社会開発調査部報告書

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

LOCA WATER UTILITIES ADMINISTRATION
REPUBLIC OF THE PHILIPPINES

CAVITE WATER SUPPLY DEVELOPMENT STUDY IN THE REPUBLIC OF THE PHILIPPINES

VOLUME 2

MAIN REPORT

MAY 1995

KOKUSAI KOGYO CO., LTD.
NIPPON JOGESUIDO SEKKEI CO., LTD.

CAVITE WATER SUPPLY DEVELOPMENT STUDY IN THE REPUBLIC OF THE PHILIPPINES

LIST OF REPORTS

VOLUME 1 SUMMARY
VOLUME 2 MAIN REPORT
VOLUME 3 SUPPORTING REPORT
VOLUME 4 DATA BOOK

The cost estimate was made based on Pesos in January 1995.
(1 dollar = 24.634 pesos = 100.77 yen)

PREFACE

In response to a request from the Government of the Republic of the Philippines, the Government of Japan decided to conduct the master plan and feasibility study on "CAVITE WATER SUPPLY DEVELOPMENT STUDY IN THE REPUBLIC OF THE PHILIPPINES" and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Philippines a study team headed by Dr. Akira Sugiyama, Kokusai Kogyo Co. Ltd. and composed of staff members of Kokusai Kogyo Co. Ltd. and Nippon Jogesuido Sekkei Co. Ltd., three times between April 1994 and March 1995.

The team held discussions with the officials concerned of the Government of the Philippines, and conducted field surveys at the study area. 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 promotion of the project and to the enhancement of friendly relations between our two countries.

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

May 1995

Kimio Fujita
President
Japan International Cooperation Agency

May 1995

Mr. Kimio Fujita
President,
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Dear Mr. Fujita,

We are pleased to submit to you the Final Report on the "CAVITE WATER SUPPLY DEVELOPMENT STUDY IN THE REPUBLIC OF THE PHILIPPINES". This report has been prepared by the Study Team in accordance with the contract signed on March 15 and April 15, 1994 and January 20 and April 19, 1995 between the Japan International Cooperation Agency and the Joint Venture of Kokusai Kogyo Co. Ltd. and Nippon Jyogesuido Sekkei Co. Ltd.

The report contains the result of basic study on the existing state of groundwater and water supply facilities in Cavite, as well as results of the feasibility study of the project on groundwater development and water supply for the selected five areas.

The existing state of groundwater in Cavite is graphically presented in the "HYDROGEOLOGICAL MAP OF CAVITE PROVINCE" attached to the report. The target year for the groundwater development and water supply project in the five areas proposed in the report is 2005. Specific study were conducted on the population and water demand of the target year, site and discharge of water sources to be developed, water supply facilities, and personnel for the operation and maintenance of these facilities. Further, estimation of project cost, financial and economic evaluation were carried out, and the water supply projects for the five areas proposed in the report were found to be feasible.

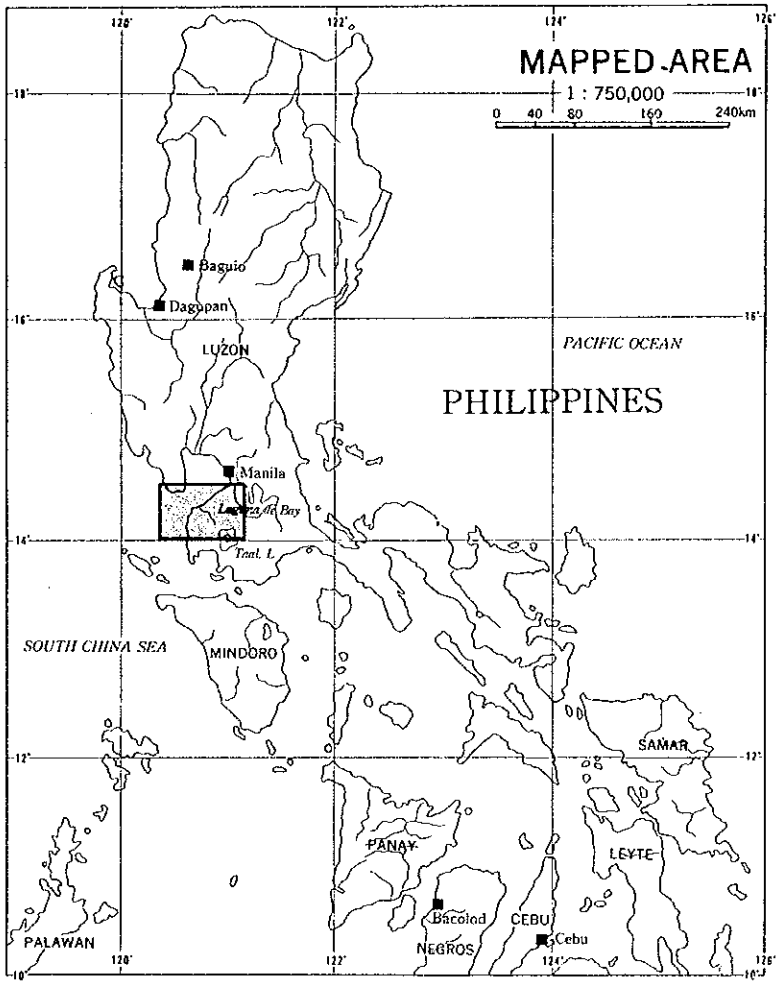
We hope that the fruits of the study shall be utilized effectively not only for the development and sustainable use of groundwater resources, but also for the improvement of the living environment of the residents.

All members of the Study Team wish to express grateful acknowledgement to the personnel of your Agency, Embassy of Japan in the Republic of the Philippines, and also to officials and individuals of the Government of the Republic of the Philippines, especially to the Local Water Utilities Administration, for the assistance they have extended to the Study Team.

Very truly yours,

杉山 明

Akira Sugiyama
Team Leader,
Cavite Water Supply Development Study
in the Republic of the Philippines


MAPPED AREA
1 : 750,000
0 40 80 160 240km
Baguio
Dagupan
LUZON
PACIFIC OCEAN
PHILIPPINES
Manila
Laguna de Bay
Taal L.
SOUTH CHINA SEA
MINDORO
SAMAR
PANAY
LEYTE
Bacolod
CEBU
Cebu
NEGROS
PALAWAN

STUDY AREA

<OUTLINE OF THE PROPOSED PROJECTS>

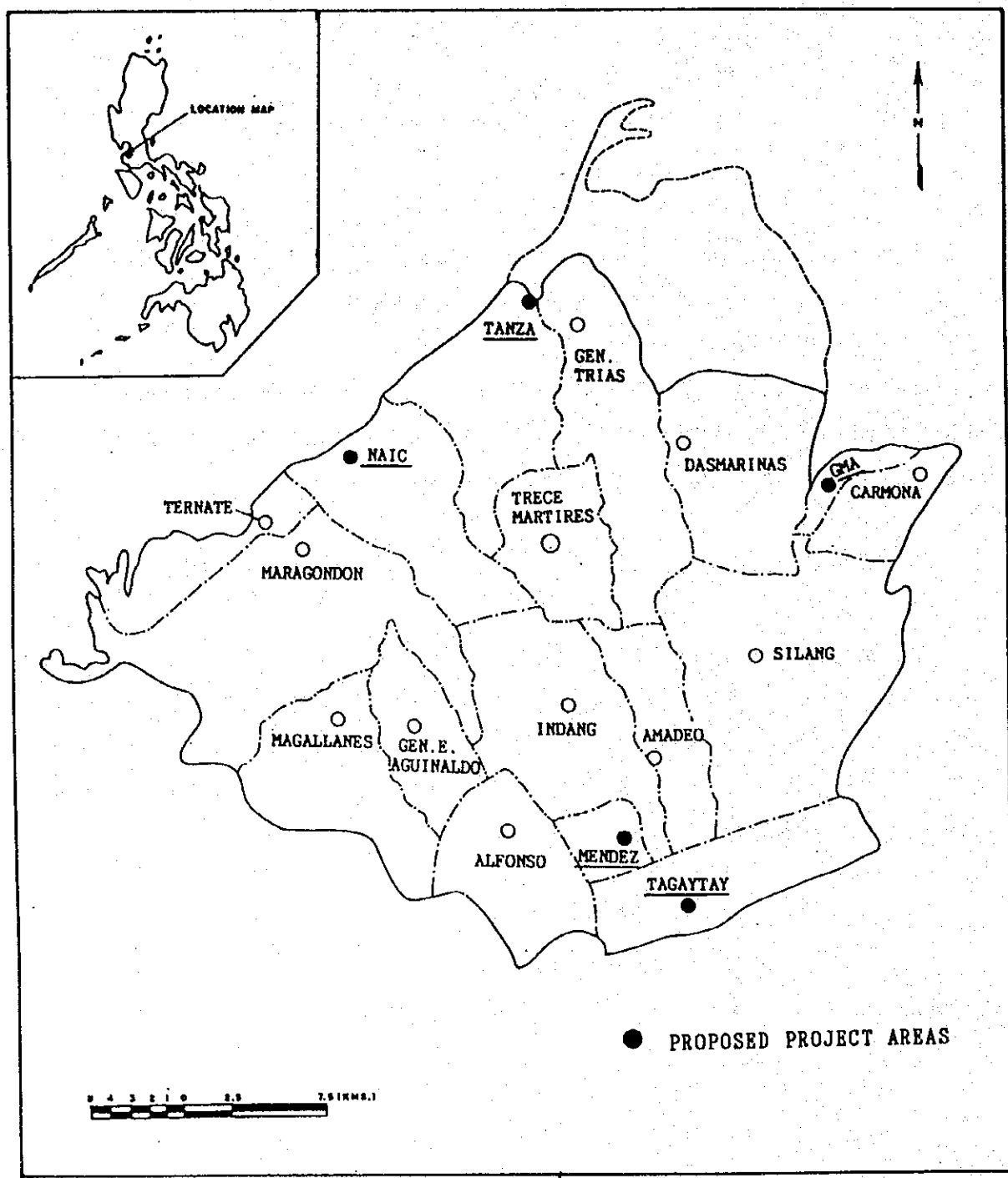
The objective areas of the water supply projects proposed in the Study are G.M.A., Mendez, Naic, Tagaytay City and Tanza as shown in Fig.1.

Table 1 summarizes population, water demand, water sources and project cost for the five areas. The total served population is estimated at 154,000 in 2005, and the total daily water demand is estimated at about 28,000 cum in average.

Fig. 2 shows the implementation schedule of the proposed project.

The project term is divided into Phase I with the target year of 2001 and Phase II with the target year of 2005. The water supply facilities used in Phase I and Phase II are scheduled to be completed by the end of the year–1997 and 2001, respectively. In Mendez and Tagaytay, however, the project shall be completed in Phase I since they have only one water source to be developed.

The project cost was calculated only for Phase I, and the total project cost for the five areas amounted about 183×10^6 pesos (about 730 million yen). According to the result of economic and financial analysis, the proposed projects are feasible for the five areas.

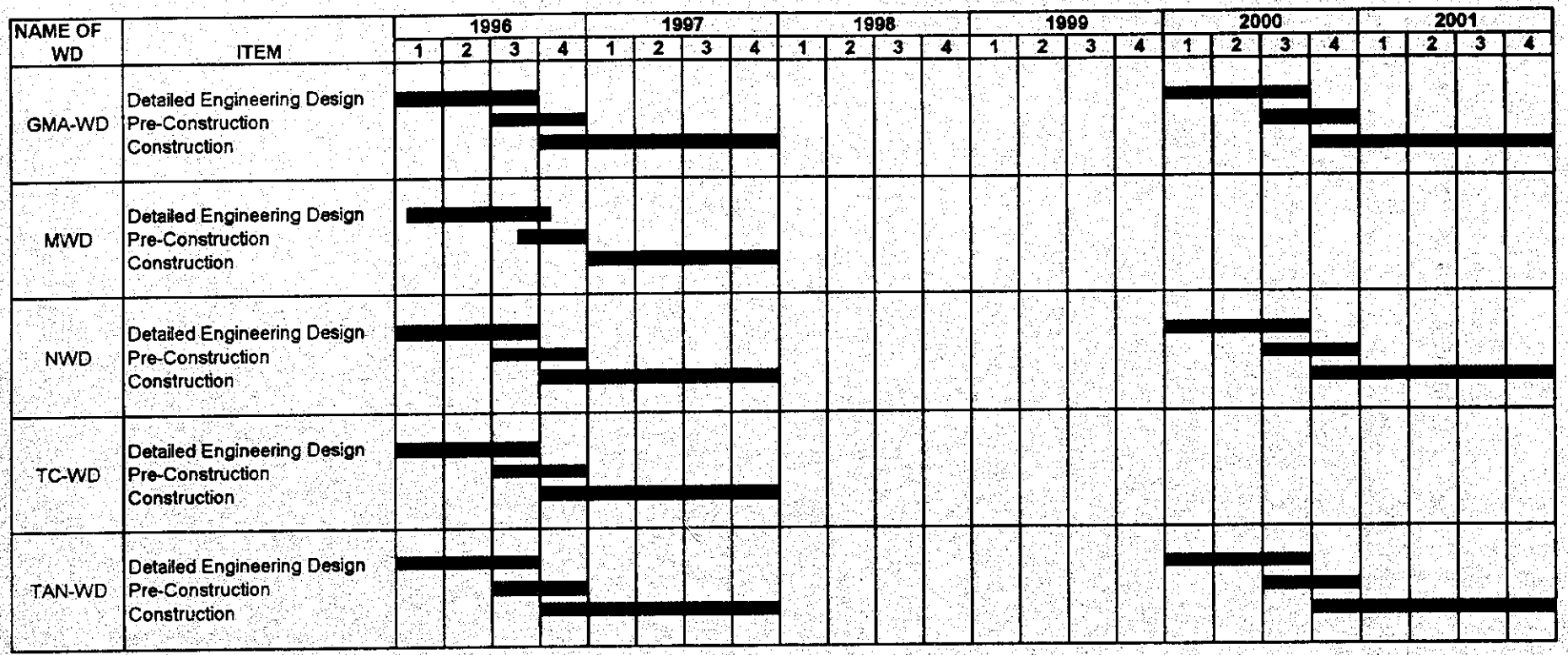


CAVITE WATER SUPPLY DEVELOPMENT STUDY	Fig.1
JAPAN INTERNATIONAL COOPERATION AGENCY	PROPOSED PROJECT AREAS

Table 1. SUMMARY OF PROPOSED PROJECT

Name of WD	Description	1994	1998	2005
G.M.A.	A. Population			
	1) Total Population	59,343	68,771	89,025
	2) Pop. in Service Area	53,404	62,461	80,104
	3) Served Population	20,504	46,151	56,892
	B. Water Demand (cum/d)			
	1) Daily Average	3,194	7,098	9,462
	2) Daily Maximum	4,152	9,227	12,300
	3) Peak Hour	6,388	14,276	18,924
	D. Water Sources	8 wells	12 wells	12 wells
	H. Project Cost (Million Peso) (Phase I only)	–	43.26	–
MENDEZ	A. Population			
	1) Total Population	14,891	15,914	17,908
	2) Pop. in Service Area	7,638	11,070	15,474
	3) Peak Hour	4,121	5,385	13,848
	B. Water Demand (cum/d)			
	1) Daily Average	603	924	2,336
	2) Daily Maximum	784	1,201	3,037
	3) Peak Hour	1,206	1,848	4,672
	D. Water Sources	1 well	2 wells	2 wells
	H. Project Cost (Million Peso) (Phase I only)	–	22.65	–
NAIC	A. Population			
	1) Total Population	25,375	28,526	35,275
	2) Pop. in Service Area	6,910	14,488	28,354
	3) Served Population	2,950	7,002	23,003
	B. Water Demand (cum/d)			
	1) Daily Average	472	1,333	4,673
	2) Daily Maximum	614	1,733	6,075
	3) Peak Hour	944	2,666	9,346
	D. Water Sources	1 spring	2 wells	4 wells
	H. Project Cost (Million Peso) (Phase I only)	–	26.32	–
TAGAYTAY CITY	A. Population			
	1) Total Population	24,316	28,326	37,080
	2) Pop. in Service Area	20,695	24,118	35,936
	3) Served Population	13,270	20,590	30,377
	B. Water Demand (cum/d)			
	1) Daily Average	1,948	4,063	6,079
	2) Daily Maximum	2,532	5,282	7,903
	3) Peak Hour	3,896	8,126	12,158
	D. Water Sources	3 springs	3 springs	3 springs
	H. Project Cost (Million Peso) (Phase I only)	–	79.46	–
TANZA	A. Population			
	1) Total Population	37,122	42,718	54,930
	2) Pop. in Service Area	5,294	31,344	43,952
	3) Served Population	1,315	13,958	29,829
	B. Water Demand (cum/d)			
	1) Daily Average	235	2,266	5,280
	2) Daily Maximum	305	2,946	6,864
	3) Peak Hour	470	4,532	10,560
	D. Water Sources	1 well	2 wells	4 wells
	H. Project Cost (Million Peso) (Phase I only)	–	11.53	–

Fig. 2 **PROPOSED IMPLEMENTATION SCHEDULE**



DEFINITIONS

Well

Deep well	:	Drilled well deeper than 20 m
Shallow well	:	Drilled well shallower than 20 m
Dug well	:	Others

Administrative Unit

Municipality	:	Subordinate executive unit of Province
Poblacion	:	Center of municipality (One poblacion for one municipality)
Barangay	:	Minimum self-governing body

Water Supply System

Level I	:	Water supply system with point source. Usually, served population is less than 500 and unit amount of water consumptions 30–40 l/head/day.
Level II	:	Water supply system with communal faucet. Usually, served population is 500 to 2,000 and unit amount of water consumption is 40–80 l/head/day.
Level III	:	Water supply system with individual household faucet. Usually, served population is more than 2,000 and unit amount of water consumption is more than 100 l/head/day.

Season

Wet season	:	from June to September
Dry season	:	from November to April
Transitional season	:	May and October

ABBREVIATION

Organization or Agency

BAS	:	Bureau of Agricultural Statistics
BLR	:	Bureau of Licensing and Regulation
BRS	:	Bureau of Research and Standards
BSWM	:	Bureau of Soil and Water Management
BWA	:	Barangay Water Association
DENR	:	Department of Environment and Natural Resources
DILG	:	Department of Interior and Local Government
DOH	:	Department of Health
DPWH	:	Department of Public Works and Highways
DTI	:	Department of Trade and Industry
EMB	:	Environmental Management Bureau
FPA	:	Fertilizer and Pesticide Authority
LGU	:	Local Government Unit
LWUA	:	Local Water Utilities Administration
MGB	:	Mines and Geoscience Bureau
MWSS	:	Metropolitan Waterworks and Sewerage System
MPDC/CPDC	:	Municipal/City Planning and Development Coordinator
NAMRIA	:	National Mapping and Resource Information Authority
(NCSO)	:	National Census and Statistic Office
NSO	:	National Statistics Office
NEDA	:	National Economic Development Autohrity
NHA	:	National Housing Authority
NIA	:	National Irrigation Authority
NPCC	:	National Pollution Control Commission
NWRB	:	National Water Resources Board
(NWRC)	:	National Water Resources Council
PAGASA	:	Philippine Atmospheric Geophysical Astronomical Service Agency
PCHRD	:	Philippine Council for Health Research and Development
PPDC	:	Provincial Planning and Development Coordinator
RWSA	:	Rural Waterworks and Sanitation Association
WD	:	Water District
WHO	:	World Health Organization

Survey Point

SP–No.	:	Spring survey point
RG–No.	:	River discharge measurement survey
WL–No.	:	Groundwater level recorder
RR–No.	:	Rainfall recorder
ER–No.	:	Electric Resistivity survey point
EM–No.	:	Electromagnetic survey point

Height

GL	:	Ground level
(MBGL)	:	Meter Below Ground Level
MSL	:	Mean Sea Level
(MAMSL)	:	Meter Above Mean Sea Level
SWL	:	Static groundwater level
DWL	:	Dynamic groundwater level

Hydraulic Terms

h	:	Hydraulic head
k	:	Permeability coefficient (cm/s)
K	:	Hydraulic conductivity
Kv	:	Vertical hydraulic conductivity
Kv/1	:	Seepage storage coefficient
1	:	Thickness of aquifer
Q	:	Pumping rate or Discharge
S	:	Storage coefficient
Sc	:	Specific capacity (m^3/d/m)
Ss	:	Specific storage coefficient
Sy	:	Specific yield
t	:	time
T	:	Transmissivity (Transmission coefficient) (cm/s)
W	:	Flow between layers

Units

cm	:	centimeter
cm/s	:	centimeter per second
cum	:	cubic meter
cum/d	:	cubic meter per day
cum/s	:	cubic meter per second
epm	:	equivalents per million
ha	:	hectare
Hp	:	horse power
hr	:	hour
kg	:	kilogram
km	:	kilometer
KVA	:	kilo volt ampere
kw	:	kilo watt
KWH	:	kilo watt per hour
1/d	:	liter per day
1/min	:	liter per minute
1/min/m	:	liter per minute per meter
1pcd	:	liter per capita per day
1ps	:	liter per second

lps/m	:	liter per second per meter
micro-S/cm	:	micro Siemens per centimeter
mm	:	millimeter
m	:	meter
m/s	:	meter per second
ohm-m	:	ohm meter
pc or pcs	:	piece(s)
ppm	:	part per million

Materials (of pipe)

GI	:	Galvanized iron (pipe)
PVC	:	Polyvinyl chloride (pipe)

Report

P/R (1)	:	Progress Report (1)
P/R (2)	:	Progress Report (2)
IT/R	:	Interim Report
DF/R	:	Draft Final Report
F/R	:	Final Report
M/R	:	Main Report
S/R	:	Supporting Report
D/B	:	Data Book
MAP	:	Hydrogeological Map and Groundwater Potential Map.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

SCOPE OF THE STUDY

CHAPTER 1

SCOPE OF THE STUDY

"Cavite Water Supply Development Study" was conducted by JICA Study Team with the cooperation of LWUA from March 1994 to April 1995 with the aim of evaluating the groundwater development potential, formulating a strategy for water supply development and examining feasibility of water supply project for selected municipalities/cities.

1.1 BACKGROUND AND OBJECTIVES OF THE STUDY

The Government of the Philippines established a long-term plan, "Integrated Water Supply Program 1980-2000" based on "The International Drinking Water Supply and Sanitation Decade" reviewed by WHO.

Cavite Province (total population in 1990 was about 1.15 million) is situated to the southwest of Metro-Manila. A rapid increase in water demand in the province is firmly predicted due to the rapid increase of population accompanying industrialization and urbanization.

LWUA, the administrative body responsible for all the water supply areas outside Metro-Manila, conducted a preliminary study on the future water demand in Cavite Province and concluded that it is impossible to meet the target in the Program through existing water sources and water supply facilities.

Furthermore, almost all the rivers in Cavite Province have low discharge. Consequently, the development of groundwater and/or spring water is necessary to satisfy the future water demand in the province. The urgent need of LWUA is for a systematic development plan for groundwater development since random development is feared to cause exhausting of groundwater resources, pollution of groundwater, salinization near the coast etc..

With this background, the Philippine Government requested the Japanese Government in January 1992 to execute the Study. In response to this request, JICA dispatched a preliminary study team in November 1993, and drew up the Implementing Arrangement on the technical cooperation related to the execution of the Study.

The objectives of the Study are:

(1) to evaluate the groundwater (including spring water) development potential and formulate a strategy for water supply development (using groundwater where available), and

(2) to examine feasibility of water supply project(s) for selected municipalities/cities.

1.2 STUDY AREA

The study area covers the following two (2) cities and fifteen (15) municipalities under LWUA'S jurisdiction in Cavite Province.

Municipality/City

(1) Dasmarinas
(2) Indang
(3) Gen. Mariano Alvarez (G.M.A.)
(4) Mendez
(5) Silang
(6) Tanza
(7) Tagaytay City
(8) Amadeo
(9) Magallanes
(10) Maragondon
(11) Ternate
(12) Alfonso
(13) Naic
(14) Gen. E. Aguinaldo
(15) Carmona
(16) Trece Martirez City
(17) Gen. Trias

A map of the study area is shown in **Fig. 1.2-1.**

1.3 STUDY COMPONENTS AND SEQUENCE

The Study was conducted for a period of fourteen (14) months from March, 1994 to April, 1995. The Study schedule was divided into two (2) phases:

Phase I : Basic Study (March, 1994 - July, 1994)
Phase II : Feasibility Study (August, 1994 - April, 1995)

The components and the flow of the Study are shown in **Fig.1.3-1** and the interrelation among the components is shown in **Fig.1.3-2.**

1.4 STUDY SCHEDULE

The Study was conducted in accordance with the Study schedule shown in **Table 1.4-1** by the assigned specialist listed in the table.

1.5 ORGANIZATION FOR THE STUDY

The Study was implemented by a joint study team composed of the JICA Study Team members and LWUA personnel. The JICA Study Team members and LWUA counterparts are listed in **Tables 1.5-1** and **1.5-2.**

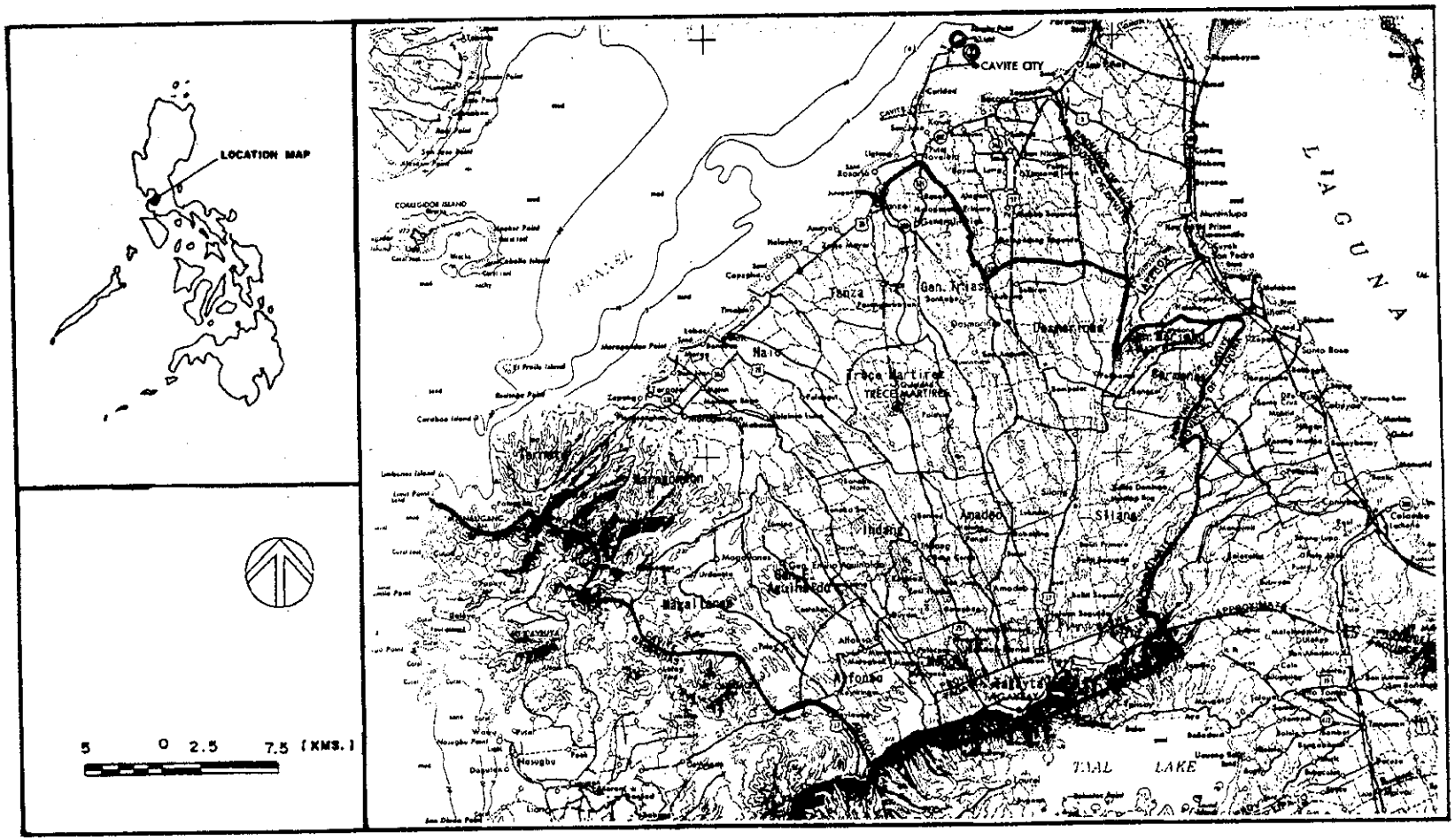


Fig. 1.2–1 STUDY AREA

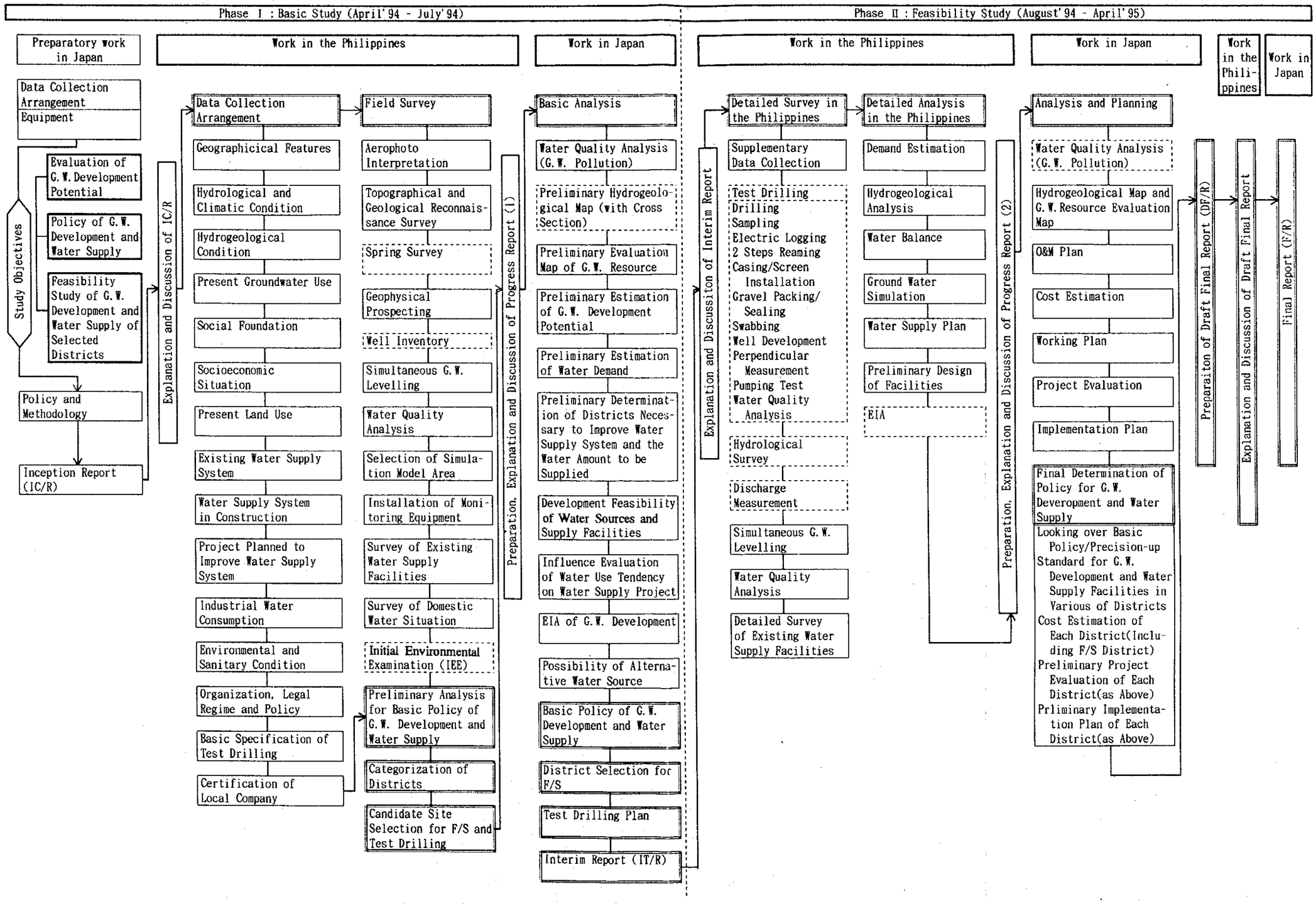


Fig. 1.3-1 STUDY COMPONENTS AND STUDY SEQUENCE

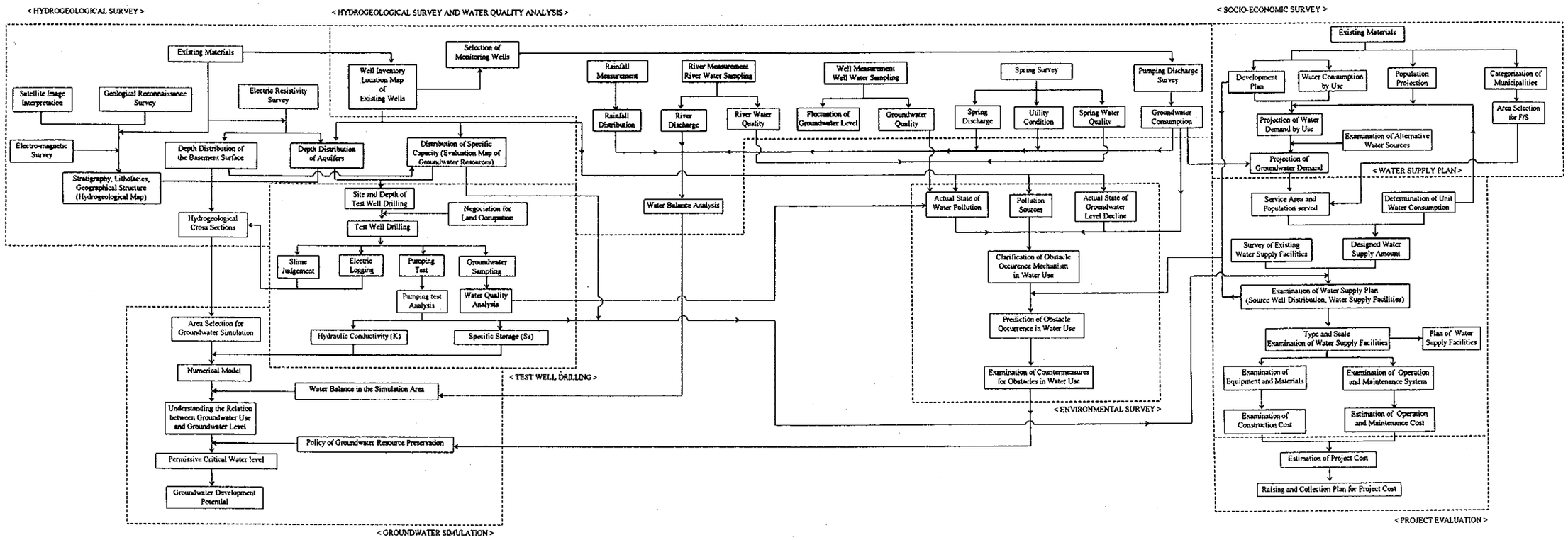


Fig. 1.3–2 INTERRELATION AMONG THE STUDY ITEMS

TABLE 1.4-1 STAFFING AND ASSIGNMENT SCHEDULE

Speciality	Name	1994 Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	1995 Jan.	Feb.	Mar.	Apr.
Team Leader	Akira Sugiyama														
Hydrogeology	Takashi Arai														
Hydrology/Water Quality	Reinald. R. Medina														
Geophysical Prospecting	Kenji Takayanagi														
Drilling Supervision	Mitsuo Tsutsumi														
Environment	Peifeng Lei														
Water Supply Planning	Tatsuyuki Kikuta														
Socioeconomics	Manabu Fujikawa														
Coordination	Andrew. Dorman														
Coordination	Hirohisa Ohmori														
Phase		← Phase I →					← Phase II →								
Reporting Schedule			△ IC/R			△ PR/R(1)	△ IT/R				△ PR/R(2)			△ DF/R	△ F/R

■ Work in the Philippines

□ Work in Japan

Table 1.5-1 MEMBER LIST OF JICA STUDY TEAM

	NAME	SPECIALTY
1	AKIRA SUGIYAMA	TEAM LEADER
2	TAKASHI ARAI	HYDROGEOLOGY
3	REYNALDO R. MEDINA	HYDROLOGY/WATER QUALITY
4	KENJI TAKAYANAGI	GEOPHYSICAL PROSPECTING
5	MITSUO TSUTSUMI	DRILLING SUPERVISION
6	PEIFENG LEI	ENVIRONMENT
7	TATSUYUKI KIKUTA	WATER SUPPLY PLANNING
8	MANABU FUJIKAWA	SOCIOECONOMICS
9	ANDREW DORMAN	COORDINATION (Phase I)
10	HIROHISA OHMORI	COORDINATION (Phase II)

Table 1.5-2 MEMBER LIST OF COUNTERPART PERSONNEL

	NAME	SPECIALTY
1	CIRIO ERNANI CRUZ	TEAM LEADER/HYDROGEOLOGY
2	ROLAND TAN	WATER SUPPLY FACILITIES
3	ARISTOTLE DOCTOR	GEOPHYSICAL PROSPECTING
4	ELI CRUZ	DRILLING AND PUMPING TEST
5	FELIX DEL CASTILLO	WATER SUPPLY PLANNING
6	EFREN PEREZ	MESSENGER

CHAPTER 2

GENERAL CONDITIONS OF THE STUDY AREA

CHAPTER 2

GENERAL CONDITIONS OF THE STUDY AREA

The Study Area covers 1,241 km^2, about 80% of the land area of Cavite Province and a large part of it forms a slope monotonously declining from Tagaytay Ridge with more than 600 m in height to the coast facing Manila Bay.

Annual rainfall significantly increases with elevation, from 2,000 mm in the coastal area to 3,800 mm in the uplands.

The Study Area comprises 15 municipalities and 2 cities. Total population amounts to 696,000 in 1990 and it is estimated to be 1,124,000 in the year 2000.

The population growth rate is especially rapid in the municipalities along the industrial belt. As for the water supply service coverage, Level III is less than 35% even in the urban area. Facilities for wastewater treatment and solid waste disposal are very poor and the deterioration of water resource is progressing.

2.1 NATURAL CONDITIONS

The Study Area belongs to Cavite Province, which is situated on the island of Luzon, the largest island in the Republic of the Philippines, and has a total land area of 1,427 km^2.

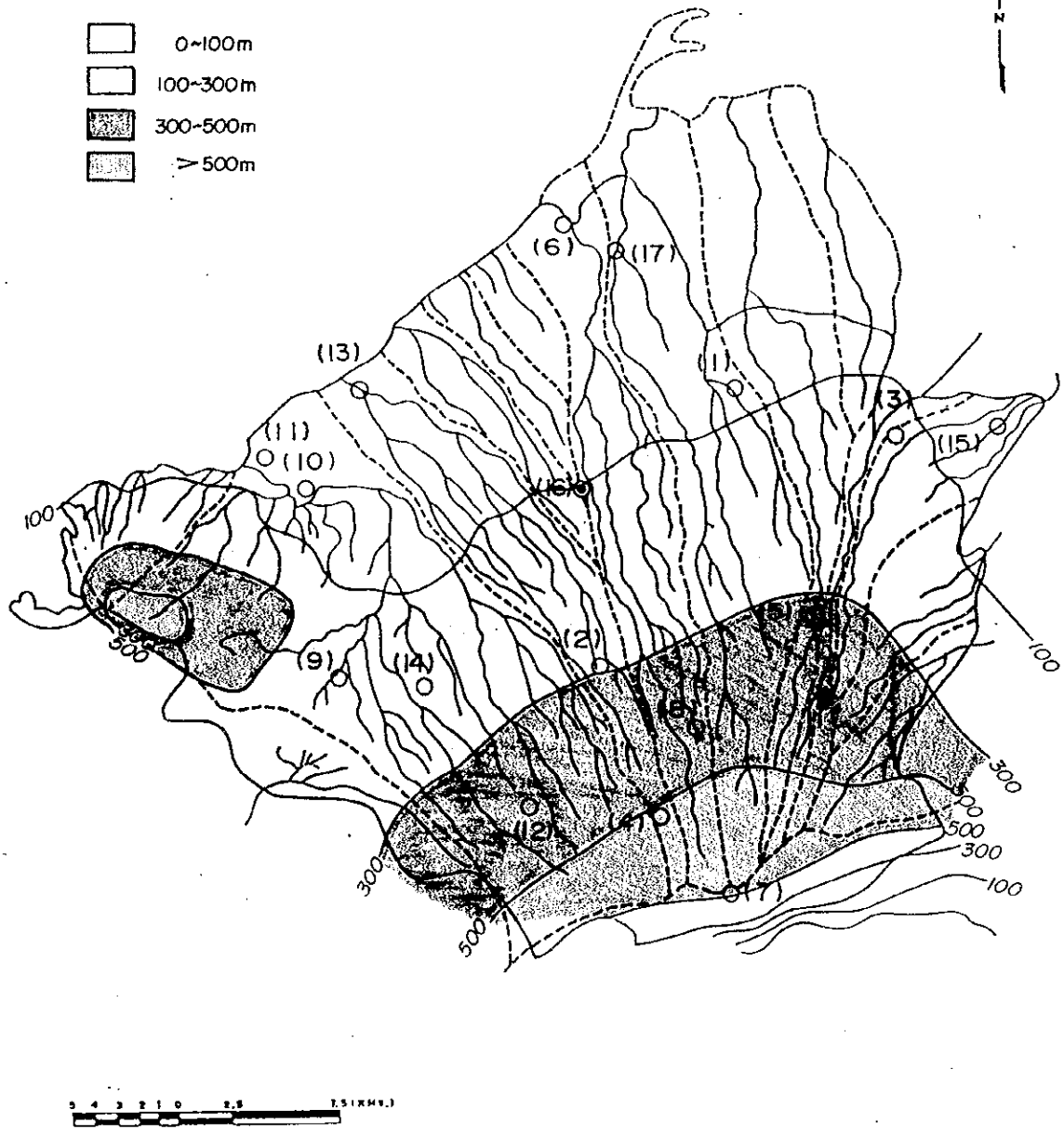
Except for 6 municipalities in the northern portion of Cavite Province, which have become a part of the metropolitan urban sprawl, 1,241 km^2, about 80% of the land area of Cavite province, is involved in the Study Area.

2.1.1 Topography

The general topographical features are reflected in the summit level map shown in **Fig. 2.1-1**. Synthesizing features such as slope, elevation, undulations, and shape of rivers or valleys, the Study Area is divided into three (3) parts; the central part, western part and eastern part.

The central part occupies about 70% of the whole Study Area and forms a vast slope monotonously declining from southeast to northwest.

Below 100 m in elevation, the slope ranges from 0–3% in inclination and comprises Gen. Trias, Naic and Tanza. The land use in this lowland is largely rice field, salt beds and marine ponds. This lowland is downstream parts or small alluvial plains of rivers.



CAVITE WATER SUPPLY DEVELOPMENT STUDY	Fig. 2.1-1 HEIGHT DISTRIBUTION AND RIVER SYSTEM
JAPAN INTERNATIONAL COOPERATION AGENCY	

Between 100 and 300 m in elevation, the slope ranges 3–8% in inclination and comprises Dasmarinas, Indang, Trece Martirez City as well as a portion of Silang. This area contains the middle reaches of the relatively large rivers.

Above 300 m in elevation, the slope ranges 8–15% in inclination and comprises Alfonso, Amadeo, Gen Aguinaldo, Mendez, Magallanes and Tagaytay City including portions of Silang. Tagaytay ridge, top of the slope, is 730 m (Mt. Sungai) above MSL at the highest point. All the large rivers in the Study Area have their sources in this area and many springs are found.

The western part of the Study Area is occupied by the mountain land with complicated topography and comprises Maragondon and Ternate. The summits of the mountain land exceed 600 m in elevation and the slope is steeper than most other regions.

The eastern part of the Study Area is occupied by the slope declining steeply to the northeast. Therefore, conspicuous bending of the slope is found between the central part and the eastern part. Carmona, G.M.A. and a portion of Silang are comprised in the eastern part.

The above mentioned topographical features are the result of the geologic development of the Study Area and closely related with the hydrological structure.

The river system is also shown in **Fig. 2.1–1**, the direction of flow being generally dictated by the slope direction of the uplands, most rivers in the Study area flow northwest emptying into Manila Bay, with long and narrow river basins. The Maragondon River, San Juan River, Canas River, Ilang–Ilang River and Imus River are the major rivers, having the largest basins in the Study area, but each has a relatively small river basin, the largest being less than 300 km^2.

2.1.2 Climate

The Study Area lies between 14°5' and 14°30' latitude north, and belongs to a tropical monsoon climatic zone, having two (2) pronounced seasons: relatively dry, from November to April; and wet, from May to October, although intermittent rainfall comes at any time during the year. About 70 percent of annual rainfall occurs within the rainy season. During the period of the dry season, rainfall is less than 50 mm per month, while in the rainy season monthly rainfall exceeds 270 mm. As shown in **Fig. 4.2–1** the annual rainfall significantly increases with elevation, from 2,000 mm in the coastal area to 3,800 mm in the uplands.

Monthly temperature ranges from a minimum of 20°C to a maximum of 35°C. Mean monthly temperature varies little around a year, from 25°C to 30°C. The coldest months are from December to February while the hottest months are April and May. Mean annual temperature is 25°C. The mean relative humidity is highest in August and September at 85%.

The Tagaytay ridge receives sea breezes from Balayan Bay and therefore has a relatively low temperature suitable as a summer resort. The lowlands receive sea breezes from Manila Bay, and except

when typhoons and storms hit, the wind velocity is about 2 m/s and having a small variation with seasons.

The Study Area is visited by an annual average of 2 tropical cyclones, 7 tropical storms and 6 typhoons, which result in widespread damage to the Study area.

2.1.3 Vegetation

The Study Area lies in the western monsoon forest zone in the Philippines, the natural vegetation is characterized by tropical rain forest. As a result of deforestation and economic development, the woodland has reduced to less than 10 percent of the land area of Cavite. Contrary to this, agricultural land including orchards have a total area of about 100,000 ha, which is about 7 times larger than the area of natural forests. Therefore, the vegetation distribution in Cavite is determined by land use more than natural condition such as climate, soil, and so on.

Based on the previous studies, the lowland with elevation below 100 m, are utilized mainly for irrigated paddies, occupying 15,169 ha or 12% of the provincial land area. Non-irrigated paddies occupy 7,146 ha or 6% of the total. Sugarcane fields extend inland to near the 100 m contour. Coconut, often inter-cropped with coffee, bananas and pineapples have a total area of 21,512 ha or 17% of the total.

2.2 SOCIOECONOMIC CONDITIONS

2.2.1 Administrative Unit

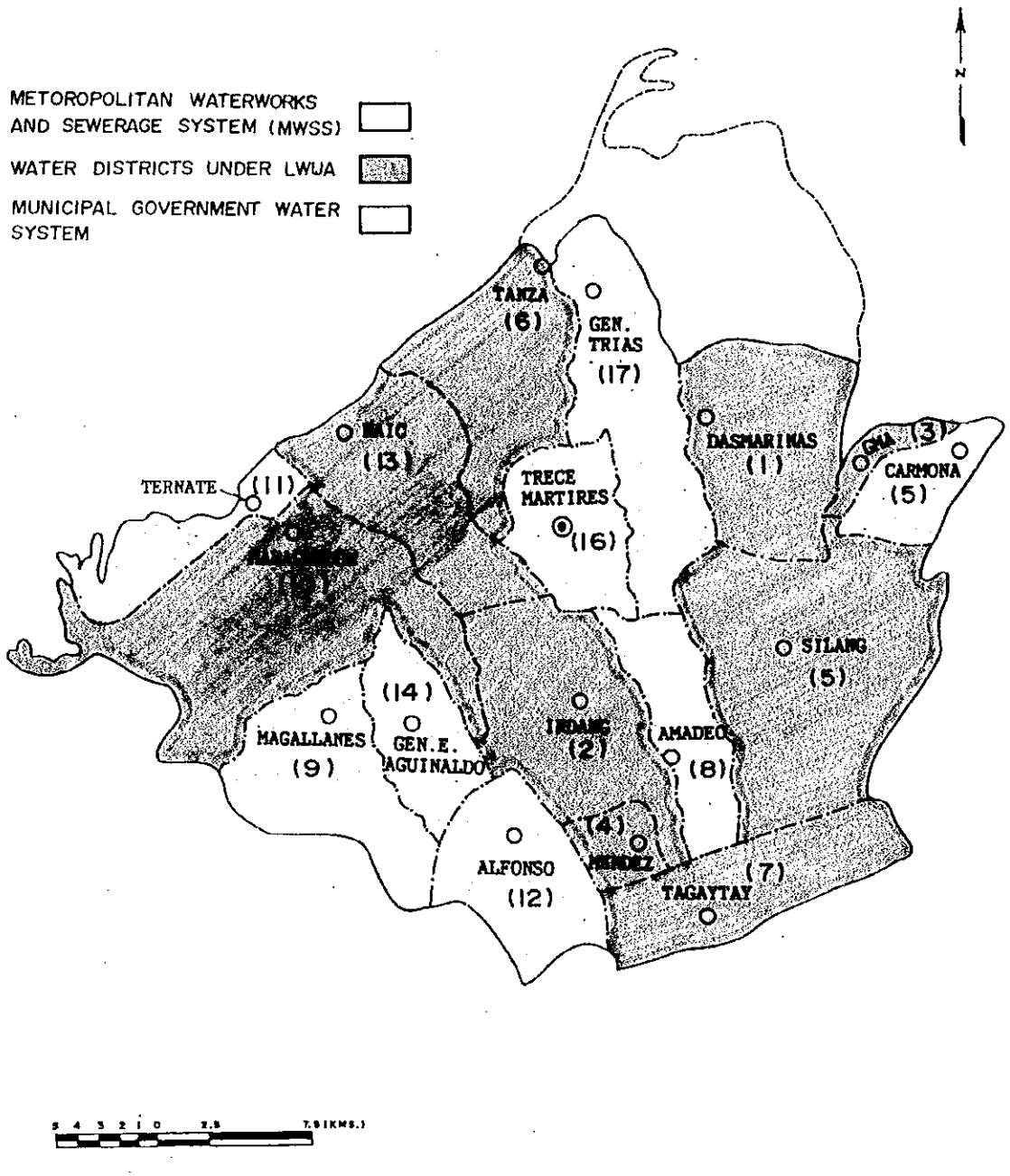
Administrative divisions of the Study Area is shown in **Fig. 2.2-1**. The Study area comprises 15 municipalities and 2 cities. Among them, G.M.A. became independent from Carmona in 1981. Area and population of the administrative units are shown in **Table 2.2-1**.

According to the classification, which is based on the revenue size of each municipality and city, most of the municipalities are included in the forth or fifth classes, while Dasmarinas belongs to the second class and G.E. Aguinaldo is in the sixth class.

2.2.2 Distribution and Mobilization of Population

Based on the NSO (National Statistics Office), the total population of the Study Area was 696,000 in 1990. This is about 60% of the total population in Cavite Province. The number of total household in the Study Area is 130,755 and the average number of persons per household is about 5.3.

Compared with the result of the 1980 population census, the Study Area population has increased by 4.5% annually, while Cavite province as a whole has increased by 4.1%.



CAVITE WATER SUPPLY DEVELOPMENT STUDY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2.2-1 ADMINISTRATIVE UNITS AND WATER MANAGEMENT AUTHORITY

Table 2.2-1 POPULATION AND LAND AREA OF EACH ADMINISTRATIVE UNIT

No.	City/Municipality	Area Size (ha)	Population (1990) Total	Urban pop.	Rural pop.	Urban pop./ Rural pop.	Population Density per ha
1	Dasmarinas	8,234	136,556	136,486	0	-	16.58
2	Indang	8,920	39,294	7,000	32,227	0.22	4.41
3	G. M. A.	938	65,977	65,973	0	-	70.34
4	Mendez	1,667	17,652	17,651	0	-	10.59
5	Silang	15,641	93,790	52,035	41,603	1.25	6.00
6	Tanza	9,630	61,785	37,147	24,607	1.51	6.42
7	Tagaytay City	6,615	23,739	9,230	13,764	0.67	3.59
8	Amadeo	4,790	21,022	6,793	14,220	0.48	4.39
9	Magallanes	7,860	12,556	2,047	10,503	0.19	1.60
10	Maragondon	16,549	22,814	4,546	18,263	0.25	1.38
11	Ternate	4,350	11,981	5,351	6,614	0.81	2.75
12	Alfonso	6,460	28,944	6,795	22,150	0.31	4.48
13	Naic	8,600	51,629	19,992	31,570	0.63	6.00
14	Gen. Aguinaldo	5,103	10,954	3,712	7,242	0.51	2.15
15	Carmona	3,092	28,247	22,339	5,894	3.79	9.14
16	Trece Martirez City	3,917	15,686	5,623	9,346	0.60	4.00
17	Gen. Trias	11,768	52,888	19,370	33,472	0.58	4.49
	Study Area Total	124,134	695,514	422,090	271,475	1.55	5.60

Source :

(1) Province of Cavite Water Supply, Sewerage and Sanitation Development Plan 1990-2000

(2) 1990 Census of Population and Housing, Socio-Economic and Demographic Characteristics, NSO

Note: Total population is not equal to the sum of the urban and rural population.

The population growth rate from 1980 to 1990 is especially large in Dasmarinas, Silang and Trece Martirez City. The rapid increase in population was not only due to urbanization and industrialization but also due to large scale resettlement conducted by the National Government.

According to the population projection by NSO, the population in the Study Area will be 1.124 million in the year 2000, and the growth rate is especially rapid in the municipalities along the industrial belt such as Dasmarinas, Silang, Carmona and Trece Martirez City (**Table 2.2-2**).

About 60% of the total population in the Study Area were considered as urban dwellers in 1990 against 40% in 1980. This result justified the transition of the Study Area from an agricultural area to an urbanized area.

2.2.3 Economic Base and Business Establishments

As shown in **Table 2.2-2**, major economic sectors in most of the municipalities in the Study Area are still agriculture and fishery, while manufacturing sector play an important role in some of the municipalities. Tagaytay's feature of economy is tourism. Employment by industrial category in 1992, which is based on NSO, is shown below, although these numbers are in Cavite province as a whole.

Employment by Industrial Category in 1992

Social/personal services	87,000	23.1%
Manufacturing	85,000	22.6
Agriculture, Fishery and Forestry	71,000	18.9
Transportation and Communication	42,000	11.2
Wholesale and Retail Trade	38,000	10.1
Construction	35,000	9.3
Insurance and other business services	11,000	2.9
Mining and Quarrying	4,000	0.5
Electricity, Gas and Water	3,000	0.3
Total	376,000	

Source: 1990 Census of Population and Housing, Socio-Economic and Demographic Characteristics, NSO

As for business enterprises, 4,299 establishments are located in the Study Area in 1992, while 8,451 in Cavite province. Commerce (wholesale and retail trade) has the largest share, followed by private services and manufacturing. Municipality wise, Dasmarinas has the largest number of establishments in manufacturing and personal services, while Naic has the largest number of wholesale and retail activities. In terms of Cavite province, the bulk of commercial and business activities are conducted in northern part of the province such as Cavite city, Dasmarinas, Kawit, Bacoor and Imus because of their proximity to Metro-Manila and the availability of transportation.

Table 2.2-2 SOCIOECONOMIC PROFILES OF CITIES/MUNICIPALITIES IN THE STUDY AREA (1/3)

City/Municipality	Actual Population (Census Results)			Population Projection	Population Ratio	Major Economic Profile and Other Factors	Number of Business Establishments (1992)					Class of Municipality City
	Population (1980)	Population (1990)	Growth Rate (1980-1990)	(2000)	2000/1990		Manuf.	Commerce	Services	Others	Total	
1 Dasmarinas	51,894	136,556	10.16	359,377	2.63	Rapid development as a part of growth corridors was experienced. Manufacturing sector (including several industrial estates) play major roles as well as agriculture sector. Commerce and trade transaction is also active.	105	294	229	19	647	3rd
2 Indang	30,977	39,294	2.41	49,860	1.27	The economy essentially depends on agriculture. Major crops are coconut, coffee and banana. Existing commercial and industrial establishments play a relatively minor role.	50	115	85	10	260	5th
3 G. M. A.	- (* G.M.A. was born in 1981.)	65,977	n.a.	95,432	1.45	Industry begin to play major roles in economy. Although agriculture is important, certain part of land is not suitable for agricultural cultivation.	79	140	93	8	320	4th
4 Mendez	15,044	17,652	1.61	20,709	1.17	Major economic activity is agriculture. Commercial activities, which has a link of Tagaytay, is expected.	31	56	37	5	129	5th
5 Silang	52,321	93,790	6.01	127,890	1.36	Agriculture is a base of economy. Major crops are coffee, coconut, banana and pineapple. The manufacturing industries are limited to small scale type.	75	274	140	19	508	5th
6 Tanza	43,675	61,785	3.53	87,407	1.41	Major economic activities are agriculture, fishery and industry. Major crop is rice.	69	169	85	19	342	4th
7 Tagaytay City	16,322	23,739	3.82	34,536	1.45	The feature of the economy is tourism. The city is located in the center of tourism belt. Tourism related commercial and service sectors are active. Agriculture is also important and the traditional economic base.	24	133	108	11	276	4th
8 Amadeo	16,234	21,022	2.62	27,227	1.30	Agriculture is major economic sector. Major crop are coffee, banana and coconut.	29	23	36	5	93	5th

Table 2.2-2 SOCIOECONOMIC PROFILES OF CITIES/MUNICIPALITIES IN THE STUDY AREA (2/3)

City/Municipality	Actual Population (Census Results)			Population Projection	Population Ratio	Major Economic Profile and Other Factors	Number of Business Establishments (1992)					Class of Municipality City
	Population (1980)	Population (1990)	Growth Rate (1980-1990)	(2000)	2000/1990		Manuf.	Commerce	Services	Others	Total	
9 Magallanes	9,691	12,556	2.62	16,262	1.30	Municipality's economy is highly dependent on th agriculture sector. Major crop is coconut.	7	10	12	1	30	5th
10 Maragondon	18,018	22,814	2.39	28,892	1.27	Agriculture is major economic sector. Major crop is rice with production of 8,600 ton.	29	66	23	1	119	5th
11 Ternate	9,739	11,981	2.09	14,734	1.23	Fishery and agriculture are major activities. Majc crops are rice, fruits and rootcrops. Also, since the municipality is included in the tourism belt, tourism industry is expected.	10	17	20	2	49	5th
12 Alfonso	21,980	28,944	2.79	38,112	1.32	Agriculture is the largest sector. 91% or 6,394ha of the total land area is used for agriculture with 3,600 farmers. Major crops are tree crops such as coconut and coffee.	55	69	91	14	229	5th
13 Naic	38,243	51,629	3.05	69,723	1.35	Agriculture and fishery are important economic sectors. Major crop is rice. Fish are marketed to Metro Manila and neighboring municipalities.	86	358	137	22	603	4th
14 Gen. Aguinaldo	9,571	10,954	1.36	12,538	1.14	Agriculture is a economic base. Major products ai coconut, rice and coffee. Other sectors' roles are very limited.	15	7	10	2	34	6th
15 Carmona	65,014 (* G.M.A. was separated from Carmona in 1981.)	28,247	-8.00	41,775	1.48	Agriculture is an important sector. 1,518 ha is devoted to agricultural activity. Major crops are sugar cane, rice and pineapple. Manufacturing sector is also active.	89	47	57	15	208	5th
16 Trece Martirez City	8,579	15,686	6.22	28,680	1.83	Agriculture is a traditional economic base. Scale c commercial and industrial business are rather small. The municipality is included in the industrial, residential and institutional mix zone.	24	63	49	8	144	5th

Table 2.2-2 SOCIOECONOMIC PROFILES OF CITIES/MUNICIPALITIES IN THE STUDY AREA (3/3)

City/Municipality	Actual Population (Census Results)			Population Projection	Population Ratio	Major Economic Profile and Other Factors	Number of Business Establishments (1992)					Class of Municipality City
	Population (1980)	Population (1990)	Growth Rate (1980-1990)	(2000)	2000/1990		Manuf.	Commerce	Services	Others	Total	
17 Gen. Trias	39,745	52,888	2.90	70,390	1.33	Agriculture is a traditional economic base. Also, industry (including industrial estate development) has become certain share of the economy.	70	142	85	11	308	4th
Study Area Total	447,047	695,514	4.52	1,123,543	1.62		847	1,983	1,297	172	4,299	-
Cavite Province	771,320	1,152,534	4.10	1,722,507	1.49		1,619	3,773	2,660	399	8,451	-

Sources:

(1) Actual population and growth rate; Population Census 1980 and 1990
(2) Population projection of municipalities/cities except Carmona, G.M.A. and Silang in 2000 : NSO of Cavite Province Office, Carmona; Municipal Development Plan, G. M. A.; Engineering Study of Water District, 1992, Silang; Water Supply Feasibility Study, Silang Water District, 1993
(3) Major Economic Profiles; Socio-economic Profile in each municipality and city. Some of them are complemented in interviews to MPDC and CPDC.
(4) Number of establishments: NSO of Cavite Province office
(5) Classification of municipality/city: Office of the Provincial Planning and Development Coordinator: Classification is based on the scale of revenue in each municipality / city.

Out of more than 1,600 manufacturing firms in Cavite province, 236 are designated as medium or large scale enterprises in 1992. These factories are mainly located in industrial estates or industrial zones in Carmona, Dasmarinas, G.M.A., Gen. Trias, Imus, Naic, Rosario, Trece Martirez City and Silang.

2.2.4 Land Use

Based on the provincial development plan (1990–2000), the existing land use in the Study Area and Cavite Province, by category is shown below. In Cavite Province, agricultural land has the largest share of 74%, while built up area is 15%. Although the land use has been changed through the development thrusts of industrialization, agricultural modernization, tourism development, and rapid urbanization, the balance and harmony between regional policies for development of growth centers and preservation of prime agricultural lands are taken into account by the Provincial and Municipal governments. Details are given in **Table 2.2–3** and **Table 2.2–4**.

Land use category	Cavite province		Study Area	
	Area(ha)	Share(%)	Area(ha)	Share(%)
Agricultural	106,080	74.3	95,009	76.5
Non–agricultural	36,626	25.7	29,125	23.5
1. Built–up	22,000	15.4	15,502	12.5
2. Woodland	13,102	9.2	13,102	10.6
3. Wetland	1,524	1.1	521	0.4
Total	142,706	100.0	124,134	100.0

2.2.5 Infrastructure

(1) Transportation

The Study Area has a hierarchical and functional roads system classified into national, provincial, municipal/city, and barangay roads. The national roads form part of the main trunk line systems and are connected by provincial roads from one municipality to another.

The road network, shown in **Fig. 2.2–2** are either concrete or asphalt with some still earth filled, graveled or with bituminous seal coat. In terms of Cavite Province, national roads have the highest percentage of paved roads with 94%, followed by the municipal/city roads with about 80%, while a little more than 50% of provincial roads are paved.

The major modes of transport in the Study Area are buses, passenger jeepneys, cars and tricycles. The volume of traffic has been increasing in the past several years. Traffic congestion

Table 2.2-3 LAND AREA BY LAND USE CATEGORY IN CAVITE PROVINCE

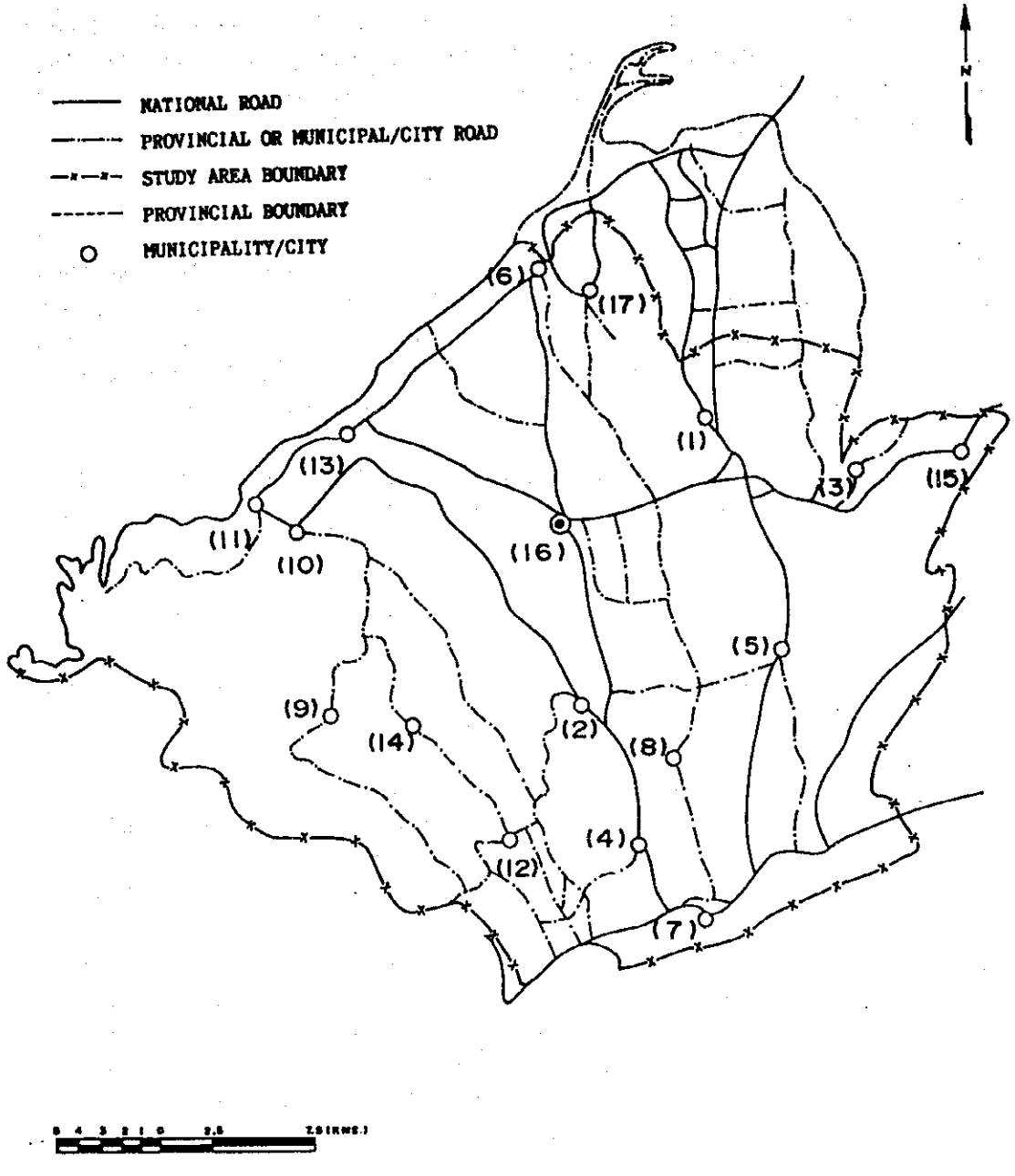
Land Use Category	Major Urban Center		Minor Urban Center		Satellite Communities		Total	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Agricultural	6,547.2	47.7	57,457.4	74.0	42,075.5	81.9	106,080.1	74.3
Urban (Built-up)	6,091.6	44.4	12,531.3	16.1	3,376.9	6.6	21,999.7	15.4
Wood Land	83.7	0.6	7,489.0	9.6	5,529.0	10.8	13,101.7	9.2
Wetland	1,003.5	7.3	153.3	0.2	367.7	0.7	1,524.5	1.1
Total	13,726.0	100.0	77,631.0	100.0	51,349.0	100.0	142,706.0	100.0

Source: Provincial Development Plan 1990-2000, Province of Cavite
Note:
(1) Major Urban Center: (Bacoor, Kawit, Noveleta, Cavite City), Trece Martirez City, (Rosario) and G. M. A.
(2) Minor Urban Center: Carmona, Dasmarinas, Gen. Trias, (Imus), Naic, Silang, Tanza, Ternate and Tagaytay City
(3) Satellite Communities: Alfonso, Amadeo, Gen. Aguinaldo, Indang, Magallanes, Maragondon and Mendez
*The municipalities or city in the bracket are out of the Study Area.

Table 2.2-4 EXISTING GENERAL LAND USE IN THE STUDY AREA BY MUNICIPALITY/CITY (1989)

City/Municipality	Total Area	Agricultural Land		Non-agricultural							
			(%)	Build-up Area	(%)	Woodland	(%)	Wetland	(%)	Total	(%)
1 Dasmarinas	8,234	6,121.3	74.3	2,112.7	25.7	0.0	0.0	0.0	0.0	2,112.7	25.7
2 Indang	8,920	7,860.0	88.1	1,060.0	11.9	0.0	0.0	0.0	0.0	1,060.0	11.9
3 G. M. A.	938	303.2	32.3	634.8	67.7	0.0	0.0	0.0	0.0	634.8	67.7
4 Mendez	1,667	1,401.0	84.0	266.0	16.0	0.0	0.0	0.0	0.0	266.0	16.0
5 Silang	15,641	14,351.5	91.8	1,288.5	8.2	0.0	0.0	1.0	0.0	1,289.5	8.2
6 Tanza	9,630	6,568.6	68.2	3,035.4	31.5	0.0	0.0	26.0	0.3	3,061.4	31.8
7 Tagaytay City	6,615	4,644.0	70.2	491.0	7.4	1,480.0	22.4	0.0	0.0	1,971.0	29.8
8 Amadeo	4,790	4,411.0	92.1	379.0	7.9	0.0	0.0	0.0	0.0	379.0	7.9
9 Magallanes	7,860	6,853.0	87.2	189.0	2.4	818.0	10.4	0.0	0.0	1,007.0	12.8
10 Maragondon	16,549	12,730.3	76.9	353.0	2.1	3,098.0	18.7	367.7	2.2	3,818.7	23.1
11 Ternate	4,350	765.5	17.6	559.2	12.9	2,914.0	67.0	111.3	2.6	3,584.5	82.4
12 Alfonso	6,460	5,381.0	83.3	1,079.0	16.7	0.0	0.0	0.0	0.0	1,079.0	16.7
13 Naic	8,600	7,476.8	86.9	1,123.3	13.1	0.0	0.0	0.0	0.0	1,123.3	13.1
14 Gen. Aguinaldo	5,103	3,439.2	67.4	50.8	1.0	1,613.0	31.6	0.0	0.0	1,663.8	32.6
15 Carmona	3,092	1,566.0	50.6	316.0	10.2	1,195.0	38.6	15.0	0.5	1,526.0	49.4
16 Trece Martirez City	3,917	3,148.0	80.4	685.3	17.5	83.7	2.1	0.0	0.0	769.0	19.6
17 Gen. Trias	11,768	7,989.0	67.9	1,879.0	16.0	1,900.0	16.1	0.0	0.0	3,779.0	32.1
Total	124,134	95,009.4	76.5	15,502.0	12.5	13,101.7	10.6	521	0.4	29,124.6	23.5

Source: Cavite Provincial Development Plan (1990-2000)



CAVITE WATER SUPPLY DEVELOPMENT STUDY	Fig. 2.2-2
JAPAN INTERNATIONAL COOPERATION AGENCY	ROAD NETWORK

occurs at the peak hours of 7:00 to 9:00 A.M. and 4:00 to 7:00 P.M. in the northeast portion of Cavite, outside the Study area. Heavy traffic also occurs during summer days when large numbers of tourists, both local and foreign, travel to the beach resorts and other tourist spots in and near the Study Area.

(2) Electricity Supply

The National Power Corporation supplies electric power to the Study Area. The total number of households supplied with electricity in Cavite Province is about 194,000 as of 1990, which is 87.6% of the total number of households. In the Study Area, G.M.A., a resettlement area, is 100% supplied with electricity. Municipalities with 95% to 99% electrification include Gen. Trias, Dasmarinas, Mendez and Tanza. The rest have 87% or below electrification.

Power failures in Cavite Province occur less frequently than in Metro Manila with the improvement of electric supply situation in Metro Manila, there seems to be little need to worry about the influence of power failures.

(3) Water Supply

Cavite obtains most of its water supply from two (2) traditional sources, surface water from rivers and lakes, and groundwater from wells and springs.

Water in Cavite Province is supplied by different service agencies. These are the Metropolitan Waterworks and Sewerage System (MWSS), Water Districts(WD), which are autonomous water authorities operating under the financial umbrella of the LWUA; and finally local authorities such as municipal governments or barangay waterworks and sanitation associations(MWS).

The MWSS provides water to the 6 urban municipalities outside the Study Area and essentially a continuation of the sprawl of Metropolitan Manila. Water Districts function in 9 of the municipalities, the total population being less than the MWSS areas but greater than the remaining municipalities. In rural areas, it's generally the rural waterworks and sanitation associations (RWSA), that are in charge of the systems. These tend the smaller schemes. The distribution of these authorities is shown in **Fig. 2.2-1.**

Based on the present standards used by the Philippine Government, water supply service levels are classified below:

Level I	Water supply system with point source. Usually, served population is less than 500 and unit amount of water consumptions 30 – 40 l/head/day.
Level II	Water supply system with communal faucet. Usually, served population is 500 to 2,000 and unit amount of water consumption is 40 – 80 l/head/day.

Level III Water supply system with individual household faucet.
Usually, served population is more than 2,000 and unit amount of water consumption is more than 100 l/head/day.

The detailed elements of water supply service coverage is shown in **Table 2.2-5** and a general representation is shown in the table below.

Water Supply Service Coverage (%)	Level I	Level II	Level III	Unserved
Urban area	41	3	33	23
Rural area	64	21	5	10

The number of Level I facilities in Cavite Province is estimated at over 30,000. A considerable number of wells are private. 90% private and 10% public has been assumed for urban areas and a split of 20% private and 80% public for rural areas.

Level II systems can be found in both urban and rural areas but they tend to be more frequently installed in rural areas.

Level III service is available to a greater proportion of the population in urban area than in rural areas, greater population of urban dwellers are nominally unserved in relation to rural dwellers.

(4) Wastewater Treatment

There are no public sewerage system in Cavite province. Most households in urban centers dispose their wastewater within their vicinity through septic tanks. These tanks, in most cases, pass effluent directly into street canals or adjacent watercourses.

In agricultural areas, water-scaled latrines are widely used which discharge their contents into a pit. However, many toilets are flushed directly into watercourses, rice fields and drains. Pit latrines, as their name suggests, contain the waste inside a pit, but high water tables particularly in the coastal areas mean that groundwater pollution is highly probable, unless special precautions are taken.

(5) Solid Waste Disposal

There are no public solid waste disposal facilities in Cavite Province except the Sanitary Landfill in Sitio Paligawang Matanda, Carmona, that was constructed for final disposal of solid wastes from areas in Metro Manila south of Pasig River and the City of Manila. Though, some solid wastes generated in adjacent municipalities such as Dasmarinas and Trece Martirez City are said

Table 2.2-5 WATER SUPPLY LEVELS IN THE STUDY AREA BY MUNICIPALITY/CITY (1993)

City/Municipality	Total Household	Level I		Level II		Level III		Doubtful Sources	
		H.H.Served	%	H.H.Served	%	H.H.Served	%	H.H.Served	%
1 Dasmarinas	29,781	2,147	7.2	4,086	13.7	23,544	79.1	4	0.0
2 Indang	7,234	314	4.3	5,112	70.7	1,808	25.0	0	0.0
3 G. M. Avarez	12,566	529	4.2	7,844	62.4	4,193	33.4	0	0.0
4 Mendez	3,163	1,157	36.6	507	16.0	1,499	47.4	0	0.0
5 Silang	13,549	2,536	18.7	5,730	42.3	4,695	34.7	588	4.3
6 Tanza	10,136	9,013	88.9	0	0.0	0	0.0	1,123	11.1
7 Tagaytay City	4,424	122	2.8	215	4.9	3,748	84.7	339	7.7
8 Amadeo	3,417	1,592	46.6	485	14.2	1,307	38.2	33	1.0
9 Magallanes	2,538	868	34.2	1,282	50.5	0	0.0	388	15.3
10 Maragondon	3,574	2,364	66.1	0	0.0	1,093	30.6	117	3.3
11 Ternate	2,796	2,796	100.0	0	0.0	0	0.0	0	0.0
12 Alfonso	5,663	1,028	18.2	1,856	32.8	2,739	48.4	40	0.7
13 Naic	8,043	7,400	92.0	341	4.2	302	3.8	0	0.0
14 G.E.Aguinaldo	2,234	915	41.0	750	33.6	516	23.1	53	2.4
15 Carmona	5,296	5,251	99.2	0	0.0	0	0.0	45	0.8
16 Trece Martirez City	3,304	2,004	60.7	521	15.8	779	23.6	0	0.0
17 Gen. Trias	10,840	10,650	98.2	0	0.0	190	1.8	0	0.0
Study Area Total	128,558	50,686	39.4	28,729	22.3	46,413	36.1	2,730	2.1

Source: Provincial Department of Health, Trece Martirez City, (Data as of December 1993)

Notes

(1) Doubtful sources mean water of river, rain water, undeveloped spring, buying water from peddler, and others.

(2) In Level I supply, certain amount of underserved households are included according to PDH officials.

to be disposed off in this landfill, most regions in the Study Area seem not to benefit from it. Because of the shortage of solid waste collection system, even in Dasmarinas or Carmona solid waste are rarely disposed in this landfill.

Several municipalities/cities disposed off their solid waste into a designated municipal dumpsite. All of these dumpsites are open dumps without provisions for leachate control. Besides, these dumpsites are limited to some residents, because of the shortage of collection trucks. Factually, the disposal of most solid waste is up to the generators. Open burning and composting as organic fertilizer are relatively sanitary method and practically used. However, littering garbage is a common sight in some poblacions and along roads causing offensive odors as well as objectionable smoke when naturally burned.

CHAPTER 3

HYDROGEOLOGICAL CONDITIONS OF THE STUDY AREAS

CHAPTER 3

HYDROGEOLOGICAL CONDITIONS OF THE STUDY AREA

The geologic profile in the Study Area is classified into Basement, Caloocan Formation, Talisay Formation, Kaybubutong Formation, Iruhin Formation and Mt. Sungai Lava in the ascending order. Except Basement, all formations are identified as Pleistocene sediments.

The screens of the existing wells are installed in the three aquifers of different stratigraphic horizon. Lower Aquifer is coarse sandstone with gravel or medium sandstone layer intercalated in Talisay Formation and is utilized mainly in the low elevation zone (lower than 50 m).

Middle Aquifer is conglomerate or coarse sand layer intercalated in the lower horizon of Kaybubutong Formation and is utilized mainly in the intermediate elevation zone (50 – 200 m).

Upper Aquifer is scoria, tuff, volcanic conglomerate or lava layer intercalated in the middle horizon of Kaybubutong Formation and is utilized mainly in the high elevation zone (higher than 200 m).

Specific capacity of the existing wells is as high as more than 0.5 l/s/m in the low elevation zone, while it is as low as less than 0.5 l/s/m in the intermediate to high elevation zone in general.

3.1 STUDY METHODS AND WORK AMOUNTS

3.1.1 Collection of Existing Data

Existing topographical maps, geological maps and reports on geology, hydrogeology and water resources were collected prior to field survey. The list of these maps and reports is shown in the S/R.

Existing well data were also collected to examine the hydrogeological characteristics of geological units constituting the Study Area. These data were also utilized to complete the well inventory survey. The total number of the collected well data is 719, of which 166 data were used to analyze the hydrogeological structure of the Study Area. Location of these 166 wells is shown in **Fig. 3.2–3.**

3.1.2 Geological Field Survey

The geological field survey was conducted throughout the Study. The geological outcrops are restricted in deep valleys, on steep cliff at the southern side of Tagaytay ridge and in gravel pits or cutting in G.M.A. and Carmona.

3.1.3 Interpretations of Satellite Images and Airphotos

Two sheets of satellite (SPOT) images, TAGAYTAY and SAN-PABLO, which are digital radar mosaic with a scale of 1/100,000 and taken on March-April, 1994, were purchased from NAMRIA (National Mapping & Resources Information Authority) to justify and find the geological structures in a larger scale. Airphotos with a scale of 1/50,000 were also used to examine in more detail the geological structures.

3.1.4 Geophysical Prospecting Survey

Considering the facts that facies change is complicated and outcrops are limited, electric resistivity and electromagnetic surveys were carried out to examine the geologic structure beneath the slope.

The electric resistivity survey was carried out using Wenner method. Survey points were set up at about 2 km interval and the prospecting depth was 300 m.

The electromagnetic survey was carried out using magnetotelluric survey meter (ABEM WADI) to detect the fault lines and fracture zones. The measurement was conducted every 10 meters. The survey lines are shown in **Fig. 3.1-1**.

3.1.5 Test Drilling

Four test wells were drilled in the Study Area as shown in **Fig. 3.1-1**. The quantity of work, the daily activity records of drilling work, the main equipments and materials used and the geologic succession are discussed in the Supporting Report.

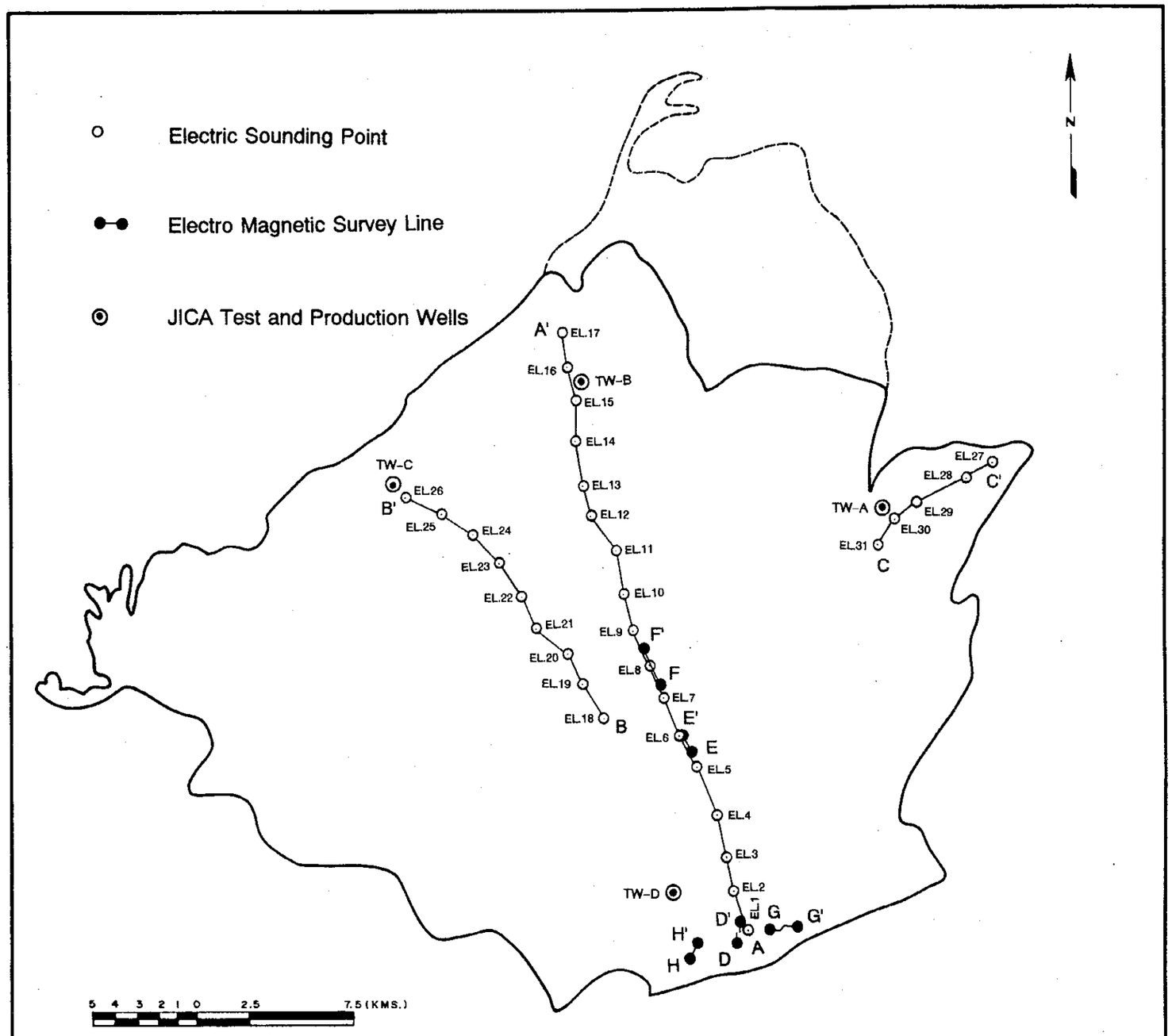
3.2 STRATIGRAPHY

3.2.1 Lithologic Succession in Type Locality

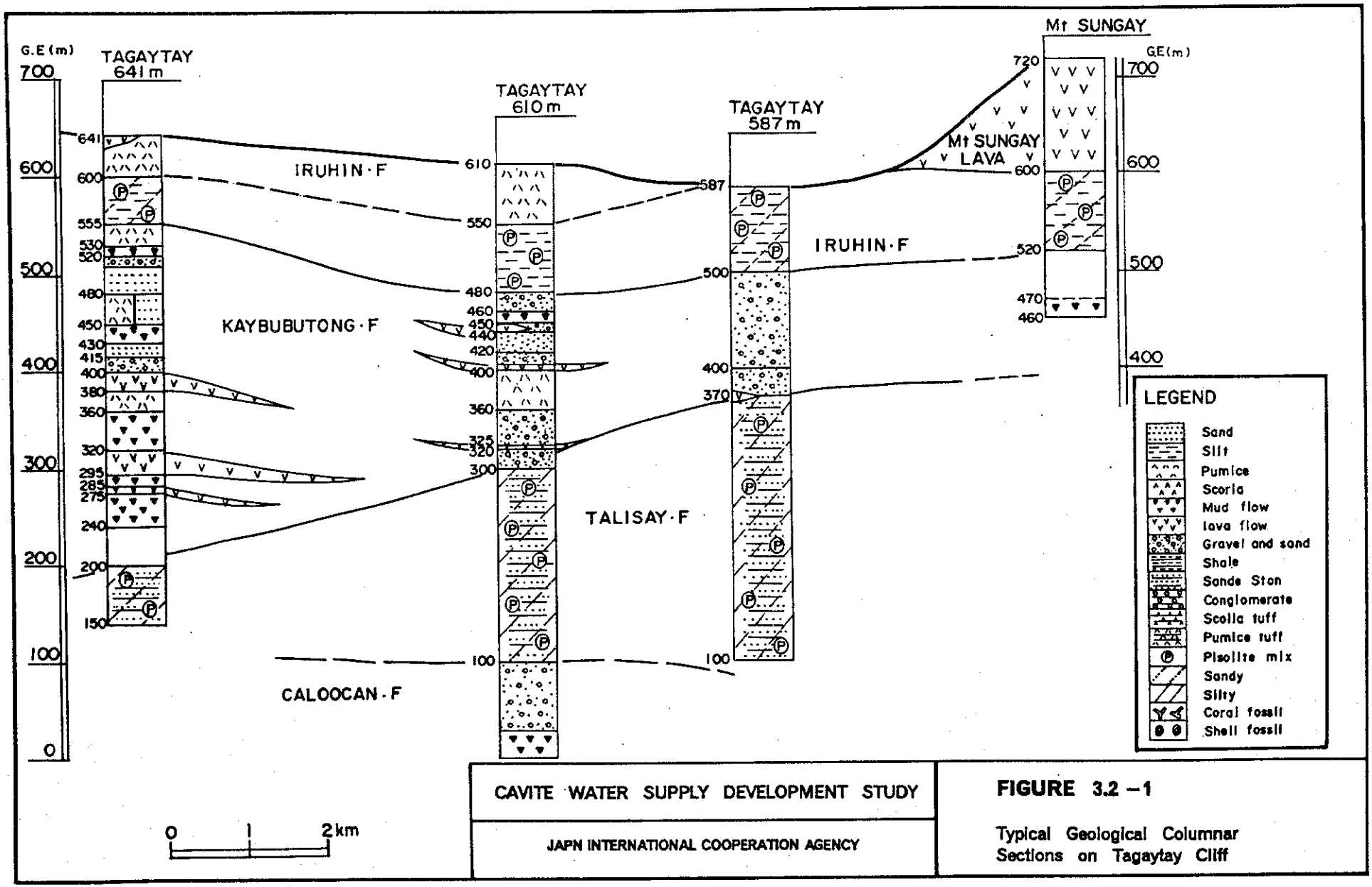
The southern side of Tagaytay Ridge (referred here as Tagaytay Cliff) was surveyed in detail to understand the stratigraphic succession in the Study Area since facies change is continuously observed on outcrops along the road cuts. **Fig. 3.2-1** shows the lithologic continuation on the cliff.

In addition, the slime obtained from the four test wells was identified and the columnar sections were depicted as shown in **Fig. 3.2-2.**

Based on the above mentioned works as well as the regional geological survey, a new stratigraphic succession was established as shown in **Table 3.2-1**.



CAVITE WATER SUPPLY DEVELOPMENT STUDY	Fig. 3.1-1 Location of Geophysical Prospecting Survey Lines and JICA Test and Production Wells
JAPAN INTERNATIONAL COOPERATION AGENCY	

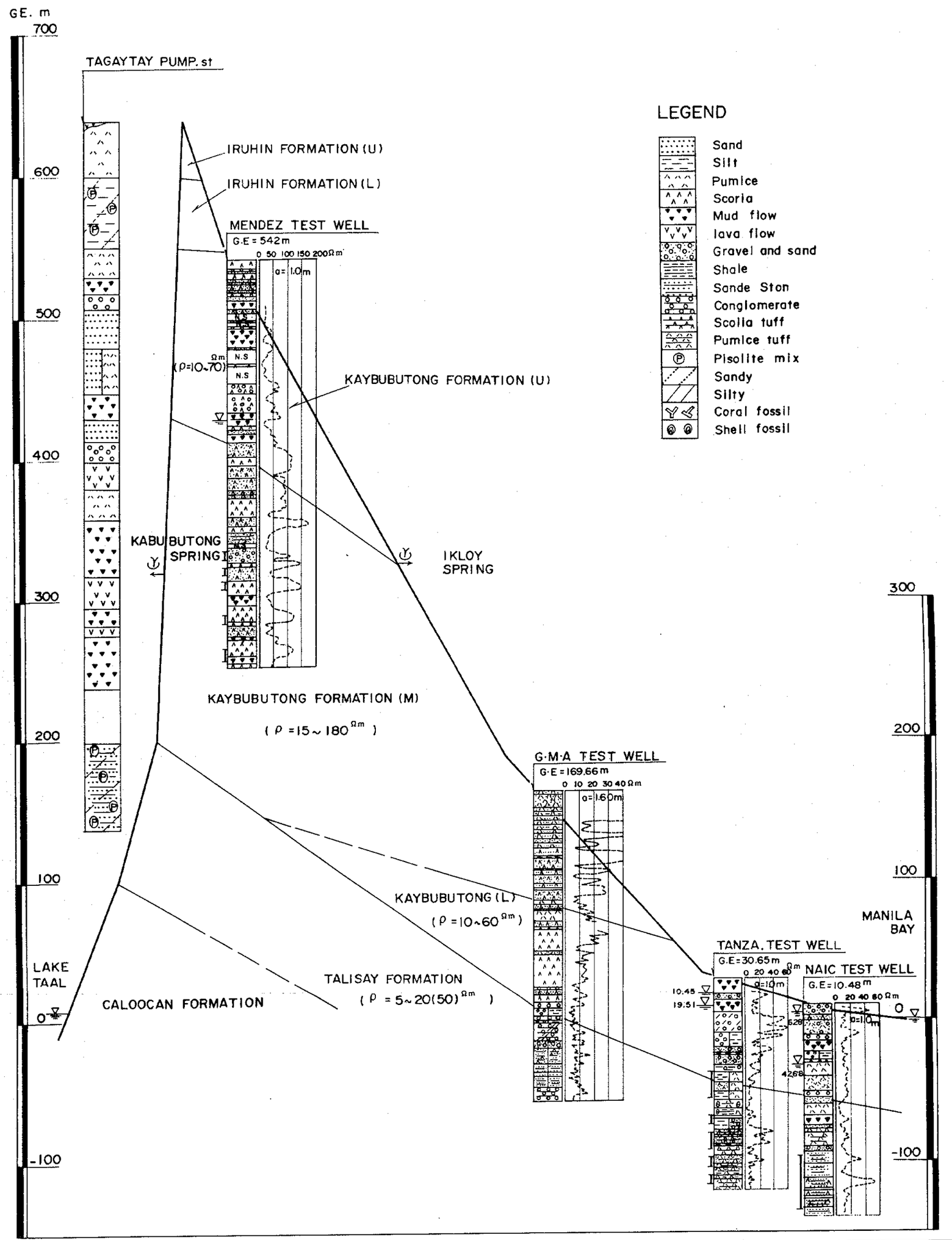


CAVITE WATER SUPPLY DEVELOPMENT STUDY

JAPN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.2 –1

Typical Geological Columnar Sections on Tagaytay Cliff



CAVITE WATER SUPPLY DEVELOPMENT STUDY	Fig. 3.2-2 CORRELATION AMONG THE GEOLOGICAL COLUMNAR SECTIONS
JAPAN INTERNATIONAL COOPERATION AGENCY	

TABLE 3.2-1 STRATIGRAPHIC TABLE FOR THE STUDY AREA

GEOLOGIC AGE				FORMATION	LITHOLOGY	HYDROGEOLOGICAL CLASSIFICATION	BMGS (1962)
ERA	PERIOD	EPOCH	AGE				
CENOZOIC	QUATERNARY	HOLOCENE		ALLUVIUM	Clay, Sand, Gravel Talus, Terrace Deposits		
		PLEISTOCENE	LATE	Mt. Sungay Lava	Andesite Lava	Upper Aquifer	Taal Tuff
				Iruhin Formation	Pisolite tuff, silt, Pumice tuff		
				Kaybubutong Formation(Upper)	Tuffaceous Sand-silt, pumice, scoria		
				Kaybubutong Formation(Middle)	Andesite lava, Mud flow		
			EARLY	Kaybubutong Formation(Lower)	Gravel and sand, scoria		
					Tuffaceous Sand-silt	Middle Aquifer	Guadalupe Formation
				Tsilisay Formation	Gravel and sand, Tuffacious		
					Tuffacious Shale-sandstone	Lower Aquifer	
				Caloocan Formation	Conglomerate		Lobo
					Gravel and sand, Lava		Agglomerate
		PLIOCENE	LATE	BASEMENT	Sand Stone, Shale	Impermeable layers	Pinamucan Formation
					Limestone		Mapulo Limestone
			EARLY		Andesite Lava Pyroclastic Rock, Tuff Sandstone		
	TERTIARY	MIOCENE	LATE				Talahib Andesite
			MIDDLE				Dagatan Wacke

(1) Basement

The formations underlying Caloocan Formation are considered collectively as Basement, since they are not penetrated by the existing well including four test wells drilled in the Study.

Talahib Andesite and Pinamucan Formation described in the existing geologic map "CAVITE" (edited by MGB, 1982) correspond to this Basement. The former mainly consisted of andesitic lava and agglomerate, and distributed around Mt. Palay Palay, located at the southern end of the Study Area. While, the latter is mainly composed of marine sediments such as sandstone, mudstone and limestone, and appreciably found in Mt. Talipusa in Maragondon.

(2) Caloocan Formation

This formation typically crops out along the lake side road between Binirayan and Caloocan.

Its thickness is more than 100 m on Tagaytay Cliff and is divided into two parts. The lower part consists of mud flow including andesitic breccia larger than 100 cm in diameter with matrix of coarse sand and silt. This part is considerably well consolidated and more than 30 m in thickness.

While the upper part consisted of poorly sorted gravels to coarse sand including boulders. The lower part has intercalation of reddish brown andesitic autobrecciated lava in some places.

The bedding plane of this formation is almost horizontal or slightly dips southward.

(3) Talisay Formation

This formation crops out from 100 m to 370 m in elevation on Tagaytay Cliff, and typically represented in Talisay. The corresponding layers are found in the test wells of G.M.A (below 155 m in depth), Tanza (below 74 m in depth), and Naic (below 65 m in depth).

Its thickness is 350 m in the northern part of Talisay and 100 m near Tagaytay pumping station.

This formation is an alternation of fine tuffaceous sandstone including pisolitic and medium-grained sandstone. It is pale gray to dark gray in color and develops laminations on Tagaytay Cliff.

In the test wells of G.M.A, Tanza, and Naic, the corresponding strata are alternation of pale gray or pale red shale and yellowish brown or dark gray fine sandstone. Fossils of pelecypoda are found in this formation at Tanza.

The predominant bedding planes developing in this formation are east to west in strike and dips about 20° southward near Talisay.

(4) Kaybubutong Formation

This formation typically crops out from 200 m to 550 m in elevation on Tagaytay Cliff.

The corresponding layers are found in the test wells of G.M.A. (between GL and GL-155 m), Tanza (between GL and GL-74 m), and Naic (between GL and GL-65 m).

Its thickness is 100 m to 350 m and mainly consists of andesitic lava, mud flow and volcanic fall deposits rich in scoria and pumice. Silt, sand, and gravel beds are also intercalated.

Upper member of this formation is composed of pumice, scoria, and mud flow deposits. Electric resistivity is 20-70 ohm-m for the corresponding part in the test wells.

Middle member is made-up of andesitic lava, mud flow and scoria. Electric resistivity is 20-80 ohm-m for the corresponding part in the test wells.

Lower member consists of tuffacious sand, gravel, and silt. Coral fossils are found from the corresponding part in the test wells of G.M.A.

Except for portion of the lower member, most of this formation consists of terrestrial deposits.

Gentle folds with north-southward axis and 5-20° limb inclinations are noted in this formation.

(5) Iruhin Formation

This formation typically crops out on Tagaytay Cliff higher than 500 m in elevation.

Its thickness is about 100 m and is divided into two parts. The lower member consisted of pumice tuff and the upper member consisted of alternation of pisolitic tuff and sandy silt. Both members are unconsolidated.

In the northern part of Mt. Sungay, it strikes N50°-60°E and dips 16°-18 northward. Along the road between Tagaytay and Talisay, the strike is N50°W and dipping 10° SW.

(6) Mt. Sungay Lava

This formation crops out around Mt. Sungay with 100 m in thickness.

It consists of andesitic lava and partly autobrecciated.

(7) Others

The surface of Tagaytay Ridge is covered by scoria from recent eruption of Taal Volcano. The thickness of this scoria is 2 to 3 m, in average and about 20 m, maximum.

3.2.2 Distribution and Facies Change of the Formations

Distribution and facies change of the formations classified in the previous section were examined on the basis of the results of field survey, satellite image interpretation, test drilling, electric resistivity survey and the analysis of existing data.

Fig. 3.2-3 is the hydrogeological map and **Fig. 3.2-4** presents the geologic cross-sections in north-south and east-west directions across the Study Area, showing the facies change of each formation described in the previous section.

The hills and mountains west of Maragondon River are basically made up of several mud flow layers with total thickness of about 200 m. The facies of these mud flow layers is similar to that of Caloocan Formation whose type locality is at the lowest part of Tagaytay Cliff. Similar strata are also found in the deeper part of Maragondon. Consequently, Caloocan Formation is widely distributed beneath the Cavite Slope and is correlated with the Lobo Agglomerate in the geological map "CAVITE".

Talisay Formation is found from 100 m to 370 m above MSL on Tagaytay Cliff and is traceable to the coastal area fronting Manila Bay, where the top of this formation is 50 m below MSL. Though the facies of this formation is characterized by fine grain sandstone at the type locality, alternation of tuffaceous shale and pumice tuff is predominant in the northern part.

The facies of Kaybubutong Formation is characterized by coarse-grain volcanic fall deposits in the southern area, while gravel, sand, and silt are rich in the northern area. The thickness of this formation is about 250 m at the type locality and gradually decrease towards north direction. On the satellite image, the distribution of the lower part of this formation looks blackish, while the area of the middle part looks whitish.

Based on the above discussion, Kaybubutong Formation almost corresponds to the Taal Tuff in the geological map "CAVITE".

Iruhin Formation is limited to the area higher than 500 m above MSL with nearly horizontal base according to the results of the electric resistivity survey.

3.2.3 Depth of the Top of Talisay Formation

Since the top of Basement could not be confirmed by the techniques adopted in the Study, the top of Talisay Formation was traced to make clear the shape of the groundwater basin.

According to the test drilling data, electric resistivity value varies greatly between the lower part of Kaybubutong Formation and Talisay Formation reflecting the difference of lithology and water content. Likewise, the existing electric resistivity data were examined to trace the top of Talisay Formation. The results are shown in **Fig. 3.2-5**.

Fig. 3.2-3 HYDROGEOLOGICAL MAP OF CAVITE PROVINCE

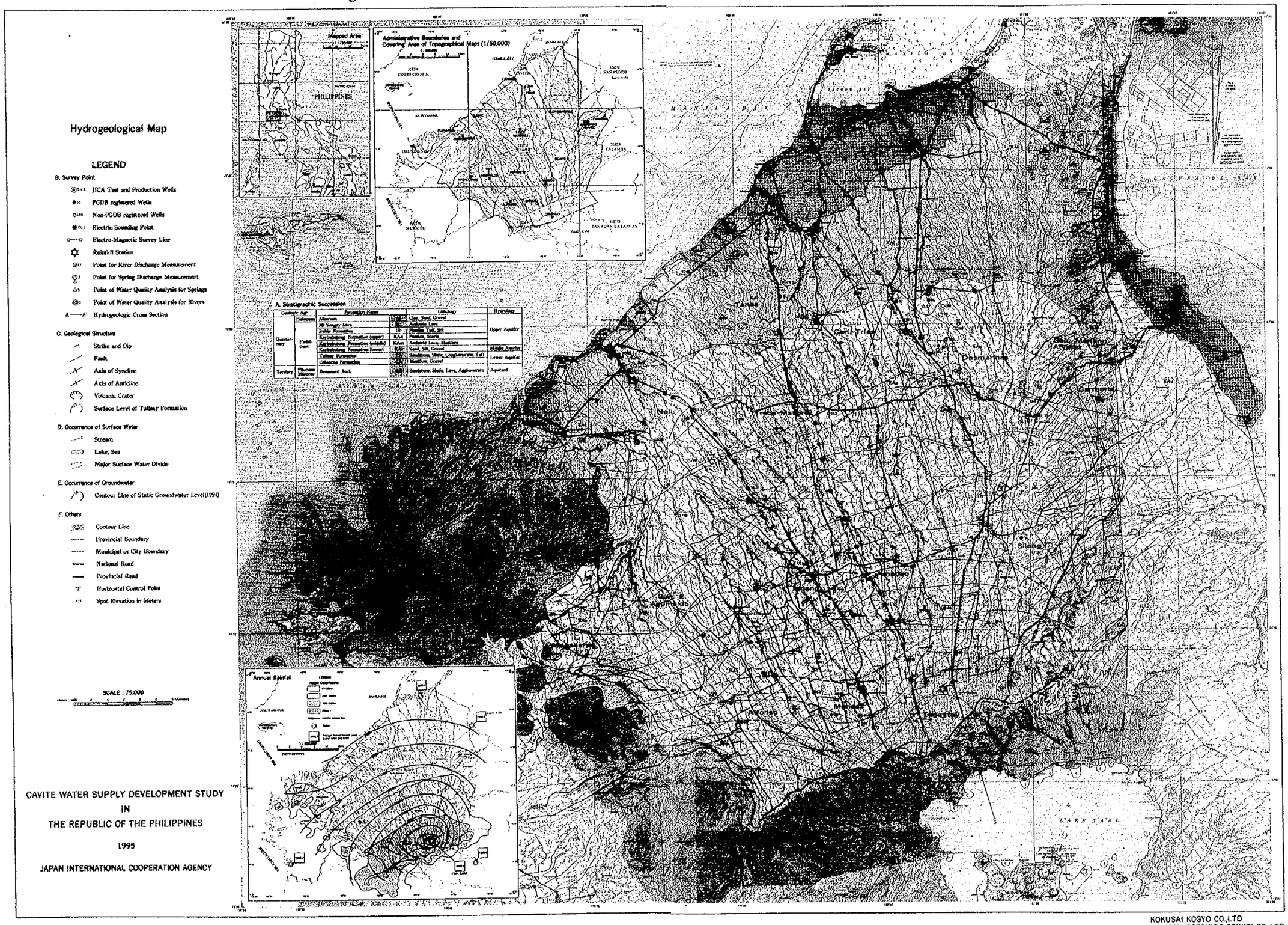
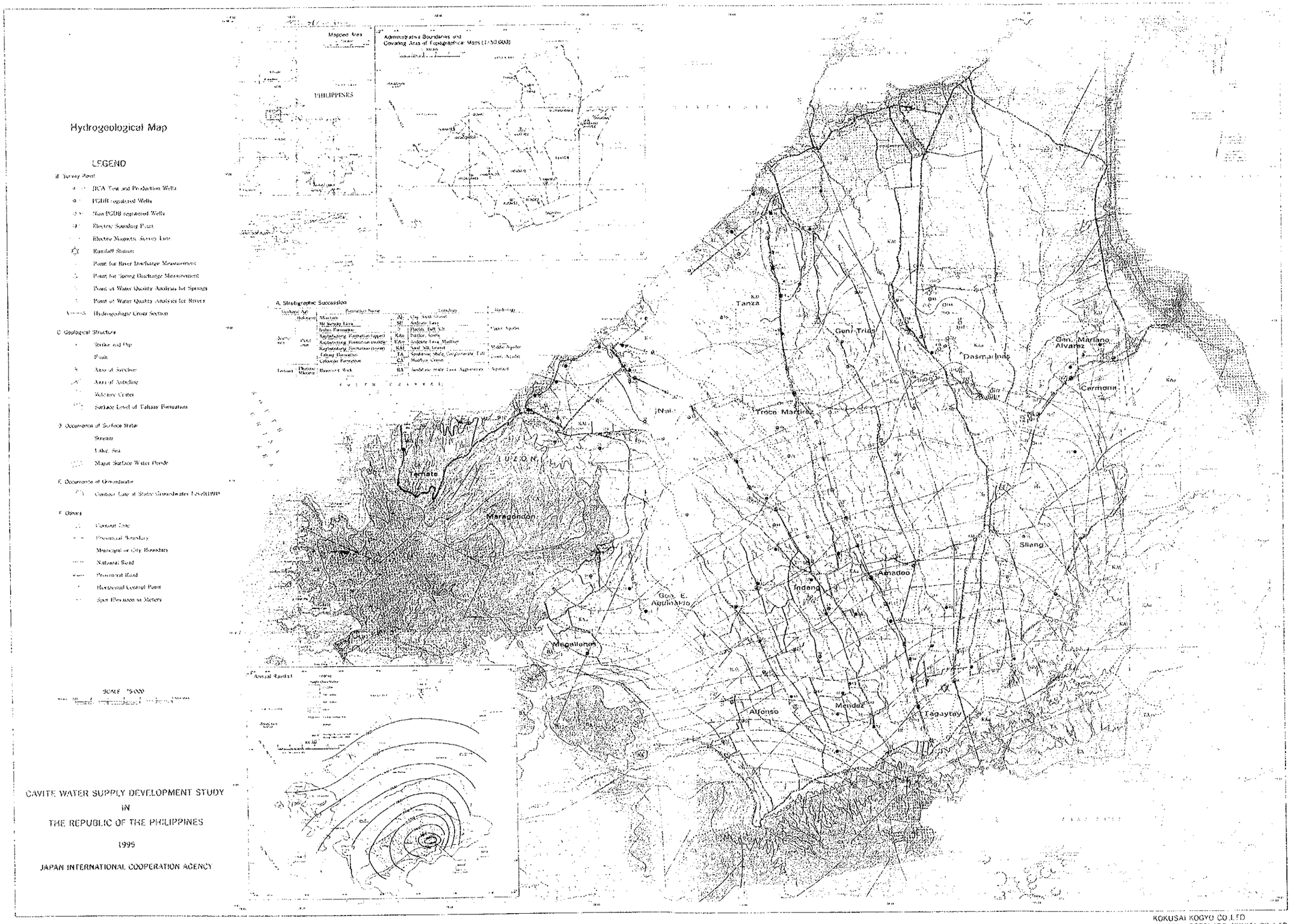
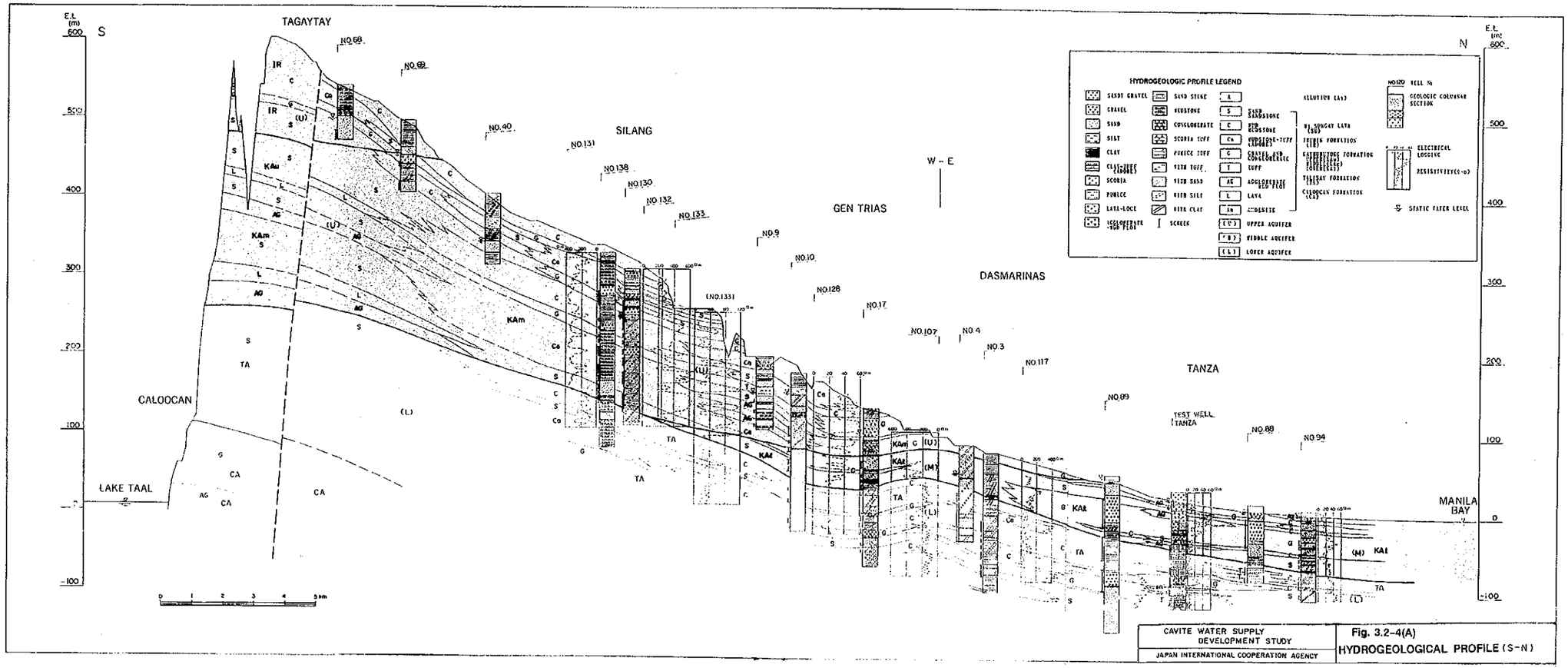


Fig. 3.2-3 HYDROGEOLOGICAL MAP OF CAVITE PROVINCE

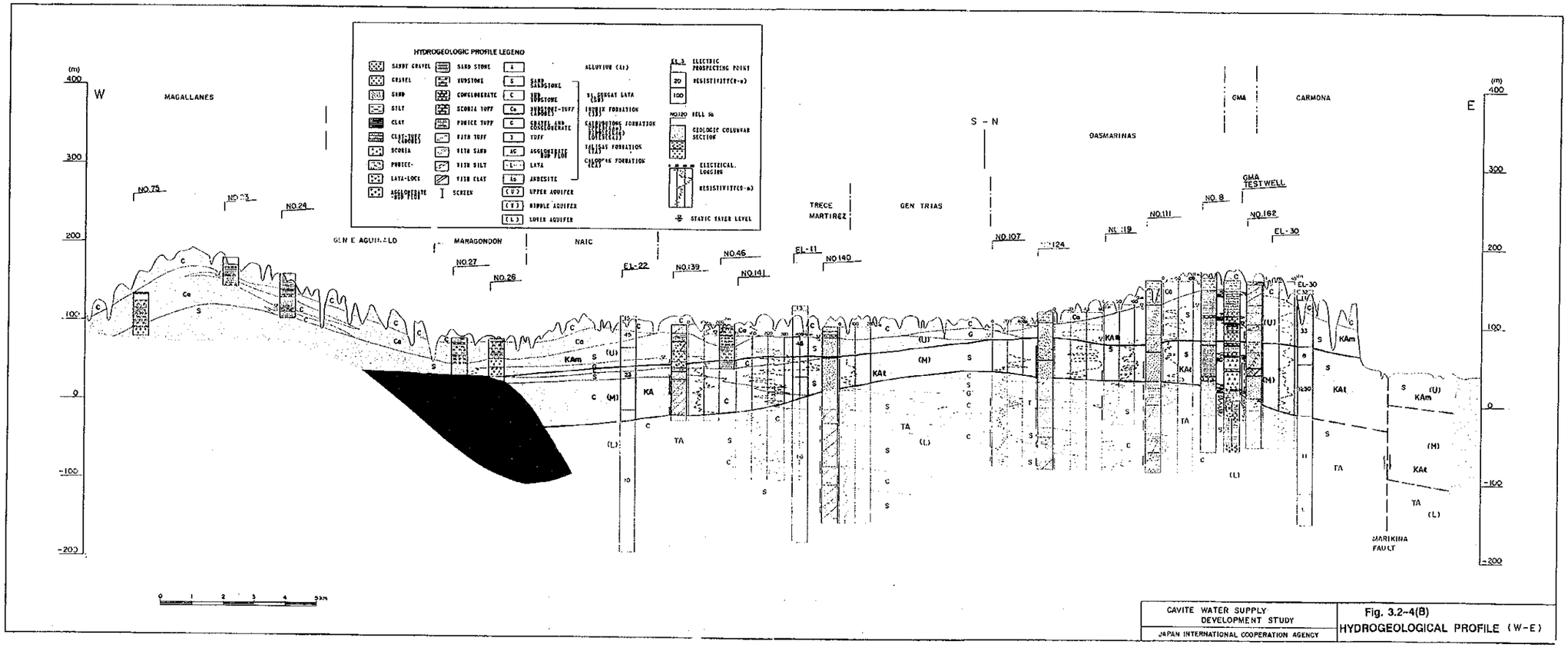


KOKUSAI KOGYO CO.,LTD.
NIPPON JOGESUIDO SEKKEI CO.,LTD.



CAVITE WATER SUPPLY DEVELOPMENT STUDY
JAPAN INTERNATIONAL COOPERATION AGENCY

Fig. 3.2-4(A)
HYDROGEOLOGICAL PROFILE (S-N)



CAVITE WATER SUPPLY DEVELOPMENT STUDY
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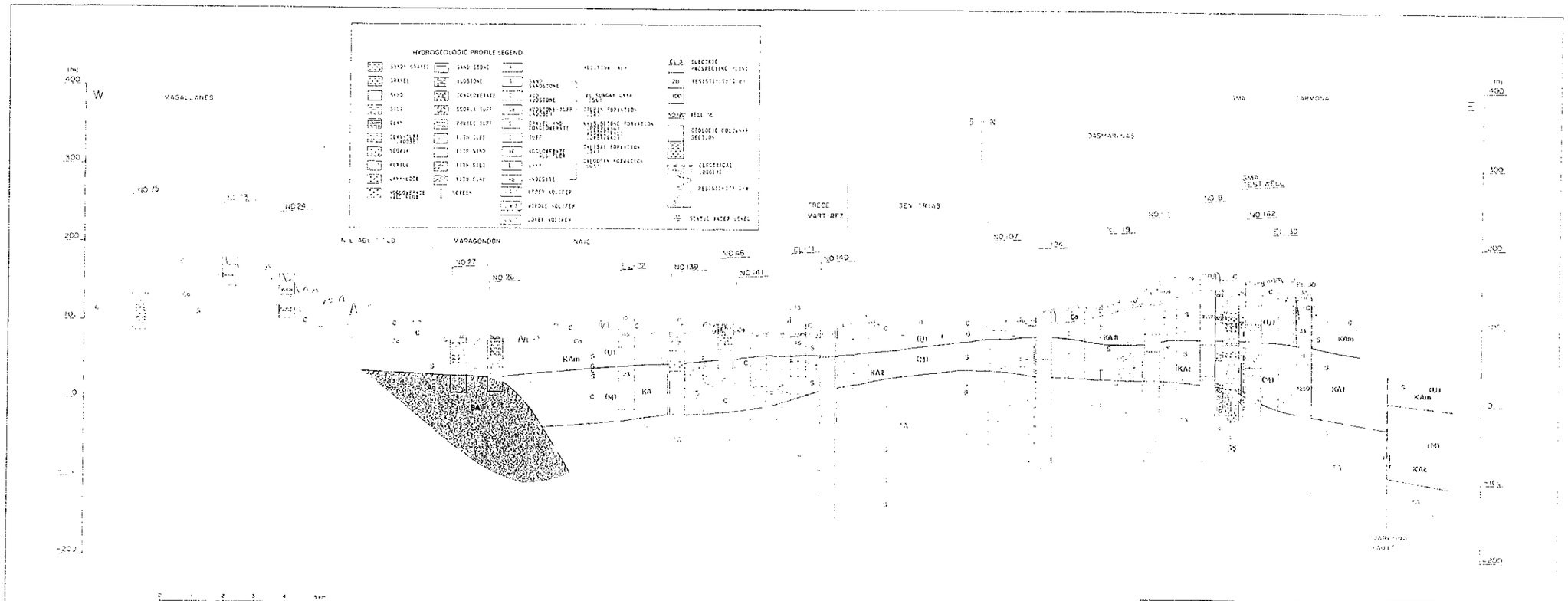
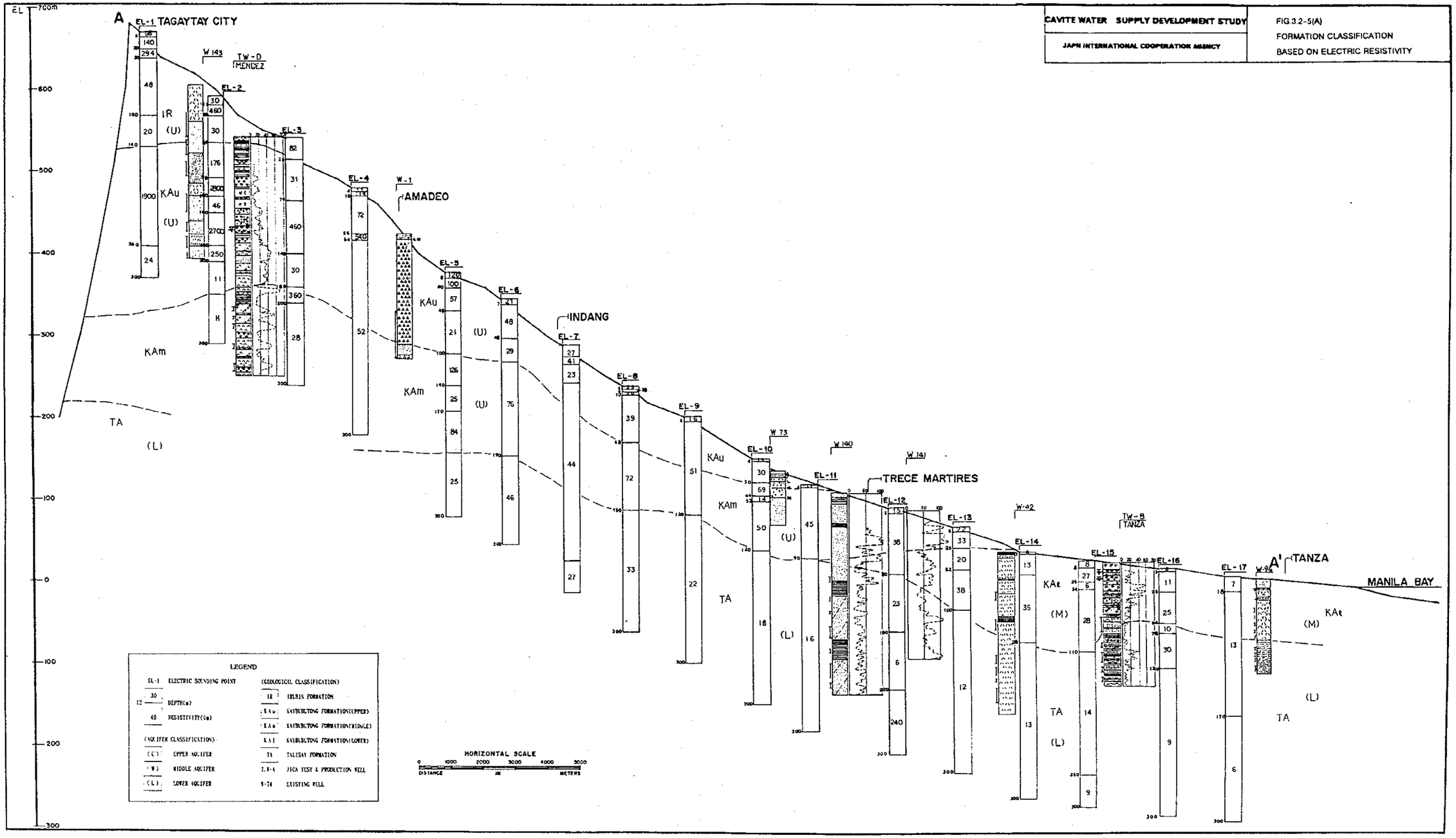
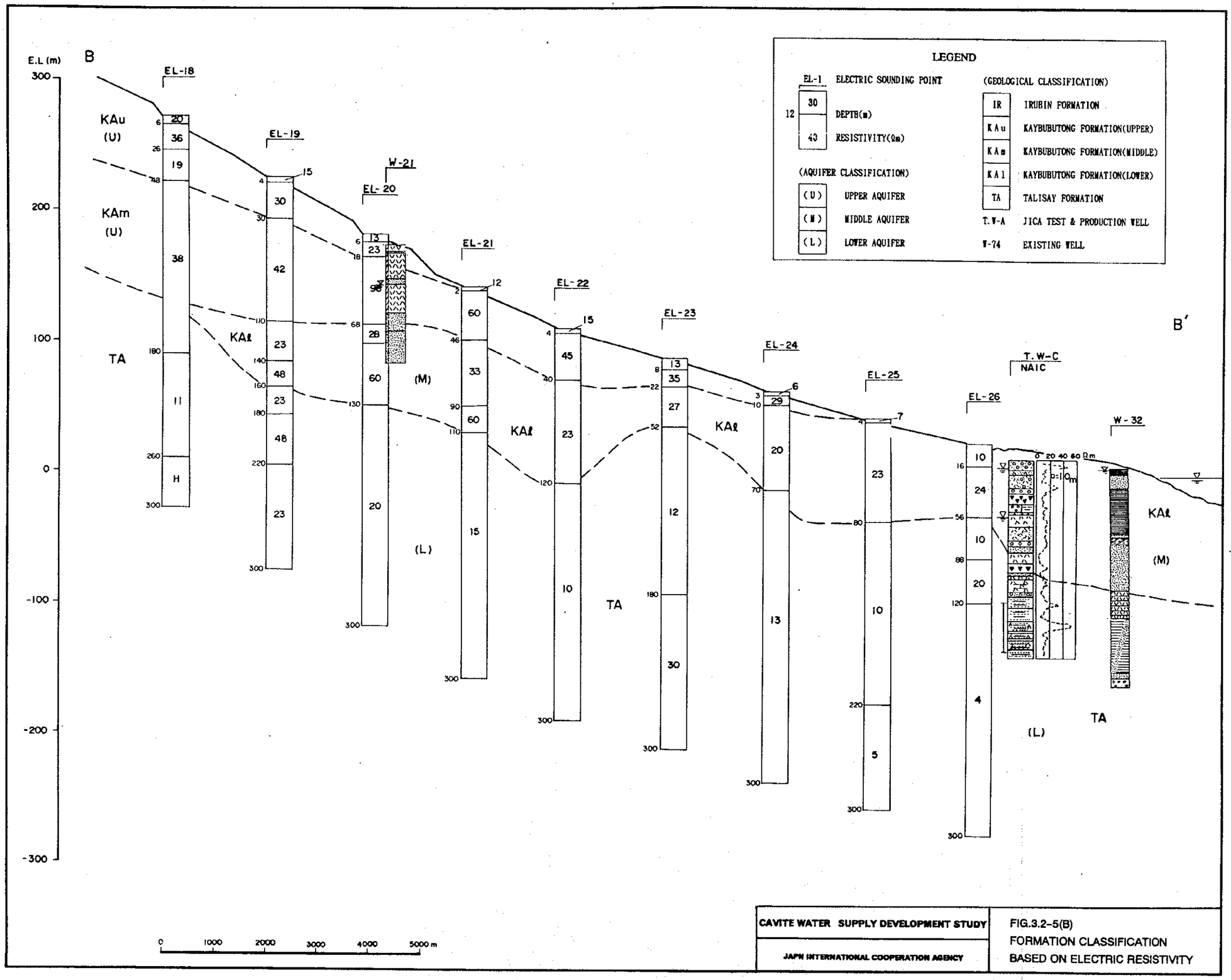
Fig. 3.2-4(B)
HYDROGEOLOGICAL PROFILE (W-E)

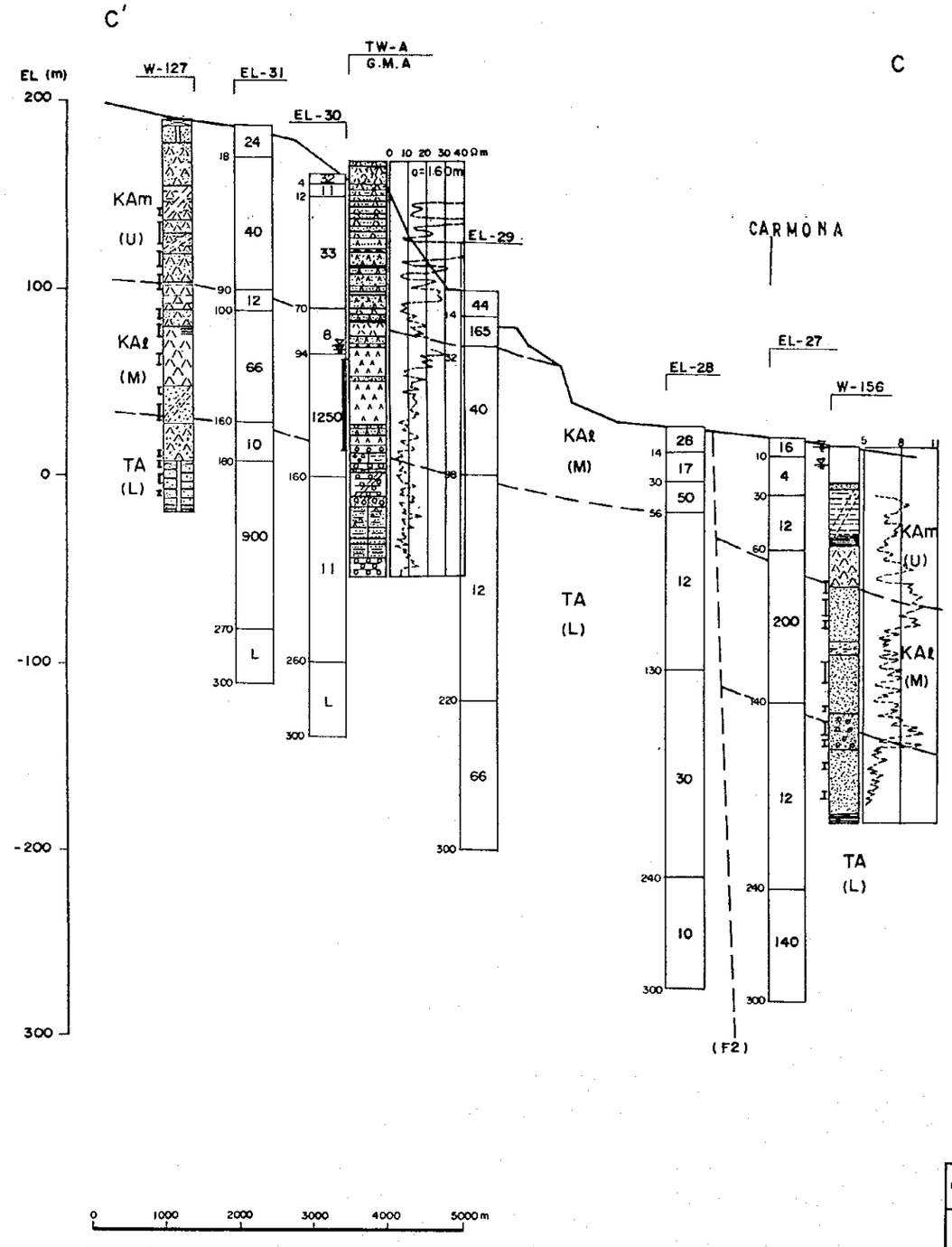


CAVITE WATER SUPPLY DEVELOPMENT STUDY JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 3.2-4(B) HYDROGEOLOGICAL PROFILE

CAVITE WATER SUPPLY DEVELOPMENT STUDY	FIG.3.2-5(A)
JAPN INTERNATIONAL COOPERATION AGENCY	FORMATION CLASSIFICATION BASED ON ELECTRIC RESISTIVITY




LEGEND
EL-1 ELECTRIC SOUNDING POINT
12 30 DEPTH(m)
40 RESISTIVITY(Ωm)
(AQUIFER CLASSIFICATION)
(U) UPPER AQUIFER
(M) MIDDLE AQUIFER
(L) LOWER AQUIFER
(GEOLOGICAL CLASSIFICATION)
IR IRUBIN FORMATION
KAu KAYBUBUTONG FORMATION(UPPER)
KAm KAYBUBUTONG FORMATION(MIDDLE)
KAl KAYBUBUTONG FORMATION(LOWER)
TA TALISAY FORMATION
T.W-A JICA TEST & PRODUCTION WELL
W-74 EXISTING WELL
E.L (m)
B
B'
EL-18
EL-19
W-21
EL-20
EL-21
EL-22
EL-23
EL-24
EL-25
EL-26
T.W-C
NAIC
W-32
KAu
(U)
KAm
(U)
TA
KAl
(M)
(L)
0 20 40 60 Ωm
ρ=10Ωm
0 1000 2000 3000 4000 5000 m
CAVITE WATER SUPPLY DEVELOPMENT STUDY
JAPN INTERNATIONAL COOPERATION AGENCY
FIG.3.2-5(B)
FORMATION CLASSIFICATION
BASED ON ELECTRIC RESISTIVITY



LEGEND

EL-1 ELECTRIC SOUNDING POINT

12 | 30 DEPTH(m)

40 RESISTIVITY(Ωm)

(AQUIFER CLASSIFICATION)

(U) UPPER AQUIFER

(M) MIDDLE AQUIFER

(L) LOWER AQUIFER

(GEOLOGICAL CLASSIFICATION)

IR	IRUHIN FORMATION
KAu	KAYBUBUTONG FORMATION(UPPER)
KAm	KAYBUBUTONG FORMATION(MIDDLE)
KAl	KAYBUBUTONG FORMATION(LOWER)
TA	TALISAY FORMATION

T.W-A JICA TEST & PRODUCTION WELL

W-74 EXISTING WELL

CAVITE WATER SUPPLY DEVELOPMENT STUDY	FIG.3.2-5(C) FORMATION CLASSIFICATION BASED ON ELECTRIC RESISTIVITY
JAPN INTERNATIONAL COOPERATION AGENCY	

The contours drawn in **Fig. 3.2-3** represent the surface plane of Talisay Formation confirmed through the above-mentioned technique.

The surface of the top of Talisay Formation gently dips northward without conspicuous undulation and its depth become shallower northwardly.

It is 300 to 450 m below GL around Tagaytay, about 300 m around Silang, about 80 m around Dasmarinas, and approximately 50-100 m at the northern end of Cavite Slope. The gradient of this surface is about 1/100.

On the surface of the top of Talisay Formation, shallow valleys are distinguished. It stretches from west of Silang to west of Tanza and the other from Indang to Maragondon. The valley extending from north of Gen. Trias to Imus has east-northeast direction.

3.3 GEOLOGIC STRUCTURE AND GEOLOGIC DEVELOPMENT HISTORY OF THE STUDY AREA

3.3.1 Distribution of Fault and Fold

(1) Fault

The steep slope with north-south direction divides the Study Area from the lowland surrounding the Laguna de Bay. According to the results of the electric resistivity survey near the slope around Carmona, a fault with 100 m throw was confirmed between EL 27 and EL 28. At a vacant quarry lot in Carmona, many small faults and joints with north-south direction developed. The above-mentioned faults correspond to Marikina Fault and it extends over 100 km from north to south along the eastern margin of Manila City. The western block of this fault is relatively uplifted as a whole against the eastern block.

On Tagaytay Cliff, the southern margin of the Study Area, several faults with east-west direction and southward dips cut Kaybubutong Formation. Such faults with east-west direction are also confirmed by electromagnetic survey.

(2) Fold

Both Kaybubutong Formation and Talisay Formation were gently folded with axis in N-S or WNW-ESE direction in the middle to western parts and becomes NE-SW in direction in the eastern portion. The directions of these fold axes tend to coincide with the directions of rivers running down the Cavite Slope.

Further, the valley and ridge on the surface plane of Talisay Formation roughly coincide with synclinal and anticlinal parts of such fold structure.

3.3.2 Geologic Development History around Taal Volcano

Fig. 3.3-1 is the geomorpholigical map around Taal Lake. The facts important in investigating the topographical and geological development history of the Study Area are derived from this map and the results of field survey. They are enumerated below.

(1) The contour lines around Taal Lake show irregular shape and do not show concentric circle like those of a stratovolcano.

(2) The steep cliff with 600 m relative height develops on the northern side of Taal Lake, while no such steep cliff is found on the eastern, western, and southern sides.

(3) The present surface elevation of Taal Lake is about 6 m above MSL, but Taal Lake was connected with Balayan Bay in the 15th century according to the existing materials.

(4) The Marikina Fault runs on the eastern margin of Cavite Slope, and the relative height between its sides is almost zero in the northern part, while about 400 m at the eastern end of Tagaytay Ridge, the southern margin of the slope. Furthermore, many faults with east-west strike direction developed on Tagaytay Cliff and its northern side is relatively uplifted.

(5) The lower parts of Kaybubutong Formation and Talisay Formation which are widely distributed beneath Cavite Slope are comprised of sandstone, pisolitic tuff, and siltstone deposited in marine environment, and the top of such marine sediments reaches to about 400 m above MSL.

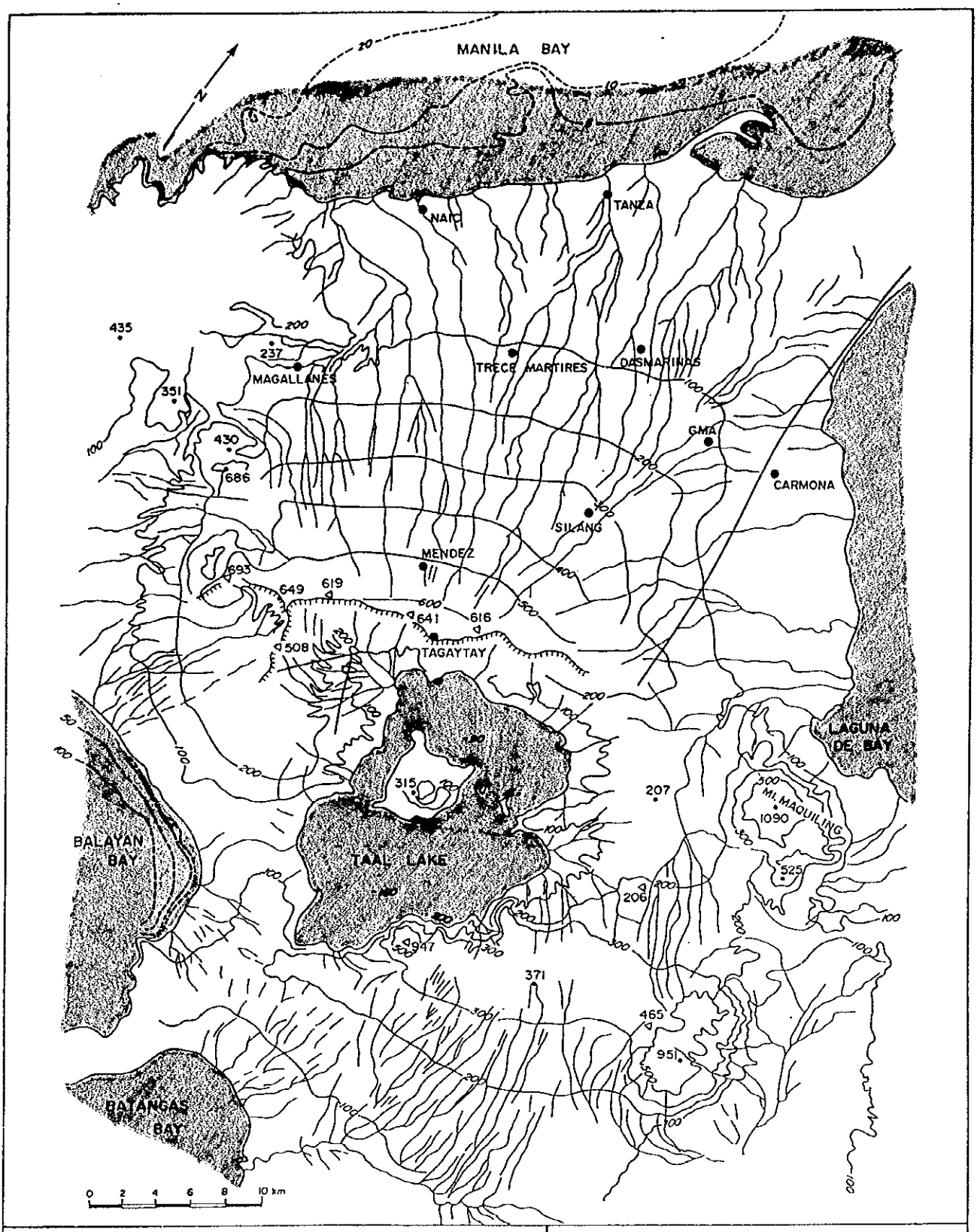
(6) Andesitic lava which should flow down to the lower ground surface is distributed on the top of Tagaytay Ridge, at more than 600 m above MSL. The lava which originated from the crater searched its way in the direction of Taal Lake whose elevation is far lower than the distribution area of the lava.

Based on these facts, it is considered that Cavite Slope is not a part of the mountainside of a stratovolcano but a structural slope formed by tilting movement of the block originally with low elevation.

The amount of displacement is largest at the southern margin of this tilted block, and the southern side of Tagaytay Ridge had developed to steep slope with large relative height. The eastern margin of the tilted block coincide with Marikina Fault.

The volcanic activities prior to the tilting movement had happened in the low-land connecting Balayan Bay with Laguna de Bay, giving off acidic tuff and pumice periodically.

The valleys running down Cavite Slope are subsequent valleys developed under such tilting movement.



CAVITE WATER SUPPLY DEVELOPMENT STUDY	Fig. 3.3-1
JAPAN INTERNATIONAL COOPERATION AGENCY	GEOMORPHOLOGICAL MAP AROUND TAAL LAKE