THE REPUBLIC OF THE PHILIPPINES

FEASIBILITY STUDY
ON
COAL-FIRED THERMAL ELECTRIC POWER
DEVELOPMENT PROJECT
IN
LUZON ISLAND

MARCH 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Republic of the Philippines, the Government of Japan decided to conduct a feasibility study on Coal-Fired Thermal Electric Power Development Project in Luzon Island and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Philippines a study team headed by Mr. Hiroshi Isaka, Advisor to Director of Thermal Power Department, Electric Power Development Co., Ltd. from March 1989 to February 1990.

The team held discussions on the Study with the officials concerned of the Government of the Philippines and conducted field surveys in the relevant areas in Luzon Island. After the team returned to Japan, further studies were made and the present report was prepared.

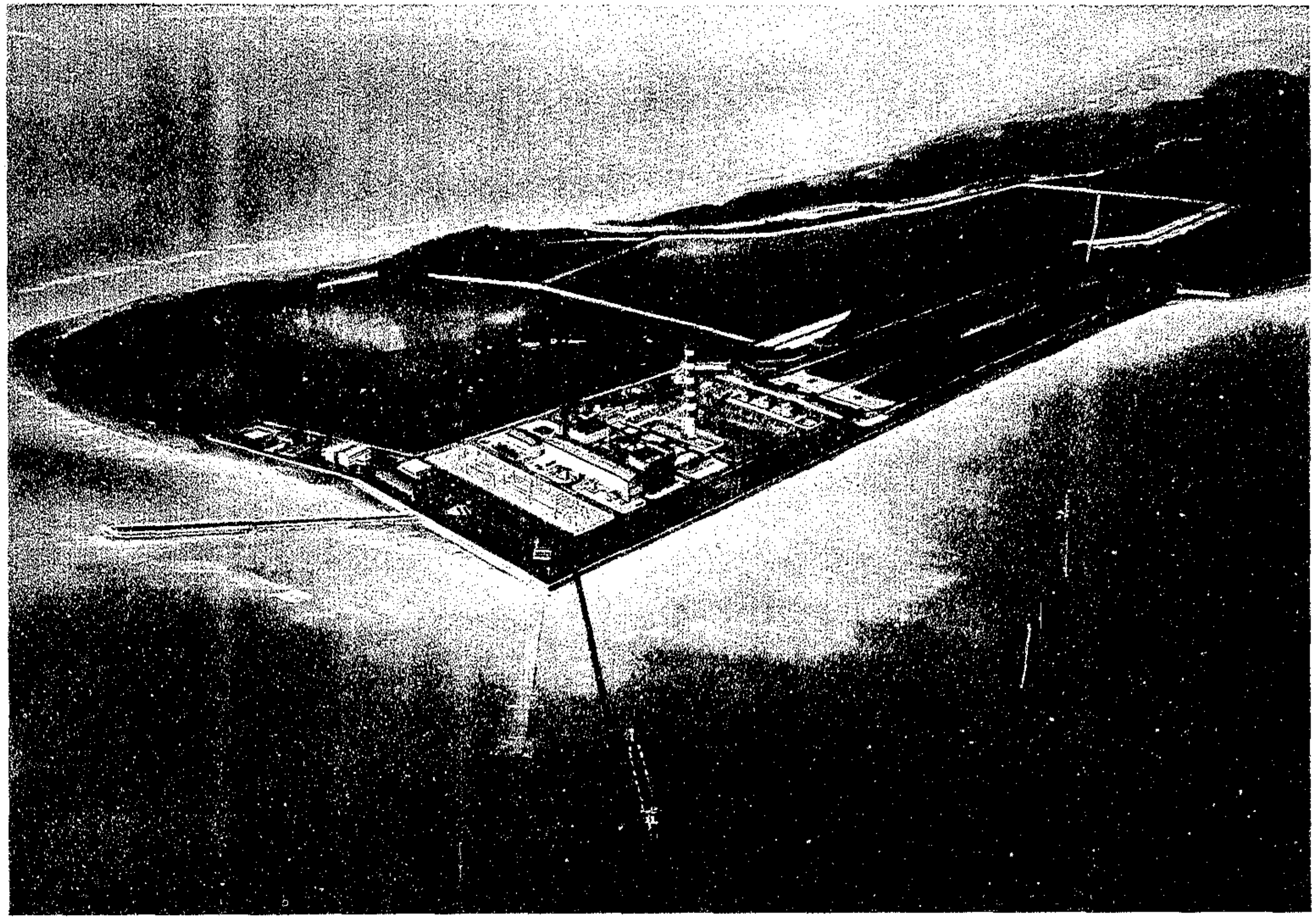
I hope that this report will contribute to the development of the project and to the promotion of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Philippines for their close cooperation extended to the team.

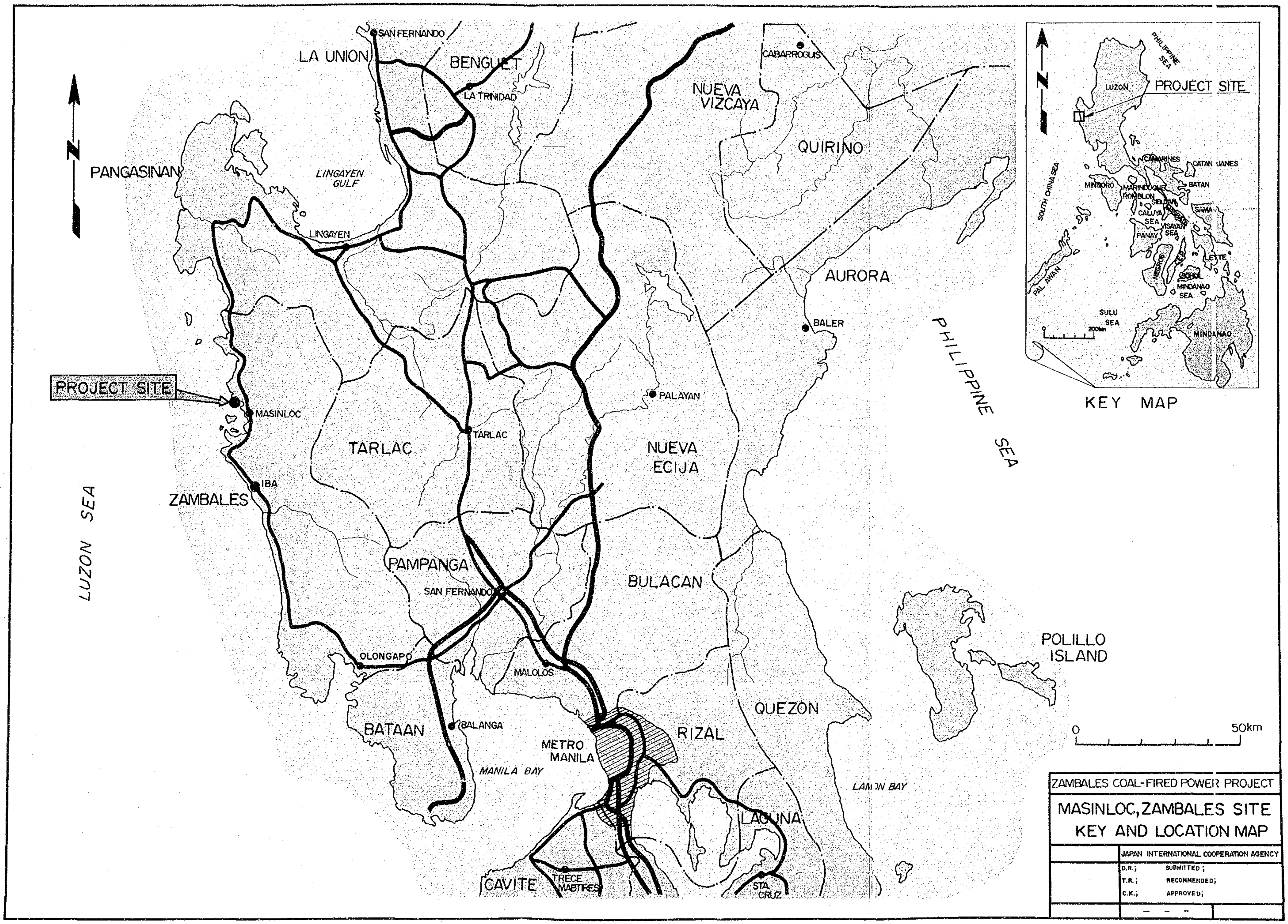
March 1990

Kensuke Yanagiya

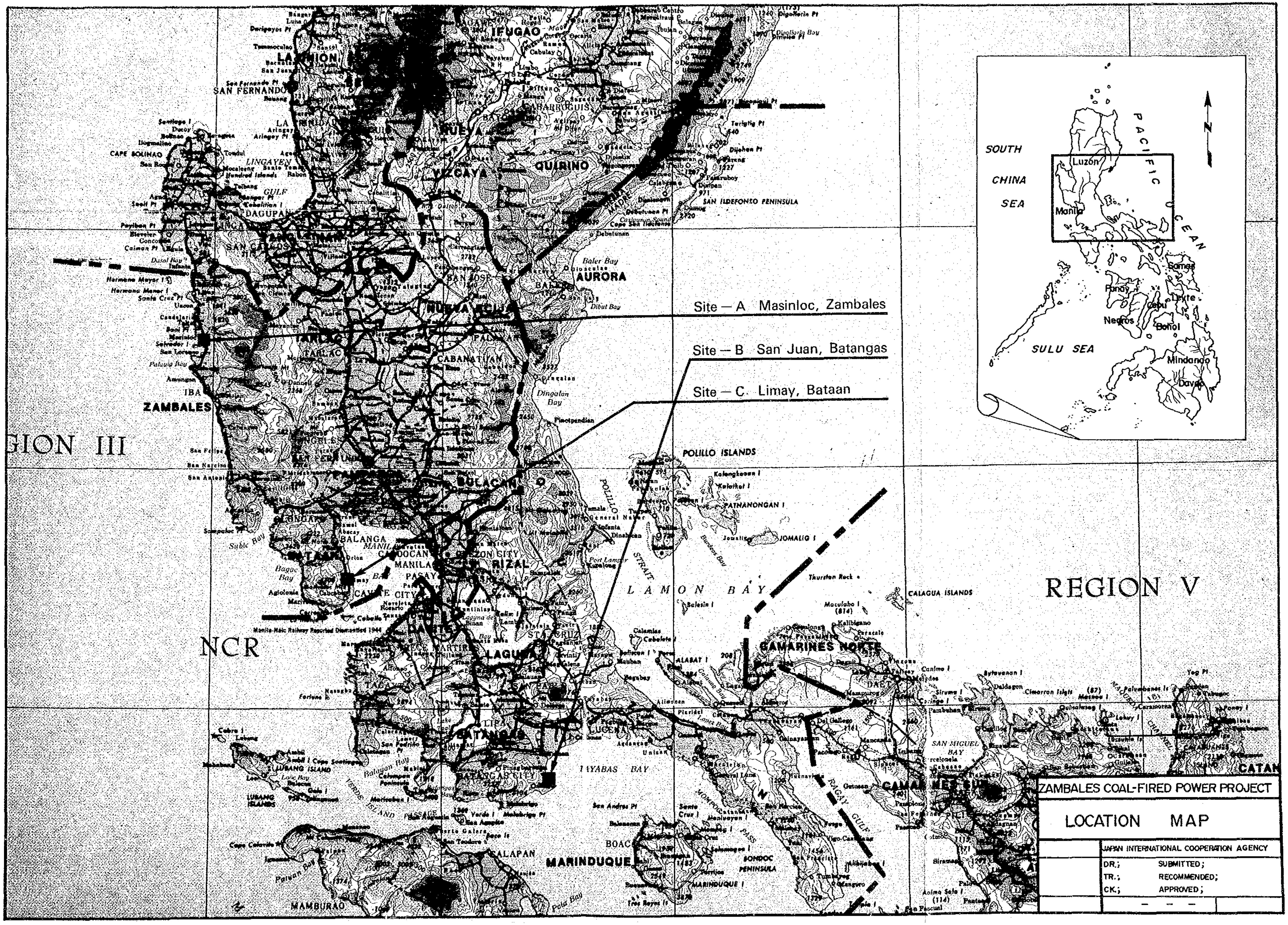
Kensuke Yanagiya
President
Japan International Cooperation Agency

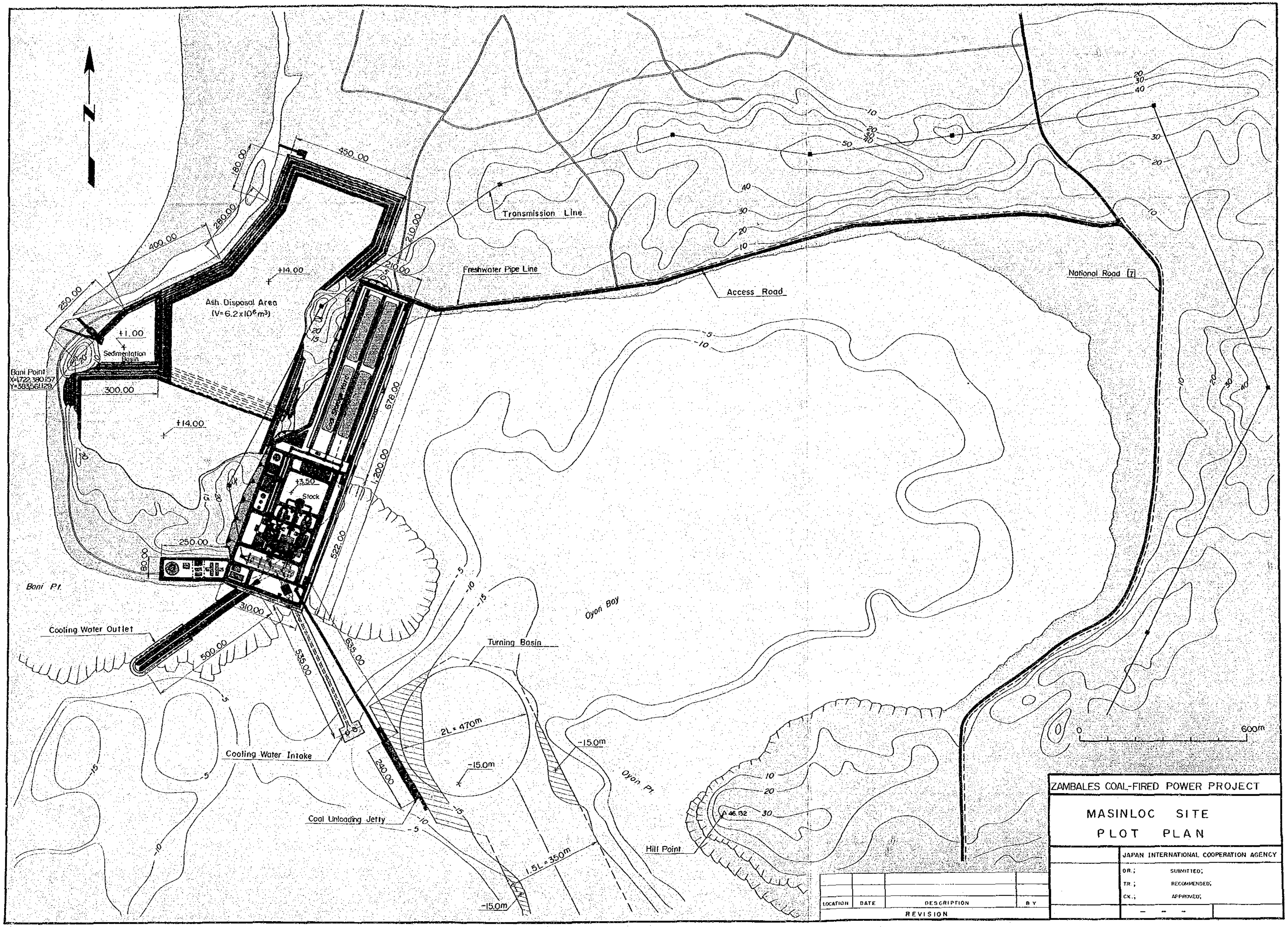


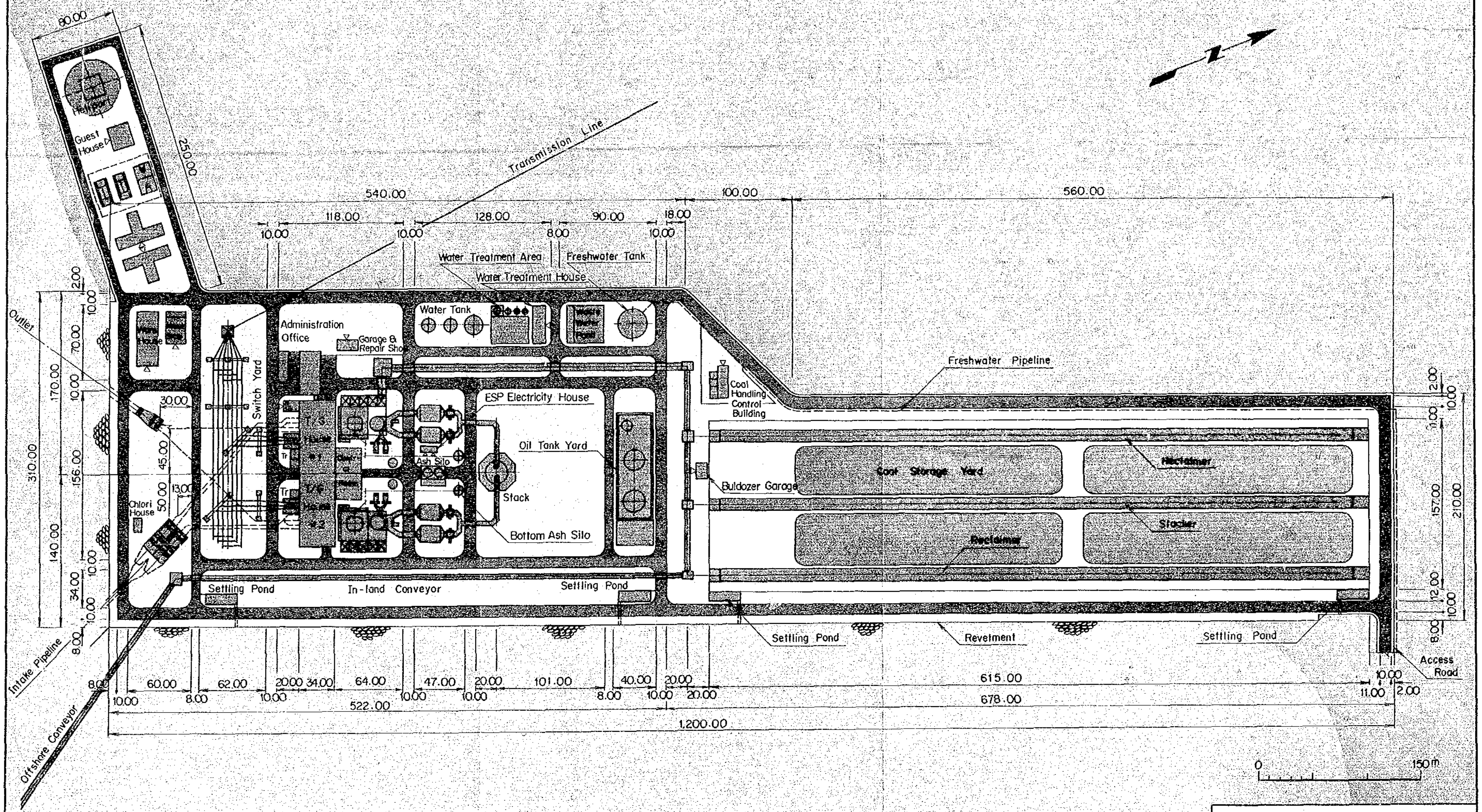
Zambales Coal-Fired Thermal Power Plant



SAN FERNANDO
LA UNION
BENGUET
LA TRINIDAD
CABARROGUIS
NUEVA VIZCAYA
QUIRINO
PANGASINAN
LINGAYEN GULF
LINGAYEN
AURORA
BALER
PHILIPPINE SEA
PROJECT SITE
MASINLOC
PALAYAN
TARLAC
TARLAC
NUEVA ECIJA
IBA
ZAMBALES
LUZON SEA
PAMPANGA
SAN FERNANDO
BULACAN
OLONGAPO
MALOLOS
POLILLO ISLAND
QUEZON
BATAAN
BALANGA
METRO MANILA
RIZAL
MANILA BAY
LAGUNA
CAVITE
TRECE MARTIRES
STA. CRUZ
0
50km
N
PHILIPPINE SEA
LUZON
PROJECT SITE
SOUTH CHINA SEA
MINDORO
BATAN
PANAY
LEYTE
NEGROS
MINDANAO SEA
SULU SEA
PALAWAN
MINDANAO
KEY MAP
ZAMBALES COAL-FIRED POWER PROJECT
MASINLOC, ZAMBALES SITE
KEY AND LOCATION MAP
JAPAN INTERNATIONAL COOPERATION AGENCY
D.R.;
T.R.;
C.K.;
SUBMITTED;
RECOMMENDED;
APPROVED;


Site – A Masinloc, Zambales
Site – B San Juan, Batangas
Site – C. Limay, Bataan
REGION III
NCR
REGION V
ZAMBALES
TARLAC
NUEVA ECIJA
BULACAN
AURORA
QUIRINO
IFUGAO
LA UNION
RIZAL
LAGUNA
BATANGAS
CAMARINES NORTE
MARINDUQUE
POLILLO ISLANDS
LAMON BAY
TAYABAS BAY
RAGAY GULF
LUCENA
CABANATUAN
MANILA
QUEZON CITY
SAN FERNANDO
SOUTH CHINA SEA
PACIFIC OCEAN
SULU SEA
Luzon
Manila
Samar
Panay
Leyte
Cebu
Negros
Bohol
Mindanao
Davao
N
ZAMBALES COAL-FIRED POWER PROJECT
LOCATION MAP
JAPAN INTERNATIONAL COOPERATION AGENCY
DR.;
TR.;
CK.;
SUBMITTED;
RECOMMENDED;
APPROVED;


N
450.00
180.00
280.00
400.00
250.00
210.00
210.00
+14.00
Ash Disposal Area
(V=6.2x10⁶m³)
+1.00
Sedimentation Basin
Bani Point
X=1,722,380.157
Y=383561.129
300.00
+14.00
678.00
1,200.00
522.00
+3.50
Stock
250.00
80.00
Bani Pt.
310.00
Cooling Water Outlet
500.00
535.00
635.00
Turning Basin
Oyon Bay
2L=470m
-15.0m
-15.0m
Cooling Water Intake
240.00
Coal Unloading Jetty
1.5L=350m
-15.0m
Oyon Pt.
Hill Point
46.132
Transmission Line
Freshwater Pipe Line
Access Road
National Road [7]
0
600m
ZAMBALES COAL-FIRED POWER PROJECT
MASINLOC SITE
PLOT PLAN
JAPAN INTERNATIONAL COOPERATION AGENCY
DR.;
TR.;
CK.;
SUBMITTED;
RECOMMENDED;
APPROVED;
LOCATION
DATE
DESCRIPTION
BY
REVISION



ZAMBALES COAL-FIRED POWER PROJECT

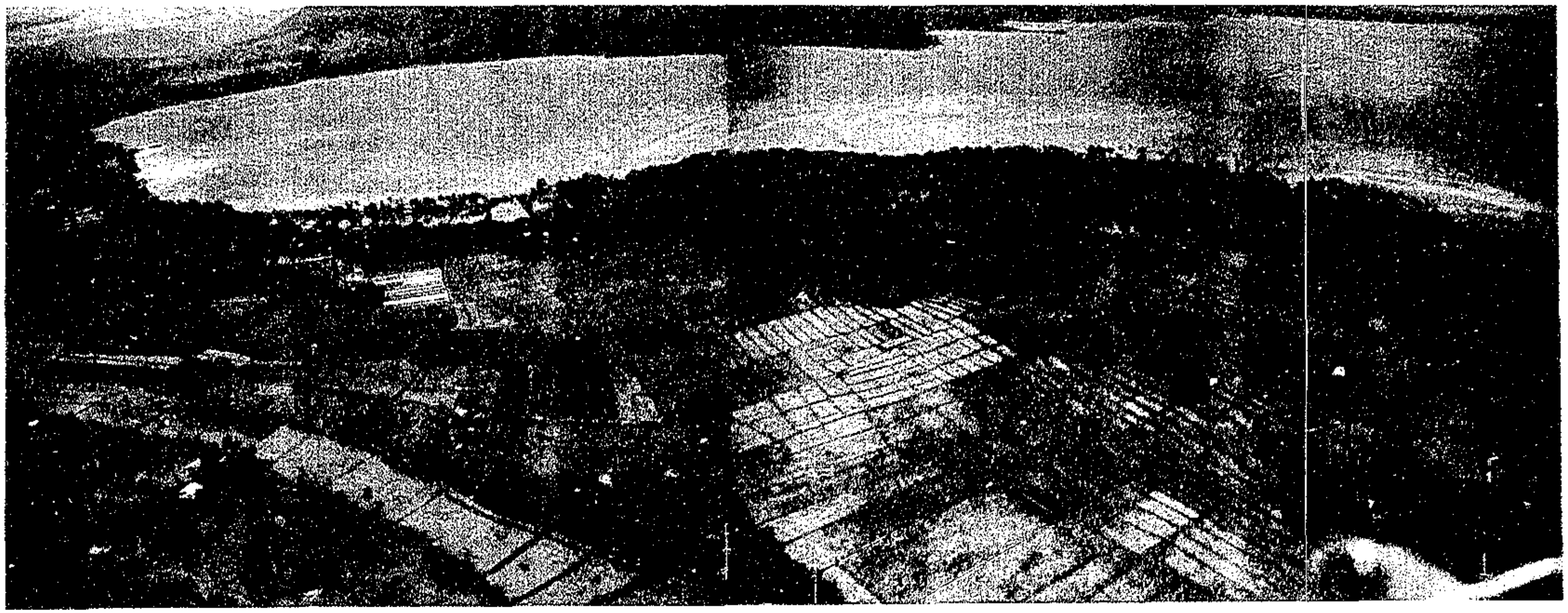
GENERAL ARRANGEMENT OF EQUIPMENT

JAPAN INTERNATIONAL COOPERATION AGENCY

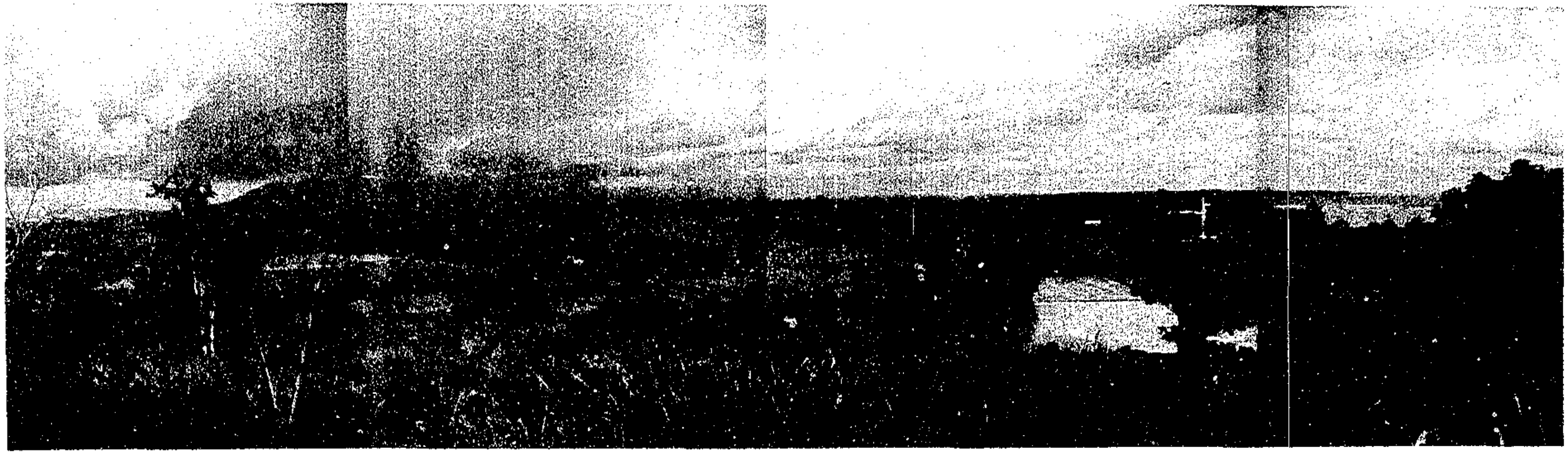
D.R.; SUBMITTED;
T.R.; RECOMMENDED;
C.K.; APPROVED;

SITE—A Masinloc, Zambales
Bird's-Eye View of the Zambales Site

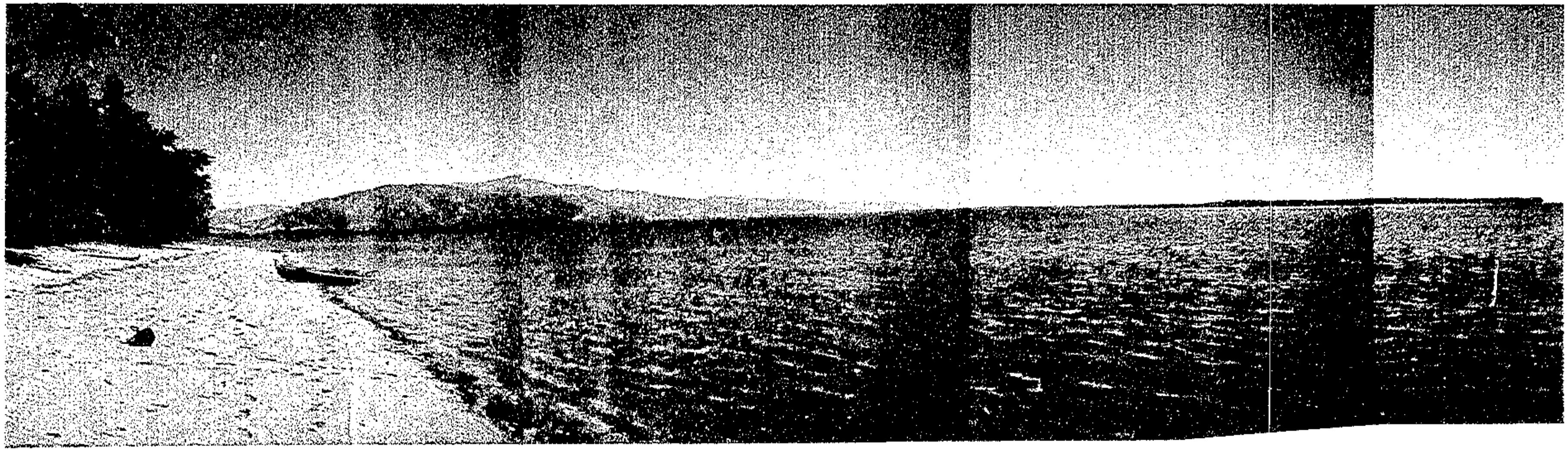
SITE–A Power Station & Coal Storage Yard



SITE–A In-land Ash Disposal Area & Oyon Bay

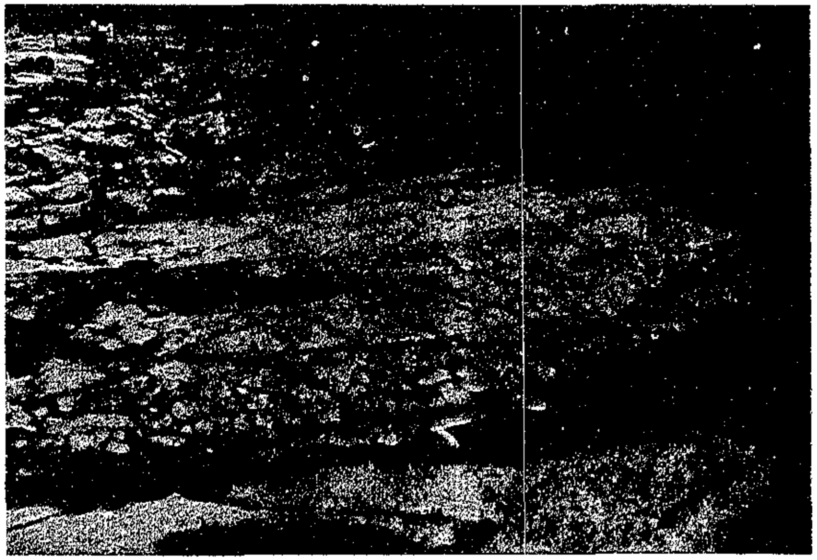


SITE–A In-land Ash Disposal Area



SITE–A Approach Channel & Coal Unloading Jetty Site

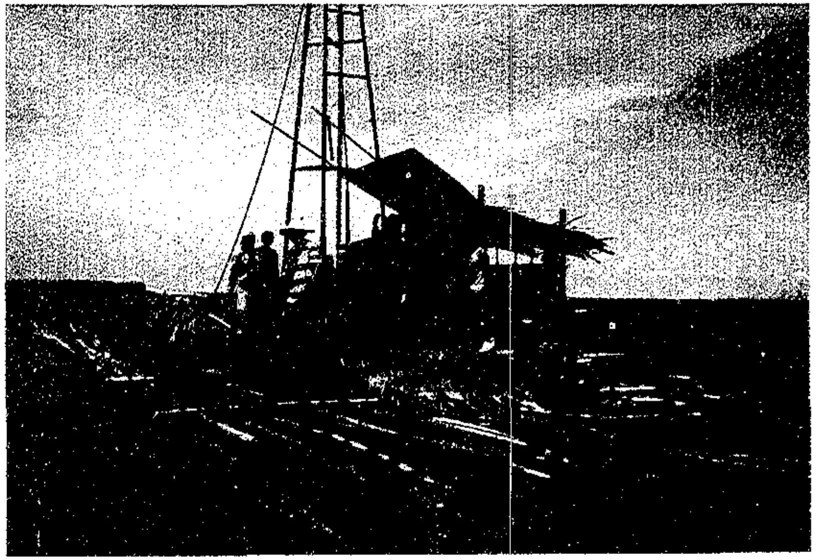
(In-land Area)



(Offshore Area)

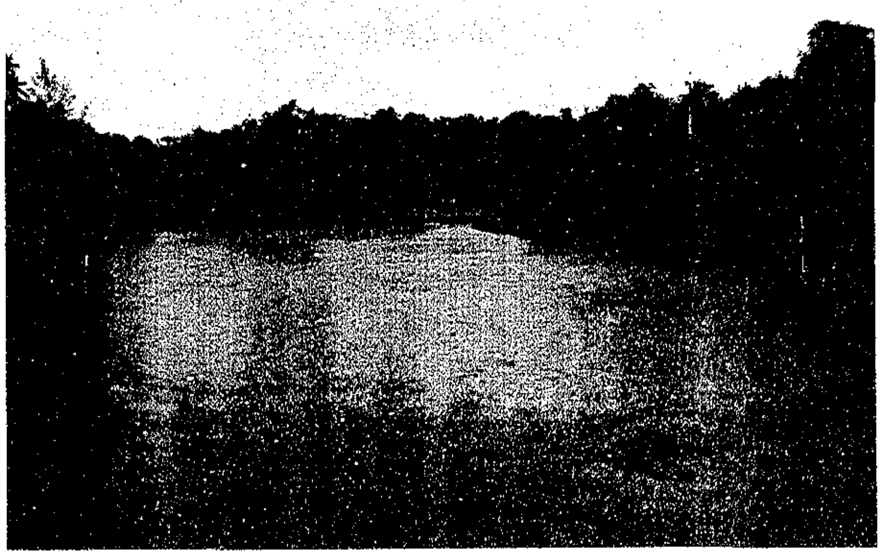
SITE–A Geological Conditions of Site

(In-land Area)



(Offshore Area)

SITE–A Boring Works in Site



SITE—A Freshwater Intake Site
(Masinloc River)

SITE—B San Juan, Batangas

SITE—C Limay, Bataan

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ABBREVIATIONS'

AD	:	Air Dried Basis
AFT	:	Ash Fusion Temperature
AH	:	Air Pre-heater
AN	:	Natural Air Cool
API	:	American Petroleum Institute
AR	:	As Received Basis
ARCO	:	Atlantic Rich Field Company
AVR	:	Automatic Voltage Regulator
B	:	Breadth
B/A	:	Base Acid Ratio
BOO	:	Build, Own and Operate
BOD	:	Biochemical Oxygen Demand
BOT	:	Build, Operte and Transfer
BP	:	British Petroleum
Cap.	:	Capacity
CCA	:	Coal Council of Adviser
CB	:	Circuit Breaker
CIF	:	Cost, Insurance and Freight
COA	:	Contract of Affreightment
COD	:	Chemical Oxygen Demand
CPI	:	Corrugated Plate Interceptor
CRA	:	Con-zinc Rio Tinte of Australia
CS	:	Conventional Substation
CW	:	Circulating Water
CWP	:	Circulating Water Pump
D	:	Diameter
DC	:	Direct Current
DD	:	Detail Design
DH	:	Drill Hole
DL	:	Datum Level
DSL	:	Diesel
DWT	:	Dead Weight Ton
E	:	East
ECR	:	Economical Continuous Rating
EIRR	:	Economic Internal Rate of Return
EMD	:	Environmental Management Department
EO	:	Executive Order

EPA	:	Environmental Protection Agency
EPDC	:	Electric Power Development Company
ERB	:	Energy Regulatory Board
ESP	:	Electrostatic Precipitator
FC	:	Foreign Currency
		Fixed Carbon
FDF	:	Forced Draft Fan
FIRR	:	Financial Internal Rate of Return
FL	:	Floor Level
FS	:	Feasibility Study
FT	:	Fluid Temperature
G	:	Gal
Geo.	:	Geothermal
GDP	:	Gross Domestic Product
GHB	:	Gladstone Harbor Board
GIS	:	Gas Insulated Substation
GNP	:	Gross National Product
GRF	:	Gas Recirculation Fan
Grid	:	Electric Power System
HGI	:	Hard Grove Index (Index of Grindability)
HO	:	Head Office
		Heavy Fuel Oil
HT	:	Hemispherical Temperature
HV	:	Heating Value
HVDC	:	High Voltage Direct Current Transmission Line
I, Is.	:	Island
IAEA	:	International Atomic Energy Agency
IDF	:	Induced Draft Fan
IDT	:	Initial Deformation Temperature
IMF	:	International Monetary Fund
JICA	:	Japan International Cooperation Agency
LNG	:	Liquefied Natural Gas
L, LOA	:	Length of Overall
LC	:	Local Currency
		Letter of Credit
LME	:	London Metal Exchange
Max.	:	Maximum

MC	:	Multi Cyclone
		Metal Clad Switchgear
MCR	:	Maximum Continuous Rating
Min.	:	Minimum
MERALCO	:	Manila Electric Company
MMIC	:	Marinduque Mining & Industrial Corp.
MSB	:	Maritime Service Board
MSV	:	Main Stop Valve
N	:	North
NAPOCOR	:	National Power Corporation
NE	:	North East
NEA	:	National Electricity Administration
NEDA	:	National Economic and Development Authority
NHI	:	Net Heat Input
NOx	:	Nitrogen Oxides
NPCC	:	National Pollution Control Commission
NPV	:	Net Present Value
NW	:	North West
OC	:	Open Cut Mining
OEA	:	Office of Energy Affairs
OFAF	:	Forced Oil Circulation, Forced Air Cooling
ONAF	:	Oil Immersed, Forced Air Cooling
OPEC	:	Organization of Petroleum Exporting Countries
Ox	:	Oxides
PA	:	Plan Area
PAGASA	:	The Philippines Atmospheric, Geophysical and Astronomical Service Administration
PAF	:	Primary Air Fan
Pf	:	Power Factor
pH	:	Potential of Hydrogen
PNOC	:	Philippine National Oil Company
PNOC-CC	:	PNOC-Coal Corporation
PS	:	Power Station
PWCS	:	Port Walata Coal Service
PWL	:	Noise Source Power Level
RO	:	Regional Office

ROM	:	Run of Mine
Rs	:	Slagging Index
RSV	:	Reheat Stop Valve
S	:	South
		Sulfur
SCR	:	Short Circuit Ratio
SOx	:	Sulfur Oxides
SPL	:	Sound Pressure Level
SPM	:	Suspended Particulate Matter
SS	:	Suspended Solid
		Substation
ST	:	Softening Temperature
SVP	:	Senior Vice President
SW	:	South West
TDS	:	Total Debt Service
		Total Dissolved Solid
TL	:	Transmission Line
TM	:	Total Moisture
Tr.	:	Transformer
UG	:	Under Ground Mining
USA	:	United Stats of America
USSR	:	Union of Soviet Socialist Republics
VAT	:	Value Added Tax
VM	:	Volatile Matter
W	:	West
XGS	:	Export of Goods and Service
ZCFPP	:	Zambales Coal-fired Power Project

UNITS

Prefixes

μ	:	micro-= 10^{-6}
m	:	milli-= 10^{-3}
c	:	centi-= 10^{-2}
d	:	deci- = 10^{-1}
da	:	deca- = 10
h	:	hecto-= 10^{2}
k	:	kilo- = 10^{3}
M	:	mega- = 10^{6}
G	:	giga- = 10^{9}

Units of Length

m	:	meter
mm	:	millimeter
cm	:	centimeter
km	:	kilometer
in	:	inch
ft	:	feet
yd	:	yard

Units of Area

cm^2	:	square centimeters
m^2	:	square meters
km^2	:	square kilometers
ft^2	:	square feet
yd^2	:	square yards
ha	:	hectare

Units of Volume

m^3	:	cubic meters
l	:	liter
kl	:	kiloliter

Units of Mass

g	:	gram
kg	:	kilogram
t	:	ton (metric)
lb	:	pound

Units of Density

kg/m^3	:	kilograms per cubic meters
t/m^3	:	tons per cubic meters

mg/m^3N	:	miligram per normal cubic meters
g/m^3N	:	gram per normal cubic meters
ppm	:	parts per million
μg/scm	:	microgram per standard cubic meters

Units of Pressure

kg/cm^2	:	kilograms per square centimeters (gauge)
lb/in^2	:	pounds per square inches
mmHg	:	millimeter of mercury
mmHg abs	:	millimeter of mercury absolute
mAq	:	meter of aqueous
lb/in^2, psi	:	pounds per square inches
atm	:	atmosphere

Units of Energy

kcal	:	kilocalorie
kWh	:	kilowatt-hour
MWh	:	megawatt-hour
GWh	:	gigawatt-hour
Btu	:	British thermal unit

Units of Heating Value

kcal/kg	:	kilocalorie per kilogram
Btu/lb	:	British thermal unit per pound

Units of Heat Flux

$kcal/m^2h$	:	kilocalorie per square meters hour
Btu/ft^2h	:	British thermal unit per square feet hour

Units of Temperature

deg	:	degree
°	:	degree
C	:	Celsius or Centigrade
°C	:	degree Celsius or Centigrade
F	:	Fahrenheit
°F	:	degree Fahrenheit

Units of Electricity

W	:	watt
kW	:	kilowatt
A	:	ampere
kA	:	kiloampere
V	:	volt
kV	:	kilovolt

kVA	:	kilovolt ampere
MVA	:	megavolt ampere
MVar	:	megavar (mega volt-ampere-reactive)
kHz	:	kilohertz

Units of Time

s	:	second
min	:	minute
h	:	hour
d	:	day
y	:	year

Units of Flow Rate

t/h	:	tons per hour
t/d	:	tons per day
t/y	:	tons per year
m^3/s	:	cubic meters per second
m^3/min	:	cubic meters per minute
m^3/h	:	cubic meters per hour
m^3/d	:	cubic meters per day
lb/h	:	pounds per hour
m^3N/s	:	cubic meters per second at normal condition
m^3N/min	:	cubic meters per minute at normal condition
m^3N/h	:	cubic meters per hour at normal condition

Units of Conductivity

μS/cm	:	microsiemens per centimeter

Units of Sound Power Level

dB	:	deci-bell

Units of Currency

₱, P	:	Peso
US$	:	USA Dollar
¥	:	Japanese Yen

CONVERSION TABLES

Length

cm	m	km	in	ft	yd
1	0.01	0.00001	0.3937	0.0328084	0.0109361
100	1	0.001	39.370	3.28084	1.09361
100000	1000	1	39370	3280.84	1093.61
2.54	0.0254	0.000025	1	0.083333	0.027777
30.48	0.3048	0.000305	12	1	0.333333
91.44	0.9144	0.000914	36	3	1

Area

cm^2	m^2	km^2	ft^2	yd^2	ha
1	0.0001	10^{-10}	0.001076	0.00012	10^{-8}
10000	1	0.000001	10.7639	1.196	0.0001
10^{10}	1000000	1	10763911	1195990	100
929.00	0.0929	$9.3x1^{-11}$	1	0.11111	9.29×10^{-6}
8361.27	0.83613	8.4×10^{-7}	9	1	8.36×10^{-5}
10^{8}	10000	0.01	107639.11	11959.90	1

Volume

m^3	l	kl
1	1000	1
0.001	1	0.001

Mass

g	kg	t	lb
1	0.001	0.000001	2.204×10^{-3}
1000	1	0.001	2.20462
1000000	1000	1	2204.62

Density

g/cm^3	kg/m^3	t/m^3
1	1000	1
0.001	1	0.001

Pressure

kg/cm^2	lb/in^2, psi	atm	mmHg	mAq
1	14.2233	0.9678	735.6	10.000
0.070307	1	0.06805	51.71	0.7031
1.0332	14.696	1	760	10.332
0.00135951	0.01934	0.001316	1	0.0135951
0.1000	1.4223	0.09678	73.56	1

Energy

kcal	Btu	kWh
1	3.96832	1.16×10^{-3}
0.251996	1	2.9307×10^{-4}
859.846	3412.14	1

Heat Flux

$kcal/m^2h$	Btu/ft^2h	Btu/in^2h
1	0.3687	2.56×10^{-3}
2.712	1	6.944×10^{-3}
3.906×10^{-2}	144	1

Exchange Rate

₱, P	US$	¥
1	0.04545	6.364
22.0	1	0.007143
0.1571	140	1

EXECUTIVE SUMMARY

OUTLINE OF THE PROJECT PLAN

1.	Name of the Project	Zambales Coal-Fired Power Project
2.	Location of the Site	Barangay Bani, Masinloc, Zambales
3.	Installed Capacity	600 MW (2 x 300 MW)
4.	Annual Utilization Factor	70%
5.	Thermal Efficiency	36.0% (annual average)
6.	Main Fuel	Coal: as design basis, indigenous coal and overseas coal are supposed to be blended 50/50 weight percent. Semirara coal is assumed as indigenous. Lemington coal (Australia) is assumed as overseas coal.

	(Semirara)	(Lemington)
Heating value (as received basis)	4,000 Kcal/kg	6,524 Kcal/kg
Ash Contents	12%	10.39%

7.	Annual Coal Consumption	1,600,000 ton (2 x 840,000 ton/unit)
8.	Coal Storage Capacity	300,000 ton (maximum)
9.	Size of Coal Carrier	60,000 DWT (for overseas coal) 5,000 DWT (for indigenous coal)
10.	Annual Ash Generation	208,000 m^3
11.	Required Site Area	Total: 106 ha.
12.	Required Fresh Water	2,600 m^3/day (maximum)
13.	Cooling Water	25 m^3/sec
14.	Project Schedule	Loan Approval January, 1991 Commencement of Work April, 1993 Taking Over May, 1996 (No.1) November, 1996 (No.2)
15.	Estimated Construction Cost	Total : US$750 million

Executive Summary

(1) Economic Environment and Demand for Electrical Power

Since 1987, the economic environment in the Philippines rapidly improved, and the country's GNP in 1987 and 1988 rose to 5.7 and 6.7 percent, respectively, demonstrating a growing pace of recovery. Alongside, demand for electrical power is growing dramatically, up nearly 9 percent. The electrical power systems in the Philippines are divided into three – Luzon, Visayas and Mindanao. Luzon system is the largest, accounting for some 70% of total capacity for the entire country. Installed capacity in 1988 was 4,100 MW. Also, power demand of this system is 76% for the whole Philippines.

The following table shows the growth in total power demand and peak demand in the Luzon grid from 1986 to 1988.

	1986	1987	1988
Total Power Demand (GWh)	14,756 (2.1)	16,030 (8.6)	17,439 (8.8)
Peak Demand (MW)	2,435 (5.4)	2,592 (6.4)	2,780 (7.3)

Note: Figures in parentheses show growth over preceding year (in percentage points).

(2) Power Development Plan for the Luzon Grid

Luzon grid's total capacity in 1988 was 4,100 MW, but obsolescence of oil-fired plant and drop in hydraulic plant during the dry season cut capable total supply capacity to around 3,200 MW. In June 1988, NAPOCOR formulated its Power Development Program. In the program, NAPOCOR outlines a plan to develop 3,200 MW of coal-fired power source up to the year 2000. 3,000 MW of the new power source is expected to be developed in Luzon Island.

However, a review of future power demand taking into account the growth in demand in 1988 shows the possibility of power shortage after 1993, even when all new power generation plants are completed as planned in the program. Hence, an earlier execution of the program is necessary, and it also shows that construction of a second unit in Masinloc must continue.

(3) Site Selection

NAPOCOR conducted a preliminary study to select the site for the new coal-fired thermal power project in 1987. The JICA study mission evaluated the three candidate sites that NAPOCOR had selected, Masinloc Zambales, San Juan Batangas and Limay Bataan. Evaluation is based on economic viewpoint in relation to items that are affected by regional characteristics such as location of port, roads, ash disposal, foundation, etc., and excludes equipment and facility-related factors that are unaffected by the locality. The following is the evaluation results of each site compared to in-land ash disposal at Masinloc site. The JICA study mission concluded after discussion with NAPOCOR that Masinloc is the most suitable candidate for the site.

(Unit: in thousand dollars)

	Masinloc	San Juan	Limay
In-land Ash Disposal	(base)	(base)+23,200	impossible
Offshore Ash Disposal	(base)+36,900	(base)+78,400	(base)+41,100

(4) Demand and Supply of Coal

NAPOCOR has requested a study of both indigenous and imported coal for use in this project. In light of the energy diversification policy instituted by the Philippine government, the use of indigenous coal to the best possible extent was studied. First, the supply capability of indigenous coal was checked, and the possibility of supply was examined based on "The Republic of the Philippines, The Master Plan Study of the Coal Mining Technology Development" executed by JICA in 1987. The results show:

(i) The indigenous coal supply for thermal power generation in Luzon is mainly Semirara coal.

(ii) NAPOCOR plans to develop 3,000 MW coal-fired thermal power projects in the Luzon island up to the year 2000. In contrast, Semirara coal supply can be maintained at 50% of necessary fuel demand until 1996 but is expected to decline to 30% in 1997 and thereafter.

Hence, there is no other alternative than to import coal to supplement the shortage.

Demand & Supply of Indigenous Coal

(Unit: 10,000 Btu/lb. in thousands tons)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Demand	2597	2631	2668	3642	4587	4669	4769	4882	6863	8853	10852	12862
Supply	1342	1415	1495	2232	2651	2811	2981	3111	3253	3410	3714	3991
Shortage	1255	1216	1173	1410	1936	1858	1788	1771	3610	5443	7138	8871
Self-Sufficiency Rate (%)	51.7	53.8	56.0	61.3	57.8	60.2	62.5	63.7	47.4	38.5	34.2	31.0

The relationship of demand and supply in all of the Philippines shows the degree of self-sufficiency in coal falls below 50% in 1997 and thereafter down to 31.0% in 2000. However, Semirara is the only indigenous coal available for the thermal power project in Luzon island, and there is little possibility of securing other sources in the Republic.

Coal Demand at Luzon Thermal Power Plant & Semirara Coal

(Unit: 10,000 Btu/lb. in thousands tons)

	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Demand from Luzon System	930	930	930	1860	2790	2790	2790	2790	4650	6510	8370	10230
Semirara Supply	609	609	609	609	1257	1473	1473	1473	1473	1473	1473	1473
Shortage	321	321	321	1251	1533	1317	1317	1317	3177	5037	6897	8757
Self-sufficiency (%)	65.5	65.5	65.5	32.7	45.1	52.8	52.8	52.8	31.7	22.6	17.6	14.4

(5) Procurement of Imported Coal

The important points to consider in the procurement of imported coal are:

1) Property and potential quantity of coal to be imported
2) Type of contract
3) Method of transport

Moreover, there is the problem of:

4) Readiness in NAPOCOR fuel organization for stable, long-term coal import.

The Pacific Rim coal producers such as Australia, Indonesia and China are geographically close to the Philippines and they produce quality bituminous coal. Australia has a history of exporting steaming coal, and Indonesia is studying expansion of steaming coal output from the Kalimantan area. China has coal potential and is a possible candidate in the future. Canada, U.S.A., Colombia, and other Pacific Rim countries also produce quality coal. Japan and some Asian countries import from these coal producers, and coal procurement from these nations is possible.

Type of contract should be directed to achieve long-term stability of electricity rates, and long-term contract must be concluded, with spot contracts included as well to adapt to fluctuations in power demand. Though related to the quantity of procurement, emphasis should be placed on long-term contracts, with 80 to 90 percent of the necessary supply obtained in this manner for assurance of quantity and stability in price. It is also closely related to supplier and how the type of contract is selected. It is a common practice to sign long-term contract with a source which is geographically close and is able to provide stable quantities of coal.

Overseas coal procurement requires not only gathering a wide variety of data of coal market, foreign exchange trends and maritime market, but also analysis, and strategy planning. Hence, an organization for coal procurement must be formed in NAPOCOR, and experts trained and assigned.

(6) Layout

The general layout of the plant has been planned in light of climate, maritime condition, topography, geology, and other natural elements, ease in power plant operation, and economic feasibility. Hence, the powerhouse and coal storage yard have been located east of Bani Point. The required area for the entire plant is 106 ha. including a coal storage yard. The area of the power station is 18 ha., and the area of coal storage yard is 15 ha. Ash disposal area has been located inland adjacent to the power plant (30 ha. for 10 years and 73 ha. for 30 years).

(7) Port Plan

The planned site is facing the Oyon Bay which includes Masinloc Port. Coral reefs prevail in the bay, so inside of the bay is relatively calm. However, the navigation route to the plant site has three winding points and is 5,500 m long. At present, 40,000 DWT bulk carriers enter Masinloc Port. Part of the existing navigation route will be used for the project for safe entry and mooring of 60,000 DWT coal carriers. The route width of 350 m and a turning basin with diameter of 470 m in front of the jetty are necessary. To secure the required water depth and route width, a volume of 900,000 m^3 must be dredged.

(8) Coal Handling System Plan

Coal unloading facilities widely used are grab bucket and continuous unloading systems. The continuous system has been selected for economic reason. Unloader capacity has been planned at 2 x 700 t/h, and storage capacity of 300,000 tons (45 days supply). Simulation was conducted to verify the optimization of these facilities. The result indicated a need of storage for 45 days for overseas coal, but storage capacity for 45 days is believed not necessary for indigenous coal. This is an issue that must be studied in greater depth in the future since indigenous coal is lignitic which is susceptible to spontaneous combustion. For noise reduction, stacker and reclaimer have been chosen for handling coal at the storage yard.

(9) Fresh Water Supply Plan

The required quantity of fresh water in the project is 2,600 m^3 per day as a maximum value. The Masinloc river has been chosen as the water source, and water will be drawn by a pipeline. The length of the pipeline is approximately 10 km.

(10) Selection of Design Coal

The preliminary design of power generation facility is based on use of indigenous and overseas coal on 50/50 weight percent blending basis. Semirara coal (Himalian pit 4,000 kcal/kg) is considered as indigenous coal, and Lemington coal (6,524 kcal/kg) of Australia is adopted as overseas coal. The representative qualities are as follows:

	Semirara Coal	Lemington Coal
Heating Value (kcal/kg)	4,000	6,524
Total Moisture (%)	29	9.77
Volatile Matter (%)	30.2	30.05
Fixed Carbon (%)	28.8	49.8
Ash Content (%)	12	10.39

Lemington coal has been selected as representative overseas coal. It was chosen from the standpoint that imported coal will be blended with Semirara coal. Procurement of a variety of overseas coal will become necessary in the course of project management in the future.

For this reason, detailed description of the method to assess coal qualities is included in this report. Reasonable source is expected to be selected from many types of overseas coal based on these standard of measurement.

(11) Preliminary Design and Outline of Power Generation Facility

The preliminary design of the power generation facility was prepared with emphasis focused on the following points:

- Each facility must be planned for economical operation
- The fact that indigenous and imported coal will be blended
- Standardized specifications will be defined to facilitate maintenance
- Electrical characteristics due to transmission over a distance of 250 km to Manila

Features in design founded on these factors are as follows:

1) Steam conditions have been defined based on economic comparison within standard range to make conditions most economical in maintenance over a 30-year span.

2) By reason that coal types with various qualities will be used, redundancy of facilities have been avoided, and the boiler has been planned after determining the prospects in supply of indigenous coal. Study of indigenous coal blending ratio found that allowable margin of 15% both in increase and decrease is possible in the design stage. This requires accumulation of know-how in the operational stage.

3) Short circuit ratio of 0.58 and power factor of 0.9 of generator have been defined after system analysis.

4) In view of the environmental effects, the stack height is planned at 120 m. For economic reason, it will be made of concrete.

The outline of the generating facilities based on the results of the study is shown in the table below.

Transmission facilities are being studied separately by NAPOCOR and have been excluded from this study.

Outline Description of Generating Facilities

1. Basic Factor of Design

(1)	Installed Capacity	600 MW (2 x 300 MW)
(2)	Annual Utilization Factor	70%
(3)	Thermal Efficiency	36.0% (annual average)
(4)	Station Service Factor	7.5%

(5) Main Fuel (coal)

	(Semirara coal)	(Lemington coal)
Heating value (as received basis)	4,000 kcal/kg	6,524 kcal/kg
Ash contents	12%	10.39%
Blending ratio	50%	50%

(6)	Annual Coal Consumption	1,680,000 ton (2 x 840,000 ton)
(7)	Coal Storage Capacity	300,000 ton (maximum)
(8)	Vessel Size	60,000 DWT (for overseas coal) 5,000 DWT (for indigenous coal)

2. Land Reclamation

(1) Site Area

Total	106 ha
Power station	18 ha
Coal yard	15 ha
Ash disposal area	31 ha (for 10 years)
	73 ha (for 30 years)

(2) Site Formation Level — DL + 3.5 m

3. Port Facilities

(1) Coal Unloading Jetty

Length	240 m
Width	25 m
Depth	15 m

(2) Water Channel

Length	5,500 m
Width	350 m
Depth	16.5 m

4. Coal Handling and Storage Facilities

(1)	Coal Unloader	Bucket-chain type continuous unloader
	Capacity	2 x 700 t/h
(2)	Stacker	1 x 1,600 t/h

(3) Reclaimer	2 x 800 t/h
(4) Coal Storage Yard	
Storage capacity	300,000 ton 150,000 ton (indigenous) 150,000 ton (overseas)

5. Fuel Oil Storage Tank

(1) Heavy Oil Tank	2 sets x 4,000 kL
(2) Light Oil Tank	1 set x 1,000 kL

6. Fresh Water Supply System

(1) Quantity	2,600 m^3/day (max)
(2) Fresh Water Tank	1 x 10,000 m^3

7. Boiler System (per unit)

(1) Boiler	Single drum, outdoor type
Evaporation	(MCR) 990 t/h (ECR) 930 t/h
(2) Induced Draft Fan	2 x 16,000 m^3N/min
(3) Forced Draft Fan	2 x 6,390 m^3N/min
(4) Coal Pulverizer	5 x 41 t/h

8. Turbine System (per unit)

(1) Turbine	Tandem compound, reheat, regenerative condensing turbine	
Rated output (at generator end)		300 MW
Steam pressure	(at MSV)	169 kg/cm^2g
Steam temperature	(at MSV)	538°C
	(at RSV)	538°C
Rotating speed		3,600 rpm
(2) Condenser		
Cooling seawater temperature (Design)	Inlet 31°C Outlet 39°C	
Cooling seawater quantity	41,500 m^3/h	

(3) Condensate Pump — 3 x 390 t/h

(4) Boiler Feed Water Pump — Motor driven 3 x 520 t/h

9. Condenser Cooling Water Facilities

(1) Intake

Type	Deep water intake
Dimension	2 sets x 9.0 m

(2) Intake Pipe Line

Type	Embedded steel pipe
Dimension	Inner diameter 3 m Length-mean 2 lines x 530 m

(3) Intake Pump Pit

Type	Reinforced concrete structure
Dimension	Width 24.6 m Height 12.7 m Length 35.0 m

(4) Outlet Pit

Type	Reinforced concrete structure
Dimension	Width 12 m Height 10.5 m Length 25 m

(5) Outlet

Type	Rubble mound revetment
Dimension	Width 6.0 m Height DL + 3.0 m Length 500 m

10. Electrical Facilities (per unit)

(1) Generator

i) Type — Indoor type, horizontal shaft, 3 phase, hydrogen-cooled

ii) Rating

Generator output	334,000 kVA
Voltage (according to manufacturer's standard)	18 to 24 kV
Power factor	90%
Short circuit ratio	0.58

iii) Exitation — Thyrister or Brushless

(2) Main Transformer

i) Type	Outdoor type, 3 phase, forced oil circulating, forced air-cooled
ii) Rating	
Capacity	320,000 kVA
Voltage	18 to 24/230 kV

(3) House Transformer

Capacity	30,000 kVA
Voltage	18 to 24 kV/6.9 kV

(4) General Service Transformer

Capacity	40,000 kVA
Voltage	230/6.9 kV

(5) Switchyard

i) System	Outdoor double bus bar
ii) Circuit breaker	
Type	Porcelain type
Rating	242 kV 2,000 A 31.5 kA (Interrupting current)

(6) 6.9 kV Metal Clad Switchgear

i) Cubicle type	Indoor, single bus, metal enclosed type
ii) Circuit breaker	SF_6 6.9 kV or vacuum type

11. Ash Handling System (per unit)

i) Chain conveyor	11.7 t/h
ii) F.A Vacuum Collector	14.6 t/h
iii) Fly ash silo	1 x 1,000 m^3

12. Powerhouse — Steel structure; Ground floor area 5,800 m^2

13. Stack — Height 120 m

14. Environmental Protection Facilities

(1)	Electrostatic Precipitator	Dry type electrostatic precipitator
	Flue gas capacity	$1,034 \times 10^3$ m^3N/h
(2)	Waste Water Treatment	
(3)	Coal Yard Water Treatment	
(4)	Waste Water Treatment for Ash Disposal Area	

(12) Environmental Control and Evaluation

In environmental control for coal-fired thermal power plant, foremost attention is given to prevention of adverse effects on the surrounding areas. The Republic of the Philippines has laws and regulations on environmental protection. Environmental policy has been implemented according to the legal regulations. Hence, the result of environmental assessment at Masinloc is far below the Philippine legal regulations, and effects of plant construction on the surroundings is designed to be extremely small.

As specific control measures, stack is 120 m in height and electrostatic precipitator with more than 99% efficiency has been recommended to maintain the favorable conditions, adequately satisfying environmental standards. Also, simulation of effect of thermal effluent shows virtually no influence on the surrounding environment.

(13) Construction Schedule

Construction schedule can be divided into:

- from submission of this report to contract award
- from contract award to the taking over

The period between contract award and the taking over is the actual period of construction, and this period has been calculated, based on existing plants of similar nature, to be 43 months.

In the period until contract award, finance preparation, tender document compilation, selection of consultants and contractors, etc., and other administrative actions must be taken. Time required for these actions can be reduced considerably by the method selected.

NAPOCOR has already built and is operating coal thermal plant in Calaca. Hence, it can prepare tender documents. Taking these factors into account, it is believed that it is possible that the plan can be completed at an early stage.

The major points in the schedule after this report has been submitted in March 1990 are as follows:

Loan Approval	Jan. 1991
Tendering	Oct. 1991
Contract award	Oct. 1992
Commencement of work	Apr. 1993
Drum lifting	Nov. 1994
Initial firing	Nov. 1995
Takeover of No.1 Unit	May 1996

(14) Construction Cost

The construction cost of the Zambales Coal-fired Power Project is estimated after due consideration cost of similar project. The estimated construction cost are shown as follows:

(US$ x 1,000)

	1U		2U		Total		
	F.C.	L.C.	F.C.	L.C.	F.C.	L.C.	F.C+L.C
Direct cost	288,642	100,333	177,359	30,722	466,001	131,055	597,056
Indirect cost	24,156	15,868	14,070	6,193	38,226	22,061	60,287
I.D.C.	22,228	49,471	11,148	11,973	33,376	61,444	94,820
Total	335,026	165,672	202,577	48,888	537,603	214,560	752,163

(15) Economic Evaluation

The economic performance of the proposed coal-fired power plant project was analyzed by using three methods of analysis:

1) "Benefit/cost" analysis,

2) "Equalizing discount rate (so-called "Economic internal rate of return - EIRR) analysis and

3) "Screening curves" (Time-cost curves) analysis

The most important factor which influences economic analysis of thermal power development project is fuel prices. The proposed project is designed to use the Semirara coal and overseas coal on a split basis, and the average cost of those coals is estimated at US$55.15/ton based on prices in 1989. On the other hand, price of heavy oil which has 1.0% of sulfur content equivalent to average sulfur content (0.55%) of coal is estimated at US$137/kl which is 1989 price.

However, range of fluctuation of heavy oil price has been around 60% in the last 4 years, for example heavy oil price which has 1.0% of sulfur content was US$207/kl.

The heavy oil price, which has wider range of fluctuation than coal price, is expected to become steadily higher. Considering the above situation, the following two kinds of heavy oil prices are adopted for the economic analysis.

	Base Analysis	Sensitivity Analysis
Coal Price (US$/t)	55.15	10% up
Heavy Oil Price (US$/kl)	137	207

Based on this evaluation, the following conclusions were obtained.

(1) The equalizing discount rate between the proposed project and the alternative thermal power plant is 4.0% in the case of the Base Analysis and is from 20.2% to 22.3% in the case of the Sensitivity Analysis.

(2) From the viewpoint of optimum power source structure for Luzon grid, the proposed project does not have an advantage over oil-fired thermal power plants until 1997 after commissioning on the assumption that market rate (assumption rate: 9%) is adopted as interest rate to finance all construction costs of both the proposed project and the oil-fired thermal power plant and heavy oil price is US$137/kl.

However, it is profitable to construct coal-fired thermal power plants which has from 1,600 MW to 1,700 MW capacity on the assumption that heavy oil price is US$207/kl.

(3) It is profitable to construct coal-fired thermal power plants which has around 710 MW capacity on the assumption that an

interest rate of some soft loan (assumption rate: 3.9%) is adopted to finance the construction cost even if heavy oil price is US$137/kl.

(16) Financial Analysis

The results of financial analysis for the project are as follows:

a) The Rate of Return (ratio of operating income to average net fixed assets in operation) will be 0.96% in average for the first 10 years from commissioning and 3.72% in average for the whole service life of 30 years.

b) The yearly cash balance will be influenced by amortization of principal and operating & maintenance costs, therefore, red figure and black figure are presented mutually with the yearly cash balance.

c) The financial internal rate of return will be about 3.37%.