3. DEVELOPMENT PROGRAM

3.1 RESOURCE ASSESSMENT

3.1.1 Numerical Model

For the potential estimation and simulation of the Amatitlan reservoir performance under exploitation the control volume shown in Fig. 3-1-1 was used. The simulation model was oriented in a NS - EW direction. The model includes a total area of 140 km^2 (14 km in the NS direction and 10 km in the EW direction), much larger than the known geothermal area.

Five different layers were devised to represent the reservoir in the "z" (depth) direction as shown in Fig. 3-1-2.

The configuration of the grid in the different layers had to be different to represent the features of the geothermal system. Layer 1 (AE) and Layer 4 (AB) have the same configuration with 225 elements each. Layer 2 (AD) and Layer 3 (AC) have the same configuration with 285 elements each and Layer 5 (AA) has 190 elements. In total there are 1210 elements in the control volume.

In addition, boundary blocks were set beneath Layer 5 (AA) to represent the portions of the conceptual model supplying hot fluids to the system and boundary blocks above layer 1 (AE) to represent air and the topography of the Amatitlan field. To represent the lateral supply of water from the regional hydrological system Layer 2 (AC) was added in boundary blocks.

Table 3-1-1 presents the values of the petrophysical properties of materials filling the several elements of the numerical model.

3.1.2 Natural state calibration

The main objective of the natural state calibration was to verify the temperature and pressure distributions and the heat/mass flow aspects of the model.

To match the calculated temperatures/pressures to those measured in wells the model had to be given two recharge sources and five discharge sinks. A hot inflow rate of about 450 tons/hour was required into the six blocks in layer 5; the inflowing fluid is single-phase water at a source temperature of 336°C. An additional inflowing fluid at 50°C is coming from the NE corner of layer 3 at a rate of 620 tons/hour that represents the NE-SW regional fluid flow pattern. Discharges from the model include sinks in layer 1 that represent shallow fluid movement and surface discharge and sinks in layer 3 that represent deep sub-surface discharge towards the Michatoya River. About 75% of the cool fluid coming from the NE corner is discharged through these sinks. The remaining 25%, or 156 tons/hour, is allowed to mix with hot geothermal fluid and then discharged through the shallow sinks in layer 1

3.1.3 History Matching calibration

Three groups of well test data were used. The first is the data collected by INDE/ West JEC during the 1994 flow tests of AMF-1 and AMF-2. The second group is the long term well test data collected by INDE/ICA/CFE on wells AMF-1, AMF-2 and

AMF-3 (reinjection) during the two years of operation of the 5 MW geothermal power plant at Calderas. The third group of data corresponds to the testing of wells AMJ-1and AMJ-2 as described here in Chapter two (refer to section 2-4). The second group of data is the most adequate and reliable set to carry out the production (history) calibration because of the length and type of data series. Thus, the production calibration was carried out using this group of data. The production period of wells AMJ-1 and AMJ-2 (one week per each of the two testing periods) was too short to provide any significant base to assess reservoir properties.

Since wellhead pressure trends do not provide a representative indication of the bottom hole pressure condition, especially in a two-phase reservoir enthalpy transients measured in flowing production wells is the matching parameter to further calibrate the model in the vicinity of the production wells

Results are presented in the following figures. For well AMF-1 Fig. 3-1-3 and Fig. 3-1-4 presents the mass /enthalpy history and the power respectively during this long term testing period. For well AMF-2 Fig. 3-1-5 and Fig. 3-1-6 presents the mass /enthalpy history and the power respectively during this long term testing period and Fig. 3-1-7 present the injection history on well AMF-3.

3.1.4 Forecasting and field potential

The Terms of Reference for the Fiscal Year 2001 required for the analysis of three scenarios (refer to Fig. 3-1-8). The exploitation of the reservoir was assumed to be done in all three cases from the inside of the Calderas depression. Two alternative P/P locations were set; one inside the Calderas depression and the second is a site close to INDE's warehouse at El Cedro. The exploitation scenarios are:

1. Production of only 20MW
2. Production of 40 MW in two steps. 20 initial MW and after 3 years the second step of 20 MW.
3. Production of 40 MW with two units of 20 MW.

The total existing power potential in wells AMF-1m AMF-2, AMJ-1 and AMJ-2 is not sufficient to generate the target power output of either scenario. Additional and spare drilling is required. Targets for future drilling (production and reinjection) were selected. The position of the drilling pads and targets are presented in Fig. 3-1-9.

The forecast simulation was carry out by letting the production wells to produce at constant wellhead pressure by allowing the mass flow to vary. By using the thermodynamic characteristics of the elements where production wells were assigned, first, a "kh" value was calculated per existing production well. The procedure is a trial and error procedure and was repeated until measured mass flow (steam and water) could be reproduced for the several wellhead pressures the well testing was done. The calculations were done using a wellbore simulator.

These "kh" values were later used to estimate, at the end of each time step, the mass production of simulated wells using thermodynamic properties of production elements delivered by the reservoir simulator. The make up (MKU) wells were assigned the "kh" value of the nearest existing production well. Therefore, the resulting data set was the steam and water produce by wells during the exploitation time. Power output at wellhead was calculated for condensing - single flash technology and the variation of the power per well and consolidated of all wells was tabulated. When the targeted power output was not reached because of well production decline, a new production element (production well) was activated.

The total simulation time was 25 years. The consolidated produced mass flow and enthalpy permitted the calculation of he amount of separated water to be reinjected. The total separated water was divided by the number of active reinjection wells in order to calculate the reinjection mass per reinjection well. To check for the need of additional reinjection wells, the water level at each reinjection well was estimated. When the water level raised up the wellhead of close to it, a new reinjection element (reinjection well) was activated.

3.1.5 Results of forecasting

Because the conditions at which the reservoir has to respond will differ for the three scenarios, three independent runs were carried out, following the results are described

1. **Scenario 1: 20 MW**

   Fig. 3-1-10 shows the estimated power output for the existing wells and one additional production well. Fig. 3-1-11 shows the estimated power output for each of the wells contributing to the power out put.

   The reservoir is able to sustain the 20 MW power plant without much difficulty with the planned number of production and reinjection, however it is recommended to drill one production and one reinjection spare wells as indicated in Fig. 3-1-8 for scenario-1.

2. **Scenario 2: 20 MW + 20MW**

   Fig. 3-1-12 shows the estimated power output for the existing wells and one additional production well. Fig. 3-1-13 and Fig. 3-1-14 shows the estimated power output for each of the wells contributing to the power out put.

   The reservoir is able to sustain the 20 MW initial and 20 MW additional power plants without much difficulty with the planned number of production and reinjection, however it is recommended to drill one production and one reinjection spare wells as indicated in Fig. 3-1-8 for scenario-2.

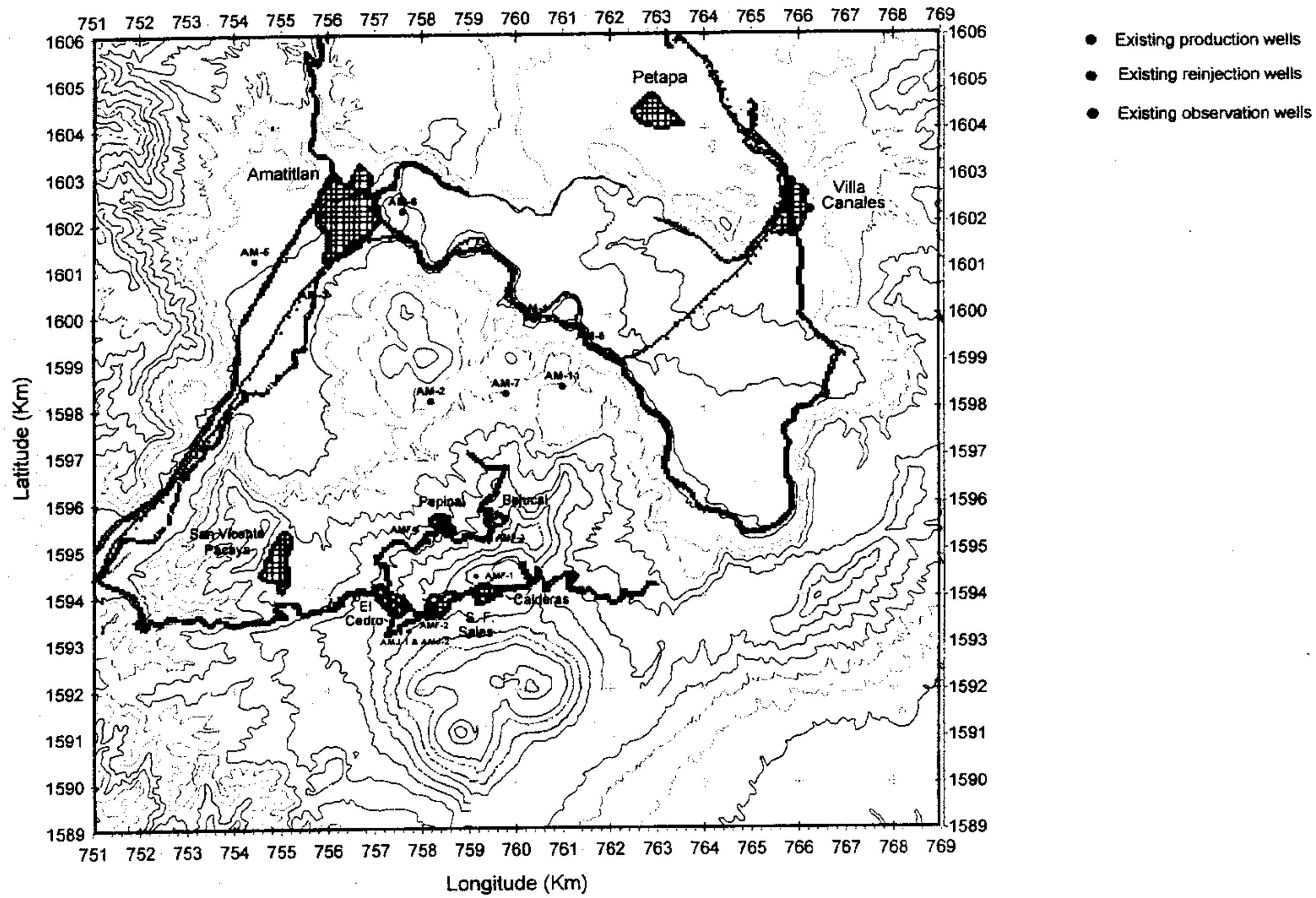
3. **Scenario 3: 40 MW**

   Fig. 3-1-15 shows the estimated power output for the existing wells and one additional production well. Fig. 3-1-16 and Fig. 3-1-17 shows the estimated power output for each of the wells contributing to the power out put.

   The reservoir is able to sustain the two 20 MW power plants without much difficulty with the planned number of production and reinjection, however it is recommended to drill one production and one reinjection spare wells as indicated in Fig. 3-1-8 for scenario-3.

Amatitlan Geothermal Field Reservoir Simulation

Fig.3-1-1 Control volume and grid used to represent the Amatitlan reservoir
アマティトラン地熱貯留層数値モデルのブロック分割

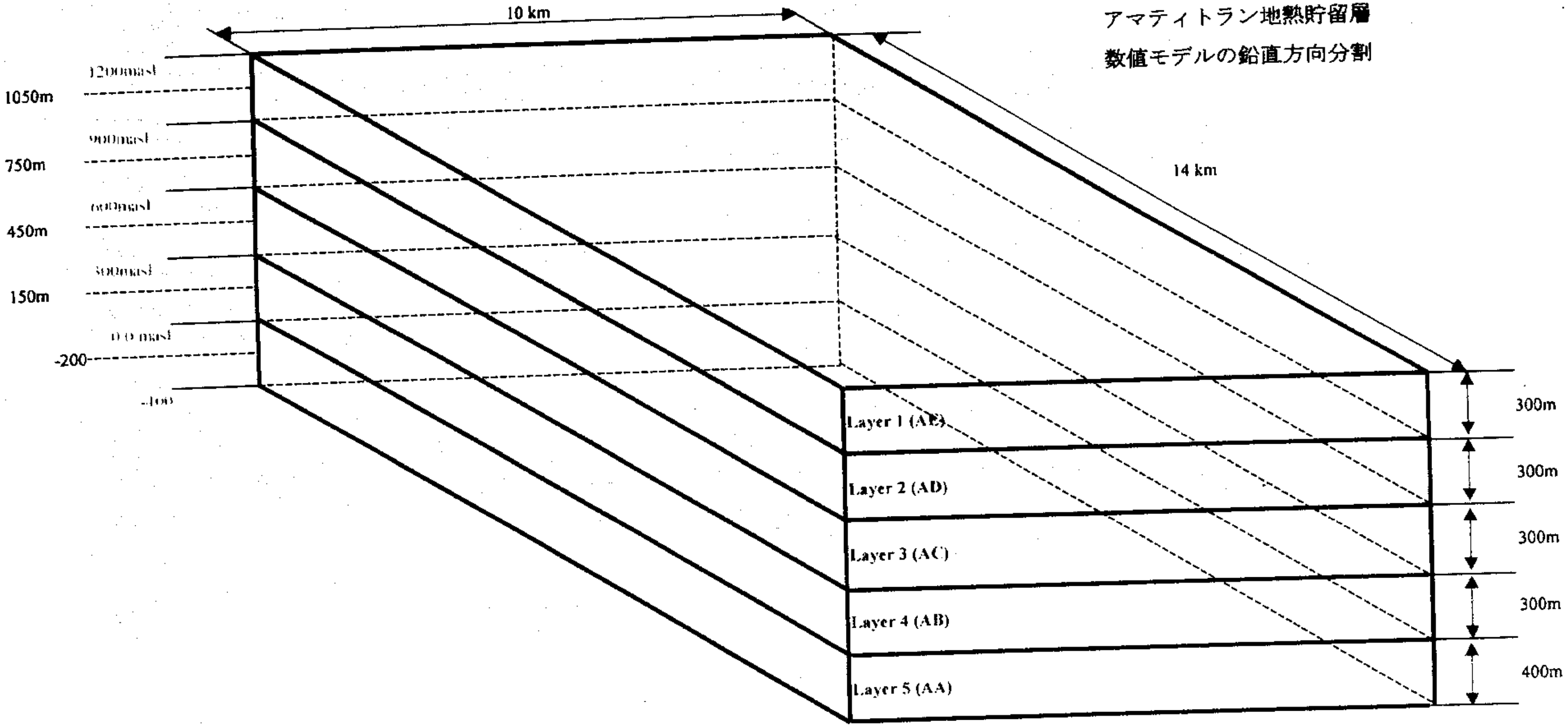


INDE/West Jec

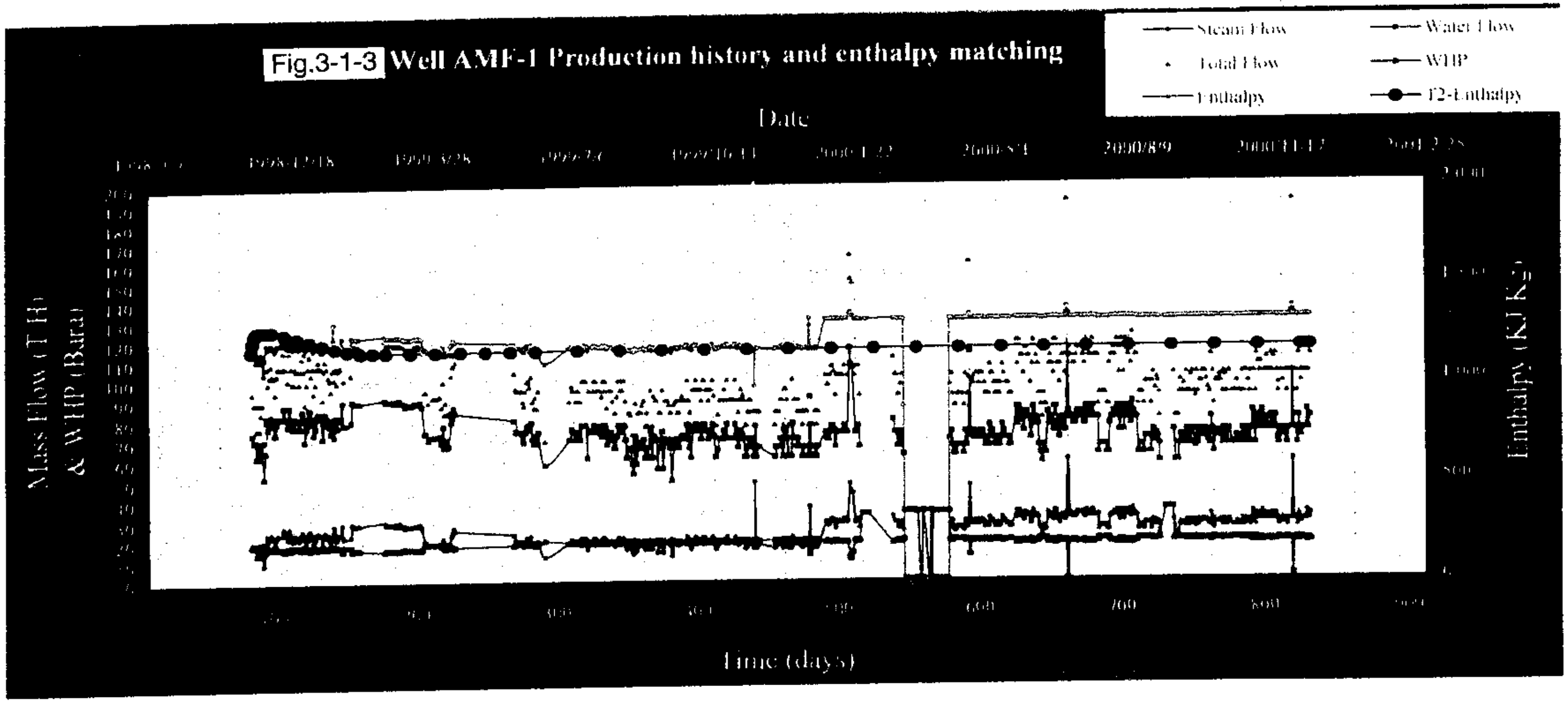
ei-2Lsurf

Fig.3-1-2 Layers of the control volume

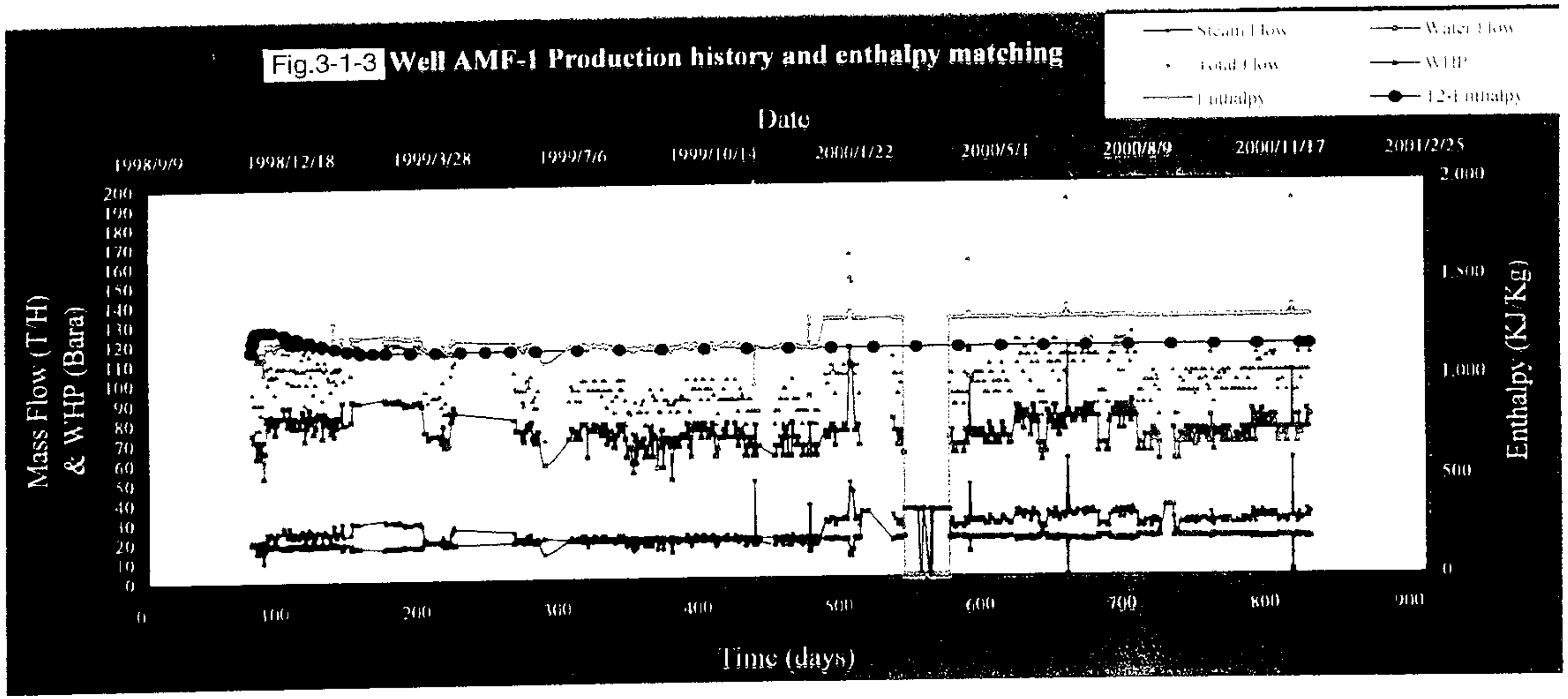
アマティトラン地熱貯留層
数値モデルの鉛直方向分割



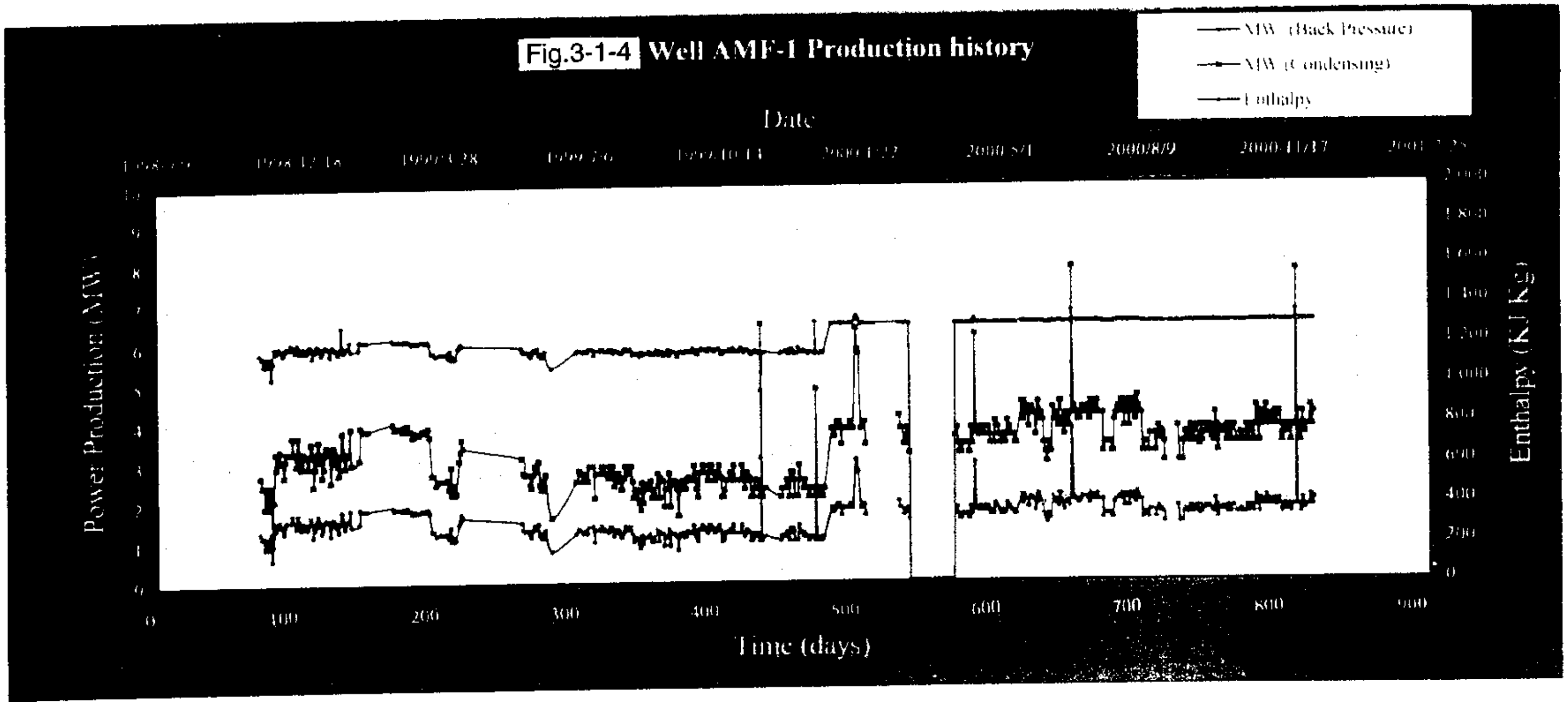
生産井 AMF-1 の噴出量変化とエンタルピーマッチング



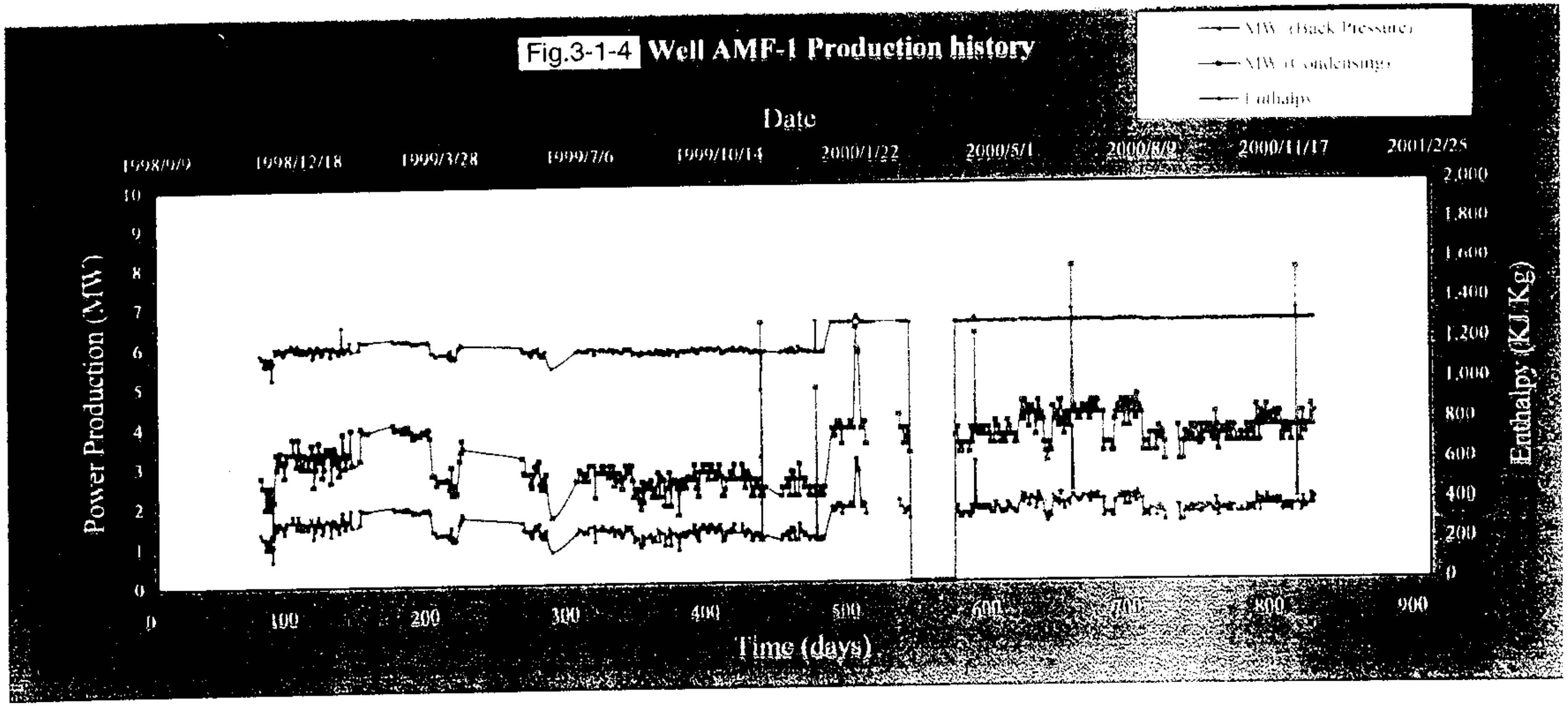
生産井 AMF-1 の噴出量変化とエンタルピーマッチング



生産井 AMF-1 の出力変化

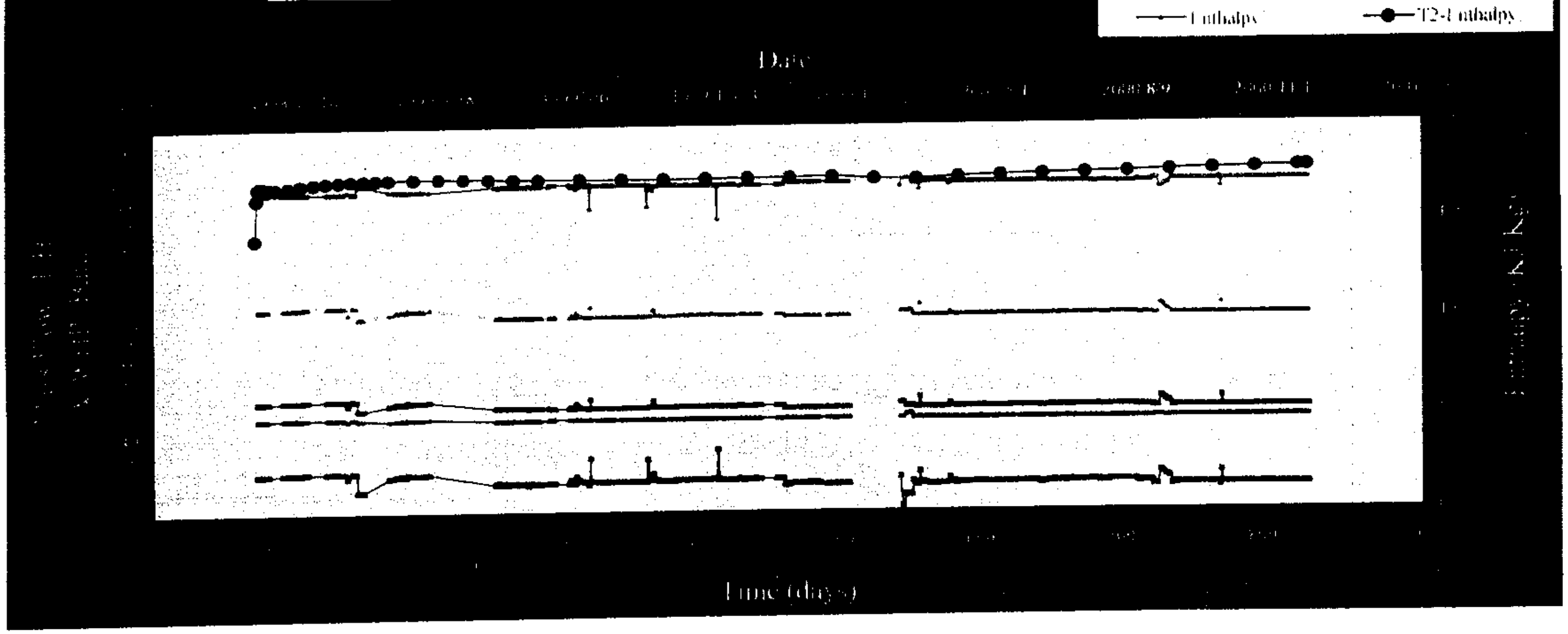


生産井 AMF-1 の出力変化



生産井 AMF-2 の噴出量変化とエンタルピーマッチング

Fig.3-1-5 Well AMF-2 Production history and enthalpy matching



生産井 AMF-2 の噴出量変化とエンタルピーマッチング

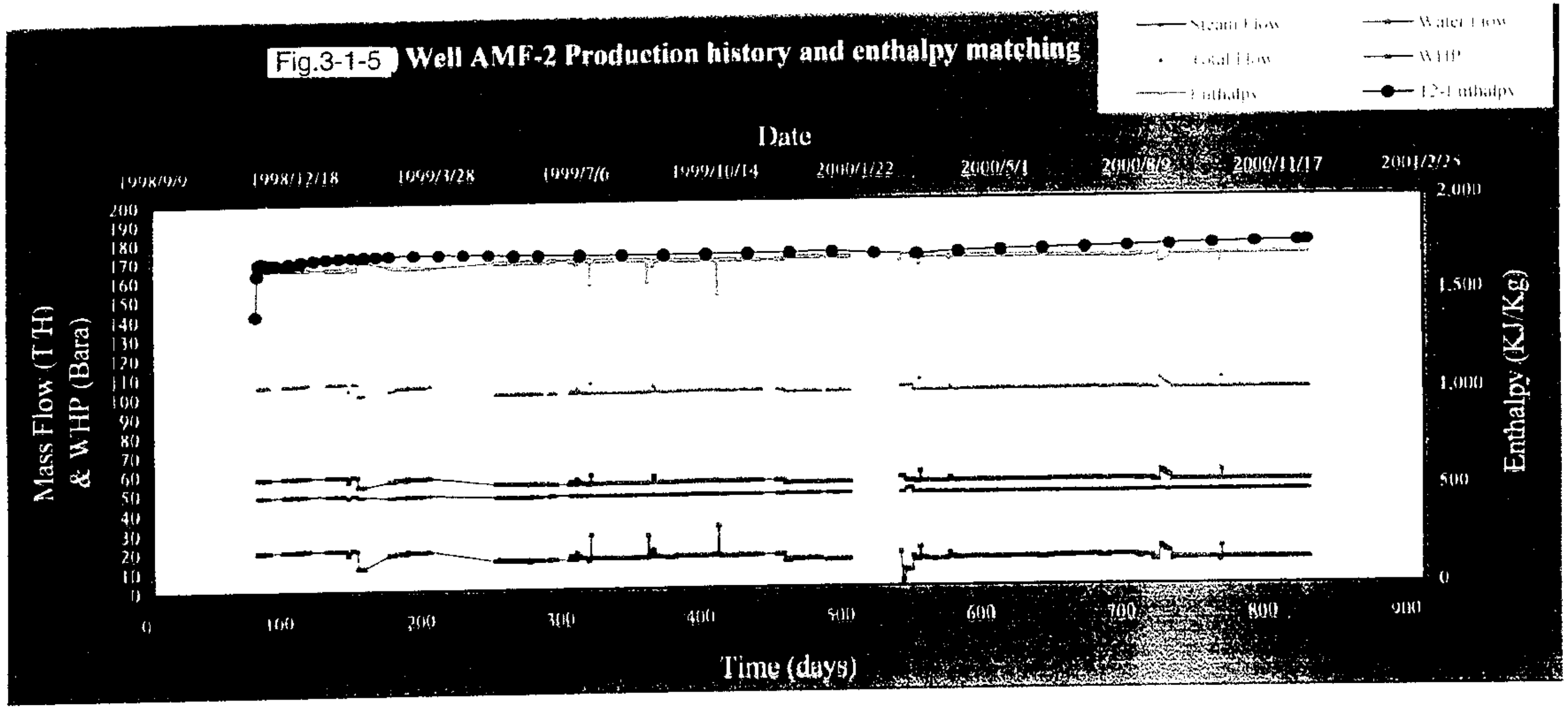
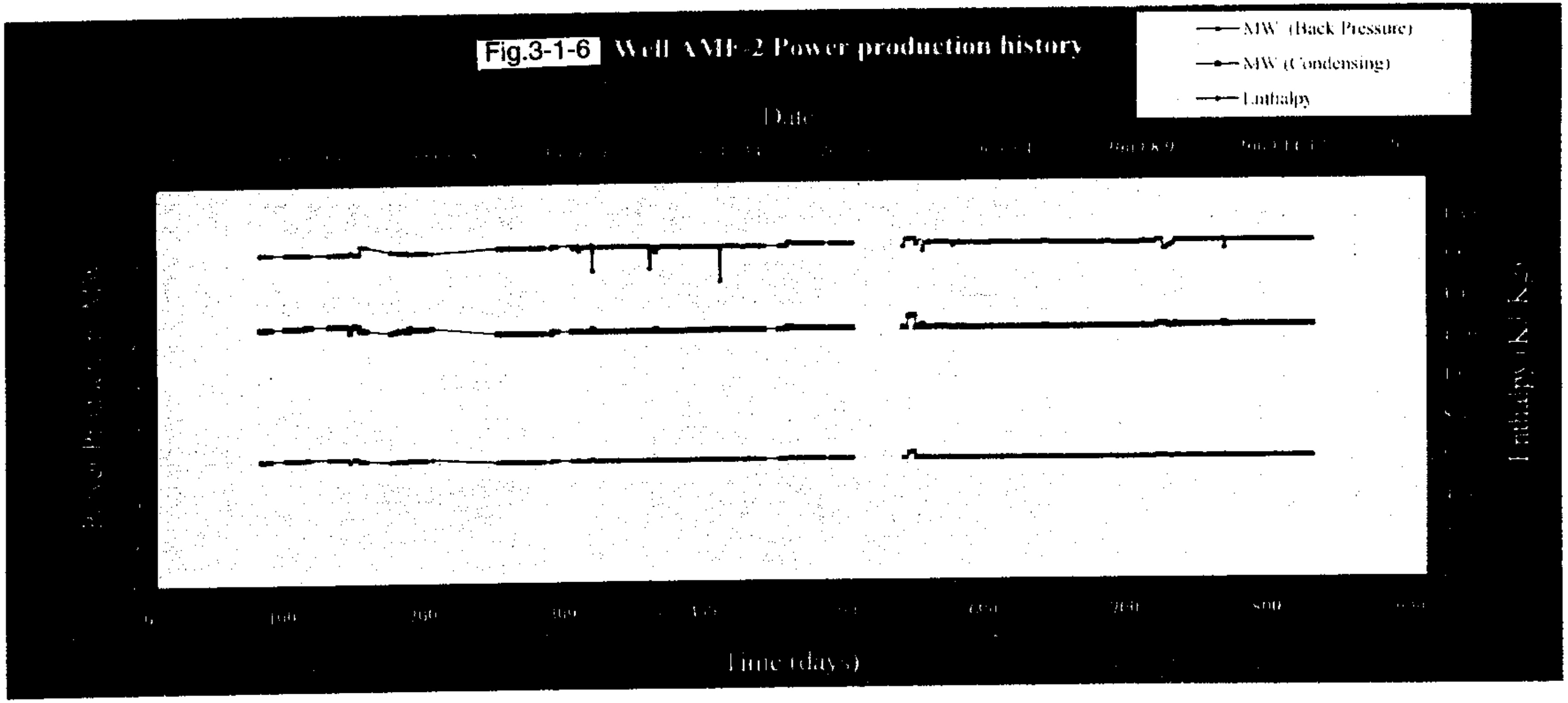
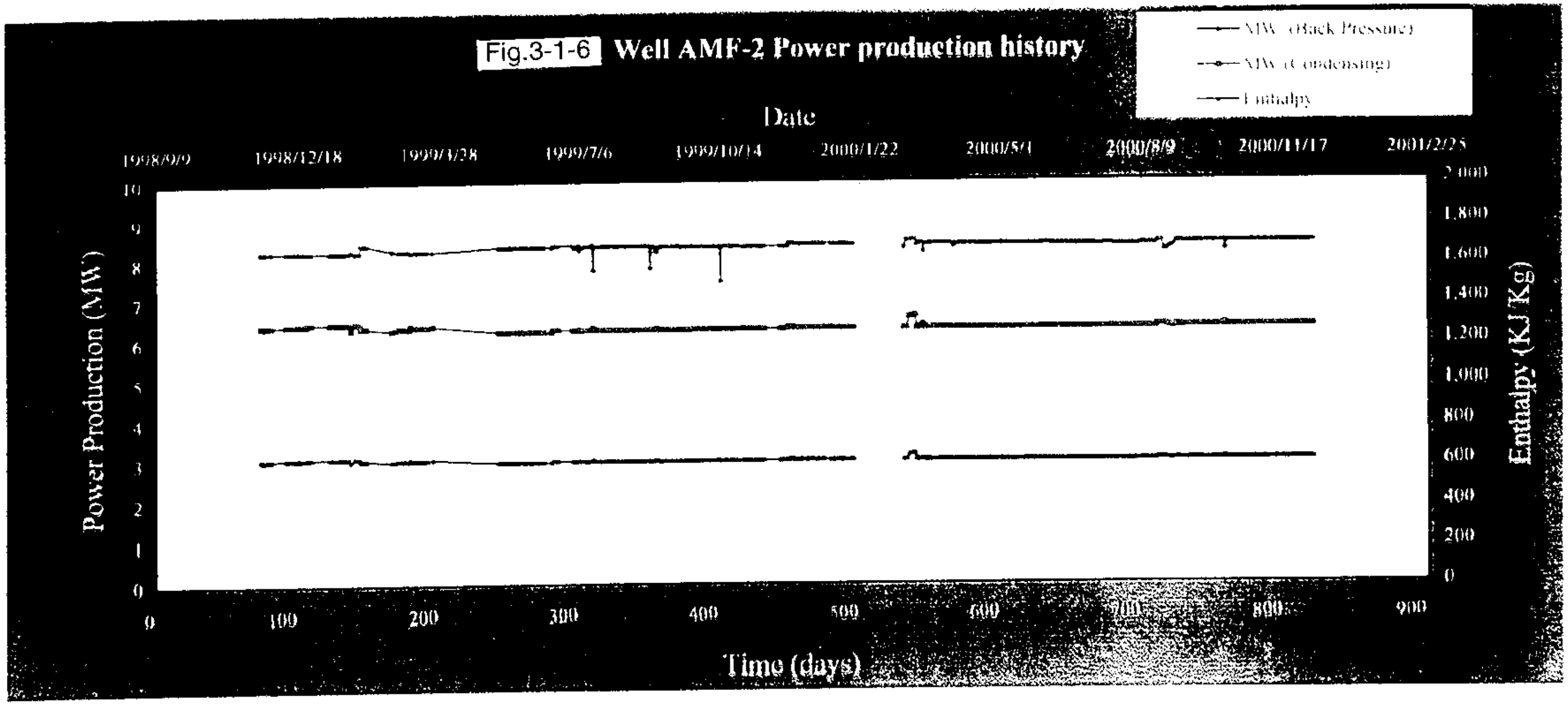


Fig.3-1-5 Well AMF-2 Production history and enthalpy matching

生産井 AMF-2 の出力変化



生産井 AMF-2 の出力変化



遷元井 AMF-3 の還元量変化

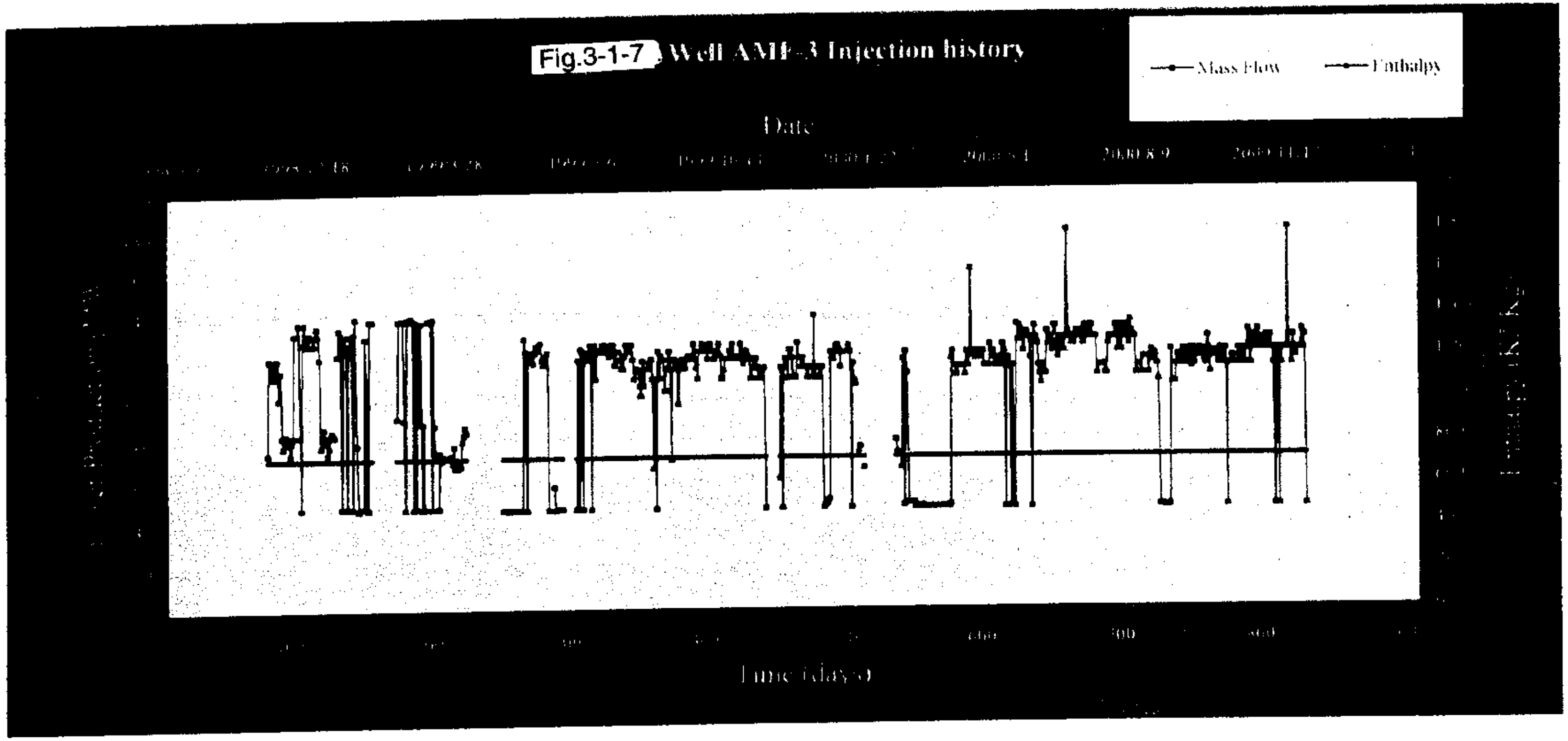
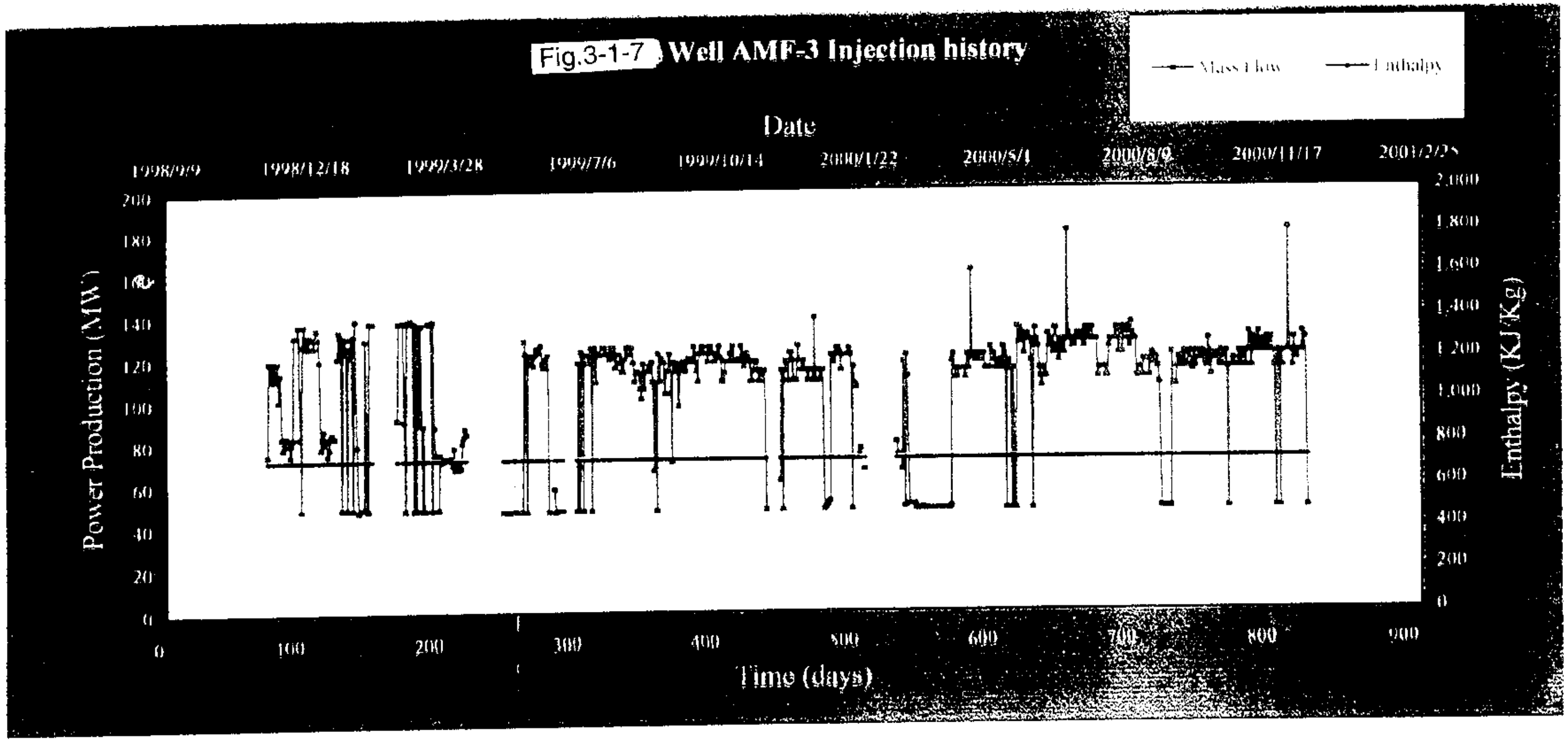


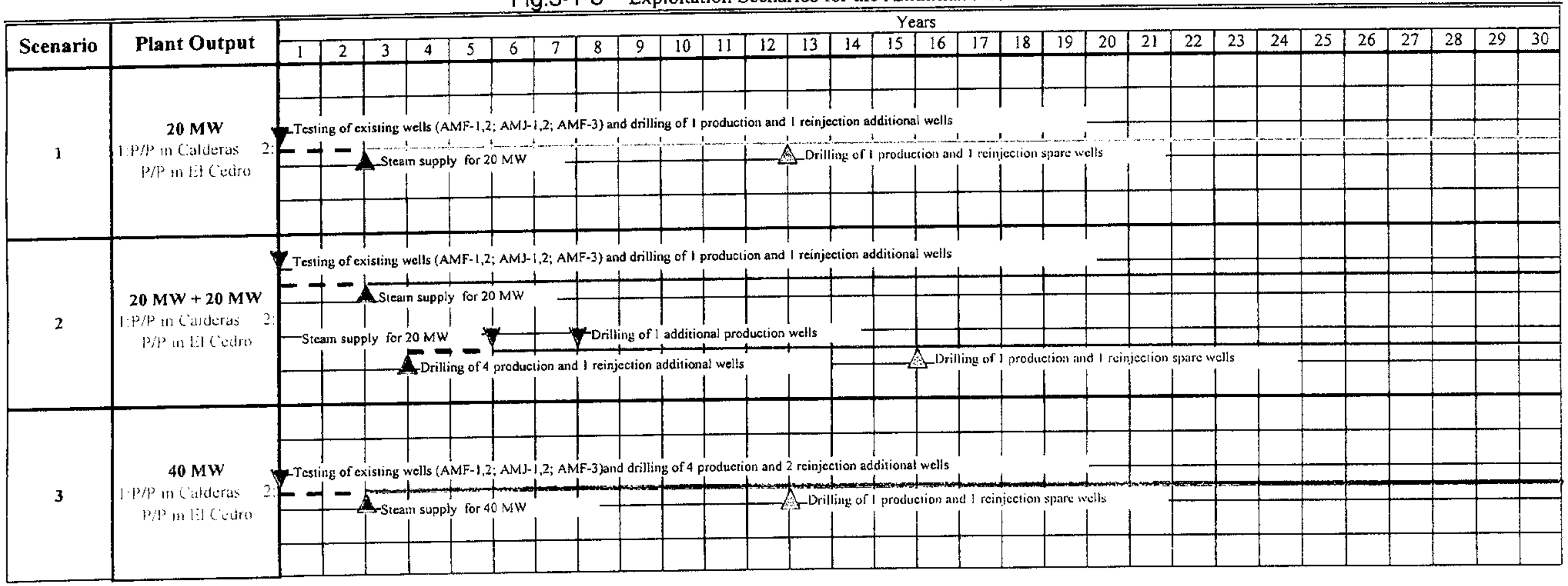
Fig.3-1-7 Well AMF-3 Injection history

還元井 AMF-3 の還元量変化



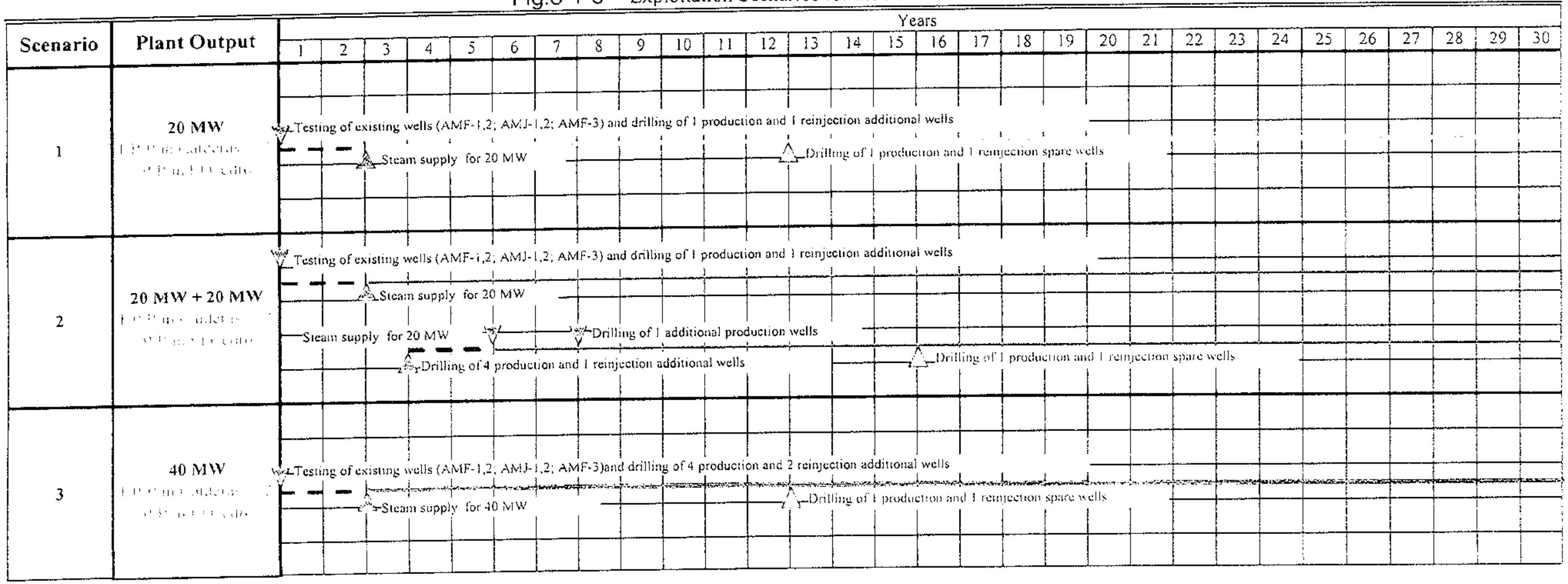
貯留層の開発シナリオ

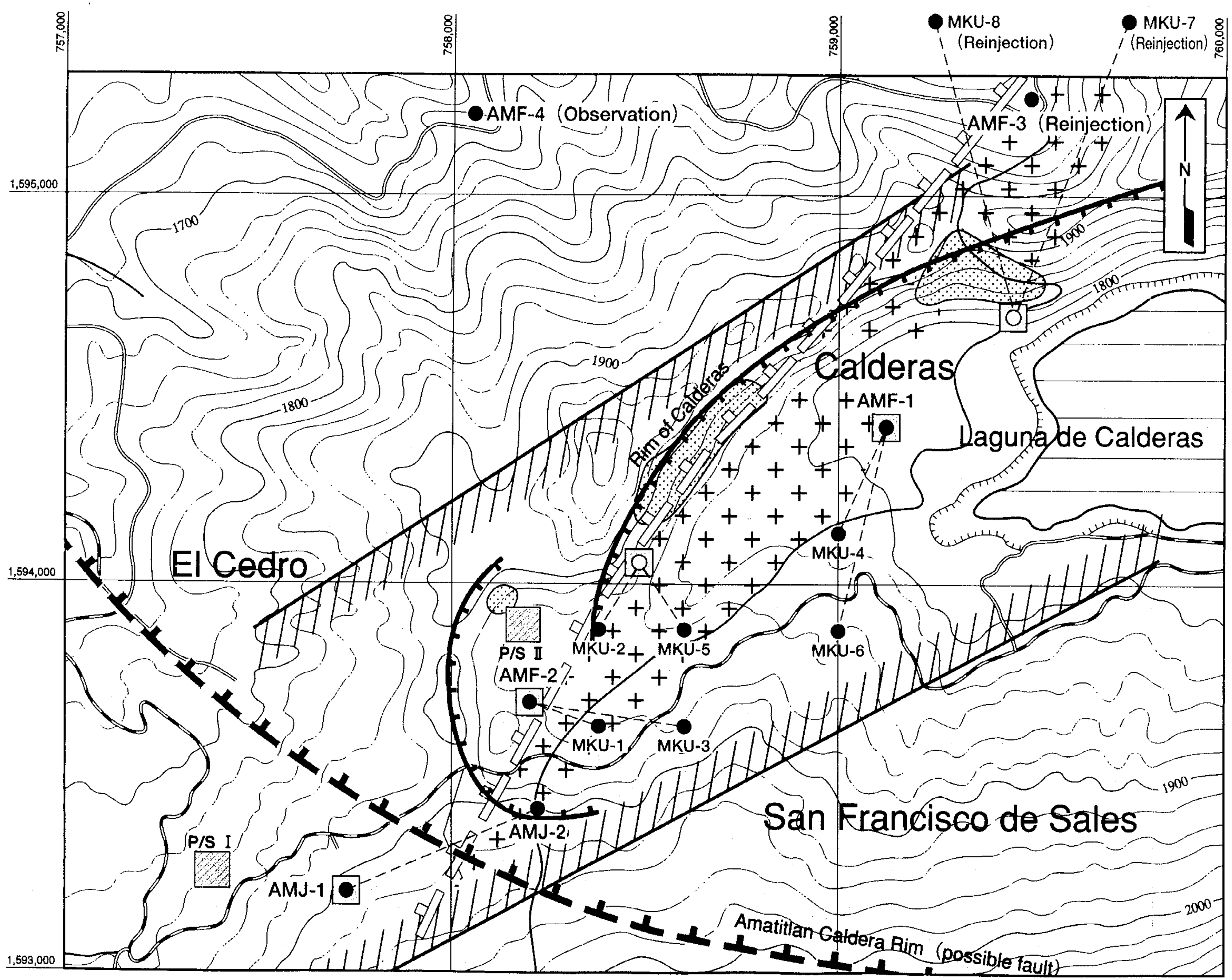
Fig.3-1-8 Exploitation Scenarios for the Amatitlan Reservoir

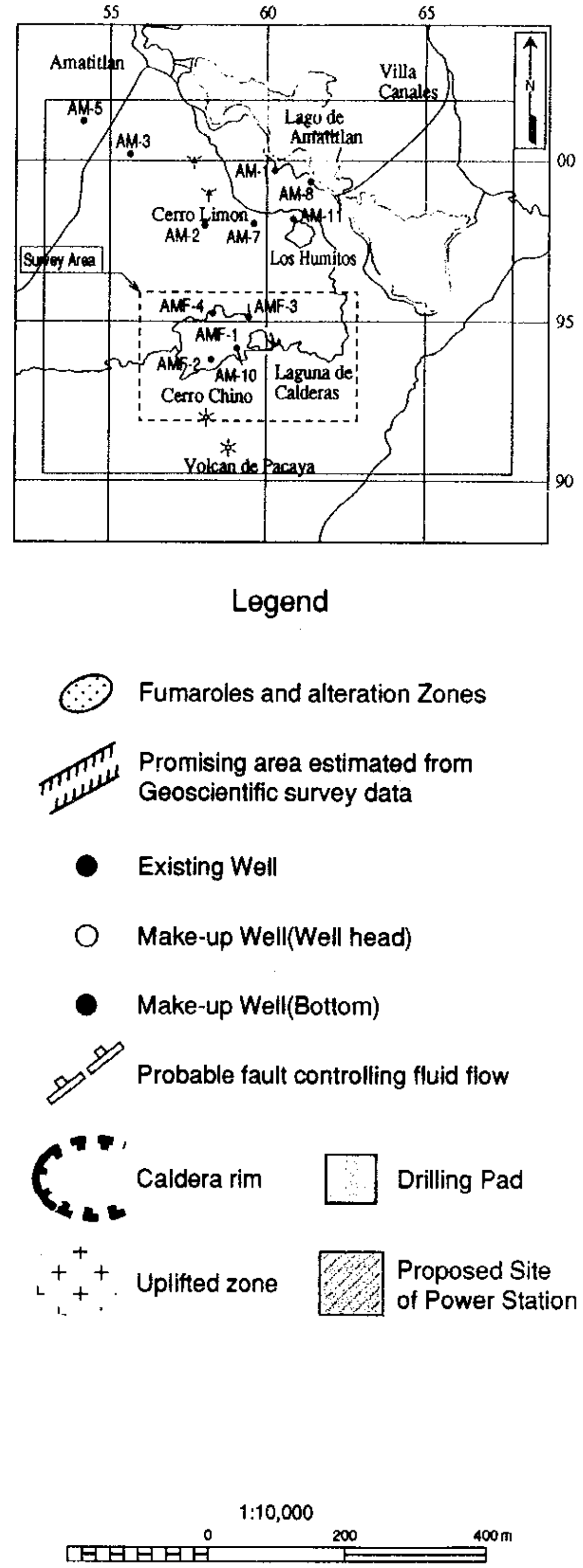


貯留層の開発シナリオ

Fig.3-1-8　Exploitation Scenarios for the Amatitlan Reservoir

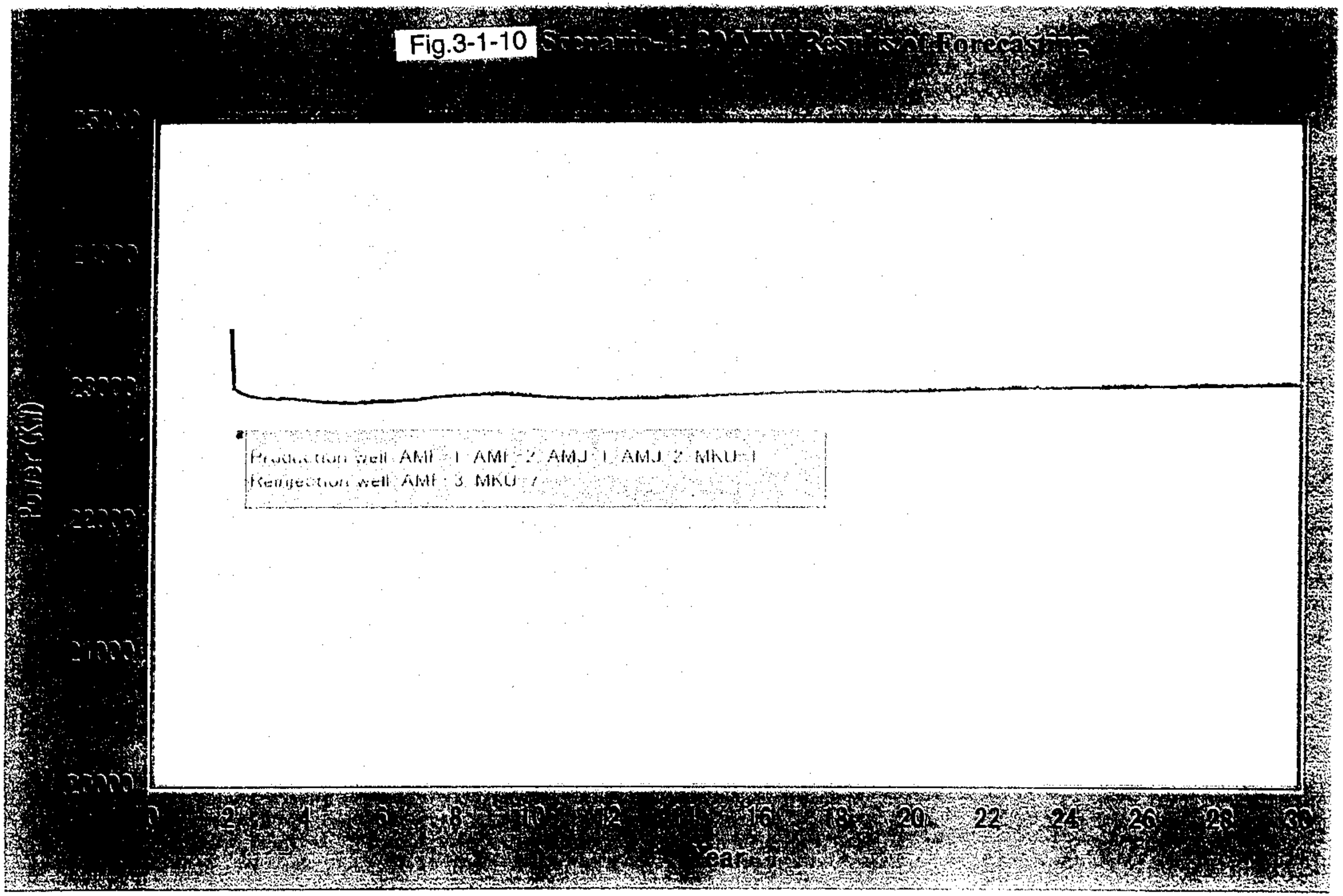


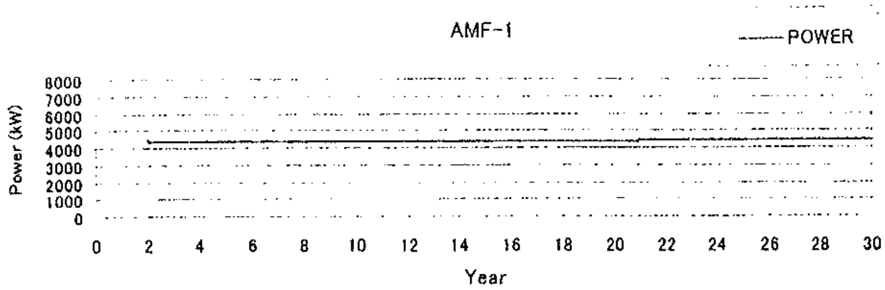


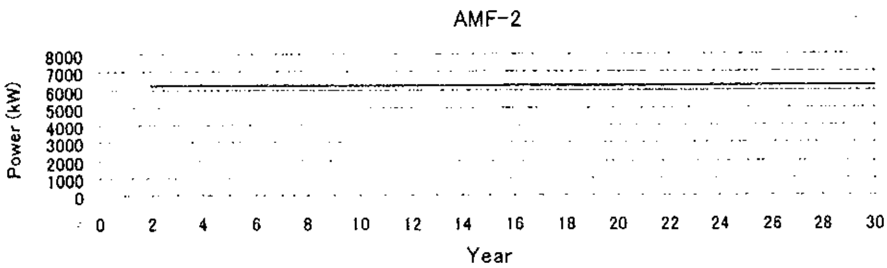


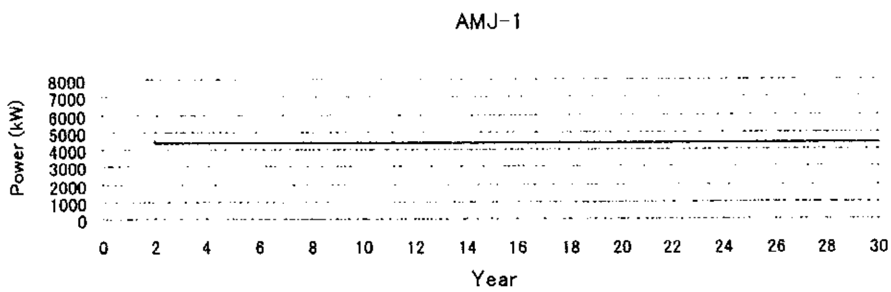
Amatitlan Geothermal Development Project
既存坑井および補充井の掘削ターゲット
Drilling Pads and Targets of Existing and Additional Wells
JICA-WEST JEC — Fig. 3-1- 9

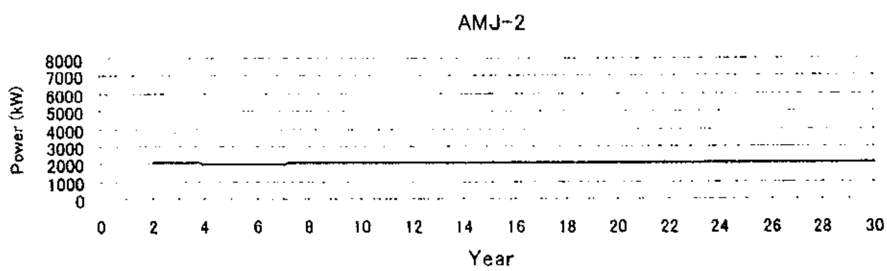
シナリオ 1: 20 MW 発電の場合の出力予測

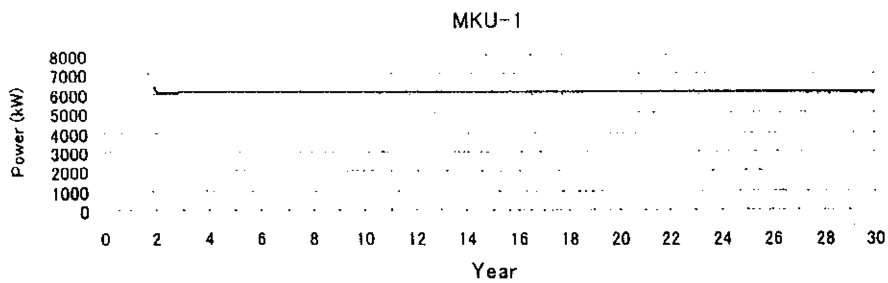










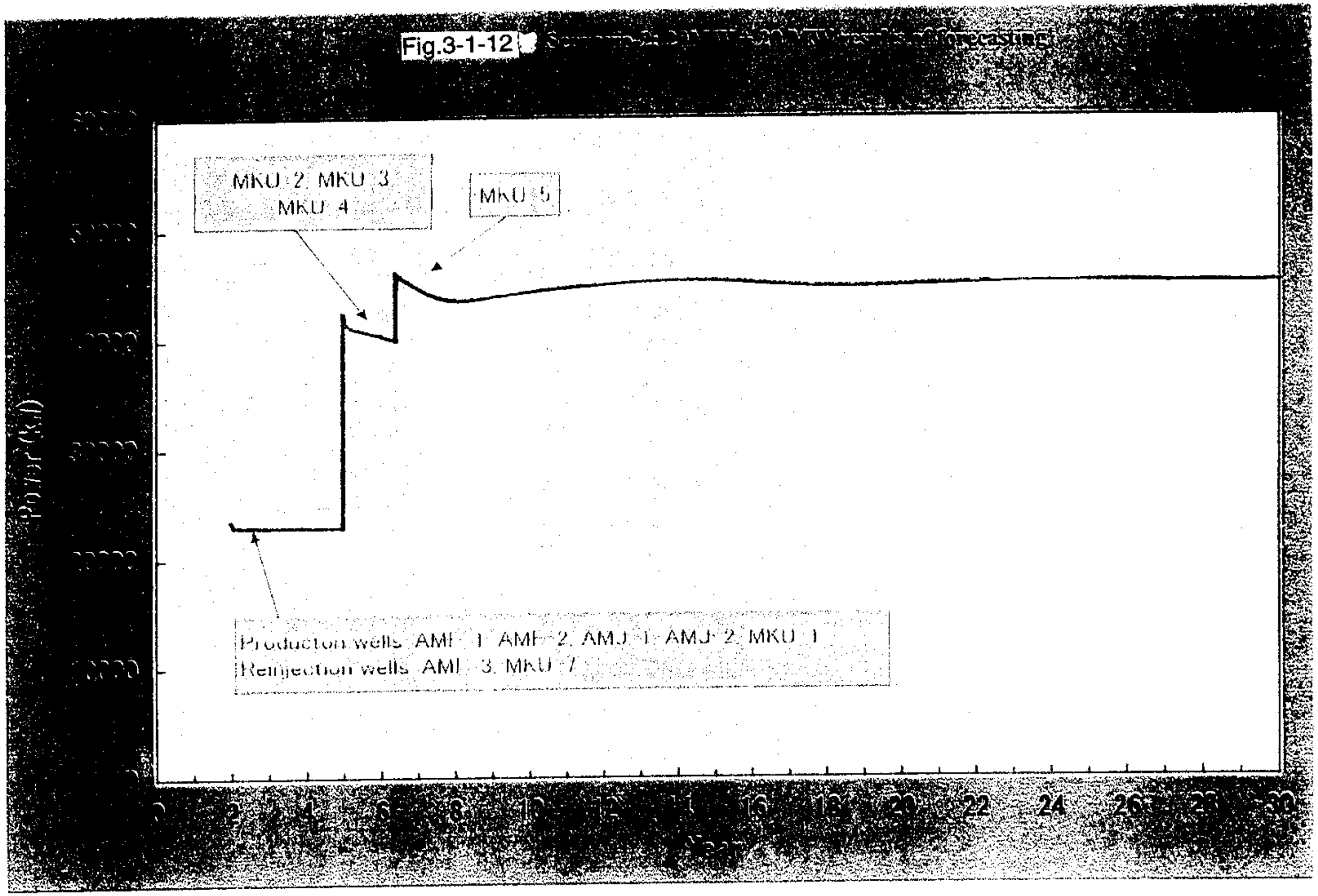


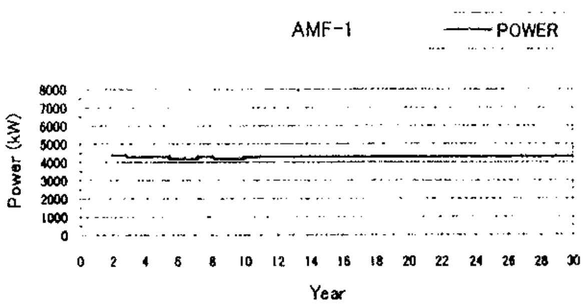
* Power : Output from primary steam (Single flashed)

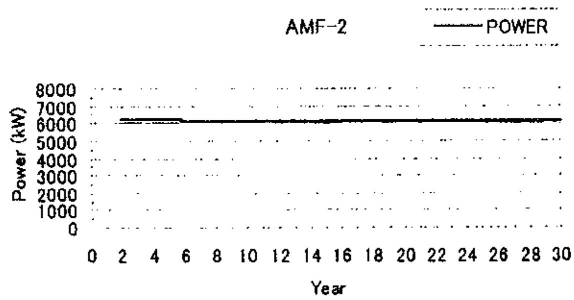
Fig.3-1-11 Scenario-1: Forecasted well production

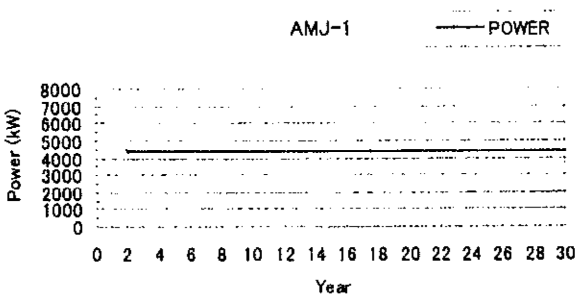
シナリオ1: 各生産井の出力予測

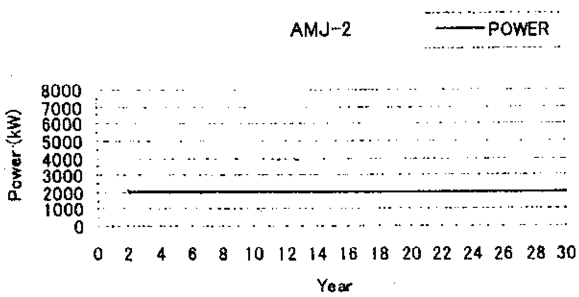
シナリオ 2: 20MW + 20 MW 発電の場合の出力予測

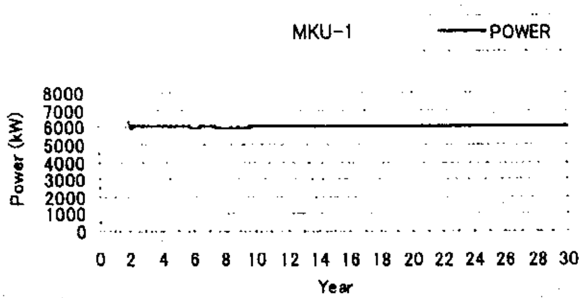








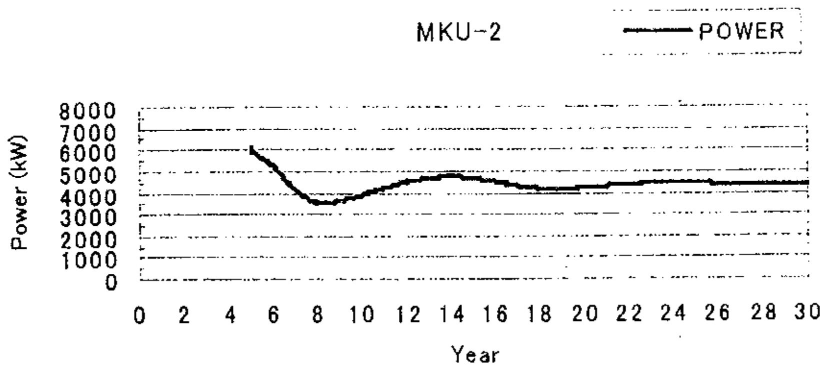


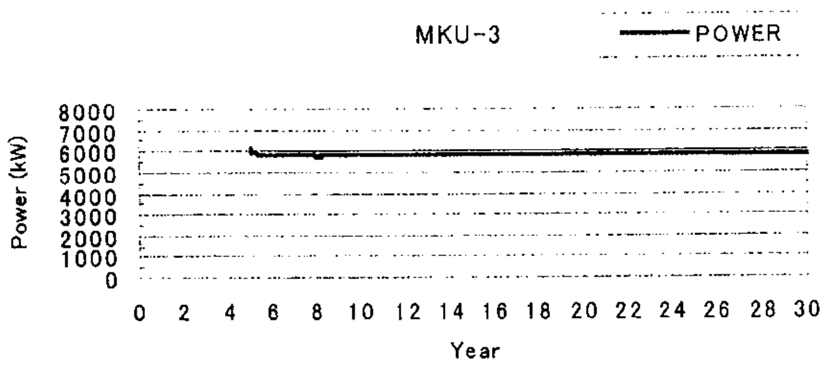


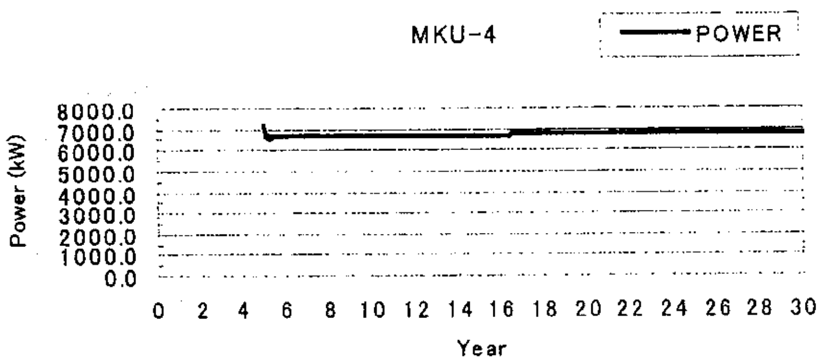
* Power : Output from primary steam (Single flashed)

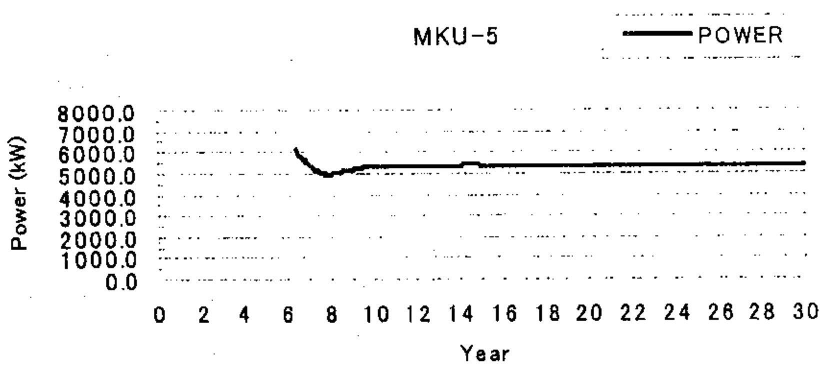
Fig.3-1-13 Scenario-2: Forecasted well production-a

シナリオ 2: 各生産井の出力予測(a)









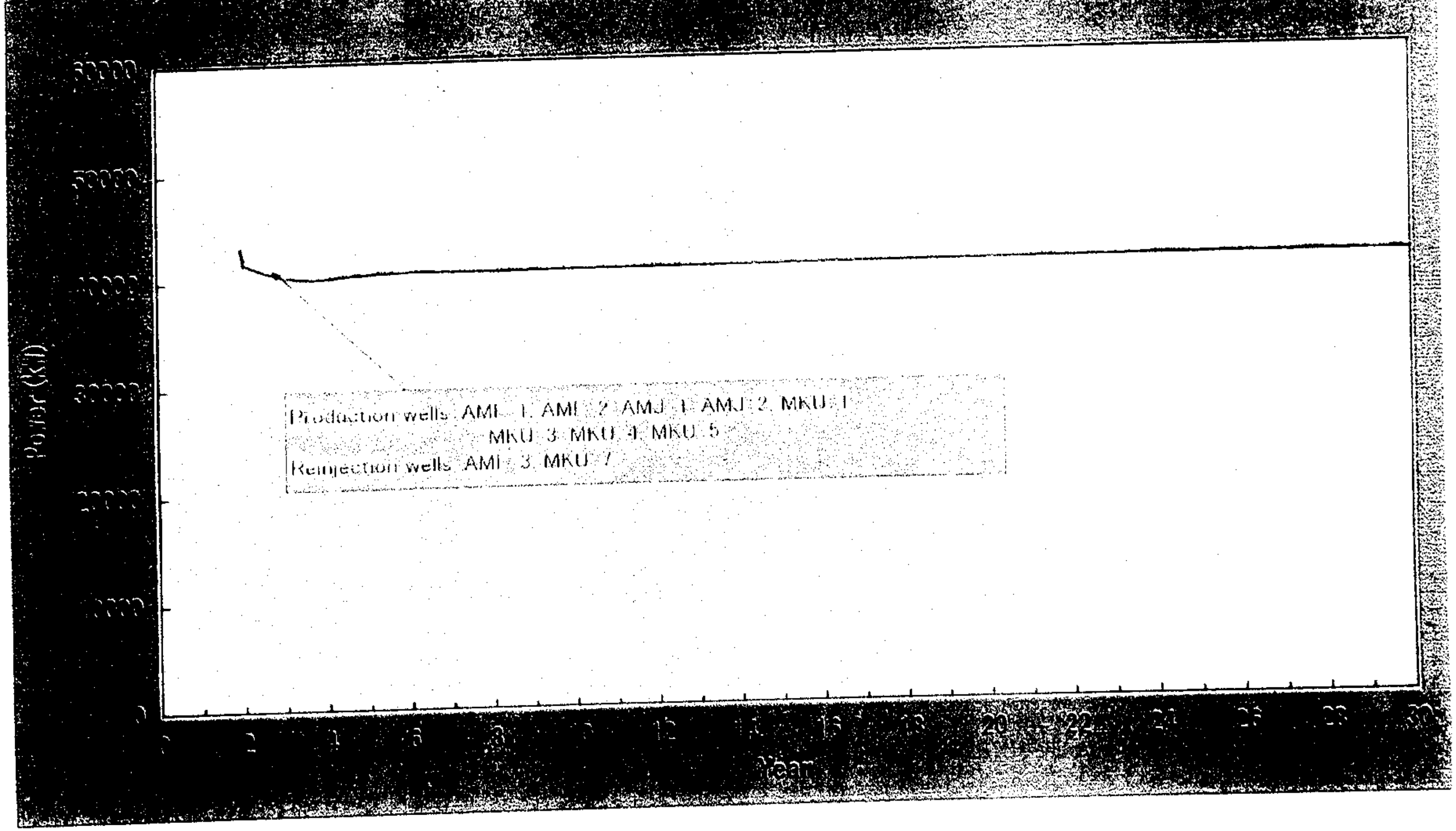
* Power : Output from primary steam (Single flashed)

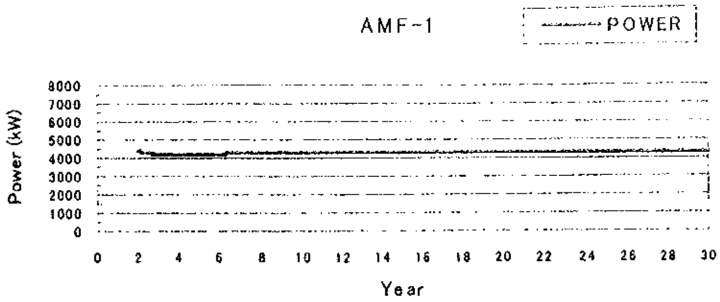
Fig.3-1-14 Scenario-2: Forecasted well production-b

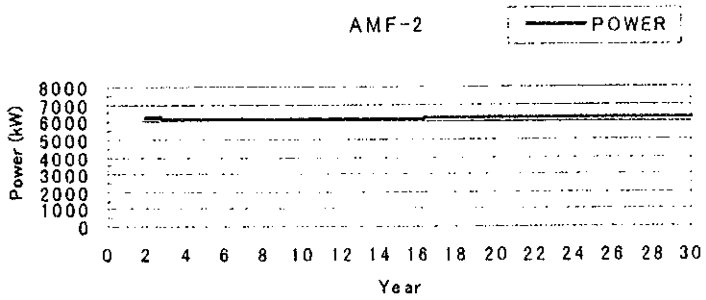
シナリオ 2: 各生産井の出力予測(b)

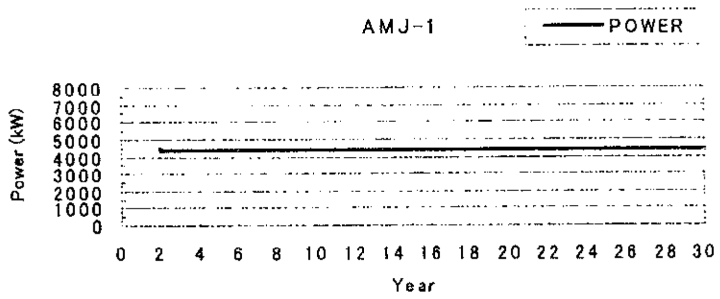
シナリオ 3: 40 MW 発電の場合の出力予測

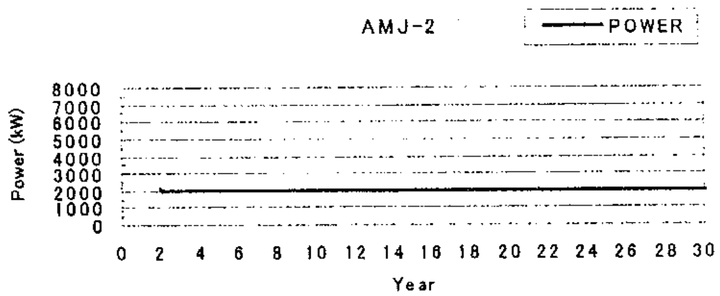
Fig.3-1-15 Scenario 3: 40 MW results of forecasting

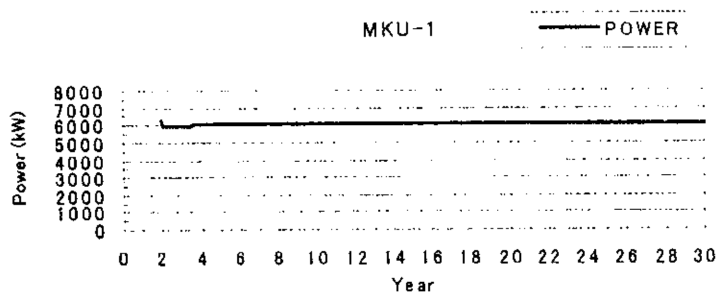








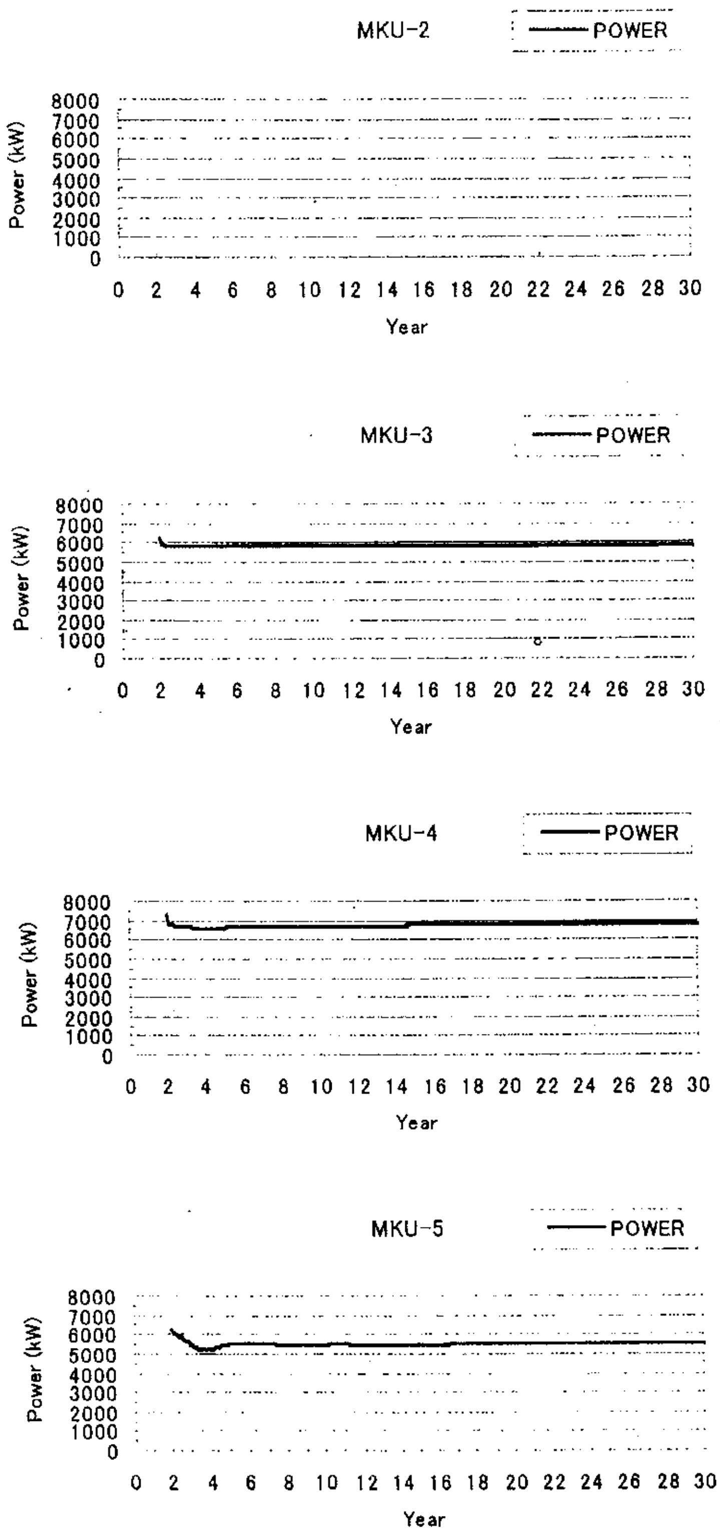




* Power : Output from primary steam (Single flashed)

Fig.3-1-16 Scenario-3: Forecasted well production-a

シナリオ3: 各生産井の出力予測(a)



* Power : Output from primary steam (Single flashed)

Fig.3-1-17 Scenario-3: Forecasted well production-b

シナリオ 3: 各生産井の出力予測(b)

数値モデルの岩石物性値

Table 3-1-1 Physical properties of materials in the numerical model

ROCK	DENSITY ROCK	POROSITY	PERMEABILITY X	PERMEABILITY Y	PERMEABILITY Z	HEAT CONDUCTIVITY	SPECIFIC HEAT
	Kg/m3		m2	m2	m2	W/m-Deg. C	J/Kg-Deg. C
AIR01	2200	0.9000	0.000E+00	0.000E+00	0.000E+00	0.03	50000
TOP01	2200	0.9000	0.000E+00	0.000E+00	0.000E+00	2.20	50000
ROK01	2200	0.1000	1.000E-16	1.000E-16	1.000E-16	2.20	1000
ROK02	2200	0.1000	2.000E-15	2.000E-15	2.000E-16	2.20	1000
ROK09	2200	0.1000	3.000E-15	3.000E-15	5.000E-16	2.20	1000
ROK03	2200	0.1000	8.000E-15	8.000E-15	1.000E-14	2.20	1000
ROK04	2200	0.1000	2.000E-14	2.000E-14	3.000E-14	2.20	1000
ROK05	2200	0.1000	6.000E-14	6.000E-14	7.000E-14	2.20	1000
ROK06	2200	0.1000	7.000E-14	7.000E-14	2.000E-16	2.20	1000
ROK07	2200	0.1000	9.000E-14	9.000E-14	2.000E-16	2.20	1000
ROK08	2200	0.1000	4.000E-15	4.000E-15	2.000E-14	2.20	1000
AQU01	2200	0.1000	6.000E-14	6.000E-14	7.000E-14	2.20	50000
BAS01	2200	0.1000	0.000E+00	0.000E+00	0.000E+00	2.22	50000
LIM01	2200	0.1000	2.000E-12	2.000E-12	3.000E-12	2.20	1000
LIM02	2200	0.1000	6.000E-14	6.000E-13	2.000E-13	2.20	1000
AQU02	2200	0.1000	6.000E-12	6.000E-12	7.000E-12	2.20	50000

3.2 Development Plan of Power Plant

3.2.1 Condition for Planning

3.2.2 Fluid Collection and Reinjection System

3.2.3 Power Plant Facilities

3.2.4 Transmission Line and Substation

3.2.5 Project Implementation

3.2.6 Project Cost Estimate

3.2 CONSTRUCTION OF POWER GENERATING FACILITY

3.2.1 CONDITIONS FOR PLANNING

1. **Power Plant Site**

   Two sites, Site-I (outside caldera) and Site-II (inside caldera), are proposed for power plant construction taking into consideration distances from the production and reinjection wells, easiness of pipeline installation, topographic/geological feature, distance from existing road, and environmental issues. Locations of each site are shown in Fig.3-2-1 and Fig.3-2-2.

2. **Type of Power Plant**

   The results of resource evaluation suggest medium sized power plant, medium specific enthalpy geofluid, and relatively low non-condensable gas (NCG) content. Considering those conditions, the single flashed steam cycle with condensing turbine is recommended for this project, and the brine in the reinjection system will be kept at high pressure and high temperature.

3. **Capacity of Power Plant**

   Two cases are studied: one 20 MW unit, and two 20 MW units totaling 40 MW.

4. **Connection to the System**

   The output of Amatitlan geothermal power plant will be connected to 138kV substation, named Palin 2 substation that is planned to be constructed newly by INDE.

3.2.2 FLUID COLLECTION AND REINJECTION SYSTEM

Fig.3-2-1 and Fig.3-2-2 show the routes of pipelines for Site-I and Site-II respectively. The pipelines cross the ridge wall on the west of the caldera in order to avoid the residential area south of AMF-2. The steam/brine-separated pipelines are employed. They has advantages over the two-phase pipeline in pressure loss and flow stability when they cross the ridge. Fig.3-2-3 and Fig.3-2-4 illustrate the system for Site-I (outside caldera) and Site-II (inside caldera). Dashed lines indicate additional portion for Unit-2.

3.2.3 POWER PLANT FACILITIES

1. **Layout**

   Fig 3-2-5 shows the layout of the power plant. The cooling towers are in the downwind. The switchyard is in the upwind The turbine building(s) is in the center of the plant site. The turbine-generator with its ancillary equipment is installed in the turbine building. The main condenser, gas removal system, mist eliminator, etc. are located outdoor.

2. **Civil and Architectural Works**

Access roads for the power plant site, the reinjection well site, the site of MKU-2 & 5 are to be newly constructed. Sites for the power plant and the reinjection well pad will be prepared. An additional production well site will be prepared when Unit-2 is constructed.

3. Power Plant Equipment

The same design will be applied to both of Units-1 and 2 so that designing cost will be suppressed, and spare parts can be shared between the units. Fig.3-2-6 shows the schematic process of the plant. Specifications of major equipment are as follows:

Equipment	Specification	
Turbine	Type	Single flow, condensing, modular type
	Rated output	20 MW
	Steam conditions	7 bar, 165 C
	NCG content	1.78 wt%
	Speed	3,600 rpm
Condenser	Type	Direct contact spray jet type
	Pressure	0.095 bar
Gas Removal System	Type	Steam jet ejector + Liquid ring vacuum pump
	NCG exhaust	Diffused by the cooling tower exhaust and discharged into atmosphere.
Cooling tower	Type	Induced draft type
	Material	Wooden or FRP
Generator	Type	Cylindrical revolving-field rotor type, totally enclosed, air- cooled, three-phase synchronous generator
	Rated output	20 MW
	Rated voltage	13.8 kV
	Power factor	0.8 (lagging)
	Excitation system	Brushless
Transformer	Main transformer	25MVA, 13.8kV/138kV
	Unit transformer	2,000kVA, 13.8kV/480V
Switchgear	13.8kV Metal-Clad Switchgear, 480V Power Center, 480V Motor Control Center, Distribution panels, and others	
Control, Instrumentation and Protection equipment	Automatic Turbine Controller, Automatic Voltage Regulator, Local Instrument panels, DCS equipment, Generator/Transformer Protection panels, and others	
Ancillary Equipment	Battery and Charger, Emergency Generator, and others	

3.2.4 TRANSMISSION LINE AND SUBSTATION

The switchyard consists of main transformers, 138kV switchgear, and dead-end structures for transmission lines. The switchyard is located at north side of the plant in order to avoid the corrosive gas from the cooling tower.

One circuit of 138kV transmission line will be installed newly up to Palin 2 substation of INDE, approximately 8km west from the power plant. See Fig.3-2-8 and 3-2-9.

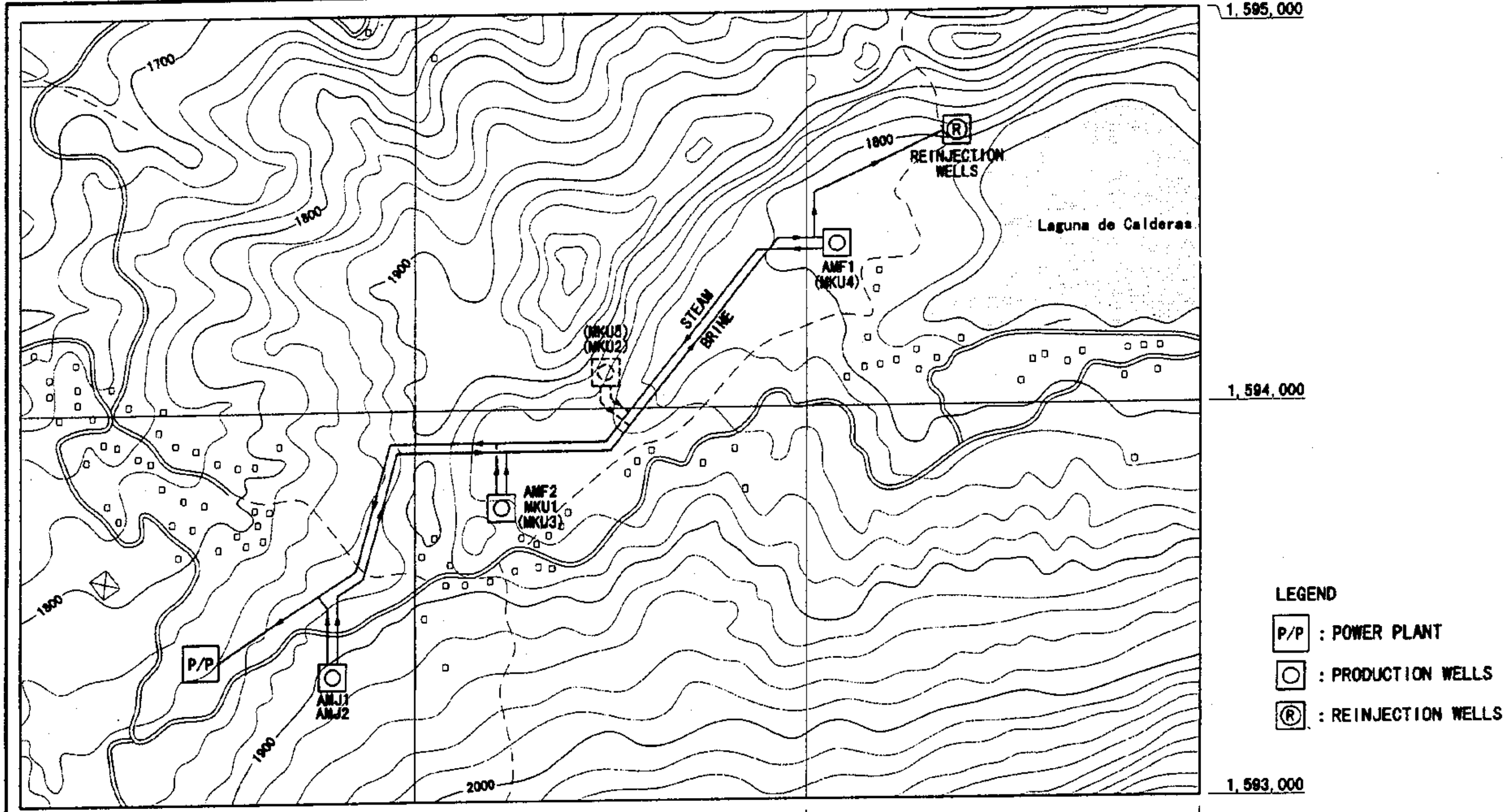
3.2.5 CONSTRUCTION WORK

Construction schedules of Scenarios 1 to 3 are shown in Fig.3-2-10 to Fig.3-2-12. Material and equipment of generating facilities will be transported by trucks from the port of unloading to the site. The nearest port appropriate for unloading equipment/material for this project is Puerto Quetzal on the Pacific Ocean. From the Atlantic side, Puerto Barrios will be the port of entry and unloading. The road conditions from the ports to the site are good so that transportation of equipment and material for the generating facilities is feasible.

3.2.6 PROJECT COST ESTIMATE

Tables 3-2-2 and 3-2-3 show estimated project costs for Power Plant Site-I (outside of caldera) and Site-II (inside caldera) respectively. The costs cover engineering/designing, material, transportation, civil/building works, and installation works. The following are included in the project:

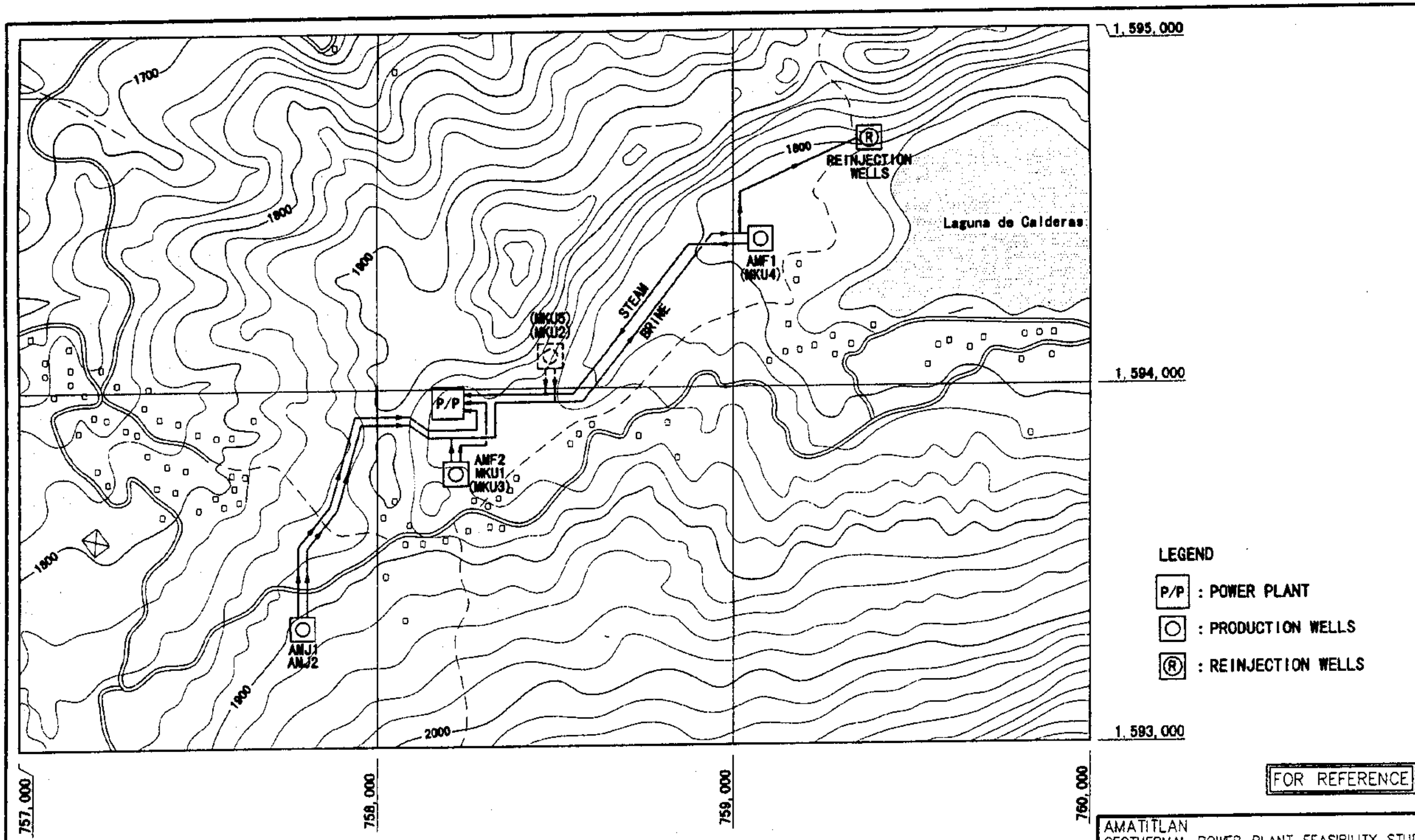
1) Construction of access roads from the existing road to the sites
2) Land leveling
3) Construction of water intake and supply facilities
4) Drilling of production/reinjection wells and installation of wellhead equipment
5) Construction of Fluid Collection and Reinjection System
6) Construction of power plant and appurtenant facilities
7) Construction of switchyard of the power plant
8) Construction of transmission line
9) Communication facilities



FOR REFERENCE

Fig.3-2-1
ROUTE OF STEAM AND BRINE PIPELINES
(OUTSIDE CALDERA)
蒸気・熱水配管ルート
[発電所建設地点Ⅰ(カルデラ外)]

AMATITLAN GEOTHERMAL POWER PLANT FEASIBILITY STUDY					
DWG. TITELE ROUTE OF STEAM AND BRINE PIPELINES (OUTSIDE CALDERA)					
SCALE	DRAWN	CHECKED	APPROVED	DATE OCTOBER,2001 / JOB.No / DWG.No.	REV.No.
NON					0
WEST JAPAN ENGINEERING CONSULTANTS INC.					



FOR REFERENCE

Fig.3-2-2
ROUTE OF STEAM AND BRINE PIPELINES
(INSIDE CALDERA)

蒸気・熱水配管ルート
「発電所建設地点Ⅱ（カルデラ内）」

AMATITLAN GEOTHERMAL POWER PLANT FEASIBILITY STUDY					
DWG.TITELE ROUTE OF STEAM AND BRINE PIPELINES (INSIDE CALDERA)					
SCALE	DRAWN	CHECKED	APPROVED	DATE OCTOBER.2001 JOB.No	
NON				DWG.No.	REV.No. ©
WEST JAPAN ENGINEERING CONSULTANTS INC.					

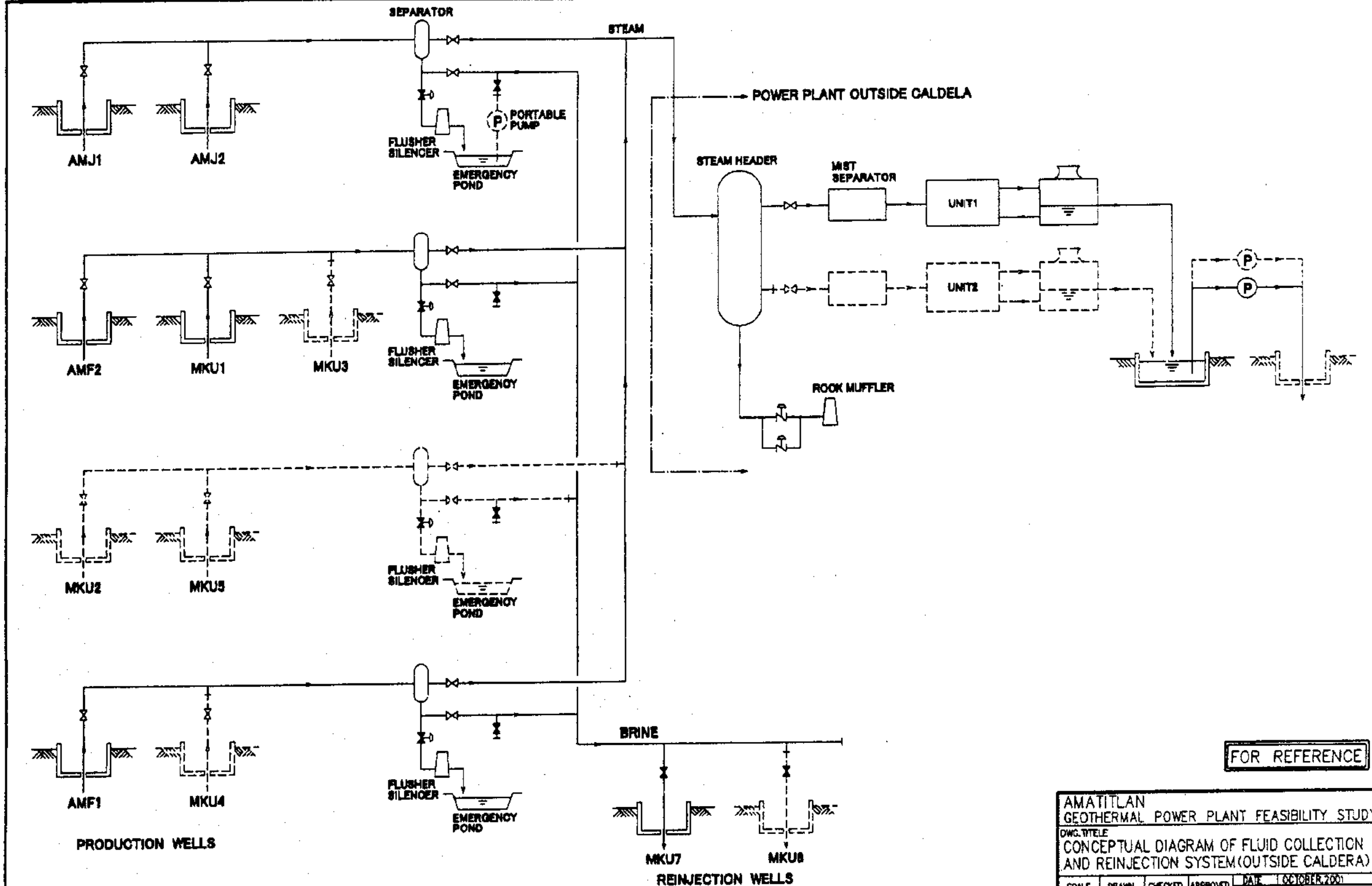


Fig.3-2-3
CONCEPTUAL DIAGRAM OF FLUID COLLECTION
AND REINJECTION SYSTEM(OUTSIDE CALDERA)
地熱流体輸送・還元設備系統図
「発電所建設地点Ⅰ(カルデラ外)」

AMATITLAN
GEOTHERMAL POWER PLANT FEASIBILITY STUDY
DWG. TITELE
CONCEPTUAL DIAGRAM OF FLUID COLLECTION
AND REINJECTION SYSTEM(OUTSIDE CALDERA)

SCALE	DRAWN	CHECKED	APPROVED	DATE OCTOBER.2001 / JOB.No. / DWG.No.	REV.No.
NON					

WEST JAPAN ENGINEERING
CONSULTANTS INC.

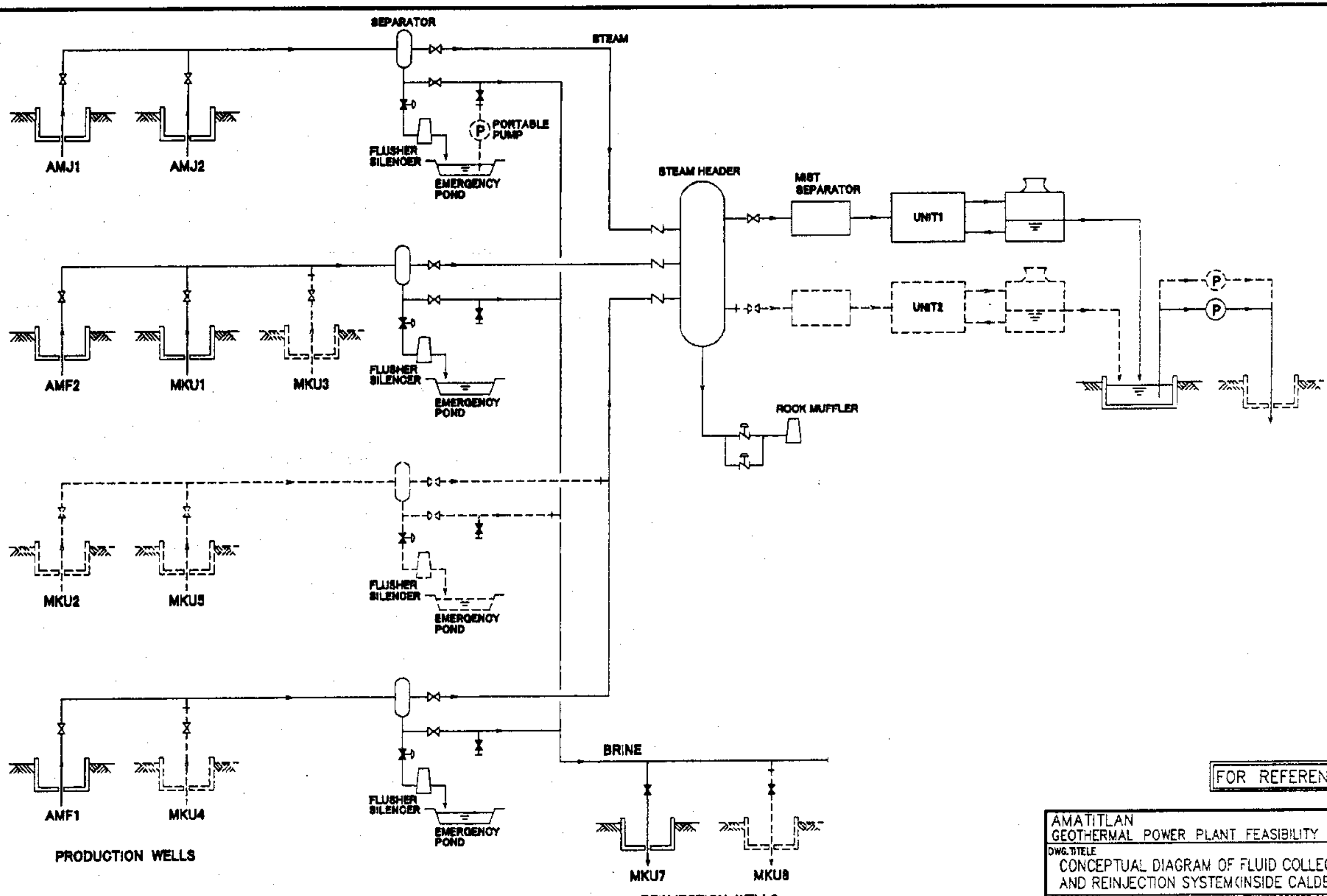


Fig.3−2−4
CONCEPTUAL DIAGRAM OF FLUID COLLECTION
AND REINJECTION SYSTEM(INSIDE CALDERA)
地熱流体輸送・還元設備系統図
「発電所建設地点Ⅱ（カルデラ内）」

AMATITLAN GEOTHERMAL POWER PLANT FEASIBILITY STUDY					
DWG.TITELE CONCEPTUAL DIAGRAM OF FLUID COLLECTION AND REINJECTION SYSTEM(INSIDE CALDERA)					
SCALE	DRAWN	CHECKED	APPROVED	DATE OCTOBER.2001 JOB No.	
NON				DWG.No.	REV.No.
WEST JAPAN ENGINEERING CONSULTANTS INC.					

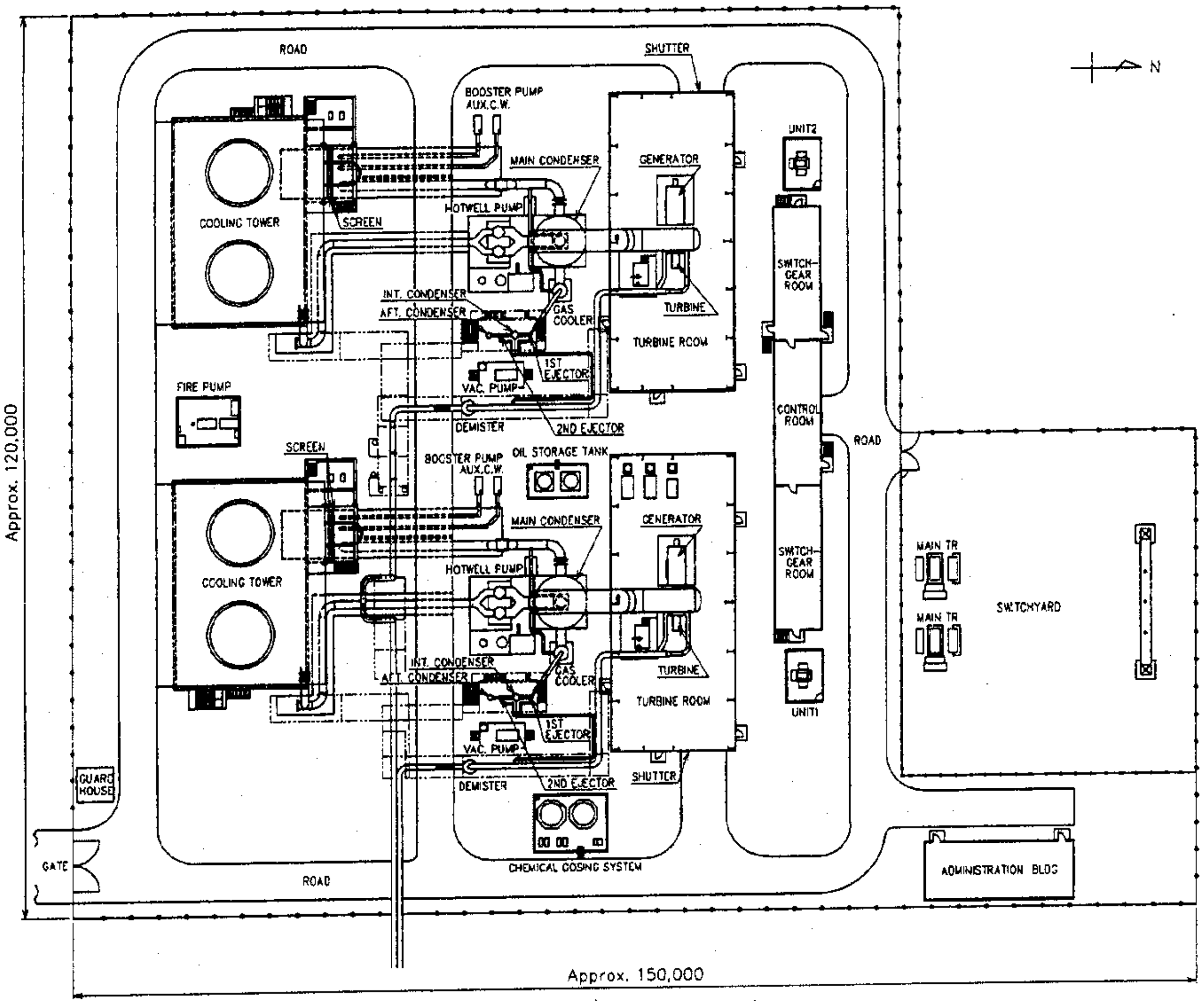


Fig.3-2-5
LAYOUT OF POWER PLANT
発電設備レイアウト

FOR REFERENCE

AMATITLAN GEOTHERMAL POWER PLANT FEASIBILITY STUDY					
DWG.TITELE LAYOUT OF POWER PLANT					
SCALE	DRAWN	CHECKED	APPROVED	DATE OCTOBER.2001 / JOB No.	
NON				DWG.No.	REV.No.
WEST JAPAN ENGINEERING CONSULTANTS INC.					

WO/MC

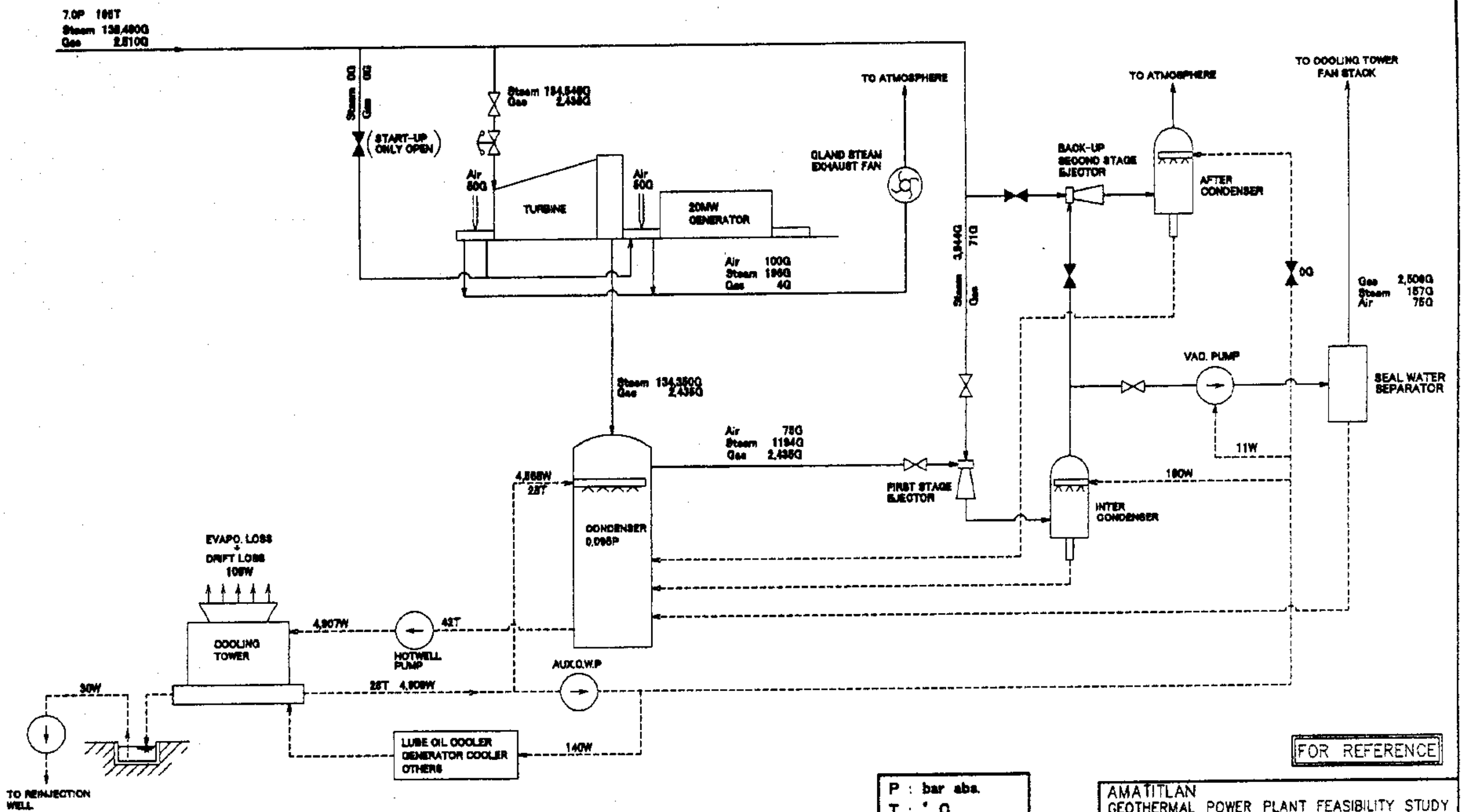


Fig 3-2-6
HEAT & MASS BALANCE DIAGRAM
ヒートバランス

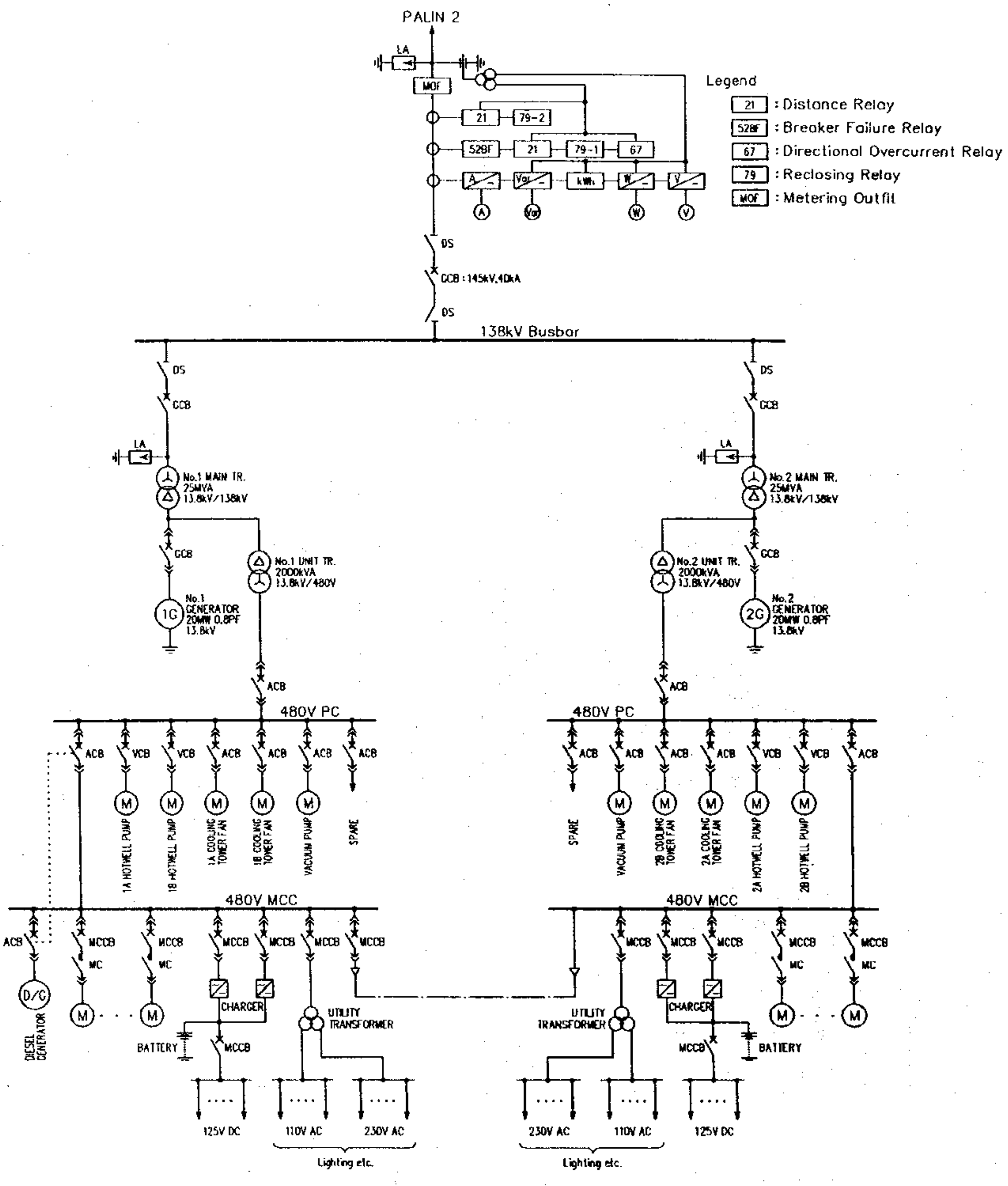
P : bar abs.
T : °C
G : kg/h
H : kJ/kg
W : m³/h

FOR REFERENCE

AMATITLAN
GEOTHERMAL POWER PLANT FEASIBILITY STUDY
DWG.TITLE
HEAT & MASS BALANCE DIAGRAM

SCALE	DRAWN	CHECKED	APPROVED	DATE OCTOBER 2001
				JOB.No
NON				DWG.No. REV.No. ◇

WEST JAPAN ENGINEERING CONSULTANTS INC.



FOR REFERENCE

Fig 3-2-7
所内単線結線図
SINGLE LINE DIAGRAM

AMATITLAN GEOTHERMAL POWER PLANT FEASIBILITY STUDY					
DWG. TITELE: SINGLE LINE DIAGRAM					
SCALE	DRAWN	CHECKED	APPROVED	DATE / JOB.No	OCTOBER, 2001
NON				DWG.No.	REV.No.
WEST JAPAN ENGINEERING CONSULTANTS INC.					

WO/MC

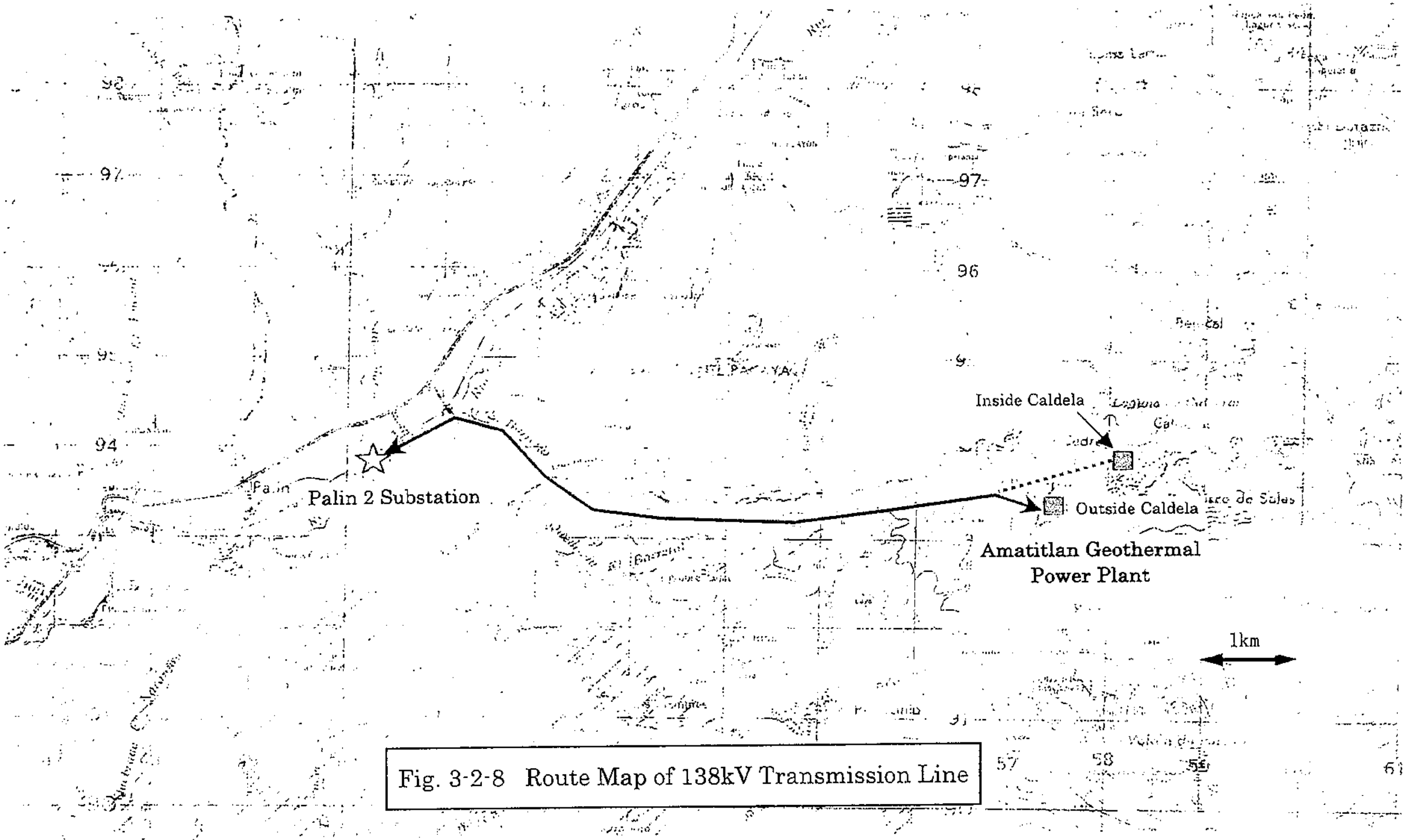


Fig. 3-2-8 Route Map of 138kV Transmission Line

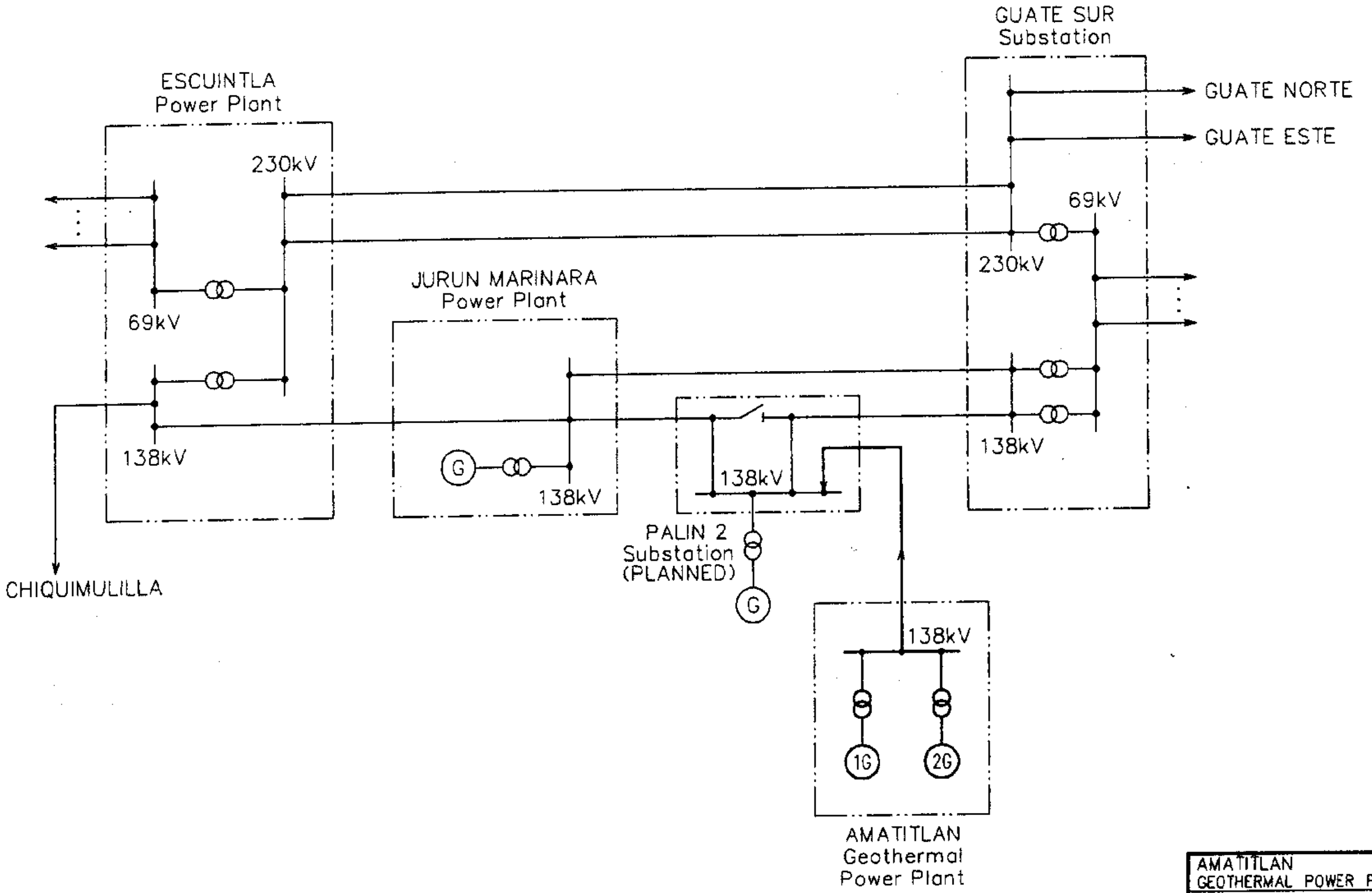


Fig 3-2-9
送電線系統図
TRANSMISSION NETWORK DIAGRAM

FOR REFERENCE

AMATITLAN GEOTHERMAL POWER PLANT FEASIBILITY STUDY					
DWG.TITELE TRANSMISSION NETWORK DIAGRAM					
SCALE	DRAWN	CHECKED	APPROVED	DATE OCTOBER.2001 JOB.No	
NON				DWG.No.	REV.No.
WEST JAPAN ENGINEERING CONSULTANTS INC.					

Fig. 3-2-10 CONSTRUCTION SCHEDULE (CASE 1)

建設計画 (CASE 1)

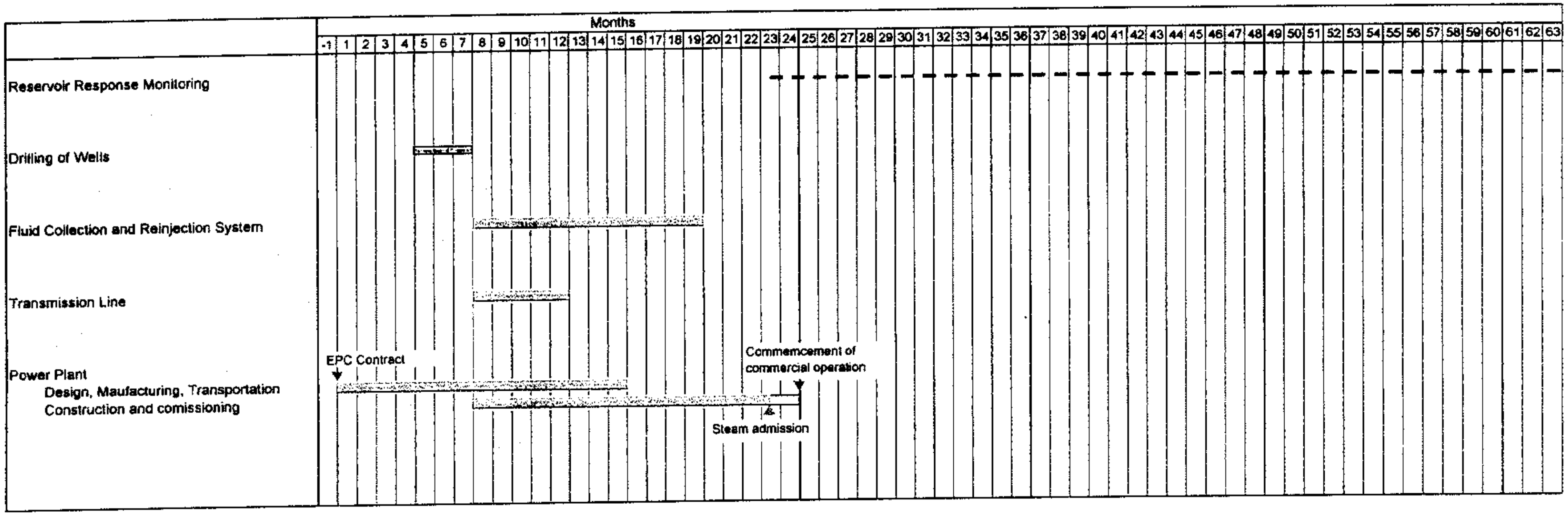
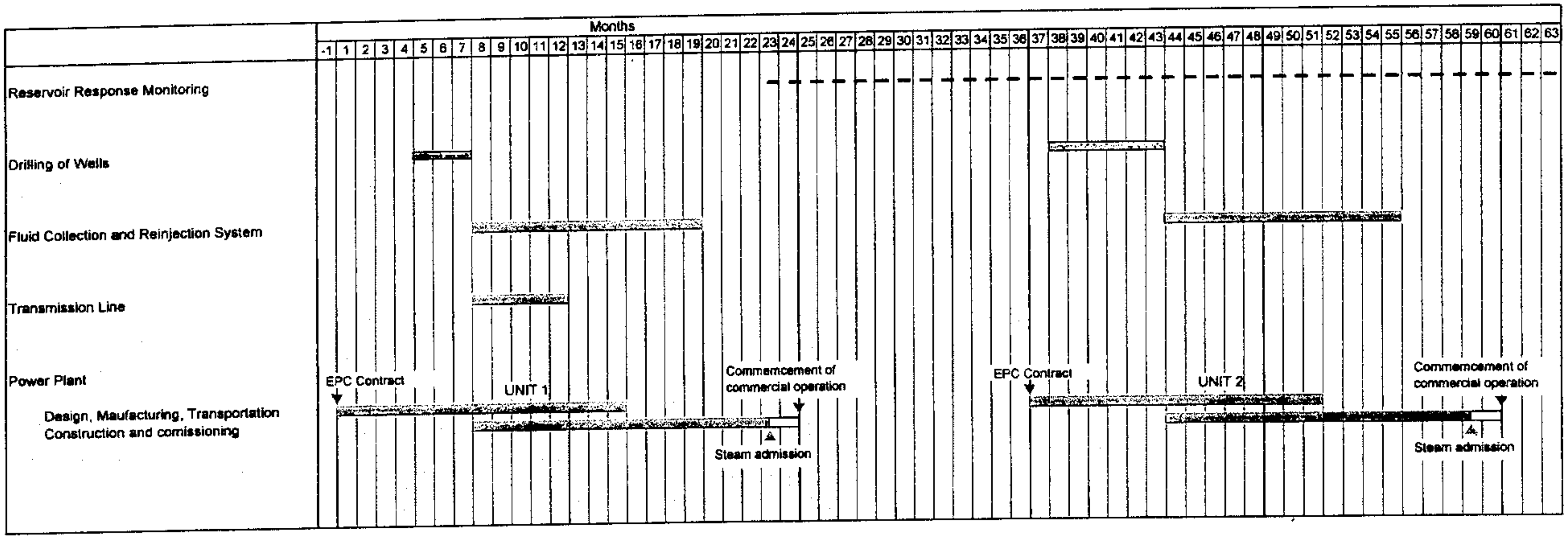


Fig. 3-2-11 CONSTRUCTION SCHEDULE (CASE 2)
建設計画 (CASE 2)



Amatitlan Geothermal Power Project

Fig. 3-2-12 CONSTRUCTION SCHEDULE (CASE 3)

建設計画 (CASE 3)

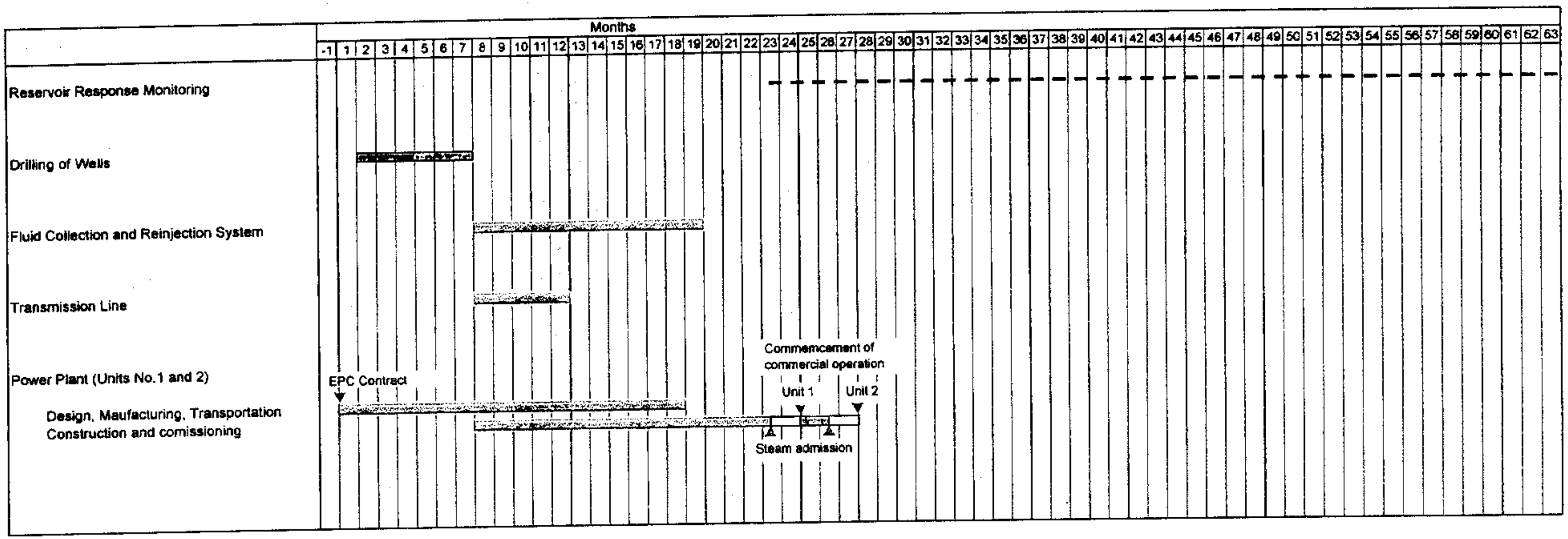


Table3-2-1 Estimated Project Cost (Plant Site I, Outside Caldera)
工事費見積（発電所建設地点Ｉ：カルデラ外）

	Scenario 1	Scenario 2	Scenario 3
1. Well Drilling			
Base cost	3.20	9.60	8.00
Price contingency	0.09	0.68	0.25
Physical contingency	0.16	0.51	0.41
2. Fluid Collection and Reinjection System			
Base cost	10.10	11.00	11.00
Price contingency	0.30	0.39	0.33
Physical contingency	0.52	0.57	0.57
3. Power Plant			
Base cost	29.15	55.65	53.00
Price contingency	0.88	3.35	1.76
Physical contingency	0.90	1.77	1.64
4. Transmission Line and Substation			
Base cost	2.90	3.50	3.50
Price contingency	0.09	0.14	0.11
Physical contingency	0.09	0.11	0.10
5. Geoscientific, General and Administrative Cost			
Base cost	5.46	10.92	7.55
Price contingency	0.16	0.67	0.26
Physical contingency	0.28	0.58	0.39
6. Land Acquisition and Compensation			
Base cost	0.75	1.50	1.50
Price contingency	0.02	0.08	0.05
Physical contingency	0.04	0.08	0.08
Project Cost Total			
Base cost	51.56	92.17	84.55
Price contingency	1.54	5.31	2.76
Physical contingency	1.99	3.62	3.19
TOTAL	**55.09**	**101.10**	**90.50**

Table3-2-2 Estimated Project Cost (Plant Site II, Outside Caldera)
工事費見積（発電所建設地点II：カルデラ内)

	Scenario 1	Scenario 2	Scenario 3
1. Well Drilling			
Base cost	3.20	9.60	8.00
Price contingency	0.09	0.68	0.25
Physical contingency	0.16	0.51	0.41
2. Fluid Collection and Reinjection System			
Base cost	7.30	8.20	8.20
Price contingency	0.22	0.31	0.25
Physical contingency	0.38	0.43	0.42
3. Power Plant			
Base cost	29.15	55.65	53.00
Price contingency	0.88	3.35	1.76
Physical contingency	0.90	1.77	1.64
4. Transmission Line and Substation			
Base cost	3.10	3.70	3.70
Price contingency	0.09	0.14	0.11
Physical contingency	0.10	0.12	0.12
5. Geoscientific, General and Administrative Cost			
Base cost	5.46	10.92	7.55
Price contingency	0.16	0.67	0.26
Physical contingency	0.28	0.58	0.39
6. Land Acquisition and Compensation			
Base cost	1.20	2.40	2.40
Price contingency	0.02	0.12	0.07
Physical contingency	0.06	0.13	0.12
Project Cost Total			
Base cost	49.41	90.47	82.85
Price contingency	1.46	5.27	2.70
Physical contingency	1.88	3.54	3.10
TOTAL	**52.75**	**99.28**	**88.65**

3.3 Envionmental Impact Assessment

3.3.1 Environmental Monitoring during the Wells Drilling & Well Tests

3.3.2 Evaluation for Environmental Impact

3.3.3 General Recommendation for Next Project

3.3 ENVIRONMENTAL IMPACT ASSESSMENT

3.3.1 Environmental Monitoring during the Well Drilling and Tests

The study on the Environmental Impact Evaluation regarding wells drilling and blowout test of AMJ-1&2 in the Amatitlan geothermal area, it will be concluded following.

a. Regarding water samples such as water streams, shallow drill hole of 50m depth and lake water in Calderas, there were no evidence that can be affected by well drilling of AMJ-1&2.

b. The whole of H_2S concentration around drilling pad were relatively low and it's concentration during blowout test of AMJ-2 were below 0.010ppm.

c. Maximum concentration of H_2S related with power plant (5MW) operation was 0.010ppm, and another measured concentrations around power plant were extremely low.

d. Whole of monitoring points without drilling pad, the noise levels were almost same as background level, even in near by residential area.

e. The drilling mud and cuttings were buried. Whole of geothermal hot water was disposed into reinjection well, and drainage was dumped to waste water pit.

3.3.2 Evaluation for Environmental Impact

1. Water Effluent

Any of water effluents on the environmental issues related to the wells drilling in this area couldn't be recognized by the results of environmental monitoring. Even so, some influence might be affected from wasted water or drainage from working places regarding power plant construction because the topography of this area shows with in a basin structure where is occupied the lowest elevation of Calderas lake, even if the power plant will be constructed within the Caldera. Therefore, it is recommended by this point of view.

a. Disposal of geothermal hot water

Whole amount of geothermal hot water discharged from 4 wells (AMF-1&2 and AMJ-1&2) will reach around 165t/h. The toxic elements like As (7-8ppm), B (40-50ppm) concentration in these geothermal hot water are extremely high, then whole of geothermal hot water should be disposed into the reinjection wells to under ground. On the other side, reninjection of hot water is necessary to help recharge the reservoir to maintain pressures in the reservoir.

b. Disposal of over flow water from cooling water system

The presence of water quality of over flowed cooling water at power plant operation stage cannot infer at the moment. The quality of the water is depending on the characteristic of condensate in general. Both As and Hg concentration in the condensate of 2 geothermal wells such as AMJ-1&2 are lower than the limit (As:0.1mg/l, Hg:0.05mg/l) for process wastewater on the environmental guideline of WB, but the concentration of these are slight higher than the limit (As:0.001ppm, Hg:0.001ppm) on standards and guidelines for drinking water of WHO. Concentration of As,Hg and B in steam condensate in a world average selected geothermal fluids are also slight high compared with limit on WHO standards for drinking water.

Besides, as an operation stage of power plant, it seems to be used a kind of chemicals like "Biocide" to be added into the cooling water system due to prevent occurring of oxidizing bacteria and algae. From this point, an over flow water from cooling water system shall be injected into another reinjection well.

c. Disposal of waste water and drainage from working area

Whole of wasted water and drainage discharged from working area should be disposed to the pond and neutralized as same as a way of treatment at the wells drilling.

d. Disposal of drilling mud and other waste

The drilling mud and drilling fluids like cuttings shale be exhausted to drainage pit at first, after the evaporation, waste dumps shall be buried as same as a way of treatment at the wells drilling.

2. Hydrogen Sulfide Emission

a. H_2S concentration at the wells drilling stages

The whole of H_2S concentration during blowout test (Nov.27, 2000) were below 0.010ppm. These concentrations were extremely low compared with a standard value which is set forth on the environmental guideline of WB (World Bank) for industrial production shows 10ppm. Even so, it will be needed about consideration how to release H_2S safely into the atmosphere, because H_2S smell is well detectable at very low concentration under 0.3ppm. Incidentally, 5 MW power plant using steam produced from AMF-1&2 has been generating, but H_2S concentration around area was 0.012ppm (Max) fairly low concentration.

b. Properties of H_2S

In general, hydrogen sulfide gas (H_2S) exist in common geothermal fields and it has a characteristic like rotten eggs odor which is well detectable at very low concentration under 0.3ppm. H_2S is a heavy gas compared with air, and extremely flammable gas and highly toxic. Due to funny odor and toxic gas, it is kept out of working places or residential area. The standard value set forth on the environmental guideline of WB (World Bank) for industrial production and TLVACGIH (Threshold Limit Value of American Conference of Government and Industrial Hygienists) shows 10ppm. As the concentration increase, the odor becomes sweeter and finally disappears above 105ppm. Consequently a human may die within one hour if concentration of H_2S exceed 600 ppm. H_2S is a kind of heavy gas and will accumulate in low lying area, then it may travel some distance in gullies, drain or pipe pits without significant diluting or mixing with air. Therefore, it can say that the concentration of H_2S in environmental circumstances is affected by atmospheric conditions. The concentration will reach high enough with weak wind, decrease in atmospheric temperature and increase in humidity. Consequently, the concentration of H_2S in circumstances at geothermal developing site can be controlled by atmospheric condition with winds, temperature and humidity.

The effects of H_2S on the wider environment are likely to be limited mainly to the secondary effects of any unoxidised gas remaining as hydrogen sulfide in the rainwater, and potential contamination of surface waters. Although, a part of H_2S will converted to sulfuric acid, and have been identified as components of acid-rain, but no direct link between H_2S emission and acidification of rainwater has been established.

c. Examination on H_2S emission

1) Conditions as a case study

- Install capacity of newly power plant : 20,000kW
- Steam consumption for generation : 146t/h
- Non-condensable gas content in steam : 2.1wt% (average)
- H_2S concentration in NC.Gas : 5.8%
- Exhausted air volume from cooling tower : 2.6×10^6 Nm^3/h

2) Estimation of H_2S emission

- Gas flow : $146\times2.1/100=3.066t/h$
- H_2S emission : $3.066\times5.8/100\times10^{-3}=178g/h$
- Total H_2S emission : $178\times22.4/34=117Nm^3/h$

3) Estimation of H_2S emission from cooling water

- H_2S concentration at cooling tower exhaust : $117/2.6\times10^6\times10^6=45ppm$

4) Comparison on H_2S emission

Total H_2S emission ($117Nm^3/h$) and H_2S concentration (45ppm) at cooling tower exhaust were examined in case of 20 MW out put. Then, estimated values were evaluated compared with other existing geothermal power plants. Table 3-3-1 shows comparison results. From this, estimated H_2S concentration around power plant won't high comparatively.

d. Planning for Mitigation of H_2S Emission

It was assumed that H_2S concentration exhausted from cooling tower is fairly low in comparison with other existing power plants above mention. An ambient H_2S concentration around developing area won't exceed the limit of 10ppm which is set forth on the environmental guideline of WB and TLVACGIH. Although, the concentration of H_2S in circumstances at the site can be controlled by atmospheric conditions with winds, temperature and humidity, and affected by land scope. Therefore, it is better choice that the power plant shall be constructed out of the caldera rim.

General options on planning for mitigation of H_2S emission for electric power generation are summarized on following subjects;

- An enlargement of forced draft due to dilution and dissemination.
- An adoption of gathering cooling tower system for well dilution.
- An adoption of completely closed system like Binary plants.
- An adoption of H_2S abatement apparatus.

3. Noise

When the blow out operation (fully open) of AMJ-1, maximum noise level was 116dB beside of the well, also measured 76 – 88dB at the point No.5 an entrance way to the pad (100m a part from the wells pad). This level is exceeding the background noise level, but almost same level of background / typical noise level in major city (1993, A.Freeston). Noise impacts in regard to the environmental issue depend on the relation between noise level and distance to the residential area. Noise level around residential area at the blow out test of AMJ-2 was 58dB as same level as background noise level.

Noise levels when the power plant is completed and operated on normal condition won't exceed the noise levels at the blow out operation of wells.

When the power plant will be installed at the site adjacent to the wells pad for AMJ-1&2 (out of the caldera rim), noise level around residential area won't exceed the standard value set forth on the environmental guideline of WB for industrial production, from the relation between noise levels and actual distance to the residential area.

3.3.3 General Recommendation for Next Project

a. The educative activities related with geothermal development should be implemented to the local communities in case of continued project.

b. Special attention must be paid to recover or repair the circumstances related to the project.

c. In case of further development program, through the construction of the power plant and operation, the Environmental Impact Evaluation plan must be implemented continuously.

d. In case of newly evaluation on further Environmental Impact Assessment, a) Plan for environmental impact monitoring (air, water, noise) b) Plan for environmental impact mitigation during drilling preparation, well drilling and blow out test c) Plan for human health protection and security on drilling preparation, drilling and blow out test shall be implemented with enrich the contents. For the monitoring of air, water and noise, measurement skill, measurement detector/devices and staffs shall be built up.

Table 3-3-1 Comparison on Total H_2S Emission and H_2S Concentration with Other Existing P/P

総 H2S 排出量と H2S 濃度の他の地熱発電所との比較

Name of Power plant	Out Put (MW)	H2S Concentration at cooling tower (ppm)	H2S Emission (Nm3/h)	Predicted H2S around P/P (ppm)
Amatitlan	(20)	45	117	————
A	27.5	62～120	58	0.03～0.06
B	50	14～120	140	0.006～0.008
C	65	49～110	～730	0.141～0.193
D	55×2	6～10	128	0.006～0.007

3.4 Economical and Financial Evaluation

3.4.1 Necessity of Project

3.4.2 Least Cost Solution

3.4.3 Financial Evaluation

3.4 ECONOMIC AND FINANCIAL EVALUATION

3.4.1 Necessity of Project

1. Power Demand

The country's dependable installed capacity was about 1,380 MW at the end of 1999 while the electric energy consumption reached 5,348 GWh at the peak demand of 1,049 MW. INDE forecast the demand increase at an average of 7.7% to 8.0% for coming 10 years in its medium scenario. When this project would be completed in 2005 or 2006, the forecast noted that total install capacity of about 1,600 MW, additional 200 MW or so capacity, would be necessary. So, taking into account the existing aged power generating facilities soon to be retired, the introduction of geothermal power units with a capacity of 20 MW x 2 units will be very significant for stable power supply and power system diversification because the geothermal power can generate at a higher capacity factor using indigenous energy source.

2. Effective Use of Renewable Energy

The geothermal power utilizes its own indigenous renewable energy resource. Once 40 MW geothermal power should be implemented, it can avoid power generation by diesel power with the equivalent annual power generation at 308 GWh and the fuel saving and therefore foreign exchange saving would amount to 30.2 million US$ annually.

In addition, the geothermal power scarcely emissions CO_2 hugely produced by combustion of fossil fuel fired thermal power, and so favorable attention has been paid to geothermal power which may greatly contribute to global environmental preservation. Thus, once CO_2 transaction among developed countries according to the Kyoto Protocol would have been realized, the country could transact CO_2 reduction with this geothermal power project.

3.4.2 Least Cost Solution

1. kW Unit Construction Cost and Generating Cost Comparison

Table 3-4-1 kW Unit Construction Cost and Generating Cost

Case	Inside Caldera			Outside Caldera		
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Total Output, MW	**20**	**40**	**40**	**20**	**40**	**40**
Unit Construction Cost, $/kW	**2,471**	**2,262**	**2,071**	**2,578**	**2,304**	**2.114**
Generating Cost, USCent/kWh	**4.73**	**4.11**	**3.82**	**4.89**	**4.17**	**3.88**
Where the investment of exist. wells is considered. USCent/kWh	**5.33**	**4.41**	**4.12**	**5.50**	**4.48**	**4.19**

2. Conclusion

As the table above shows, the Case 3 Inside Caldera, construction of 20 MW x 2 Units in parallel, can provide the least cost both for unit construction cost per kW and generating cost.

Meanwhile, there are not so big differences between development of inside and outside caldera, 0.16 cent/kWh for Case 1 and 0.06 cent/kWh for Case 2 and 3. Thus, the selection between inside and outside will be made at the practical stage taking into detailed investigation on land acquisition, compensation, etc.

So, it is concluded that the geothermal power development in the country is a highly economic solution and worth to pursue.

3.4.3 Financial Evaluation

1. Project Cost and Contingencies

Table 3-4-2 Project Cost

Unit: Million US$

Case	Inside Caldera			Outside Caldera		
	Case 1	Case 2	Case 3	Case 1	Case 2	Case 3
Base Cost	49.41	90.47	82.85	51.56	92.17	84.55
Price Contingency	1.46	5.27	2.70	1.54	5.31	2.76
Physical Contingency	1.88	3.54	3.10	1.99	3.62	3.19
Project Cost	52.75	99.28	88.65	55.09	101.10	90.50

2. Financial Terms and Opportunity Cost of Capital

Table 3-4-3 Loan Term

	Japanese Bank	Int'l Develop. Bank
Currency	US$	US$
Share	40%	60%
Interest Rate	6.03% +3.08%	8.0%
Repayment	12 years	20 years
Grace Period	2 years (3 years) *	2 years (3 years)

Note to * : The grace period of Case 3 is considered 3 years as the construction period is scheduled for 2. 5 years.

From the table above, the WACC (weighted average cost of capital) becomes 8.44% and the value is an opportunity cost of capital for comparison with FIRR.

3. Other Conditions for Eavluation

Steam Rate: 1.1 US Cent/kWh
Power Rate: 8.0 US Cent/kWh

Depreciation: Straight line method without residual value
Steam field for 10 years
Power Plant for 20 years

Tax: 31% as against sales profit

4. Financial Internal Rate of Return and Cash Flow

As a result of calculations with the conditions mentioned above, the obtained financial internal rate of returns are tabulated below and the calculation process of each case is shown in Appendix.

Table 3-4-4 FIRR

	Financial Internal Rate of Return	
	Inside Caldera	Outside Caldera
Case 1	11.14%	10.57%
Case 2	11.15%	10.87%
Case 3	13.75%	13.40%

As shown above, all the cases exceeds the opportunity cost of capital at 8.44% and are concluded as financially feasible.

Table 3-4-5 Accumulated Profit

	Accumulated Profit (Million US$)	
	Inside Caldera	Outside Caldera
Case 1	47.22	35.79
Case 2	76.81	73.44
Case 3	111.33	106.56

From the point of cash flow, the Case 1 and Case 2 will fall into short working fund for several years after commissioning, mainly due to repayment burden. On the other hand, the Case 3 could appropriate the profit soon after commissioning and will only fall in short fund in the year when the supplementary well will become necessary. Such a shortfall could be sufficiently recovered with the accumulated profit. In view of the debt service ratio, the Case 1 and Case 2 can not be said financially feasible. As a conclusion, only Case 3 is financially feasible. (Refer to the calculation processes in Appendix)

5. Conclusion

As a result of financial evaluation, it is concluded that Case 3 is financially feasible. In view of cash flow, however, it is necessary to investigate the financial procurement in term of interest rate, grace period and repayment period. It is recommended that INDE seek for the more favorable loan than the assumed ones.

4 INTEGRATION AND RECOMMENDATION

4.1 Integration

4.2 Recommendation

4. INTEGRATION AND RECOMMENDATIONS

4.1 INTEGRATION

From geo-scientific surveys such as geological reconnaissance, geochemical and geophysical survey and well surveys, the geothermal conceptual model in the Amatitlan area was prepared and updated. Based on these surveys, two exploratory wells, AMJ-1 and AMJ-2, were drilled and the production test was run. Finally, the extent and volume of geothermal reservoir was revealed and the exploitable resource was calculated within the target area.

An uplift zone related to faults in N-S direction and a dacitic intrusion characterizes the geological structure in the Amatitlan geothermal field. The geothermal reservoir exists place in the deeper portion along fractures developed with the formation of these geological structures. From the result of drilling wells, AMJ-1 and AMJ-2, the fracturing typed reservoir is recognized to locate at the volcanic rocks above the granitic basement.

The geothermal system in this area is the hydrothermal convection type. Dacite intrusion plays a role as the direct heat source at the deeper portion beneath western Calderas and meteoric water comes from the southern highland and Amatitlan Lake. Volcanic activities has been activating since the Late Pleistocene (around 0.7Ma), representing as Pacaya Volcano. The residual magma reservoir and volcanic gas resulted in these activities became the regional heat source in Amatitlan geothermal area.

The meteoric water infiltrated into the deep underground forms the neutral Cl-typed reservoir with the temperature of 300 to 340℃ in the granitic basement. The fluid of this reservoir flows and rises along fractures at the western edge of NE-SW uplift zone and ring-shaped faults by caldera rim. Through these passages, the neutral-typed reservoir with the temperature of 290 to 300℃ (Cl content; 2,700mg/l) is formed at the elevation of 500masl.

This hot water migrates from southwest to northeast along the NE-SW trend fracture at the great depth and partly flows toward west to northwest through the south rim of Amatitlan Caldera.

From the chemical analysis of well fluid, it was clarified that the geothermal fluid around the drilled wells shows neutral in pH, high Cl content, 260 to 280℃ and is distributed from the same above-mentioned reservoir. The fluid from all of these wells is suitable for the geothermal generating use.

Of two JICA wells, well AMJ-1 was interpreted to have been drilled close to the western border of the targeted reservoir from the evidence of two-phase fluid condition and relatively low permeability around the well. On the other hand, two feed zones were found in well AMJ-2. An upper feed zone shows steam dominant and the lower zone indicates water dominant. Well AMJ-2 is similar to well AMF-2 in the outflow condition

The total existing power potential in wells AMF-1, AMF-2, AMJ-1 and AMJ-2 is not sufficient to generate the 20MW output. However, according to the result of numerical simulation based on 3-D model, we could get a conclusion that there is the capacity of 50MW generation in Amatitlan geothermal resource.

Wells AMF-1 and AMF-2 show constant steam/water ratio. Furthermore, well AMF-2 has produced for last 2 years. Therefore, these facts suggest the possibility of the huge geothermal potential in Amatitlan area.

The generating output was calculated by three kinds of scenarios and the additional drilling was scheduled for each scenario. The exploitable reservoir is targeted at the inside of the Calderas depression in all cases. Two alternatives of power plant locations are set as follows; one is inside the Calderas depression and the second is close to INDE's warehouse at EL Cedro.

For medium specific enthalpy geofluid, relatively low non-condensable gas (NCG) content and silica-rich brine produced in Amatitlan geothermal area, the single flashed steam cycle with condensing turbine is recommended for this project and the brine in the reinjection system will be kept at high pressure and high temperature.

Taking into consideration of INDE's opinion, the power plant was conceptually designed by two cases; 20MW x 1 unit and 20MW x 2 units. In case of 40MW P/P construction, both units will be installed at the same site.

The output of Amatitlan geothermal power plant will be connected to 138kV substation, named Palin 2 substation.

Regarding fluid collection and reinjection system (FCRS), steam/brine separate pipeline is employed because it has advantages in pressure loss and flow stability when the pipeline cross the caldera ridge.

The steam turbine for this project shall be designed and proven for geothermal application. Skid-mounted modular type turbine is preferred because of shorter design and manufacturing period, easy to transport, smaller foot print, faster installation at site and lower construction cost.

Environmental regulations in Guatemala have changed recently, so in order to execute any kind of works relate to well drilling in connection with geothermal survey that is required to have an authorization extended by CONAMA. In the standards book published by CONAMA, no definite description regarding the environmental regulation and on the standard value was found. Up to day, EIA applications submitted to CONAMA standard value set forth by the WHO or IDB have been adopted.

On the basis of the proposed conceptual design of power plant, the measurement regarding water effluent, air emission and noise was assessed. Since the elements like As (7 to 8 ppm) and B (40 to 50 ppm) in geothermal hot water are high, the whole exhausted water from power plant should be disposed into the reinjection wells to the underground. The reinjection of hot water is necessary to help recharge the reservoir to maintain pressures in the reservoir. In addition, over flow water from cooling water system shall be also injected into the underground. Though H_2S concentration exhausted from cooling tower in Amatitlan field is fairly low in comparison with other existing power plants, it is desired to mitigate of H2S emission by dilution and dissemination.

In addition, two alternatives for power plant site are technically and environmentally considered, i.e., inside and outside caldera. The result is as follow:

	Generating Cost (US Cent/kWh)		
	Scenario 1	Scenario 2	Scenario 3
Inside Caldera	4.73	4.11	3.82
Outside Caldera	4.89	4.17	3.88

As the above, the Scenario 3 Inside Caldera, construction of 20MW x 2 Units in parallel, can provide the least generating cost. On the contrary, the Scenario 1 Outside Caldera, 20MW x 1 Unit, shows the highest cost.

Nonetheless, even this highest generating cost scenario of 20 MW development is still competitive with the other thermal power under operation as its total generating cost including the conceivable steam cost of 1.1 cent/kWh becomes 5.99 cent/kWh. There are not so big differences between development of inside and outside caldera.

Financial internal rate of return (FIRR) for each case of assumed development plan was obtained, and the financial viability of each case was evaluated by comparison between the obtained FIRR and opportunity cost of capital. In addition, the cash flow of each case was prepared to check for financial soundness of the project.

All the cases are within 10 to 14 % in FIRR and are concluded as financially feasible. Because FIRRs of Case 1 and Case 2 are close to the opportunity cost of capital and subject to further study by cash flow, the Case 3, constructed and attained commissioning in a shorter period, is the most suitable to pursue. From the point of cash flow, the Case 3 could appropriate the profit soon after commissioning and will only fall in short fund in the year when the supplementary well will become necessary. As a conclusion, only Case 3 is financially feasible.

4.2 RECOMMENDATION

4.2.1 Exploitation in Amatitlan Geothermal Field

Reservoir evaluation in the survey area was done based on the conceptual model constructed and the reservoir characteristics from geothermal wells. From this evaluation, it became clear that the geothermal resources with the capacity of 40MW generation exist in Amatitlan area. Among 6 alternatives of exploitation scheme, the most economical alternative is evaluated to be scenario 3, which constructs 20MW x 2 units at the same time for the shortest lead time to the operation start. US$ currency loan of 8 to 9 % interest rate is applied in this Final Report to avoid risk of variable exchange rate. As an alternative of project financial viability, it is recommended to apply for Japanese government's yen credit (interest rate: about 2%), ordinary credit or environmental credit.

4.2.2 Site of Power Plant

Two sites are considered for power plant construction. One (site-I) is near INDE's warehouse outside caldera and the other (site-II) is adjacent to the center of the targeted geothermal reservoir inside caldera. Site-II is close to the existing wells and shows relatively lower generating cost compared than Site-I. However, at the point of environmental preservation, some disadvantage remains in H2S gas emission and dilution due to the topographical caldera feature. Since there are not so big differences between development of inside and outside caldera in economical evaluation, Site-I is desirable for plant construction.

4.2.3 Educative Activities and Understanding to Local Communities

In order to proceed smoothly to geothermal exploitation project, it is necessary to implement the educative activities related with geothermal development to the local communities in understanding and cooperation with CONAMA. If the site of power plant is selected inside caldera, it must be examined to install the H2S removal device in the power plant. In addition, it hopes for the additional simulation based on the detailed examination regarding wind direction, too.

4.2.4 Geothermal Potential in Surrounding Areas

As for the amount of the geothermal resources, the generating potential is clarified beyond 40MW inside caldera within the survey area. Since the residual magma chamber related to this dacite dome in the northern part of the survey area has the possibility to play a role of another heat source, the exploitable geothermal reservoir might spread to the south of the Amatitlan Lake.

Including the surrounding area, geothermal potential becomes huge amount of generating resources. It is also important to explore at the northern dacite dome area in effective utilization of geothermal resource, as well as electricity generating in Calderas.

JICA