Country	: Costa Rica
Project	: Miraballes Geothermal Project
Borrower	: Instituto Costarricense de Electricidad
Executing Agency	: Instituto Costarricense de Electricidad
Date of Loan Agreement	: December 1985
Loan Amount	: ¥ 13,547 million
Local Currency	: Colon
Report Date	: November 1997 (Field Survey: August 1997)

Construction of 2nd Plant

［**Reference**］

1. Units

MW: Megawatt=1,000,000W=1,000KW
GW: Gigawatt=1,000MW
MWh: Megawatt hour = 1,000,000Wh = 1,000KWh
GWh: Gigawatt hour =1,000MWh
Nm^3: Normal cubic meters (m^3 at 0℃, one atmosphere)
tonC: Weight when converted to reflect the weight of carbon (C) only (to distinguish from the total weight of CO_2).

2.Abbreviations

ICE: Instituto Costarrnse de Electricidad
IDB: Inter American Development Bank
NIS: National Interconnected System
WJEC: West Japan Engineering Consultant, Inc.

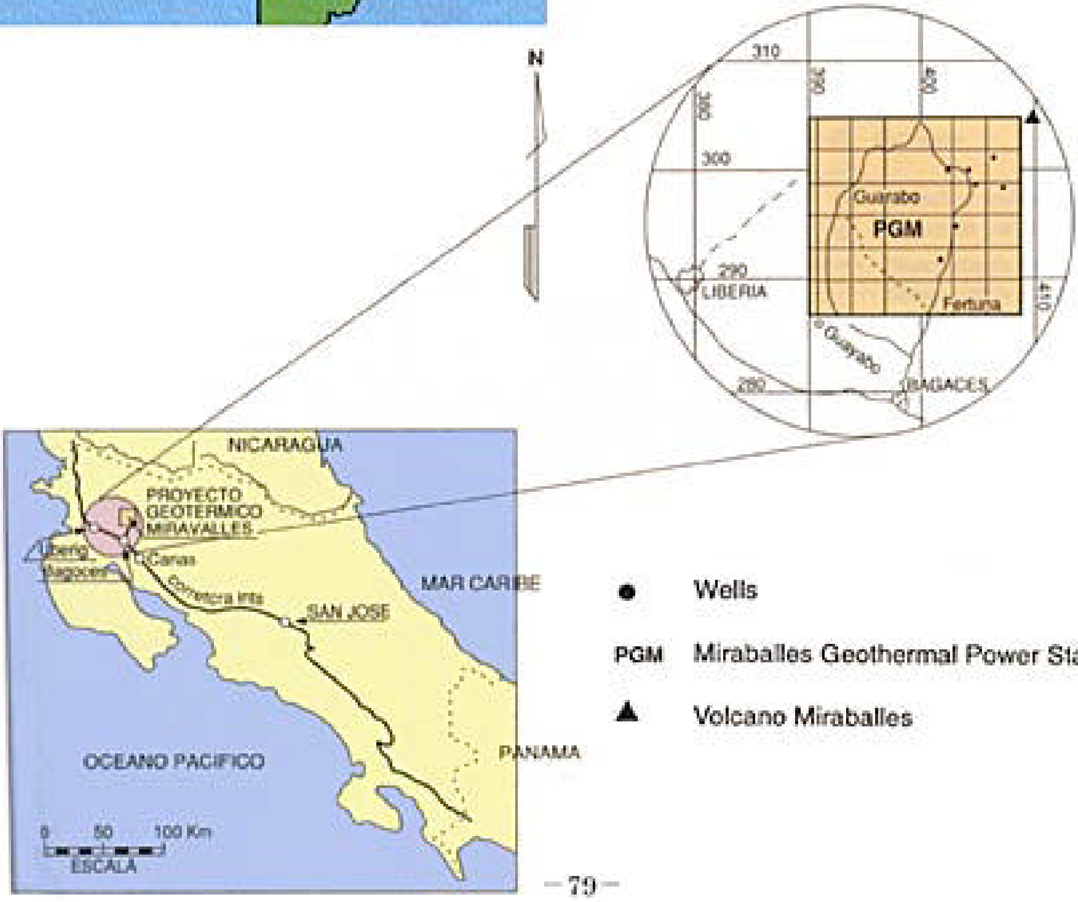
3.Terminology

Thermal breakthrough: When the impact of returned water on the geothermal strata causes reductions in the pressure and temperature of steam produced.
Scale: Material adhering to a surface.

1. Project Summary and Comparison of Major Plan and Actual Result

1.1 Project Location

Construction Scene of Production Well

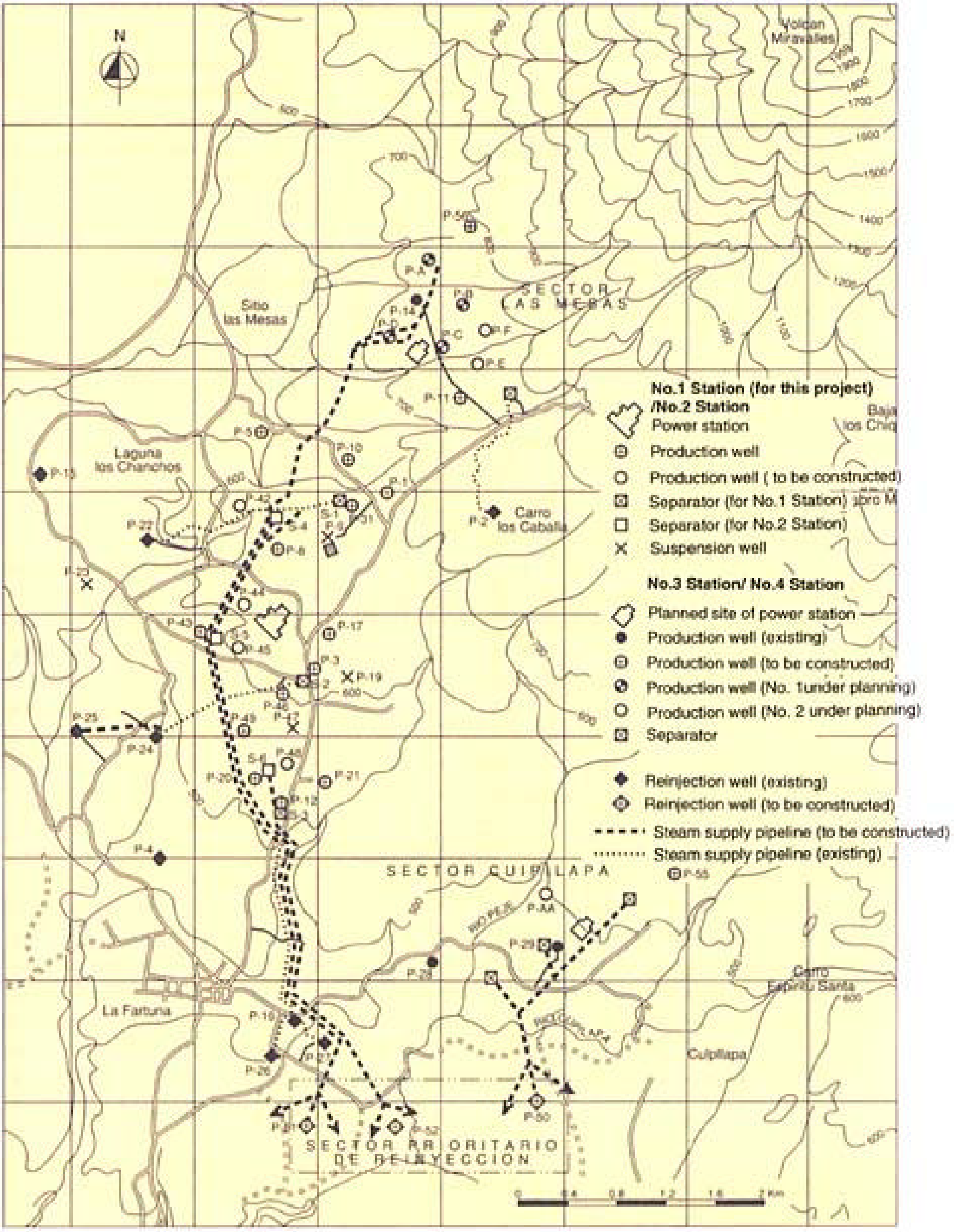


● Wells

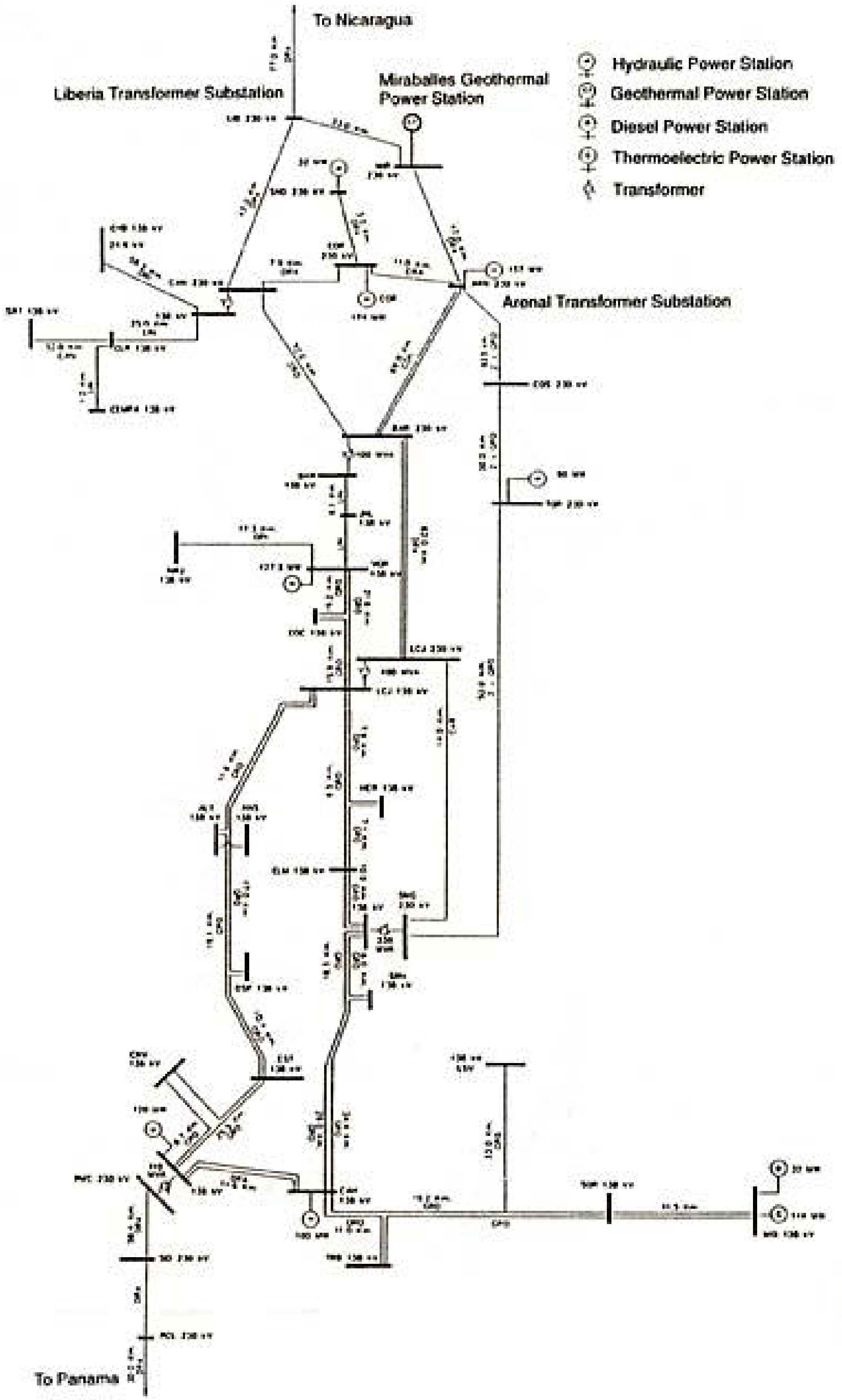
PGM Miraballes Geothermal Power Station

▲ Volcano Miraballes

Location Map of Production Well / Reinjection Well



Costa Rican Electric Grid (1997)



1.2 Project summary and the OECF’s share

This project (Miraballes Geothermal Power Station No.1) is to construct a geothermal power station with a single 55MW generator in the foothills of the Volcano Miraballes, approximately 220km north of San Jose, the capital city. This power station, running at base load, is intended to provide a stable supply of power throughout the year, and also to save foreign exchange by using geothermal energy, a domestic source of power. The project was a cooperative finance project with the IDB, which finance the boring and construction of the wells. The ODA loan financed the entire foreign-currency cost of the project and a part of the local currency which were not financed by the IDB.

1.3 Background

(1) Economic Development Plans

Until the time of the appraisal by OECF, Costa Rica has implemented four economic development plans, as listed below.

- 1965~1968 " National Development Plan"
- 1969~1972 "Plan for Economic and Social Development and Stimulation of the Public Sector".
- 1974~1978 " National Development Plan"
- 1979~1982 " National Development Plan"

Each of these plans stated a direction of economic and social development and defined roles of the government and public sector, but due to problems concerning political decision-making mechanisms and implementation systems, none of them are achieved to the full extent.

In the light of these failures, National Economic Planning Ministry (OFIPLAN) was established to make the 1982~1986 National Development Plan, to coordinate between agencies and to unify the final decisions. The plan aimed to make the maximum use of domestic resources and services, and to promote agriculture, stock farming and industries. The key policies to achieve these goals were:

① Effective use of domestic natural resources for import substitution.

② Agricultural development (to achieve self-sufficiency in main agricultural products and promote processing industry of agricultural products for export) in order to nurture industry and increase exports.

Measures for the first of the above key policies were combined in an action plan entitled "Program for the Development of National Energy Resources". The basic policy direction of this plan was to develop domestic energy resources and improve the efficiency of their use, in order to encourage the replacement of imported oil. In line with this action plan, government agencies such as ICE drew up a development plan for the electricity sector under which they planned and executed projects related to national energy resources, and coordinated matters between themselves, with the ICE in a key position. This was a reorganization around a long-term viewpoint which includes private-sector projects. This plan included hydroelectric power generation of Garita-Ventanas (96MW, started in 1987) and Miraballes Geothermal Power Station No.1 (55MW, started in 1990).

(2) Economic Background

Substitution of imported oil was made as a major policy objective because of rising foreign debt, which coincided with sluggish performance of the Costa Rican economy from the start of the 1980s. The country's GDP developed steadily, growing at an average of 5.9% per year in the 1960s and

5.6% in the 1970s. However, from the start of the 1980s, the import substitution efforts of the manufacturing sectors of the countries in the Central American Common Market came home to roost, reducing Costa Rica's manufactured exports within the region. Thereafter, the economies of the Central American Common Market fell into crises, and the prices of agricultural produce fell, reducing the production of traditional export produce (bananas, coffee, sugar and beef). The impact of slumps in agriculture and manufacturing sectors which usually support the Costa Rican economy, drove the annual GDP growth rate down to 0.8% in 1980, -2.3% in 1981 and -7.3% in 1982.

In 1983 the GDP growth rate returned to the positive, but this economic recovery was supported by the construction of power plant and roads with the introduction of foreign capital, which increased the accumulated national debt. The level of accumulated foreign debt approximately doubled from US$1.817 billion in 1980 to US$3.532 billion in 1984. As a result, a debt restructuring of approximately US$200 million was agreed by the Paris Club in 1983. In 1985 the IMF and the World Bank implemented an economic stability program (SAL 1), IMF standby credit was made available and the World Bank provided US$8 million in finance. To combat the fiscal deficit, the Monhe Administration increased taxes of all kinds and cut government expenditures from 1982, bringing it down to 1.5% of GDP in 1985.

【Table 1　GDP Growth Rate and the Ratio of Fiscal Deficit to GNP】

(Units: %)

	1980	1981	1982	1983	1984	1985
Annual GDP growth rate	0.8	−2.3	−7.3	2.3	6.6	0.7
Ratio of fiscal deficit against GNP		14.3	9.0	3.4	2.5	1.5

Source:　Costa Rica Central Bank

【Table 2　Trade Balance (Products Base) 】

(Units: $ 1 million)

	1980	1981	1982	1983	1984	1985
Export (Traditional products)	1,000.9	1,008.6	869.8	852.5	997.5	939.1
Import (Consumer goods, petroleum products, etc.)	1,527.5	1,213.3	894.2	993.2	1,101.2	1,089.2
Trade balance	−526.6	−204.7	−24.4	−140.7	−103.7	−150.1

Source:　World Bank

【Table 3　Foreign Public Debt】

(Units: $ 1 million)

	1980	1981	1982	1983	1984
Bilateral loans	362.7	453.9	585.9	895.4	N/A
International organization	552.0	601.9	628.5	659.0	N/A
Commercial bank	708.1	797.7	813.7	1,287.1	N/A
Credit	141.4	458.3	490.4	403.8	N/A
Suppliers credit	53.0	58.0	59.4	52.2	N/A
Total	1,817.2	2,369.8	2,577.9	3,297.5	3,531.6

Source:　Costa Rica Central Bank

(3)The Position of this Project

The ICE's basic policy direction for power supply development is to meet domestic demand for electricity power through hydroelectric generation. Learning the lessons of the 1973 oil crisis, thermal power generation using imported oil is only to be used as a last resort. Therefore Costa Rica is aggressively pursuing the development of hydroelectric power generation, to the extent that some 80% of its generation plant is hydroelectric[1]. The country is now highly reliant on hydroelectric power. However, hydroelectric generation is affected by the reduced volume of available water in the dry season (around April), and this leads to tight restriction of power supply at that time of year. To remedy this situation, geothermal power generation is being given a high priority in electrical supply plans as a domestic source of energy which can be applied to the stable delivery of base load supply.

A preliminary study on the potentiality for geothermal power generation was conducted in the Miraballes region in 1975, with the assistance of the IDB. The survey confirmed that the Miraballes region had geothermal reserves equivalent to 140MW. Therefore, when electrical supply again became tight in 1990 after the Garita-Ventanas Hydraulic Power Station came on line in 1987, the Miraballes Geothermal Power Station No.1 was added to the plan, alongside the San Dejal Hydroelectric Power Station (32MW). The electricity surplus generated in the rainy season will be exported using the Central American Power Cable (230kV, which was completed in 1982 to link Costa Rica, Nicaragua, Honduras and El Salvador) to earn foreign currencies.

(4)Situation of Electricity in Costa Rica

Table 4 shows the capacity of Costa Rica's generation plant and the demand for electricity. Power consumption increased around 5% per year over the five years from 1980 to 1984. The usage rate is around 40%, but considering the fact that the 20% of total capacity provided by thermal generation is held on standby for emergency use only, the real load rate is around 60%. This is in line with the ICE target figures.

【Table 4　Capacity of Costa Rica’s Generation Plant and Power Demand】

	Unit	1980	1981	1982	1983	1984
Capacity of generation plant	MW	603	603	777	777	777
Generating power	GWh	2,144	2,291	2,400	2,855	3,011
Usage rate		40.6%	43.4%	35.3%	41.9%	44.2%
Consumption of power	GWh	1,894	2,047	2,079	2,150	2,337
Growth rate			8.1%	1.6%	3.4%	8.7%

Source:　ICE

The ICE has calculated forecasts of demand from 1985 to 2000 by summing up the demand in each category. Electricity supply plans are set to meet these forecasts. The results of this process are shown in Table 5. The ICE plans to have a balance of geothermal and hydroelectric generation capacity which will cover peak demands with a supply capacity reserve of 60MW, or 10% of peak demand.

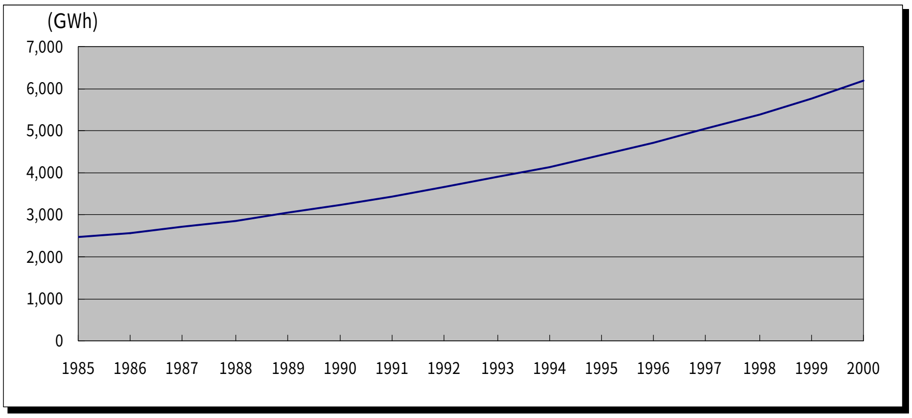
---

[1] This ratio has remained unchanged to the present.

【Table 5　Electrical Forecast of Demand in Costa Rica】

	Unit	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Consumption of power	GWh	2,456	2,584	2,719	2,870	3,035	3,227	3,429	3,649	3,885	4,144	4,424	4,722	5,048	5,400	5,779	6,185
Growth rate			5.2%	5.2%	5.6%	5.7%	6.3%	6.3%	6.4%	6.5%	6.7%	6.8%	6.7%	6.9%	7.0%	7.0%	7.0%
Installed capacity	MW	777	767	854	854	845	941	941	941	1,118	1,118	1,118	1,173	1,173	1,446	1,446	1,831

Source:　ICE



【Figure 1　Graph of Predicted Electrical Demand in Costa Rica】

1.4　Summary of IDB's Cooperation

【Table 6　Summary of IDB's Cooperation for this Project】

Phase	Summary of IDB's cooperation	Budget
Phase 1 (1975~1976)	Making of preliminary F/S	$400,000
Phase 2 (1975~1983)	Boring of test wells (2 for production, 1 for reinjection)	$4,100,000
Phase 3 (1984~1985)	Boring of test wells (4 for production, 1 for reinjection, 1 for other)	$8,800,000
Phase 4 (1985~1990)	Boring of wells for power generation (Total of 20 wells for production and reinjection for this project)	$60,502,000

Source:　Appraisal materials

History of the IDB Finance Portion

1975		Start of feasibility study (preceding survey of the potentiality for costruction of a geothermal power station with IDB finance)
1977	May	Boring of three test begun in the Las Ornijas region with IDB finance (completed in 1983).
1980	December	Boring of a further six test wells in the same region with IDB finance (completed in 1985).
1984	October	Dispatching of program mission.
1985	September	Dispatching of appraisal mission (due to a delay in the Japanese government's pledge, the Costa Rican Government began to sound the possibility of obtaining the ODA loan portion from the IDB).
1985	November	Appraisal by the highest appraisal committee (CAM) at the administrative level.
1986	March	Sign of loan agreement

1.5 Comparison of Major Original Plan and Actual Result

① Project Scope

Project Scope	Plan	Actual Result	Difference
Wells (excluded from ODA loans)	20 wells	20 wells	None
Piping system	3 circuits	As planned	None
Gathering	1 set		
Reinjection	1 set		
Geothermal Power Station	55MW×1 unit	As planned	None
Turbine	1		
Generator	1		
Cooling tower	1		
Distribution cable			
Power station ~ Arenal Transformer Station	230kV, 36km	As planned	None
Power station ~ Liberia Transformer Station	230kV, 33km	Not carried out	Started in 1997
Transformer station			
Juxtaposed transformer station	13.8/230/4.8kV	As planned	None
Expansion of Arenal Transformer Station		As planned	None
Expansion of Liberia Transformer		Not carried out	Started in 1997
Consulting Service	138M/M	166M/M	+28M/M (Content of contract +80M/M

② Implementation Schedule

	Plan	Actual Result	Difference
Selection of consultant	1985.11~1987.01	1985.12~1988.02	+12 months
Selection of contractor	1986.05~1988.04	1988.02~1990.07	+6 months
Procurement of equipment	1988.05~1989.10	1990.07~1992.12	+12 months
Transportation of equipment	1989.06~1989.11	1991.08~1993.11	+22 months
Civil works	1989.01~1989.11	1992.01~1993.10	+11 months
Installation of equipment	1989.07~1990.05	1992~04.1993.11	+9 months
Inspection	1990.06~1990.09	1993.11~1994.03	+1 month
Completion	1990.09	1994.03	+42 months

③ Project Cost

(Unit: million yen)

Item	Plan* (at the time of appraisal)		Actual Result		Difference	
	Foreign currency	Local currency	Foreign currency	Local currency	Foreign currency	Local currency
Wells (not for ODA loans)	8,088	50	5,886	413	－2,202	363
Piping system	1,762	917	1,574	445	－188	－472
Geothermal Power Station						
Turbine + generator	6,305	615	6,638	1	333	－614
Buildings	462	440	0	632	－462	192
Civil works	0	476	0	512	0	36
Distribution cable	765	588	308	454	－457	－134
Transformer station	685	203	0	445	－685	242
Consulting service	359	36	304	924	－55	888
Administration fee	0	0	0	3,879		3879
Reserve fund	1,034	328			－1,034	－328
Total (excluding wells)	11,372	3,603	8,824	7,292	－2,548	3,689

Exchange rate: Plan 1US$=¥258 (1985) Actual 1US$=¥132.25 (Average for 1988~1994)

* : The ODA loan covered the entire foreign currency portion and ¥2.175 billion equivalent of the local currency portion. The discrepancy between the actual foreign currency portion and the amount disbursed by the OECF is due to the difference in the US$ exchange rate.

2 Analysis and Evaluation

2.1 Evaluation of the implementation of the project (project scope, implementation schedule, project cost, implementation scheme, etc.)

2.1.1 Project content

(1) IDB-financed Portion

A total of 39 wells were bored, including both production and reinjection wells. Of these, 20 were bored for the use of this project (Miraballes No. 1). Of these, only 17 are actually used by Miraballes No. 1, because it was judged that 17 wells would be adequate, considering the steam balance. This decision does not seem to have caused any significant problems. The remaining three wells for Miraballes No. 1 are all production wells with spare steam production, so each has been connected to a compact unit-type generator (procured independently by the ICE). These generators generate 15MW (5MW x3), but they are thermodynamically inefficient, so they will be deactivated when Miraballes No. 2 comes on line.

(2) OECF-financed Portion

The piping system to carry steam from the production wells to the turbine was constructed in three circuits (satellites 1, 2 and 3) as planned. The Miraballes Geothermal Power Station itself was also constructed according to plan. Of the two planned electricity distribution cables, the one from Miraballes to the Arenal Transformer Station was constructed, but the other to the Liberia Transformer Station was not, except for one tower on the site of the power station. Further construction was not allowed to proceed beyond the limits of the budget. The reason the construction was stopped prematurely in this way was that a Dollar-based ceiling was set on the cost of the project to guard against the appreciation of the Yen[2]. It was not possible to complete all the construction works within this budget, so parts of comparatively low priority were dropped completely. Considering the quantity of power to be generated at the time, one distribution line was sufficient to carry the full capacity. The line to Arenal was given priority because Arenal is on the national grid. As a result of this decision, the transformer station at Liberia was not expanded. Provision of at least one distribution line was an essential precondition for operation of the power station. To stop the construction of other line was unavoidable, as the ceiling was unavoidably exceeded to pay for its construction.

In February 1997, construction of the second distribution line from Miraballes to the Liberia Transformer Station began, using IDB finance for the materials and equipment, also using the ICE's own funds for the construction costs. Construction was restarted because the Miraballes No. 2 Power Station, now under construction with IDB finance, is going to be completed at the end of 1997. There is concern at that time that three circuits (satellites 1, 2 and 3) the single distribution line via the Arenal Transformer Station will prove inadequate to serve the future needs of Northern Costa Rica and electricity sales to Nicaragua[3].

For procurement, the ICE stated a preference at the time for procurement of equipment separately on a piece-by-piece basis. However, considering the ICE's lack of experience in the construction of geothermal power stations, procurement was divided into three lots for tendering as the OECF advised.

---

[2] See section 2.2.3 for details.

[3] Adjacent to Costa Rica, to the north.

Lot 1: Power generation equipment (turbine, generator)
Lot 2: Piping system (the piping network linking the wells to the turbine)
Lot 3: Distribution cable and transformer station

2.1.2 Implementation schedule

The loan agreement was signed on schedule in December 1985, but it was due to come into effect within one year after signed. In fact, the loan agreement did not come into effect until one year and three months later. As a result, all other stages of the project fell behind schedule. This delay occurred because of the difficulty of obtaining the guarantee from the Costa Rican Government, which was a condition for the loan agreement to come into effect. The government guarantee requires a resolution under Special Act 7058 in the Costa Rican legislative assembly to proceed with the project as a government project. The legislative assembly's resolution under the special act was delayed by two factors:

① The steep appreciation of the Yen since 1985 let the assembly have concern as to the future burden of repaying a Yen-based ODA loan.
② The procurement conditions of the loan were LDC untied, while the principle for Costa Rican Government projects is international competitive bidding[4].

There was also a change of government during the process, which encouraged further delays. This situation led the Costa Rican Government to request extensions of the period twice for putting twice the loan agreement into effect. The OECF agreed to make the final deadline March 1987, in line with the date set by the IDB loan. The assembly produced the following two decisions:

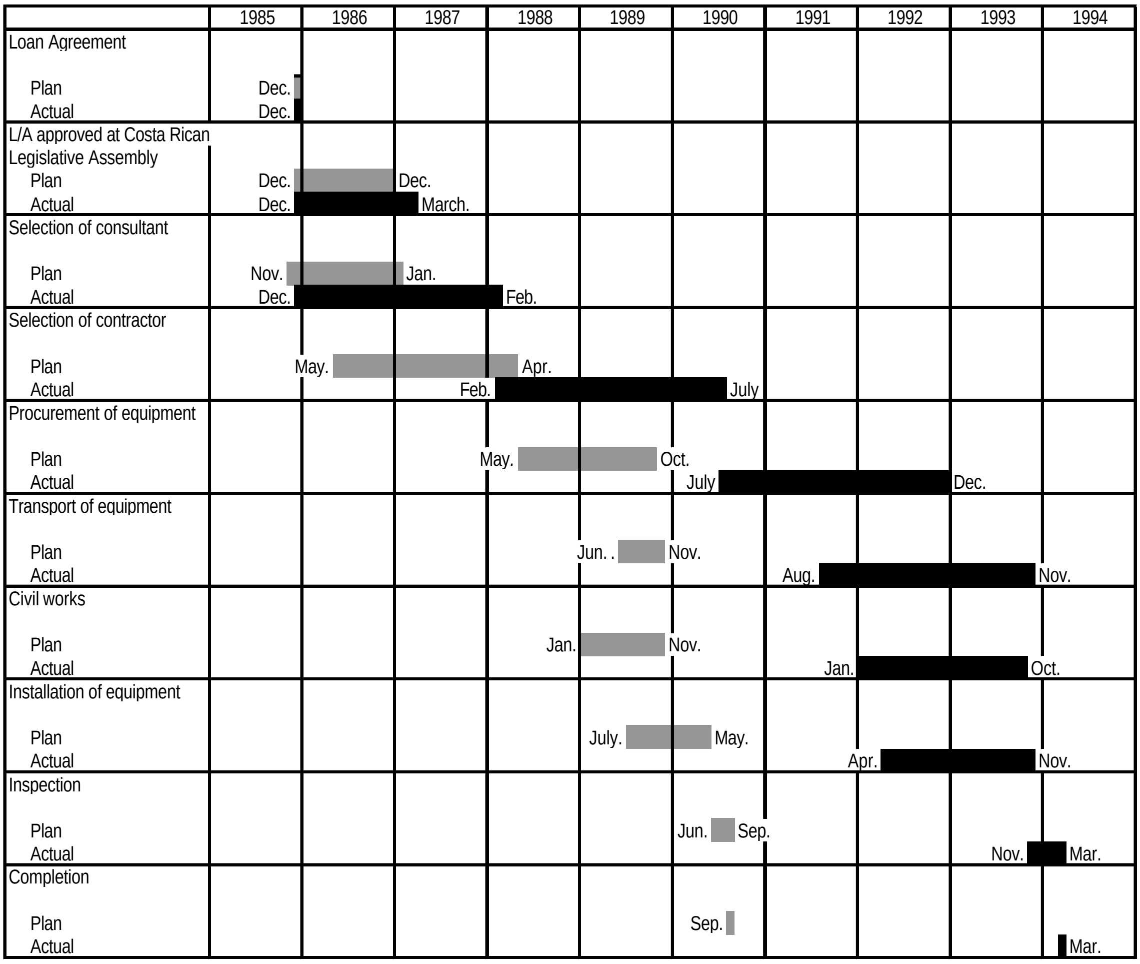
① The government's guarantee for the ODA loan portion was set at the Dollar-based sum of US$52.5 million.
② The tender documentation was to be prepared in two parts, allowing comparison between tenders using the ODA loan and international competitive tenders using suppliers' credit.

With the addition of these two provisos, the resolution for the project under Special Act 7058 was passed, and the documents to activate the loan agreement were submitted to the OECF. The OECF consented to activate the contract on the grounds that the borrower had completed the necessary legal procedures to activate the loan up to a sum in Yen equivalent to US$52.5 million, and out of respectation for the principles of bilateral aid. In fact, there were no tenders using suppliers' credit and the process only served to consume time. In any case, this delay originated in the deliberations of the Costa Rican Legislative Assembly and could not have been foreseen, so this delay appears to have been unavoidable. Thereafter, the Yen's appreciation continued, forcing an increase in the government guarantee to approximately US$80 million.

---

[4] All ODA loans are now completely untied, so the kind of problem in [1] can no longer happen.

【Table 7　Progress Schedule】



Source:　ICE

The next delay was over one year in the selection of consultants by ICE. The application for approval of consultants' terms of reference and L/I were submitted in June 1986, and the application for approval of the shortlist was submitted in August 1986.

These applications were approved in August and September of 1986, respectively, but the application for approval of the results of evaluation of consultants' proposals was not submitted until August 1987. Then, it was approved by OECF in September 1987. This happened because the Costa Rican Legislative Assembly's lengthy deliberations over Special Act 7058 delayed approval of the content of consultant contracts. Furthermore, cost cutting in the foreign currency portion of the project led to the scrapping of part of the consultant M/M. This meant that it took more time for the OECF to judge the technical suitability of the contracts, delaying approval until February 1988.

According to Special Act 7058, tendering documents for international competitive bidding for the plant　were drawn up, delaying the tendering process as a whole, and the selection of contractors. As a result, start of the procurement and shipping of equipment delayed, and the entire construction period also delayed. One factor of the delay was the time for shipping of equipment. The plan allowed only six months for shipping, but in fact it took as much as 28 months, so this part of the plan was clearly unfeasible[5]. As a result of these various problems, the completion of construction and the start of operation were delayed by three and a half years. However, the project was completed before the balance of supply and demand in Costa Rica crumbled severely, so the delay of the schedule did not cause any grave difficulties in the country's power supply situation.

2.1.3 Project cost

The total project financing was divided into the OECF-financed portion, the IDB-financed portion and the ICE's self-funded portion. The total financial load of the three parts (the total project cost) was planned to be US$151,043,000, but rose to US$223,104,000, a cost overrun of approximately 48%. As Table 8 shows, the cost of the IDB-financed portion rose by 22%, the OECF-financed portion by 51% and the ICE-funded portion by so much as 188%. Despite the cost overrun, the project was implemented largely according to plan. This was possible because countermeasures against the Yen's appreciation were taken at an early stage, and sufficient local currency could be allocated to the project. The costs of this project were managed in Dollar terms, so the following explanations will also be in Dollar. The causes of these cost overruns are described below respectively.

(1) IDB Portion

The cost of the IDB portion suffered increases of approximately 40% in the cost of well boring, approximately 76% in the transmission cable construction, and approximately 45% in the cost of consultants. On the other hand, interest cost fell by approximately 7% and survey costs by approximately 28%. As a result, the total cost of the IDB portion was as planned. The increased cost of the well borings seems to have been due to the delays in construction caused by the protracted contract approval process in the Legislative Assembly. Furthermore, the construction extended to 39 wells, of which some are to be used by the new Miraballes No. 2 power station, so it is not clear how much of the well boring cost should be counted in the cost of this project. The increase in the construction cost of the transmission cable occurred because more than half of the cost of equipment and materials was transferred from the OECF portion to the IDB portion as a countermeasure against the rising Yen.

(2) OECF Portion

The financial limitation for this project was set by converting the total estimated costs (US$52.5 million), including a local currency finance portion of ¥2.175 billion, into Yen (¥13.547 billion) at the ongoing exchange rate of the appraisal ($1=¥258 in 1985). However, contracts for most of the foreign currency portion (lots 1, 2 and 3) were in Yen, so their Dollar-based cost increased greatly by the appreciation of the Yen. Costa Rica had not received any ODA loans before this project, so there were concerns over the impact of the appreciation of Yen on the national finances, and the acceptance of the loan was debated in the Legislative Assembly. As a result, the Special Act 7058, which was passed in February 1987, provided a government guarantee with a ceiling equivalent to US$52.5 million in foreign currency. The Costa Rican Government issued an application for activation of the loan agreement on the condition that the current exchange rate at the time of loan activation be applied. In response, the OECF issued a loan agreement activation notice with the condition that the upper limit be a sum of Yen equivalent to US$52.5 million (approximately ¥7.4

---

[5] The equipment shipping plan was unchanged from the schedule presented in the contractors' tenders, without reflecting the content of the eventual contracts or the timing requirements. The contractors only handled C&F shipping as far as a Costa Rican port. Overland shipping was not to be handled by the contractor.

billion when converted at a rate of $1=¥140).

However, the values of tenders for lots 1~3 was ¥11.4 billion (approximately $80 million when converted at a rate of $1=¥140). Therefore split procurement was used for some equipment (separate arrangements were made to procure these items using the ICE's own funds), and the return pumps for the return wells (worth approximately ¥1.6 billion) were made optional[6]. These measures reduced the Yen-based project cost. The changes mainly involved changes of sources and were made with the agreement of the OECF, so they do not present any significant problems. The transmission line from Miraballes to the Liberia Transformer Station, which was a problem in the project content, was not a critically urgent element of the project, so its construction only continued as far as funds permitted[7].

Thus the predicted cost of the three lots was pared down to approximately US$6 billion (¥8.35 billion). After that point, the Yen rose still further until finally[8] the amount of the government guarantee had to be approximately US$80 million. Because the ICE was limiting its budget for this project to a Dollar base, it transferred some of the equipment which was to be covered by the ODA loan to the IDB loan, or to its own financing arrangements. Under this situation, the ICE made great efforts to avoid the impact of the strong Yen, and it was also helped by its relatively large financial reserves. Completing this project under such conditions was a commendable achievement.

The use of consultants was extended slightly from the planned 138M/M to 166M/M[9] because the scope of the project was extended partway through. The appreciation of the Yen increased the Dollar cost of consultants by 85%.[10]

(3) Local Portion

As for the local portion of the project, as a result of including overhead costs at the ICE head office, when this is added to the local currency portion of the OECF finance, the total represents a real cost increase of almost 200%. There was no shortage of local currency in this portion of the project because the ICE had adequate reserves to maintain cashflow. However, in future projects of this type, there is a possibility that the burden of further financial support could cause a shortage of local currency which would impede the implementation of the project. With countries or executing agencies which have not received ODA loans before, the OECF should pay close attention to the existence of such financial support commitments and allocation methods when making a financial analysis of their ability to carry out the project.

---

[6] These were not needed consequentially.

[7] The construction cost of the transmission cables amounted to approximately 10% of the project cost, even though one of them was not completed.

[8] At the time of the application for agreement on the main construction contracts. (August 1991).

[9] Design 80M/M, training 86M/M.

[10] On a Yen base, the loan agreement allocation for consultant service fees included allowances for price escalations and supplementary expenses, so this was actually a cost reduction compared to the appraisal (loan agreement allocation ¥359 million, initial value of contracts ¥247 million, after change in scope ¥304 million).

【Table 8　Project Cost in Dollar】

(Unit: $ Thousand)

	Plan				Actual				Variation
	IDB	OECF	ICE	Total	IDB	OECF	ICE	Total	
Boring of wells	31,347	0	192	31,539	43,864	0	3,165	47,029	49%
Generating facility	0	24,144	0	24,144	0	55,276	2,594	57,870	140%
Buildings	0	3,289	0	3,289	0	3,810	4,988	8,798	168%
Piping system	0	5,669	0	5,669	0	15,007	3,773	18,779	231%
Distribution cable	1,819	5,586	0	7,405	3,201	2,424	2,501	8,126	10%
Other	7,703	0	443		7,656	0	0	7,656	
Consultant	1,277	1,418	2,841	5,536	1,857	2,593	9,244	13,694	147%
Administration	0	914	8,663	9,577	0	0	29,526	29,526	208%
Interest rates during construction	17,419	0	3,865	21,284	16,218	0	9,215	25,432	19%
Commission	0	0	3,018	3,018	0	0	5,663	5,663	88%
Inspection	740	0	0	740	530	0	0	530	-28%
Reserve fund	4,947	2,168	1,214	8,329	0	0	0	0	-100%
Price escalation	8,748	9,312	4,307	22,367	0	0	0	0	-100%
Total	74,000	52,500	24,543	151,043	73,325	79,110	70,669	223,104	48%
Growth rate					-1%	51%	188%	48%	
Ratio	44%	38%	17%	100%	35%	37%	28%	100%	

Source:　ICE

2.1.4　Implementation Scheme

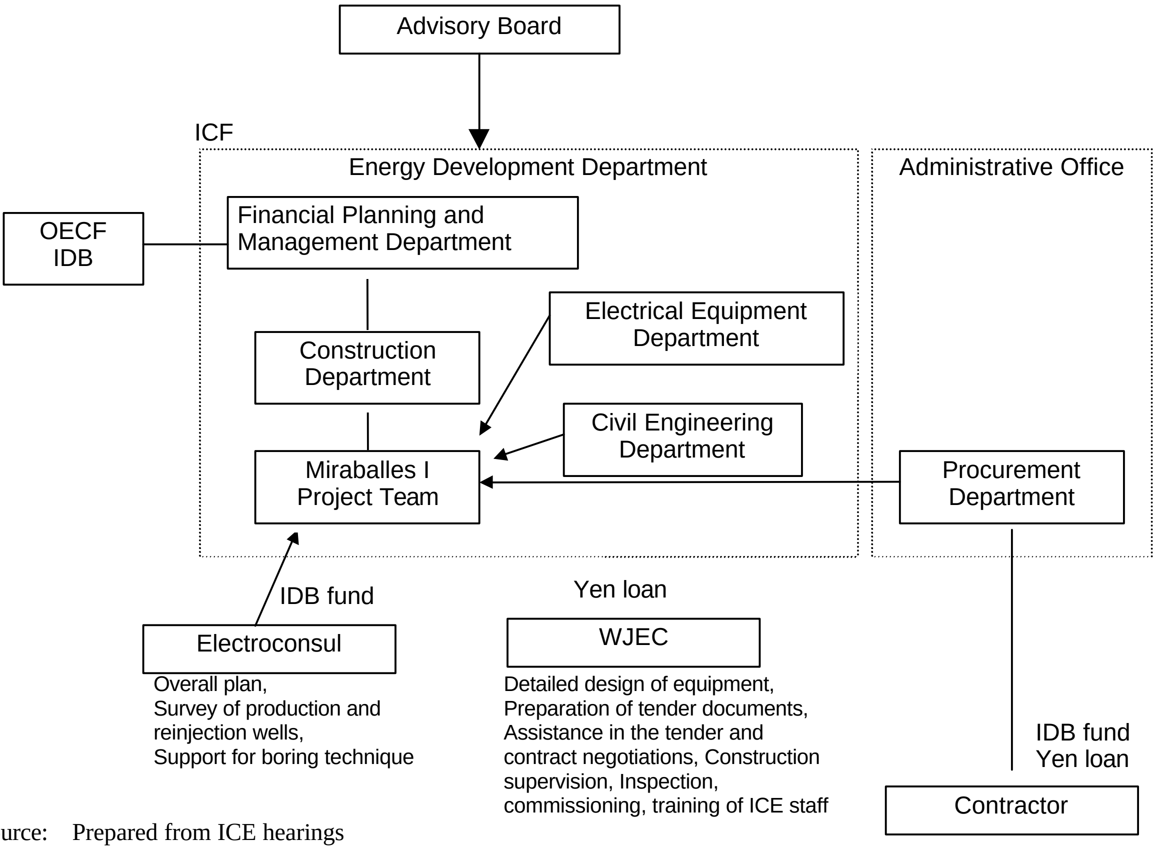
(1)Executing Agency

This project was constructed by the Energy Development Department under the direct management of the ICE. Construction teams under the Construction Department are brought together for each project, the team for this project being the Miraballes 1 Project Team. The construction team led the progress of the construction works. However, the detailed design of equipment is performed by the Electrical Devices Department[11] (known as the Engineering Department at the time), while the civil engineering design and construction are performed by the Civil Engineering Department. The Financial Planning and Management Department dealt with aid agencies such as the OECF and IDB. Purchasing machinery and materials was the job of the Procurement Department of the Main Management Office.

The ICE directly manages all construction work, because it has a technical team large enough for the task. This project was the ICE's first geothermal power station, but it directly managed all stages, starting from the training of all of its engineers. The construction suffered some delays, but there were no problems at all in the implementation scheme, and the executive ability of the executing agency was praiseworthy. Two consultancy firms were employed in this project, one for the well development and the other for the equipment design. In this way the ICE made adequate arrangements to supplement its areas of inexperience. This approach should be recognized as a major contributory factor in the success of the project. Appendix two shows an organizational diagram for the ICE (this is the current organization and differs slightly from that at the time of the project). Figure 2 shows the implementation scheme for this project.

---

[11] The use of equipment was determined by the Thermal Generation Plant Office of the Equipment Design Section of the Electrical Devices Department.



Source: Prepared from ICE hearings

【Figure 2 Implementation Scheme】

(2)Consultants

Different consultants were employed for the construction works of the IDB portion and the OECF portion, because of making up for the ICE's inexperience in their first geothermal generation project. The Italian firm Electroconsul was used for the IDB portion in overall planning, surveys for the production and reinjection wells, and technical support in the well boring. West Japan Engineering Consultant Inc. (WJEC) was used for the OECF portion for the detailed design of equipment, the preparation of tender documents, assistance in the main tender and contract negotiations, construction supervision, inspection, commissioning, training ICE staff and other tasks. The scope of WJEC's work was changed partway through, leading to their deeper involvement in the basic design. Decisions on site selection and the basic design of generation plant, etc. were reached through discussions between the ICE and the two consultant firms. Other than these consultant firms, Advisory Board[12] of six third-party experts was used. These experts held regular meetings (every three months) to provide the ICE with technical advice and provide final judgements in case of differences of opinion between the consultancy firms. The ICE provided coordination between the Advisory Board, the consultants and the contractors. The ICE had no particular complaints over the abilities of the consultants, and there seem to have been no significant problems with them.

---

[12] The board comprised American university professors and other experts. It has now been reduced to three members and it continues to function as a council for the Miraballes II project (financed by the IDB).

(3)Contractors

One contractor was employed for each lot, three contractors in total. The contractors themselves caused no delays or other problems, and there were no notable faults in their performance. In particular, the Japanese manufacturer for lot one (generation plant) provided considerable technical expertise notwithstanding this was the ICE's first geothermal project. The ICE engineers were favorably impressed by this manufacturer and placed their trust in it. They still closely follow the operation manuals prepared by the manufacturer in the operations and maintenance of the generation plant.

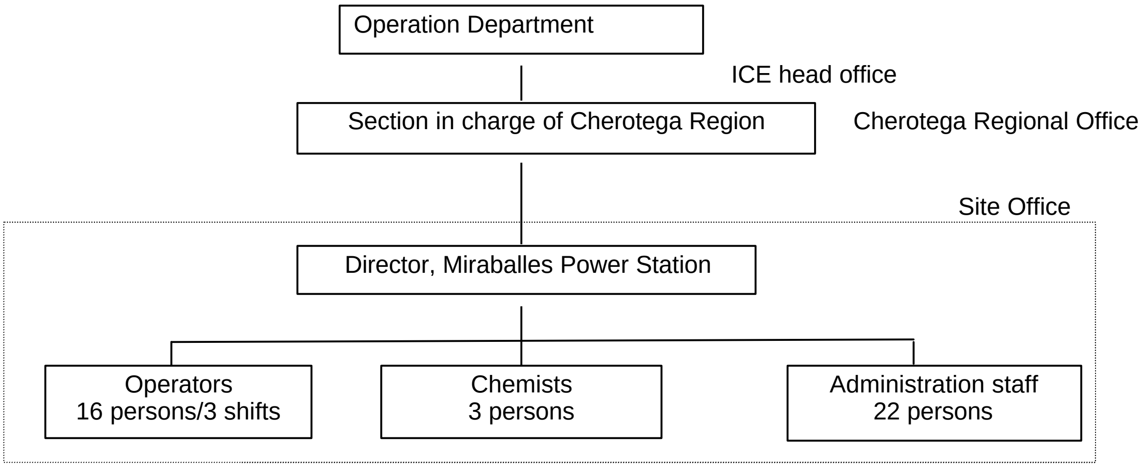
2.1.5 Acquisition of the land

In this project, there happened no removal of neighboring people, because the site of the plant and wells were wild land or pasture, and there was no trouble reports by the executing agency concerning the acquisition of land . At the same time, required land was only limited area around the plant and well site ,and consideration not to violate the right of farming of neighboring people was made. In addition, gates were made at important points to prevent cows coming into the dangerous site. Judging from the amiable coexistence of the plant and the neighboring people, it may be right to conclude that there were no problems concerning the acquisition of the land. It may also worthy to mention that many people had opportunities of works by the construction of the plant

2.2 Evaluation of Operations and Maintenance

2.2.1 Operations and Maintenance Scheme

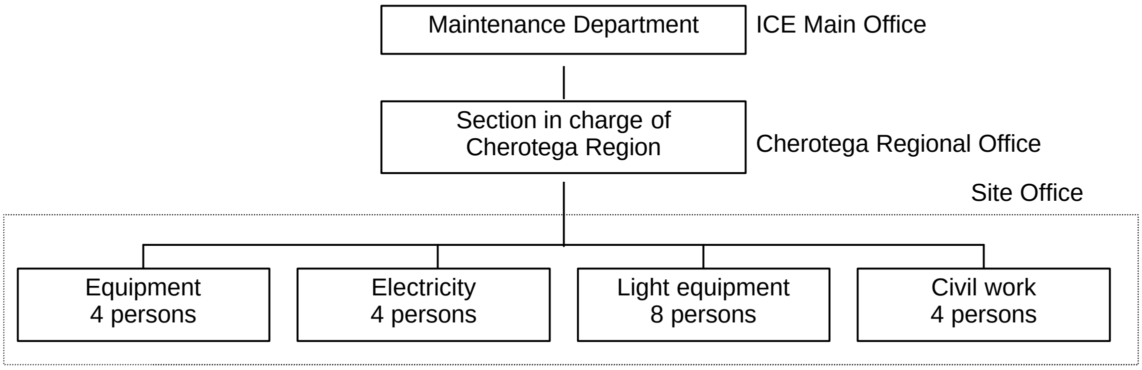
The ICE's operations and maintenance scheme for its equipment is basically divided into two organizations. Operation is handled by the Operation Section of the Systems Department, while maintenance is the responsibility of the maintenance sections of the same department. Operation sections are organized individually for each power station, while maintenance sections are organized for each region, which have a regional office as their base and handle the maintenance of power stations in their region. The planning section of the Energy Development handles the management of geothermal energy and steam supply which provide the energy for geothermal power stations.



Source: ICE

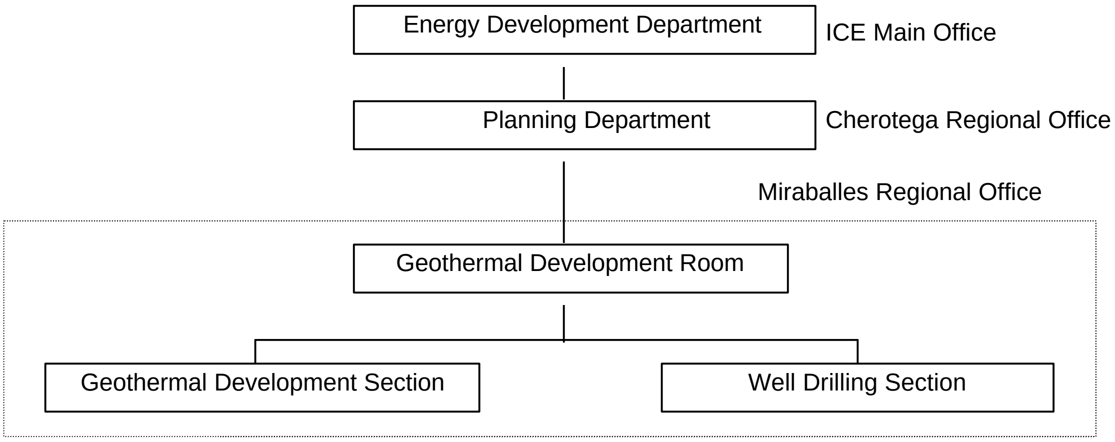
【Figure 3 Organization Chart of Operation】

In short, the operations and maintenance of the Miraballes I Geothermal Power Station is divided into three organizations. This makes any procedures, which go beyond the boundaries of one organization, very complex and there are apparently times when problems arise, such as poor communication and cooperation between operation staff and maintenance staff[13]. There is also the risk that the final chain of responsibility will be unclear when a problem occurs. This situation has yet to cause any serious problems, but in the future there could be problems in steam supply when Miraballes II comes on line, and Miraballes I could begin to require increasingly frequent and timely maintenance and intervention as its plant ages. Considering such risks, the responsibility for all matters within the power station should be unified in the station chief, and the lines of command from the station chief need to be slimmed down. The problem of division of operation and maintenance between two organizations is not confined to the Miraballes I power station. It is actually a common problem in all of the ICE's plant and equipment. To change this situation it will require wholesale alteration of the ICE's organizational structure, and the issue must be addressed as soon as possible to allow sufficient time to consider the correct course of action.



Source: ICE

【Figure 4　Organization Chart of Maintenance】



Source: ICE

【Figure 5　Organization Chart of Geothermal Development/Steam Maintenance】

---

[13] Conversation from Director, Miraballes Geothermal Power Station

On the personnel side, there are enough staff for both the operations and the maintenance of the power station, and these staff seem to have reached a certain technical level. Credit for this is due to the steady process of technological transfer, which had been provided by consultants and the manufacturers and installers of equipment throughout the planning, construction and operation stages of the project. For the well boring, engineers received university degrees in geology, geophysics and resource engineering, followed by UN-sponsored geothermal training courses from ENEL (the Italian Electricity Corporation). These courses produced around 20 experts in fields such as geology, geophysics, drilling and storage strata engineering who are now working in the Miraballes Geothermal Field Development Project. Most of these experts seem to have started with no knowledge or experience of geothermal energy, but in the course of this project's development and operation they have received technical guidance from WJEC, Electroconsul, Geothermex and others so far, gaining a full range of geothermal survey and analysis skills in the process. These skills will be put to good use in future geothermal development.

For reference, actual operation and maintenance costs is shown in Table 9.

【Table 9　Actual Operation and Maintenance Costs of Miraballes #1 generator】

(Unit: colon Thousand)

	Operation cost	Maintenance and administrative cost			Total	Exchange rate	Total in US$
		Direct cost	In-direct cost	Administrative cost			
						1US$=colon	$ Thousand
1994	15,485	169,567	0	0	185,052	165.1	1,121
1995	458,661	186,207	6,428	89,317	740,613	180.5	4,103
1996	101,239	80,238	196,275	98,478	476,230	207.8	2,291
1997	124,805	92,553	294,710	99,434	611,502	232.9	2,625

Source:　ICE

2.2.2　Operation Status

(1)Wells

A suitable system of observation and surveys is used by ICE to keep a grasp of the status of production wells. The results of these observations show that there is some loss of pressure in the geothermal aquifers of Miraballes geothermal field. This is a normal phenomenon, which is due to fluid takeoff. The figures are largely in line with expectations, and there are no sudden fluctuations as time passed.

The state of the steam is largely as expected, with no notable problems. At present, used steam (waste water) is returned to the ground through the return wells, and monitoring of chlorine and silica concentration indicates that the returned water is circulating (i.e. the water returned to the ground through the reinjection wells is emerging again from the production wells as steam). There is no dramatic fluctuation of enthalpy, and there has been no thermal breakthrough[14] to cause a drop in output. Waste water separated at the separator is held in a lagoon before being returned to the ground through the reinjection wells. The state of the reinjection wells is monitored properly and the

---

[14] When the impact of returned water on the geothermal strata causes reductions in the pressure and temperature of steam produced

results gained show that there has been no major change in the return index and other return parameters due to production and reinjection since generation began. The return volume varies each month, but this is due to variations in the volume of fluid used and does not indicate variations in the production capacity of the wells.

The equipment for injection of scale[15] inhibitor[16] is functioning very smoothly and achieving good results in preventing the buildup of calcium carbonate scale. Water/steam separation and the opening and closing of valves causes flashing[17] which causes deposition of silica scale in some parts, but this does not cause a serious problem.

(2) Steam Supply

The supply of steam is remarkably stable, and sufficient to produce an output of 60MW at the generator. There have been no steam supply problems to impede electricity generation. There is actually a surplus of steam supply, so three of the wells have been equipped with independent generator units of 5MW respectively. These units are inefficient, using twice as much steam for a given capacity as the Miraballes I generator. In summary, the generation capacity of the Miraballes field can be taken as equivalent to 90MW as it stands now.

The Miraballes field is stable and it is continuously monitored by the ICE (for pressure, temperature, chemical composition and enthalpy), so its condition is well known. This accumulated data is important for the operation of Miraballes generators Nos. II and III, and beyond that it will be valuable reference material for the development of other geothermal fields in the future. The accumulation of data is the result of a remarkable improvement in the ICE's geothermal field management abilities through their superb efforts over the past three years. Of the 39 wells drilled so far, 17 wells deliver steam to generator No.1, but some of these wells are also connected to generator No.2, so the ICE appears to have the skills and methods it will need for the overall energy management of the Miraballes geothermal field.

The project was planned and implemented on the basis of the results of the feasibility study conducted in 1982, but that study proposed the double flash method as the steam collection method[18]. This method has the advantage of producing a high output from a given amount of steam, compared to the single flash method, but the temperature of the returning fluid is low, and this can cause scale buildup in the return lines. This disadvantage prompted the ICE to select the single flash method at the detailed design stage, after the feasibility study. Considering the fact that this power station is not facing any serious problems with scale buildup, the single flash method was the right choice.

---

[15] Material adhering to the inner surfaces of pipes.

[16] A solvent (polyacrylate).

[17] The production of bubbles.

[18] The Hatchobara Geothermal Power Station operated by Kyushu Electric Power Co., Ltd which was the model for this project, uses the double flash method.

(3) Generation and Transmission

The operation status of the generation equipment is as shown in Table 9. The generator, which is rated at 55MW, is surpassing the original plan by producing an output of 60MW[19]. The stability of the amount generated is also impressive. The usage rate[20] for the equipment has been stable at over 90% for three years, which indicates a stable supply of steam. The work rate[21] has an average record of 93.5%, which is equal to geothermal power stations in developed countries. This excellent operation record is largely due to excellent well management and maintenance of the equipment. There were none of the teething troubles at startup which are so commonly seen, and three years have passed since then without serious problems, a praiseworthy record.

【Table 10　Operational Performance of Generating Facility】

	Units	1994	1995	1996	1997 (Up to May)
Facility fixed volume	MW	55	55	55	55
Operational maximum output	MW	60	61	60	59
Steam supply volume	Ton	2,691,867	3,340,470	3,631,866	1,543,626
Steam supply ratio	Kg/h	419.45	432.49	444.97	543.13
Usage rate	%	91.30%	90.61%	96.21%	101.28%
Generating volume	MWh	341,058	436,548	464,794	198,681
Self consumption	MWh	16,500	20,249	21,862	9,301
Net generating volume	MWh	324,558	416,299	442,932	189,380
Steam consumption rate	Kg/kWh	7.89	7.65	7.81	7.77
Operation hours	h	6,418	7,723	8,162	2,842
Working rate	%	94.49%	88.14%	93.35%	98.03%
No. of stoppage by starting		50	37	26	3
No. of stoppage by planning		24	10	3	1
No. of stoppage by accidents		26	27	23	2

Source:　ICE

Of the 78 stoppages by accident which have occurred so far, around half were due to failures of the grid and 42 stoppages were due to internal problems in the power station. However, the average duration of each accidental stoppage was only a few hours, indicating swift response in the power station. Except for problems related to starting and stopping, all of the following problems have occurred after the station went into commercial operation:

① Seizure of motor bearings. (Due to an inappropriate initial selection of lubricant oil, which had been dealt with by changing the oil type).

② Excessive noise from the silencer. (Due to poor design. The internal structure has been revised).

③ Excessive vibration in a hot well pump. (Due to poor installation. The expansion joints have been readjusted and recentered).

The improvement works to rectify these problems have been implemented in a planned manner to coincide with periodic inspections, so none of them resulted in prolonged stoppages.

---

[19] When the post-evaluation mission visited, the station's output was 58MW.

[20] Usage rate = Average output 1. ated capacity of the equipment

[21] Work rate = hours of operation in a year 1. ours in a year

【Table 11　Breakdown of the Causes of Power Stoppages】

Incident cause	No. of incidents	Duration
Level of mist eliminators	10	11:36
Circuit failures	22	88:02
Transformer failures	14	43:29
Condenser level (failures of water level regulator valves)	9	18:43
Steam leaks from pipes, auxiliary equipment etc.	7	108:56
Gas compressor failures	7	7:09
Cooling tower failures	5	41:39
Other failures	4	27:17
Total	78	351:31

Source:　ICE

(4) Training

Various training programs (six operation courses and 14 maintenance courses) were prepared to coincide with the start of operation. Some courses were to be attended by all engineers working on the site. There were also training courses in overseas countries with advanced knowledge of geothermal power (such as Japan, Italy, Mexico, Nicaragua). The number of trainees attending these courses has risen to 276. The content of the courses seems to have been quite useful, and this is probably one of the reasons why the power station did not suffer any initial teething troubles. Supervisors from the equipment manufacturers were also at site to provide guidance for the first two months of operation. The manufacturers still provide occasional technical advice where it is required, and the support they provide has been good. In total, 9,000 of ICE staff received training inside the company or elsewhere in 1995. This executing agency seems very eager about educating its staff and raising its technical level.

2.2.3　Operations and Maintenance

More than three years have passed since this power station began operation and, as far as can be seen from appearance, the equipment seems to be maintained and managed in very good condition. The ICE has its own engineers and technicians on site at all times to maintain the generation plant and wells according to the manufacturers' manuals. The frequency of maintenance and the methods employed are at least equal to Japanese counterparts. Consideration for the environment and response to emergency situations are handled well and all facilities and equipment are maintained sound, stable and reliable. A panel of experts has been organized to examine plans for well boring and give accurate advice. The selection of well boring positions for backup and expansion is based on accurate and detailed surveys and analysis of the geothermal strata.

(1) Management of the Geothermal Field

① Plans and actual results

The initial plan was to bore the production wells in the center of the field and the reinjection wells around the periphery, particularly to the south. The plant at present is to establish a production area for No.1 and No.2 in the center, No.3 in the north, and reinjection area for all wells in the south. So far, 39 wells have been bored.

② Methods of managing the geothermal strata

Four factors are monitored to ascertain the state of the geothermal strata.

- Monitoring of the pressure inside the well shafts: Capillary tubes[22] are used to monitor the pressure at suitable depths within the well shafts.
- Temperature and pressure measurement: Every six months, testers are used to measure the temperature and pressure of the venting steam.
- Return testing: Both hot water and cold water are reinjected for test at least twice a year.
- Water level measurement: The water level using unused well is measured at least once in two months.

(2) Steam Supply Management

Steam is monitored as described below. Each monitoring operation includes all the composition analyses usually carried out in a geothermal field.

- Sampling of hot water and gas at the production well vent pressure. (Three times per year)
- Sampling of hot water and gas from the production wells at an altered vent pressure. (Annually)
- Sampling of condensed steam from the steam lines. (Twice a month)
- Sampling of hot water from the return line. (Twice a year)
- Sampling of non-condensing gas. (Monthly)

The results of analyses show the fluid produced to be largely neutral NaCl type. After separation of water and steam the concentration of Cl in the water is approximately 4,000mg/l. Non-condensing gas is present in the steam, at about 0.6wt% by weight. By composition, the non-condensing gas is 97%CO_2, 2.3% N_2, 0.6% H_2S and traces of CH_4, H_2 and O_2. The analytical results are put to effective use in management of the strata.

(3) Problems of Scale and Corrosion

The water separated out at the separator is still at a high temperature when it is returned to the ground, which prevents buildup of silica scale in the return wells. Calcium carbonate scale is generated at the production wells, but an inhibitor is used to prevent it from adhering to the pipes. So far, there have been almost no scale problems in the separators, distribution pipes or any other above-ground equipment. Geothermal fluid causes as usual unique corrosion problems, and regular inspections have revealed corrosion in several valves, but overall equipment is in good condition and is not suffering from corrosion. Corrosion in future is a problem which can be controlled through regular, planned inspection and repair.

(4) Generation Facility

The generation facility is serviced regularly as specified in the instruction manuals and is not operated beyond its limits. Spare parts specified by the manufacturers are kept in stock at the standard inventory level, so there are no problems. The fact that no serious problems have occurred for three years of operation also indicates that the equipment is being maintained well.

Day-to-day inspections are carried out regularly by power station engineers and operators. The content of inspections is managed in the form of check lists for machinery, electricity and measurements. Periodic inspections are implemented in a planned manner following the annual inspection and repair plan, which is drawn up for all ICE power stations. Normally, periodic inspections are implemented in October or November, and the content and frequency of periodic inspections is as follows:

---

[22] Very small tubes like a hair.

- Initial periodic inspection, A inspections (Detailed inspection) (37-day intervals)
- Second periodic inspection, C inspections (simple inspection) (15-day intervals)
- Third periodic inspection, B inspections (semi-detailed inspection) (22-day intervals)
- Fourth periodic inspection, C inspections (simple inspections) (15-day intervals)
- The fifth and later inspections are repeats of the above cycle.

The content and frequency of the above inspections are set according to the recommendations of the manufacturers and installers of the equipment. The classifications and content of the inspections are based on those used in Japan. Inspection and servicing is being planned and carried out with a long-term view. Other than periodic maintenance, overhauls are scheduled at intervals of two years. The first overhaul was carried out in 1995.

(5) Preventive Conservation Measures

Geothermal power stations normally require countermeasures against corrosion of machinery, particularly electrical contacts, by hydrogen sulfide gas (H_2S). In this power station the level of H_2S is extremely low, so no special countermeasures are required. When the electrical contacts were inspected, there was no trace of corrosion. When the steam distribution pipes and related parts are given their regular annual inspection, the thickness of the walls is measured as a preventive measure against corrosion. This measure was recommended by the manufacturer, who designed and delivered the equipment. The cooling water pipes are lined with epoxy resin, and other parts which come into contact with corrosive gases, such as the gas compressors, are made of corrosion-resistant materials such as stainless steel and titanium. These and other measures give adequate protection against corrosion.

2.2.4 Consideration for the environment

Costa Rica has not yet to enact laws on regulations and evaluation guidelines for environmental protection, such regulations equivalent to the Japanese Environmental Pollution Prevention Act, governing environmental standards, regulatory standards, environmental impact assessment, environmental monitoring etc. Therefore the ICE has drawn up its own environmental protection guidelines with reference to related laws in California. The autonomous action for the environment on the part of the ICE is highly commendable.

As the entire Miraballes zone is surrounded by pasture, not acquiring the entire area for the project, the wells have been placed at various locations within pasture that is under private ownership, with distribution pipes acrossing the land. There are also two villages nearby, so the power station is relatively close to an inhabited environment. Therefore, this is an area where consideration for the environment is particularly important. Fortunately, the area does not appear to give particular cause for concern over the environment, and the results of monitoring of rainwater such as pH measurement, and other aspects do not show any problems neither. No complaints from the residents of the area have been reported.

(1) Water Quality

For geothermal power stations, the effects of the H_2S contained in the steam from the wells can be a problem, but the system runs as a closed loop, so that most H_2S is caught by separators in the piping system before being returned to the ground together with the waste water. In case of problems with the reinjection wells, there is a lagoon which can be used as a temporary store for waste water. The capacity of the lagoon for the No.1 generator is more than adequate for emergency use, and a further lagoon is being built for the No.2 generator. The lagoons are lined with rubber sheet to prevent water from seeping into the ground, as such seepage could have an adverse impact on nearby rivers.

(2) Atmosphere

The H_2S gas is concentrated within the non-condensing gas extracted from the condenser by the gas extractor, but even so, its concentration does not rise above 0.6%[23]. It is then diluted by the large volume of air passing through the cooling tower and dispersed into the atmosphere. The distinctive smell of H_2S is barely distinguishable in the air near the power station, and the impact on the surrounding environment can be assessed as extremely slight.

(3) Noise and Vibration

The steam receiver and other potential sources of noise are equipped with silencers which restrict the noise output of these parts to around 80dB. Noise at the boundaries of the site is around 60dB[24], so noise has little impact on the nearby living environment.

(4) Monitoring

To investigate the actual impact on the environment, the ICE monitors the composition of exhaust gas at the cooling tower, the nearby weather conditions (at ten places), river pollution (at ten places), acid rain (at nine places), earthquake observation (at six places) and various other aspects of the environment. Other than earthquake monitoring, which is continuous, all other factors are monitored at monthly intervals. For measurements of climatic conditions, river water quality and rainwater quality, the necessary instruments are loaded into a large bus which is attached to the Miraballes regional office. This bus tours the measurement points to monitor these conditions. The results of this monitoring showed no impact on the surrounding environment due to H_2S contained in non-condensing gas discharged by the power station. No impact on the aquifers due to the wells has been detected, and no results have been reported which give any cause for concern over any impact on nearby residents.

This kind of monitoring must be continued in future, and if any abnormal results are detected, more detailed studies must be made to determine the cause.

2.3 The financial position of the ICE

Judging from the financial condition of the ICE from 1992 to 1996, the operating profit showed stable growth, but ordinary profit was very unstable having a bottom in 1995. In that year, ROA and ROE fell to 0.3% and 0.4% respectively before rebounding to 3% and 5% in 1996. Comparing the spreads in ROA and ROE with TEPCO (Tokyo Electric Power Co.), TEPCO showed a ROE spread of 2.2% and an ROA spread of 0.4%. The equivalent figures for the ICE were 9.2% and 4.8%, indicating extreme volatility.

These fluctuations are caused by the accounting of non-operational costs from 1993 to 1995 which produced greater exchange losses than in normal years. Finance from the IDB amounts to 70% of the ICE's long-term debts, which is a debt structure highly susceptible to exchange losses. This situation leads the ICE to re-evaluate its debt balance every year due to exchange rate fluctuations. As a result, the exchange profits and losses are capitalized in each year's profits and

---

[23] Non-condensing gases amount to about 0.6% of the steam by weight. By composition, the non-condensing gas is 97%CO_2, 2.3% N_2, 0.6% H_2S and traces of CH_4, H_2 and O_2.

[24] These are equal to the Japanese Environmental Standards Act levels for daytime noise in mixed residential, commercial and industrial areas.

expenditures. The amount of this capitalization varies every year because it depends on the Dollar-based debt balance. The dip, which happened in 1995, was apparently due to an unusually large Dollar-based debt balance, coupled with exchange rate movements, which were also larger than usual.

An overall returns on assets of 0.1% is extremely low, so the use of the ICE's assets cannot be evaluated as efficient. This is because the amount of fixed assets is unusually high due to the ICE's practice of re-evaluating its tangible assets every year. This practice is sensible as it raises depreciation costs to a suitable level and increases the ICE's cashflow to a comfortable level. As a result, the fixed assets ratio is over 100%, but its fixed long-term conformity rate is nearly 100%, so its finance procurement situation is stable. The ICE also has a few percentage points of interest coverage ratio, so it has the ability to meet its interest payments and it has a degree of financial stability. In the future, the ICE must consolidate its idle assets to improve its financial situation.

【Table 12　ICE Balance Sheet and Statements of Income】

(Unit: 1,000¢)

	1992	1993	1994	1995	1996
Current assets	17,051,205	17,672,240	28,769,627	25,936,779	34,961,211
Fixed assets	248,976,790	302,414,996	367,727,671	481,316,387	572,408,346
Accumulative amount of depreciation	(55,302,213)	(67,045,253)	(82,203,580)	(107,807,776)	(136,764,847
Other assets	664,527	1,250,590	1,255,245	1,637,621	5,410,749
Reserve	2,134,546	2,790,052	3,702,581	4,703,461	5,595,416
Total of assets	213,524,855	257,082,625	319,251,544	405,786,472	481,610,875
Fixed liabilities	71,902,352	83,633,410	101,776,524	130,454,450	141,438,540
Current liabilities	30,078,070	34,738,813	42,688,654	50,569,291	55,740,920
Capital	111,524,251	138,710,402	174,786,366	224,762,731	284,431,386
Total of Debt	213,504,673	257,082,625	319,251,544	405,786,472	481,610,845

Source:　ICE (The index is calculated on the basis of ICE material.)

【Table 13　Statements of Income】

(Unit: 1,000¢)

	1992	1993	1994	1995	1996
Sales	25,263,115	30,453,487	37,528,631	42,069,719	49,863,411
Business expenses	12,141,986	14,482,255	20,480,845	23,196,417	27,037,084
Business profit	13,121,129	15,971,232	17,047,786	18,873,302	22,826,328
Non-operating profit	1,675,307	1,152,227	1,281,378	2,338,499	2,014,914
Non-operating expenditure	3,977,939	9,721,099	13,427,162	20,067,464	10,392,484
Recurring profit	10,818,497	7,402,360	4,902,002	1,144,337	14,448,758
Tax	86,808	105,090	130,940	165,727	114,456
Profit	10,731,689	7,297,270	4,771,062	978,610	14,334,302
ROA	5.1%	2.9%	1.5%	0.3%	3.0%
ROE	9.6%	5.3%	2.7%	0.4%	5.1%
Turnover ratio over total assets	0.12	0.12	0.12	0.10	0.10
Capital ratio	52.2%	54.0%	54.7%	55.4%	59.1%
Current ratio	56.7%	50.9%	67.4%	51.3%	62.7%
Fixed assets ratio	173.7%	169.7%	163.4%	166.2%	153.2%
Ratio of fixed assets to long-term capital	105.6%	105.9%	103.2%	105.1%	102.3%
Interest coverage ratio	3.75	4.87	4.62	3.69	4.58
ROA of TEPCO	1.3%	1.3%	1.2%	1.6%	1.2%
ROE of TEPCO	5.4%	5.2%	4.4%	5.7%	3.5%

Source:　ICE (The index is calculated on the basis of ICE material)

2.4 Project Effects and Impacts

2.4.1 Qualitative Effects

(1) Stable Supply of Electricity

As explained in the section on operational status, this project has been stably generating and supplying electricity for baseload electrical demand since it began operation. It has made a great contribution to Costa Rica's balance of electricity supply and demand.

【Table 14 Energy Supply and Demand Structure】

	Unit	1990	1991	1992	1993	1994	1995	1996	1997
Installed capacity	MW	－	－	－	－	55	60	65	70
Geothermal generating ratio		－	－	－	－	5.0%	5.1%	5.1%	5.1%
Total of installed capacity	MW	828	1008	1043	1043	1102	1166	1267	1369
Generating volume									
Geothermal generating	GWh	－	－	－	－	325	416	442	442
Ratio of geothermal generating volume		－	－	－	－	6.9%	8.6%	8.9%	8.5%
Yearly generating volume	GWh	3707	3828	4080	4383	4719	4843	4994	5212
Peak electrical demand	MW	682	718	764	814	859	872	n/a	n/a
Load ratio		62.05%	60.86%	61.06%	61.47%	62.79%	63.40%	n/a	n/a
Yearly consumption volume	GWh	3304	3411	3652	3890	4204	4343	4504	4750
Consumption ratio		89.12 %	89.11%	89.51%	88.75%	89.09%	89.68%	90.19%	91.14%

Source: ICE (1997 is planned value.)

(2) Saving on Crude Oil Imports

By using geothermal energy, which is a domestic energy source, the project saves at least US$25 million of foreign exchange to import oil. Particularly for a non-oil producing country, geothermal saves foreign exchange and diversifies the spread of energy sources. For these reasons, geothermal energy is certainly a form of power generation which should be encouraged as an element in the national energy supply strategy. Costa Rica has some potential for production of oil and natural gas, and some studies have been conducted, but the legal system to enable the exploitation of any reserves was only put in place in 1994 and no actual projects have begun yet.

【Table 15 Saving Amounts of Crude Oil Imports】

	Units	1994	1995	1996	1997
Generating volume	GWh	341	437	465	477
Heavy oil volume for substitution	Kl	78,538	100,527	107,031	109,804
Heavy oil price	¢ ／l	47.3	51.5	51.5	51.5
Saving amount	$ million	22.5	26.6	25.0	25.7
Total import amount of heavy oil	$ million	236	264	280	281
Saving ratio		9.5%	10.1%	8.9%	8.9%

Note: Assuming the calorific value of heavy oil is 10,400kcal/kg, its specific gravity is 0.945 and its efficiency in thermal power stations is 38%.

Source: Costa Rica Central Bank, ICE, IIF etc.(1997 is predicted value)

2.4.2 Quantitative Effects

(1) Financial Internal Return Rate (FIRR)

At the time of the appraisal, the FIRR was estimated at 8.8%, but the actual figure was 8.1%. For this reassessment of FIRR, the preconditions were revised as shown below according to recorded results. In the appraisal it was assumed that the proportion provided to large users would be 27% (these users draw their electricity directly from transmission lines, avoiding distribution losses). In fact, the only large user was a cement factory, using amount of electricity was not specified, so the transmission and distribution loss rates were applied to the whole volume of electricity sales. The boring cost for additional wells was calculated at a rate of one well per two years[25], starting from 1998. This rate of well boring was based on the experience of the South Negros Geothermal Power Station Construction Project[26] in the Philippines (loan agreement No. PH-P41), in which eight additional wells were bored in 14 years.

【Table 16 Preconditions of FIRR Calculation】

	At the time of appraisal	This time	Remarks
Installed capacity	55MW	55MW	
Project cost	$115,847,000	$223,104,000	
Usage rate	80%	94%	Average of actual result for 1994 ~ May 1997
Usage rate within the station	7%	4.72%	-Ditto-
Net yearly generating volume	358,460MWh	404,300MWh	-Ditto-
Transmission & distribution electrical loss ratio	12.86%	11.5%	Actual in 1996
Direct sales to large user	27%	0%	Disregarded because there is only one.
Selling price of electricity	$0.045/kWh (Jan. 1985)	$0.07kWh (Jan. 1997)	Average for Jan. 1997 in the country
Operation and maintenance cost	$2,786,000/year	$1,500,000/well	1997 budget
Additional boring cost of wells	Included avove	$ 2,625,000/year	Actual result of Miraballes

Source: ICE, etc.

2.4.3 Environmental and Economic Effects

The energy for geothermal power generation comes only from groundwater heated to steam by magma. Compared to thermal power stations, which burn fuels, it is a very clean form of energy. Now that concern over global warming is growing, and restrictions on the gas emissions from the burning of fossil fuels are becoming tighter, the environmental superiority of geothermal generation is attracting attention. This superiority can be evaluated in economic terms. One specific method for this evaluation is to calculate the investment cost and operation and maintenance management costs which would be required to reduce the atmospheric emissions of a thermal power station to the level of an equivalent geothermal power station. We can then calculate the impact of cost to the FIRR. It should be noted that this kind of calculation of the FIRR can only produce rather rough one,

---

[25] Commonly known as Palinpinon I.

[26] In the case of the South Negros power station, the volume of steam supply fell by 25% in eight years, but in Miraballes, no reduction has been observed in four years of operation, and no additional production wells have been bored for the Miraballes No.1 generator. Therefore it does not appear likely that one new well in two years will be required.

because it uses assumptions of cashflow based on some suppositions. Table 16 summarizes the impacts on the environment of geothermal power generation and thermal (coal-fired) power generation (hydroelectric power generation is also included for reference).

The point to note here is that, in contrast to thermal generation, geothermal generation discharges no particulates, SOx or NOx. The emission of CO_2 varies between regions, but the volume is far lower than that for thermal power stations (in Costa Rica, CO_2 emission is one tenth that produced by thermal generation). Therefore, for this calculation we will compare these four factors (particulates, SOx, NOx, CO_2).

【Table 17　Environmental Impacts of Each Generation Method】

		Geothermal		Thermal (coal fired)		Hydraulic (reference)	
		Impacts	Counter-measures	Impacts	Counter-measures	Impacts	Counter-measures
4 items	Particulates	○		×	Particle precipitator	○	
	SOx	○		×	Cool washing, heavy oil desulfurizing, smoke desulfurizing, LNG, LPG use	○	
	NOx	○		×	Cumbustion improvement, smoke denitration	○	
	CO_2	△ Slight amount	Afforestation	×	Afforestation	× (Submerging of forests)	Afforestation
Others	H_2S	×	Reinjection well	○		○	
		×	Sound-proofing		Sound-proofing	○	
	Resettlement of residents					×	Compensation
	Deterioration of ecosystem	High temperature, drainage	Cooling reservoir	× High temperature, drainage	Cooling	×	
	Soil erosion	○		○		×	Afforestation

(×: Has an impact,　△: Has an impact in some cases,　○: Has no impact/ can be largely avoided).

Table 17 summarizes the impact of the cost of limiting gas emissions on the FIRR. The FIRR of thermal (coal-fired) generation is calculated for the case where no countermeasures are taken against gas emissions, and where equipment is installed against emissions, and the difference compared. The premise for this FIRR calculation are shown in Table 19. The results of the calculation (which appear in appendix four) show that the difference in the FIRR when environmental protection measures are taken is as much as 5%. Therefore, if the difference between the FIRR of a thermal generation project and that of a geothermal generation project is within 5%, there is a strong likelihood that the geothermal option will be superior even in economic terms. However, in recent thermal generation projects it is quite normal for them to install devices such as particle precipitators. If the cost of such devices has already been figured into the FIRR calculation, the geothermal option will only enjoy an advantage in the remaining three of the above factors, and only those should be included in the comparison.

【Table 18　Impacts on FIRR by Cost of Restricting the Emissions of Gases】

			Particulates	So$_X$	NO$_X$	CO$_2$
Facility		Thermal	Particle precipitator	Smoke desulfurizing equipment	Smoke denitration equipment	Cost to fix carbon by plants
Method		Coal fired	Electric method	Wet Coal-gypsum method	Ammonia reduction method	
Premise for trial calculation	Facility cost (per 1MW)	¥240 million	¥1.3 ~ ¥13 million	¥7 ~ ¥15 million	¥4 ~ ¥5 million	
	Yearly operation and maintenance cost (per 1MW)	¥9.6/kWh	¥0.12 ~ ¥1.2 million	2% of facility cost	¥0.9 ~ ¥9 million	$34,700
Impacts on FIRR			Approx.–1%	Approx. –0..5%	Approx. –1.5%	Approx. –1.5%

Note:　Ammonia storage tank and ammonia consumption cost are not included.

Sources of costs:　Agency of Natural Resources and Energy “Anthology of Energy-related Documentation” Technical Manual of Smoke Reduction compiled by The Japan Society of Industrial Machinery Manufacturers), “Manual on Countermeasures of Fixed Occurring Sources for Air Pollution Problems in the Developing Countries (Electricity Version)” compiled by Global Environmental Center in 1997 (supervised by Environment Agency)

The costs of equipment, operation and maintenance used in this calculation are based on Japanese yen. Compared to other developed countries, Japan's base unit for gas emissions (g/kWh) is 1/20 for SOx volume, 1/7 for NOx volume, and 30% lower in the CO$_2$ volume[27]. Where it is not strictly necessary to reduce gas emissions to Japanese levels, and where American levels for SOx and NOx are deemed adequate for example, the equipment cost and annual operation and maintenance cost will be cheaper, the impact on FIRR will be smaller. For CO$_2$, a figure of US$20/tonC was used, but among WRI[28] projects, figures of US$2/tonC or less have been used in interim reports, so it is possible to achieve reductions more cheaply. The reasons why coal was chosen to represent the fuels for thermal generation for the purpose of comparison, are that its energy cost is lower than that of other fuels (such as oil, LNG etc.), it is still the dominant fuel in developing countries, and it has the greatest impact on the environment[29]. If the fuel burned is LNG or LPG, the emissions of particulates and SOx are practically zero, so there is no need to spend money on reducing these emissions. However, these fuels require equipment investment for delivery terminals, so they do not necessarily have an economic advantage.

---

[27] Based on thermal power stations of all types (coal, oil, LNG and LPG classifications). Japan's average is compared against the average for six OECD nations.

[28] World Resource Institute, Washington DC

[29] Where the fuel is LNG or LPG, there are almost no emissions of particulates and SOx.

【Table 19　Estimation of Costs of Emission Gas Reduction】

Power station	The cost of equipment was set at ¥240 million/MW, based on "Anthology of Energy-related Documentation" by Agency of Natural Resources and Energy. This cost is almost same to the unit cost (¥286 million) of construction for coal-fired thermal power stations which began construction in Japan in 1992 minus the cost (¥253 million) of equipment against emissions of particulates, SOx, NOx etc. The usage rate was assumed as 80%, the unit generation price as ¥5/kWh and the unit price for electricity as ¥10/kWh.
Particulates	Equipment cost was assumed as ¥4,400/Nm^3/h and the volume of fuel gas consumption as 3,000Nm^3/MW/h[30]. The equipment cost is based on a type of electrostatic precipitator, which is widely used for generator boilers because it causes low pressure losses, is capable of efficient particle collection (secondary collection of fine dust is also possible) and is easy to operate and maintain.
SO_X	Methods for restricting the production of SOx include switching to low-sulfur fuel and installing smoke desulfurizers. The fuel with the lowest sulfur content is natural gas. Smoke desulfurizers use alkali materials to absorb and eliminate SOx from the exhaust gases. The most common method is the wet absorption method, which uses an alkali dissolved in water or in a slurry as the absorption agent. In this calculation, the smoke desulfurization equipment using the wet coal-gypsum method most commonly used in Japan was assumed to cost ¥15 million/MW. In America, the most common way of reducing sulfur emissions is to switch to low-sulfur fuel, with the use of scrubbers to remove sulfur from exhaust gases accounting for only 30% of reductions (based on total volume of sulfur removed)[31]. The remainder is covered by the trading of SOx emission rights.
NO_X	The emission of NOx depends more on the method of burning than on the type of fuel. It is said that the higher the combustion temperature, the more NOx is emitted. In Japan combustion improvement methods aiming to reduce NOx emissions include two-stage combustion, the exhaust gas admixture combustion method and the use of low-NOx burners. NOx in exhaust gas is also removed by smoke denitrification devices. It is difficult to calculate the cost of combustion improvements, so for this calculation the cost of the standard-specification denitrification device using the ammonia contact reduction process (based on a nitrogen removal rate of 80%) was assumed as ¥6 million/MW[32]. The operation cost was assumed as ¥4.2 million/ MW. These figures do not include the cost of ammonia storage tanks or ammonia consumption.
CO_2	For limitation of CO_2, there is still no prospect of the practical application and engineering method so the cost of CO_2 reduction was based on the cost of tree planting for the CO_2 fixation method. In recent years considerable progress has been made in investigations and research into the CO_2 fixation capacity of forests, spurred by concern over global warming. By linking this research data with the cost of planting trees, it is possible to calculate a CO_2 reduction cost of this method. However, both the CO_2 fixation capacity and the cost of planting vary with the type of forest and the varieties of tree, so there is no real unit value. In this calculation, the figure of US$20/tonC[33] was assumed as a figure used by the World Bank and others for approximate calculations. The base unit for CO_2 emission was assumed as 225g-C/kWh, which is the average for six developed countries.

In the case of geothermal power generation, it is not possible to build a large power station in one stroke. A more realistic approach is to build the power station in phases with watching the state of geothermal reserves, as was done in Miraballes. Nevertheless, the capacity available from one geothermal field could well be in the region of 200MW. Therefore, although geothermal generation

---

[30] From "Boiler Handbook" (Japan Boiler Association).

[31] Investigated by Energy Ventures Analysis Inc. (The Utility Report, 1995)

[32] This method incurs high equipment and operation costs, so another method is under development which will break the NOx down to nitrogen and oxygen over a catalyst without a reducing agent.

[33] These are not official figures.

is limited to small-scale plant (around 50MW/generator), the efficiency of thermal generators in this class is reduced, reducing the FIRR. Therefore, geothermal power remains a valid option worthy of full consideration.

Also, if strict controls on CO_2 emissions are introduced around the world, the kind of trading of SOx emission rights which is practiced in the United States could also be applied to CO_2 emission rights. If that happened, geothermal generation would be a more efficient way of restricting CO_2 emissions than planting trees, and the geothermal option would then become an attractive project for businesses targeted by CO_2 emission controls (particularly electricity companies). The "joint implementation"[34] proposed by the UN could also be applicable, which would make geothermal projects very attractive to developing countries as a way of introducing foreign investment.

2.4.4 Other effects

(1) Technology Transfer

ICE hired an American consultant for the test boring of wells between 1975 and 1983. Then Electroconsul took over as consultant for the development of wells for the Miraballes project. Since 1994 Geothermex has been employed again to prepare for the start of operation of the Miraballes Geothermal Power Station No. 2 generator. At the same time, one or two trainees a year were dispatched to geothermal power stations overseas for periods of nine months to a year. There are now 25 to 30 geothermal experts (in fields such as chemistry and geology) within the ICE who are working on the preparations for the construction of the second and third Miraballes generators. The way these engineers have reached this level within ten years, starting from zero, through the continuous use of consultants, proves that technological transfer in this case has been highly effective.

The ICE has already bought its own drilling rig and is building the organization needed to bore its own wells. It is now boring a test well in the Miraballes area. For the time being, the rig is to be used for maintenance of wells in the Miraballes area, but it is to be used for boring test wells in other areas in future. The ICE itself has been dispatching its engineers overseas (several to Japan) to study other geothermal power stations as part of its work for this project. The ICE's enthusiasm and initiative in acquiring new technology are praiseworthy.

(2) Effects on introducing private capital

Evaporated groundwater is more difficult to understand than other energy sources, such as oil. It is hard to grasp the scale of a geothermal field and geothermal development is thought to be difficult. The survey of the Miraballes field took ten years (1975~1985), so it certainly can take a long time to find whether the potential for geothermal generation is there or not, and decide to construct a geothermal power station. Clearly the judgement must be made with great care. Therefore, this is a type of project with a high level of risk for participating private companies, making it difficult to introduce private-sector activity.

However, once the geothermal power station has been built and has gone into operation with a good service record, as in this project, the unknown factors are eliminated from new development of the geothermal field and the risk is greatly reduced. When construction began on this project

---

[34] This approach was advocated by the UN in the UNFCCC. Under JI, developed country partners provide technology and finance and the developing country partner provides the site for CO_2 reduction projects. The CO_2 emission volume reduced (freed) by the project can be supplied to the developed country partner in the form of an emission right. Through this program, developed countries are assured of the rights to discharge CO_2 and the developing countries draw in investment.

(Miraballes Geothermal Power Station No.1), the decision was taken to proceed with the construction of generators 2 and 3. (see 2.6.1). The introduction of private investment is particularly planned for generator No. 3 as a BOT project, and it is attracting considerable attention as a result. In this way, in projects and sectors where the risk is too high to attract the private sector, ODA loans and other public finance can be used to promote the project reducing the development risk. This will create a condition to mobilize private-sector capital easily. This method of drawing in the private sector merits close consideration in future as one valuable role ODA loans can play.

2.5 Plans for the Future

2.5.1 Development Plan for the Miraballes Field

The Miraballes area has a number of fault lines, which allow geothermal heat to rise up through the cracks from greater depths. As a result, the entire area has abundant geothermal energy, and there are plans for several geothermal generation projects. If the geothermal development of the whole area is to be economic and effective, it must be supported by exhaustive analysis and management of the geothermal strata. The ICE has formulated a number of numerical models of the geothermal strata, and it is now calibrating these models on the basis of production and measurement data on temperature, pressure, flow volumes, geochemistry and other fields gathered over a period of three years. As a result it is now possible to have an accurate grasp of the nature of the geothermal strata, and the positions of the well borings have been determined on the simulation results. These wells will be used to refine the numerical model and predict the distribution of the geothermal strata. This process will require high-level computer techniques and strata analysis techniques based on deep experience of geothermal energy. At that stage it will be important to make further use of the skills of suitable foreign consultants.

The development of the Miraballes geothermal field will require ongoing evaluation of the geothermal strata as a whole from a long term viewpoint. Beyond the Miraballes No.2 generator, which is now under construction, the construction of the No.3 and No.4 will inevitably have an impact on the power generation of No.1. At that stage the optimum scale, distribution and process for development of the entire area will have to be decided on the basis of analysis of the geothermal strata, in order to prevent excessive and ill-considered development. The capacity of the production and reinjection wells is expected to decline over time, and supplementary wells will have to be bored in a planned manner to compensate for the decline of the original wells.

【Table 20　Geothermal Projects in Miraballes Region】

Project	Scale	Status	Finance
Miraballes No.1	55MW	Operation started in 1994	OECF
Miraballes No.2	55MW	Operation to be started in 1998	IDB
Miraballes No.3	27.5MW	Sign of agreement in 1997, waiting to take effect	BOT
Miraballes No.4	27.5MW	Under planning	BOT
Miraballes No.5	20MW	Start operation in 2000 (binary cycle)	BOT

Source:　ICE

2.5.2 Geothermal Generation Projects in Costa Rica

Following on from Miraballes, the ICE is looking at the area of the Rincon de la Vieja and Tenorio Volcanoes,Which are adjacent to Miraballes, as candidates sites for the construction of the next geothermal power station. Investigations of the potential areas are already under way and the results seem favorable. Although the Condera Jaya area is inside a national park, it has a capacity equivalent to 140MW. The Tenorio area has steam with 230~240℃ and a low salinity, therefore it is expected to have a capacity of 100~120MW. There are no specific plans for building power stations in either area yet, but they are expected to be the next geothermal development areas after Miraballes. Geothermal power is clearly taking its place as one of the main forms of electricity generation in Costa Rica.

2.6 Geothermal generation around the world

As shown in Table 20, geothermal generation is being positively pursued in countries of the Pacific Rim. Developments in the Philippines and Indonesia are particularly remarkable. Five major geothermal fields already exist in the Philippines and the existence of a further nine fields on the islands of Luzon, Leyte and Mindanao has been confirmed. All of these (equivalent to a total of 754MW) are to be developed by the BOT method. In Indonesia, geothermal developments planned for the future are to proceed in a JOC (joint operating contract) form, with a central role for Pertamina, the nationally-owned oil company. A law has already been enacted to allow Pertamina to sell electricity to PLN (the Indonesian power corporation) and in the future it will become easier for private enterprise to participate in geothermal development. The World Bank has been enthusiastic in financing a wide range of geothermal generation projects (small, medium and large scale) in Indonesia and this seems to have had a strong influence in fostering the country's positive attitude to geothermal power. The OECF has performed a similar role in other countries with the potential for geothermal development.

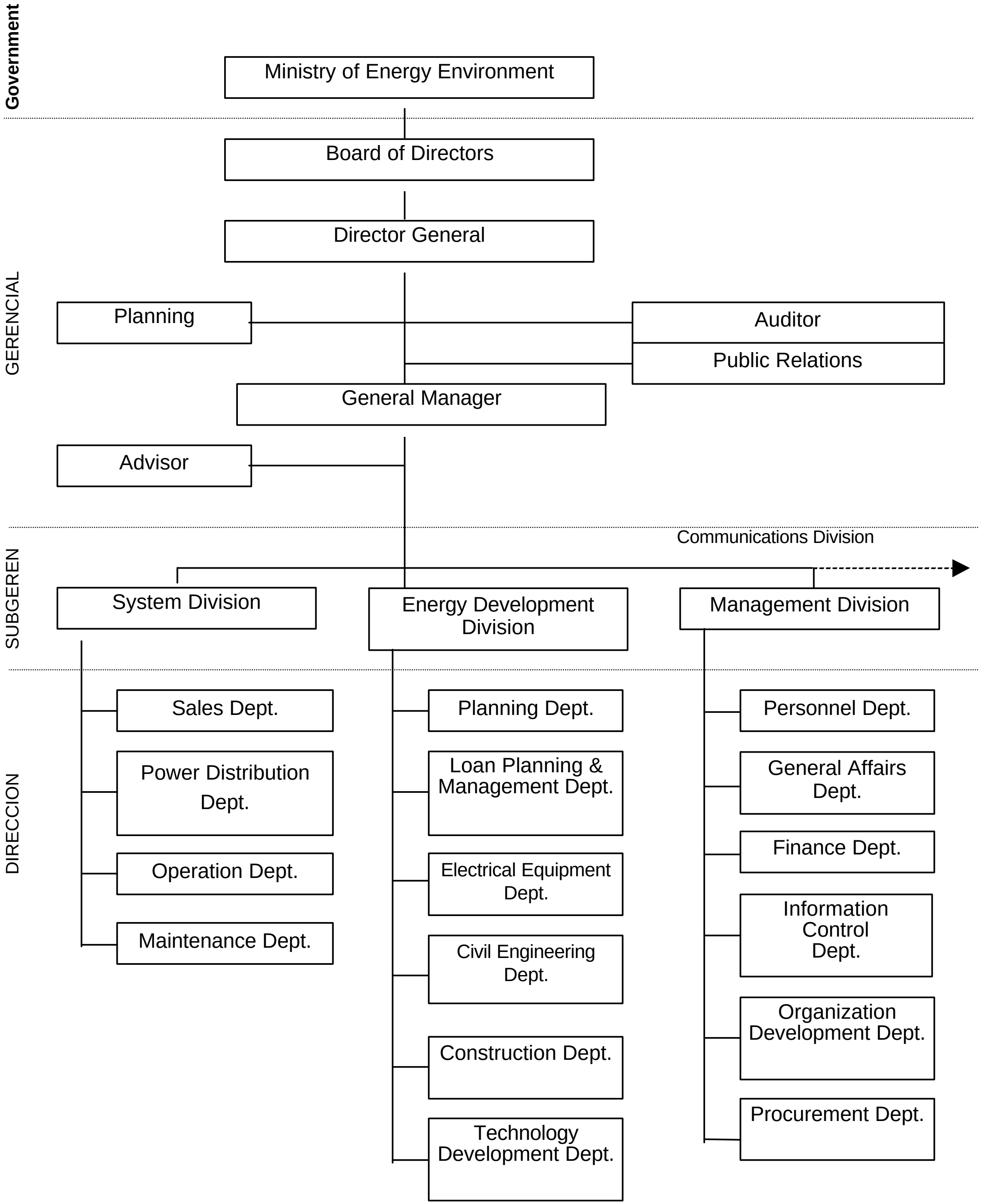
【Table 21　Geothermal Generation Facilities in the World】

(Unit: MW)

Country		1990	1995	2000 (Plan)	Remarks
1	USA	2,775	2,817	3,395	Primarily in California, Nevada
2	Philippines	891	1,191	1,945	Many BOT projects(equivalent to 754mm)
3	Mexico	700	753	960	3 geothemal fields
4	Italy	545	632	856	Development is made mainly by private companies
5	Japan	215	414	600	11 power stations as of 1993
6	Indonesia	145	310	1,080	Pertamina and JOC
7	New Zealand	283	286	440	Privatization of electricity sector is set as task
8	El Salvador	95	105	165	Operation started in 1975
9	Cost Rica	0	55	170	
10	Iceland	45	49	n/a	
11	Kenya	45	45	n/a	
12	Nicaragua	35	35	n/a	TGC is under construction of 105MW BOT plant
13	China	19	29	81	
14	Turkey	21	21	125	
15	Russia	11	11	110	
	Other	8	10	n/a	
	Total	5,832	6,762	9,927	

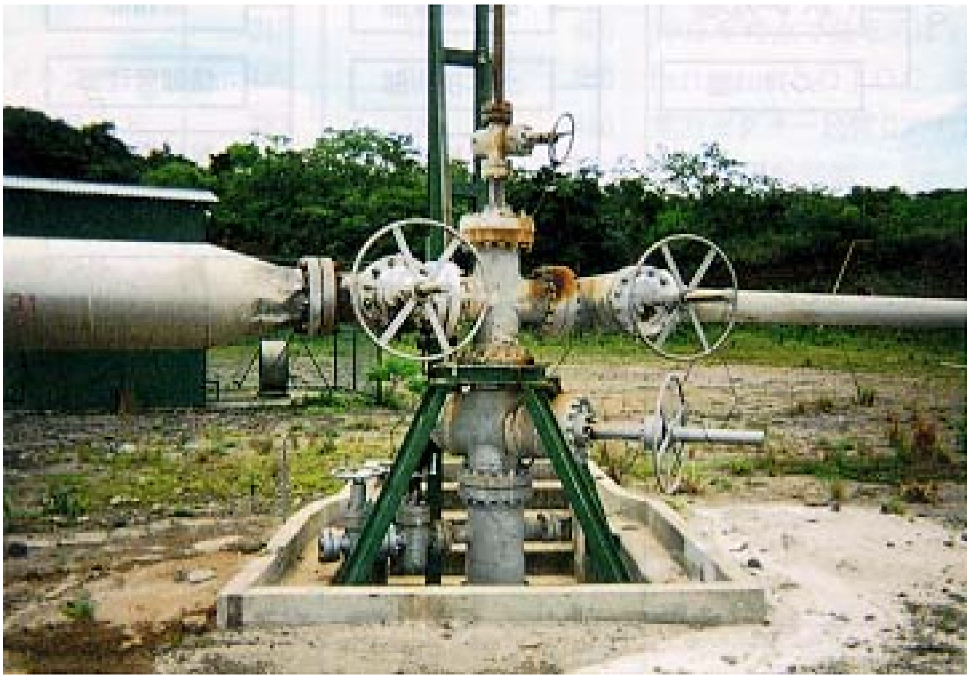
Source:　Gerald Huttrer "The Status of World Geothermal Power 1990-1994"

Appendix Organization Chart of ICE (as of 1997)



Source: ICE

Steam Separator



Head of production well