chaparral (HWL212 m). In this case, the sediment volume for El Chaparral dam was reduced by that of La Honda dam and the inflow for El Chaparral dam was estimated as the total of regulated water from La Honda dam and the water for the remaining catchment area between the two dams.
- As Table 9.10 shows, energy of El Chaparral project increases with the regulated discharge from the La Honda reservoir and its economy showed improvement.
- However, the economy of the La Honda project itself is poor, and the combined economy of the two projects is still less than desired as explained by the following unfavorable values:

  (energy cost = US$ 0.077/kWh, B/C=0.88, B − C=US$ − 3.94 ×10^6)

Therefore it seems difficult to develop the two projects at the same time.

(Change in the required peaking time)

Based on the above examination results, the required peaking time has been changed. A peaking time is hydroelectric operation hours (three to four hours) required to meet the peak energy demand, and, in this case, four hours were applied. Table 9.11 shows a result of the economic comparison made, just applying the three-hour peaking time to the technical profiles selected in the scale examination study above.

By changing the peaking time, the kW benefit was boosted, and the development scheme's economical conditions were also boosted to an extent of US$ 0.065/kWh (energy cost), 1.14 (B/C) and US$2.10 ×$10^6$ (B − C).

9.3 Selection of Development Scheme

9.3.1 Selection of Development Scheme

Based on the above-mentioned comparative development study results for development schemes (single and joint development schemes), a development scheme was selected.

- La Honda project is the key project in the downstream area of the Torola River, because the regulated discharge from La Honda dam would contribute to the elevation of the economy of the downstream El Chaparral project. However, the economy of the La Honda project itself is poor and the combined economy by the joint development along with the El Chaparral project also fails to reach the level that would allow us to approve the development scheme .
- On the other hand, the El Chaparral project has successfully reached the level required to proceed with its development, after an increase in the HWL to the limit and a change to three hours of peaking time. This, in our opinion, offers an economically high possibility of development.

Therefore, the single development scheme for the El Chaparral project is proposed, while the La Honda project will be retained as a potential project to be launched in some future time.

Table 9.1 Project Features of Torola River (Phase 1A)

Project	HWL (m)	TWL (m)	Pmax (MW)	Energy (GWh/year)	Construction Cost(10^6\$)	B/C	Remark
El Chaparral							
Dam type	202	141	43	175	103.8	1.3	
Dam type	255	141	80	352	210.9	1.28	
Carolina							
Dam type	202	150	36	149	77.7	1.47	
Dam type	202	141	42	176	89.1	1.5	riverbed excavation
Dam & waterway	202	141	41	169	126.3	1.04	tunnel
Dam type	255	150	72	310	165.8	1.43	
Dam type	255	141	79	338	177.5	1.46	riverbed excavation
Dam & waterway	255	141	77	331	214.5	1.19	tunnel
La Honda							
Dam type	285	202	50	205	146.6	1.09	
Dam type	352	202	90	407	406.4	0.77	
Las Marias							
Dam type	285	255	16	67	44.5	1.17	
Dam type	352	255	51	226	135.9	1.27	
Cerro Pando							
Dam type	352	285	31	128	115.1	0.87	
Las Mesas							
Dam type	352	290	20	84	61.1	1.07	
Dam type	456	290	55	247	372.3	0.52	
Maroma							
Dam type	456	352	33	145	107.8	1.04	
Dam & waterway	456	285	54	235	155	1.17	tunnel

Table 9.2 Project Features of Development Scheme (Phase 1A)

Scheme	HWL (m)	TWL (m)	Pmax (MW)	Pf (MW)	Energy (GWh/year)	Ve (10^6m^3)	Construction Cost(10^6\$)	B/C	Area (km^2)	Resettled Houses
Scheme 1										
Carolina	202	141	49.8	43.2	188.4	54	89.1	1.5	4.23	2
La Honda	285	202	60.1	49.7	222	251	146.6	1.09	12.38	24
Las Mesas	352	290	24.6	21.5	94.4	43	61.1	1.07	2.72	3
Maroma	456	352	40	31	144.9	278	107.8	1.04	10.14	86
			174.5	145.4	649.7	626	404.6	1.23	29.47	115
Scheme 2										
Carolina	202	141	49.8	42.6	188.7	54	89.1	1.5	4.23	2
La Honda	285	202	60.1	48.4	221.5	251	146.6	1.09	12.38	24
Maroma (tunnel)	456	285	61.2	51.1	234.7	278	155	1.17	10.14	86
			171.1	142.1	644.9	583	390.7	1.27	26.75	112
Scheme 3										
Carolina	255	141	93.6	95.8	361.4	450	177.5	1.46	17.29	44
Las Marias	352	255	62.2	57	234.9	464	135.9	1.27	18.19	94
Maroma	456	352	40	31	144.9	278	107.8	1.04	10.14	86
			195.8	183.8	741.2	1192	421.2	1.34	45.62	224
Scheme 4										
Carolina	255	141	93.6	80.6	352.7	450	177.5	1.46	17.29	44
Las Marias	285	255	19.2	15.2	72.6	23	44.5	1.17	0.95	4
Maroma (tunnel)	456	285	61.2	51.1	234.7	278	155	1.17	10.14	86
			174	146.9	660	751	377	1.34	28.38	134

250

Table 9.3 Project Features of Torola River (Phase 1B)

Project	HWL (m)	TWL (m)	Pmax (MW)	Energy (GWh/year)	Construction Cost(10^6\$)	B/C
El Chaparral	202	133	58.8	205.6	92.5	1.61
Carolina	240	152	76.3	267.6	118	1.64
La Honda	285	204	59.6	207.8	130.7	1.18
Las Marias	285	257	19.7	55.2	65.5	0.64
Las Mesas	352	292	30.2	105	81.4	0.97
Maroma	456	352	42.7	148.4	100.2	1.1
Las Cruces	456	394	24.4	85.1	78.7	0.82

Table 9.4 Environmental Features of Projects (Phase 1B)

Project	Biological Impact Index	Social & Economical Impact	Physical Impact Index	Total of Index	Index/kWh	Evaluation
El Chaparral	26	55	18	99	0.48	very good
Carolina	27	80	23	132	0.49	very good
La Honda	28	66	24	118	0.57	good
Las Marias	21	32	12	65	1.2	very bad
Las Mesas	24	58	14	96	0.91	regular
Maroma	29	112	28	169	1.14	bad
Las Cruces	23	42	16	81	0.95	regular

Table 9.5 Project Features of Development Scheme (Phase 1B)

Project	HWL (m)	TWL (m)	Pmax (MW)	Energy (GWh/year)	Construction Cost (10^6\$)	A (km^2)	Relocated People (people)
El Chaparral	202	133	59	206 (223*)	92.5	8.2	210
La Honda	285	204	60	208 (221*)	129	11.6	195
Las Mesas	352	292	30	105 (107*)	81	2.7	190
Maroma	456	352	43	148 (148*)	98.7	10.1	600

* : Energy that considered the upstream projects operation

25/

Table 9.6 Comparison Study of La Honda and Upstream Alternative

Case		La Honda	Upstream Alternative
Catchment Area	km^2	1,065	1,059
High Water Level HWL	EL m	275	275
Low Water Level LWL	EL m	254	257
Drawdown Depth Hd	EL m	21	18
Normal Water Level NWL	EL m	268	269
Sedimentation Level SL	EL m	244	247
Tail Water Level TWL	EL m	198	204
Penstock Diameter (V=5m/s)	m	4.5	4 5
Gross Storage Capacity Vg	10^6m^3	182	156
Effective Storage Capacity Ve	10^6m^3	114	91
Peaking Time	hr	4	4
Firm Discharge Qf without EMF $2m^3/s$	m^3/s	8.6	7.1
Maximum Discharge Qmax	m^3/s	80 0	80.0
Gross Head Hg	m	70 0	65.0
Effective Head He	m	69.0	64.0
Installed Capacity P1max (main)	MW	48.8	45.3
Installed Capacity P2max (sub)	MW	1.3	1.2
Pmax=P1max+P2max	MW	50.1	46.5
Dependable Capacity Pf1 (main)	MW	24.6	0.0
Dependable Capacity Pf2 (sub)	MW	0.9	0 9
Pf=Pf1+Pf2	MW	25 5	0.9
Annual Average Inflow	10^6m^3	1,300 6	1,293.3
Annual Average Power Discharge	10^6m^3	1,030 5	1,016.0
Annual Average Overflow	10^6m^3	203 9	214.6
Annual Average Energy E1 (main)	GWh	179.5	163.6
Annual Average Energy E2 (sub)	GWh	9.9	7.9
Annual Average Energy E3 (15Sep)	GWh	2.0	2.0
E=E1+E2+E3	GWh	191.3	173.5
Plant Factor	%	44	43
Project Cost	10^6\$	157.6	152.2
Energy cost per kw	\$/kW	3,143	3,273
Energy cost per kwh	\$/kWh	0.092	0 098
B/C		0.74	0.48
B-C	10^6\$	-4.46	-8.64

EMF : Ecological Minimum Flow

252

Table 9.7 Alternative Thermal Power Plant for Comparison Study

Item	Unit	Diesel (Motor)
Installed Capacity	MW	10×6
Annual Usage	hr	3500 (pf=40%)
Capital Cost	$/kW	1000
O&M Cost (Fixed)	$/kW/year	25
O&M Cost (Variable)	$/kWh	0.0055
Fuel Cost (Bunker C)	$/kWh	0.0387
Discount Rate	%	10
Service Life	Year	20
Construction Period	Year	2
Capital Recovery Factor		0.1175

Annual Cost		Fixed Cost	Variable Cost
Capital Recovery	$10^6$$	7.05*1	0
O&M Cost	$10^6$$	1.50*2	1.16*3
Fuel Cost	$10^6$$	0	8.13*4
Total	$10^6$$	8.55	9.29

Annual Cost at Receiving End		
kW Cost	$/kW	171.0*5
kWh Cost	$/kWh	0.046*6

Adjustment Factor for kW & kWh		Diesel		Hydro Power	
		kW	kWh	kW	kWh
Transmission Loss Rate	%	0.0	0.0	3.3	1.9
Station Service Rate	%	5.0	5.0	0.3	0.3
Forced Outage Rate	%	10.0	-	0.3	
Scheduled Outage Rate	%	8.0	-	2.0	

kW adjustment factor = $(1-0.033) \times (1-0.003) \times (1-0.003) \times (1-0.02) / ((1-0.05) \times (1-0.1) \times (1-0.08)) = 1.20$

kWh adjustment factor = $(1-0.019) \times (1-0.003) / (1-0.05) = 1.03$

*1 : $60000 \times 1000 \times 0.1175 = 7.05 \times 10^6$
*2 : $60000 \times 25 = 1.50 \times 10^6$
*3 : $60000 \times 3500 \times 0.0055 = 1.16 \times 10^6$
*4 : $60000 \times 3500 \times 0.0387 = 8.13 \times 10^6$
*5 : $8.55 \times 10^6 / (60000 / 1.20) = 171.0$
*6 : $9.29 \times 10^6 / (60000 \times 3500 / 1.03) = 0.046$

254

Table 9.8 Scale Examination of El Chaparral Project by Single Development Scheme

Case			CH1-1	CH1-2	CH1-3	CH2-1	CH2-2	CH2-3	CH3-1	CH3-2	CH3-3
High Water Level	HWL	EL m	212	212	212	204	204	204	198	198	198
Low Water Level	LWL	EL m	195	196	198	194	195	197	191	193	194
Drawdown Depth	Hd	EL m	17	16	14	10	9	7	7	5	4
Normal Water Level	NWL	EL m	206	207	207	201	201	202	196	196	197
Sedimentation Level	SL	EL m	185	185	185	185	185	185	185	185	185
Tail Water Level	TWL	EL m	133	133	133	133	133	133	133	133	133
Penstock Dia	(V=5m/s)	m	4.2	5.0	5.8	3.6	4.5	5.5	2.3	3.2	3.9
Gross Storage Capacity	Vg	10^6m^3	189	189	189	128	128	128	93	93	93
Effective Storage Capacity	Ve	10^6m^3	111	106	96	54	50	40	31	23	19
Peaking Time		hr	4	4	4	4	4	4	4	4	4
Firm Discharge Qf without $2m^3/s$		m^3/s	8.9	8.6	8.0	4.9	4.5	3.8	3.0	2.3	2.0
Maximum Discharge	Qmax	m^3/s	70	100	130	50	80	120	20	40	60
Gross Head	Hg	m	73.0	74.0	74.0	68.0	68.0	69.0	63.0	63.0	64.0
Effective Head	He	m	71.8	72.8	72.8	66.8	66.8	67.8	61.8	61.8	62.8
Installed Capacity P1max (main)		MW	44.5	64.4	83.7	29.5	47.3	72.0	10.9	21.9	33.3
Installed Capacity P2max (sub)		MW	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.1
Pmax=P1max+P2max		MW	45.8	65.7	85.1	30.8	48.5	73.2	12.0	23.0	34.4
Dependable Capacity Pf1 (main)		MW	29.3	26.6	21.5	14.6	10.8	0.0	5.5	4.1	0.0
Dependable Capacity Pf2 (sub)		MW	1.1	1.1	1.1	1.0	1.1	1.1	1.0	1.0	1.0
Pf=Pf1+Pf2		MW	30.4	27.7	22.6	15.6	11.9	1.1	6.5	5.1	1.0
Annual Average Inflow		10^6m^3	1489.1	1489.1	1489.1	1489.1	1489.1	1489.1	1489.1	1489.1	1489.1
Annual Average Power Discharge		10^6m^3	1065.9	1226.9	1304.7	844.0	1088.4	1303.1	419.6	697.9	921.6
Annual Average Overflow		10^6m^3	355.4	194.9	117.7	578.4	334.0	153.0	1003.6	726.0	513.1
Annual Average Energy E1 (main)		GWh	190.2	219.7	235.9	139.0	178.9	210.4	64.9	107.0	140.2
Annual Average Energy E2 (sub)		GWh	10.5	10.6	10.7	9.8	9.9	10.0	9.1	9.3	9.4
Annual Average Energy E3 (15Sep)		GWh	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
E=E1+E2+E3		GWh	202.7	232.3	248.6	150.8	190.7	222.4	76.0	118.3	151.6
Plant Factor		%	51	40	33	56	45	35	72	59	50
Project Cost		10^6\$	128.5	135.3	142.2	110.3	117.0	125.7	95.8	100.1	104.3
Energy cost per kw		\$/kW	2806	2059	1672	3586	2413	1717	7958	4356	3029
Energy cost per kwh		\$/kWh	0.071	0.065	0.064	0.081	0.068	0.063	0.140	0.094	0.077
B/C			1.00	1.01	0.96	0.77	0.82	0.74	0.43	0.56	0.61
B-C		10^6\$	0.00	0.16	-0.67	-2.72	-2.26	-3.51	-5.98	-4.76	-4.38

Table 9.9 Scale Examination of La Honda Project by Single Development Scheme

Case			LH1-1	LH1-2	LH1-3	LH2-1	LH2-2	LH2-3	LH3-1	LH3-2	LH3-3
High Water Level	HWL	EL m	295	295	295	285	285	285	275	275	275
Low Water Level	LWL	EL m	255	256	258	254	255	257	253	254	256
Drawdown Depth	Hd	EL m	40	39	37	31	30	28	22	21	19
Normal Water Level	NWL	EL m	282	282	283	275	275	276	268	268	269
Sedimentation Level	SL	EL m	244	244	244	244	244	244	244	244	244
Tail Water Level	TWL	EL m	198	198	198	198	198	198	198	198	198
Penstock Dia.(V=5m/s)		m	5	6	6	4	5	6	4	5	5
Gross Storage Capacity	Vg	10^6m^3	376	376	376	268	268	268	182	182	182
Effective Storage Capacity	Ve	10^6m^3	304	300	292	200	196	188	117	114	106
Peaking Time		hr	4	4	4	4	4	4	4	4	4
Firm Discharge Qf without $2m^3/s$		m^3/s	19	18	18	14	14	13	9	9	8
Maximum Discharge	Qmax	m^3/s	90	120	150	70	100	130	50	80	110
Gross Head	Hg	m	84	84	85	77	77	78	70	70	71
Effective Head	He	m	83	83	84	76	76	77	69	69	70
Installed Capacity P1max (main)		MW	66	88	111	47	67	89	31	49	68
Installed Capacity P2max (sub)		MW	2	2	2	1	1	1	1	1	1
Pmax=P1max+P2max		MW	68	90	113	49	69	90	32	50	69
Dependable Capacity Pf1 (main)		MW	36	37	36	29	32	32	22	25	25
Dependable Capacity Pf2 (sub)		MW	1	1	1	1	1	1	1	1	1
Pf=Pf1+Pf2		MW	37	38	37	30	32	33	23	26	26
Annual Average Inflow		10^6m^3	1301	1301	1301	1301	1301	1301	1301	1301	1301
Annual Average Power Discharge		10^6m^3	1124	1158	1193	1014	1114	1164	839	1031	1120
Annual Average Overflow		10^6m^3	108	75	40	219	120	70	395	204	114
Annual Average Energy E1 (main)		GWh	239	251	258	195	219	230	145	179	199
Annual Average Energy E2 (sub)		GWh	11	12	12	11	11	11	10	10	10
Annual Average Energy E3 (15Sep)		GWh	2	2	2	2	2	2	2	2	2
E=E1+E2+E3		GWh	252	264	272	208	231	243	156	191	211
Plant Factor		%	43	34	27	49	38	31	56	44	35
Project Cost		10^6\$	217.7	224.5	231.6	182.2	188.8	195.7	151.2	157.6	164.2
Energy cost per kw		\$/kW	3213	2501	2047	3753	2748	2173	4749	3143	2364
Energy cost per kwh		\$/kWh	0.096	0.095	0.095	0.098	0.091	0.090	0.108	0.092	0.087
B/C			0.73	0.73	0.72	0.71	0.75	0.76	0.65	0.74	0.76
B-C		10^6\$	-6.39	-6.51	-7.08	-5.68	-5.10	-5.10	-5.75	-4.46	-4.23

255

Table 9.10 Joint Development of La Honda and El Chaparral

Case		La Honda	Chaparral	Combined
High Water Level HWL	EL m	275	212	
Low Water Level LWL	EL m	254	196	
Drawdown Depth Hd	EL m	21	16	
Normal Water Level NWL	EL m	268	207	
Sedimentation Level SL	EL m	244	161	
Tail Water Level TWL	EL m	198	133	
Penstock Dia (V=5m/s)	m	4.5	5	
Gross Storage Capacity Vg	$10^6 m^3$	182	189	
Effective Storage Capacity Ve	$10^6 m^3$	114	106	
Peaking Time	hr	4	4	
Firm Discharge Qf without $2m^3/s$	m^3/s	8.6	11.3	
Maximum Discharge Qmax	m^3/s	80	100	
Gross Head Hg	m	70.0	74.0	
Effective Head He	m	69.0	72.8	
Installed Capacity P1max (main)	MW	48.8	64.4	113.2
Installed Capacity P2max (sub)	MW	0.0	1.3	1.3
Pmax=P1max+P2max	MW	48.8	65.7	114.5
Dependable Capacity Pf1 (main)	MW	24.6	29.2	53.8
Dependable Capacity Pf2 (sub)	MW	0.0	1.1	1.1
Pf=Pf1+Pf2	MW	24.6	30.3	54.9
Annual Average Inflow	$10^6 m^3$	1300.6	1502.7	
Annual Average Power Discharge	$10^6 m^3$	1030.5	1271.1	
Annual Average Overflow	$10^6 m^3$	203.9	547.0	
Annual Average Energy E1 (main)	GWh	179.5	229.0	408.5
Annual Average Energy E2 (sub)	GWh	0.0	10.6	10.6
Annual Average Energy E3 (15Sep)	GWh	2.0	2.0	4.0
E=E1+E2+E3	GWh	181.5	241.6	423.1
Plant Factor	%	42	42	
Project Cost	10^6\$	156.6	135.3	292.0
Energy cost per kw	$/kW	3207	2060	2549
Energy cost per kwh	$/kWh	0.096	0.062	0.077
B/C		0.71	1.07	0.88
B-C	10^6\$	-4.94	1.00	-3.94

256

Table 9.11 El Chaparral Project Comparison of Peaking Time

Case		CH1-1	CH1-2	CH1-3	CH1-1	CH1-2	CH1-3
Peaking Time	hr	4 hr	4 hr	4 hr	3 hr	3 hr	3 hr
High Water Level HWL	EL m	212	212	212	212	212	212
Low Water Level LWL	EL m	195	196	198	195	196	198
Drawdown Depth Hd	EL m	17	16	14	17	16	14
Normal Water Level NWL	EL m	206	207	207	206	207	207
Sedimentation Level SL	EL m	185	185	185	185	185	185
Tail Water Level TWL	EL m	133	133	133	133	133	133
Penstock Dia (V=5m/s)	m	4.2	5.0	5.8	4.2	5.0	5.8
Gross Storage Capacity Vg	10^6m^3	189	189	189	189	189	189
Effective Storage Capacity Ve	10^6m^3	111	106	96	111	106	96
Peaking Time	hr	4	4	4	3	3	3
Firm Discharge Qf without $2m^3/s$	m^3/s	8.9	8.6	8.0	8.9	8.6	8.0
Maximum Discharge Qmax	m^3/s	70	100	130	70	100	130
Gross Head Hg	m	73.0	74.0	74.0	73.0	74.0	74.0
Effective Head He	m	71.8	72.8	72.8	71.8	72.8	72.8
Installed Capacity P1max (main)	MW	44.5	64.4	83.7	44.5	64.4	83.7
Installed Capacity P2max (sub)	MW	1.3	1.3	1.3	1.3	1.3	1.3
Pmax=P1max+P2max	MW	45.8	65.7	85.1	45.8	65.7	85.1
Dependable Capacity Pf1 (main)	MW	29.3	26.6	21.5	35.9	38.4	33.2
Dependable Capacity Pf2 (sub)	MW	1.1	1.1	1.1	1.1	1.1	1.1
Pf=Pf1+Pf2	MW	30.4	27.7	22.6	37.0	39.5	34.3
Annual Average Inflow	10^6m^3	1489.1	1489.1	1489.1	1489.1	1489.1	1489.1
Annual Average Power Discharge	10^6m^3	1065.9	1226.9	1304.7	1065.9	1226.9	1304.7
Annual Average Overflow	10^6m^3	355.4	194.9	117.7	355.4	194.9	117.7
Annual Average Energy E1 (main)	GWh	190.2	219.7	235.9	190.6	220.6	238.1
Annual Average Energy E2 (sub)	GWh	10.5	10.6	10.7	10.5	10.6	10.7
Annual Average Energy E3 (15Sep)	GWh	2.0	2.0	2.0	2.0	2.0	2.0
E=E1+E2+E3	GWh	202.7	232.3	248.6	203.1	233.2	250.8
Plant Factor	%	51	40	33	51	40	34
Project Cost	10^6\$	128.5	135.3	142.2	128.5	135.3	142.2
Energy cost per kw	$/kW	2806	2059	1672	2806	2059	1672
Energy cost per kwh	$/kWh	0.071	0.065	0.064	0.071	0.065	0.063
B/C		1.00	1.01	0.96	1.08	1.14	1.08
B-C	10^6\$	0.00	0.16	-0.67	1.08	2.10	1.31

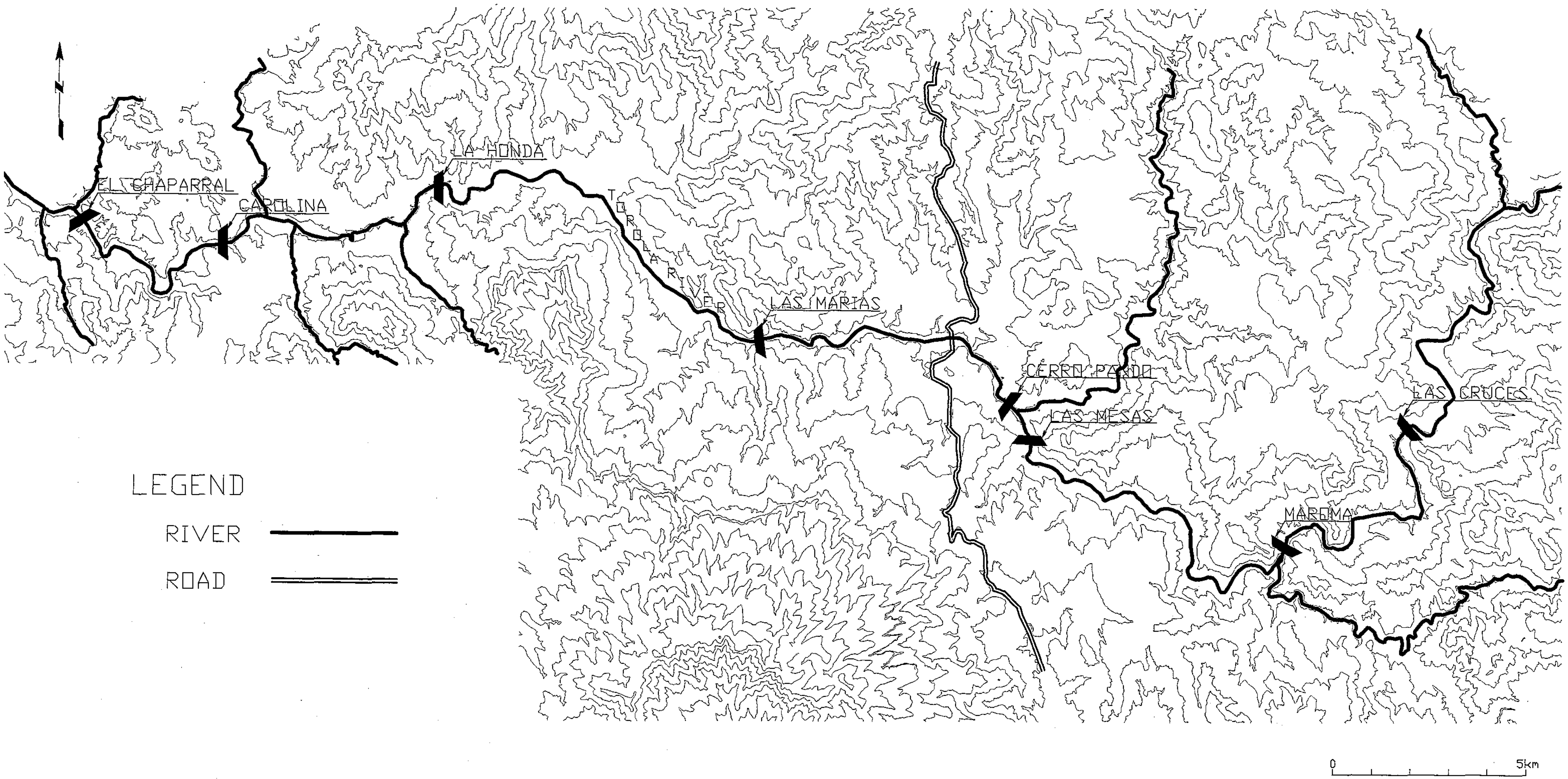
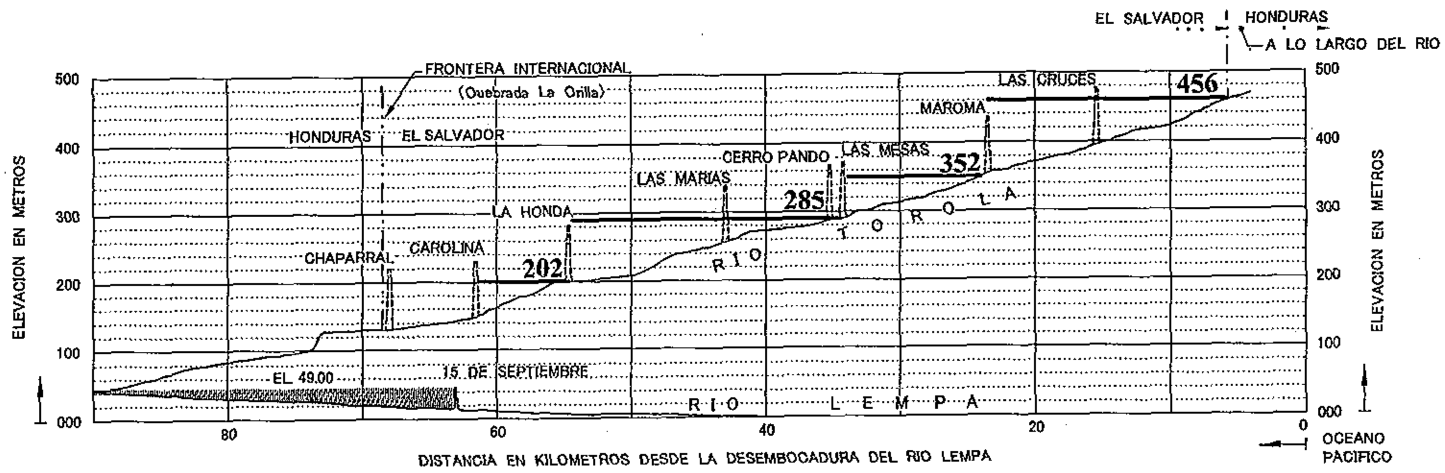


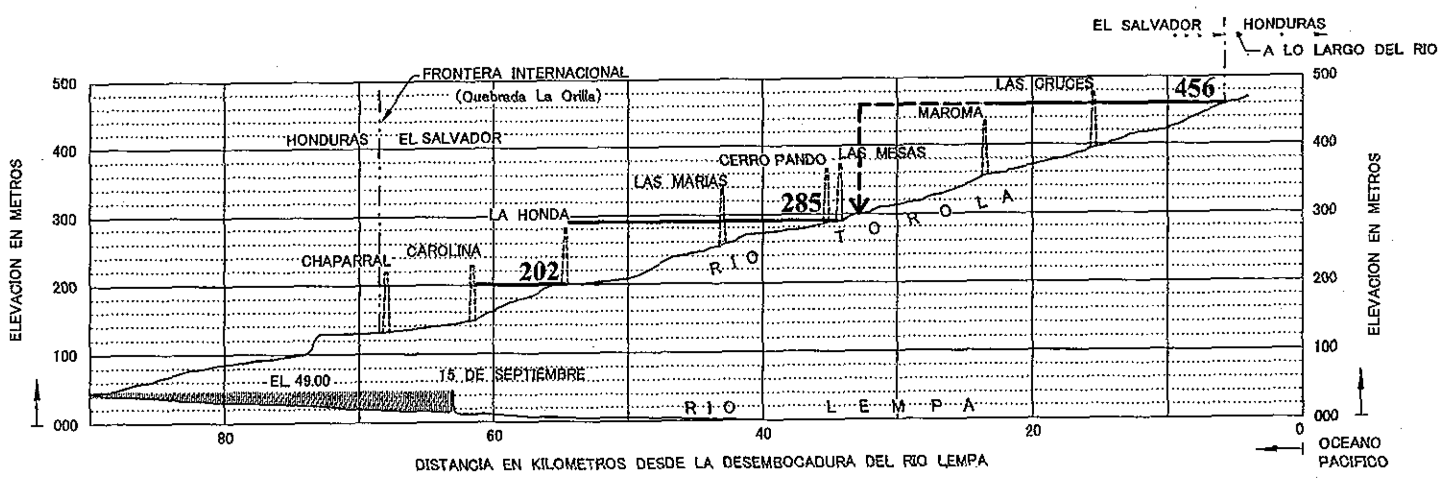
Fig. 9.1 Projects in Torola River (Phase 1A ·Phase 1B)

Phase 1A

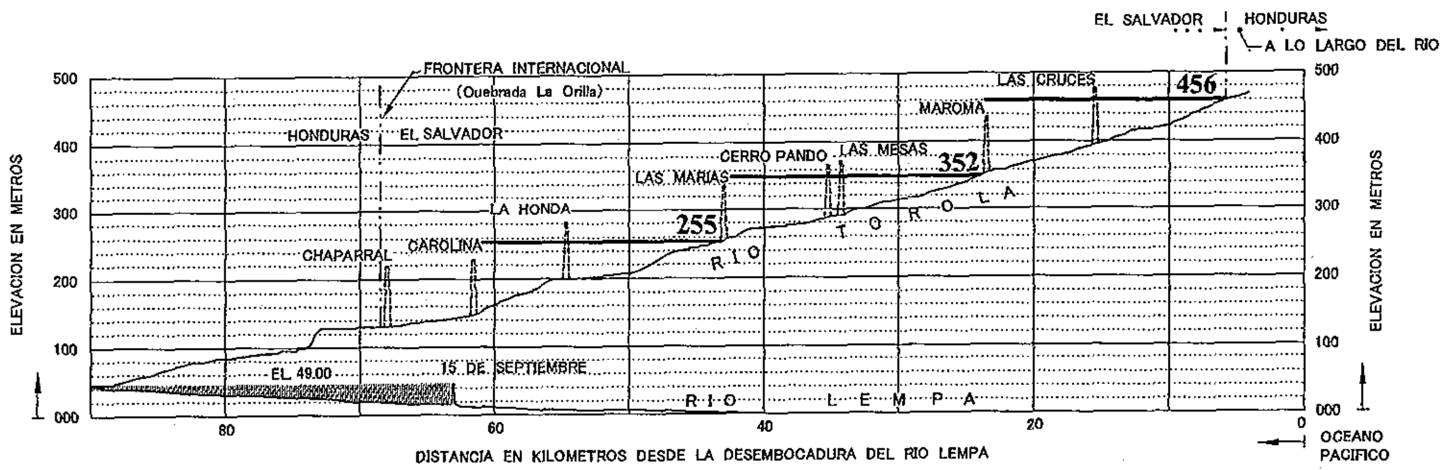
(Scheme 1)



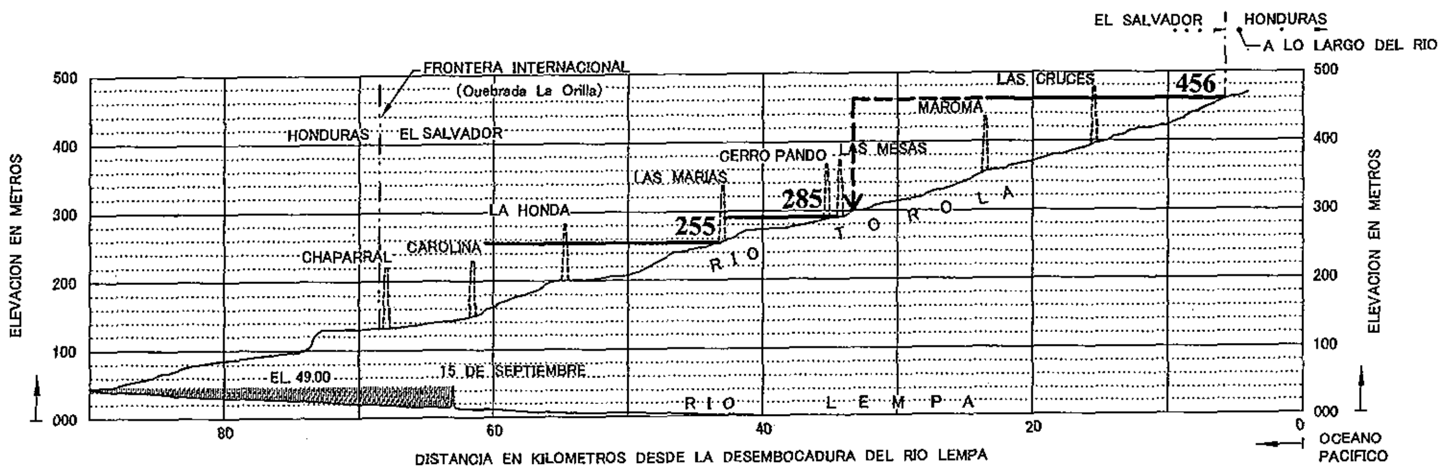
(Scheme 2)



(Scheme 3)



(Scheme 4)



Phase 1B

(Proposed Scheme)

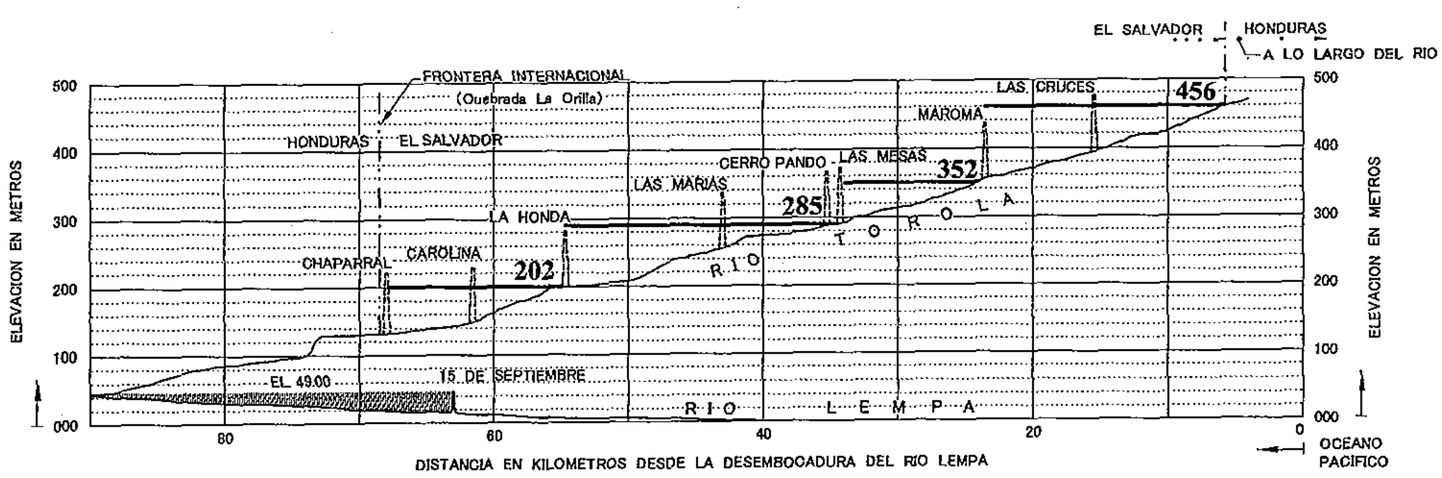


Fig. 9.2 Development Scheme in Torola River (Phase 1A, Phase 1B)

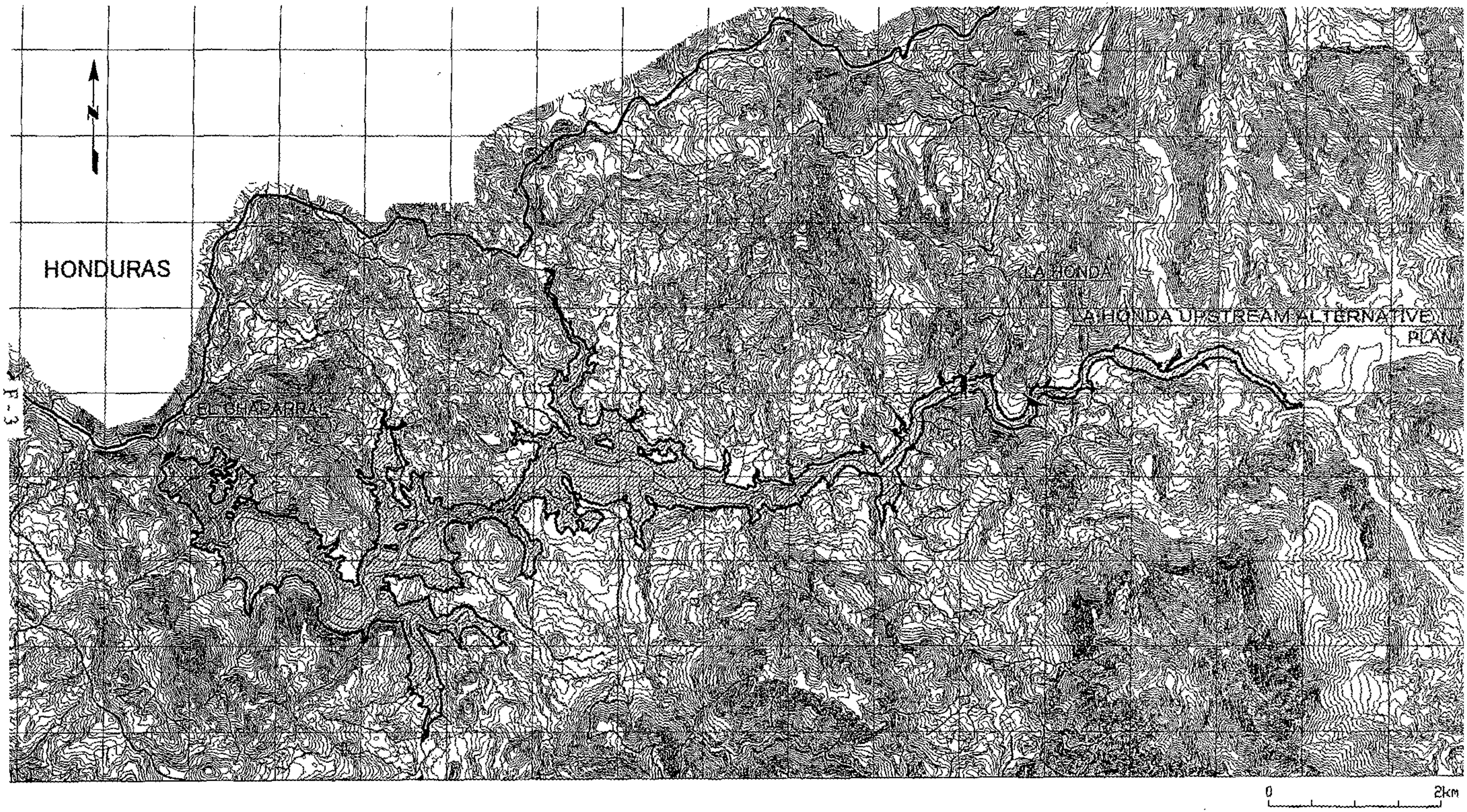
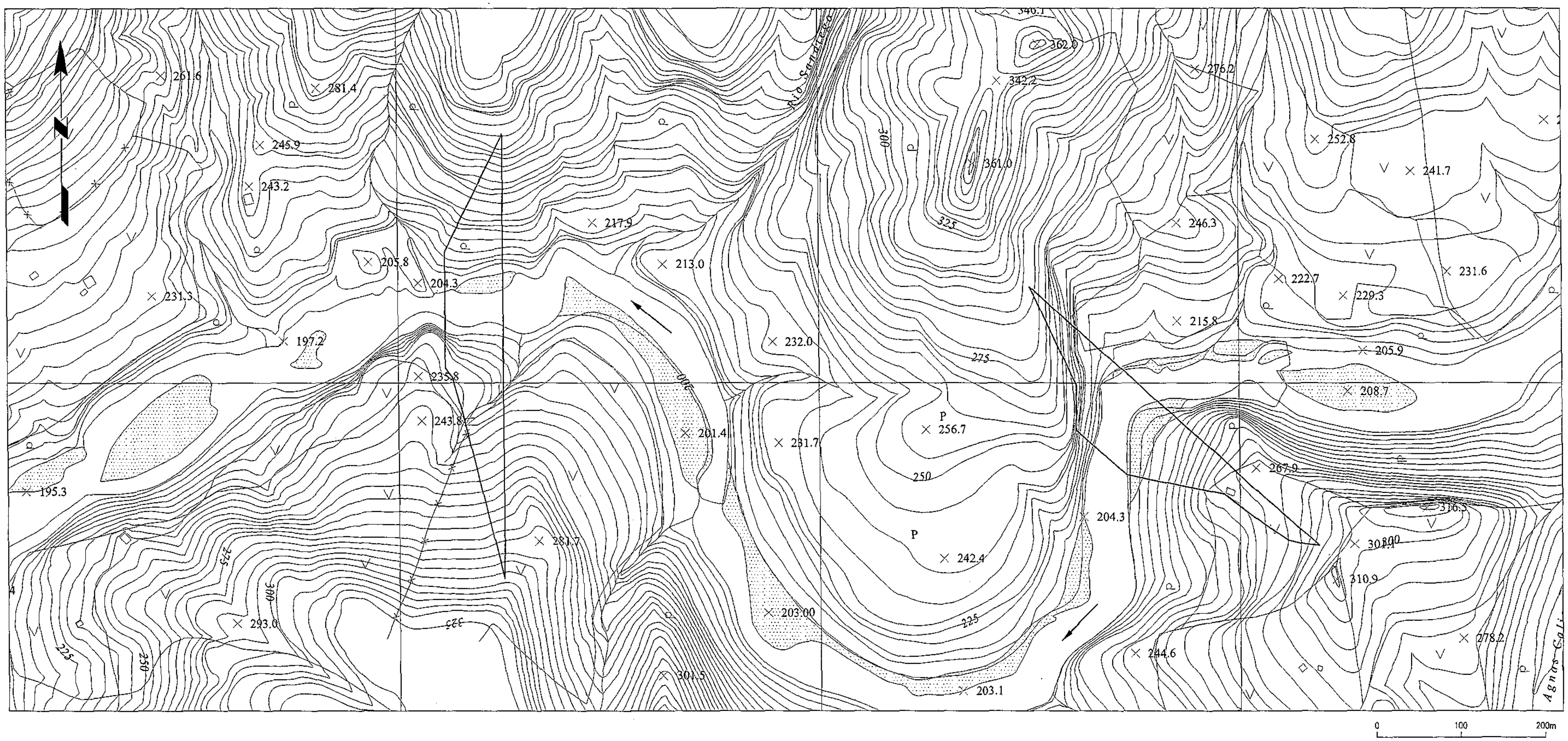
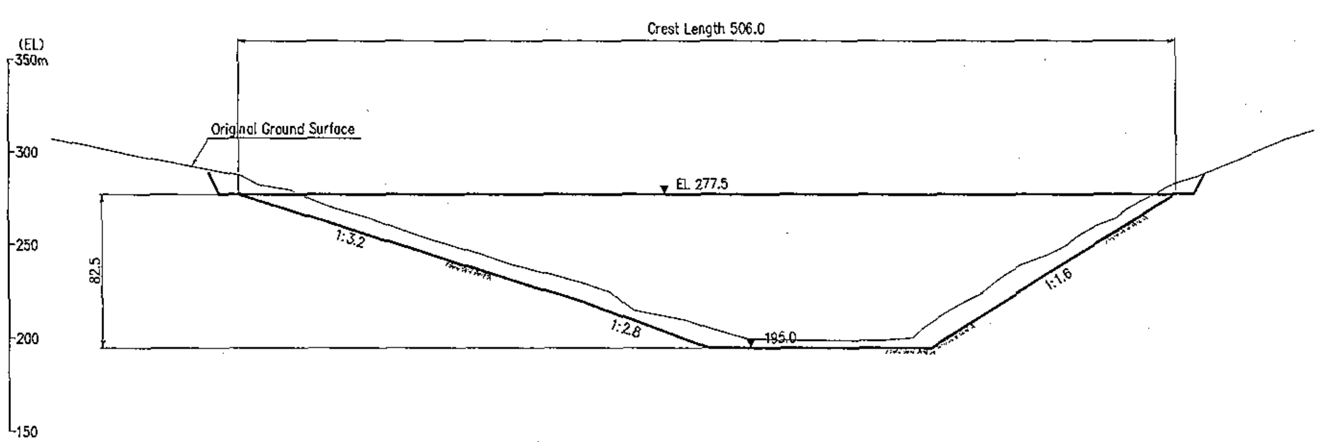


Fig. 9.3 Location of El Chaparral and La Honda Development Plan

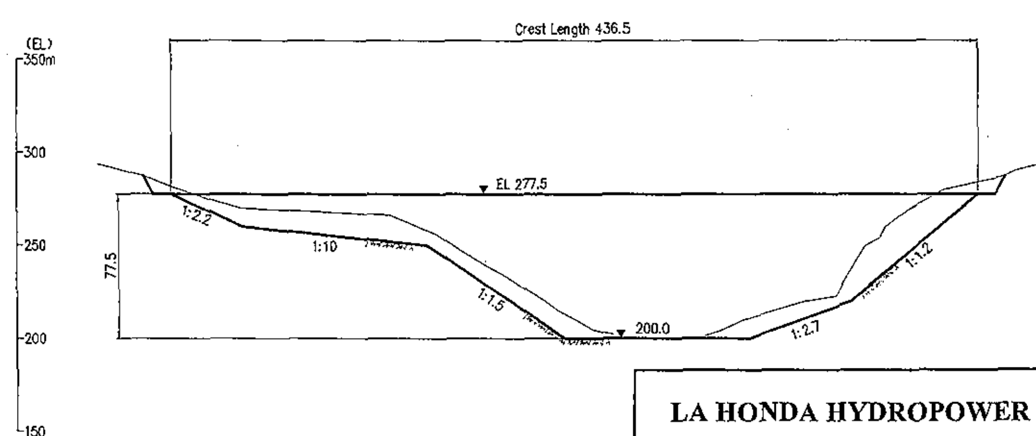
PLAN



LA HONDA



LA HONDA UPSTREAM ALTERNATIVE



LA HONDA HYDROPOWER PROJECT
UPSTREAM ALTERNATIVE DAM
Fig. 9.4 DATE

F - 4 SHEET NO. OF

262

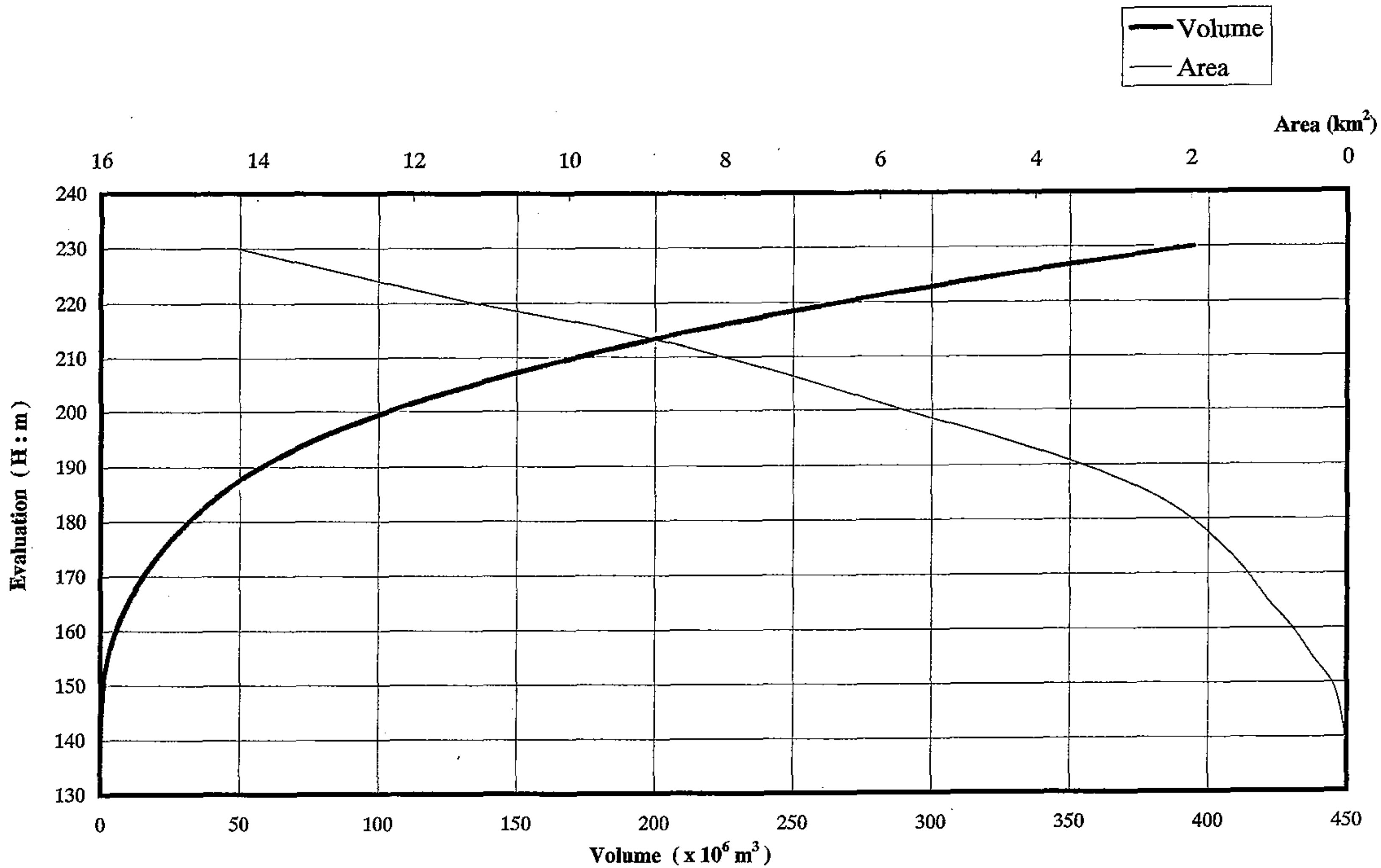


Fig. 9.5 H-V & H-A Curve (EL Chaparal)

253

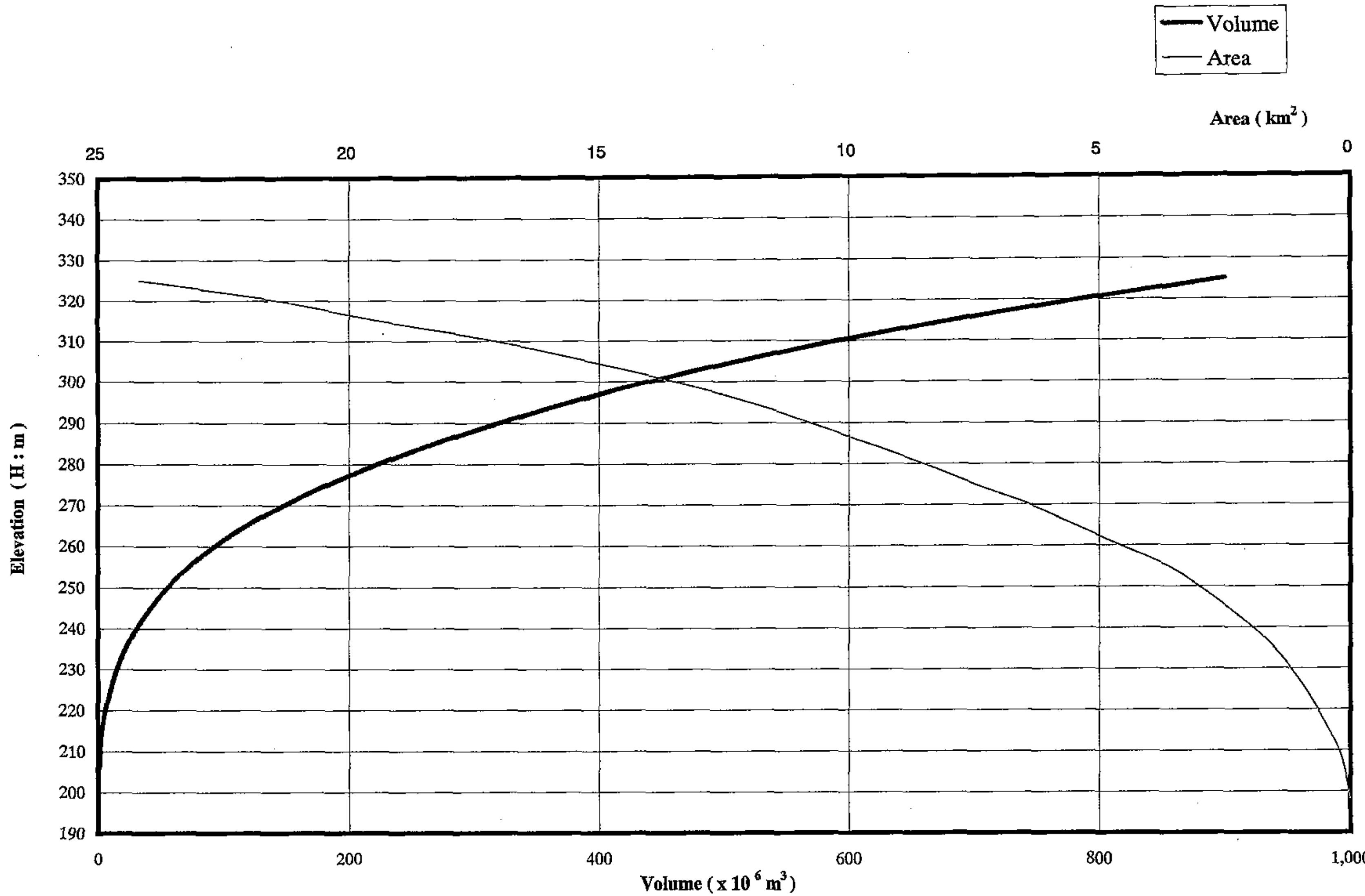


Fig. 9.6 H-V & H-A Curve (La Honda)

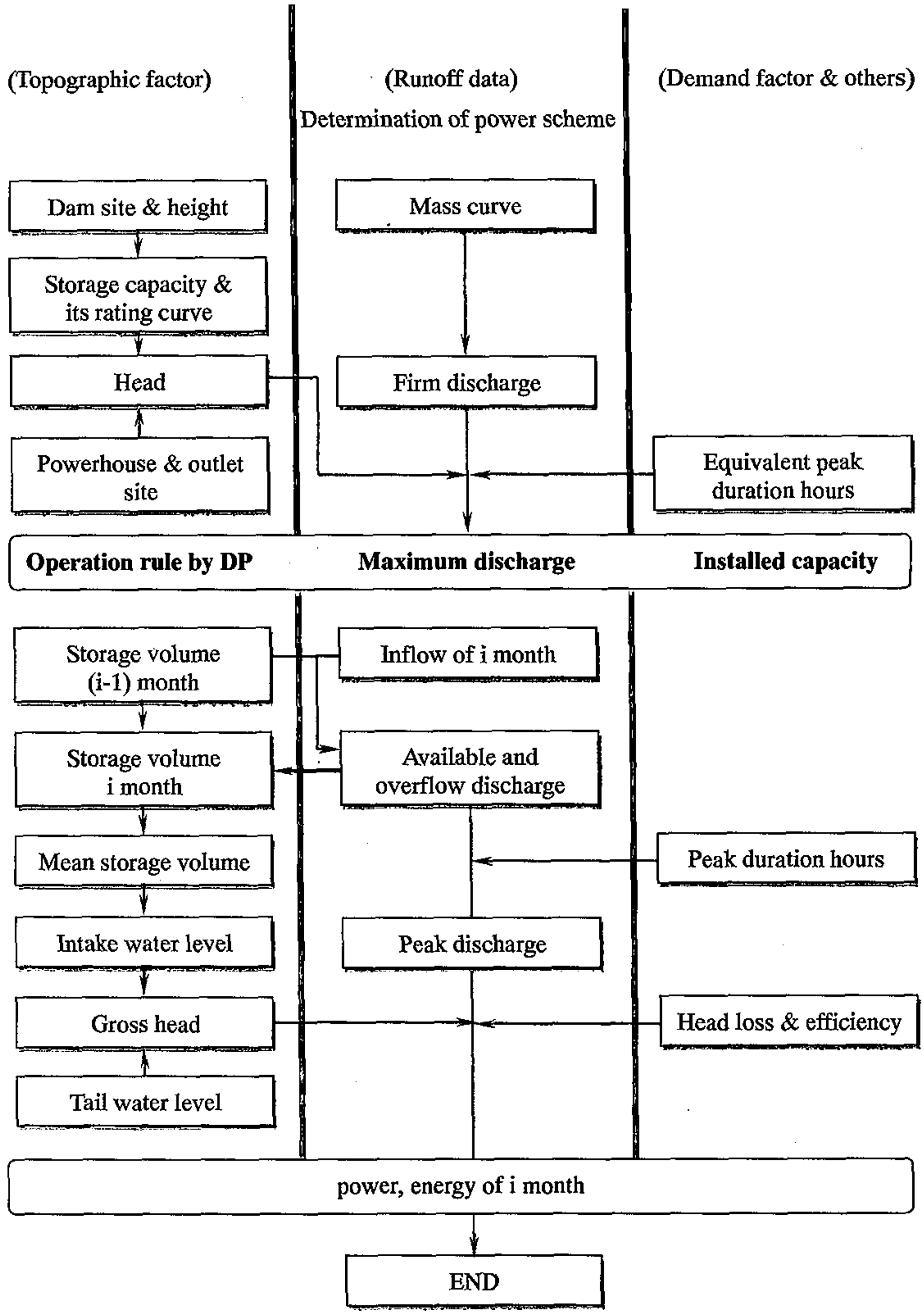
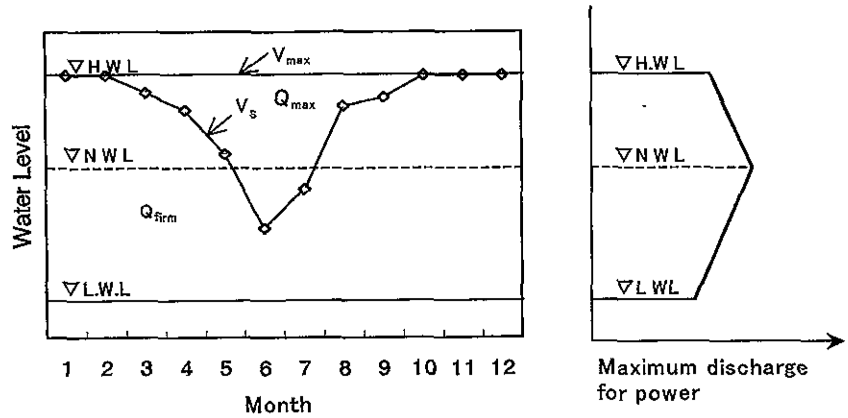


Fig. 9.7 Flow Chart of Power and Energy Calculation



Symbols

Vn-1	:	Storage at the end of previous month
Vn	:	Storage at the end of current month
V′n	:	Temporary storage at the end of current month
Vmax	:	Maximum storage (effective storage capacity)
Vs	:	Secured storage for firm discharge
Fn	:	Spill in current month
Qn	:	Inflow in current month
Qn	:	Available discharge for power in current month
Qfirm	:	Firm discharge for power
Qmax	:	Maximum discharge for power, variable depending on water level
En	:	Evaporation at the end of current month

Operation Rule

V′n = Vn-1 + qn – En

1. V′n ≧ Vs
   (1) V′n – Vs ≧ Qmax → Qn = Qmax
   (2) Qmax > V′n – Vs ≧ Qfirm → Qn = V′n – Vs
   (3) Qfirm > V′n – Vs → Qn = Qfirm
2. Vs > V′n
   (1) V′n ≧ Qfirm → Qn = Qfirm
   (2) Qfirm > V′n → Qn = V′n

V′n – Qn – Vmax ≧ 0.0 → fn = V′n – Qn – Vmax

V′n – Qn – Vmax < 0.0 → fn = 0.0

Vn = V′n – Qn – fn

Fig.9.8 Operation Rule of Reservoir by Dynamic Program method for Energy Maximum

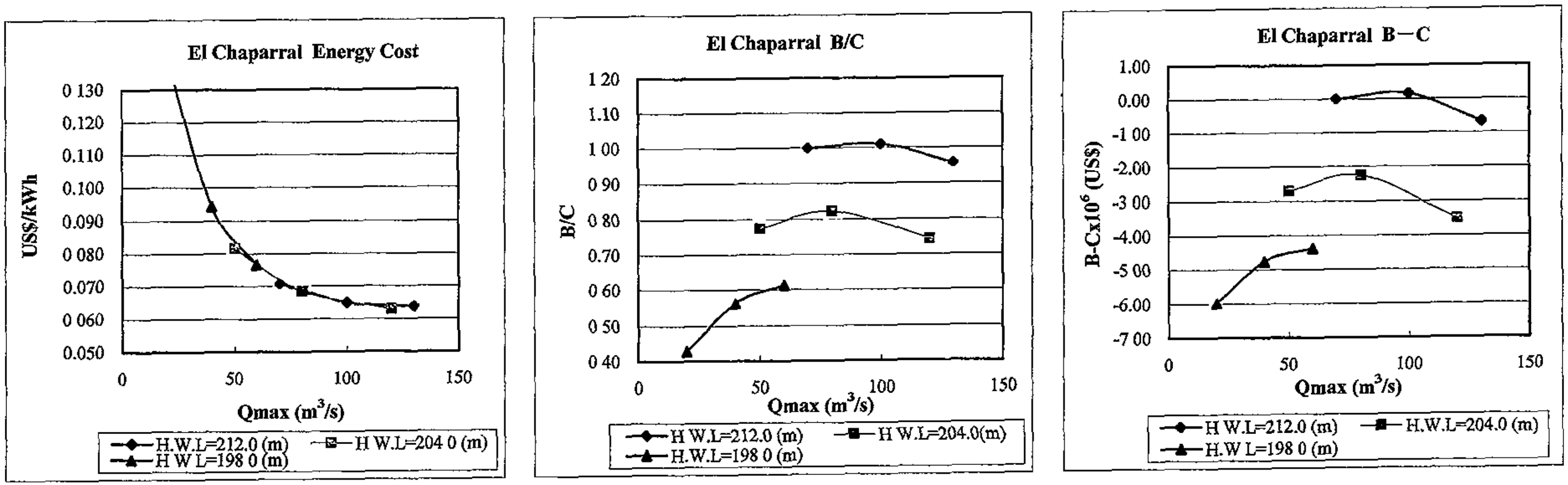


Fig.9.9 Energy Cost, B/C, B−C

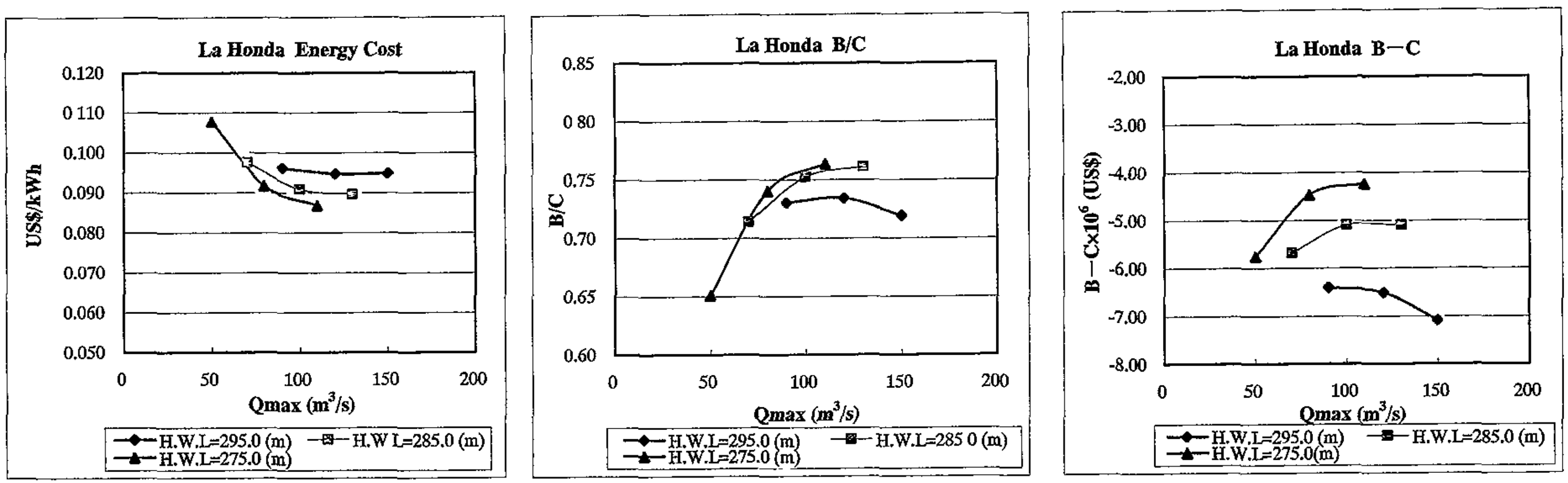


Fig.9.10 Energy Cost, B/C, B−C

25

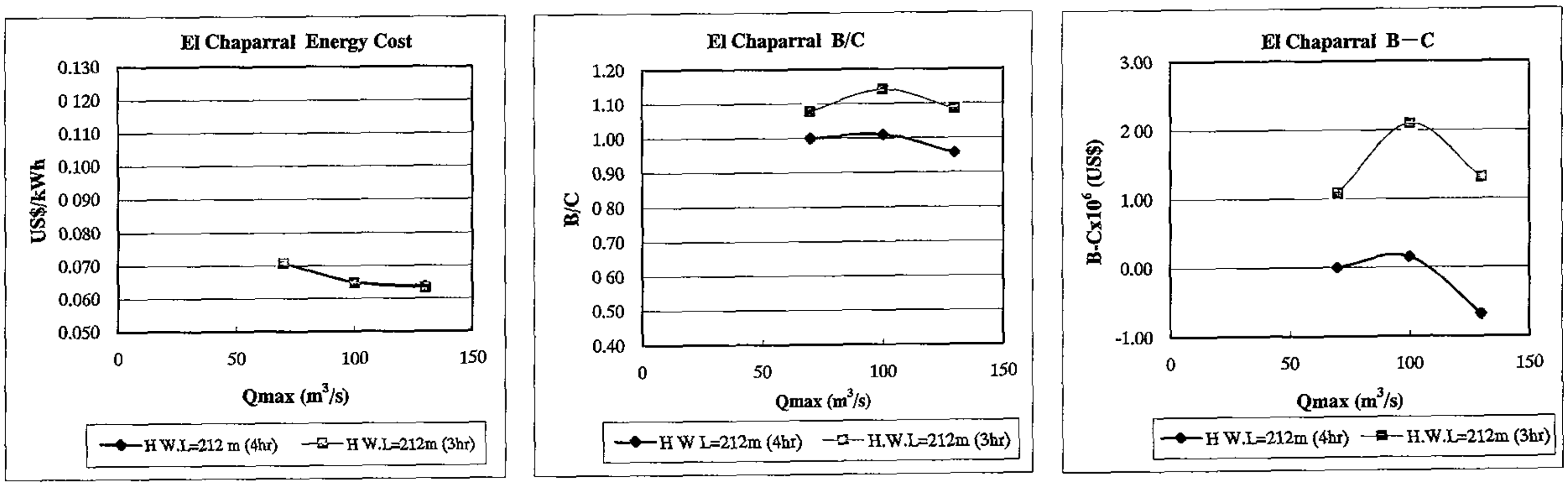


Fig. 9.11 Energy Cost, B/C, B-C

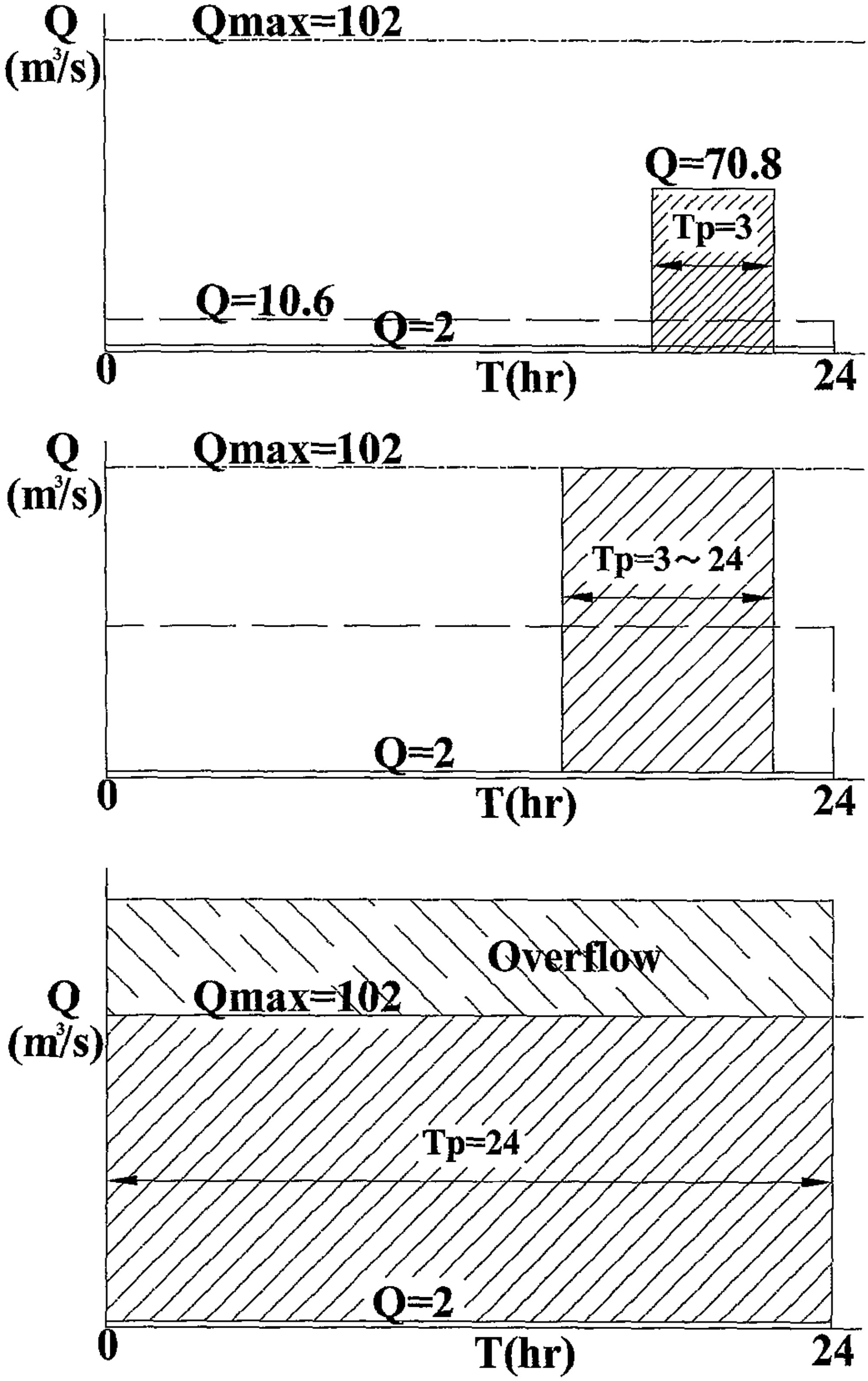


Fig. 9.12 Daily Operation Pattern at El Chaparral Power Plant

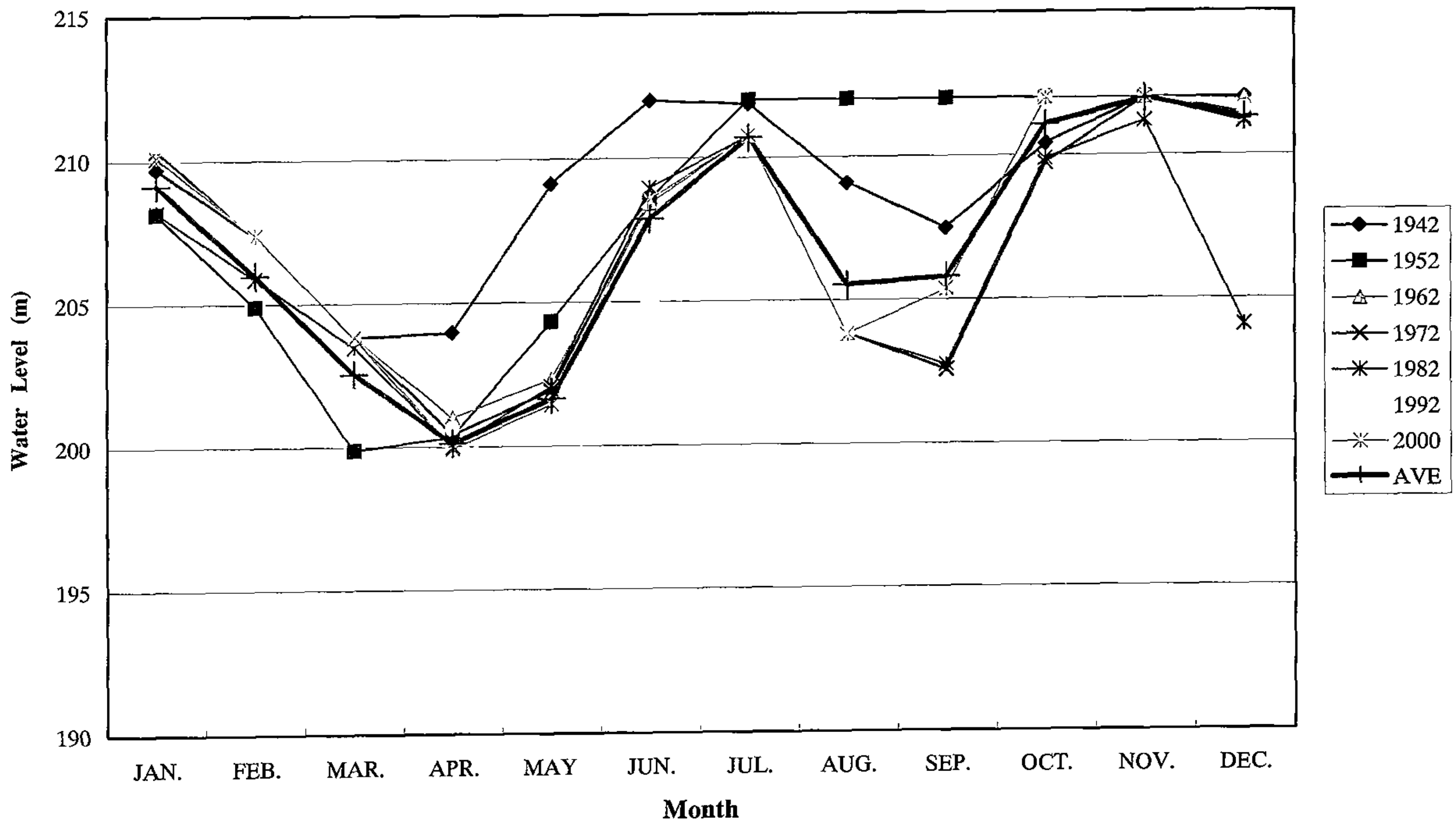


Fig. 9.13 Yearly Reservoir Water Level

10. TRANSMISSION PLAN

272 (2732)

CONTENTS

274 (2792)

10. Transmission Plan

10.1 Outline of Transmission System

Fig.10.1 shows the transmission system in El Salvador as of 2002. The transmission system in this country is composed of 230 kV/115 kV transmission lines. Each transmission line length is 1022 km for the 115 kV lines and 107 km for the 230 kV lines (as of 2002). The main transmission systems are based on 115 kV.

The main power stations, such as the largest thermal power station, Acajutla, and the four major hydro power stations, 15 de Septiembre, Cerron Grande, 5 de Noviembre and Guajoyo, are connected to the power system by two routes or two circuits to maintain reliability, and the power is supplied to the metropolitan area and local cities. Moreover, for the metropolitan area with the greatest power demand, the system, composed of an outer ring transmission line, contributes to better reliability.

The interconnection line exists with the neighboring country of Guatemala at present. The transmission voltage is 230 kV, and transmission capacity is 120 MW. The line is connected to Ahuachapan Substation. The 230 kV interconnection line (with a transmission capacity of 100 MW) between Honduras and El Salvador was connected to the 15 de Septiembre Substation (230 kV) in 2002.

Fig.10.2 shows the expected transmission system to be completed by 2010. The 230 kV transmission system will be enhanced in line with the plan for the Central American interconnection system (SIEPAC), which will connects six countries of Central America. It is planned that the present interconnection line between El Salvador and Guatemala and the interconnection line between El Salvador and Honduras will be run on two circuits, and 230 kV transmission lines connecting the east and west of El Salvador are going to be constructed. The second 230 kV interconnection line, which connects the combined-cycle power plant (IPP) in Puerto Cortes in northern Honduras and Nejapa Substation, is going to be constructed. It is planned that the transmission line length will be 373 km and the capacity of power purchase will be about 450 MW.

10.2 Transmission Line Plan

10.2.1 Transmission Line Routes

Fig. 10.3 shows alternative transmission line route plans that were proposed for this project. The respective outlines are as follows.

(1) Route A

Route A runs from El Chaparral Power Station to 15 de Septiembre Substation by way of Cerro Chucuyote. It passes the northern side of 15 the de Septiembre dam. The route must cross rivers that flow into the dam, but the width of the rivers is about 150 m. Therefore, long-span steel towers are unnecessary. The transmission line length is 43 km (14 km from El Chaparral to Cerrro Chucuyote, 29 km from Cerro Chocuyote to 15 de Septiembre).

(2) Route B

Route B runs from El Chaparral Power Station to San Miguel Substation. It passes the west side of Cerro Cacahuatique. The transmission line length is 51 km from El Chaparral to San Miguel.

10.2.2 Transmission System

Plans based on one circuit transmission were proposed for the sake of economic efficiency. For the enhancement of reliability, the use of a single-phase reclosing system will be necessary. The transmission line route used in this study and the reasons for the selection will be explained later.

The transmission voltage is set at 115 kV, which is the voltage used in most part of the transmission system in El Salvador. Because the rated output of El Chaparral Power Station is 65.7 MW (main turbine: 64.4 MW, sub turbine: 1.3 MW) and the transmission line length will be about 50 km regardless of the selection of Route A or Route B, the transmission voltage (115 kV) is sufficient for the heat capacity of the transmission line and for the power system stability. The number of conductors per phase was examined as a parameter. The results of the study will be described later.

10.2.3 Composition of Switching Station

The single bus system (Fig. 10.4) was given attention as a candidate to be selected from the point of view of economic efficiency, but we propose using the $1\frac{1}{2}$ CB bus system instead (Fig. 10.5), because (1) Almost no damage on the power system in case of a bus fault, and the transmission line is available for use during maintenance and circuit breaker trouble, (2) the $1\frac{1}{2}$ CB bus system is used in El Salvador System as the standard system, and it is desirable to apply the standard system from the viewpoint of operation and maintenance. Fig. 10.5 shows the switching station of El Chaparral plant operation. Because there are only two circuits in the switching station, the installation of a bypass circuit is necessary for the maintenance of the circuit breaker. This will also make it easier should the need develop in the future for additional circuits to be connected to the switching station. Fig. 10.6 shows general arrangements of the switching station. The switching station needs the space of more than 65 m x 25 m.

10.2.4 Specifications of Main Equipment

Specifications of the main equipment are outlined below. They basically conform to the standard specifications used in El Salvador.

(1) Conductors

477 MCM ACSR (Flicker) was selected. The capacity is about 126 MVA (630 A) per conductor.

(2) Type and Number of Insulators

- Type: Ball and Socket Type
- Disc Diameter: 254 mm
- Spacing: 146 mm
- Standards: ANSI C.29.1/29.2

To determine the number of insulators investigation of contamination will be needed in the area of this project.

For the time being, however, we selected the suspension insulator with eight discs and the tension insulator with nine discs, both of which correspond to CEL's existing 115 kV transmission system.

(3) Overhead Ground Wire

To protect the transmission line from lightning, the overhead ground wire is placed over the entire length of the transmission line. The following galvanized steel overhead ground wire is appropriate.

- Type and Material: E.H.S galvanized steel
- Exterior diameter: 9.52 mm
- Standards: ASTM-A-363

(4) Transmission Tower

Fig. 10.7 shows the conceptual diagram of the 115 kV transmission tower based on CEL's specifications. This type of tower has been selected for this project.

(5) Circuit Breaker

- Type: Gas (live tank or dead tank)
- Rated voltage (RMS): 115 kV
- Rated continuous current: 2,000 A
- Symmetrical interrupting capability at rated voltage: 40 kA RMS
- Rated Duty Cycle: O-0.3s-CO-3min-CO

10.2.5 Comparison of Transmission Systems

In terms of transmission routes, two alternative route plans were prepared. In one of the route plans, the line is connected to 15 de Septiembre Substation, and in another plan it is connected to San Miguel Substation. In addition, the number of conductors used in a phase needed to be reviewed (single or double). Therefore, a total of four transmission patterns were compared, whose results are indicated below.

Table 10.1 shows the transmission capacity, construction cost and annual expense for each of the transmission patterns. The calculation method for the initial cost and annual expense is shown in Table 10.2.

The cost was calculated for all of the circuit breakers and disconnectors at the switching stations, and a series of a circuit breaker and disconnectors at the connected substation. The construction cost in Case 1 is smallest, with k$4,138, because in Case 1, the transmission line length is the shortest, and the conductor per phase is single. As for the annual expense, Case 2, where the number of conductors per phase is double, costs the least, due to the conversion of the transmission loss into the monetary term. However, the difference between Case1 and Case 2 in terms of the annual expense is insignificant, as it would require about 15 years of operations to fully recapture the difference in the construction cost by the difference in the annual expense. It is possible to add two circuits in all cases for future expansion. However, the double conductor per phase offers slightly more advantages.

In addition, El Salvador has a plan to build a hydropower station (Eltigre) near the border in cooperation with Honduras, and its electric power will be sent to Cerro Chokuyote via the 230 kV transmission line. Since the plan is not clear at present, the expenses of building transmission lines of 230 kV specifications from Cerro Chokuyote to 15 de Septiembre is shown in Table 10.2 for reference purposes.

In this study, we propose using Case1 for the following reason.

(1) Lower construction cost

The difference between Case 1 and Case 2 in terms of annual expenses is considered insignificant.

(2) Specifications concerning the heat capacity and stability are satisfied. (The results of the stability study will described later)

(3) In the cases where the connection is made to San Miguel Substation (Case 3 and Case 4), it may be difficult to acquire the rights of way along and around the transmission route.

10.3 Power System Analysis

10.3.1 Scope of Simulation Studies

The simulated range for the power system analysis is the entire length of the transmission system (230 kV / 115 kV transmission system) in El Salvador. The following items were added to the present power transmission system in an attempt to better reflect the future configuration to be available in 2010, which is the subject of this power system analysis.

- El-Chaparral Power Station and related transmission lines.
- Removal of two generators (installed capacity of single generator: 37 MW) and addition of three generators (ditto: 16 MW) at Acajutla Power Station
- Addition of a generator (installed capacity: 27.5 MW) at Berlin Power Station

- The 230 kV transmission lines related to Central American interconnection system (SIEPAC)
- Newly-established 115 kV transmission line between Acajutla and Ateos
- The 115 kV transmission line between Acajutla and Opico will be go through Sonsonate Substation
- The 115 kV transmission line between San Bartoro and Sun Martin will be replaced by a double circuit line.
- Addition of shunt capacitors to Nejapa, Ateos and Ozatlan Substations

Fig. 10.8 shows the positive sequence impedance map reflecting the above-mentioned items.

10.3.2 Load Flow Calculation

(1) Load Conditions

The peak demand and off-peak demand in 2010 were predicted by using the data of the actual load of each substation in 2000 (Table 10.3 reference) received from CEL. According to the actual load in 2000, the peak demand of the dry season is the annual maximum demand, and the off-peak demand of the wet season is the annual minimum demand. Two cases (peak demand and off-peak demand) in 2010 were predicted by using these actual loads. The results are summarized in Table 10.4. The detailed points of view used in the prediction are as follows.

- The peak demand in 2010 (national sum total) was set to be 1,076 MW. It was decided based on the assumption that 96% of the expected peak power of 1,121 MW is supplied to the load (transmission loss: 4%).
- The off-peak demand in 2010 (national sum total) was set to be 488 MW. It was decided based on the assumption that the ratio of the maximum load to the minimum load in 2010 would not change from the ratio based on the actual loads observed in 2000.
- The load for each substation was assigned based on the actual load in 2000.
- The load power factor was determined based on the actual load in 2001 whose data was obtained from CEL.

(2) Supply Conditions

Power supply was determined based on the following assumptions.

- The power stations where operating cost is low are operated at maximum output levels as much as possible.

This means that the output of the geothermal power plant and the hydroelectric power stations are raised, while demand and supply are kept balanced by adjusting the generator output of Acajutla and Nejapa Power Stations.

- Power supplies from Guatemala and Honduras are assumed to be 50 MW and 100 MW (Power purchase from IPP: 50 MW is included) during peak demand.
  During off-peak demand it is assumed that there is no power supply from other countries.
- In order to check that the generating power of El Chaparral P/S would not cause the overload of transmission lines near the power station, Cerron Grande, 5 de Noviembre, 15 de Septiembre, El Chaparral are operated at maximum output levels.

(3) Operating Conditions of System

- System voltage: Within 95% - 105 %
- Generator voltage: 100 ±5 %
- Generator's power factor: From 95% (lag) to 100%

(4) Load Flow Calculation Results

Fig. 10.9 and Fig. 10.10 show load flow calculation results for peak demand and off-peak demand. Calculation results are summarized as follows.

- System voltage can be maintained within the proper range (95-105 %) during peak demand and off-peak demand, without relying on additional reactive power suppliers who are not considered in the plan.
- There is no overloaded transmission line caused by the addition of El Chaparral Power Station.

The determination of overloads is carried out based on the Flicker's transmission capacity of 630 A /conductor.

10.3.3 Three-Phase Short Circuit Capacity

Three-phase short circuit capacities and currents of each bus in 2010 were calculated. In order to calculate the maximum short circuit capacities and currents, it was assumed that all the generators of El Salvador's system are parallel in the system (Generators are simulated as Xd"). Results are shown in Table 10.5. The maximum three-phase short circuit current in each voltage class is shown in the following table.

282

Nominal voltage [kV]	Maximum three-phase short circuit current [kA]
230	10.7
115	18.7
46	9.3
34	6.2
23	20.0
13.8	55.1
13.2	24.8

When the calculation results were compared with specifications of circuit breakers in the 230 kV /115 kV system received from CEL (Table 10.6), it was found that most breakers are capable of cutting off short-circuit currents. However, the interrupting capacity of the circuit breaker (rated interrupting capacity is 3,500 MVA) in 115 kV at Nejapa Substation may be insufficient, and it is considered that the potential replacement need to be investigated. In addition, the rated interrupting current of the circuit breaker at the low-voltage of El Chaparral power station is required to be more than 30 kA.

10.3.4 Power System Stability

Power system stability in peak demand and off-peak demand was studied separately. A one-phase ground fault and a three-phase ground fault were simulated in stability studies. The following outlines each of the cases.

Fault point	Point close to El-Chaparral Power Station	Point close to 15 de Septiembre S/S on the transmission line connecting 15 de Septiembre and San Martin
Fault aspects	1LG-(150 ms)-1LO-(300 ms)-1LC	3LG-(150 ms)-3LO (no reclosing)
Peak demand in 2010	Fig. 10.11	Fig. 10.12
Off-peak demand in 2010	Fig.10.13	Fig. 10.14

* 1LG : Single line-to-ground fault / 1LO : One line open / 1LC : One Line Close (Automatic reclose)

* 3LG : Triple line-to-ground fault / 3LO : Three lines open

Fault clearing time was set at 150 ms, which is the maximum fault clearing time carried out by UT. In the case of the three-phase ground fault, reclosing was not carried out to make conditions severe.

The excitation control systems of each generator were simulated based on the data received from CEL. The governor systems were not simulated, as this study focused on the confirmation of short-range stability. Results are shown in Fig. 10.11-10.14. All cases were confirmed to be stable.

10.4 Recommendation of Transmission System

The transmission system recommended for this project is as follows based on the results of economic comparisons and the power system analysis.

1) Transmission route: El Chaparral Power Station -(43 km)- 15 de Septiembre Substation
2) Transmission voltage: 115 kV
3) Transmission line: 3*1-477 MCM ACSR (Flicker)
4) Overhead Ground Wire: D=9.52 mm (E.H.S galvanized steel)

284

285

Table 10.1 Comparison of Alternative Transmission Plans for El Chaparral Power Station

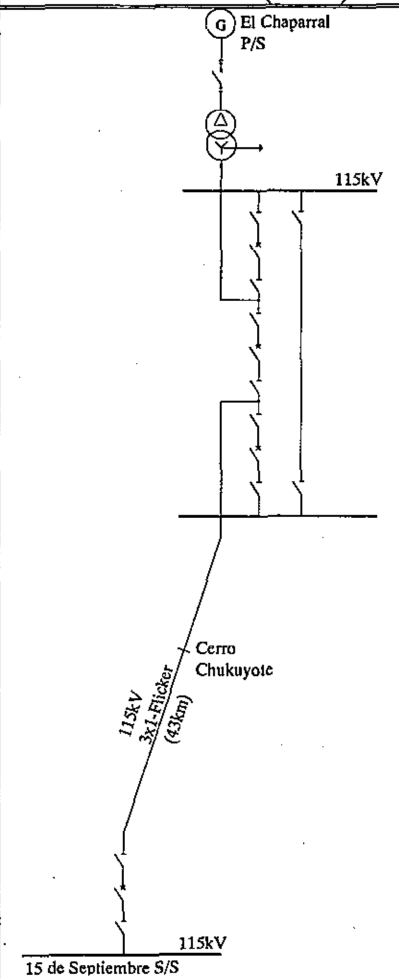
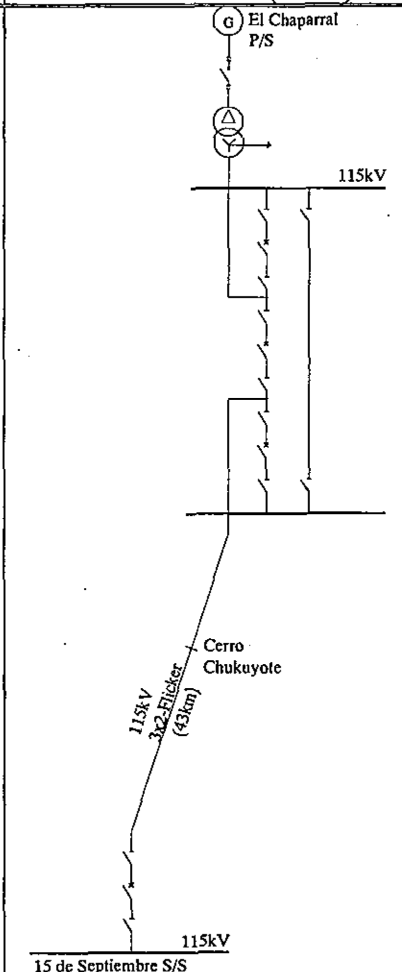
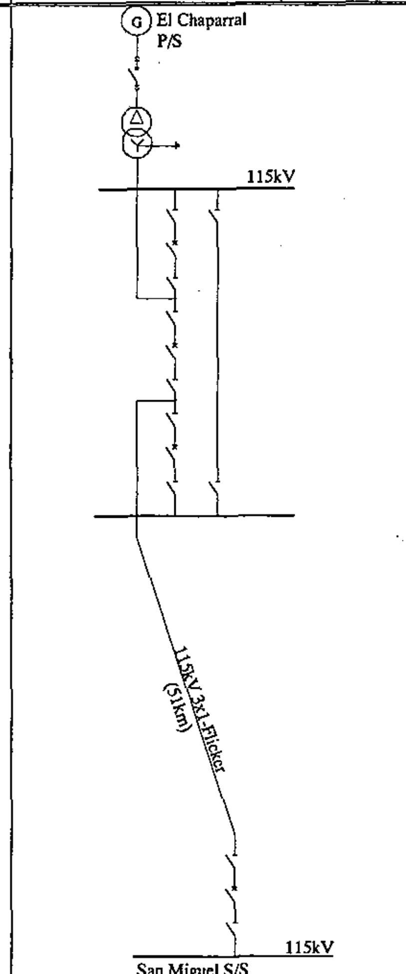
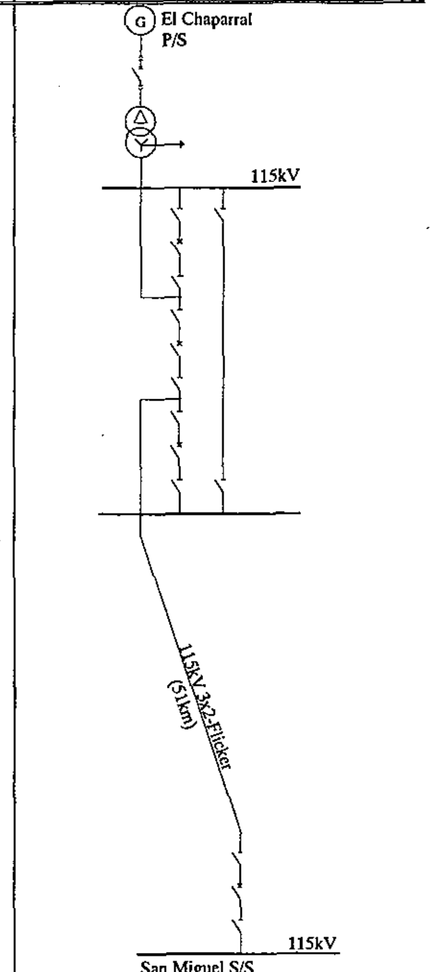
Item	El Chaparral - 15 de Septiembre		El Chaparral - San Miguel	
	Case 1	Case 2	Case 3	Case 4
	115kV 3×1-Flicker (ACSR)	115kV 3×2-Flicker (ACSR)	115kV 3×1-Flicker (ACSR)	115kV 3×2-Flicker (ACSR)
Single Line Diagram				
Transmission Capacity	126 MVA	253 MVA	126 MVA	253 MVA
Construction Cost	4,138 k$	4,905 k$	4,587 k$	5,497 k$
Annual Expense	819 k$	766 k$	931 k$	869 k$
Extendibility	○	◎	○	◎
Evaluation	◎	○	○	○

Table 10.2 Economic Comparison of Alternative Transmission Plans

Item	El Chaparral - 15 de Septiembre				El Chaparral - San Miguel	
	Case 1	Case 2	reference		Case 3	Case 4
	115kV 3×1-Flicker (43 km)	115kV 3×2-Flicker (43 km)	115kV 3×1-Flicker(14km) + 230kV 3×2-Flicker(29km)	115kV 3×2-Flicker(14km) + 230kV 3×2-Flicker(29km)	115kV 3×1-Flicker (51 km)	115kV 3×2-Flicker (51 km)
1. Construction cost [$*1000]						
a. Transmission line	2,416	3,183	3,771	4,020	2,865	3,775
b. Transformer & Switch	1,722	1,722	1,722	1,722	1,722	1,722
c. Subtotal [$*1000]	**4,138**	**4,905**	**5,493**	**5,742**	**4,587**	**5,497**
2. Annual expense rate						
a. C.R.F [%]*1						
Transmission line	10.61	10.61	10.61	10.61	10.61	10.61
Transformer & Switch	11.02	11.02	11.02	11.02	11.02	11.02
b. O/M [%]*2						
Transmission line	2.00	2.00	2.00	2.00	2.00	2.00
Transformer & Switch	1.50	1.50	1.50	1.50	1.50	1.50
c. Sub-total [%]						
Transmission line	12.61	12.61	12.61	12.61	12.61	12.61
Transformer & Switch	12.52	12.52	12.52	12.52	12.52	12.52
3. Transmission line loss						
a. Peak power loss [kW]	2,180	1,090	1,445	1,090	2,585	1,293
b. Annual energy loss [MWh]*3	4,258	2,129	2,822	2,129	5,050	2,525
4. Annual expense [$*1000]						
a. Transmission line	305	401	475	507	361	476
b. Transformer & Switch	216	216	216	216	216	216
c. Transmission line loss (loss profit)*4	298	149	198	149	354	177
Total [$*1000]	**819**	**766**	**889**	**872**	**931**	**869**

Note)

*1 : *C.R.F (Capital Recovery Factor) is calculated from the following assumptions.*
- Annual discount rate : 10.0 %
- Service life of equipment
  Transmission line : 30 years / Transformer & Switch : 25 years
- (C.R.F. for Transmission line) = 0.10*(1+0.10) ^{30} / {(1+0.10) ^{30}-1}*100 = 10.61 [%]
- (C.R.F. for Transformer & Switch) = 0.10*(1+0.10) ^{25} / {(1+0.10) ^{25}-1}*100 = 11.02 [%]

*2 : O/M (Operation and Maintenance of the equipment) : Annual expense rate on the construction costs (%/annum)

*3 : *Annual energy loss is calculated as follows.*
(Annual Energy Loss) = (Peak Power Loss)*8,760*(Loss Factor)
(Loss Factor) = 0.3*(Annual Load Factor)+0.7*(Annual Load Factor) ^{2}

*4 : power rate : 0.07 US$/kWh

Table 10.3 Actual Load of Each Substation in 2000

Voltage	Substation	Dry Season		Wet Season	
		Peak Demand [MW]	Off-peak Demand [MW]	Peak Demand [MW]	Off-peak Demand [MW]
23 kV	Nuevo Cuscatlan	53.0	25.8	54.1	25.5
	Nejapa	64.1	48.6	71.0	42.9
	San Antonio Abad	71.0	28.1	73.5	27.9
	San Bartolo	43.1	28.5	43.3	25.3
	Soyapango	73.5	39.2	77.7	42.3
34 kV	Acajutla	8.1	3.5	8.2	3.5
	Ateos	6.8	5.1	6.5	4.5
46 kV	15 de Septiembre	24.8	10.0	25.3	9.4
	Acajutla	11.1	4.5	11.8	4.5
	Ahuachapán	16.1	6.7	12.0	4.3
	Ateos	27.2	13.3	26.0	13.1
	Cerrón Grande	12.7	4.4	12.5	3.6
	Guajoyo	-4.1	-7.4	-4.1	-7.4
	Opico	14.4	8.3	13.4	6.5
	Santa Ana	42.6	21.6	42.6	19.6
	San Miguel	43.3	19.7	26.5	11.2
	Sonsonate	10.8	2.5	8.7	0.6
	Soyapango	19.7	8.9	20.6	7.3
	San Rafael Cedros	27.6	9.5	27.5	9.0
	Santo Tomás	44.0	19.4	41.9	20.3
	Tecoluca	14.4	6.2	13.9	4.3
TOTAL		624.2	306.4	612.9	278.2

287

Table 10.4 Forecasted Load of Each Substation in 2010

Voltage	Substation	Peak Demand			Off-peak Demand		
		P [MW]	Q [MVar]	PF [%]	P [MW]	Q [MVar]	PF [%]
23 kV	Nuevo Cuscatlan	89.1	22.9	96.9	42.8	11.0	96.9
	Nejapa	107.8	30.5	96.2	72.0	20.3	96.2
	San Antonio Abad	119.4	25.6	97.8	46.8	10.1	97.8
	San Bartolo	72.5	12.5	98.5	42.5	7.3	98.5
	Soyapango	123.6	26.6	97.8	71.0	15.3	97.8
34 kV	Acajutla	13.6	4.5	95.0	5.9	1.9	95.0
	Ateos	11.4	2.0	98.5	7.6	1.3	98.5
46 kV	15 de Septiembre	41.7	11.4	96.5	15.8	4.3	96.5
	Acajutla	18.7	6.1	95.0	7.6	2.5	95.0
	Ahuachapán	27.1	5.9	97.7	7.2	1.6	97.7
	Ateos	45.7	19.8	91.8	22.0	9.5	91.8
	Cerrón Grande	21.4	6.4	95.8	6.0	1.8	95.8
	Guajoyo	8.6	2.7	95.4	2.7	0.8	95.4
	Opico	24.2	9.6	93.0	10.9	4.3	93.0
	Santa Ana	71.6	20.2	96.2	32.9	9.3	96.2
	San Miguel	72.8	27.8	93.4	18.8	7.2	93.4
	Sonsonate	18.2	7.0	93.4	1.0	0.4	93.4
	Soyapango	33.1	4.5	99.1	12.3	1.7	99.1
	San Rafael Cedros	46.4	8.9	98.2	15.1	2.9	98.2
	Santo Tomás	74.0	23.3	95.4	34.1	10.7	95.4
	Tecoluca	24.2	7.2	95.8	7.2	2.2	95.8
	El Pedregal	11.0	2.2	98.0	6.0	1.2	98.0
TOTAL		1,076.2	287.6	-	488.0	127.6	-

Table 10.5 Maximum Short Circuit Currents in 2010 (1/2)

No.	Bus Name	Rated Voltage [kV]	3-phase Short Capacity [MVA]	3-phase Fault Current [kA]
1	AHUA-230	230	4267	10.7
2	NEJA-230	230	3898	9.8
3	15SE-230	230	3992	10.0
4	PAVA-230	230	4191	10.5
5	AHUA-115	115	3111	15.6
6	SANA-115	115	1369	6.9
7	GUAJ-115	115	682	3.4
8	SONS-115	115	2358	11.8
9	ACAJ-115	115	2306	11.6
10	OPIC-115	115	1878	9.4
11	ATEO-115	115	1912	9.6
12	SANT-115	115	2575	12.9
13	NCUS-115	115	1479	7.4
14	NEJA-115	115	3720	18.7
15	SOYA-115	115	2726	13.7
16	SBAR-115	115	2461	12.4
17	STOM-115	115	1838	9.2
18	SMAR-115	115	3058	15.4
19	CGRA-115	115	2524	12.7
20	SRAF-115	115	2377	11.9
21	TECO-115	115	916	4.6
22	ELPE-115	115	640	3.2
23	5NOV-115	115	1759	8.8
24	OZAT-115	115	698	3.5
25	15SE-115	115	3656	18.4
26	BERL-115	115	1896	9.5
27	SMIG-115	115	1185	5.9
28	ELCH-115	115	728	3.7
29	AHUA-46	46	710	8.9
30	GUAJ-46	46	296	3.7
31	SANA-46	46	333	4.2
32	OPIC-46	46	168	2.1
33	SONS-46	46	392	4.9
34	ACAJ-46	46	146	1.8
35	ATEO-46	46	496	6.2
36	SOYA-46	46	397	5.0
37	STOM-46	46	506	6.3
38	ELPE-46	46	261	3.3
39	TECO-46	46	308	3.9
40	SRAF-46	46	377	4.7
41	15SE-46	46	250	3.1
42	15SE-46b	46	739	9.3
43	SMIG-46	46	600	7.5
44	CGRA-46	46	213	2.7
45	OZAT-46	46	302	3.8
46	ACAJ-34	34	363	6.2
47	ATEO-34	34	195	3.3
48	SANT-23	23	665	16.7
49	NCUS-23	23	561	14.1
50	SBAR-23	23	668	16.8

Note : Calculation Conditions
- All the generators are connected to the power system.
- El Chaparral P/S is connected to 15 de Septiembre S/S. (Transmission line : 3*1 Flicker)

Table 10.5 Maximum Short Circuit Currents in 2010 (2/2)

No.	Bus Name	Rated Voltage [kV]	3-phase Short Capacity [MVA]	3-phase Fault Current [kA]
51	SOYA-23	23	797	20.0
52	NEJA-23	23	755	19.0
53	AHUA-U1	13.8	699	29.2
54	AHUA-U2	13.8	699	29.2
55	AHUA-U3	13.8	412	17.2
56	ACAJ-U1	13.8	510	21.3
57	ACAJ-U2	13.8	524	21.9
58	ACAJ-U5	13.8	1171	49.0
59	ACAJ-U6	13.8	292	12.2
60	ACAJ-U7	13.8	292	12.2
61	ACAJ-U8	13.8	292	12.2
62	GUAJ-U1	13.8	276	11.5
63	SOYA-U1	13.8	559	23.4
64	SOYA-U2	13.8	558	23.3
65	CGRA-U1	13.8	1098	45.9
66	CGRA-U2	13.8	1316	55.1
67	5NOV-U1	13.8	338	14.1
68	5NOV-U2	13.8	290	12.1
69	5NOV-U3	13.8	193	8.1
70	5NOV-U4	13.8	485	20.3
71	5NOV-U5	13.8	485	20.3
72	15SE-U1	13.8	1585	66.3
73	15SE-U2	13.8	1585	66.3
74	BERL-U2	13.8	566	23.7
75	BERL-U3	13.8	516	21.6
76	SOYA-U3	13.2	511	22.4
77	SMIG-U1	13.2	306	13.4
78	BERL-U1	13.2	566	24.8
79	ELCH-U1	13.8	618	25.9

Note : Calculation Conditions

- All the generators are connected to the power system.
- El Chaparral P/S is connected to 15 de Septiembre S/S. (Transmission line : 3*1 Flicker)

291

Table 10.6 Specifications of Circuit Breakers in Transmission System (1/5)

No.	Substation	Code	Manufacturer	Model-Type	Voltage [kV]	Rated Opening Time [cycle]	Rated Current [kA]	Rated Interrupting Current [kA]	Methods of Current Interruption	Year of Manufacture
1	5 de Noviembre	10-7-01	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
2	5 de Noviembre	10-7-02	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
3	5 de Noviembre	10-7-03	HVB	HVB121-40000	121	1.9	2,000	40	SF_6	
4	5 de Noviembre	10-7-04	HVB	HVB121-40000	121	1.9	2,000	40	SF_6	
5	5 de Noviembre	10-7-05	HVB	HVB121-40000	121	1.9	2,000	40	SF_6	
6	5 de Noviembre	10-7-06	ABB	LTB145D1/B	145	1 8	3,150	40	SF_6	1995
7	5 de Noviembre	10-7-07	ASEA	HLD 145/1250 B	138	3.0	1,250	5,000 MVA	Oil	
8	Guajoyo	11-7-01	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
9	Acajutla	12-7-06	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
10	Acajutla	12-7-07	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
11	Acajutla	12-7-08	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
12	Acajutla	12-7-09	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
13	Acajutla	12-7-10	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
14	Acajutla	12-7-11	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
15	Acajutla	12-7-13	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
16	Acajutla	12-7-14	ABB	HPL145/25A1	145	1 4	2,500	40	SF_6	1992
17	Acajutla	13-7-01	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
18	Acajutla	13-7-02	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
19	Acajutla	13-7-03	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
20	Acajutla	13-7-04	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
21	Acajutla	13-7-05	ABB	HPL145/25A1	145	1.4	2,500	40	SF_6	1992
22	Acajutla	13-7-91	ASEA	HLR-123/2501E	123	1.8	2,500	30	Oil	1979
23	Ahuachapán	16-7-01	MAGRINI Office	OCERFP145	115	3.0	1,200	25	Oil	1974
24	Ahuachapán	16-7-02	MAGRINI Office	OCERFP145	115	3 0	1,200	25	Oil	1974
25	Ahuachapán	16-7-03	ASEA	HLR-123/25 01E	123	1.8	2,500	40	Oil	1979
26	Ahuachapán	16-7-04	ASEA	HLR-123/25 01E	123	1.8	2,500	40	Oil	1979
27	Ahuachapán	16-7-05	MAGRINI Office	OCERFP145	115	3.0	1,200	25	Oil	1974
28	Ahuachapán	16-7-07	BBC	ELFSL2-1	123	1.8	2,000	25	SF_6	1985
29	Ahuachapán	16-7-08	BBC	ELFSL2-1	123	1.8	2,000	25	SF_6	1985

Table 10.6 Specifications of Circuit Breakers in Transmission System (2/5)

No	Substation	Code	Manufacturer	Model-Type	Voltage [kV]	Rated Opening Time [cycle]	Rated Current [kA]	Rated Interrupting Current [kA]	Methods of Current Interruption	Year of Manufacture
30	Ahuachapán	16-7-91	MAGRINI Office	OCERFP145	115	3.0	1,200	25	Oil	1974
31	Ahuachapán	16-7-92	ASEA	HLR-123/250 1E	123	1 8	2,500	40	Oil	1979
32	Ahuachapán	16-8-01	BBC	ELFSL4-2	245	2.0	2,000	31.5	SF_6	1985
33	Ahuachapán	16-8-01	BBC	ELFSL4-2	245	2.0	2,000	31.5	SF_6	1985
34	Ahuachapán	16-8-03	BBC	ELFSL4-2	245	2 0	2,000	31.5	SF_6	1985
35	Cerrón Grande	17-7-03	ASEA	HLD 145/1250 B	115	3.0	1,250	27.5	Oil	1975
36	Cerrón Grande	17-7-11	ASEA	HLD 145/1250 B	115	3.0	1,250	27.5	Oil	1975
37	Cerrón Grande	17-7-12	ASEA	HLD 145/1250 B	115	3.0	1,250	27.5	Oil	1975
38	Cerrón Grande	17-7-13	ASEA	HLD 145/1250 B	115	3.0	1,250	27.5	Oil	1975
39	Cerrón Grande	17-7-21	ASEA	HLD 145/1250 B	115	3.0	1,250	27.5	Oil	1975
40	Cerrón Grande	17-7-22	ASEA	HLD 145/1250 B	115	3.0	1,250	27.5	Oil	1975
41	Cerrón Grande	17-7-23	ASEA	HLD 145/1250 B	115	3.0	1,250	27.5	Oil	1975
42	Cerrón Grande	17-7-32	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
43	Cerrón Grande	17-7-33	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
44	Cerrón Grande	17-7-42	ASEA	HLD 145/1250 B	115	3.0	1,250	27.5	Oil	1975
45	Cerrón Grande	17-7-43	ASEA	HLD 145/1250 B	115	3.0	1,250	27.5	Oil	1975
46	15 de Septiembre	18-7-01	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
47	15 de Septiembre	18-7-02	ASEA	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
48	15 de Septiembre	18-7-11	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
49	15 de Septiembre	18-7-12	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
50	15 de Septiembre	18-7-13	ASEA	HLR123/2501E1	123	1.8	2,500	35 6	Oil	1980
51	15 de Septiembre	18-7-21	ALSTHOM	S1-121-F34031	121	1.9	2,000	40	SF_6	1998
52	15 de Septiembre	18-7-22	ALSTHOM	S1-121-F34031	121	1.9	2,000	40	SF_6	1998
53	15 de Septiembre	18-7-23	ASEA	HLR123/2501E1	123	1.8	2,500	35.6	Oil	1980
54	15 de Septiembre	18-7-31	BBC	121PA40-20B	121	1.9	2,000	40	SF_6	1987
55	15 de Septiembre	18-7-32	ASEA	HLR123/2501E1	123	1.8	2,500	35.6	Oil	1980
56	15 de Septiembre	18-7-33	ASEA	HLR123/2501E1	123	1 8	2,500	35 6	Oil	1980
57	Soyapango	30-7-01	BBC	121PA40-20B	121	1.9	2,000	40	SF_6	1987
58	Soyapango	30-7-02	BBC	121PA40-20B	121	1.9	2,000	40	SF_6	1987

Table 10.6 Specifications of Circuit Breakers Operated in Transmission System (3/5)

No.	Substation	Code	Manufacturer	Model-Type	Voltage [kV]	Rated Opening Time [cycle]	Rated Current [kA]	Rated Interrupting Current [kA]	Method of Current Interruption	Year of Manufacture
59	Soyapango	30-7-03	ABB	LTB 145D1/B	145	1.8	3,150	40	SF_6	1995
60	Soyapango	30-7-04	BBC	121PA40-20B	121	1.9	2,000	40	SF_6	1987
61	Soyapango	30-7-05	BBC	121PA40-20B	121	1.9	2,000	40	SF_6	1987
62	Soyapango	30-7-06	SIEMENS	TCP-121-40-2000	121	1.9	2,000	40	SF_6	1987
63	San Rafael Cedros	32-7-01	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
64	San Rafael Cedros	32-7-02	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
65	San Rafael Cedros	32-7-03	ASEA	HLD 145/1250 B	138	3.0	1,250	27.5	Oil	
66	San Rafael Cedros	32-7-04	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
67	San Rafael Cedros	32-7-05	McCraw Edison	ALP-54	121	1.5	1,200	40	Oil	1986
68	San Rafael Cedros	32-7-06	McCraw Edison	ALP-54	121	1.5	1,200	40	Oil	1986
69	San Rafael Cedros	32-7-07	General Electric	FK-121-40000-8	121	5.0	1,600	40	Oil	1983
70	San Miguel	34-7-01	ALSTHOM	S1-121-F34031	121	1.9	2,000	40	SF_6	1998
71	San Miguel	34-7-02	ASEA	HLD145/1250C	123	3.0	1,250	27.5	Oil	1978
72	San Miguel	34-7-03	ASEA	HLR123/2501E	123	1.8	2,500	36.6	Oil	1980
73	San Miguel	34-7-04	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
74	Santa Ana	35-7-01	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
75	Santa Ana	35-7-02	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
76	Santa Ana	35-7-03	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
77	Santa Ana	35-7-04	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
78	San Antonio Abad	36-7-01	BBC	121 PA 40-20B	121	1.9	2,000	40	SF_6	1987
79	San Antonio Abad	36-7-02	BBC	121 PA 40-20B	121	1.9	2,000	40	SF_6	1987
80	San Antonio Abad	36-7-03	BBC	121 PA 40-20B	121	1.9	2,000	40	SF_6	1986
81	San Antonio Abad	36-7-04	BBC	121 PA 40-20B	121	1.9	2,000	40	SF_6	1987
82	Nejapa	37-7-01	ISODEL	HPF311L	123	1.9	1,250	3,500MVA	Oil	
83	Nejapa	37-7-02	ISODEL	HPF311L	123	1.9	1,250	3,500MVA	Oil	
84	Nejapa	37-7-03	ISODEL	HPF311L	123	1.9	1,250	3,500MVA	Oil	
85	Nejapa	37-7-11	ASEA	HLD145/1250B	115	3.0	1,250	40	Oil	1974
86	Nejapa	37-7-12	ASEA	HLD145/1250B	115	3.0	1,250	40	Oil	1974
87	Nejapa	37-7-13	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995

293

Table 10.6 Specifications of Circuit Breakers in Transmission System (4/5)

No.	Substation	Code	Manufacturer	Model-Type	Voltage [kV]	Rated Opening Time [cycle]	Rated Current [kA]	Rated Interrupting Current [kA]	Methods of Current *Interruption*	Year of Manufacture
88	Nejapa	37-7-21	BBC	121PA40-20B	121	1 9	2,000	40	SF_6	1996
89	Nejapa	37-7-22	ASEA	HLD 145/1250 B	115	3.0	1,250	40	Oil	1974
90	Nejapa	37-7-23	ASEA	HLD 145/1250 B	115	3.0	1,250	40	Oil	1974
91	Nejapa	37-7-31	ASEA	HLD 145/1250 B	115	3 0	1,250	40	Oil	1974
92	Nejapa	37-7-32	ASEA	HLD 145/1250 B	115	3.0	1,250	40	Oil	1974
93	Nejapa	37-7-33	ASEA	HLD 145/1250 B	115	3.0	1,250	40	Oil	1974
94	Nejapa	37-7-41	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
95	Nejapa	37-7-42	ABB	121 PM40-20	121	1.8	2,000	40	SF_6	1994
96	Nejapa	37-7-43	ABB	121 PM40-20	121	1.8	2,000	40	SF_6	1994
97	Opico	38-7-01	ABB	LTB145D1/B	145	1 8	3,150	40	SF_6	1995
98	Opico	38-7-02	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
99	Opico	38-7-03	ISODEL	HPF311L	123	1.9	1,250	3,500MVA	Oil	
100	Tecoluca	39-7-01	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
101	Tecoluca	39-7-02	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
102	Tecoluca	39-7-31	ABB	LTB145D1/B	145	1 8	3,150	40	SF_6	1995
103	Tecoluca	39-7-32	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
104	Tecoluca	39-7-33	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
105	Sonsonate	41-7-01	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
106	Sonsonate	41-7-02	ABB	LTB145D1/B	145	1 8	3,150	40	SF_6	1995
107	Sonsonate	41-7-11	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
108	Sonsonate	41-7-12	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
109	Sonsonate	41-7-31	ASEA	HLD 145/1250 C	123	3.0	1,250	25	Oil	1978
110	Sonsonate	41-7-32	ASEA	HLD 145/1250 C	123	3.0	1,250	25	Oil	1978
111	Sonsonate	41-7-33	ASESA	HLD 145/1250 C	123	3.0	1,250	25	Oil	1978
112	Nuevo Cuscatlán	42-7-11	SIEMENS	SPS-121-40-2000	121	2 0	2,000	40	SF_6	1993
113	Nuevo Cuscatlán	42-7-12	SIEMENS	SPS-121-40-2000	121	2 0	2,000	40	SF_6	1993
114	Nuevo Cuscatlán	42-7-13	SIEMENS	SPS-121-40-2000	121	2.0	2,000	40	SF_6	1993
115	Nuevo Cuscatlán	42-7-21	ASEA	HLD 145/1250 C	123	3.0	1,250	25	Oil	1978
116	Nuevo Cuscatlán	42-7-22	ASEA	HLD 145/1250 C	123	3.0	1,250	25	Oil	1978

2%

Table 10.6 Specifications of Circuit Breakers in Transmission System (5/5)

No.	Substation	Code	Manufacturer	Model-Type	Voltage [kV]	Rated Opening Time [cycle]	Rated Current [kA]	Rated Interrupting Current [kA]	Methods of Current Interruption	Year of Manufacture
117	Nuevo Cuscatlán	42-7-23	ASEA	HLR123/1250C	123	1.8	1,250	25	Oil	1980
118	Nuevo Cuscatlán	42-7-31	ASEA	HLR123/1250C	123	1.8	1,250	25	Oil	1978
119	Nuevo Cuscatlán	42-7-32	SIEMENS	SPS-121-40-2000	121	2.0	2,000	40	SF_6	1993
120	Nuevo Cuscatlán	42-7-41	ABB	HPL145/2500	145	1.4	2,500	40	SF_6	1992
121	Nuevo Cuscatlán	42-7-42	ABB	HPL145/2500	145	1.4	2,500	40	SF_6	1992
122	San Martín	43-7-21	ASEA	HLR123/2501E1	123	1.8	2,500	40	Oil	1980
123	San Martín	43-7-22	ASEA	HLR123/2501E1	123	1.8	2,500	40	Oil	1980
124	San Martín	43-7-23	ASEA	HLR123/2501E1	123	1.8	2,500	40	Oil	1980
125	San Martín	43-7-31	ASEA	HLR123/2501E1	123	1.8	2,500	40	Oil	1980
126	San Martín	43-7-32	ASEA	HLR123/2501E1	123	1.8	2,500	40	Oil	1980
127	San Martín	43-7-33	ASEA	HLR123/2501E1	123	1.8	2,500	40	Oil	1980
128	San Martín	43-7-41	Mc Craw Edison	ALP-54	121	1.5	1,200	40	Oil	1986
129	San Martín	43-7-42	Mc Craw Edison	ALP-54	121	1.5	1,200	40	Oil	1986
130	San Martín	43-7-43	Mc Craw Edison	ALP-54	121	1.5	1,200	40	Oil	1986
131	San Martín	43-7-52	ASEA	HPL123/25A1	121	1.4	2,000	40	SF_6	1988
132	San Martín	43-7-53	ASEA	HPL123/25A1	121	1.4	2,000	40	SF_6	1988
133	San Bartolo	45-7-01	ABB	121PM40-20	121	1.8	2,000	40	SF_6	1993
134	San Bartolo	45-7-02	ABB	121PM40-20	121	1.8	2,000	40	SF_6	1993
135	Santo Tomás	46-7-01	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
136	Santo Tomás	46-7-02	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
137	Santo Tomás	46-7-12	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
138	Santo Tomás	46-7-13	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
139	Santo Tomás	46-7-31	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
140	Santo Tomás	46-7-32	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995
141	Santo Tomás	46-7-33	ABB	LTB145D1/B	145	1.8	3,150	40	SF_6	1995

295