identified between depths of 65m to 100m in the Las Piñas test well sites. Tuffaceous sandstone is prominent below this layer. Beneath the clayey layer are alternating beds of fine to coarse sand, gravel, pumice and scoria. These beds intercalate two thin clayey layers located between depths of about 200m and 300m. The formation which is about 300m in thickness can thus be roughly divided into two aquifer units.

The first aquifer has a thickness of about 60m and is confined. Since groundwater is highly salinized, no existing deep well taps this aquifer. The second aquifer has a thickness of more than 200m and is also confined. Existing deep wells have their screen sections at this aquifer. The second aquifer may again be subdivided into two aquifers because of the existence of a thin clayey layer at a depth of about 200m. The clayey layers are semipervious and considered to be aquitards or aquicludes. The first aquitard particularly has an important role in saline water intrusion because of the high salinity of the first aquifer.

The Guadalupe formation tilts towards the coast at about 3 degrees. Therefore, the second aquifer identified in Las Piñas test well No.2 crops out the nearby LPS T-210 located about 3.5 km inland from the coast. The first aquifer is also similarly exposed. The formation is folded and two anticlinal structures extending in the north-south direction are found in the hilly area between Las Piñas and Muntinlupa. These factors explain why a well of the same depth but which is drilled inland taps a different aquifer (Figures 3.2.20 and 3.2.22).

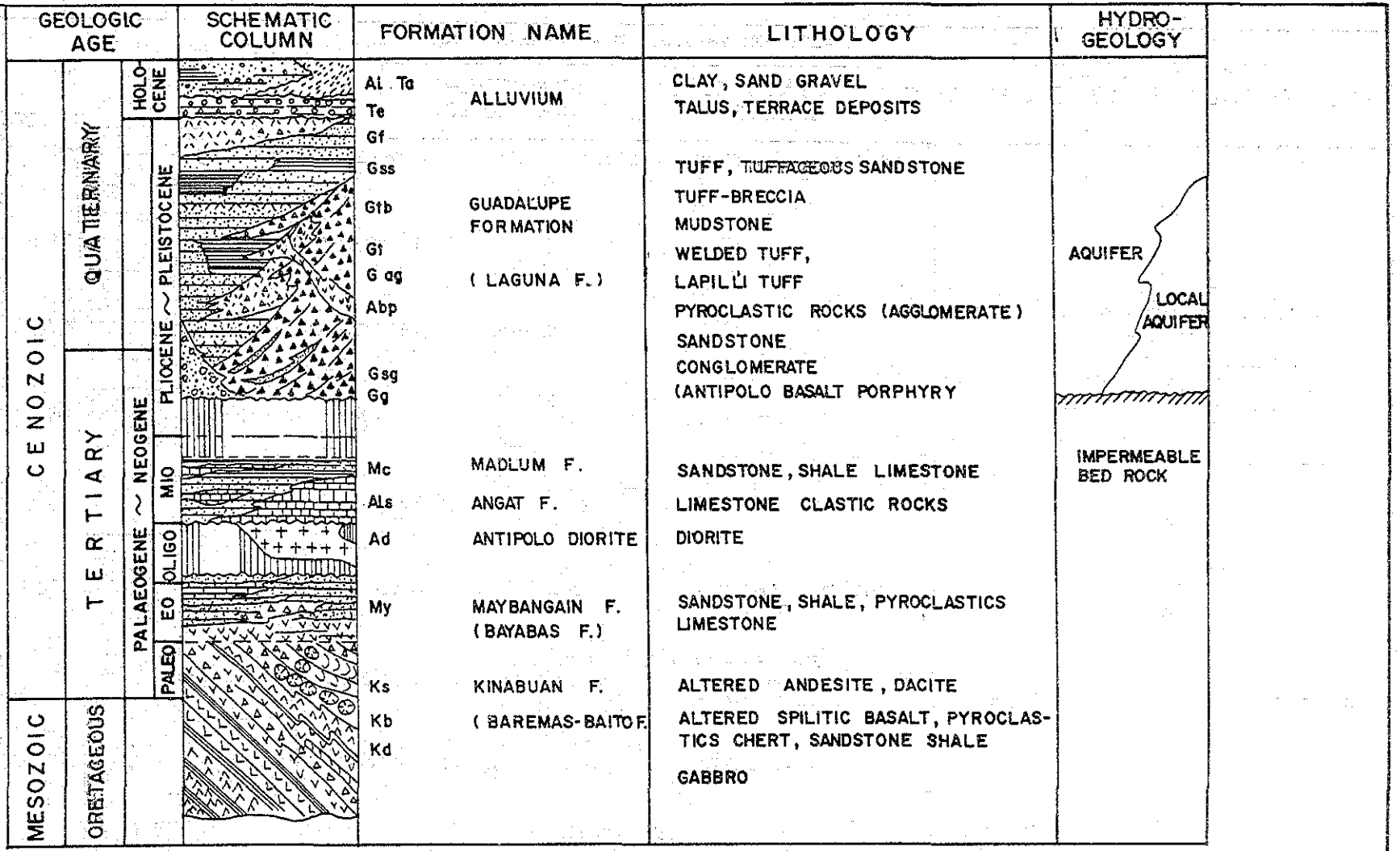
3.2.3.4 Groundwater Level

Groundwater level varies from aquifer to aquifer. For instance, water levels of the 100m-test wells at Las Piñas are 4.6m and 3.7m for No.1 and No.2, respectively. In contrast, water levels of the two 200m-test wells are 37.3m for No.1 and 43.4m for No.2. Water levels in the 300m-test wells are 44.5m (No.1) and 50.0m (No.2), a little lower than those of the 200m-test wells, indicating that groundwater is mainly pumped out from the second aquifer as previously mentioned (Figure 3.2.23).

Based on the simultaneous measurements done in May 1991, a piezometric contour map of the Las Piñas area was made. It is shown in Figure 2.4.1.

Since all existing wells have their screen sections at 100m to 300m, water levels measured in these wells represent piezometric heads of the second aquifer.

The marked drop of the piezometric surface of the second aquifer to 60m below sea level near Pamplona points to the heavy pumping in this area. Regional groundwater flows towards the depression in Pamplona, from the first aquifer to the second aquifer through downward leakage.



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

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TABLE 3.2.1 STRATIGRAPHY OF THE STUDY AREA

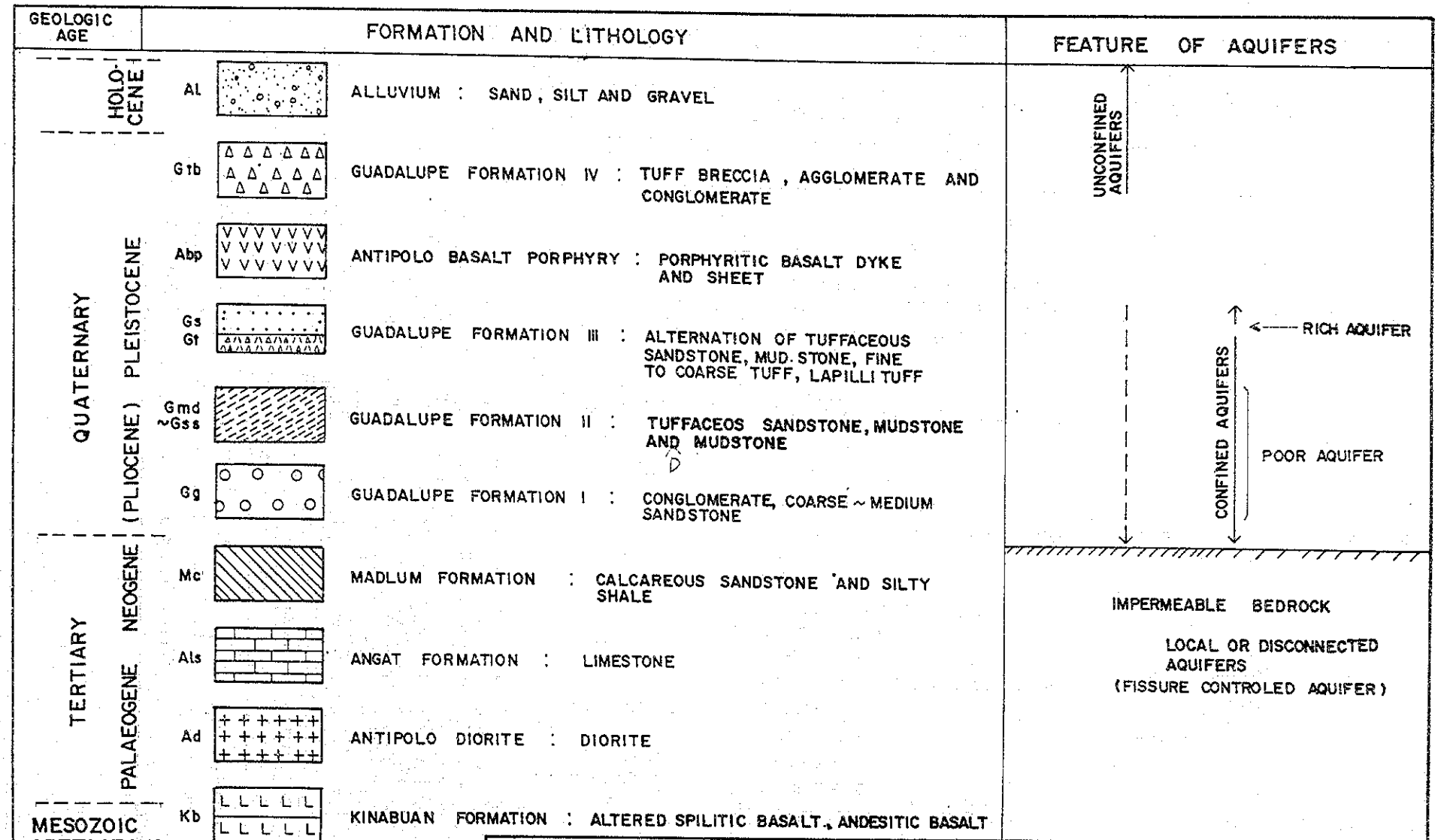

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TABLE 3.2.2 STRATIGRAPHY OF THE ANTIPOLO AREA

TABLE 3.2.3 FISSION TRACK AGES OF ZIRCON

SAMPLE NO.	SPONTANEOUS TRACK NUMBER	SPONTANEOUS TRACK DENSITY X10 cm	INDUCED TRACK NUMBER	INDUCED TRACK DENSITY X10 cm	THERMAL NEUTRON DOSE X10 cm	F	NUMBER OF GRAINS	AGE AND STD. ERROR (Ma)	RELATIVE STD. ERROR (%)	METHOD	ID
PM1	263	8.646 ± 0.533	53	1.742 ± 0.239	3.94 ± 0.14	1.62	4	116.4 ± 18	15.5	ESED	9104003
PM2	68	5.365 ± 0.651	20	1.578 ± 0.353	3.94 ± 0.14	0.01	2	80.0 ± 20.6	25.7	ESED	9104004
PM3	125	8.218 ± 0.735	21	1.381 ± 0.301	3.94 ± 0.14	0.32	4	139.5 ± 33.3	23.8	ESED	9104005
PM4	76	9.993 ± 1.146	19	2.495 ± 0.573	3.94 ± 0.14	1.82	2	94.1 ± 24.4	25.9	ESED	9104006
PM5	75	7.718 ± 0.891	14	1.441 ± 0.385	3.94 ± 0.14	0.05	4	125.7 ± 36.9	29.3	ESED	9104007

*1 Thermal neutron dose $\delta = \delta k \times u \times k$

δk : thermal neutron dose of standard glass (NBS SRM-913) irradiated at NBS nuclear reactor
= 4.75 ± 0.05 ($\times 10^{4} cm^{-2}$)

u : track density of muscovite attached to standard glass irradiated with sample
= $7.370 \times 10^{4} cm^{-2}$ = 2201 tracks/$3.0 \times 10^{-2} \times cm^{2}$

k : track density of muscovite attached to standard glass which irradiated at NBS nuclear reactor
= $8.885 \times 10^{4} cm^{-2}$ = 1770 tracks/$2.0 \times 10^{-2} cm^{2}$

*2 F-value, Hayashi and Sugiyama, 1987

*3 $Age = 6.45 \times 10^{9} \ln (1 + 9.32 \times 10^{-18} \times \sigma \times s / i)$

^{235}U

s = spontaneous track density of ^{235}U

i = induced track density of ^{235}U

*4 ESED, External-Surface External-Detector method, Daishi et al., 1986

(Ma): Mega-annum

TABLE 3.2.4 DIATOM ANALYSIS OF CORE SAMPLES IN LAS PINAS (JICA NO.1 TESTWELL)

NAME OF FOSSILS	M.O.L.	7.7m	-10.5	-24.8	-63-3	-116m	-150.	-238.	-295m
Achnanthes brevipes var intermedia	M	3	8						
Achnanthes covergens	F-B			12					
Achnanthes delicatula	B	1							
Achnanthes sp.	M		1						
Amphora holsatica	M	1	5						
Amphora spp.	F-B			2					
Amphora strigosa	B		2						
Bacillaria paradoxa	F-B		2						
Cyclotella sp.	F					3			
Cyclotella striata? sp.	M	84	1						
Cymbella sp.	F			1					
Diploneis interupta	B	3	6						
Diploneis ovalis?	F			1					
Dioloneis smithii	M	1	55						
Diploneis sp.	F							1	
Diploneis suborbicularis	M-B	9	14						
Epthemia sp.	F					2			
Fragilaria sp.	F					1			
Comphonema spp.	F			3					
Grammatophora macilenta	M	7							
Gyrosigma scalproides	F		1						
Gyrosigma spp.	F		2	3					
Hyalodiscus scoticus	B-M	1							
Melosira roeseana	F							2	
Melosira sp.	F			1					

NAME OF FOSSILS	M.O.L.	7.7m	-10.5	-24.8	-63-3	-116m	-150.	-238.	-295m
Navicula contenta	F					1		15	
Navicula gregaria	M			5					
Navicula mutica	F		1			1			
Navicula pupula	F			3					
Navicula spp.	F		2	6				1	
Navicula thienemanni	F			1					
Nitzschia cocconeiformis	M	28	27						
Nitzchia fonticola	F			1					
Nitzschia glanurata	M	11	17						
Nitzshia hohnkii	B		1						
Nitzshia hungarica	F-B		1						
Nitzshia littoralis	B		2						
Nitzschia obtusa	F			21					
Nitzschia palea	F					1			
Nitzschia parvula	F-B			1					
Nitzschia punctata	M	2	2						
Nitzschia sigma	M	2	20						
Nitzschia sp.1	F					1			
Nitzschia sp.2	F					5			
Nitzschia sp.3	F-B			1					
Nitzschia spp.	?	1	4	13					
Nitzschia supralitorea	F			42					
Paralia sulcata	M	20							
Pinnularia hemiptera	F		1						
Pinnularia spp.	F	4		19				2	
Rhaphoneis surirella	M	1							

NAME OF FOSSILS	M.O.L.	7.7m	-10.5	-24.8	-63-3	-116m	-150.	-238.	-295m
Rhopalodia gibberula	F-B	2		71					
Synedra rumpens	F					5			
Synedra sp.	F					32			
Talasiosira sp.	?	6							
Thalassionema nitzschioides	M	14							
Thalassiosira bramaptrae	F-B		1						
gen. et sp. indet	?	1	6	3				5	
TOTAL		202	182	210	0	52	0	26	0

M.O.L. : Mode of Life
F : Fresh, B: Brackish, M: Marine

TABLE 3.2.5(1) GRAIN COMPOSITION

SAMPLE NO.	DEPTH (m)	VOLCANIC GLASS				WEATHER PARTICLES	ROCK FRAGMENTS	LIGHT MINERAL	HEAVY MINERAL
		WHITE	BROWN	BLACK	TOTAL				
1	10.0	49.8	0.0	0.0	49.8	24.9	19.9	5.0	0.5
3	24.0	0.0	0.0	0.0	0.0	68.0	26.6	4.9	0.5
6	41.0	0.0	0.0	0.0	0.0	70.0	11.0	17.0	2.0
10	79.3	0.0	0.0	0.0	0.0	56.9	4.0	7.1	2.0
11	95.9	39.0	31.0	4.0	74.0	0.0	9.0	14.0	3.0
12	105.1	43.9	36.1	7.8	87.8	0.0	7.8	3.9	0.5
13	114.1								
14	123.8	0.0	0.0	0.0	0.0	89.6	5.0	5.0	0.5
15	134.0	26.0	32.0	9.0	67.0	0.0	20.0	8.0	5.0
16	143.9	7.1	49.5	4.0	60.6	0.0	35.4	3.0	1.0
17	156.0	0.0	0.0	0.0	0.0	88.6	5.0	6.0	0.5
18	165.0	0.0	0.0	0.0	0.0	89.6	5.0	5.0	0.5
19	177.5								
20	184.0	90.5	0.0	0.0	90.5	3.0	5.0	1.0	0.5
21	197.0	64.0	14.0	5.0	83.0	0.0	8.0	8.0	1.0
22	207.1	8.1	30.3	6.0	44.4	0.0	30.3	15.2	10.1
23	216.5	25.0	16.0	5.0	46.0	0.0	40.0	12.0	2.0
24	231.7	71.8	17.4	3.1	92.3	0.0	6.2	1.0	0.5
25	241.5	47.3	19.7	14.8	81.8	0.0	13.8	3.9	0.5
26	249.5								
27	264.5	0.0	0.0	0.0	0.0	98.5	0.5	0.5	0.5
28	277.1	36.0	0.0	3.0	39.0	28.0	20.0	16.0	2.0
29	280.7	29.9	24.9	39.8	94.6	0.0	0.5	4.0	1.0
30	283.8								
31	290.5	0.0	0.5	0.5	1.0	97.1	0.5	1.0	0.5
32	297.6	0.0	0.0	0.0	0.0	73.4	15.2	8.9	2.5

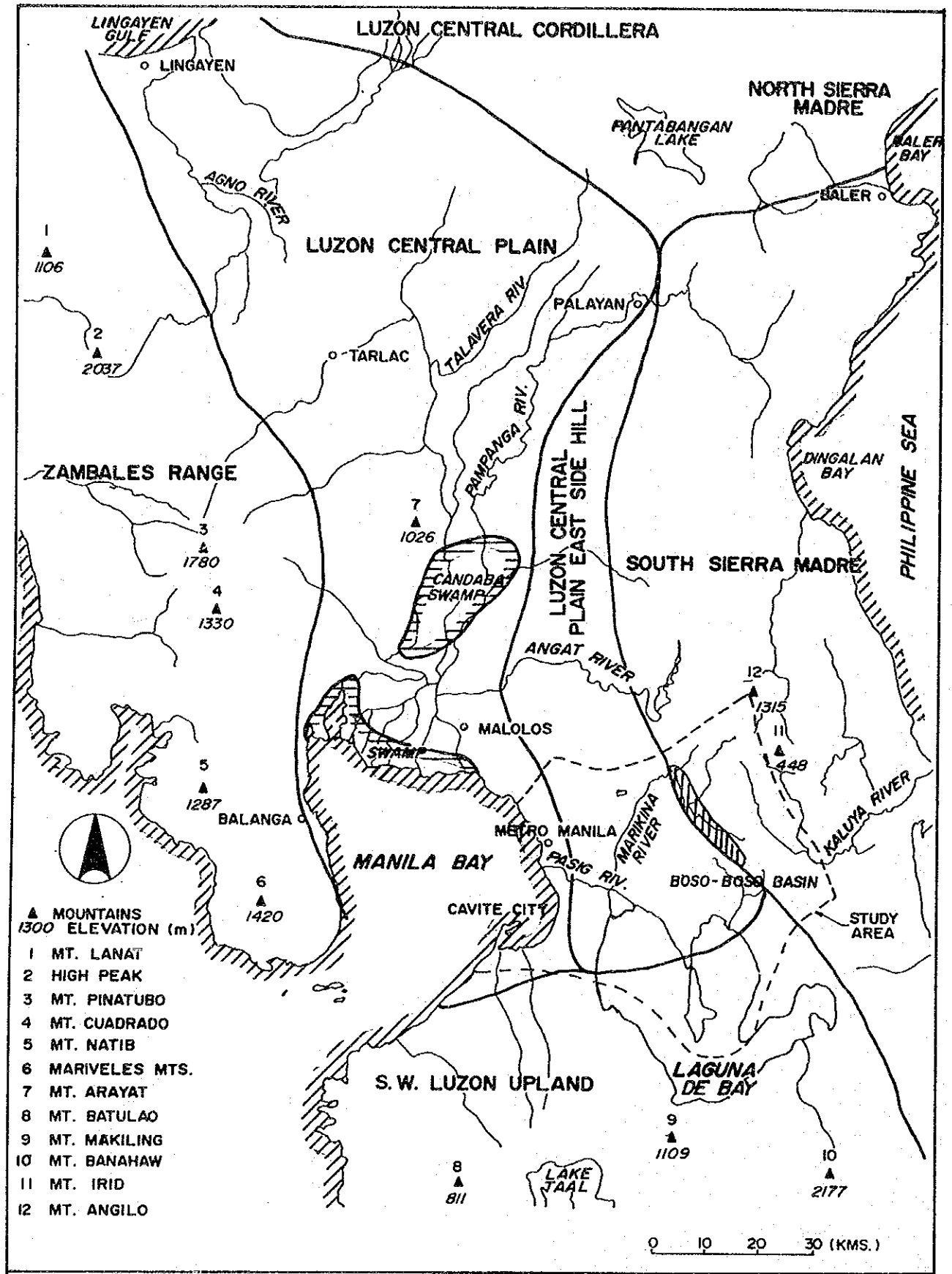
TABLE 3.2.5(2) HEAVY MINERAL COMPOSITION (%)

SAMPLE NO.	DEPTH (m)	Au	Hy	Ho	Zi	Mg	Py
1	10.0	70.0	20.0	5.0	0.0	5.0	0.0
3	24.0	96.0	1.0	1.0	0.0	2.0	0.0
6	41.0	71.0	18.0	5.0	0.0	6.0	0.0
10	79.3	0.0	0.0	0.5	0.0	99.5	0.0
11	98.9	31.0	37.0	0.0	0.0	32.0	0.0
12	105.1	50.0	20.0	0.0	0.0	30.0	0.0
13	114.1						
14	123.8	24.0	10.0	10.0	0.0	56.0	0.0
15	134.0	38.0	28.0	0.0	0.0	34.0	0.0
16	143.9	50.5	12.1	0.0	0.0	36.4	1.0
17	156.0	14.0	0.0	0.0	0.0	86.0	0.0
18	165.0	58.5	12.7	8.8	0.0	0.5	19.5
19	177.5						
20	184.0	50.0	20.0	0.0	0.0	30.0	0.0
21	197.0	51.0	34.0	0.0	0.0	15.0	0.0
22	207.1	58.0	5.0	0.0	1.0	36.0	0.0
23	216.5	56.0	32.0	0.0	0.0	7.0	5.0
24	231.7	49.0	13.0	0.0	0.0	23.0	15.0
25	241.5	19.0	53.0	0.0	0.0	28.0	0.0
26	249.5						
27	264.5	35.0	30.0	0.0	0.0	35.0	0.0
28	277.1	59.4	0.5	0.0	0.5	39.6	0.0
29	280.7	64.4	0.5	0.0	0.5	34.7	0.0
30	283.8						
31	290.5	80.0	0.0	0.0	0.0	20.0	0.0
32	297.6	58.0	1.0	0.0	0.0	41.0	0.0

Au: Augite Hy: Hypersthene Ho: Hornblende
Zi: Zircon Mg: Magnetite Py: Pyrite

TABLE 3.2.6 CHLORIDE CONTENT OF CORE SAMPLES IN LAS PINAS NO.1

SAMPLE NO.	QUANTITY (g)	CHLORIDE (g)	CHLORIDE QTY. (g) PER SAMPLE (kg)
1	0.5023	2.48×10^{-2}	49.0
4	0.4984	3.9×10^{-3}	7.8
7	0.5132	6.74×10^{-3}	13.0
11	0.5181	5.9×10^{-4}	1.1
15	0.5514	2.4×10^{-4}	0.4
19	0.5412	1.2×10^{-4}	0.2
21	0.5107	1.4×10^{-4}	0.3
24	0.5186	2.1×10^{-4}	0.4
26	0.5017	3.9×10^{-4}	0.8
29	0.5361	3.2×10^{-4}	0.6
32	0.5213	5.7×10^{-4}	1.1



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

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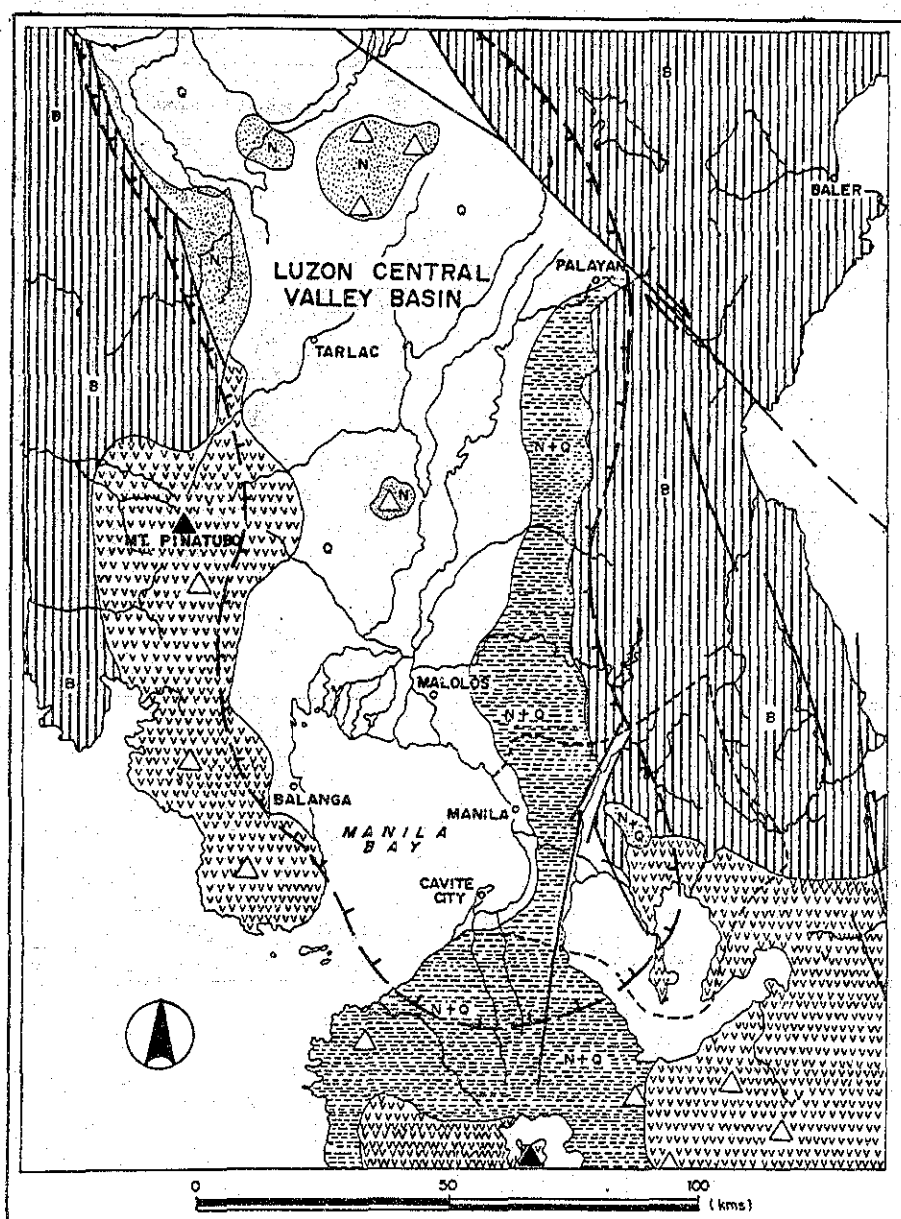
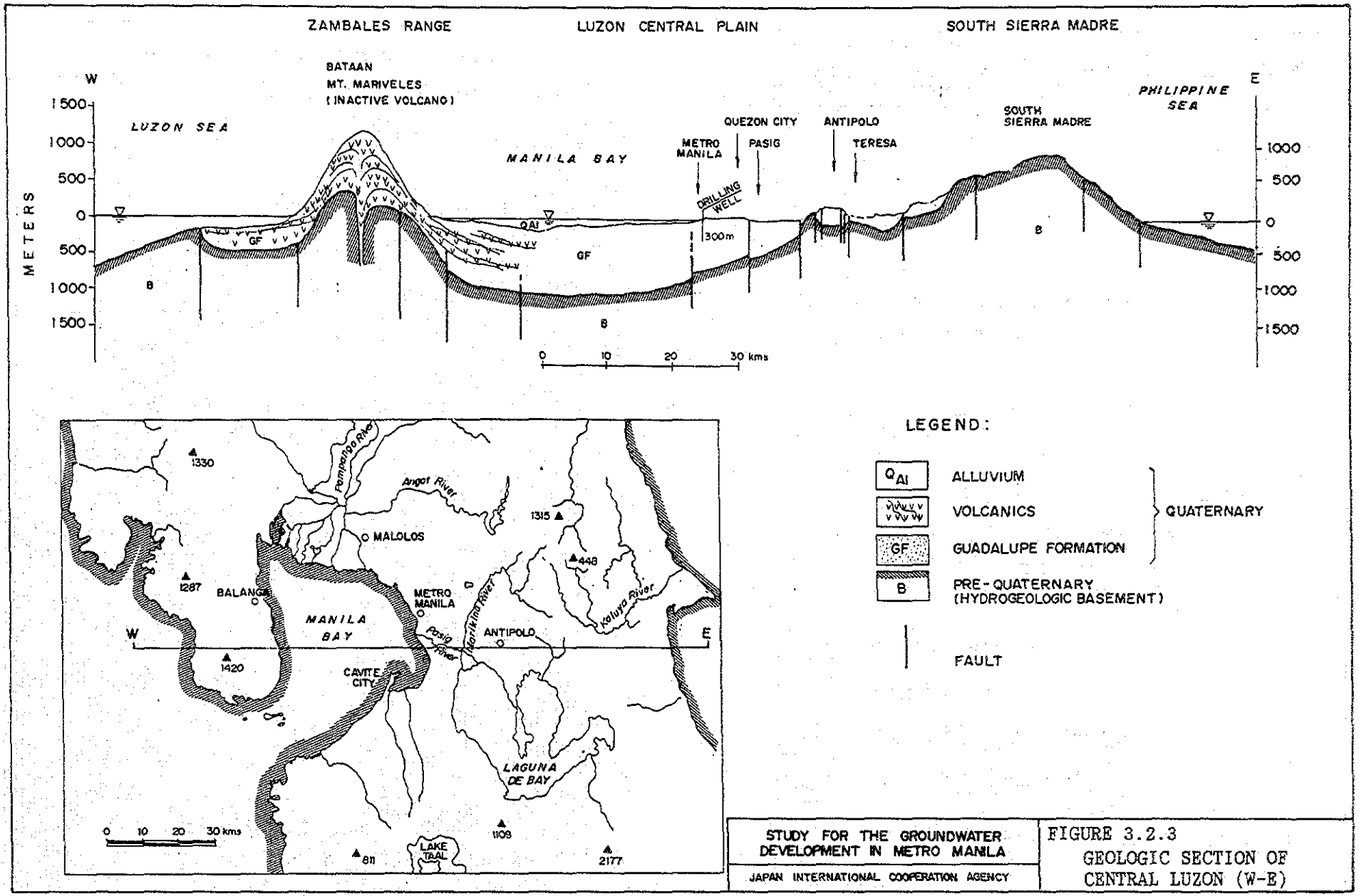
FIGURE 3.2.1 PHYSIOGRAPHIC PROVINCES OF CENTRAL LUZON



LEGEND

- Q — QUATERNARY SYSTEM
- N+Q — NEOGENE - QUATERNARY SYSTEM (GUADALUPE FORMATION)
- NEOGENE - QUATERNARY SYSTEM (MAINLY VOLCANOGENIC FORMATION)
- N — NEOGENE SYSTEM
- B — PRE - NEOGENE SYSTEM
- FAULT, DASHED WHERE INFERRED (ARROWS INDICATE RELATIVE MOVEMENT)
- SEDIMENTARY BASIN
- ▲ QUATERNARY ACTIVE VOLCANO
- △ PLIOCENE-QUATERNARY INACTIVE VOLCANO

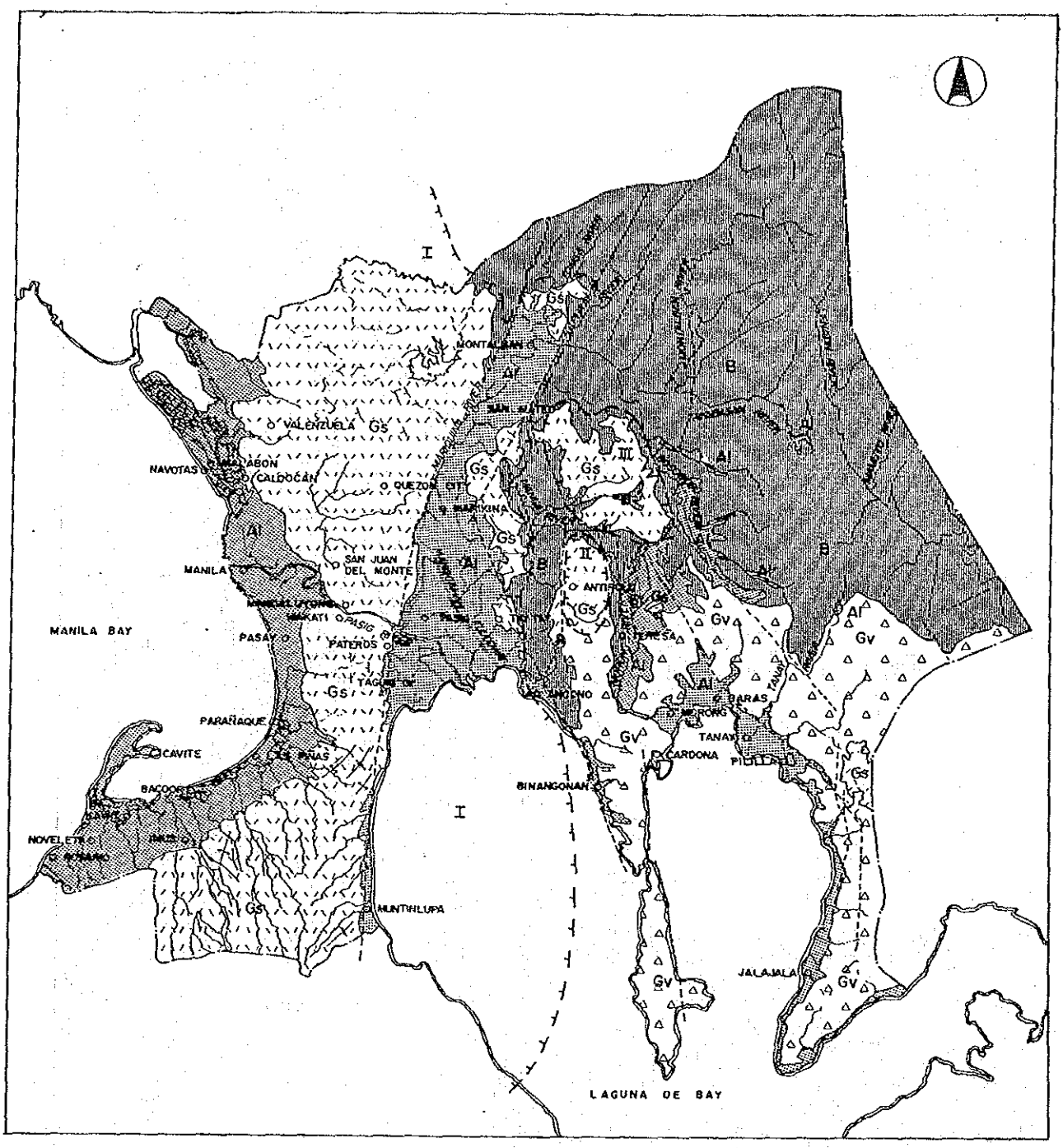
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA JAPAN INTERNATIONAL COOPERATION AGENCY	FIGURE 3.2.2 GEOLOGIC STRUCTURE MAP OF CENTRAL LUZON



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.2.3
GEOLOGIC SECTION OF CENTRAL LUZON (W-E)



LEGEND :

- Al : ALLUVIUM, TALUS, TERRACE — PLEISTOCENE - HOLOCENE
- Gs : GUADALUPE FORMATION (SEDIMENTARY FACIES) — PLIOCENE - PLEISTOCENE
- Gv : GUADALUPE FORMATION (VOLCANIC FACIES) — PLIOCENE - PLEISTOCENE
- B : BASEMENT ROCKS — PRE - QUATERNARY
- GEOLOGICAL BOUNDARY
- FAULT
- I. GUADALUPE SEDIMENTARY BASIN
- II. ANTIPOLO SEDIMENTARY BASIN
- III. NORTH ANTIPOLO SEDIMENTARY BASIN

0 10 20 (Kms.)

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FIGURE 3.2.4

SIMPLIFIED GEOLOGIC MAP - STUDY AREA

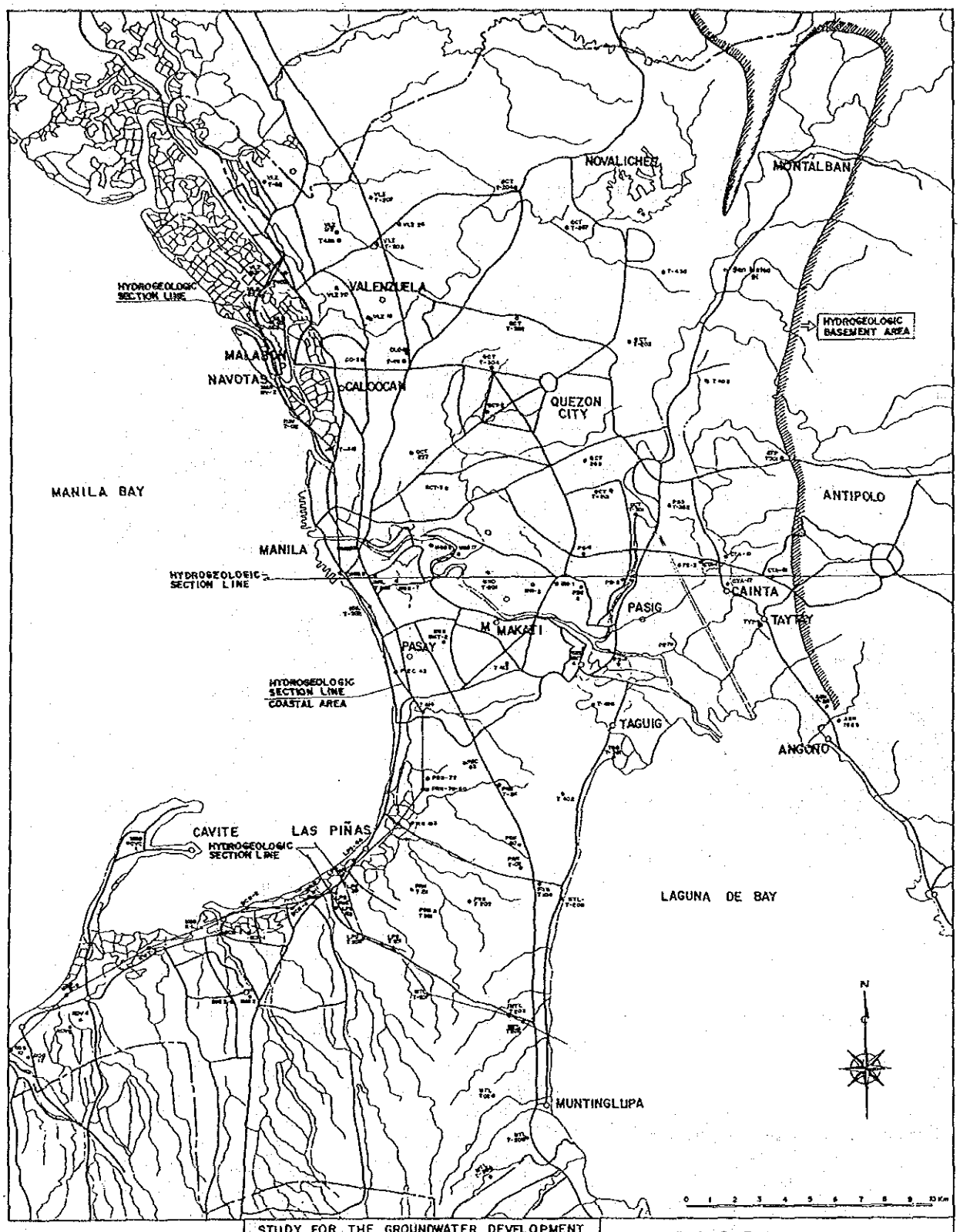

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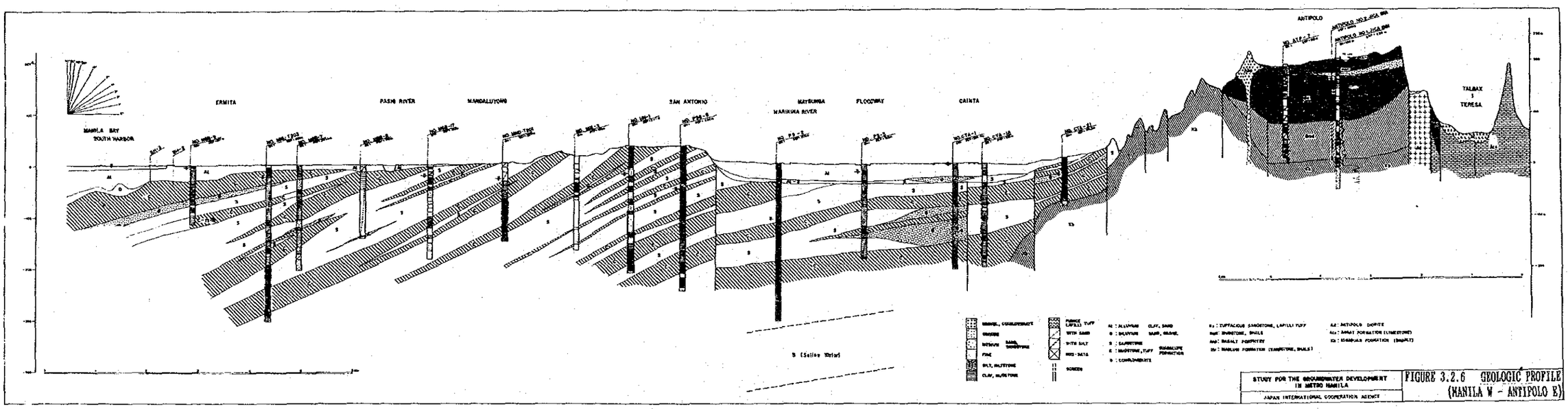
FIGURE 3.2.5
LOCATION OF SECTION LINE



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

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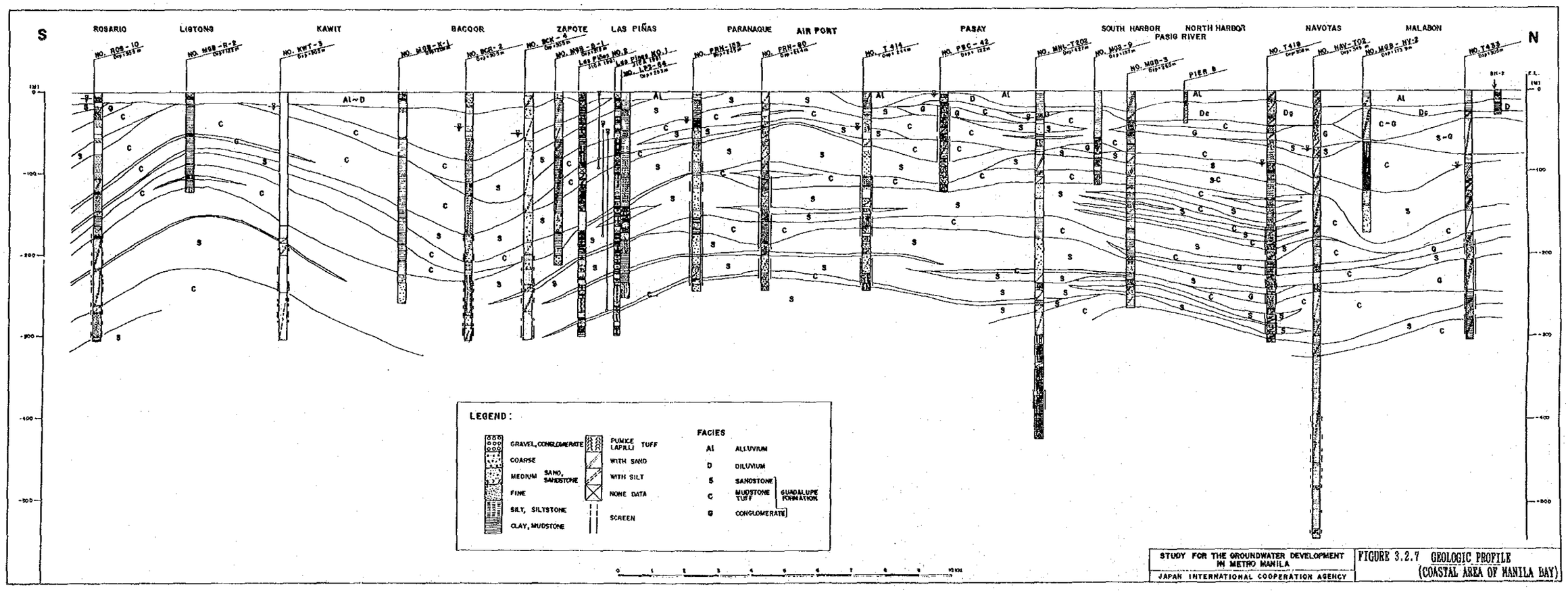
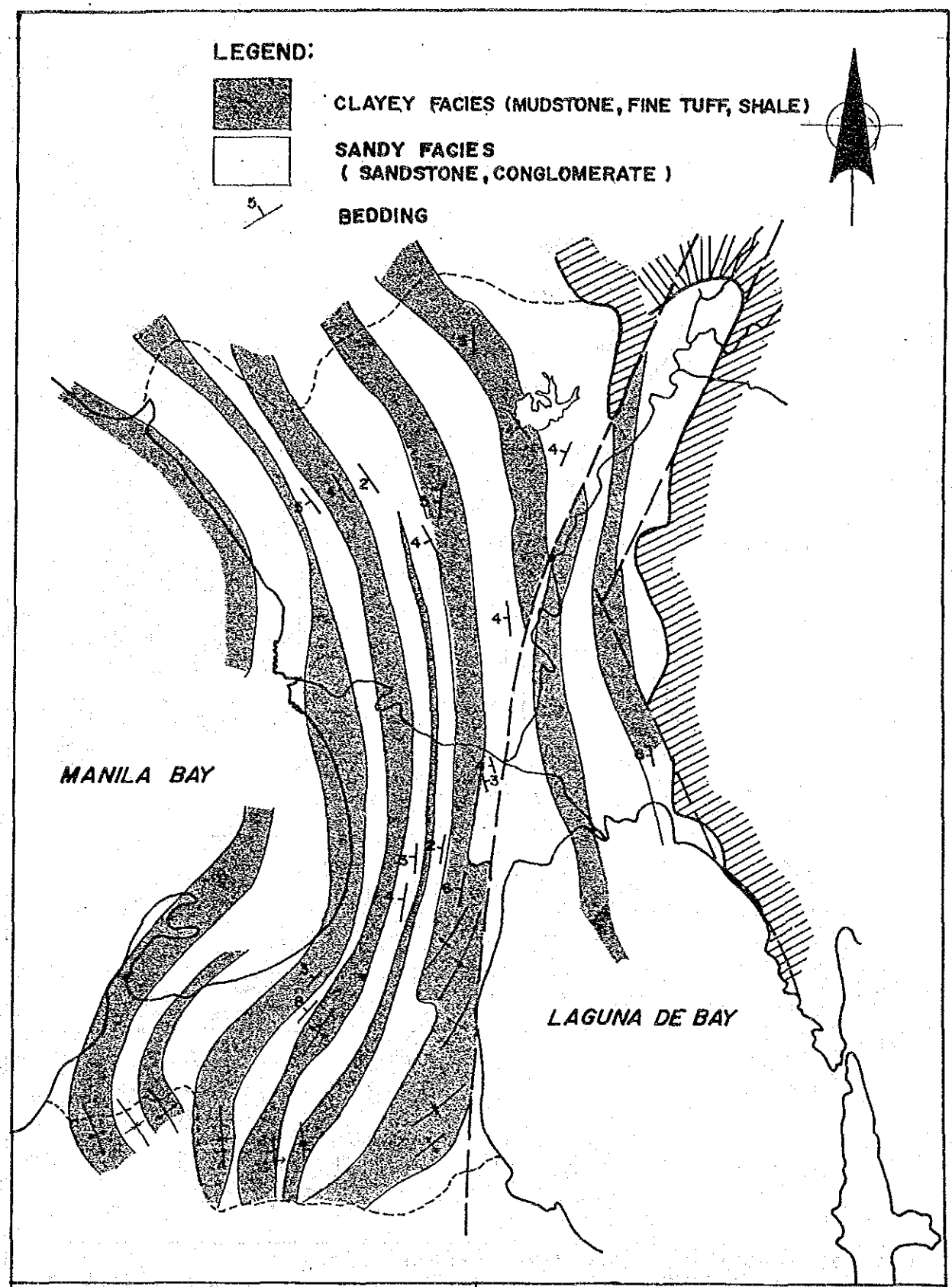
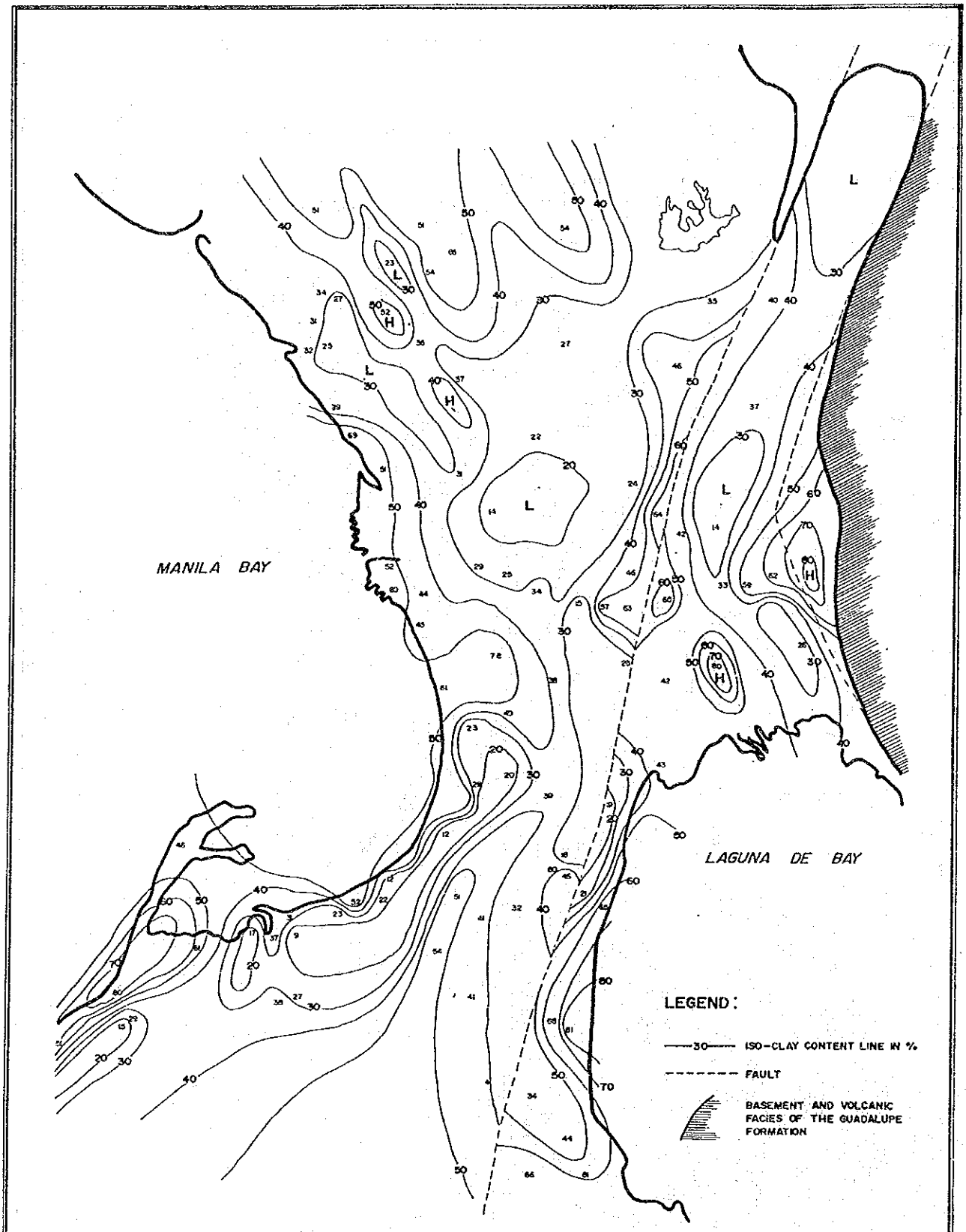
FIGURE 3.2.6 GEOLOGIC PROFILE (MANILA W - ANTIPOLO E)



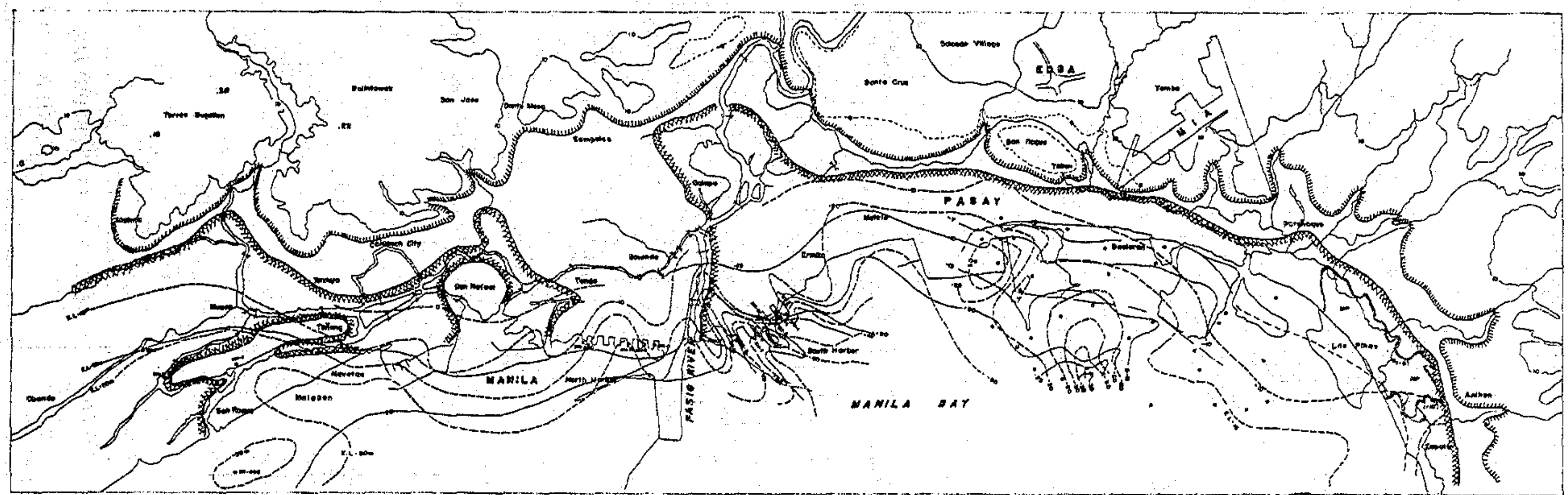
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.7 GEOLOGIC PROFILE (COASTAL AREA OF MANILA BAY)
JAPAN INTERNATIONAL COOPERATION AGENCY	

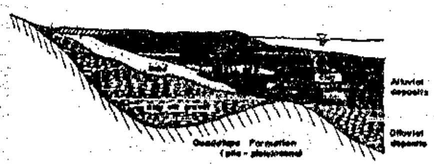


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.8 FACIES MAP OF THE GUADALUPE FORMATION
JAPAN INTERNATIONAL COOPERATION AGENCY	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.9
JAPAN INTERNATIONAL COOPERATION AGENCY	DISTRIBUTION OF CLAY CONTENTS IN THE GUADALUPE FORMATION

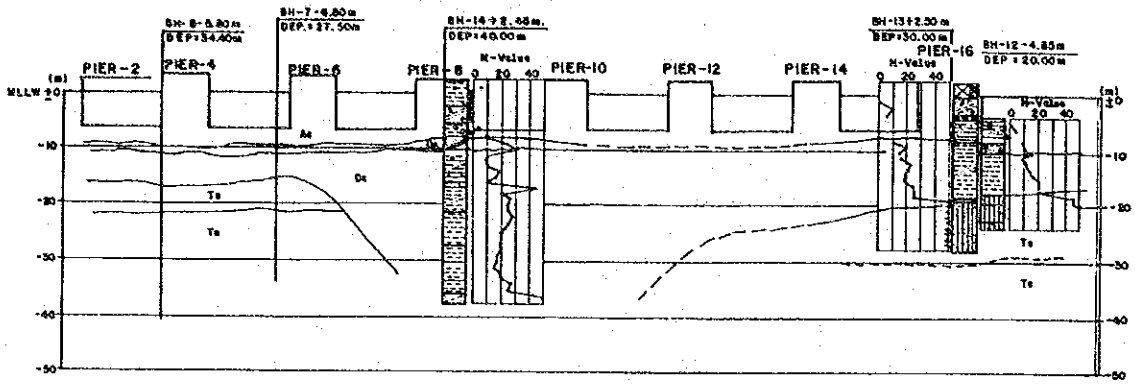




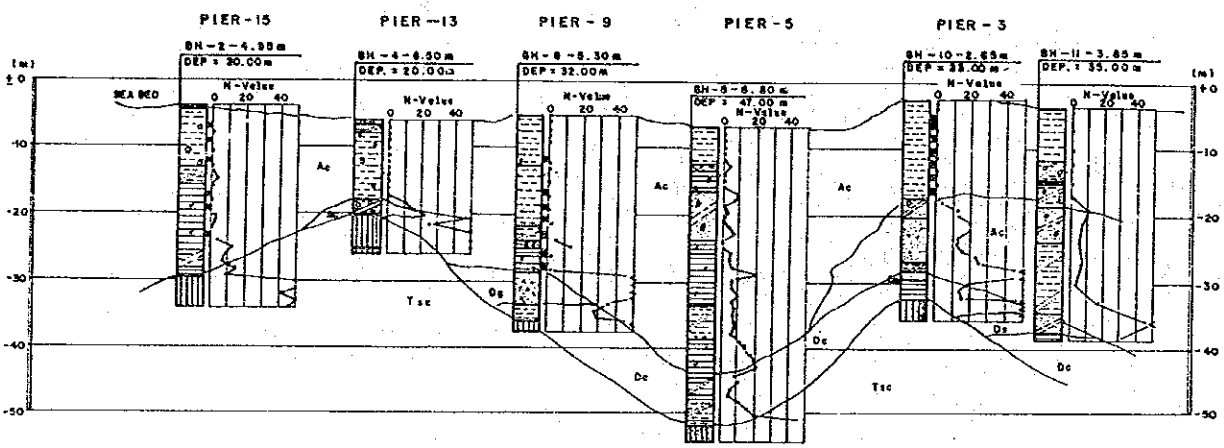
Profile of Coastal Area

FIGURE 3.2.10
DISTRIBUTION OF QUATERNARY - MANILA BAY

STUDY FOR GROUNDWATER



NORTH HARBOR



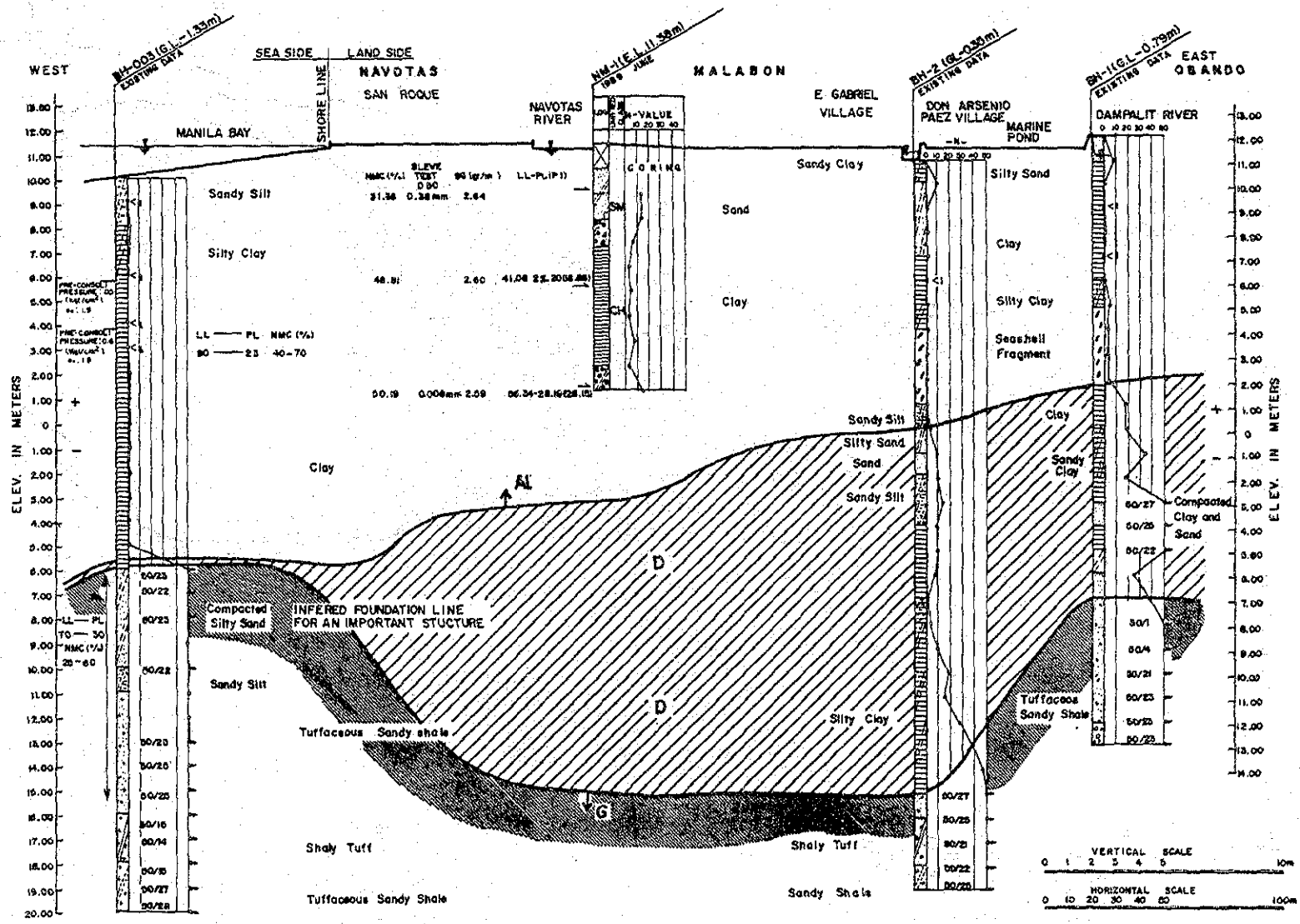
SOUTH HARBOR

LEGEND

Mark	Deposit
Fsc	Filling Material
Ac	Alluvial Cohesive Soils
Ds	Diluvial Sandy Soils
Dc	Diluvial Cohesive Soils
Ts	Tertiary Formation
Tc	

SOURCE: MANILA SOUTH PORT REHABILITATION PROJECT, JICA (1987)

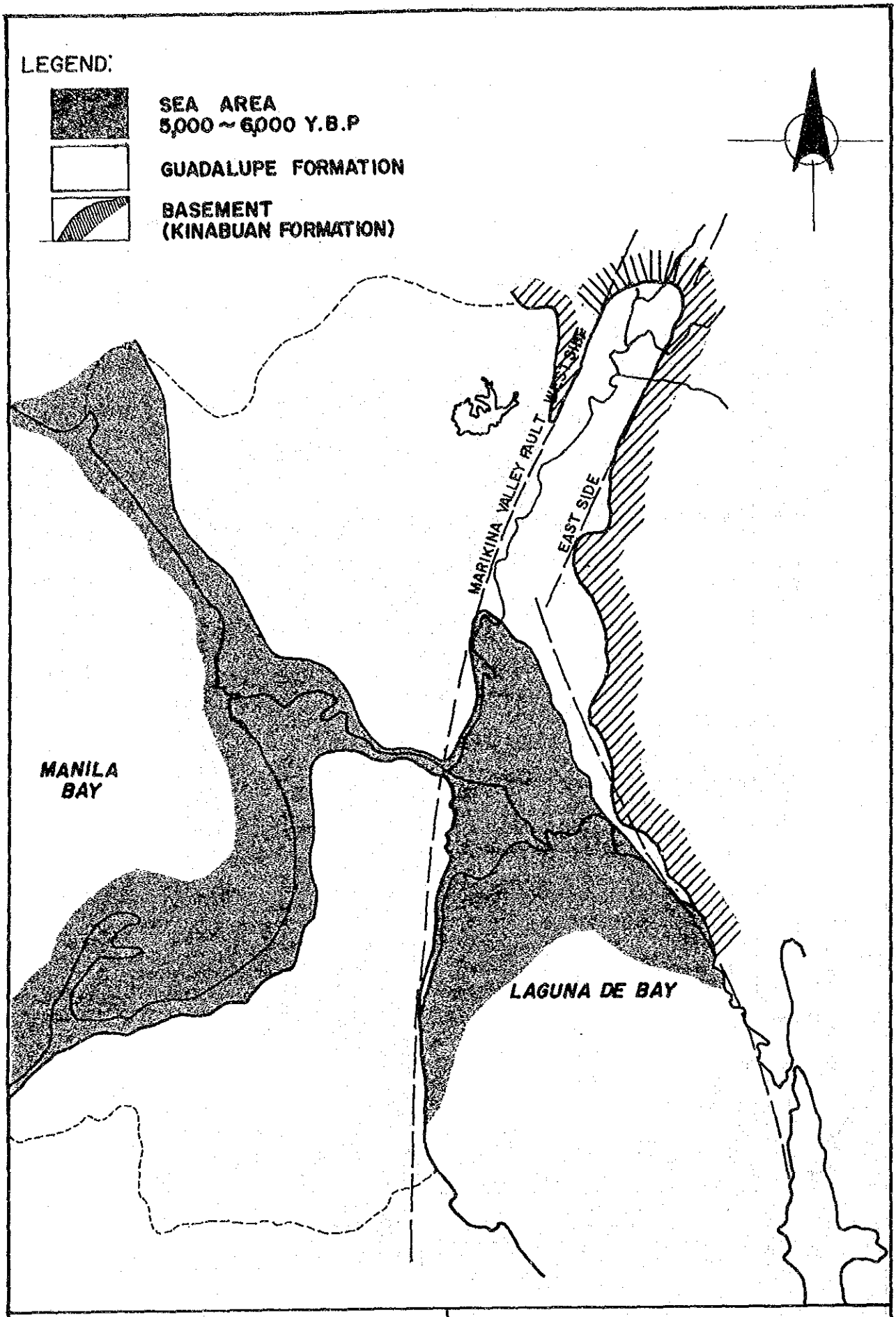
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.11 SUBSURFACE GEOLOGY OF MANILA HARBOR
JAPAN INTERNATIONAL COOPERATION AGENCY	



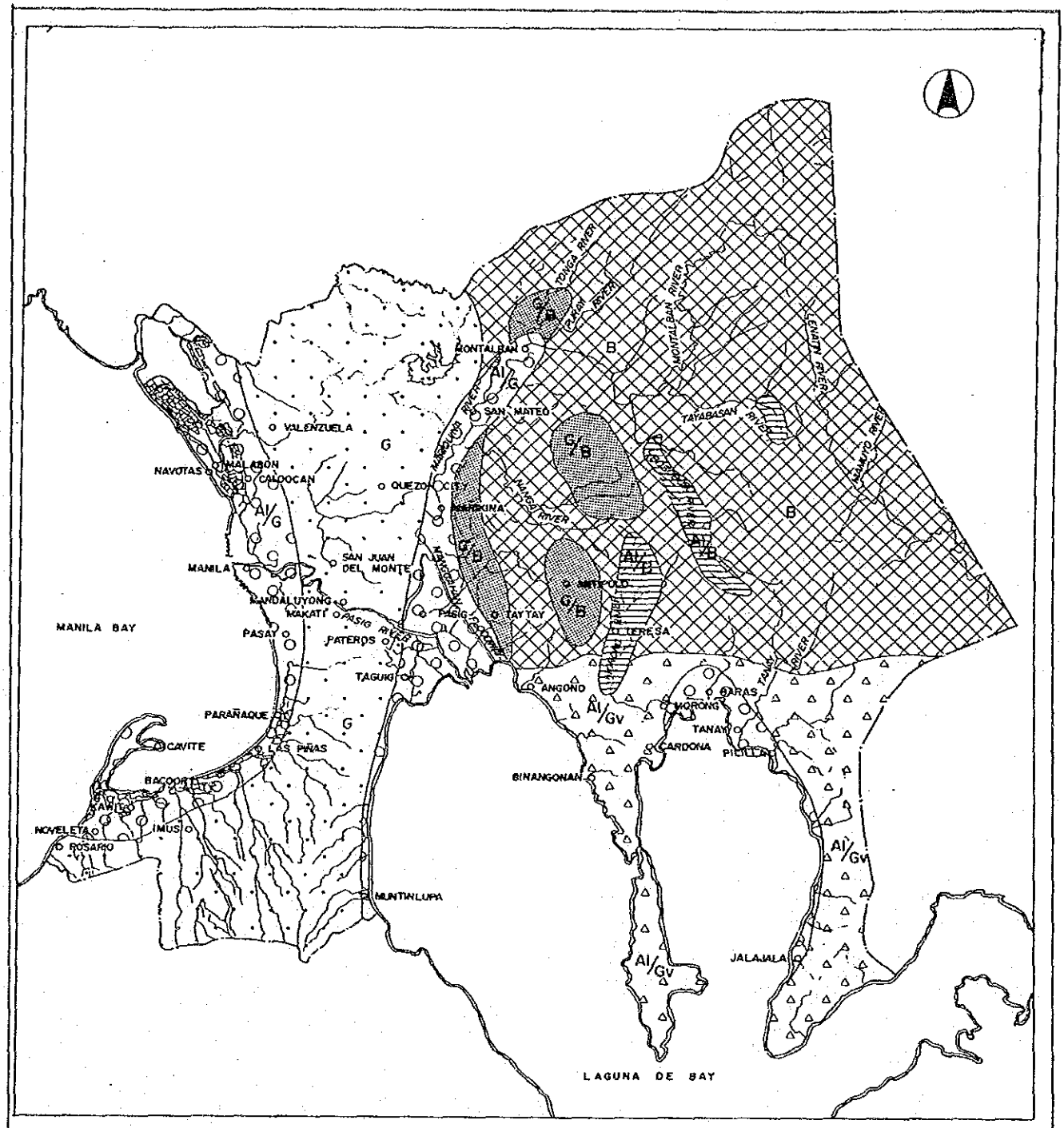
NOTE: NMC = NATURAL MOISTURE CONTENT
D50 = DIAMETER OF 50 per cent PASSING SIEVE
SG = SPECIFIC GRAVITY
LL-PL (PI) = LIQUID LIMIT - PLASTIC LIMIT
eo = INITIAL VOID RATIO

Source: THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES, JICA 1990

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.12 GEOLOGICAL PROFILE OF MALABON - NAVOTAS (MODIFIED BY PRESENT STUDY)
JAPAN INTERNATIONAL COOPERATION AGENCY	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.13 THE SEA AREA OF 5,000 ~ 6,000 Y.B.P
JAPAN INTERNATIONAL COOPERATION AGENCY	

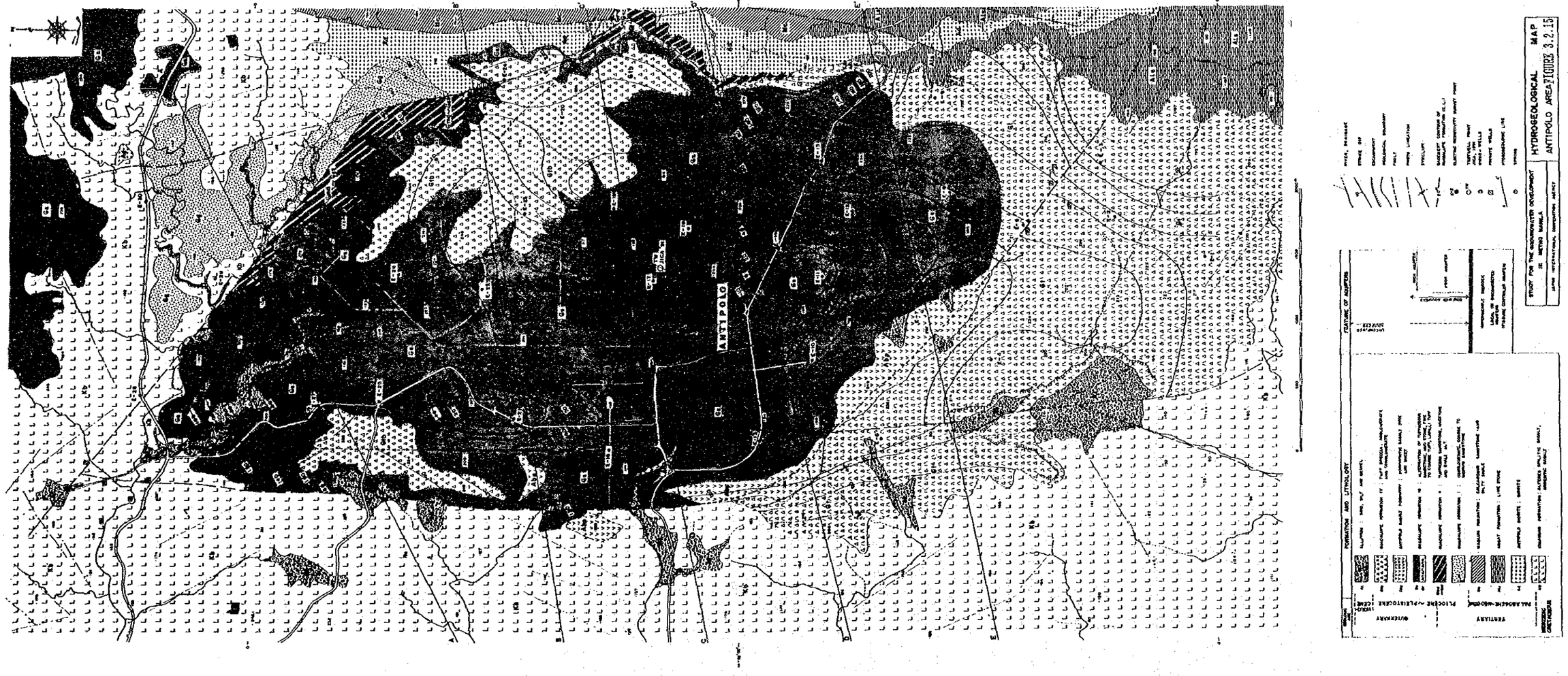


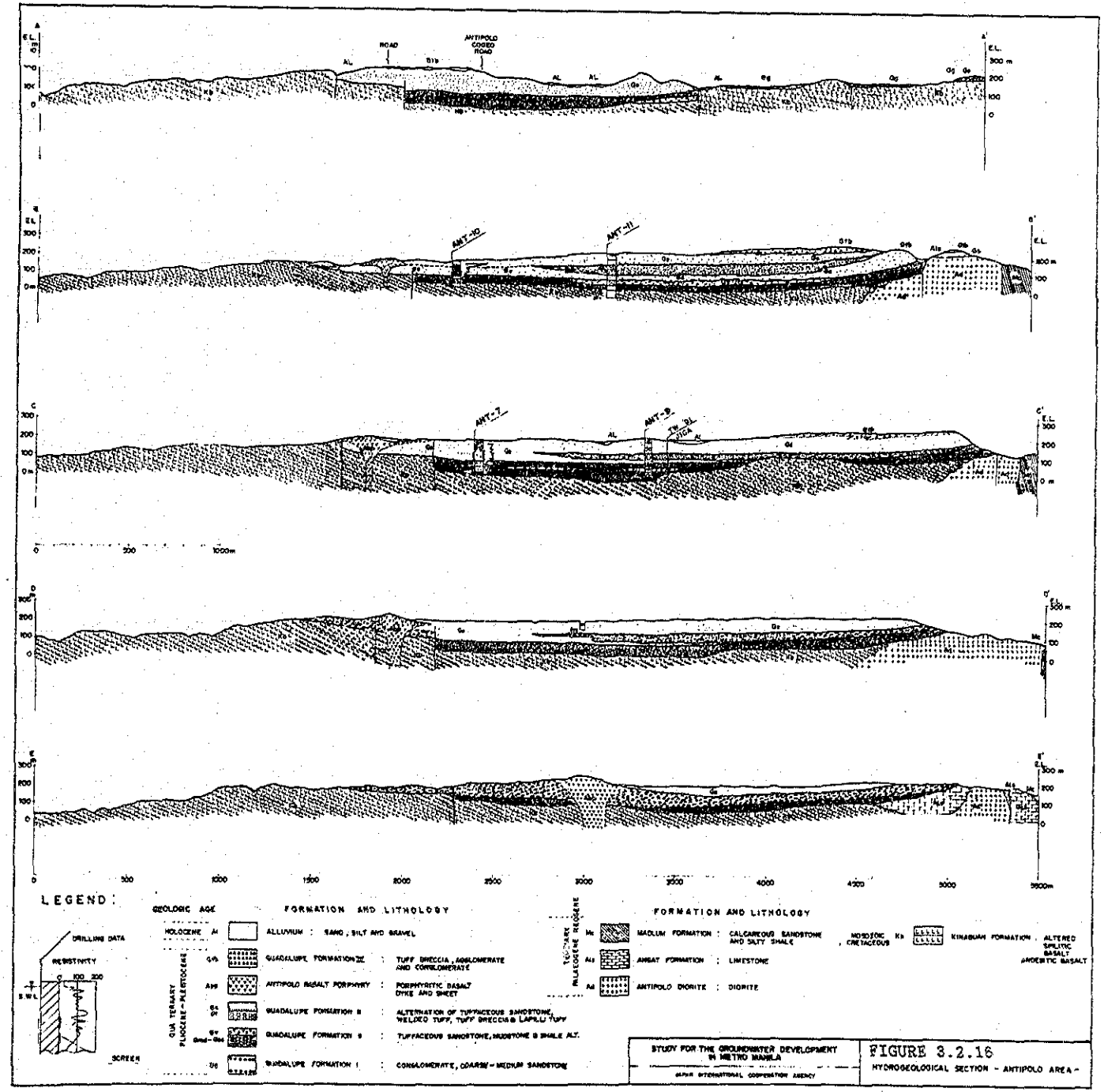
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

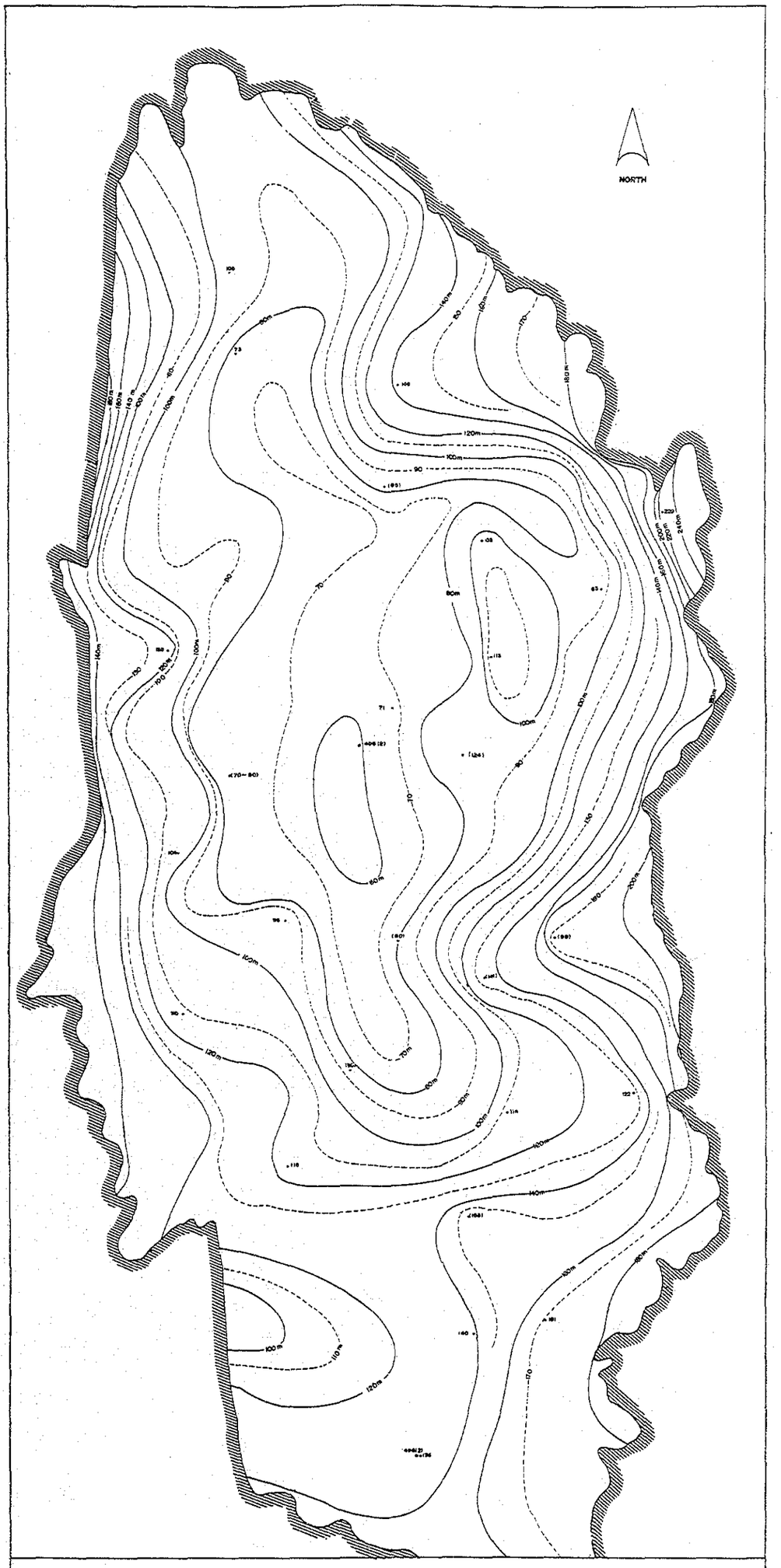
JAPAN INTERNATIONAL COOPERATION AGENCY

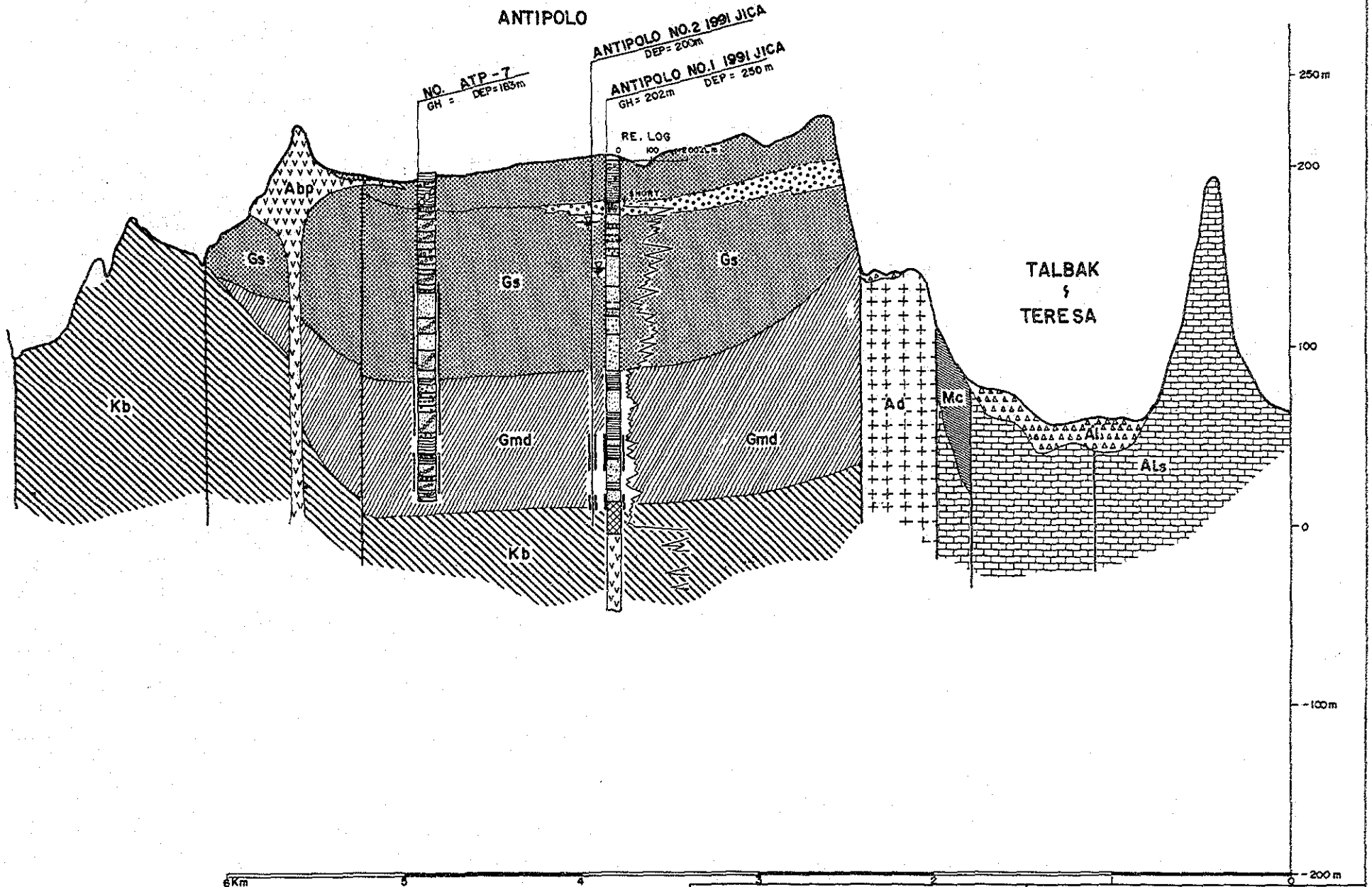
FIGURE 3.2.14

TYPE OF SEDIMENTARY FACIES FOR GROUNDWATER POTENTIALITY

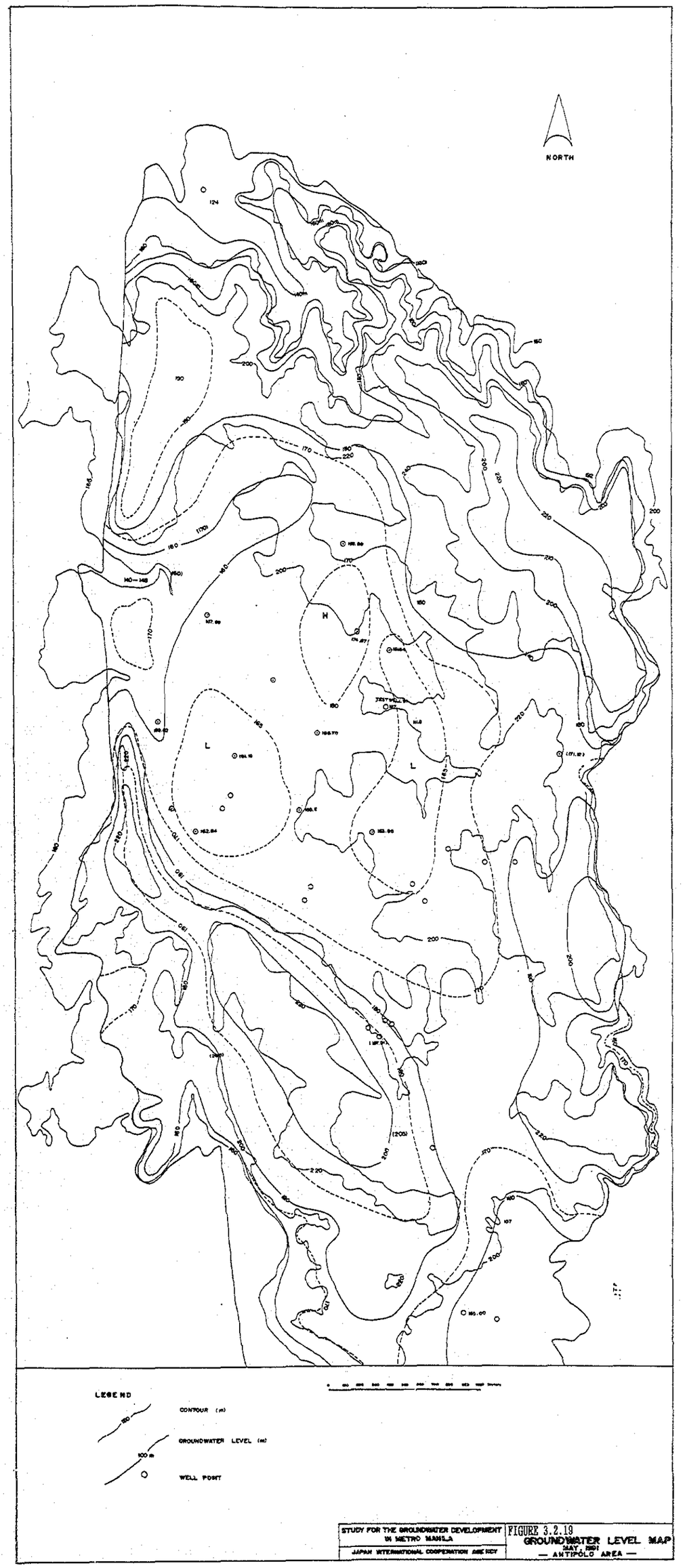

ANTIPOLO
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA
JAPAN INTERNATIONAL COOPERATION AGENCY
HYDROGEOLOGICAL MAP
ANTIPOLO AREA
FIGURE 3.2.15

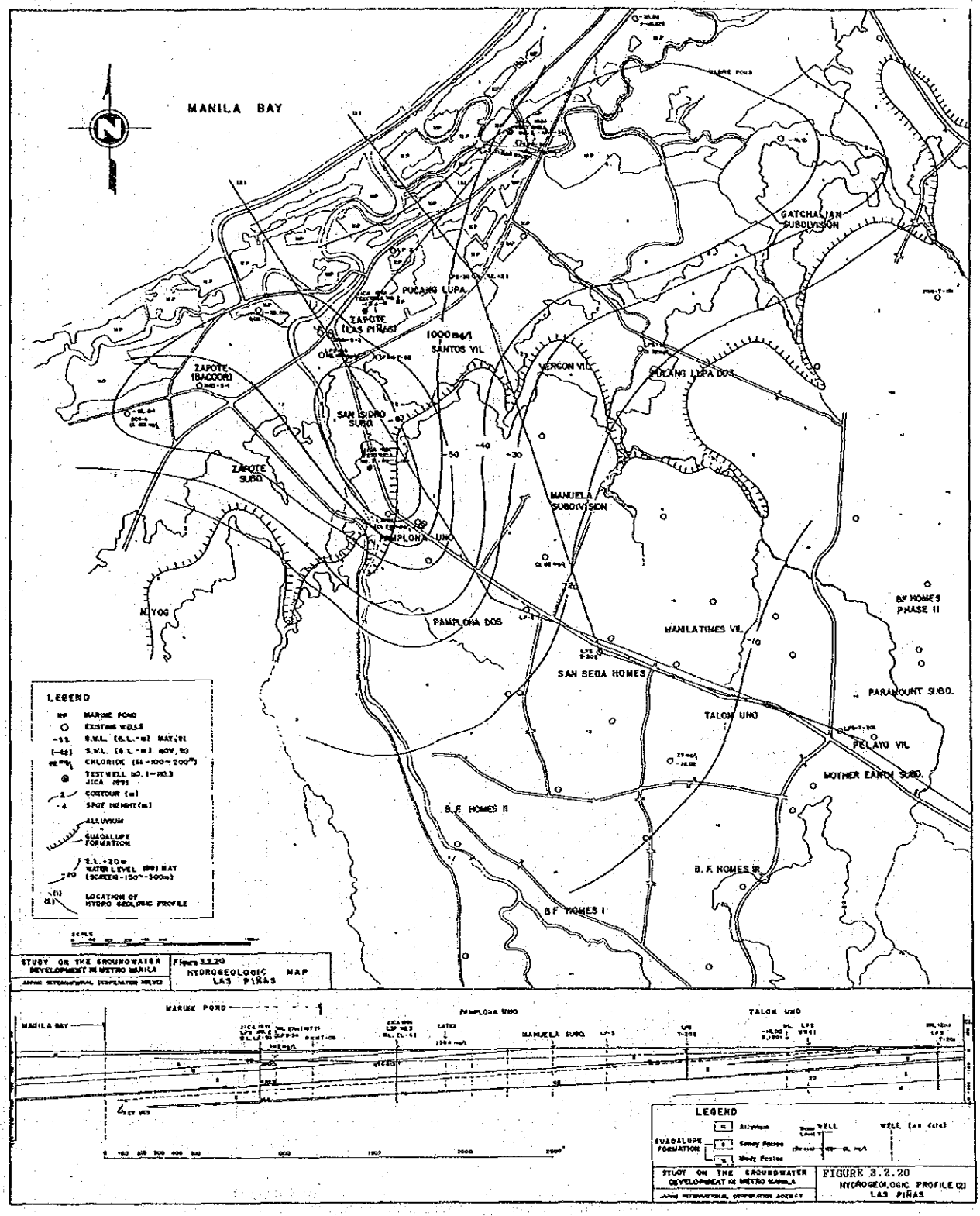

ROAD
ANTIPOLO COGEO ROAD
ANT-10
ANT-11
ANT-7
ANT-9
LEGEND :
DRILLING DATA
RESISTIVITY
S.W.L.
SCREEN
GEOLOGIC AGE
FORMATION AND LITHOLOGY
HOLOCENE
ALLUVIUM : SAND , SILT AND GRAVEL
QUATERNARY PLEISTOCENE - PLEISTOCENE
GUADALUPE FORMATION III : TUFF BRECCIA , AGGLOMERATE AND CONGLOMERATE
ANTIPOLO BASALT PORPHYRY : PORPHYRITIC BASALT DYKE AND SHEET
GUADALUPE FORMATION II : ALTERNATION OF TUFFACEOUS SANDSTONE, WELDED TUFF, TUFF BRECCIA & LAPILLI TUFF
GUADALUPE FORMATION II : TUFFACEOUS SANDSTONE, MUDSTONE & SHALE ALT.
GUADALUPE FORMATION I : CONGLOMERATE, COARSE - MEDIUM SANDSTONE
TERTIARY PLIOCENE - MIOCENE
FORMATION AND LITHOLOGY
MALIM FORMATION : CALCAREOUS SANDSTONE AND SILTY SHALE
ANGAT FORMATION : LIMESTONE
ANTIPOLO DIORITE : DIORITE
MESOZOIC , CRETACEOUS
KINABUAN FORMATION : ALTERED SPILITIC BASALT, ANDESITIC BASALT
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA
JAPAN INTERNATIONAL COOPERATION AGENCY
FIGURE 3.2.16
HYDROGEOLOGICAL SECTION - ANTIPOLO AREA -

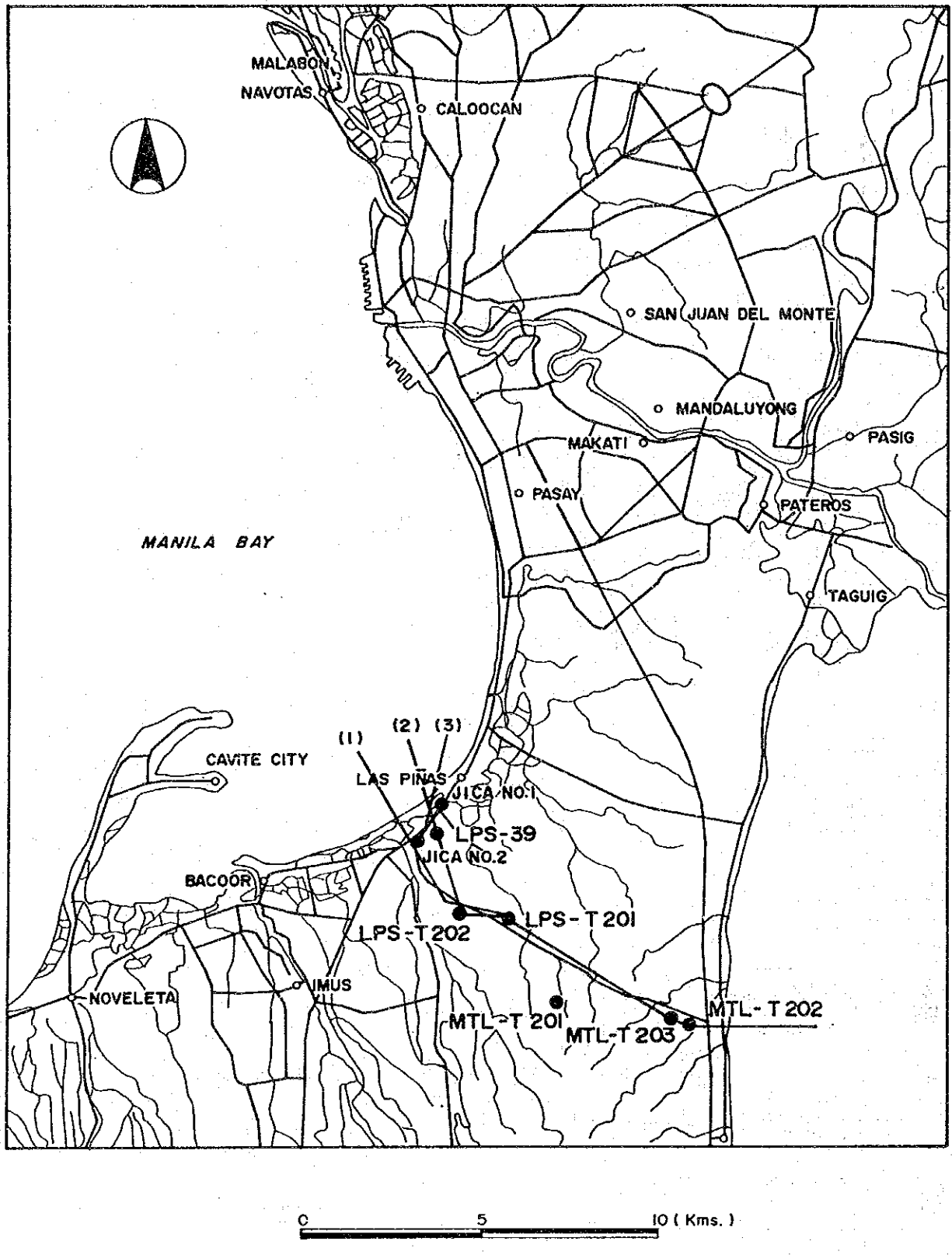

NORTH
LEGEND
HYDROGEOLOGIC BASEMENT
CONTOUR OF HYDROGEOLOGIC BASEMENT ELEVATION
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA
JAPAN INTERNATIONAL COOPERATION AGENCY
FIGURE 3.2.17
HYDROGEOLOGIC BASEMENT MAP
— ANTIPOLO AREA —



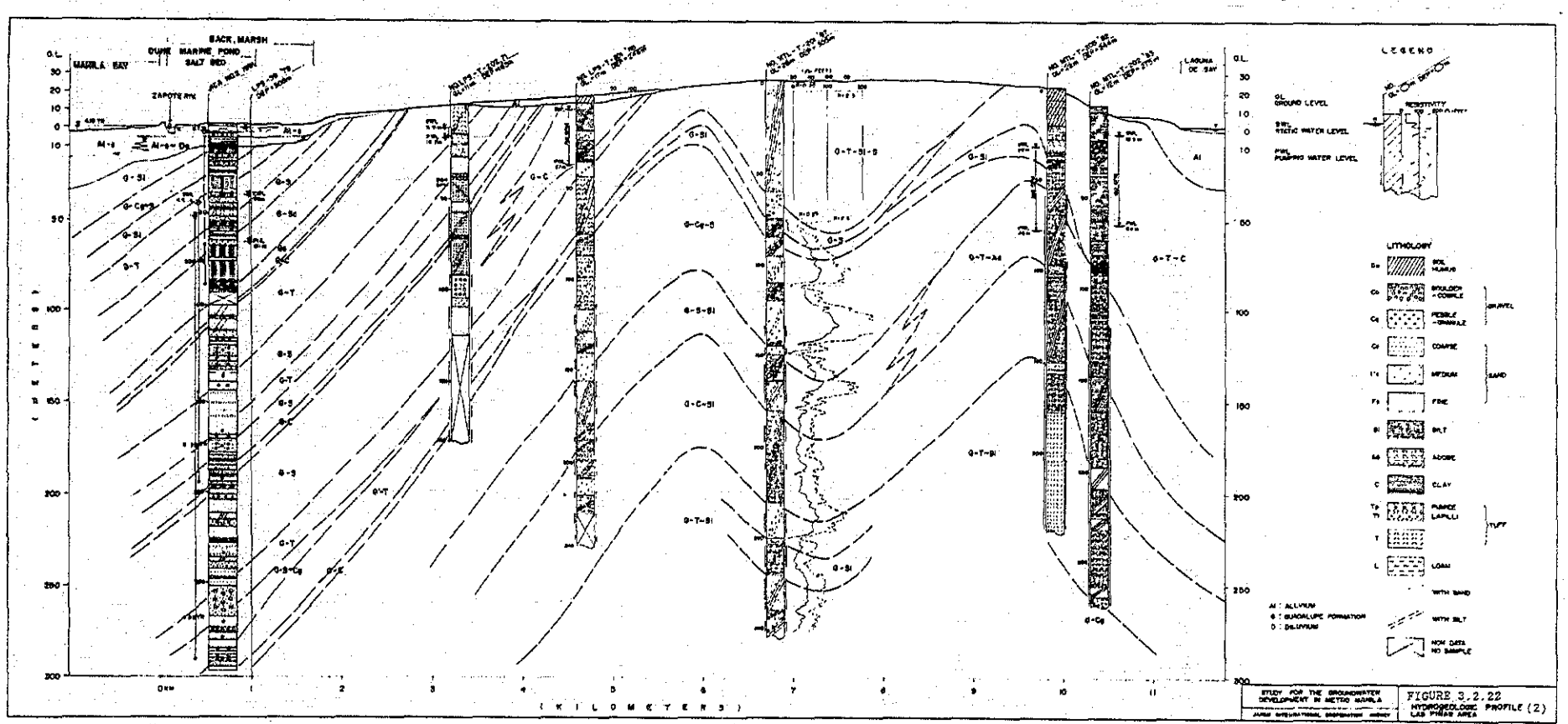
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.18 HYDROGEOLOGIC PROFILE - ANTIPOLO AREA
JAPAN INTERNATIONAL COOPERATION AGENCY	

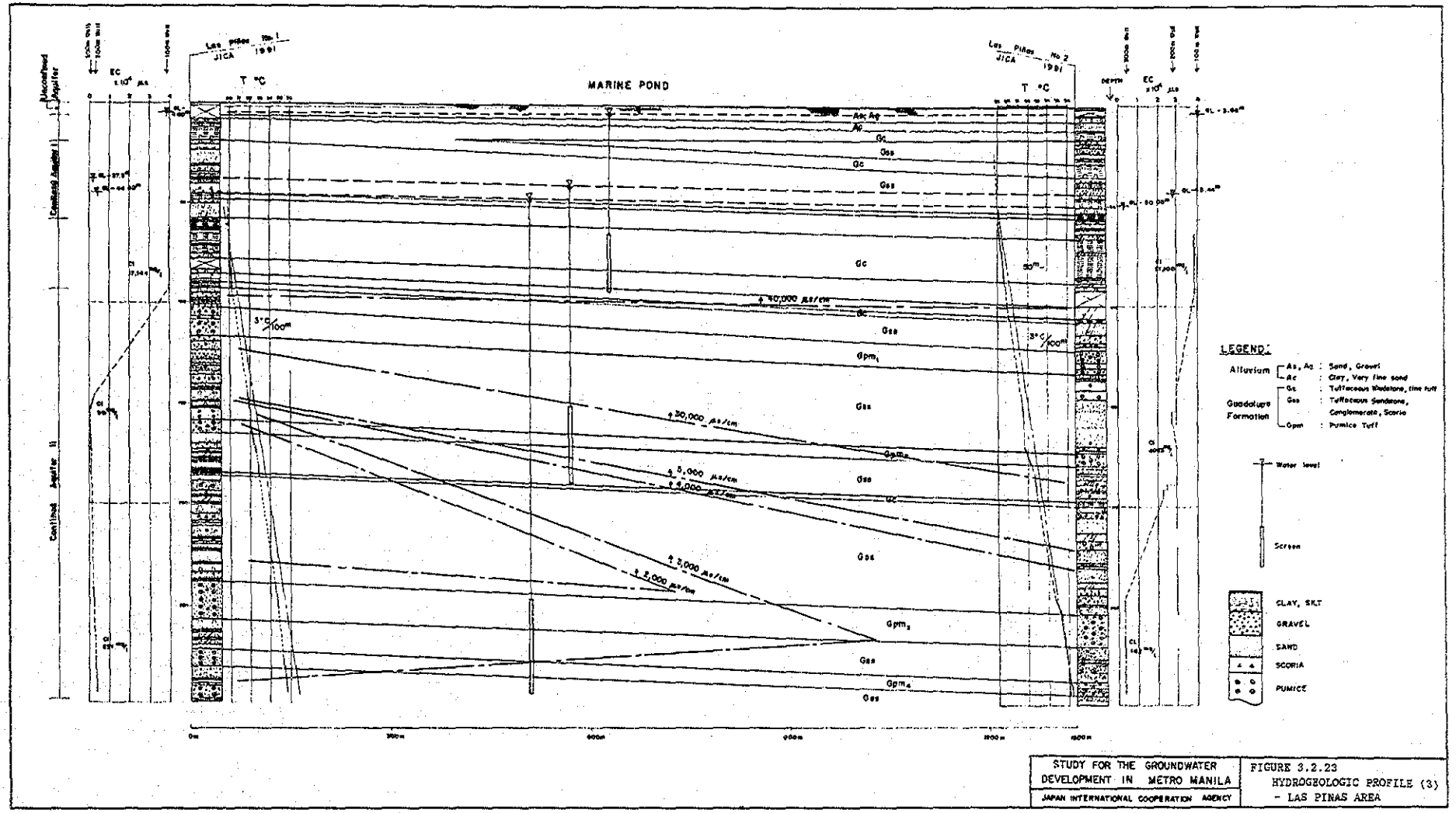

NORTH
H
L
L
LEGEND
CONTOUR (m)
GROUNDWATER LEVEL (m)
WELL POINT
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA
JAPAN INTERNATIONAL COOPERATION AGENCY
FIGURE 3.2.19
GROUNDWATER LEVEL MAP
MAY, 1981
— ANTIPOLO AREA —


MANILA BAY
GATCHALIAN SUBDIVISION
PUCANG LUPA
ZAPOTE (LAS PIÑAS)
1000 mg/l
SANTOS VIL
VERGON VIL
PUCANG LUPA DOS
ZAPOTE (BACOOR)
SAN ISIDRO SUBD.
-50
-40
-30
ZAPOTE SUBD.
MANUELA SUBDIVISION
PAMPLONA UNO
NIYOG
PAMPLONA DOS
MANILATIMES VIL.
BF HOMES PHASE II
SAN BEDA HOMES
PARAMOUNT SUBD.
TALON UNO
PELAYO VIL
MOTHER EARTH SUBD.
B.F. HOMES II
B.F. HOMES IR
BF HOMES I
LEGEND
MARINE POND
EXISTING WELLS
CHLORIDE (64~100~200 mg/l)
TEST WELL NO. 1~NO. 3 JICA 1991
CONTOUR (m)
SPOT HEIGHT (m)
ALLUVIUM
GUADALUPE FORMATION
LOCATION OF HYDRO GEOLOGIC PROFILE
STUDY ON THE GROUNDWATER DEVELOPMENT IN METRO MANILA
Figure 3.2.20
HYDROGEOLOGIC MAP
LAS PIÑAS
MARINE POND
MANILA BAY
PAMPLONA UNO
MANUELA SUBD.
TALON UNO
LEGEND
ALLUVIUM
GUADALUPE FORMATION
Sandy Facies
Muddy Facies
WELL
WELL (no data)
STUDY ON THE GROUNDWATER DEVELOPMENT IN METRO MANILA
FIGURE 3.2.20
HYDROGEOLOGIC PROFILE (2)
LAS PIÑAS



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.21
JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION MAP OF THE CROSS-SECTIONS FOR THE LAS PINAS AREA


BACK MARSH
DUNE MARINE POND
SALT BED
MANILA BAY
ZAPOTE RIV.
LAGUNA DE BAY
LEGEND
G.L. GROUND LEVEL
STATIC WATER LEVEL
PUMPING WATER LEVEL
LITHOLOGY
SOIL HUMUS
BOULDER + COBBLE
PEBBLE + GRAVEL
COARSE
MEDIUM
FINE
SILT
ADOBE
CLAY
PUMICE LAPILLI
LOAM
WITH SAND
WITH SILT
NON DATA NO SAMPLE
GRAVEL
SAND
TUFF
Al : ALLUVIUM
G : GUADALUPE FORMATION
D : DILUVIUM
(K I L O M E T E R S)
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA
FIGURE 3.2.22
HYDROGEOLOGIC PROFILE (2)
LAS PIÑAS AREA



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.23 HYDROGEOLOGIC PROFILE (3) - LAS PINAS AREA
JAPAN INTERNATIONAL COOPERATION AGENCY	

3.3 GROUNDWATER USE

3.3.1 Private Deep Wells

The total number of inventoried private wells in Metro Manila is 3,434, of which 35.47% or 1,218 are estimated as abandoned wells (Table 3.3.1). Of the estimated 2,216 operational private deep wells, 307 or 13.9% are concentrated in Quezon City, 178 (12.6%) in Parañaque, and 197 (8.9%) in Pasig.

Table 3.3.2 gives the detailed distribution of the estimated 2,216 operational private deep wells classified by type of user, depth of depression and specific capacity, per municipality. Around 47.7% (1,056) of the wells are mostly for domestic consumption. The distribution of the rest consists of 21.1% (468) for other industries; 9.2% (204) for commercial use; 6.6% (146) for institutional use; 4.0% (89) for the food and beverage industry; 2.3% (51) for the chemical industry; and 0.5% (11) for the leather industry.

Table 3.3.3 presents the year-1990 pumpage level generated by the wells previously presented in Table 3.3.2, using average annual pumpage computed from the survey data.

Table 3.3.4 gives the percent share of each municipality in the year-1990 total pumpage of private wells, by type of user, by depth of depression and by specific capacity. Figure 3.3.1 shows the year-1990 combined total withdrawals of domestic, institutional, commercial and industrial users in each municipality. Muntinlupa and Quezon City posted the highest shares, at 10.9% each, in the total pumpage. Las Piñas came in next with a 9.7% share, followed by Pasig with 9.0%. The high pumpage share of Quezon City and Muntinlupa could be attributed to the concentration in these areas of both domestic and industrial users. Pasig has the highest share of pumpage for industrial purposes.

More than half of the total pumpage went to private wells for public (domestic and institutional) consumption. Of this amount of pumpage, Las Piñas and Muntinlupa got the biggest shares, at 6.8% and 6.3%, respectively, followed by Parañaque at 5.8% and Quezon City at 4.2%.

The share of private wells for commercial purposes amounted to 8.6% of the total pumpage. In this category, Quezon City has the biggest share with its 2.8%

For industrial purposes, the textile, paper and pulp industries used up the biggest share (17.9%) in the total pumpage, followed by other industries (17.6%). In terms of municipality, the breakdown for this industrial use is topped by Pasig at 7.0%, followed by Taguig at 5.0% and Muntinlupa at 4.1%.

Figure 3.3.2 shows the percent distribution of domestic (45.1%), institutional (41.1%), commercial (8.6%) and industrial uses (42.2%) in the year-1990 total pumpage of 306.85 MCM by private deep wells in the Study Area.

3.3.2 MWSS Wells

As of March 1991, MWSS wells total 258. Of this number, 131 are operational, 75 inactive, and 52 abandoned (Table 3.3.5). The location map of MWSS wells is shown in Figure 3.3.3. Inactive wells are those under going rehabilitation, those on stand-by, those located in places where surface water is sufficient, and those wells--8% of the inactive wells and 42% of the abandoned wells--are outside the NCR.

Data on actual pumpage and hours of operation of these wells were culled from the production records (1981-1990) of the Pumping Plants Section of MWSS. These data were tabulated monthly per station and will be entered into the database system. Figure 3.3.4 shows the monthly groundwater production of MWSS wells in the Study Area while Figure 3.3.5 shows their yearly water production. These figures indicate year-to-year increase in withdrawals of groundwater by MWSS. Table 3.3.6 lists the year-1990 total groundwater pumpage by municipality. The total groundwater production in 1990 of MWSS wells was 32.75 MCM.

Based on the MWSS CORPLAN data on groundwater production, the major uses for MWSS wells are shared as: public supply, 63%; commercial supply, 30%; and industry, 7%. Of the abovementioned annual withdrawals, MWSS contributes 20.54 MCM for public supply, 10.00 MCM for commercial supply and 2.2 MCM for industry.

3.3.3 Estimated Year-1990 Total Pumpage

Table 3.3.7 summarizes the results of the estimated year-1990 total pumpage by municipality, combining the estimated year-1990 total pumpage of private deep wells (Table 3.3.3) and the year-1990 production of MWSS wells (Table 3.3.6). The results are shown in Figures 3.3.6 and 3.3.7.

Combined total withdrawals amounted to 339.6 MCM and are distributed as: 171.51 MCM for domestic institutional uses; 36.34 MCM for commercial uses; and 131.74 MCM for industrial uses. Combined distribution (MWSS and private deep wells is 50% for public supply (domestic and institutional), 11% for commercial supply and 39% for industry.

Figure 3.3.8 shows the percent share of each municipality in the total year-1990 pumpage of 339.6 MCM. The year 1990 main centers of pumpage are Quezon City, Muntinlupa, Las Piñas, Pasig, Parañaque, Taguig, Antipolo, Cainta and Taytay. Their combined abstraction amounted to 238.07 MCM, or 70% of the total pumpage in 1990.

TABLE 3.3.1 DISTRIBUTION OF PRIVATE DEEP WELLS IN METRO MANILA BY MUNICIPALITY AND STATUS, YEAR-1990

Location	Operational	Abandoned	Total
Antipolo	115 (5.19)	5 (0.41)	120 (3.49)
Bacoor	47 (2.12)	8 (0.66)	55 (1.60)
Caloocan	114 (5.14)	32 (2.63)	146 (4.25)
Cainta	78 (3.52)	5 (0.41)	83 (2.42)
Cavite City	11 (0.50)	9 (0.74)	20 (0.58)
Imus	9 (0.41)	8 (0.66)	17 (0.50)
Kawit	4 (0.18)	0 (0.00)	4 (0.12)
Las Pinas	157 (7.08)	26 (2.13)	183 (5.33)
Mandaluyong	31 (1.40)	54 (4.43)	85 (2.48)
Makati	98 (4.42)	101 (8.29)	199 (5.79)
Malabon	67 (3.02)	71 (5.83)	138 (4.02)
Manila	49 (2.21)	150 (12.32)	199 (5.79)
Marikina	36 (1.62)	70 (5.75)	106 (3.09)
Montalban	23 (1.04)	4 (0.33)	27 (0.79)
Muntinlupa	182 (8.21)	26 (2.13)	208 (6.06)

TABLE 3.3.1 (CONTINUATION)

Location	Operational	Abandoned	Total
Navotas	17 (0.77)	11 (0.90)	28 (0.82)
Noveleta	8 (0.36)	1 (0.08)	9 (0.26)
Paranaque	278 (12.55)	41 (3.37)	319 (9.29)
Pasay City	47 (2.12)	36 (2.96)	83 (2.42)
Pasig	197 (8.89)	53 (4.35)	250 (7.28)
Pateros	2 (0.09)	2 (0.16)	4 (0.12)
Quezon City	307 (13.85)	315 (25.86)	622 (8.11)
Rosario	16 (0.72)	0 (0.00)	16 (0.47)
San Juan	2 (0.09)	12 (0.99)	14 (0.41)
San Mateo	11 (0.50)	17 (1.40)	28 (0.82)
Taguig	121 (5.46)	69 (5.67)	190 (5.53)
Taytay	62 (2.80)	0 (0.00)	62 (1.81)
Valenzuela	127 (5.73)	92 (7.55)	219 (6.38)
Total	2216 64.53	1218 35.47	3434 100.00

TABLE 3.3.2 YEAR-1990 DISTRIBUTION OF PRIVATE DEEP WELLS BY TYPE OF USER, DEPTH OF DEPRESSION AND SPECIFIC CAPACITY, PER MUNICIPALITY

	ATP	BCR	CLC	CTA	CVC	INS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NCV	PRN	PSC	PSG	PTR	QCT	RGS	SJM	SMT	TGG	TYY	VLZ	Total Deepwells
PUBLIC-DOMESTIC	78	45	89	15	1	6	4	104	4	35	16	10	17	16	101	7	8	199	14	29		144	5	1	9	39	34	27	1056
+40m to +0m																													
Small	32		20											16											5				74
Medium	22		24																						2				49
Large	23					6																	5						34
+0m to -40m																													
Small				4				15	4						53				9							12	5		102
Medium								50							20				4							10	12		96
Large		45		11	1		4	39							28		8		1							17	17		171
-40m to -80m																													
Small										13		7	6			7		125		1		38		1					198
Medium										4		3						53		4		95							158
Large										18			11					22		23		11							85
-80m to -120m																													
Small			12								16																	26	55
Medium			32																									1	33
Large																													
PUBLIC-INSTITUTION	1	1	2	4	10	2		1	1	30	4	6	5	2	14			3	16	7		27				5	2	3	146
+40m to +0m																													
Small	1																												
Medium														2															3
Large						2																							2
+0m to -40m																													
Small				1					1						7				4							1			14
Medium				2				1							2				1								2		7
Large		1		1	10										5				11							4			32
-40m to -80m																													
Small										2		6	3					1				3							15
Medium													1					1				20							22
Large										28			1					1		7		4							41
-80m to -120m																													
Small			1								3																	3	7
Medium			1								1																		2
Large																													

TABLE 3.3.2 (CONTINUATION)

	ATP	BCR	CLC	CTA	CVC	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCY	ROS	SJN	SMT	TGG	TYY	VLZ	Total Deepwells
COMMERCIAL	7	1	8	6				9	5	21	1	12	3	1	12	2		15	10	14		59	1		1	6	2	7	204
+40m to +0m																													
Small			1											1											1				3
Medium	7																												7
Large																							1						1
+0m to -40m																													
Small				5				1	5						4				6							5	1		27
Medium				1				4							3				4								1		13
Large		1						4							5											1			10
-40m to -80m																													
Small										11		10	3			2		13		2		8							50
Medium												2						1				40							44
Large										10								1		12		11							34
-80m to -120m																													
Small			2								1																	6	9
Medium			5																									1	6
Large																													
INDUSTRIAL-FOOD & BEVERAGES	4		4	7				5	8	2	13	1	2		10			4	1	13		3				8	1	4	89
+40m to +0m																													
Small	1		1																										2
Medium	3																												3
Large																													
+0m to -40m																													
Small				1					8						5											6			20
Medium				1				5							3														9
Large				5											2				1							2	1		10
-40m to -80m																													
Small										2			1					2		2		1							8
Medium												1						2				2							5
Large													1							11									12
-80m to -120m																													
Small											13																	4	17
Medium			3																										3
Large																													

TABLE 3.3.2 (CONTINUATION)

	ATP	BCR	CLC	CTA	CVC	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJN	SMT	TGG	TYY	VLZ	Total Deepwells
INDUSTRIAL-CHEMICALS				6				2	2	2	2	1			7			2		11		4	1			5	1	5	51
+40m to +0m																													
Small																													
Medium																													
Large																							1						1
+0m to -40m																													
Small				1					2						2											2	1		8
Medium				3				2							5														10
Large				2																						3			5
-40m to -80m																													
Small												1						2		1		1							5
Medium										1										1		2							4
Large										1										9		1							11
-80m to -120m																													
Small											2																	4	6
Medium																												1	1
Large																													
INDUSTRIAL-LEATHER											4									1		5							11
+0m to -40m																													
Small																													
Medium																													
Large																													
-40m to -80m																													
Small																						1							1
Medium																						4							4
Large																				1									1
-80m to -120m																													
Small											4																		4
Medium																													
Large																													

TABLE 3.3.2 (CONTINUATION)

	ATP	BCR	CLC	CTA	CVC	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	RDS	SJN	SMT	TGG	TYY	VLZ	Total Deepwells
INDUSTRIAL - TEXTILE, PAPER & PULP			1	17				2			13	2	6	4	19			6	1	34		25			1	12	9	39	191
+40m to +0m																													
Small																									1				5
Medium																													
Large														4															
+0m to -40m																													
Small				3				2							9											4	3		22
Medium				2											7											2	2		13
Large				12											3				1							6	4		26
-40m to -80m																													
Small													2					5		3		3							13
Medium												2						1				18							21
Large													4							31		4							39
-80m to -120m																													
Small			1								13																	28	41
Medium																												11	11
Large																													
INDUSTRIAL-OTHERS	25		11	23		1		34	10	8	13	17	4		21	7		49	7	90	2	39	9			45	13	40	458
+40m to +0m																													
Small	2																												2
Medium	9		5																										14
Large	14					1																	9						24
+0m to -40m																													
Small				5				7	10						9				5							22	7		65
Medium				9				16							5				2							2	1		35
Large				9				11							7						2					21	5		55
-40m to -80m																													
Small										5		15	2			7		37				7							73
Medium												2	1					11		14		26							53
Large										3			1					1		76		6							87
-80m to -120m																													
Small			1								13																	32	46
Medium			5																									8	13
Large																													
TOTAL	115	47	114	78	11	9	4	157	31	98	67	49	36	23	182	17	8	278	47	197	2	307	16	2	11	121	62	127	2216

TABLE 3.3.3 YEAR-1990 PUMPAGE OF PRIVATE DEEP WELLS BY TYPE OF USER, DEPTH OF DEPRESSION AND SPECIFIC CAPACITY, PER MUNICIPALITY

	ATP	BCR	CLC	CTA	CVC	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJN	SNT	TGG	TYY	VLZ	Total
PUBLIC - DOMESTIC	10.72	11.50	6.99	3.38	0.31	1.19	1.03	20.86	0.55	3.68	0.69	0.81	1.95	1.55	17.93	0.62	2.07	17.35	2.13	3.37		11.42	1.00	0.09	0.97	7.85	7.17	1.15	138.32
+40m to +0m	10.72		5.13			1.19								1.55									1.00		0.97				20.56
Small	3.16		1.97											1.55											0.59				7.26
Medium	2.91		3.16																						0.31				6.38
Large	4.65					1.19																	1.00		0.07				6.92
+0m to -40m		11.50		3.38	0.31		1.03	20.86	0.55						17.93		2.07		2.13							7.85	7.17		74.77
Small				0.54				2.04	0.55						7.20				1.17							1.64	0.68		13.82
Medium								8.75							3.50				0.70							1.79	2.10		16.83
Large		11.50		2.84	0.31		1.03	10.07							7.23		2.07		0.26							4.43	4.39		44.12
-40m to -80m										3.68		0.81	1.95			0.62		17.35		3.37		11.42		0.09					39.29
Small										1.14		0.61	0.55			0.62		10.82		0.09		3.30		0.09					17.21
Medium										0.28		0.20						3.76		0.29		6.78							11.30
Large										2.26			1.40					2.78		2.99		1.34							10.77
-80m to -120m			1.86								0.69																	1.15	3.70
Small			0.50								0.69																	1.11	2.30
Medium			1.36																									0.04	1.40
Large																													
PUBLIC - INSTITUTION	0.12	0.13	0.33	0.38	1.27	0.24		0.07	0.14	1.73	0.64	0.36	0.27	0.18	1.47			0.18	1.88	0.41		1.54		0.03		0.65	0.14	0.50	12.65
+40m to +0m	0.12					0.24								0.18															0.54
Small	0.09													0.18															0.27
Medium	0.03																												0.03
Large						0.24																							0.24
+0m to -40m		0.13		0.38	1.27			0.07	0.14						1.47				1.88							0.65	0.14		6.13
Small				0.10					0.14						0.71				0.40							0.09			1.44
Medium				0.14				0.07							0.11				0.06								0.14		0.52
Large		0.13		0.13	1.27										0.66				1.43							0.55			4.17
-40m to -80m										1.73		0.36	0.27					0.18		0.41		1.54		0.03					4.52
Small										0.12		0.34	0.17					0.06				0.17		0.03					0.89
Medium										0.02		0.02	0.04					0.06				1.15							1.28
Large										1.60			0.06					0.06		0.41		0.23							2.35
-80m to -120m			0.33								0.64																	0.50	1.47
Small			0.11								0.49																	0.50	1.10
Medium			0.22								0.15																		0.37
Large																													

TABLE 3.3.3 (CONTINUATION)

	ATP	BCR	CLC	CTA	CWC	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJM	SMT	TGG	TYY	VL2	Total
COMMERCIAL	0.89	0.13	1.01	0.78				1.27	0.64	2.55	0.09	1.34	0.24	0.13	1.53	0.23		1.62	1.33	2.02		8.55	0.13	0.01	0.14	0.69	0.29	0.75	26.34
+40m to +0m	0.89		0.13											0.13									0.13		0.14				1.41
Small			0.13											0.13											0.08				0.34
Medium	0.89																								0.06				0.95
Large																							0.13						0.13
+0m to -40m		0.13		0.78				1.27	0.64						1.53				1.33							0.69	0.29		6.85
Small				0.62				0.12	0.64						0.47				0.74							0.61	0.12		3.32
Medium				0.16				0.65							0.49				0.59								0.16		2.04
Large		0.13						0.50							0.58											0.08			1.29
-40m to -80m										2.55		1.34	0.24			0.23		1.62		2.02		8.55		0.01					16.55
Small										1.02		0.97	0.24			0.23		1.23		0.21		0.78		0.01					4.69
Medium										0.04		0.37						0.20				6.14							6.75
Large										1.49								0.19		1.81		1.63							5.12
-80m to -120m			0.89								0.09																	0.75	1.73
Small			0.16								0.09																	0.57	0.82
Medium			0.73																									0.18	0.90
Large																													
INDUSTRIAL - FOOD & BEVERAGES	0.54		0.52	1.44				1.18	0.97	0.30	0.98	0.13	0.23		1.72			0.52	0.17	1.64		0.49				1.21	0.22	0.30	12.53
+40m to +0m	0.54		0.16																										0.70
Small	0.16		0.16																										0.32
Medium	0.37																												0.37
Large																													
+0m to -40m				1.44				1.18	0.97						1.72				0.17							1.21	0.22		6.90
Small				0.13					0.97						0.64											0.76			2.49
Medium				0.24				1.18							0.74														2.16
Large				1.06											0.34				0.17							0.45	0.22		2.25
-40m to -80m										0.30		0.13	0.23					0.52		1.64		0.49							3.31
Small										0.26			0.09					0.25		0.23		0.16							1.02
Medium												0.13						0.26				0.31							0.70
Large										0.04			0.13							1.41									1.58
-80m to -120m			0.36								0.98																	0.30	1.63
Small											0.98																	0.30	1.28
Medium			0.36																										0.36
Large																													

TABLE 3.3.3 (CONTINUATION)

	ATP	BCR	CLC	CTA	CVC	IKS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PS6	PTR	QCT	ROS	SJN	SMT	TG6	TYT	VLZ	Total
INDUSTRIAL - CHEMICALS				0.32				0.09	0.10	0.23	0.21	0.09			0.33			0.16		1.05		0.42	0.21			0.29	0.05	0.53	4.08
+40m to +0m																													
Small																							0.21						0.21
Medium																							0.21						0.21
Large																													
+0m to -40m				0.32				0.09	0.10						0.33											0.29	0.05		1.18
Small				0.05					0.10						0.09											0.11	0.05		0.39
Medium				0.14				0.09							0.24														0.47
Large				0.13																						0.19			0.32
-40m to -80m										0.23		0.09						0.18		1.05		0.42							1.96
Small										0.05		0.09						0.18		0.10		0.10							0.51
Medium										0.05										0.10		0.22							0.37
Large										0.13										0.85		0.10							1.08
-80m to -120m											0.21																	0.53	0.74
Small											0.21																	0.42	0.63
Medium																												0.11	0.11
Large																													
INDUSTRIAL - LEATHER											1.45								0.34		1.76					0.16		0.06	3.76
+40m to +0m																													
Small																													
Medium																													
Large																													
+0m to -40m																										0.16			0.16
Small																													
Medium																													
Large																										0.16			0.16
-40m to -80m																			0.34		1.76								2.09
Small																					0.34								0.34
Medium																					1.42								1.42
Large																			0.34										0.34
-80m to -120m											1.45																	0.06	1.51
Small											1.45																		1.45
Medium																												0.06	0.06
Large																													

TABLE 3.3.3 (CONTINUATION)

	ATP	BCR	CLC	CTA	CWC	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJN	SNT	TGG	TYY	VLZ	Total
INDUSTRIAL - TEXTILE, PAPER & PULP			0.14	7.12				0.43	0.08		2.47	0.45	1.93	1.07	7.09			1.73	0.45	9.87		6.26		0.02	0.18	4.58	3.53	7.65	55.05
+40m to +0m														1.07											0.18				1.25
Small														1.07											0.18				1.25
Medium																													
Large																													
+0m to -40m				7.12				0.43	0.08						7.09				0.45							4.58	3.53		23.28
Small				0.64				0.43	0.08						1.93											0.96	0.64		4.69
Medium				1.09											3.82											1.03	1.09		7.02
Large				5.38											1.35				0.45							2.60	1.80		11.57
-40m to -80m												0.45	1.93					1.73		9.87		6.26		0.02					20.27
Small													0.77					1.51		0.93		0.92		0.02					4.13
Medium												0.45						0.23				4.04							4.73
Large													1.17							8.94		1.29							11.41
-80m to -120m			0.14								2.47																	7.65	10.26
Small			0.14								2.47																	5.46	8.07
Medium																												2.19	2.19
Large																													
INDUSTRIAL - OTHERS	3.85		1.05	4.33		0.19		5.95	0.81	0.71	0.21	1.44	0.33		3.37	0.63		4.02	0.61	9.03	0.64	2.90	1.74	0.01	0.04	8.80	2.26	1.17	54.11
+40m to +0m	3.85		0.63			0.19																	1.74		0.04				6.46
Small	0.01																								0.04				0.06
Medium	1.13		0.63																				1.74						3.50
Large	2.71					0.19																							2.90
+0m to -40m				4.33				5.95	0.81						3.37				0.61		0.64					8.80	2.26		26.78
Small				0.39				0.54	0.78						0.66				0.37							1.71	0.54		5.02
Medium				1.06				1.88	0.03						0.59				0.23							0.26	0.12		4.16
Large				2.89				3.53							2.11						0.64					6.83	1.60		17.59
-40m to -80m										0.71		1.44	0.33			0.63		4.02		9.03		2.90		0.01					19.07
Small										0.40		1.34	0.19			0.63		3.22				0.62		0.01					6.42
Medium												0.10	0.05					0.69		0.84		1.63							3.31
Large										0.31			0.10					0.11		8.19		0.65							9.35
-80m to -120m			0.42								0.21																	1.17	1.80
Small			0.02								0.21																	0.51	0.74
Medium			0.41																									0.66	1.06
Large																													
Estimated Annual Pumpage, in MCM	16.12	11.76	10.03	17.75	1.58	1.62	1.03	29.85	3.28	9.19	6.74	4.62	4.95	2.93	33.44	1.48	2.07	25.61	6.57	27.72	0.64	33.33	3.09	0.15	1.33	24.23	13.65	12.11	306.86

TABLE 3.3.4 PERCENT SHARE TO TOTAL YEAR-1990 PUMPAGE

	ATP	BCR	CLC	CTA	CVC	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRM	PSC	PSG	PTR	QCT	ROS	SJN	SMT	TSG	TYY	VLZ	PERCENT SHARE
PUBLIC - DOMESTIC	3.5	3.7	2.3	1.1	0.1	0.4	0.3	6.8	0.2	1.2	0.2	0.3	0.6	0.5	5.8	0.2	0.7	5.7	0.7	1.1		3.7	0.3	0.0	0.3	2.6	2.3	0.4	45.1
+40m to +0m	3.5		1.7			0.4								0.5									0.3		0.3				6.7
Small	1.0		0.6											0.5											0.2				2.4
Medium	0.9		1.0																						0.1				2.1
Large	1.5					0.4																	0.3		0.0				2.3
+0m to -40m		3.7		1.1	0.1		0.3	6.8	0.2						5.8		0.7		0.7							2.6	2.3		24.4
Small				0.2				0.7	0.2						2.3				0.4							0.5	0.2		4.5
Medium								2.9							1.1				0.2							0.6	0.7		5.5
Large		3.7		0.9	0.1		0.3	3.3							2.4		0.7		0.1							1.4	1.4		14.4
-40m to -80m										1.2		0.3	0.6			0.2		5.7		1.1		3.7		0.0					12.8
Small										0.4		0.2	0.2			0.2		3.5		0.0		1.1		0.0					5.6
Medium										0.1		0.1						1.2		0.1		2.2							3.7
Large										0.7			0.5					0.9		1.0		0.4							3.5
-80m to -120m			0.6								0.2																	0.4	1.2
Small			0.2								0.2																	0.4	0.7
Medium			0.4																									0.0	0.5
Large																													
PUBLIC - INSTITUTION	0.0	0.0	0.1	0.1	0.4	0.1		0.0	0.0	0.6	0.2	0.1	0.1	0.1	0.5			0.1	0.6	0.1		0.5		0.0		0.2	0.0	0.2	4.1
+40m to +0m	0.0					0.1								0.1															0.2
Small	0.0													0.1															0.1
Medium	0.0																												0.0
Large						0.1																							0.1
+0m to -40m		0.0		0.1	0.4			0.0	0.0						0.5				0.6							0.2	0.0		2.0
Small				0.0					0.0						0.2				0.1						ERR	0.0			0.5
Medium				0.0				0.0							0.0				0.0								0.0		0.2
Large		0.0		0.0	0.4										0.2				0.5				0.2	ERR	0.2			1.4
-40m to -80m										0.6		0.1	0.1					0.1		0.1		0.5	0.0						1.5
Small										0.0		0.1	0.1					0.0				0.1	0.0						0.3
Medium										0.0		0.0	0.0					0.0				0.4							0.4
Large										0.5			0.0					0.0		0.1		0.1							0.8
-80m to -120m			0.1								0.2																	0.2	0.5
Small			0.0								0.2																	0.2	0.4
Medium			0.1								0.0																		0.1
Large																													

TABLE 3.3.4 (CONTINUATION)

	ATP	BCR	CLC	CTA	CWC	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJN	SNT	TGG	TYT	VLZ	PERCENT SHARE
COMMERCIAL	0.3	0.0	0.3	0.3				0.4	0.2	0.8	0.0	0.4	0.1	0.0	0.5	0.1		0.5	0.4	0.7		2.8	0.0	0.0	0.0	0.2	0.1	0.2	8.6
+40m to +0m	0.3		0.0											0.0									0.0		0.0				0.5
Small			0.0											0.0											0.0				0.1
Medium	0.3																								0.0				0.3
Large																							0.0						0.0
+0m to -40m		0.0		0.3				0.4	0.2						0.5				0.4							0.2	0.1		2.2
Small				0.2				0.0	0.2						0.2				0.2							0.2	0.0		1.1
Medium				0.1				0.2							0.2				0.2								0.1		0.7
Large		0.0						0.2							0.2											0.0			0.4
-40m to -80m										0.8		0.4	0.1			0.1		0.5		0.7		2.8		0.0					5.4
Small										0.3		0.3	0.1			0.1		0.4		0.1		0.3		0.0					1.5
Medium										0.0		0.1						0.1				2.0							2.2
Large										0.5								0.1		0.6		0.5							1.7
-80m to -120m			0.3								0.0																	0.2	0.6
Small			0.1								0.0																	0.2	0.3
Medium			0.2																									0.1	0.3
Large																													
INDUSTRIAL - FOOD & BEVERAGES	0.2		0.2	0.5				0.4	0.3	0.1	0.3	0.0	0.1		0.6			0.2	0.1	0.5		0.2				0.4	0.1	0.1	4.1
+40m to +0m	0.2		0.1																										0.2
Small	0.1		0.1																										0.1
Medium	0.1																												0.1
Large																													
+0m to -40m				0.5				0.4	0.3						0.6				0.1							0.4	0.1		2.2
Small				0.0					0.3						0.2											0.2			0.8
Medium				0.1				0.4							0.2														0.7
Large				0.4											0.1				0.1							0.1	0.1		0.7
-40m to -80m										0.1		0.0	0.1					0.2		0.5		0.2							1.1
Small										0.1			0.0					0.1		0.1		0.1							0.3
Medium												0.0						0.1				0.1							0.2
Large										0.0			0.0							0.5									0.5
-80m to -120m			0.1								0.3																	0.1	0.5
Small											0.3																	0.1	0.4
Medium			0.1																										0.1
Large																													

TABLE 3.3.4 (CONTINUATION)

	ATP	BCR	CLC	CTA	CVC	INS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJM	SMT	TGG	TYT	VLZ	PERCENT SHARE
INDUSTRIAL - CHEMICALS				0.1				0.0	0.0	0.1	0.1	0.0			0.1			0.1		0.3		0.1	0.1			0.1	0.0	0.2	1.3
+40m to +0m																							0.1						0.1
Small																							0.1						0.1
Medium																													
Large																													
+0m to -40m				0.1				0.0	0.0						0.1											0.1	0.0		0.4
Small				0.0					0.0						0.0											0.0	0.0		0.1
Medium				0.0				0.0							0.1														0.2
Large				0.0																						0.1			0.1
-40m to -80m										0.1		0.0						0.1		0.3		0.1							0.6
Small										0.0		0.0						0.1		0.0		0.0							0.2
Medium										0.0										0.0		0.1							0.1
Large										0.0										0.3		0.0							0.4
-80m to -120m											0.1																0.2		0.2
Small											0.1																0.1		0.2
Medium																											0.0		0.0
Large																													
INDUSTRIAL - LEATHER											0.5									0.1		0.6				0.1		0.0	1.2
+40m to +0m																													
Small																													
Medium																													
Large																													
+0m to -40m																										0.1			0.1
Small																													
Medium																													
Large																										0.1			0.1
-40m to -80m																				0.1		0.6							0.7
Small																						0.1							0.1
Medium																						0.5							0.5
Large																				0.1									0.1
-80m to -120m											0.5																	0.0	0.5
Small											0.5																		0.5
Medium																												0.0	0.0
Large																													

TABLE 3.3.4 (CONTINUATION)

	ATP	BCR	CLC	CTA	CVC	INS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	NTB	NTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJN	SMT	TGG	TYY	VLZ	PERCENT SHARE
INDUSTRIAL - TEXTILE, PAPER & PULP			0.0	2.3				0.1	0.0		0.8	0.1	0.6	0.3	2.3			0.6	0.1	3.2		2.0		0.0	0.1	1.5	1.1	2.5	17.9
+40m to +0m														0.3											0.1				0.4
Small														0.3											0.1				0.4
Medium																													
Large																													
+0m to -40m				2.3				0.1	0.0						2.3				0.1							1.5	1.1		7.6
Small				0.2				0.1	0.0						0.6											0.3	0.2		1.5
Medium				0.4											1.2											0.3	0.4		2.3
Large				1.6											0.4				0.1							0.8	0.6		3.8
-40m to -80m												0.1	0.6					0.6		3.2		2.0		0.0					6.6
Small													0.2					0.5		0.3		0.3		0.0					1.3
Medium												0.1						0.1				1.3							1.5
Large													0.4							2.9		0.4							3.7
-80m to -120m			0.0								0.8																	2.5	3.3
Small			0.0								0.8																	1.8	2.6
Medium																												0.7	0.7
Large																													
INDUSTRIAL - OTHERS	1.3		0.3	1.4		0.1		1.9	0.3	0.2	0.1	0.5	0.1		1.1	0.2		1.3	0.2	2.9	0.2	0.9	0.6	0.0	0.0	2.9	0.7	0.4	17.6
+40m to +0m	1.3		0.2			0.1																	0.6		0.0				2.1
Small	0.0																								0.0				0.0
Medium	0.4		0.2																				0.6						1.1
Large	0.9					0.1																							0.9
+0m to -40m				1.4				1.9	0.3						1.1				0.2		0.2					2.9	0.7		8.7
Small				0.1				0.2	0.3						0.2				0.1							0.6	0.2		1.6
Medium				0.3				0.6	0.0						0.2				0.1							0.1	0.0		1.4
Large				0.9				1.1							0.7						0.2					2.2	0.5		5.7
-40m to -80m										0.2		0.5	0.1			0.2		1.3		2.9		0.9		0.0					6.2
Small										0.1		0.4	0.1			0.2		1.0				0.2		0.0					2.1
Medium												0.0	0.0					0.2		0.9		0.5							1.1
Large										0.1			0.0					0.0		2.7		0.2							3.0
-80m to -120m			0.1								0.1																	0.4	0.6
Small			0.0								0.1																	0.2	0.2
Medium			0.1																									0.2	0.3
Large																													
PERCENT SHARE	5.3	3.8	3.3	5.8	0.5	0.5	0.3	9.7	1.1	3.0	2.2	1.5	1.6	1.0	10.9	0.5	0.7	8.3	2.1	9.0	0.2	10.9	1.0	0.0	0.4	7.9	4.4	3.9	100.0

TABLE 3.3.5 DISTRIBUTION OF MWSS DEEP WELLS IN THE MSA BY MUNICIPALITY AND STATUS (AS OF MARCH 1991)

MUNICIPALITY\STATUS	OPERATIONAL	INACTIVE	ABANDONED	TOTAL
National Capital Region				
MANILA	0	0	3	3
PASAY CITY	3	1	1	5
QUEZON CITY	16	9	0	25
CALOOCAN CITY	0	2	1	3
LAS PINAS	2	3	3	8
MAKATI	11	23	1	35
MALABON	3	3	3	9
MANDALUYONG	0	0	3	3
MARIKINA	0	13	2	15
MUNTINLUPA	7	0	0	7
NAVOTAS	2	7	0	7
PARANAQUE	5	2	5	12
PASIG	2	1	2	5
PATEROS	0	0	2	2
SAN JUAN	0	0	0	0
TAGUIG	3	1	3	7
VALENZUELA	3	4	1	8
NCR Sub-Total	57	69	30	156
Cavite Province				
CAVITE	15	0	7	22
BACOOR	8	0	2	10
IMUS	2	0	3	5
KAWIT	4	2	1	7
ROSARIO	1	2	0	3
NOVELETA	9	0	0	9
Cavite Sub-Total	39	4	13	58
Rizal Province				
ANTIPOLO	15	0	1	16
CAINTA	5	2	2	9
MONTALBAN	3	0	2	5
SAN MATEO	5	0	3	8
TAYTAY	7	0	1	8
Rizal Sub-Total	35	2	9	46
GRAND TOTAL	131	75	52	258

Source: Water Distribution & Maintenance Dept., MWSS Aug. 1990
Metro Manila Groundwater Dev't. Project Well Inventory. MWSS March 1991

TABLE 3.3.6 YEAR-1990 GROUNDWATER PRODUCTION OF MWSS DEEP WELLS IN THE MSA (UNIT : m³)

MUNICIPALITY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Antipolo	367,565.00	314,537.00	341,398.00	325,011.00	340,700.00	343,214.00	343,850.00	346,398.00	333,541.00	387,191.00	389,308.00	408,940.00	4,241,653.00
Bacoor	195,761.00	149,981.00	211,912.00	136,574.00	192,481.00	181,712.00	213,432.00	274,535.00	169,884.00	182,169.00	192,457.00	203,865.00	2,304,763.00
Cainta	139,379.00	130,884.00	137,892.00	127,800.00	126,228.00	122,677.00	115,636.00	107,762.00	99,319.00	105,425.00	84,930.00	83,623.00	1,381,555.00
Caloocan City													
Cavite City	230,166.00	200,374.00	192,867.00	192,867.00	219,802.00	219,976.00	225,005.00	231,874.00	219,790.00	254,561.00	*	263,329.00	2,450,611.00
Imus	52,882.00	49,692.00	49,940.00	45,130.00	47,435.00	47,432.00	49,401.00	57,339.00	47,432.00	46,032.00	50,146.00	60,709.00	603,570.00
Kawit	151,838.00	127,885.00	147,331.00	123,406.00	122,482.00	122,186.00	131,264.00	140,142.00	124,734.00	124,296.00	127,170.00	137,373.00	1,580,107.00
Las Pinas	55,479.00	46,218.00	52,397.00	46,230.00	48,584.00	40,493.00	42,063.00	48,976.00	41,511.00	46,107.00	42,837.00	46,481.00	557,376.00
Makati	78,214.00	84,115.00	97,521.00	141,887.00	133,177.00	104,346.00	113,527.00	89,329.00	125,004.00	127,829.00	135,259.00	140,474.00	1,370,682.00
Malabon	17,637.00	16,803.00	18,156.00	15,733.00	16,091.00	16,119.00	17,477.00	18,445.00	12,444.00	17,979.00	17,399.00	17,898.00	202,181.00
Mandaluyong													
Manila													
Marikina													
Montalban	100,621.00	92,197.00	102,328.00	97,570.00	97,063.00	102,187.00	104,779.00	101,476.00	100,367.00	97,236.00	91,290.00	96,668.00	1,183,782.00
Muntinlupa	201,759.00	178,272.00	193,804.00	174,512.00	180,780.00	153,755.00	170,191.00	171,702.00	164,851.00	160,414.00	176,505.00	182,032.00	2,108,577.00
Navotas	8,843.00	7,127.00	7,196.00	3,847.00	2,834.00	N.O.	N.O.	N.O.	N.O.	N.O.	3,842.00	4,956.00	38,645.00
Noveleta	147,313.00	259,686.00	262,170.00	307,670.00	180,540.00	251,582.00	248,201.00	232,758.00	222,029.00	257,107.00	N.D.	211,429.00	2,580,476.00
Paranaque	17,477.00	39,755.00	44,896.00	38,886.00	43,572.00	33,254.00	35,121.00	35,345.00	31,953.00	33,754.00	32,225.00	32,529.00	418,767.00
Pasay City	155,575.00	131,752.00	166,293.00	143,815.00	144,916.00	123,492.00	153,476.00	125,679.00	125,098.00	121,457.00	110,727.00	125,942.00	1,628,222.00
Pasig	N.O.	N.O.	N.O.	N.O.	N.O.	N.O.	N.O.	N.O.	N.O.	3,799.00	6,719.00	7,239.00	17,757.00
Pateros													
Quezon City	349,188.00	322,513.00	374,662.00	353,680.00	426,899.00	438,855.00	446,942.00	477,558.00	481,569.00	507,437.00	493,387.00	505,085.00	5,177,775.00
Rosario	27,947.00	22,217.00	25,322.00	21,376.00	23,535.00	24,467.00	25,332.00	26,947.00	26,999.00	36,020.00	28,331.00	35,999.00	324,492.00
San Juan													
San Mateo	144,772.00	140,423.00	140,109.00	110,167.00	135,743.00	138,908.00	142,780.00	143,596.00	148,191.00	162,328.00	158,797.00	151,902.00	1,717,716.00
Taguig	20,722.00	18,488.00	31,891.00	19,730.00	22,159.00	19,211.00	23,078.00	18,560.00	17,960.00	14,056.00	13,602.00	14,055.00	233,512.00
Taytay	188,983.00	207,123.00	223,952.00	182,843.00	146,184.00	201,975.00	216,104.00	185,058.00	179,347.00	207,994.00	204,389.00	211,574.00	2,355,526.00
Valenzuela	18,136.00	17,837.00	22,946.00	20,839.00	22,477.00	22,994.00	24,654.00	29,654.00	24,342.00	22,087.00	21,882.00	23,036.00	270,884.00
Total	2,670,257.00	2,557,879.00	2,844,983.00	2,629,573.00	2,673,682.00	2,708,835.00	2,842,313.00	2,863,133.00	2,696,365.00	2,915,278.00	2,381,202.00	2,965,129.00	32,748,629.00
Average	121,375.32	116,267.23	129,317.41	119,526.05	121,531.00	123,128.86	129,196.05	130,142.41	122,562.05	132,512.64	108,236.45	134,778.59	1,169,593.89

TABLE 3.3.7 YEAR-1990 GROUNDWATER PUMPAGE IN THE MSA

(UNIT : MCM)

Municipality	PRIVATE						KWSS		TOTAL	
	Number of Wells	Public	Institutional	Commercial	Industrial	1990 Production	Number of Wells	1990 Production	Number of Wells	1990 Production
ATP	115	10.78	0.12	0.89	4.33	16.12	15	4.24	130	20.36
BCR	47	11.50	0.13	0.13		11.76	8	2.31	55	14.07
CIC	114	6.39	0.53	1.01	1.70	10.03	0		114	10.03
CTA	78	5.38	0.38	0.78	10.36	17.74	5	1.38	83	19.12
CWC	11	0.21	1.27			1.48	15	2.45	26	4.03
IMS	9	1.19	0.24		0.19	1.62	2	0.60	11	2.22
KWT	4	1.03				1.03	4	1.35	8	2.61
LPS	167	20.36	0.22	1.07	7.85	29.85	2	0.56	169	30.41
MDL	31	0.65	0.14	0.64	1.95	3.29	0		31	3.29
MKT	98	3.68	1.73	2.65	1.33	9.19	11	1.37	109	10.56
MSB	67	0.59	0.64	0.09	5.22	6.74	3	0.20	70	6.94
MNL	49	0.81	0.36	1.34	2.11	4.62	0		49	4.62
MRA	36	1.95	0.27	0.24	2.49	4.95	0		36	4.95
MTP	28	1.55	0.18	0.18	1.37	3.28	3	1.15	26	4.11
MTL	182	17.92	1.47	1.53	12.51	33.44	7	2.11	189	35.55
NAY	17	0.62		0.23	0.63	1.48	2	0.04	19	1.52
NOY	3	2.07				2.07	9	2.58	17	4.65
PRN	378	17.56	0.18	1.62	6.46	25.81	5	0.42	283	26.05
PSC	47	2.13	1.68	1.33	1.33	6.57	3	1.63	50	8.20
PSG	197	3.37	0.41	2.02	21.93	27.72	2	0.02	199	27.74
PTR	2				0.64	0.64	0		2	0.64
QCP	307	11.43	1.54	8.55	11.81	33.33	16	5.18	323	38.51
ROS	16	1.60		0.13	1.36	3.09	1	0.32	17	3.41
SJN	2	0.09	0.03	0.01	0.02	0.15	0		2	0.15
SMP	11	0.97		0.14	0.22	1.33	5	1.72	16	3.05
TGG	121	5.35	0.65	0.69	15.04	21.33	3	0.23	124	24.45
TYY	82	7.17	0.15	0.29	6.05	13.65	7	2.36	89	16.01
YLZ	127	1.15	0.50	0.75	9.71	12.11	3	0.27	130	12.38
Total	2216	139.33	12.65	35.34	123.54	306.86	131	32.73	2347	339.59

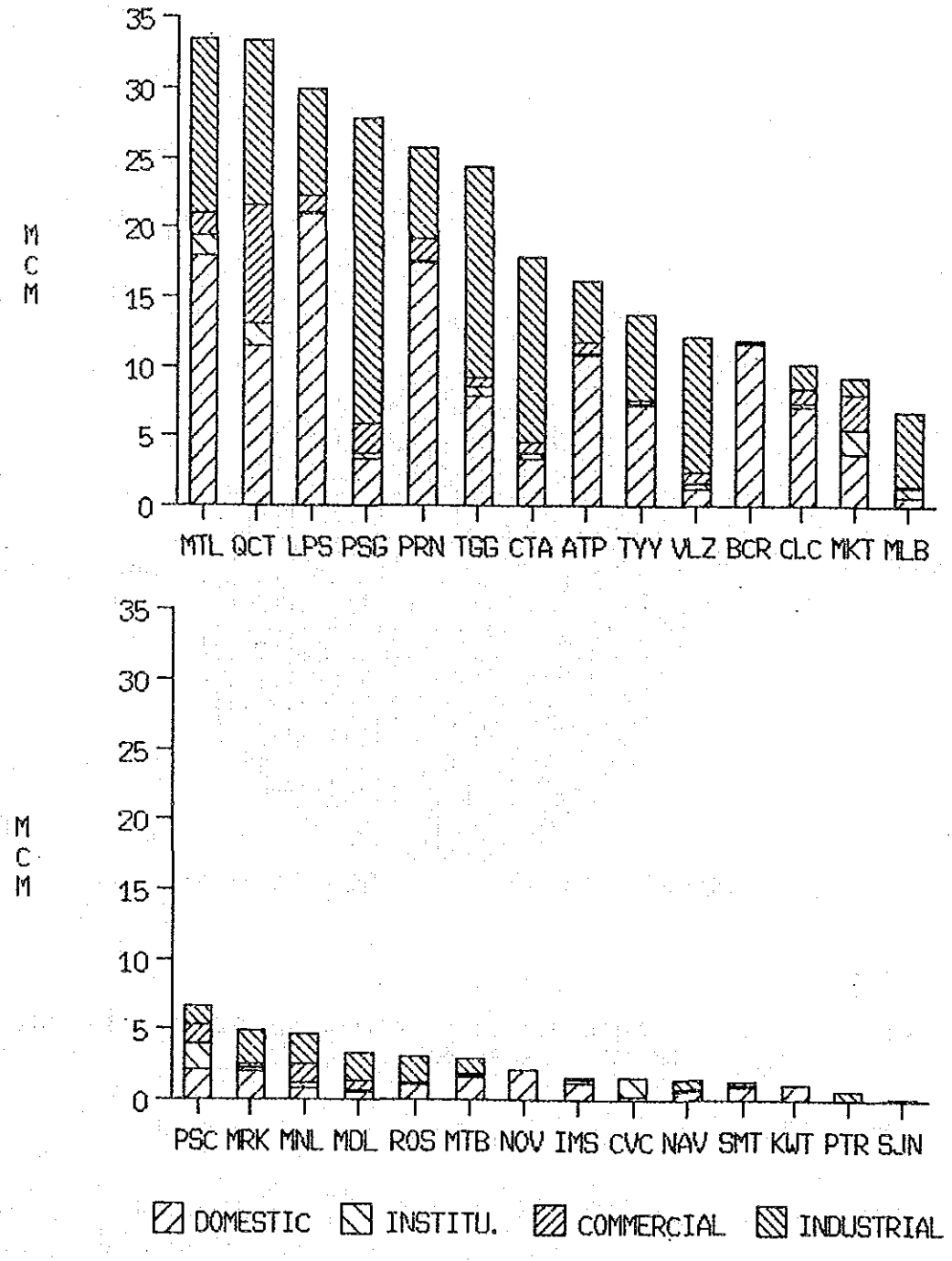


FIGURE 3.3.1 YEAR-1990 TOTAL PUMPAGE BY PRIVATE DEEP WELLS IN THE MSA (TOTAL PUMPAGE = 306.85 MCM)

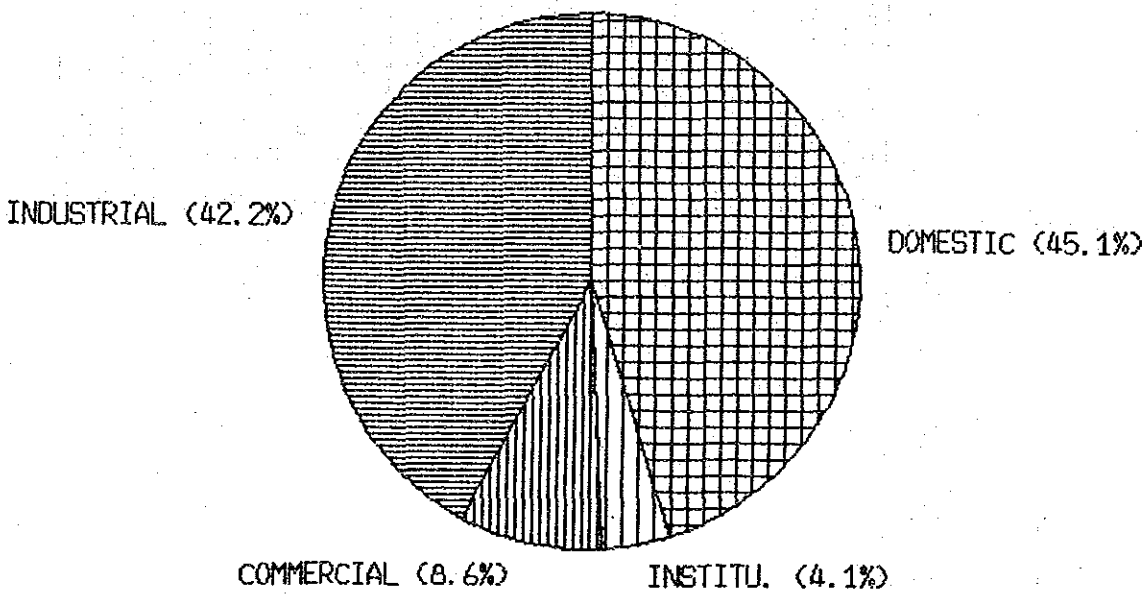
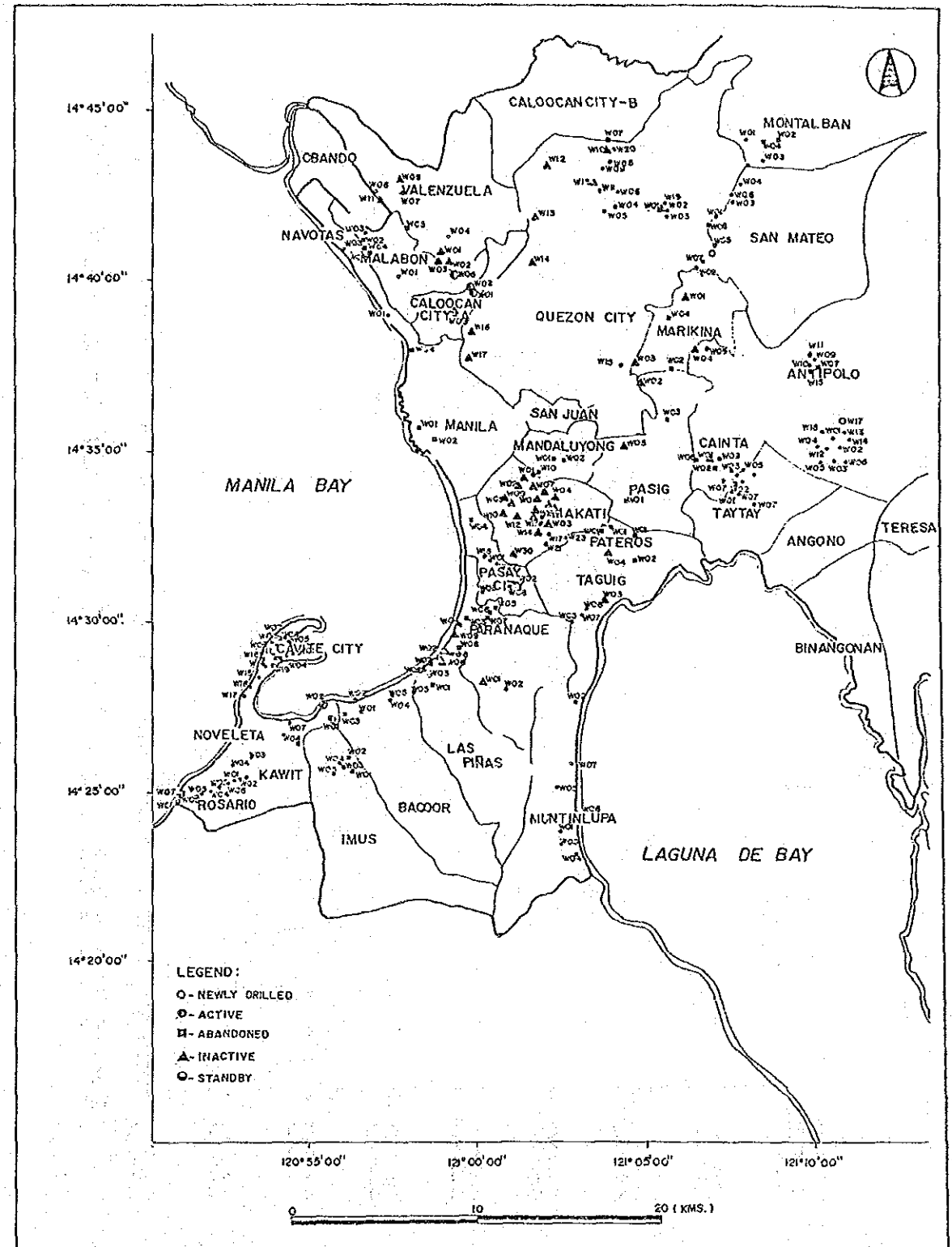


FIGURE 3.3.2 YEAR-1990 TOTAL PUMPAGE BY PRIVATE DEEP WELLS IN THE MSA, (TOTAL PUMPAGE = 306.85 MCM)



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.3.3
JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION MAP OF MWSS WELLS

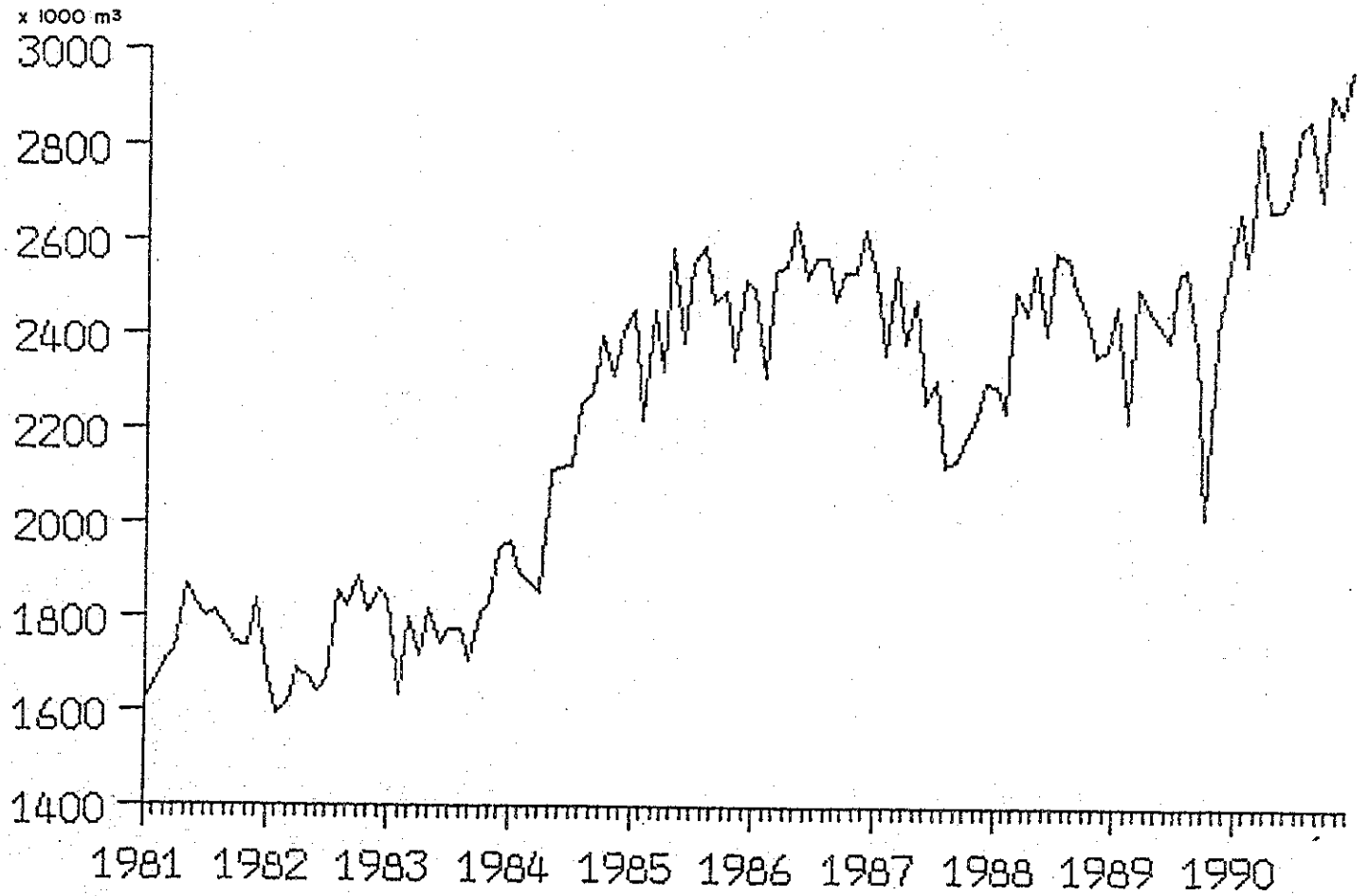


FIGURE 3.3.4 MONTHLY GROUNDWATER PRODUCTION OF MWSS WELLS IN THE MSA

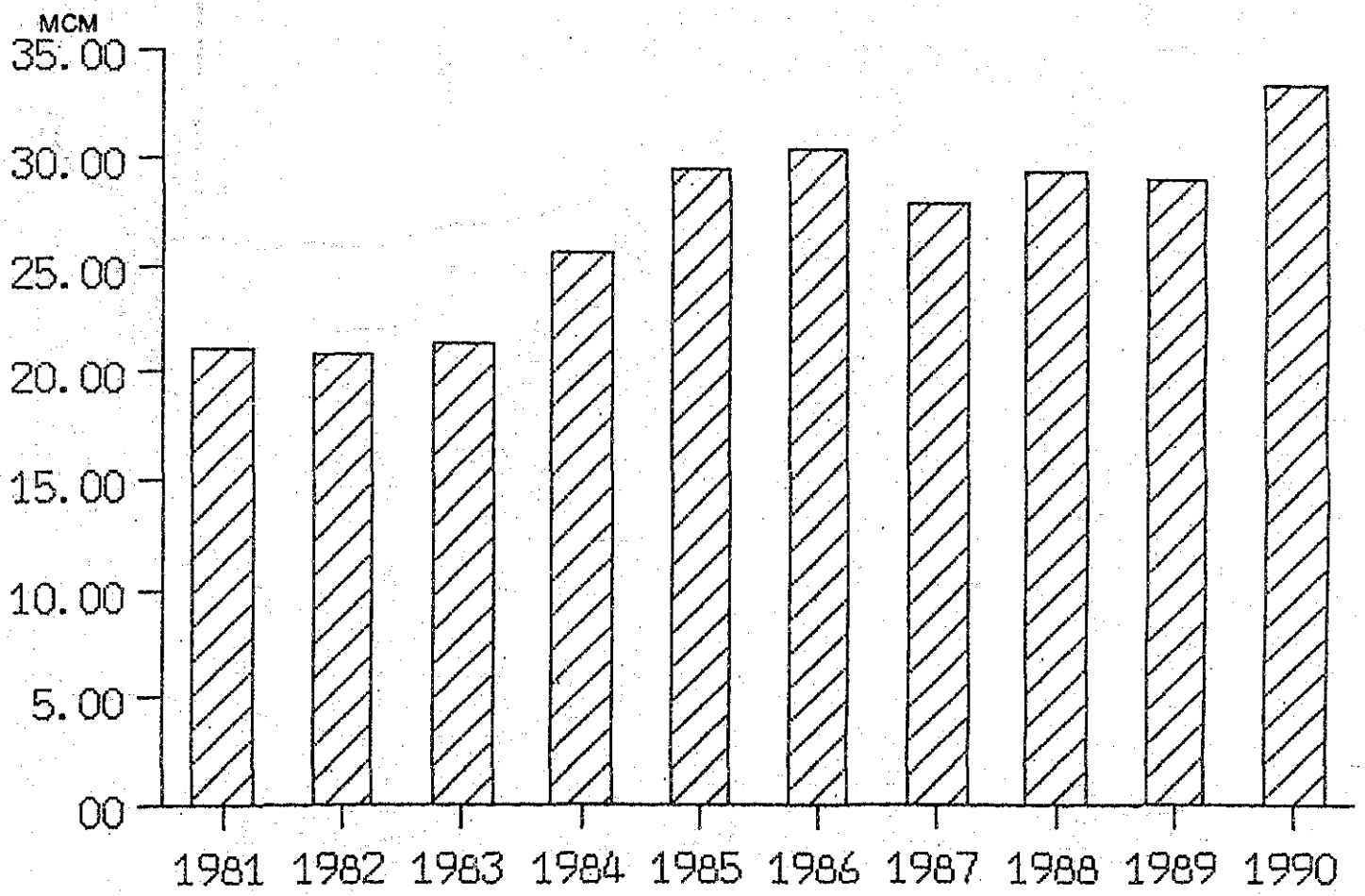
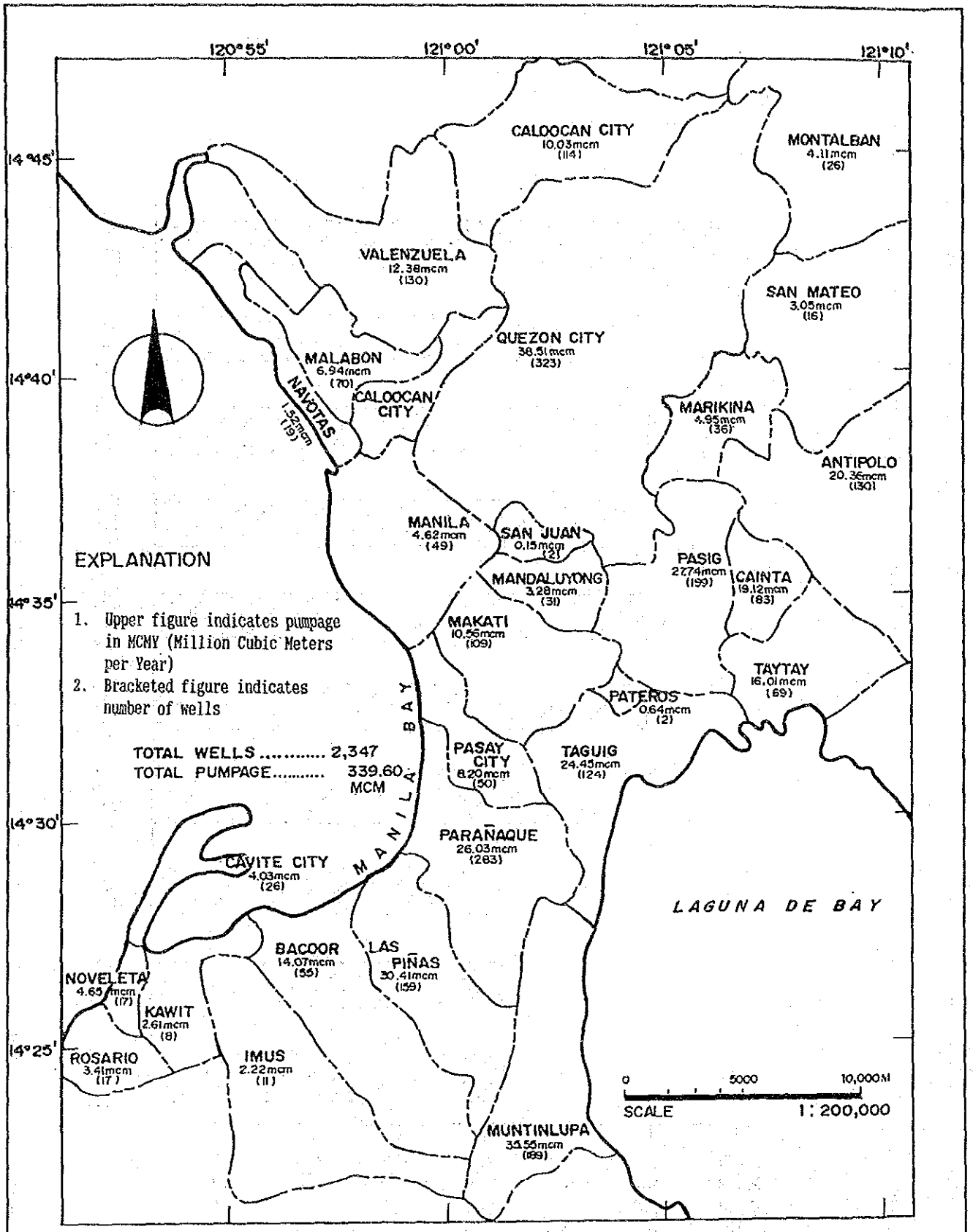


FIGURE 3.3.5 YEARLY GROUNDWATER PRODUCTION OF MWSS WELLS IN THE MSA



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.3.6 1990 GROUNDWATER PUMPAGE IN THE STUDY AREA

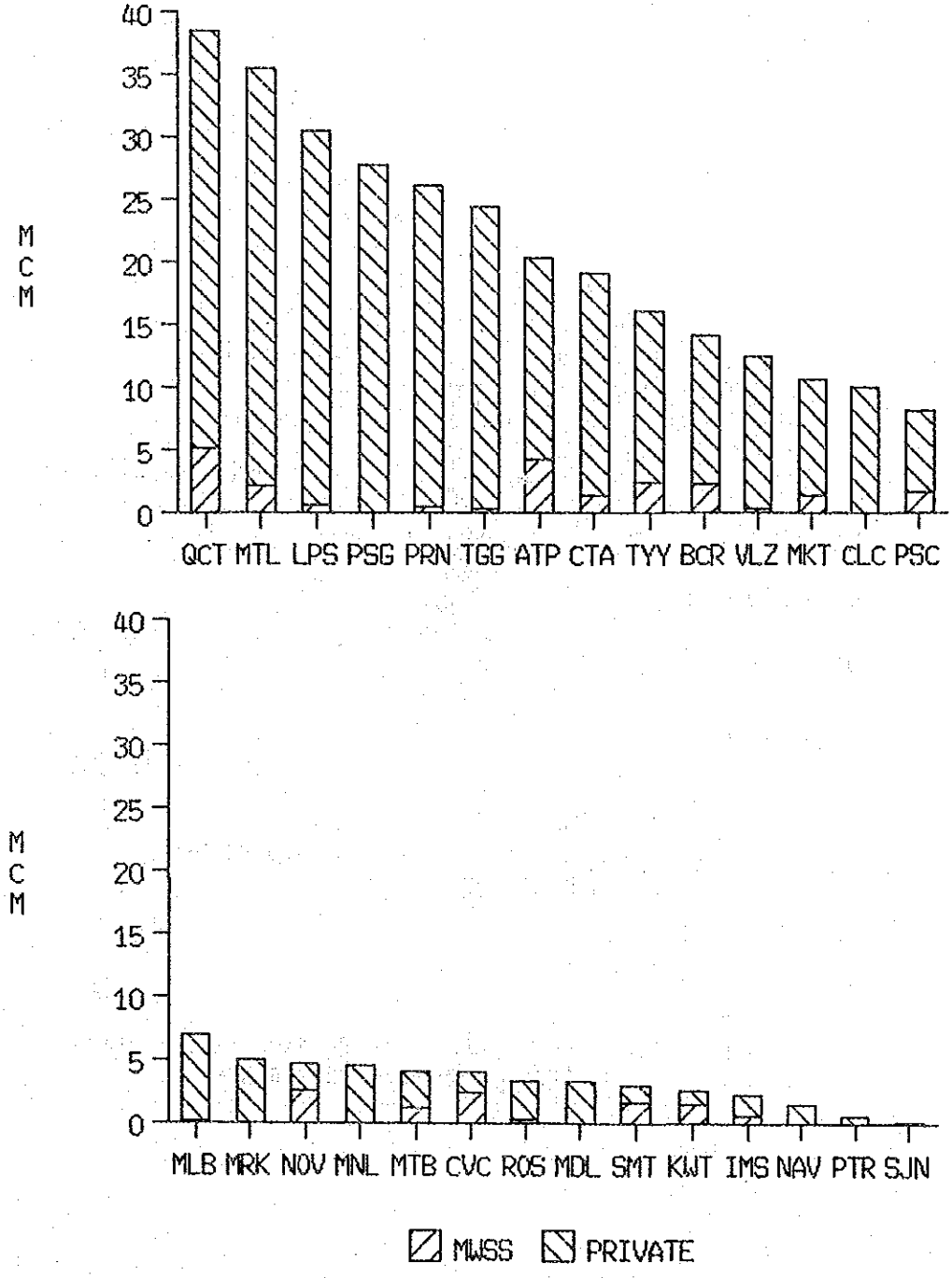


FIGURE 3.3.7 YEAR-1900 TOTAL PUMPAGE IN THE MSA
(TOTAL PUMPAGE = 339.6 MCM)

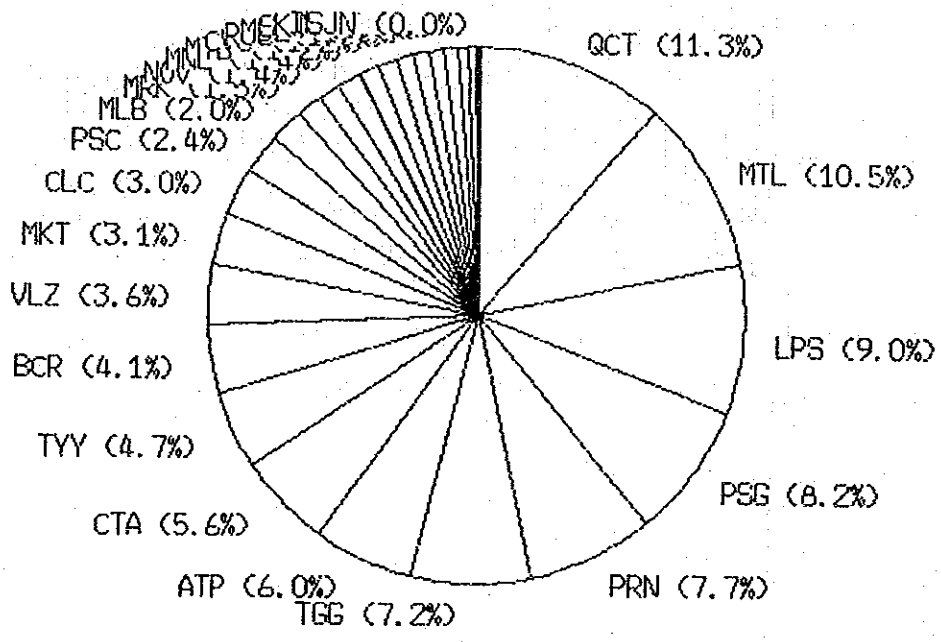


FIGURE 3.3.8 YEAR-1990 TOTAL PUMPAGE IN THE MSA
(TOTAL PUMPAGE = 339.6 MCM)

3.4 GROUNDWATER LEVELS

3.4.1 Groundwater Leveling

The purposes of groundwater leveling are as follows:

- To prepare a groundwater contour map of the Study Area;
- To investigate the changes between the 1981 and 1990 groundwater levels in the Study Area; and
- To determine the seasonal changes of groundwater levels in the Study Area.

A survey involving three sets of simultaneous observations of groundwater levels was carried out in the Study Area and the Antipolo Plateau in November 1990 (end of wet season), April-May 1991 (end of dry season), and August 1991 (peak of the rainy season). This survey was done by MWSS Staff under the supervision of the Study Team.

Of the 231 observation wells, only 204 were considered in the preparation of groundwater contour maps. The rest of the wells were unreliable for said purpose. The 1990 piezometric contour map shown in Figure 3.3.1 was prepared using the simple average of three measurements.

Figure 3.4.2 shows the configuration in 1981 of the piezometric contours in the Study Area. The 1981 piezometric surface map was replotted using previously plotted point piezometric elevations on the piezometric contour map that was included in the Final Report of the Manila Water Supply II - Groundwater Development. Figure 3.4.3 shows the change in the piezometric contours between 1981 and 1990.

Figure 3.4.4 shows the 1990 piezometric contour map of the Antipolo Area.

3.4.2 Groundwater Contours

Metro Manila Groundwater Basin

Groundwater, which coursed naturally to Manila Bay or to Laguna Bay, either directly or via the Marikina Alluvium, flows towards areas of heavy groundwater pumpage.

The aquifer system in the western part of Metro Manila, including Navotas, Malabon, Caloocan, Valenzuela and Quezon City, is fed by recharge from the higher ground in the north, as well as by sea intrusion. Recharge from the north moves towards Manila Bay, but a large amount of flow is diverted to the depression in the Valenzuela-Malabon-Caloocan area.

Along Manila Bay from Navotas to Cavite City the groundwater flow is from the bay to the depressions.

The depressions in southern Makati, Parañaque, northern Muntinlupa and Las Piñas are recharged on the west by Manila Bay and on the east by Laguna de Bay.

The piezometric surface is higher southward--up to 50m above MSL--in the southern areas of Imus, Bacoor and Muntinlupa. Flow is from a recharge area in the south (Tagaytay) to areas of heavy pumpage in Las Piñas, the northern portions of Muntinlupa and Bacoor, and the southern portion of Parañaque where the piezometric levels are 70-80m below MSL.

The Marikina Valley lying east of the Marikina Fault receives recharge from the mountains to the north. The depression in Pasig intercepts much of the recharge from the north.

Comparison of the piezometric condition in 1981 (Figure 3.4.2) and 1990 (Figure 3.4.1) reflects that little has changed since 1981, except in areas where piezometric heads have recovered somewhat in recent years as a result of reduced pumpage owing to the implementation and completion of MWSP II; and also, except for areas considered as centers of pumpage and where water levels have continued to decline substantially below sea level. This result can be easily discerned in Figure 3.4.3 where the