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STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

VOLUME 3
SUPPORTING REPORT

JUNE 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

REPUBLIC OF THE PHILIPPINES

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SUPPORTING REPORT

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ABBREVIATIONS

LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AWSOP	Angat Water Supply Optimization Project
BMG	Bureau of Mines and Geosciences
BSWM	Bureau of Soils and Water Management
CDS	Central Distribution System
CMD	Cubic Meter Per Day
DTI	Department of Trade and Industry
DPWH	Department of Public Works and Highways
EMB	Environmental Management Bureau
ERS	Electric Resistivity Survey
FAWSP	Fringe Areas Water Supply Project
GMA	Greater Manila Area
GNP	Gross National Product
GRDP	Gross Regional Domestic Product
GWD-MWSP II	Groundwater Development - Manila Water Supply Project II
HLURB	Housing and Land Use Regulatory Board
IA	Implementing Arrangement
IDRCC	International Development Research Center of Canada
JICA	Japan International Cooperation Agency
LPS	Liter Per Second
MCM	Million Cubic Meters
MGB	Mines and Geosciences Bureau
MLD	Million Liters Per Day
MCD	Million Cubic Meters Per Day
MMA	Metropolitan Manila Authority
MMGWDP	Metro Manila Groundwater Development Project
MMWDP	Metro Manila Water Distribution Project
MSA	MWSS Service Area
MSL	Mean Sea Level
MWSP II	Manila Water Supply Project II
MWSP III	Manila Water Supply Project III

MWSRP I	Manila Water Supply Rehabilitation Project I
MWSRP II	Manila Water Supply Rehabilitation Project II
MWSS	Metropolitan Waterworks and Sewerage System
NAMRIA	National Mapping and Resource Information Authority
NCR	National Capital Region
NDA	No Data Available
NEDA	National Economic and Development Authority
NEPC	National Environmental Protection Council
NHA	National Housing Authority
NHRC	National Hydraulic Research Center
NIA	National Irrigation Administration
NPC	National Power Corporation
NSO	National Statistics Office
NSCB	National Statistical Coordination Board
NWRB	National Water Resources Board
OPPDC	Office of the Provincial Planning and Development Coordinator
OPPDC-RP	Office of the Provincial Planning and Development Coordinator - Rizal Province
PAGASA	Philippine Atmospheric, Geophysical and Astronomical Services Administration
PGSCS	Philippine Groundwater Salinity Control Study
PIA	Philippine Information Agency
PNR	Philippine National Railways
RDFP	Regional Development Framework Plan
RPWSIP	Rizal Province Water Supply Improvement Project
WRMM-MM	Water Resources Management Model for Metro Manila

CHAPTER 1

PREVIOUS STUDIES ON GROUNDWATER IN METRO MANILA

CHAPTER 1 A REVIEW OF STUDIES ON GROUNDWATER IN METRO MANILA

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CHAPTER 1 A REVIEW OF PREVIOUS STUDIES ON GROUNDWATER IN METRO MANILA

1.1 STUDIES IN THE LATE SIXTIES AND SEVENTIES

Studies on groundwater resources in Metro Manila date back to the 1960s with most of them having been undertaken by researchers of the Bureau of Mines and Geosciences (BMG). But these studies were only preliminary and were general unpublished, with the more useful ones for assessing the groundwater condition in the late 1960s having been written by Hernando Quiazon of the BMG. Such Quiazon studies are contained in two reports: in 1966, "Geology and Groundwater Resources of Quezon City"; in 1968, "Geology and Groundwater Resources of Manila and Suburbs."

In the 1968 report, Quiazon discussed the water bearing properties of rocks, the hydrometeoric condition, water balance and hydrology. It is worth noting that at that time the groundwater level had already dropped to 40 meters below sea level in the Malabon, Navotas and Caloocan areas. From near-surface to about 300 feet, saline groundwater was found in the near-shore groundwater zone from Las Piñas to Malabon and in the vicinity of areas away from shore with salty surface water.

Quiazon concluded in the same report that no less than twenty (20) additional square kilometers of aquifers from depths of 300 to 500 feet were lost to salty water during the 1959-1966 period, and that the experience at the Manila Bay basins could guide the use of other groundwater basins.

Moreover, he stressed the necessity of regulating the disposition of the groundwater that underlies private lands and those in the public domain, as groundwater is in the same category as underground mineral resources. His concluding remark on not exceeding the safe yield of basin, unless the public interest requires it, deserves thoughtful attention.

Throughout the 1970s very little studies were done on Metro Manila's groundwater resources. As far as Quiazon's work is concerned, he made at least two unpublished reports regarding Manila and its environs in 1971 and 1975.

In the 1971 report and based on the construction records of wells and other data, he discussed the water levels, hydrogeologic properties of formations, groundwater movement, recharge and discharge, and the water quality in Manila and suburbs. Quiazon observed that in an area of about 300 square kilometers of the pumped zone between Guiguinto (in Bulacan province), Manila, Quezon City and Marikina Valley, the decline of the groundwater level had reached 2 to 50 feet per year, and he warned that many pumpwell sites may become inoperative within a span of 10 years.

1.2 STUDIES FROM 1980-1983 (THE ELECTROWATT STUDY)

In 1980 and in the light of the government's "crash program" of groundwater development to augment the MWSS supply, the Groundwater Development - Manila Water Supply Project II (GWD-MWSPII) was launched with the aim of transforming it into a long range program of water management. This long range program was envisioned to provide for a most effective exploitation and use of the groundwater resources of the Metro Manila area.

The above project was jointly implemented by MWSS and Electrowatt. It constitutes the first study that tried to comprehensively delineate existing and future conditions of the capital region's groundwater resources.

A corollary feature of GWD-MWSP II was the preparation of a program of groundwater development which shall keep pace with the demand in outlying areas and also relieve shortages of water supply within the nominal service area of the central distribution system (CDS) of the MWSS.

The scope of GWD-MWSP II or the Electrowatt Study focused on four aspects:

- o Groundwater development including completion of the ongoing program, and siting and specifications for 50 project wells.

- o Hydrogeologic investigations to describe groundwater conditions in Metro Manila and to determine the effects of present developments on the occurrence and quality of groundwater and the future prospect for groundwater development.

- o Master Plan studies to lay out the future program of investigation, regulation and development
- o Training and Institutional Development to create an organization within MWSS that will carry out the future program of investigaion and development.

1.2.1 Hydrogeologic Investigations

(1) Well Inventory and Groundwater Use

The Electrowatt Study had carried out an inventory of existing wells which in end-August 1982 had 2292 records of wells collected and inventoried with location maps. Water levels of 58 idle wells were measured and 381 operating wells were sampled for laboratory analysis of major chemical and physical properties based on inventoried well data. These data were used as the basis for the 1981 water level contour map and the water quality characteristics map.

Aquifer parameters such as transmissibility and specific capacity were processed and represented on a map according to pumping test data and discharge-drawdown data (Table 1.2.1).

Since there were no wells equipped with meters, groundwater pumpage in the Metro Manila area was estimated by using the discharge capacity of wells, their energy consumption or other indirect data.

According to the estimation, total withdrawals for industrial, commercial and public supply wells were 261 MCMY (689 MLD) as shown in Table 1.2.2 and Figure 1.2.1. In addition, total withdrawal for domestic supply from about 20,000 privates shallow wells in the Metro Manila Area was estimated as 14 MCMY(38 MLD).

(2) Groundwater Condition

Surface geological studies were carried out by using aerial photographs, satellite imagery and field observations throughout the Metro Manila Area. A detailed surface geologic survey was made for Cogeo and the vicinity of Antipolo.

Surface resistivity surveys were done in the Marikina Valley to try to locate shallow salt-water bodies, and around the municipalities of Antipolo and Cogeo, to try to locate structural breaks in the rocks.

In addition, electric logs of about 100 wells were collected. The results of these studies were represented on a geological map of 1/50,000 scale.

Based on such work mentioned, groundwater condition in the Metro Manila Area was described in the Electrowatt report, from which some of the important findings are:

Groundwater Geology

The rocks and sediments of the Metro Manila Area are divided into the Manila Bay Aquifer System, the Antipolo Plateau Aquifer System and the Volcanic rocks of the Cogeo Area. The alluvial and diluvial sediments in Marikina Valley graben are included in the Manila Bay Aquifer System.

The Manila Bay Aquifer System consists of rocks and unconsolidated sediments of the Quaternary alluvium and underlying Guadalupe Formation. A part of the Guadalupe formation consists of sediments of volcanic rock reworked and deposited. These sands and conglomerate comprise the most productive water bearing rocks in the Metro Manila Area.

The Antipolo Plateau Aquifer System consists of rocks which are classified as part of the Guadalupe formation, but which are isolated from the Guadalupe rocks of the Manila Bay Aquifer System by fissure basalt along the bounding Cogeo fault of the east side of Marikina Valley. The water bearing zone is made up of coarse-grained facies of the Guadalupe formation.

The Volcanic rocks of the Cogeo Area include basaltic and andesitic lava flows and related eruptive rocks. The water bearing zone of these rocks contains cracks and fractures.

In the north and east of Montalban and the Antipolo Plateau, folded clastic rocks and limestone of Tertiary age occur, but these sedimentary rocks have not supported any groundwater development other than a few wells in the Teresa area.

Water Bearing Properties of the Aquifer

The distributions of transmissibility and specific capacity of the Manila Bay Aquifer System are shown in Figures 1.2.2 and 1.2.3.

The transmissibility commonly ranges from about 100 to 250 m^2/d. A high range of transmissibility can be found in the Muntinlupa-San Pedro area located east of the Marikina Fault, where the value ranges from 450 to 1192 m^2/d.

Southwest of the Metro Manila area from Imus to Rosario, the transmissibility values range from 400 to 700 m^2/d. In most of the Antipolo town, the transmissibility exceeds 200 m^2/d. This is true as well in the vicinity of Taytay, in a large area in Cavite Province, and much of the Marikina Valley.

Effects of Development

Large-scale development of groundwater from the Manila Bay Aquifer System greatly altered the flow regime in the underground. This was elucidated by the historical piezometric surface maps reproduced from the records obtained in the years 1955, 1967 and 1981. (Figure 1.2.4,5,6)

The groundwater flow pattern in 1955 suggests that recharges from southern Tagaytay reached Taguig, Makati, Parañaque, Pasay, and Manila Bay and Laguna de Bay. By 1967, the recharge was still able to reach these areas. However, the 1981 map indicates that the groundwater flow from the south is largely diverted to the areas of heavy groundwater pumpage in Sucat-Bicutan, Las Piñas, Cavite City and Bacoor and is no longer reaching Makati.

The water level however, has continuously declined since 1955. In 1981 the rate of decline had reached 5 to 12 m/year with a deep cone of depression appearing in the heavy pumping area. This lowering of water level resulted to saline water intrusion of the Manila Bay Aquifer System and has largely affected the quality of groundwater. Figure 1.2.7 shows the distribution of conductivity that were observed in the coastal area along the Manila Bay.

In regard to saline water, Electrowatt's study subdivided the Metro Manila into 4 areas based on the occurrence and source of saline water (Figure 1.2.8):

A: Sea water intrusion

This zone is affected by seawater intrusion due to the increase in groundwater pumpage and the downward drainage of seawater through faulty well.

B: Connate water zone

The presence of connate water at depths was positively verified in the southern Marikina Valley, the vicinity of the Manila International Airport (MIA), and the industrial area of Sucat and Bagumbayan.

C: Saline water from compound source

In San Dionisio, Parañaque and MIA, seawater intruded the shallow part of the aquifer and connate water occurs at depth.

D: Freshwater to possibly 400m depth

1.2.2 *Master Plan Studies*

Master plan studies were carried out in two contexts. One is in the projection of the future condition of the groundwater in the Metro Manila Area to guide future MWSS development programs; the other is in the identification of priority projects and of potentially serious problems and the determination of potentials for groundwater development in unexplored reaches of aquifer system.

A finite-element groundwater model was formulated to simulate groundwater flow in the Manila Bay Aquifer System. Calibration of the model was done and parameters such as transmissibility and storativity were identified. Aerial recharge rate was taken at 100mm/year.

Results of simulation indicate that if pumpage were continued to the year 2000 at the 1982 rate, the mean water level would approach 90m below MSL, more than double the 1982 depth. The model's projection also indicated that even if pumpage were completely stopped in 1990, water level recovery would be at a rate of only 2m/year, and after 10 years, at a rate of about 1m/year. This means that the aquifer parallel to Manila Bay would be vulnerable to sea water intrusion for several decades.

Based on the conclusion, recommendations concerning construction, pumpage modification, legal and administrative investigations were made.

1.3 RECENT STUDIES

1.3.1 Philippine Groundwater Salinity Intrusion Control Study (PGSICS)

This study was undertaken in 1985 by the National Environmental Protection Council (NEPC) and was aimed at a definition of the affected area by saline water intrusion, the formulation of a proposal for a comprehensive measurement and monitoring system, and recommendations for the development and management of groundwater considering economic, legal and institutional aspects.

The study focused on Metro Manila and the provinces of Cebu, Bulacan, Pampanga, Capiz and Sorsogon.

Most of the data used in this study were secondary and collected from various agencies. However, in Metro Manila, groundwater samples were taken and water levels were measured at selected wells in pilot areas. Chemical analysis were made and plotted on the trilinear diagram. The Electric conductivity map and piezometric surface map in 1985 were presented and compared to those of 1981. These maps are useful in the assessment of groundwater condition in Metro Manila in the mid-1980s (Figure 1.3.1 and 1.3.2), but they are only approximate as the surveyed wells were limited in number. They may at least indicate, however, that the groundwater level and salinity condition in 1985 are virtually the same as in 1981.

Based on PGSICS water quality data in Metro Manila, cation-anion composition are represented on hexa-diagram in the present Study (Table 1.3, Figure 1.11). It is evident that the water affected by saline water intrusion is shaped so differently in the diagram when compared to non-affected water.

Moreover, the relation between bicarbonate and chloride is very clear as shown in Figure 1.3.4. The position of contaminated groundwater in the graph gradually moved to the upper portion in accordance with the degree of salinity.

In the PGSICS, the economic impact of salinity in groundwater use was discussed and evaluated based on case studies. In addition, regulatory and institutional measures were discussed and recommended. These will provide the basis in the establishment of groundwater monitoring system in Metro Manila and shall require further discussions.

1.3.2 Fringe Areas Water Supply Project (FAWSP)

This is an ongoing project of MWSS and feasibility studies have been developed to identify potential groundwater resources, and also, to design a feasible scheme of supply for the fringe areas of Metro Manila. The project aims to supply water to areas not served by surface water even after the completion of AWSOP or MWSP II.

In September 1990, the draft feasibility study report No. 1 covering Antipolo, Montalban, San Mateo, Imus and Muntinlupa has been finished.

The No. 1 report incorporates study results on existing water supply systems, population and water demand projections, and water resource evaluation. Based on the study, locations and design of wells have been proposed, with the contract for construction of several wells having already been awarded and executed.

With regard to hydrogeological study, meteorological and hydrological data were collected, but primary data were not obtained yet, except for those on water quality of existing wells and measurements of water levels and spring flows, also in limited areas and numbers.

In the project, one (1) well in Antipolo has been completed and another in Cogeo has been under construction since October 1990.

1.3.3 Rizal Province Water Supply Improvement Project (RPWSIP)

This is a feasibility study for improving the water supply in the nine (9) municipalities of Rizal Province: Angono, Baras, Binangonan, Cardona, Jala-Jala, Morong, Pililla, Tanay and Teresa. It was carried out by MWSS and SOGREAH Consulting Engineers and financed by the Government of France.

A feasibility study report of the RPWSIP was submitted in December 1989. The study scope includes water demand, water resources, alternative schemes, financial analysis and institutional aspects.

According to the study, the only source of water supply in the nine towns is groundwater. One of the important conclusions reached in the report is that the groundwater would be able to supply the whole population of the nine (9) towns up to the year 1999.

Regarding groundwater investigations, existing geological and hydrogeological data were collected and analyzed, but little primary data were obtained. Flow measurements of springs in Teresa and rivers in Morong and Tanay were done for nine (9) months (February to September, 1989). In addition, electric resistivity survey (ERS) was carried out in order to explore the alluvial aquifers along the coast of Laguna de Bay between Angono and Jala-Jala. Another ERS was carried out in a specific location in the study area in order to decide the sites of investigation boreholes.

Based on hydrological and hydrogeological data, recharge to the aquifers is roughly estimated to be from 1,340 to 2,640 LPS (116-228 MLD) for the whole study area. These aquifers were considered as a potential groundwater sources.

As of October 1990, five (5) exploratory boreholes have been drilled in the project. But the pumping tests have yet to be started. These wells would be converted to MWSS production wells if their productivity would be favorable for supply.

1.3.4 Other Ongoing Studies

The National Hydraulic Research Center (NHRC), in association with the International Development Research Center (IDRC) of Canada, is conducting a research project entitled "Water Resources Management Model for Metro Manila" (WRMM-MM). Cooperating agencies of the project are MWSS, NEDA, NWRC, MGB and EMB.

The main objective of the project is to develop a Water Resources Management Model for Metro Manila and its environs, and it will take into account both surface water and groundwater resources in the region. The project will devote attention to the following aspects:

a) aquifer characteristics and basin yield

b) total hydrologic cycle which accounts for the conjunctive use of surface water and groundwater

c) actual recharge, distribution points and their recharge potential within the Laguna Lake Basin

d) policy recommendation on water resources development and management

The project which started in May 1990 shall last for 3 years. The first and second progress reports were published in August 1990 and November 1990, respectively.

Another groundwater-related study that was begun in 1988 is being conducted by EMB. Groundwater samples from Metro Manila and other provinces where saline water had intruded had been taken. Several radioactive isotopes, such as deuterium, tritium, oxygen 18 and carbon 14 have been measured. But the report is yet to be published.

TABLE 1.2.1 PUMPING TEST RESULTS AND AQUIFER CHARACTERISTICS OF SELECTED WELLS IN METRO MANILA

MWSS No.	OWNER	Depth (m)	S.W.L. (m)	Drawdown (m)	Test Pumping Rate (/s)	Specific Capacity (/s/m)	Transmissibility (m /d)	Aquifer Tapped
ATP-54	Sumulong #7	183	26	11	18.0	1.60	210	GP
ATP-73	San Isidro Elem. School	177	-	20	28.4	1.41	208	GP
ATP-101	Ang Tahanan	213	28	23	28.0	1.20	444	GP
ATP-102	Cogeo	117	13	74	10.0	0.13	-	GP
BCR-3	Banalo	305	21	26	15.8	0.61	137	Gal.Gt.
BCR-4	Bo. Niog	274	39	15	30.0	2.00	220	Gal.Gt.
BCR-11	Magdiwang Realty Corp.	152	17	1	6.0	6.00	700	Gal.Gt.
BCR-13	NIA, Bo. Bayanan	161	9	19	13.5	0.70	245	Gal.Gt.
CLC-36	Bagong Barrio #1	305	167	10	6.9	0.73	160	GS
CLC-37	Bagong Barrio #2	274	120	22	4.4	0.20	20	GS
CLC-B-53	Sacred Heart Novitiate	213	16	71	22.1	0.31	51	GS
CTA-19	San Juan	213	31	6	13.0	2.20	255	Gal.Gt.
CTA-20	Sumulong Highway	198	69	16	15.8	0.99	192	Gal.Gt.
CTA-66	Marick Subdivision	177	52	34	25.4	0.75	103	Gal.Gt.
CTA-67	Irma Street	177	42	40	26.5	0.65	63	Gal.Gt.
CVC-11	Crescini Street	317	25	7	12.6	1.80	360	
CVC-12	Public Market	247	7	18	25.3	1.41	350	
CVC-17	Antonio Street	268	14	17	11.4	0.68	88	
GTR-2	NIA, Brgy. Santiago	61	3	6	19.0	3.40	430	Gal.Gt.
GTR-3	NIA, Brgy. San Juan	98	7	6	16.7	2.80	350	Gal.Gt.
IMS-3	Topacio	244	15	15	18.0	1.20	100	Gal.Gt.
IMS-6	NIA, Alapan II	192	13	17	46.6	2.70	220	Gal.Gt.
IMS-7	NIA, Anabu II	200	8	14	33.6	2.50	420	Gal.Gt.
IMS-8	NIA, Tinabunan	190	8	11	10.4	0.90	600	Gal.Gt.
IMS-21	P. Garcia Plaza	305	27	35	33.0	0.97	137	Gal.Gt.
LPS-37	Naga Rd. #1	306	43	36	10.0	0.30	28	Gal.Gt.
LPS-48	General Motors Inc. #1	306	43	36	10.0	0.30	28	Gal.Gt.
LPS-64	Las Pinas Elem. School	228	37	10	21.0	2.10	243	Gal.Gt.
MKT-11	Cambridge Circle F. Park	306	17	31	32.0	1.00	118	GS
MKT-12	Kayamanan "O"	310	14	19	32.0	1.70	212	GS
MKT-18	Ayala #21	263	15	19	30.0	1.60	18	GS
MKT-23	Ayala #26	214	11	15	36.0	2.40	275	GS
MKT-25	Ayala #28	206	10	25	30.0	1.20	120	GS
MKT-31	Ayala #31	201	9	33	11.0	0.30	50	GS
MKT-33	Ayala #36	310	35	44	6.0	0.10	20	GS
MKT-46	Bank of America Bldg.	305	18	42	7.0	0.20	32	GS
MKT-48	China Banking Corporation	274	25	53	9.0	0.20	22	GS
MKT-67	Peninsula Hotel	305	45	29	7.0	0.20	30	GS
MKT-122	Banaba Circle	204	20	17	9.0	0.50	70	GS
MKT-128	Poblacion Elem. Sch.	274	78	50	12.9	0.26	23	GS
MKT-136	Eastern Telecom	305	50	30	33.0	1.10	135	GS
MKT-145	Ecology Village	303	58	34	7.9	0.23	57	GS
MLB-20	Brgy. Catmon	263	82	35	5.0	0.10	21	Gal.Gt.
MLB-32	Bo. Dampalit	233	31	52	8.0	0.20	25	Gal.Gt.
MLB-57	MWSS Niugan	305	20	61	13.0	0.20	22	Gal.Gt.
MLB-110	Santolan	305	99	13	7.9	0.62	23	Gal.Gt.

MWSS No.	OWNER	Depth (m)	S.W.L. (m)	Drawdown (m)	Test Pumping Rate (/s)	Specific Capacity (/s/m)	Transmis-sibility (m /d)	Aquifer Tapped
MLB-113	Dampalit	305	65	38	9.0	0.20	23	Qal.Qt.
MDL-10	National Mental Hospital	201	31	20	11.0	0.50	65	Qal.Qt.
MNL-101	F.E.U.	305	8	75	4.0	0.10	9	Qal.Qt.
MNL-148	Balut, Tondo	305	87	22	7.0	0.32	33	Qal.Qt.
MRK-3	Industrial Valley	178	39	12	13.0	1.10	120	Qal.Qt.
MTB-15	Manggahan	213	11	22	31.8	1.47	240	
MTL-1	Bliss Project	305	11	105	12.0	0.10	12	Qal.GS
MTL-7	CDCP Sucat Interchange	152	15	7	4.0	0.60	68	Qal.GS
MTL-8	Ford Philippines	305	43	90	7.0	0.10	13	Qal.GS
MTL-17	Pepsi Cola	305	13	33	37.8	1.15	580	Qal.GS
MTL-22	Tahanan Village #3	305	24	51	15.0	0.30	40	Qal.GS
MTL-23	Tahanan Village #1	213	24	33	17.0	0.50	70	Qal.GS
MTL-27	Ayala Corp. Well 8	305	13	110	33.0	0.30	31	Qal.GS
MTL-34	Ayala Corp. Well #10	305	37	30	35.0	1.20	455	Qal.GS
MTL-44	Pacific Multi Homes Inc.	305	50	24	20.0	0.80	110	Qal.GS
MTL-59	International Textile	363	37	85	11.0	0.10	13	Qal.GS
MTL-69	PECCO	249	7	29	24.0	0.80	105	Qal.GS
MTL-91	Ayala #12	305	52	67	19.0	0.30	40	Qal.GS
MTL-147	MWSS Sucat Elem. School	302	18	30	29.5	0.98	750	Qal.GS
MTL-148	MWSS Poblacion	305	15	36	22.3	0.62	195	Qal.GS
MTL-149	MWSS Tunasan	305	9	17	3.6	4.72	400	Qal.GS
MTL-150	MWSS Alabang	250	13	9	20.3	2.09	350	Qal.GS
MTL-151	MWSS Putatan	305	6	12	39.4	3.24	222	Qal.GS
MTL-152	Transpacific Prop.,Tunasan	305	13	4	23.7	6.41	1,150	Qal.GS
MTL-159	Cupang Elem. School	287	10	12	23.4	1.95	1,192	Qal.GS
NAV-3	NHA #4	244	20	33	11.0	0.30	45	Qal.GS
NAV-4	NHA #5	277	76	24	7.0	0.30	38	Qal.GS
NAV-8	NHA #3	305	8	45	10.0	0.20	30	Qal.GS
NAV-17	Mervilie, Tanza	305	92	28	7.0	0.30	30	Qal.GS
NOV-5	PNR 7	299	13	17	28.1	1.67	302	Qal.GS
NOV-6	PNR 8	299	14	18	41.0	2.24	217	Qal.GS
NOV-7	Noveleta Elem. School	304	13	8	34.2	4.16	592	Qal.GS
PRN-8	Gelmart Inc.	244	52	43	22.0	0.50	61	Qal.GS
PRN-14	Standard Elect. Mfg.	230	72	37	5.0	0.10	13	Qal.GS
PRN-20	Naga Road #2	244	32	9	15.0	1.60	197	Qal.GS
PRN-66	Packaging Product #2	274	42	36	10.0	0.30	35	Qal.GS
PRN-74	Bo. San Dionisio	181	26	47	21.0	0.40	55	Qal.GS
PRN-78	MIA #2	256	29	44	20.0	0.50	65	Qal.GS
PRN-77	MIA #1	256	28	19	21.0	1.10	135	Qal.GS
PRN-135	Johnson & Johnson	244	42	14	12.0	0.90	105	Qal.GS
PRN-153	Sucat Rd. 3, S. Dionisio	177	20	56	11.6	0.20	48	Qal.GS
PRN-154	MIA #3	250	47	31	20.5	0.66	85	Qal.GS
PRN-155	MIA #4	244	45	61	23.1	0.38	80	Qal.GS
PRN-156	Bo. San Dionisio #4	143	26	47	26.5	0.56	55	Qal.GS
PRN-157	South Bay, San Dionisio	305	84	53	6.6	0.12	14	Qal.GS
PSC-20	PAL Inflight Center	244	40	23	19.9	0.86	100	Qal.GS
PSC-44	Manila Sanitarium	305	81	27	4.0	0.10	9	Qal.GS
PSC-49	Maricaban	244	44	25	15.0	0.60	81	Qal.GS
PSC-55	Nayong Kabataan #1	152	11	11	3.0	0.30	33	Qal.GS
PSC-69	School of Deaf	610	61	98	12.7	0.13	16	Qal.GS

MWSS No.	OWNER	Depth (m)	S.W.L. (m)	Drawdown (m)	Test Pumping Rate (/s)	Specific Capacity (/s/m)	Transmis-sibility (m /d)	Aquifer Tapped
PSG-12	Meralco	366	37	26	11.0	0.40	47	Qal.GS
PSG-186	Dreamhouse, dela Paz	226	72	14	12.0	0.85	207	Qal.GS
PSG-187	Urban Bliss	243	34	39	18.8	0.48	81	Qal.GS
PSG-188	Marbay & Co.	305	62	16	8.6	0.54	107	Qal.GS
QCT-65	ABS-CBN #2	122	40	17	3.0	0.20	22	Qal.GP
QCT-86	Capital Hills Golf Club #1	171	37	10	12.0	1.20	130	Qal.GP
QCT-121	Veterans Hospital #1	290	25	43	14.0	0.30	45	GS.GP
QCT-122	Veterans Hospital #2	271	31	13	15.0	1.20	135	GS.GP
QCT-195	Constitution Hill #1	274	16	67	15.0	0.20	30	GS.GP
QCT-250	Poblacion Novaliches	244	26	15	14.0	0.90	109	GS.GP
QCT-251	Bo. Bagbag	200	35	26	14.0	0.50	63	GS.GP
QCT-257	Project 8, Congressional	274	101	12	11.0	0.90	110	GS.GP
QCT-269	Bo. Escopa Project 4	274	85	20	13.0	0.70	100	GS.GP
QCT-276	D. Tuazon Pumping Station	244	11	59	8.0	0.10	15	GS.GP
QCT-277	D. Tuazon Elem. School	244	11	104	8.0	0.10	8	GS.GP
QCT-330	Constitutional Hill #4	305	56	27	12.0	0.40	45	GS.GP
ROS-10	Sapa	286	10	16	21.6	1.39	402	
ROS-11	PNR - 1	305	13	21	34.9	1.66	352	
ROS-12	PNR - 2	305	13	24	34.9	1.43	340	
ROS-13	PNR - 3	305	15	22	21.2	0.95	490	
ROS-14	PNR - 4	302	13	27	29.1	1.07	265	
ROS-15	PNR - 5	302	8	24	38.0	1.60	-	
ROS-16	Wawa	302	8	24	42.5	1.77	230	
ROS-17	Town Plaza	299	10	18	44.7	2.37	266	
ROS-18	PNR - 6	299	13	20	31.7	1.56	235	
SJN-6	Bo. Once, San Juan	220	5	49	12.0	0.20	29	GS.GP
SMT-2	Bo. Ampid	152	6	12	35.0	2.90	365	Qal.Qt.
SMT-3	Bo. Malanday	183	12	24	14.0	0.60	70	Qal.Qt.
SMT-4	Bo. Maly	209	12	54	14.0	0.30	40	Qal.Qt.
SMT-10	Dulong Bayan	123	13	20	18.9	0.94	125	Qal.Qt.
SMT-11	Ampid	174	11	8	32.8	4.31	1,150	Qal.Qt.
SPD-5	Cosmos Bottling Co.	305	Flowing	8	55.3	7.00	600	Qal.Qt.
TGG-16	Triumph Builders	213	34	68	6.0	0.10	10	Qal.Qt.
TGG-18	Tuktukan	183	20	25	17.0	0.70	87	Qal.Qt.
TGG-19	Maharlika Village	183	29	33	19.0	0.60	70	Qal.Qt.
TGG-24	Bicutan Military	183	21	5	13.0	2.60	320	Qal.Qt.
TGG-32	Mrs. Betina de Leon	152	28	20	8.0	0.40	51	Qal.Qt.
TGG-48	Century Canning	244	50	51	11.0	0.20	30	Qal.Qt.
TGG-97	Upper Bicutan	213	58	29	13.9	0.48	52	Qal.Qt.
TGG-138	Signal Village 1	177	33	30	23.9	0.80	166	Qal.Qt.
TGG-139	Signal Village 2	171	65	38	20.8	0.57	150	Qal.GS.
TNZ-2	NIA, Calibuyo	100	5	9	9.5	1.10	150	Qal.GS.
TNZ-3	NIA, Punta	200	9	5	15.7	3.30	495	Qal.Qt.
TYY-10	Bo. San Isidro	179	26	7	40.0	5.70	700	Qal.GS.
TYY-11	Sta. Ana	153	27	6	16.0	2.70	330	Qal.GS.
VLZ-18	Bo. Marulas	305	128	16	5.0	0.30	38	Qal.GS.
VLZ-37	Tamaraw Hills	305	95	53	6.0	0.10	13	Qal.GS.
VLZ-106	Isla Valenzuela	274	38	61	9.0	0.10	14	Qal.GS.

MWSS No.	OWNER	Depth (m)	S.W.L. (m)	Drawdown (m)	Test Pumping Rate (/s)	Specific Capacity (/s/m)	Transmis-sibility (m /d)	Aquifer Tapped
VLZ-125	MWSS T. de Leon, Malinta	308	106	25	7.9	0.27	25	Qal.SS.
VLZ-212	MWSS - Malinta	308	106	29	8.0	0.30	65	Qal.SS.
VLZ-213	Arkong Bato	305	104	13	8.0	0.60	114	Qal.SS.
VLZ-214	Pasolo Elem. School	305	107	10	8.0	0.80	110	Qal.SS.
VLZ-215	Malanday, Kadiwa Center	304	106	16	7.6	0.47	64	Qal.SS.
VLZ-216	Bagong Lipunan Health Center, Coloong	302	62.5	10.3	6.8	0.65	17	Qal.SS.

Source: BWD-MWSPII

TABLE 1.2.2 GROUNDWATER PUMPAGE IN THE GREATER MANILA AREA, BY USER TYPE: 1981-1982

(million cubic meters)

Municipality	No. of wells	Industrial	Public Supply	Commercial	Agricultural	Total
1. Antipolo	71	1.32	4.87	0.25	-	6.44
2. Bacoor	35	-	2.04	-	0.66	2.70
3. Cainta	65	7.47	1.51	0.23	-	9.21
4. Caloocan City A & B	76	2.75	1.405	1.963	-	6.118
5. Cavite City	28	-	7.20	-	-	7.20
6. General Trias	24	-	0.02	-	1.44	1.46
7. Imus	20	0.32	1.05	0.12	0.08	1.57
8. Kawit	11	-	0.99	-	0.58	1.57
9. Las Piñas	118	4.59	8.55	0.35	-	13.49
10. Makati	133	1.69	10.48	6.94	-	19.11
11. Malabon	120	4.72	1.39	0.28	-	6.39
12. Mandaluyong	69	2.76	0.34	1.02	-	4.12
13. Manila	120	1.35	1.16	1.457	-	3.967
14. Marikina	54	6.10	1.21	0.59	-	7.90
15. Meycauayan	26	4.90	1.79	-	-	6.69
16. Montalban	14	1.29	0.45	0.05	-	1.79
17. Muntinlupa	143	7.48	6.99	1.35	-	15.82
18. Navotas	22	1.05	0.94	0.304	-	2.294
19. Noveleta	6	-	0.10	-	-	0.10
20. Paranaque	142	0.68	7.62	2.87	-	11.17
21. Pasay City	57	0.11	3.74	1.78	-	5.63
22. Pasig	161	14.37	2.53	2.17	-	21.07
23. Pateros	6	0.20	0.38	-	-	0.58
24. Quezon City	383	23.25	17.394	11.32	-	51.964
25. Rosario	18	0.97	0.09	0.68	-	1.74
26. San Juan	9	1.40	0.41	0.05	-	1.86
27. San Mateo	9	0.40	2.12	-	-	2.52
28. San Pedro	31	9.08	1.22	0.37	-	10.67
29. Taguig	137	7.20	3.95	2.97	-	14.12
30. Tanza	17	0.90	-	-	0.46	1.36
31. Taytay	45	2.32	2.78	1.18	-	6.28
32. Valenzuela	122	8.71	4.063	0.97	-	13.74
T O T A L	2,292	119.38	98.78	39.26	3.22	260.64

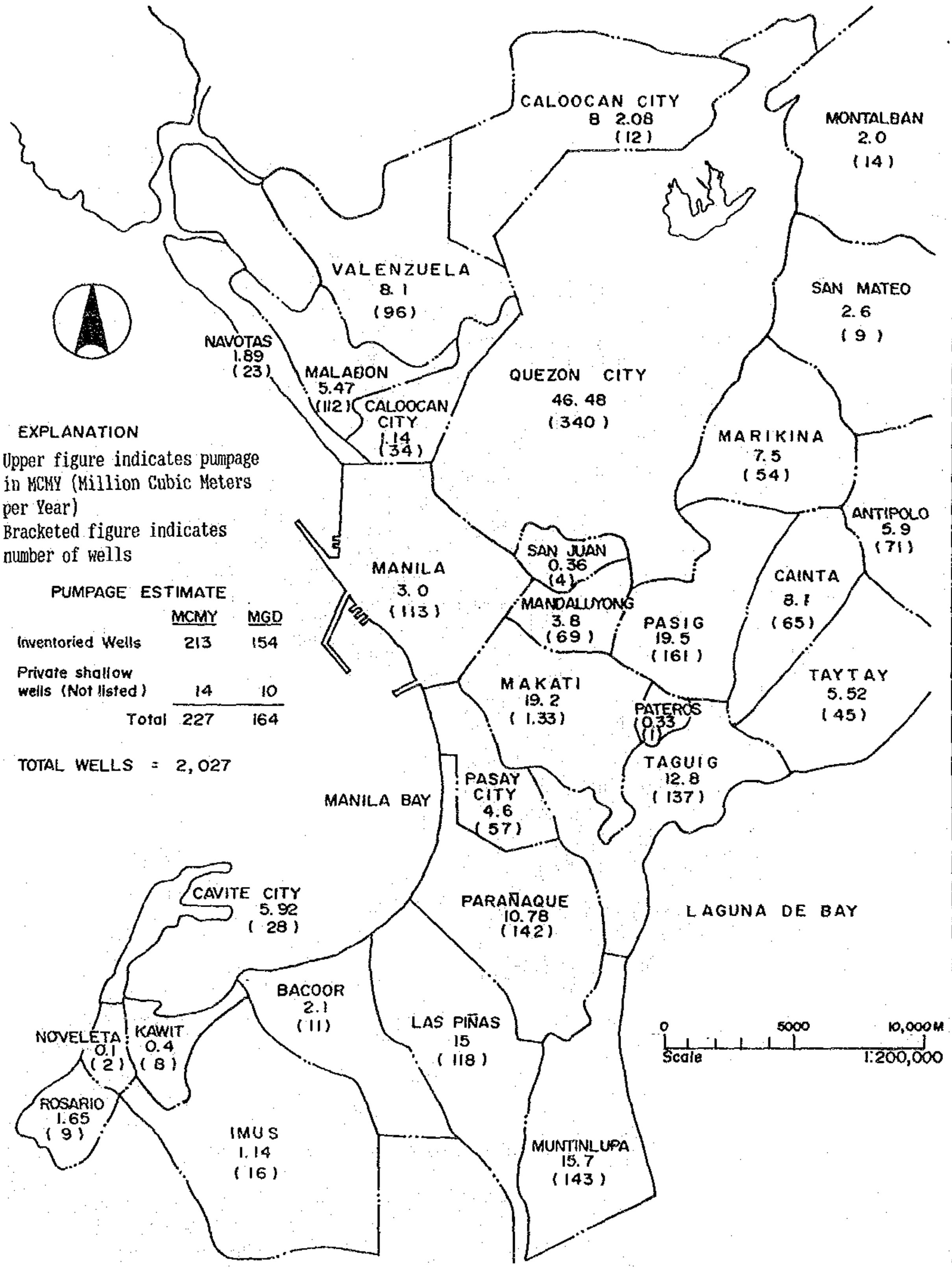
Source: BWD-MWSPII

TABLE 1.3.1 MAJOR ION ANALYSIS OF SELECTED SAMPLES IN METRO MANILA, 1985

WELL NO.	WELL DESCRIPTION					DATE OF	Na		K		Ca		Mg		Cations		Cl		HCO3		SO4		Anions	
	LOCATION/OWNER	YEAR	DEPTH	SCREEN	AQUIFER	SAMPLING	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm
CTA 12	Hooven Camalo Id.	1971	48.80	-	A	09-05-85	157.5	5.98	10.0	0.26	185.6	9.28	15.5	1.29	-	16.81	344.4	9.70	208.6	3.42	68.0	1.42	-	14.54
MDL 3	Insular Sugar Ref.	1949	132.23	-	G	09-04-85	1200.0	52.17	52.5	1.35	150.4	7.52	149.7	12.48	-	73.52	2026.0	57.07	612.4	10.04	61.0	1.27	-	68.38
MKT 92	Fort Bonifacio #9	1977	136.90	-	G	09-03-85	140.0	6.09	10.0	0.46	38.4	1.92	13.6	1.13	-	9.80	108.0	3.04	361.6	5.93	30.0	0.63	-	9.60
MNL 146	RM Center	-	-	-	-	09-04-85	1425.0	61.96	115.0	2.95	1056.0	52.80	1283.0	106.92	-	224.63	6968.4	196.57	236.7	3.88	91.0	1.90	-	202.35
PSC 1	PAF, Nichols A.B. #1	-	240.80	-	G	09-02-85	142.5	6.20	20.0	0.51	16.0	0.80	9.7	0.81	-	8.32	27.0	0.76	431.1	7.07	6.5	0.14	-	7.97
PSC 7	PAF, Nichols A.B. #7	-	206.60	-	G	09-02-85	130.0	5.65	3.5	0.09	6.4	0.32	7.8	0.65	-	8.71	54.0	1.52	334.3	5.48	4.5	0.09	-	7.09
PSC 11	PAF, Nichols A.B. #11	-	225.50	-	G	09-02-85	187.5	8.15	9.2	0.24	9.6	0.48	5.8	0.48	-	9.35	63.0	1.77	417.2	6.84	10.0	0.21	-	8.82
PSC 13	PAF, Nichols A.B. #13	-	249.90	-	G	08-30-85	208.0	9.04	8.5	0.22	6.4	0.32	5.8	0.48	-	10.06	80.1	5.07	336.7	5.52	6.0	0.13	-	10.72
PSC 14	PAF, Nichols A.B. #14	1977	249.90	-	G	09-02-85	192.5	8.37	20.5	0.53	44.9	2.24	7.8	0.65	-	11.79	130.6	3.68	458.7	7.52	12.5	0.26	-	11.46
PSC 44	Manila Sanitarium	1979	305.00	272-362	A	09-06-85	400.0	17.39	7.5	0.19	76.8	3.84	7.8	0.65	-	22.07	535.7	15.09	273.3	4.48	81.0	1.69	-	21.26
PSC 46	Derham Park	-	200.00	144-193	A	09-06-85	105.0	4.57	2.5	0.06	86.4	4.32	27.2	2.27	-	11.22	58.5	1.65	361.2	5.92	216.0	4.50	-	12.07
PSC 50	US Seafront Cpd.	1978	457.30	-	A	09-06-85	297.5	12.93	25.0	0.64	22.4	1.12	11.7	0.98	-	15.67	279.1	7.86	258.6	4.24	234.0	4.87	-	16.97
PSG 52	Metro Lab.	1979	182.90	90-182	G	09-05-85	3600.0	156.52	100.0	2.56	25.6	1.28	112.7	9.39	-	169.75	4254.5	119.85	403.8	6.62	174.0	3.63	-	130.10
PSG 57	Philippine Cement	1969	182.90	91-182	G	09-05-85	107.5	4.67	15.0	0.38	16.0	0.80	5.8	0.48	-	6.33	114.8	3.23	152.5	2.50	22.0	0.46	-	6.19
PTR 1	MWSS Fort Bonifacio	1976	99.10	-	G	09-03-85	450.0	19.57	50.0	1.28	179.2	8.96	60.3	5.03	-	34.84	855.0	24.08	511.2	8.38	14.0	0.29	-	32.79
PTR 6	Camera Steel	-	-	-	-	09-05-85	275.0	11.96	10.0	0.26	131.2	6.56	56.4	4.70	-	23.48	576.3	16.23	194.7	3.19	128.0	2.67	-	22.09
TGG 14	Elizalde Steel	-	243.90	-	G	09-05-85	682.5	29.67	57.5	1.47	67.2	3.36	21.4	1.78	-	36.28	1238.1	34.81	167.1	2.74	76.0	1.58	-	39.13
TGG 20	MWSS Ususan	1978	180.00	-	G	09-05-85	387.5	16.85	60.0	1.54	54.4	2.72	21.4	1.78	-	22.89	567.3	15.98	222.0	3.64	11.0	0.23	-	19.85
TGG 102	Eusebio Elem. School	-	-	-	-	09-05-85	412.5	17.93	37.5	0.96	19.2	0.96	9.7	0.81	-	20.66	405.2	11.41	403.0	6.62	89.5	1.84	-	19.87
TGG 115	Century Canning	-	-	-	-	09-06-85	195.0	8.48	21.0	0.54	32.0	1.60	3.9	0.33	-	10.95	117.0	3.30	389.2	6.38	3.0	0.06	-	9.74
TYY 11	MWSS Sta. Ana	1980	153.00	-	G	09-05-85	70.0	3.04	10.0	0.26	76.8	3.84	21.9	1.83	-	8.97	90.0	2.54	346.5	5.68	32.0	0.67	-	8.69

AQUIFER: A; Alluvium, G; Guadalupe

source: 1985 Major Ion Analysis by PASIG (1985)
Details of Well Inventory by GWD-MWSP II
Compiled by JICA



EXPLANATION

1. Upper figure indicates pumpage in MCMY (Million Cubic Meters per Year)
2. Bracketed figure indicates number of wells

PUMPAGE ESTIMATE

	MCMY	MGD
Inventoried Wells	213	154
Private shallow wells (Not listed)	14	10
Total	227	164

TOTAL WELLS = 2,027

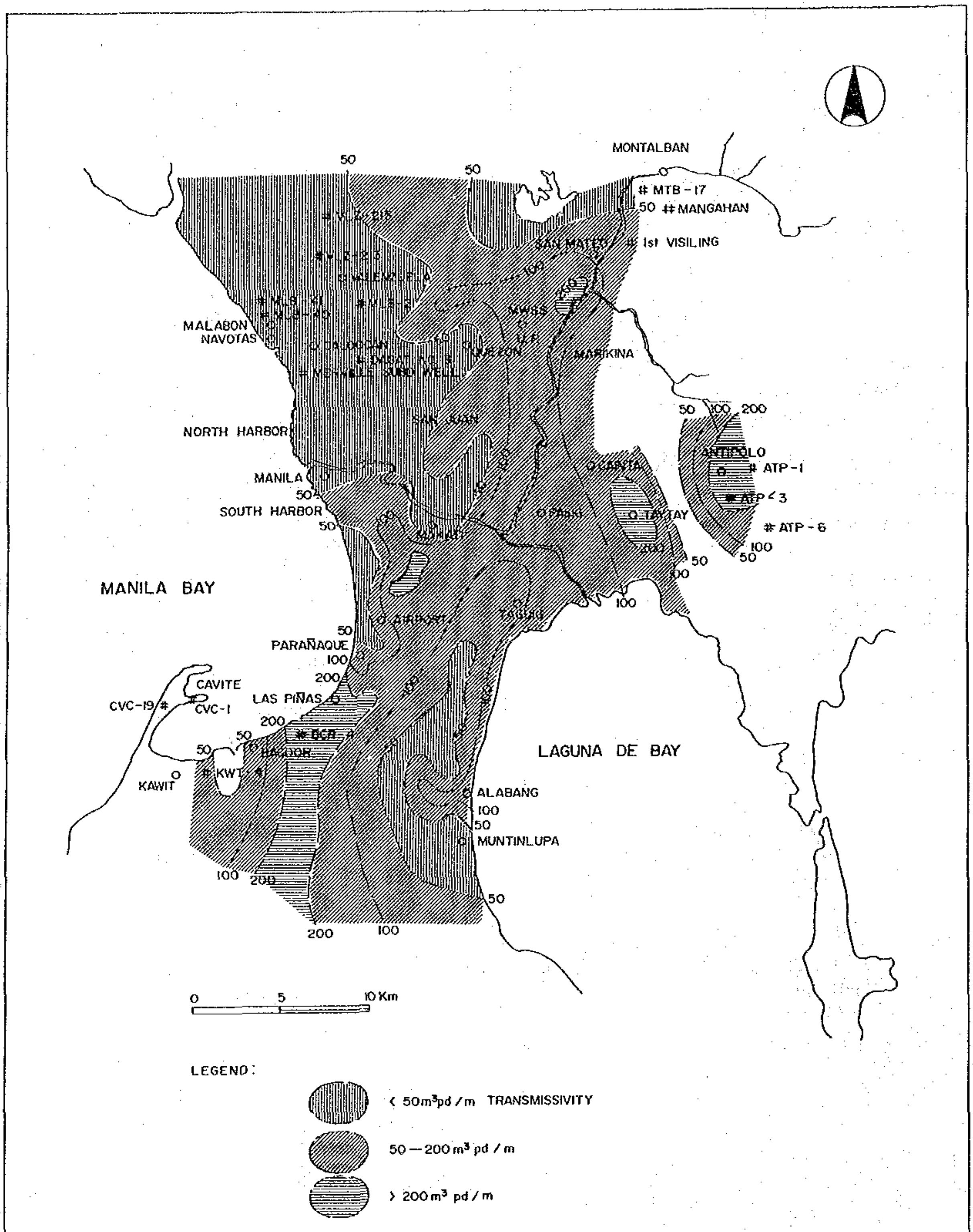
Source: MWSP II, 1983

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

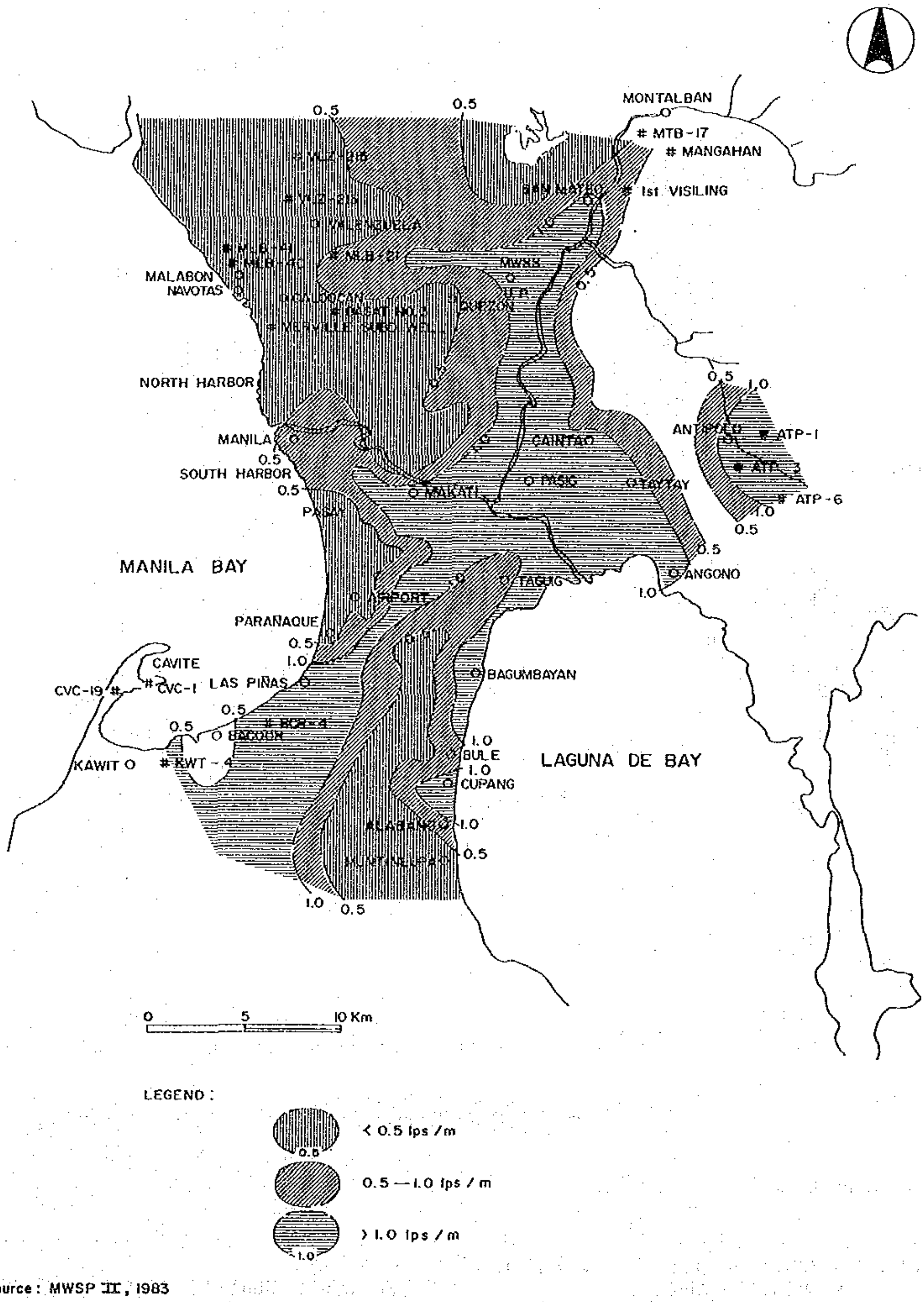
FIGURE 1.2.1

GROUNDWATER PUMPAGE IN THE GMA, 1981

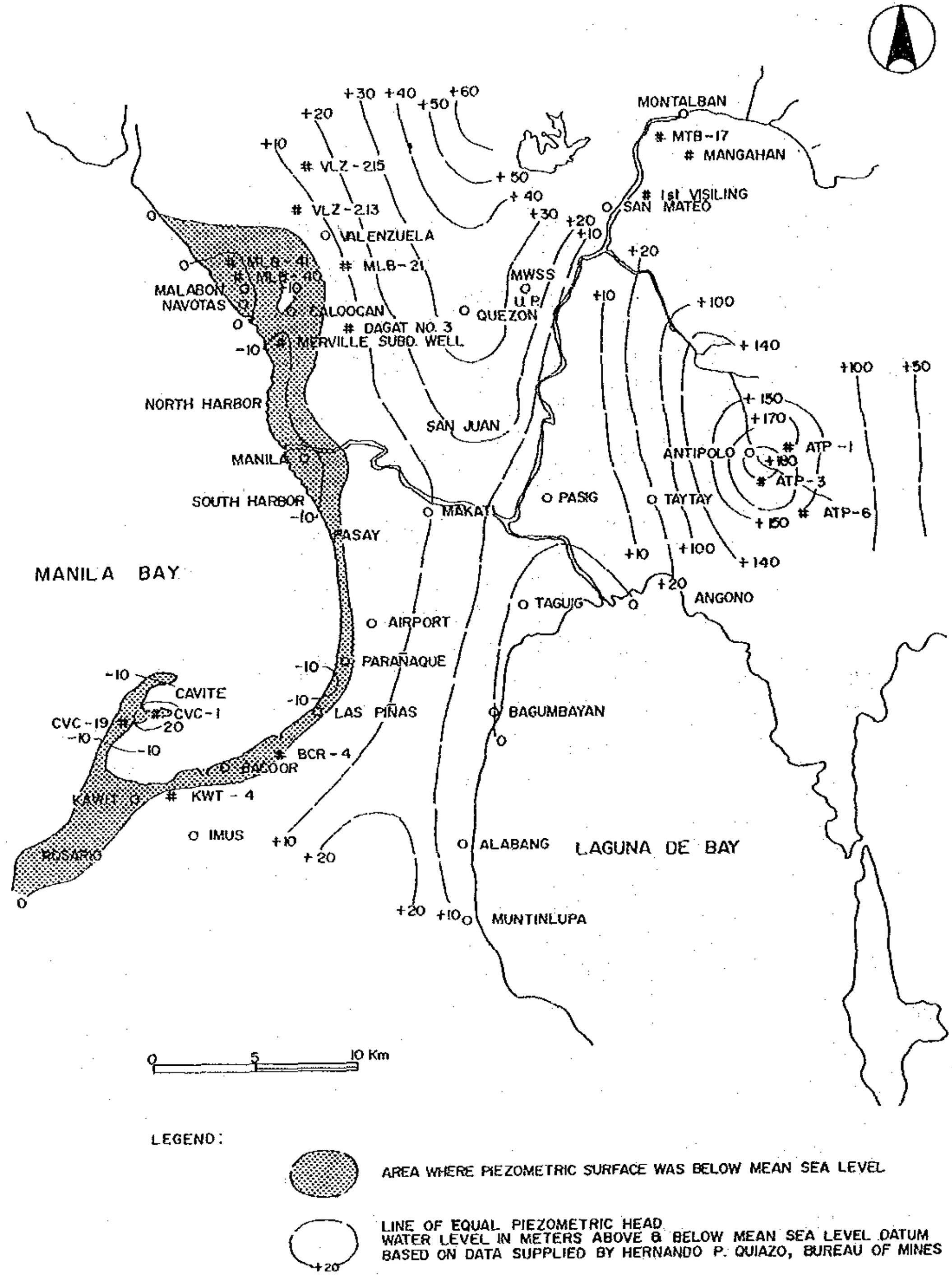


Source: MWSP II, 1983

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 1.2.2 TRANSMISSIVITY OF THE AQUIFER SYSTEM IN METRO MANILA
JAPAN INTERNATIONAL COOPERATION AGENCY	

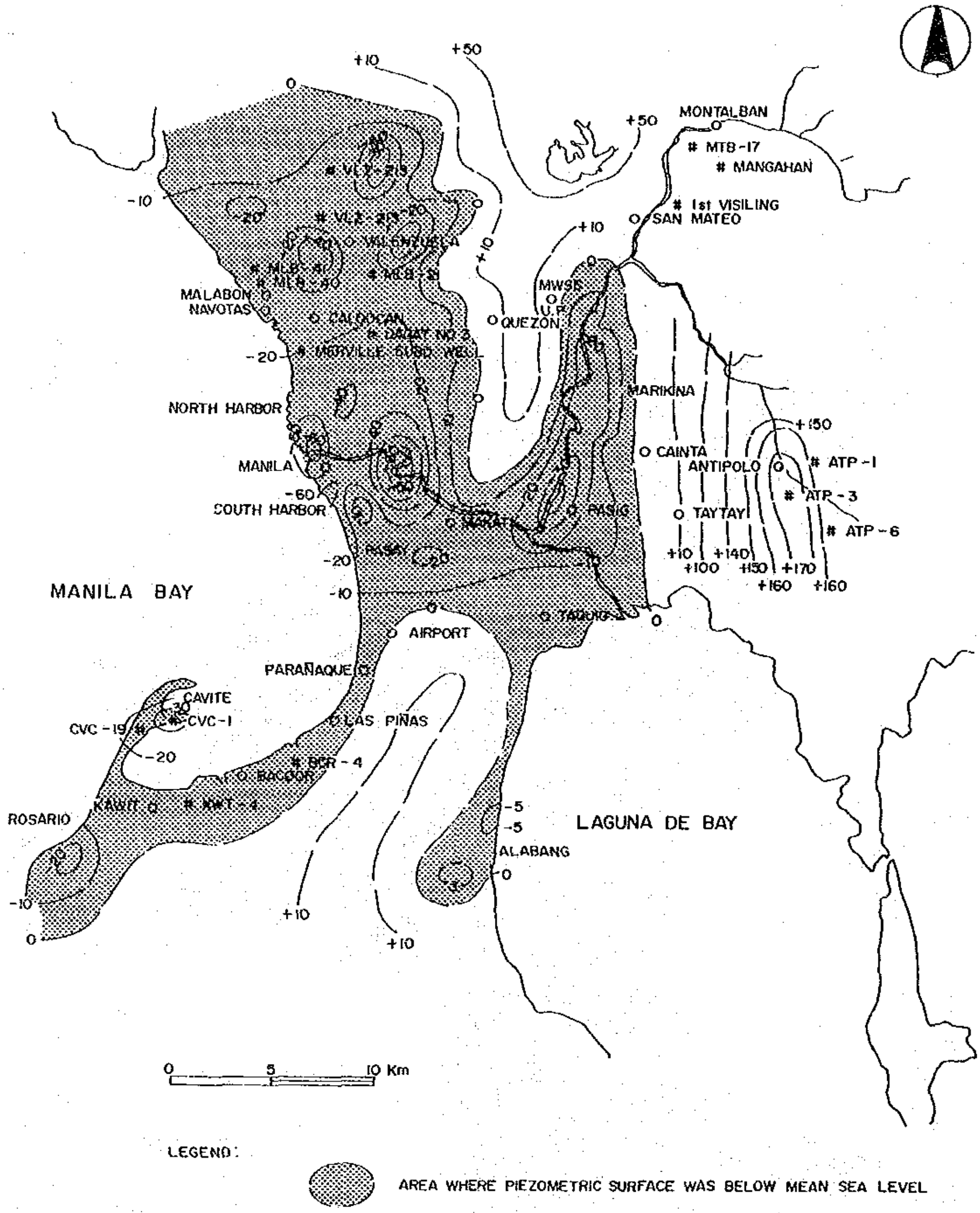


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 1.2.3 SPECIFIC CAPACITY OF GROUNDWATER IN METRO MANILA
JAPAN INTERNATIONAL COOPERATION AGENCY	



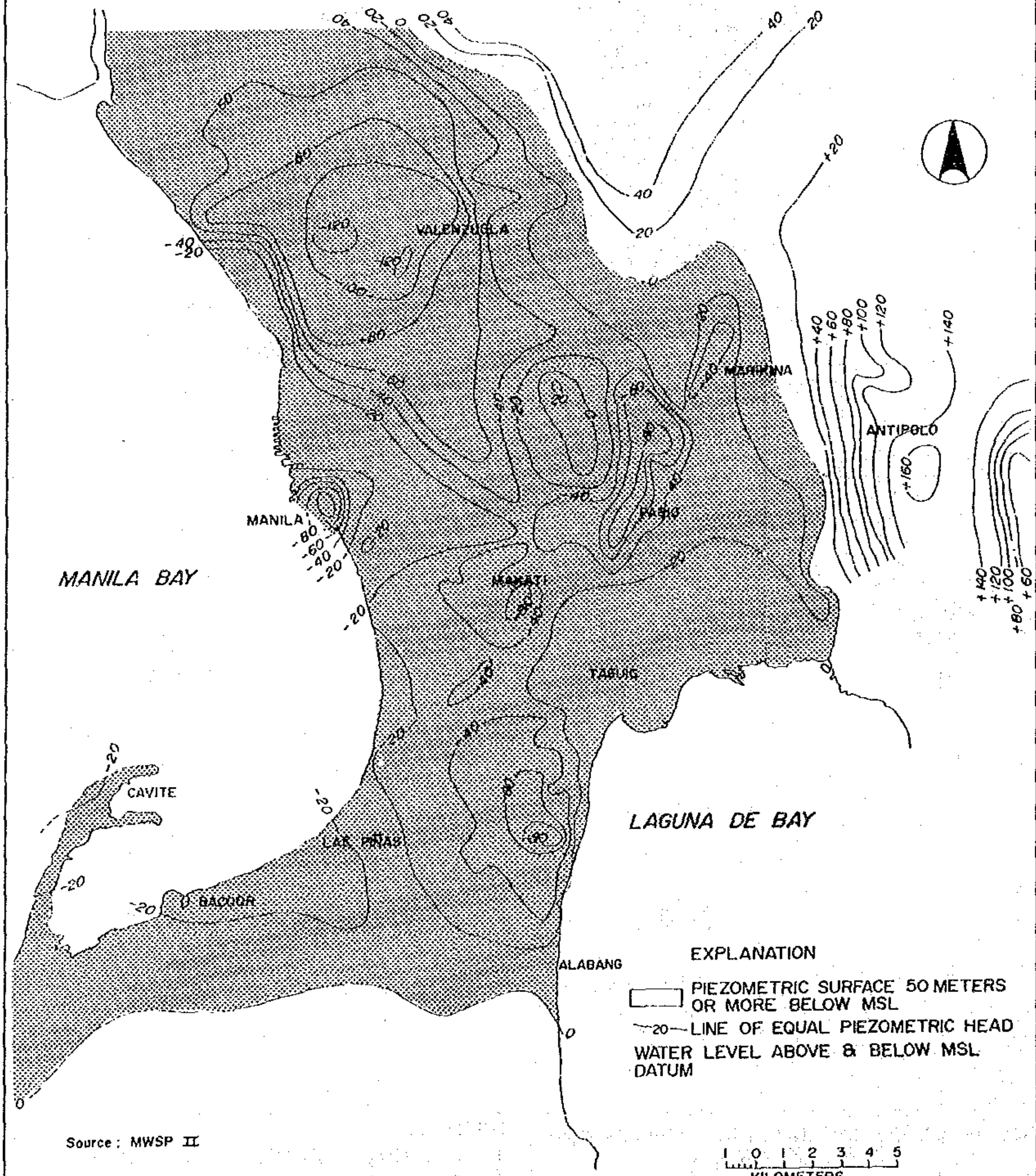
Source : MWSP II, 1983

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 1.2.4 PIEZOMETRIC SURFACE OF THE AQUIFER SYSTEM IN METRO MANILA, 1955
JAPAN INTERNATIONAL COOPERATION AGENCY	

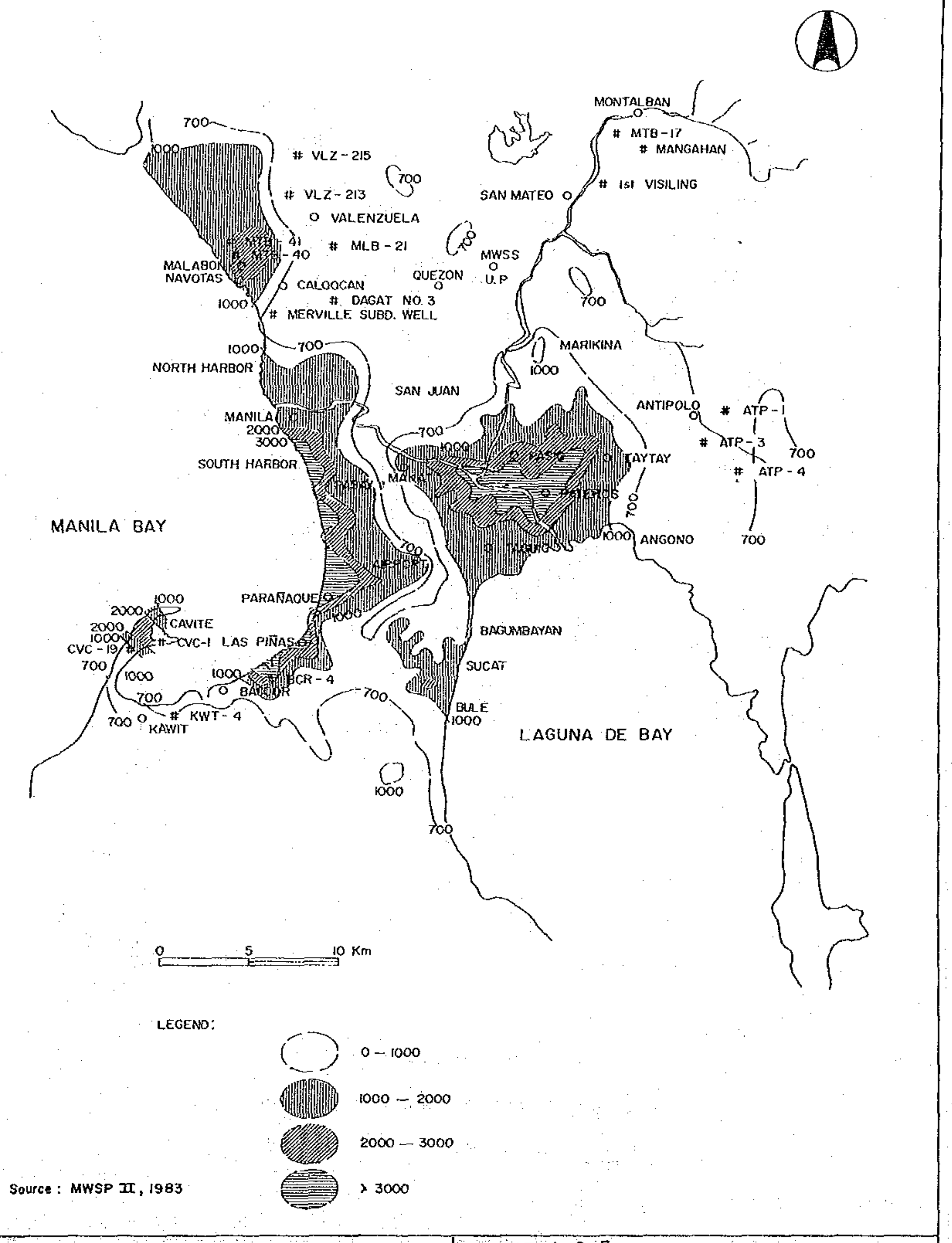


Source: MWSP II, 1983

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 1.2.5 PIEZOMETRIC SURFACE OF THE AQUIFER SYSTEM IN METRO MANILA, 1967
JAPAN INTERNATIONAL COOPERATION AGENCY	



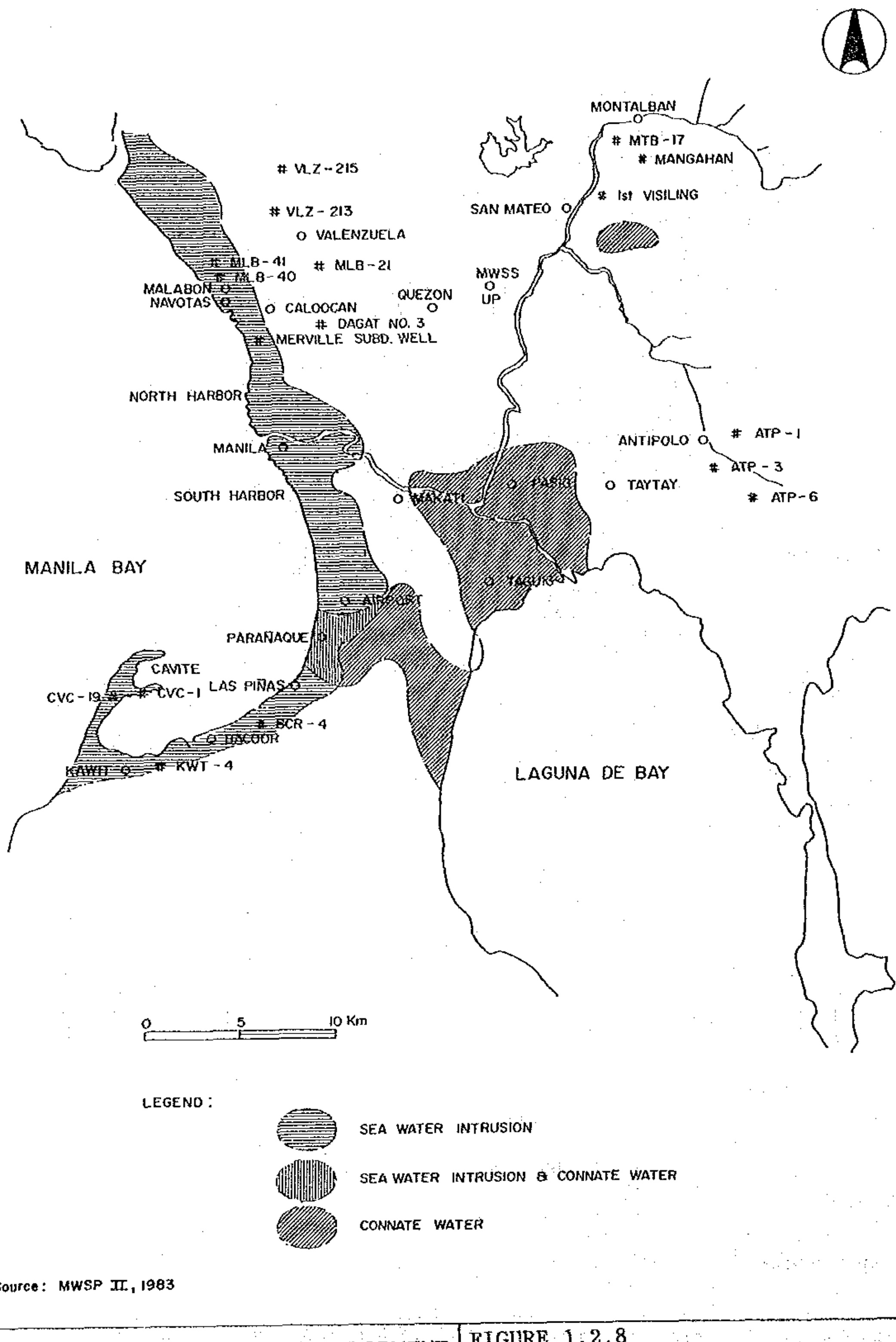
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 1.2.6 PIEZOMETRIC SURFACE OF THE AQUIFER SYSTEM IN METRO MANILA, 1981
JAPAN INTERNATIONAL COOPERATION AGENCY	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

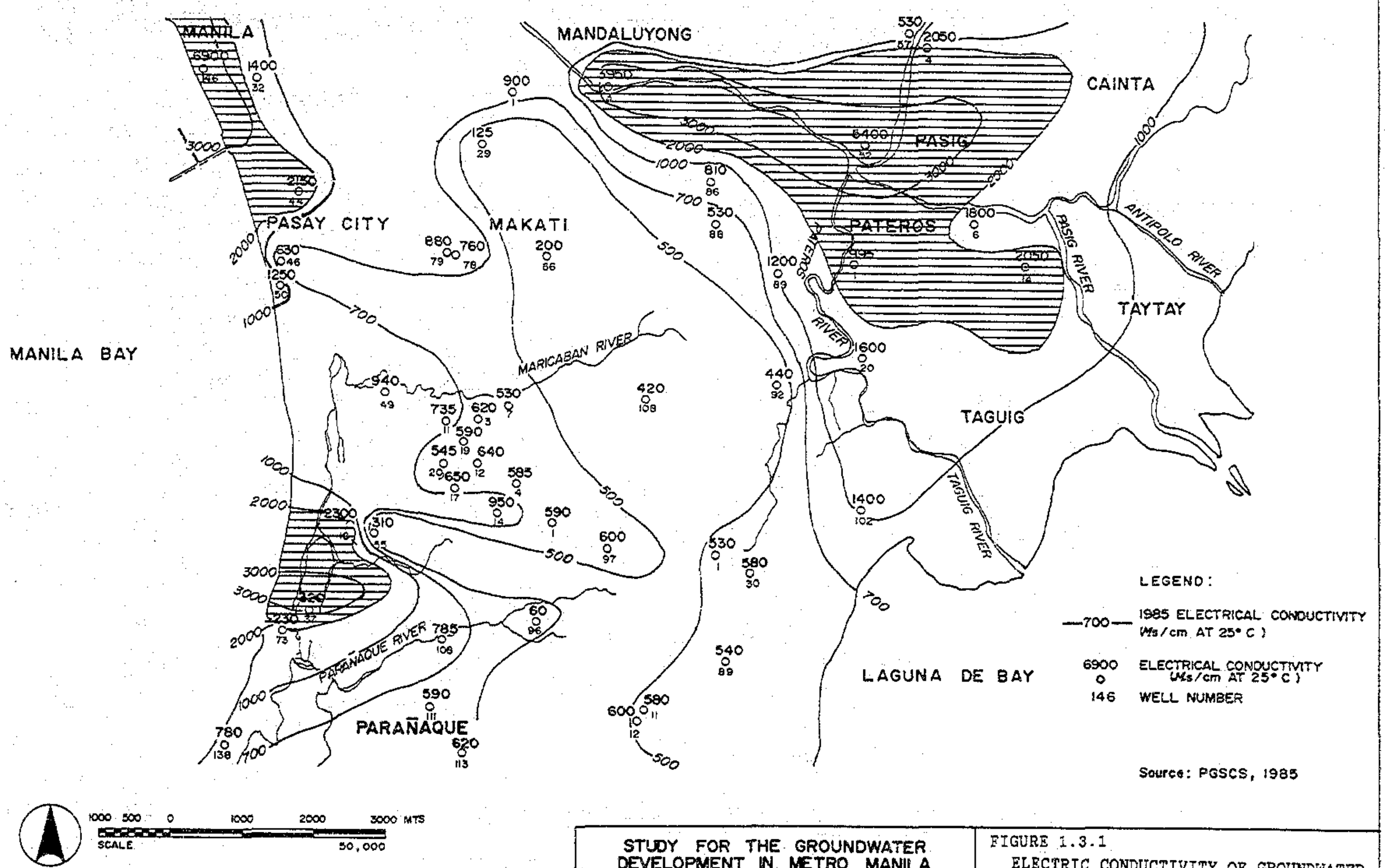
JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 1.2.7
ELECTRIC CONDUCTIVITY OF GROUNDWATER IN METRO MANILA



Source: MWSP II, 1983

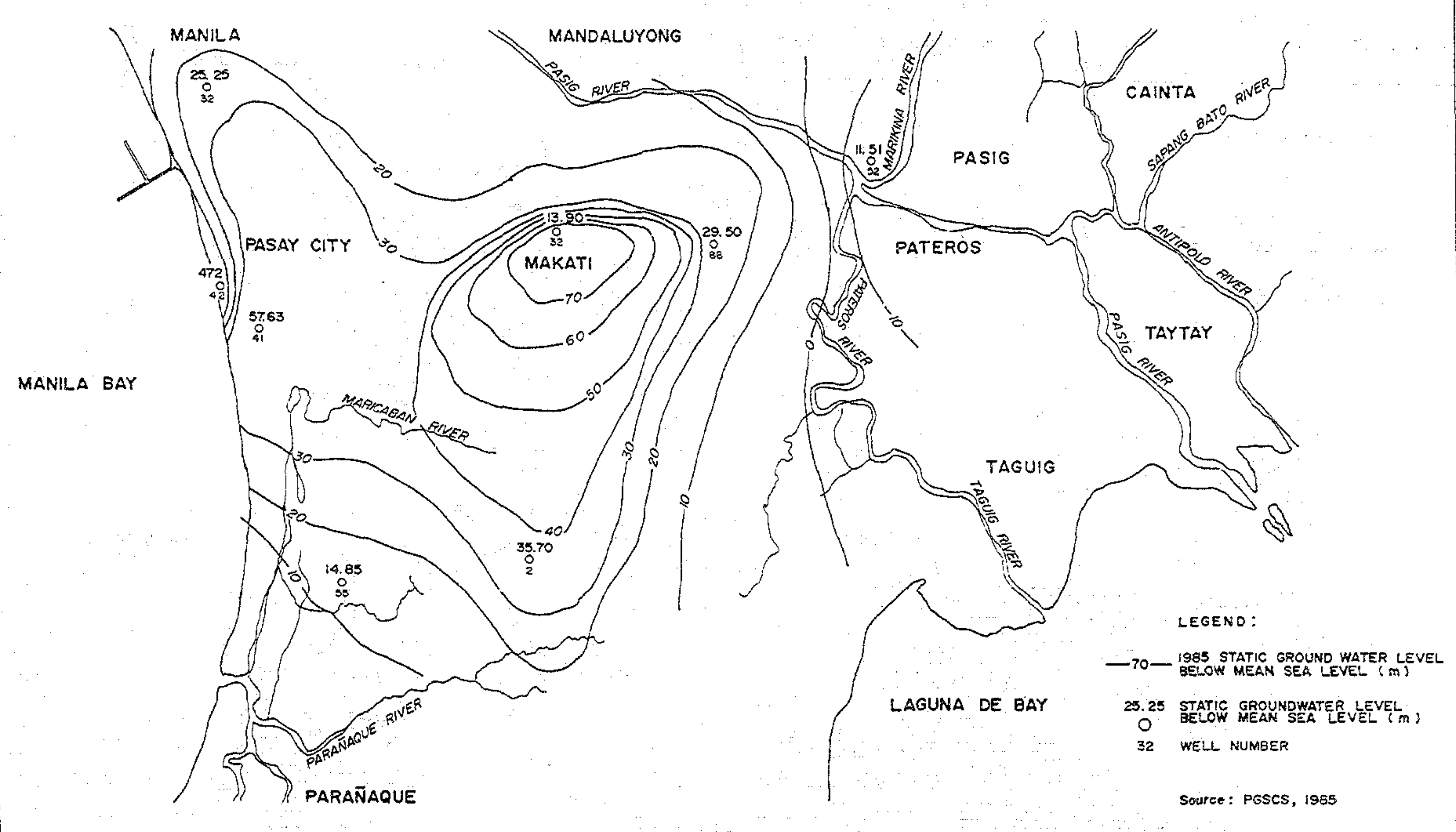
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 1.2.8 AREA OF SALINE WATER CONTAMINATION
JAPAN INTERNATIONAL COOPERATION AGENCY	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

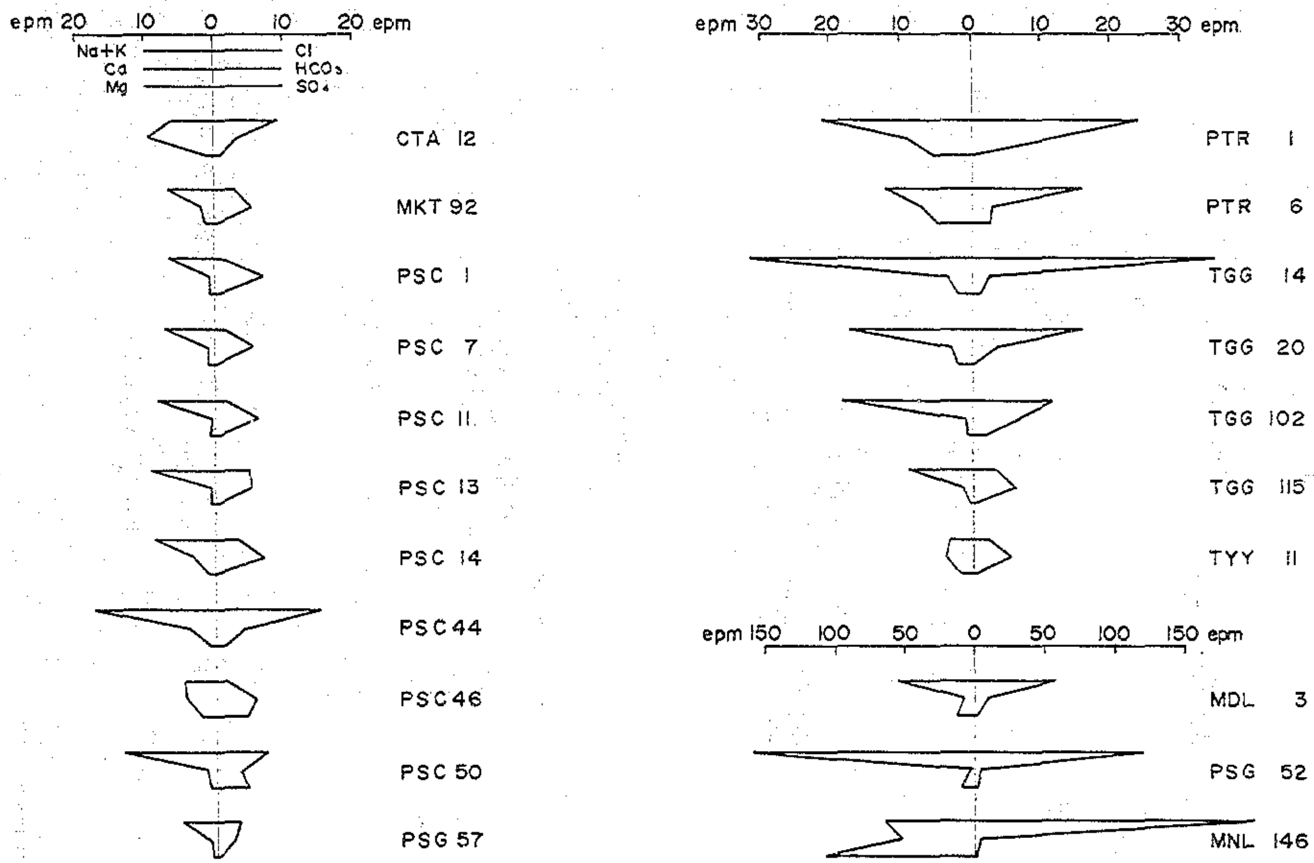
FIGURE 1.3.1
ELECTRIC CONDUCTIVITY OF GROUNDWATER IN THE PILOT AREA, 1985



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 1.3.2
PIEZOMETRIC SURFACE OF GROUNDWATER IN THE PILOT AREA, 1985

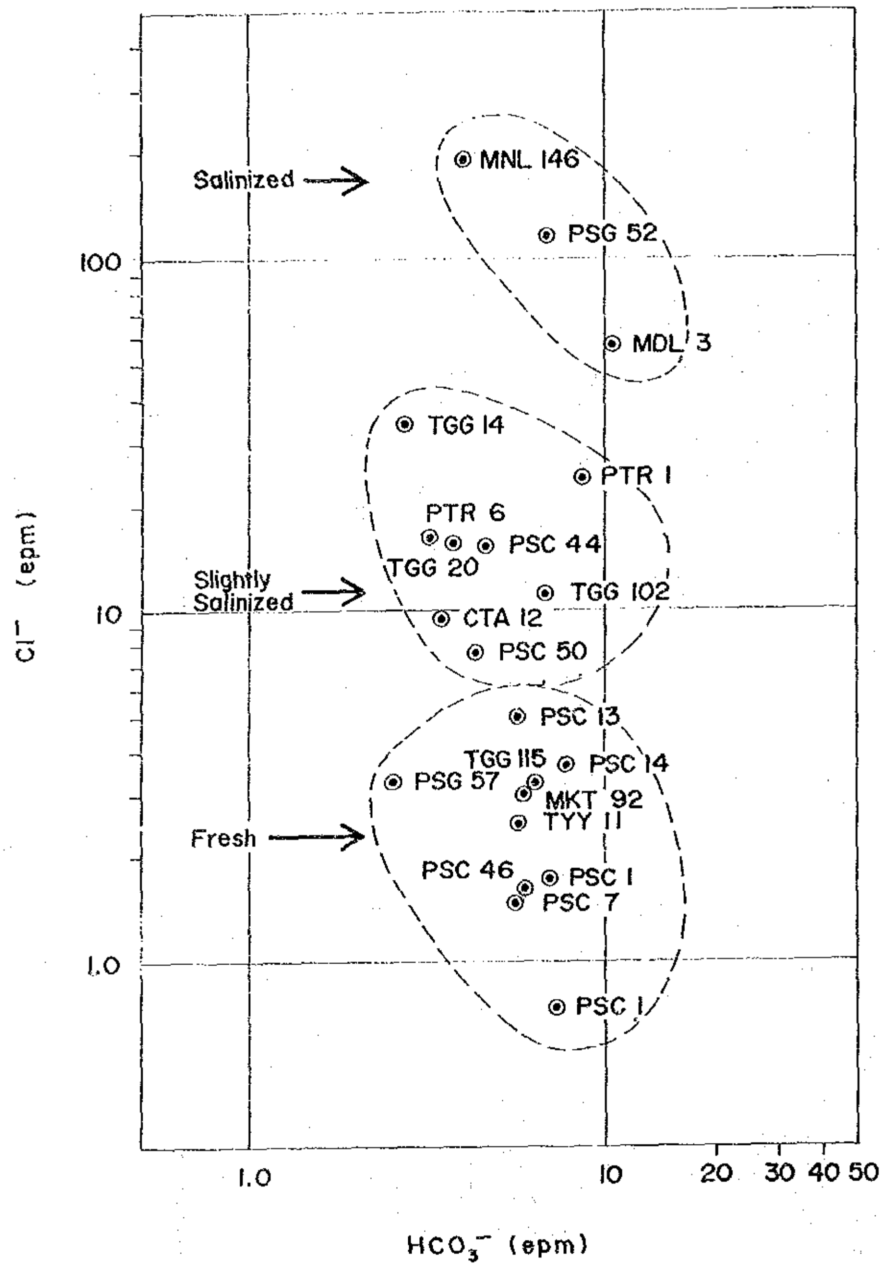


PRIMARY DATA FROM PGSCS, 1985

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 1.3.3 HEXA-DIAGRAM REPRESENTATION OF WATER QUALITY



PRIMARY DATA FROM PGSCS, 1985

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 1.3.4 RELATION BETWEEN BICARBONATE AND CHLORIDE
JAPAN INTERNATIONAL COOPERATION AGENCY	

CHAPTER 2

ELECTRIC RESISTIVITY SURVEY

CHAPTER 2 ELECTRIC RESISTIVITY SURVEY

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CHAPTER 2. ELECTRIC RESISTIVITY SURVEY

2.1 METHOD OF SURVEY

An electric resistivity survey was conducted in the Antipolo area, located east of Manila, to determine its geological structure and to obtain and investigate hydrogeological information.

The survey area is a distinct and independent plateau having steep slopes and an elevation range of 160 m to 260 m. It has a land size of approximately 9.2 km. x 4 km. and is developing as a new settlement site for the spill-over population of the swelling capital. This inparticularly, facilities for the delivery of adequate and efficient water supply, with groundwater as an immediate alternative.

The survey was conducted from October 3 to October 23, 1990 using the McOhm resistivity survey meter and Wenner's measuring method. The results were examined for match or harmony with the data of geological survey and the columnar sections of existing wells to precisely interpret the geological structures.

The survey was conducted in thirty (30) points widely distributed in the area and along the roads, excluding the downtown at the center of the Antipolo area because of its urbanization and the heavy traffic. The survey points are shown in Fig. 2.1.1 Measuring depth was 260 m in most points but was less than 190 m in three points as there were no straight roads and the topography was uneven.

The data of the survey were plotted on the log-log papers to present σ - a curves. The analysis was by direct visual interpretation method using a Sundberg standard curve. The results of the analysis were presented on the topographical sections connecting each measuring point. Such results were also presented in vertical directions for each measuring depth. For these maps, similar and same tendencies of measuring values were justified to be equivalent formations and were connected. The results of the analysis are shown in Figure 2.1.1(1) - Figure 2.2.1(3). Prior to the resistivity survey, the peculiar resistivities of typical formations distributed in the Antipolo area were measured as reference for the interpretation and analysis of the survey results in seven sites.

This time, there were no available data on existing columnar sections of wells near the measuring points. Thus, the data could not be compared with the sections. Interpretation of the survey results may involve some unreliability, and the results of test boring in the area which shall also be used in conjunction with the survey result may likewise modify the interpretation and analysis.

2.2 INTERPRETATION

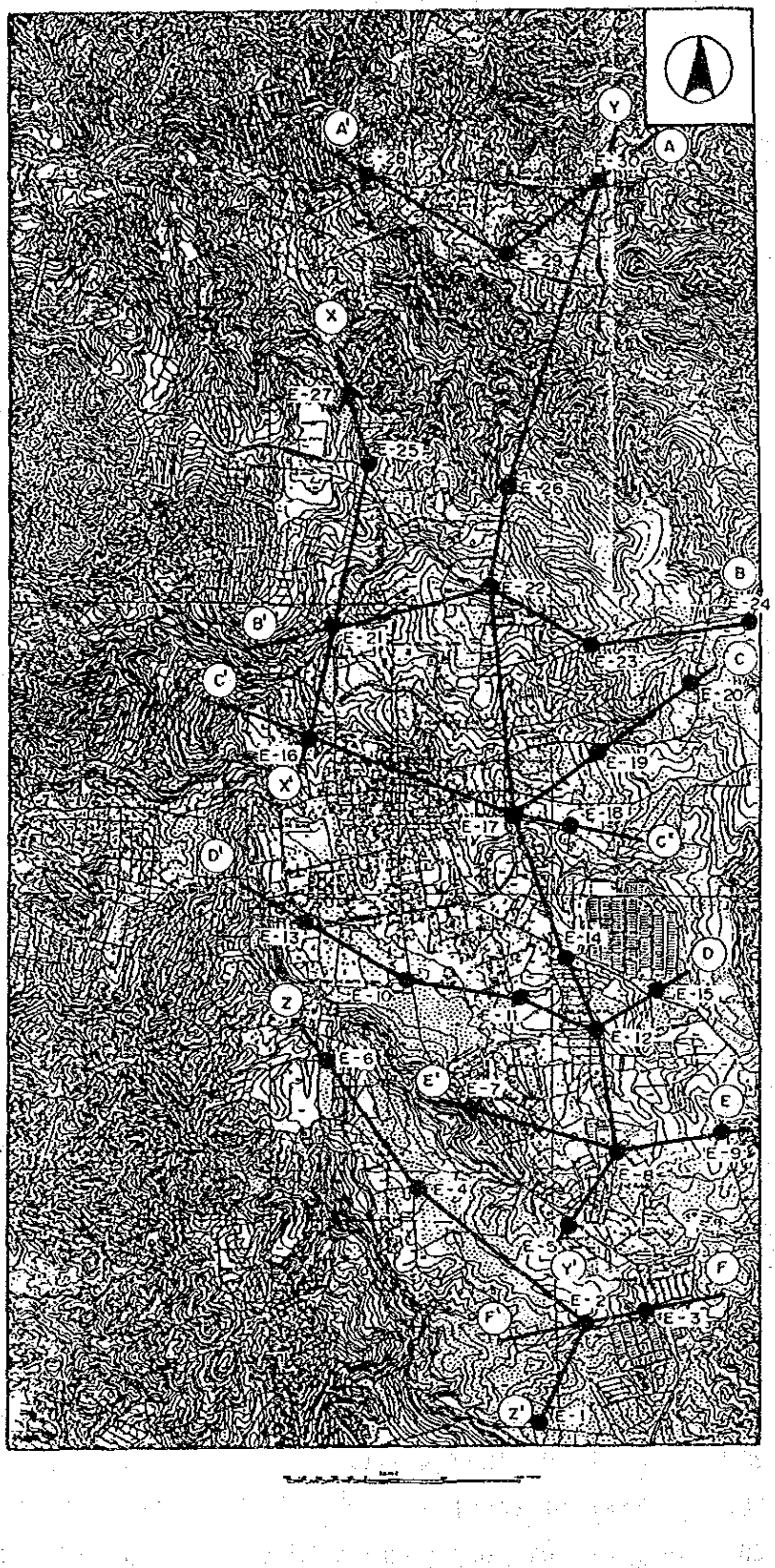
The survey data show that the geological structures fall under six formations.

The columnar sections are shown in Figures 2.2.1(1)-2.2.1(3).

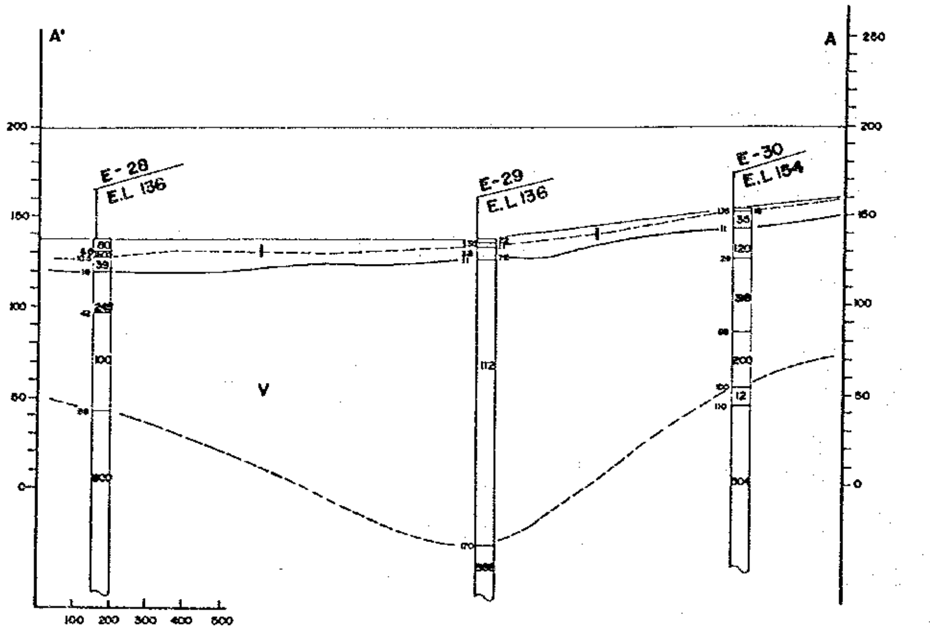
The resistivity range and corresponding formation such as formation name, geologic age and lithology are also shown the said Figures.

TABLE 2.1.1 LIST OF MEASURING POINTS

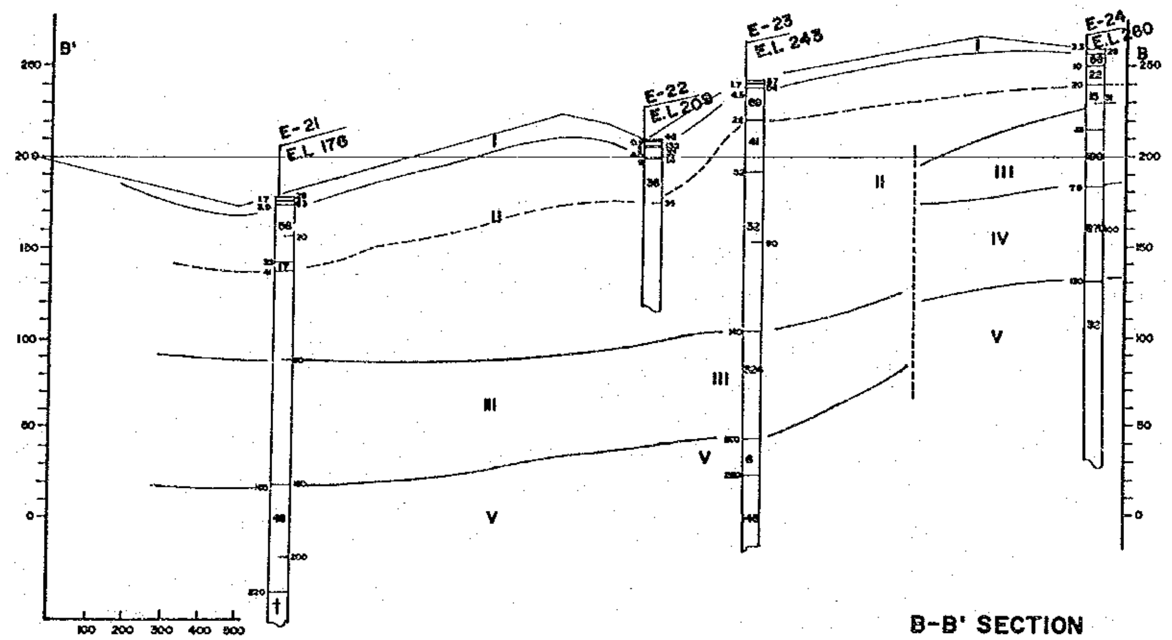
Measuring Number	Measuring Points	Measuring Date
E - 1	South of Angono	Oct. 19, 1990
E - 2	East of Angono	Oct. 23, 1990
E - 3	Yupangco Subd.	Oct. 4, 1990
E - 4	Northwest of Angono	Oct. 13, 1990
E - 5	South of Sra. Dela Paz Subd.	Oct. 4, 1990
E - 6	South of Ponde Rosa Height	Oct. 18, 1990
E - 7	Nayong Silangan Subd.	Oct. 4, 1990
E - 8	Sra. Dela Paz Subd.	Oct. 19, 1990
E - 9	East of Sra. Delapaz Subd.	Oct. 17, 1990
E - 10	East of Ponde Rosa Heights Subd.	Oct. 4, 1990
E - 11	West of San Antonio Vil.	Oct. 18, 1990
E - 12	San Antonio Vil.	Oct. 17, 1990
E - 13	Grand Heights Subd.	Oct. 22, 1990
E - 14	San Antonio Vil.	Oct. 8, 1990
E - 15	East of San Antonio Vil.	Oct. 8, 1990
E - 16	Villa Ligaya	Oct. 18, 1990
E - 17	Antipolo Town	Oct. 13, 1990
E - 18	Antipolo Town	Oct. 18, 1990
E - 19	East of Antipolo Town	Oct. 9, 1990
E - 20	La Salle Heights	Oct. 9, 1990
E - 21	Bankers Vil. III	Oct. 15, 1990
E - 22	North of Bermuda Subd.	Oct. 15, 1990
E - 23	North of La Salle Heights	Oct. 15, 1990
E - 24	East of Europa Subd.	Oct. 23, 1990
E - 25	North of Angela Vil.	Oct. 16, 1990
E - 26	East of Europa Subd.	Oct. 19, 1990
E - 27	North of Angela Vil.	Oct. 16, 1990
E - 28	West of Padella Subd.	Oct. 23, 1990
E - 29	South of Town Country Hill	Oct. 16, 1990
E - 30	Town Country Hill	Oct. 22, 1990



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 2.1.1 MEASURING POINT & CROSS-SECTION LINE
JAPAN INTERNATIONAL COOPERATION AGENCY	MEASURING POINTS (E-1~E-30), CROSS-SECTION LINES (A-A'~Z-Z')

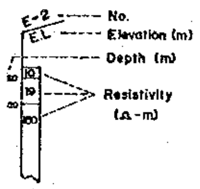


A-A' SECTION

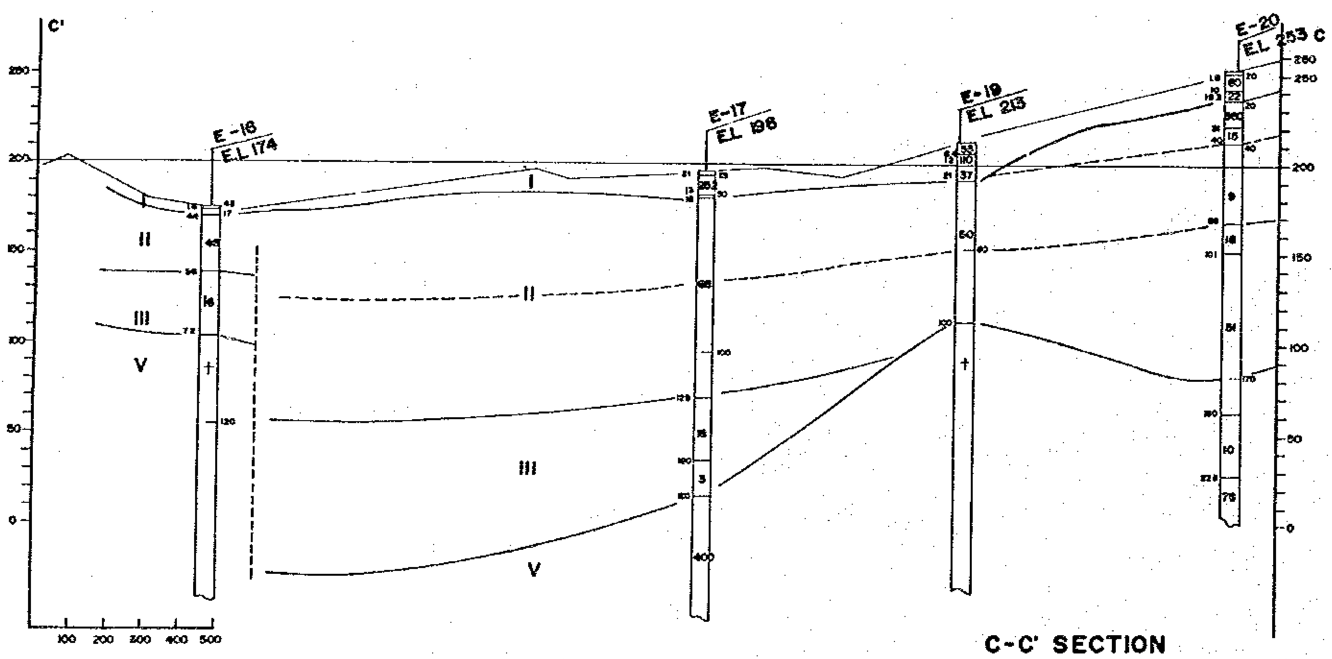


B-B' SECTION

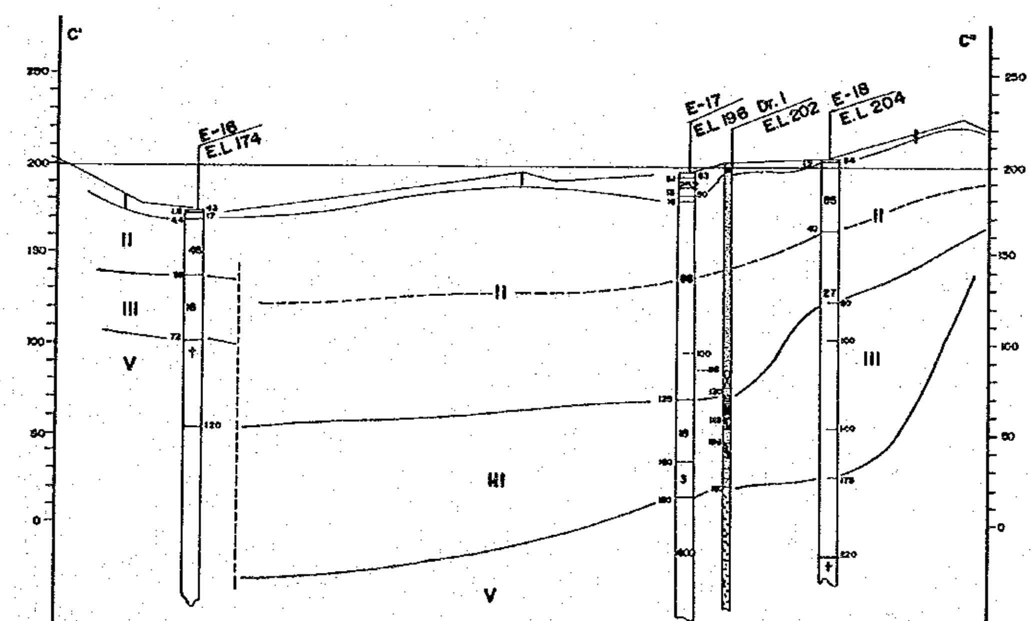
LEGEND



Strata Classification	Resistivity (Ω-m)	Corresponding Formation		
		Formation	Geologic Age	Lithology
I	10 100	Surface layer	Quaternary Holocene	Soil humus Weathered rock
II	20 70	Guadalupe Formation	Pleistocene ~	Tuffbreccia Welded tuff Lapilli tuff Tuffacious sandstone
III	20 300		Pliocene	Mudstone Sandstone Conglomerate
IV	870	Angat Formation	Neogene Miocene	Limestone
V	50 800	Antipolo Diorite Kinabuan F.	Palaeogene ~ CRETACEOUS	Diorite Propyrite Altered Spilitic Basalt
VI		Antipolo Basalt Porphyry	Pleistocene ~ Pliocene	Basalt Porphyry dyke and sheet

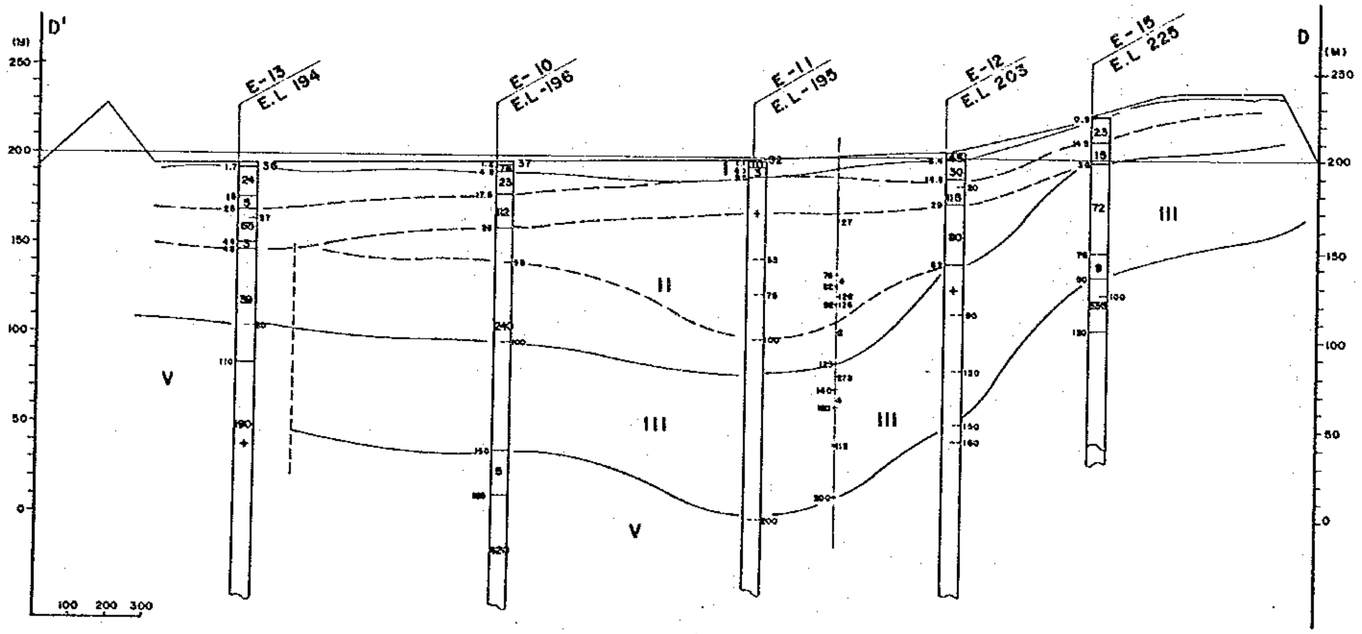


C-C' SECTION

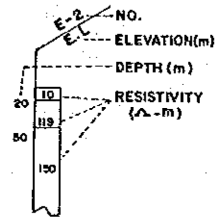


C'-C" SECTION

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	Figure ELECTRIC RESISTIVITY SURVEY Profile (I)
JAPAN INTERNATIONAL COOPERATION AGENCY	

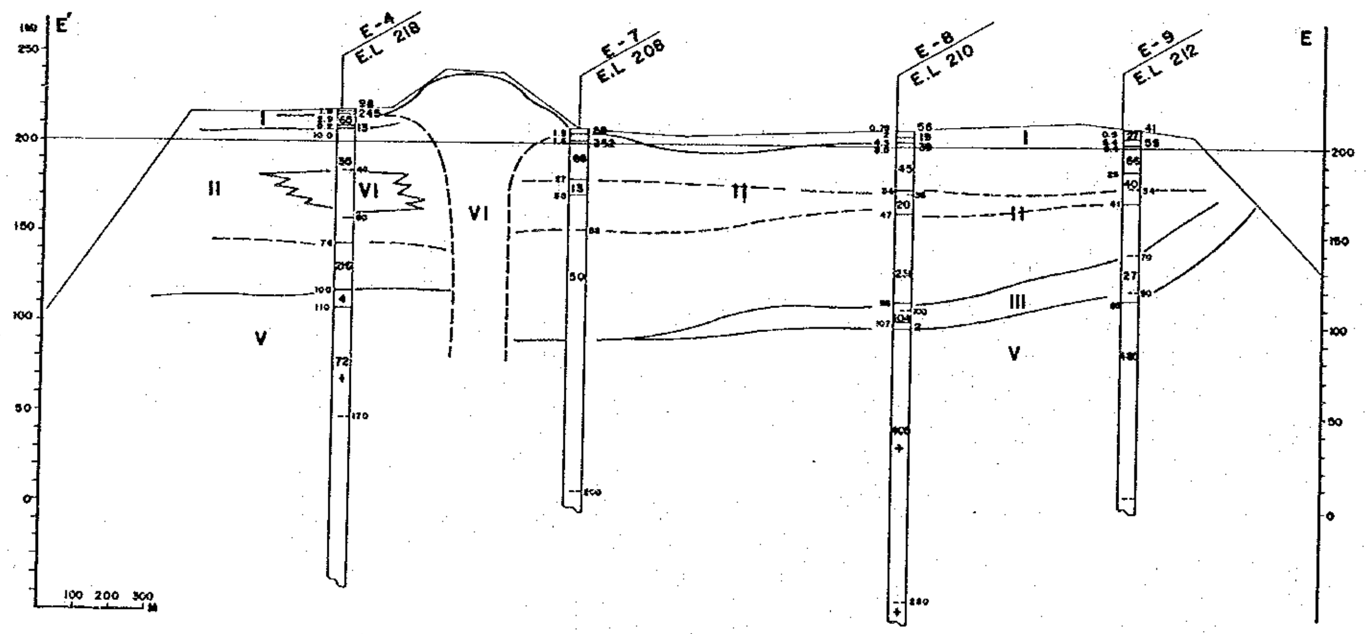


D – D' SECTION

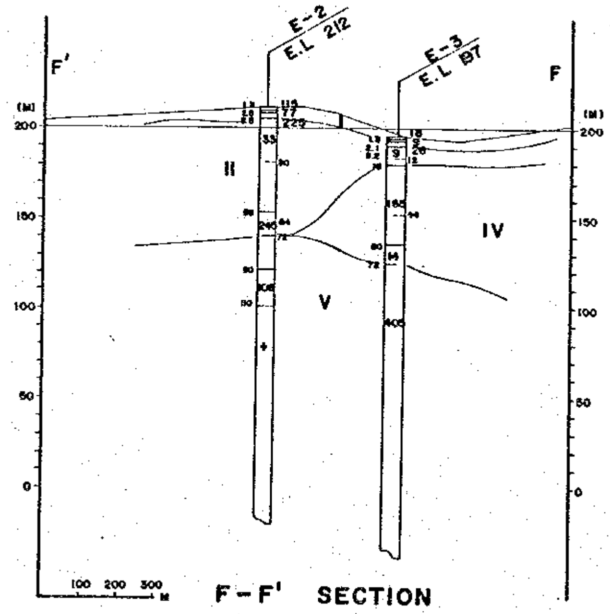


LEGEND

Strata Classification	Resistivity (Ω-m)	Corresponding Formation		
		Formation	Geologic Age	Lithology
I	10~100	Surface layer	Quaternary Holocene	Soil humus Weathered rock
II	25~230	Guadalupe Formation	Pleistocene ~	Tuffbreccia Welded tuff Lapilli tuff Tuffacious Sandstone
III	30~100		Pliocene	Mudstone Sandstone Conglomerate
IV	165	Angat Formation	Neogene Miocene	Limestone
V	70~400+	Antipolo Diorite	Paleogene ~ CRETACEOUS	Diorite Propyrite Altered Spilic Basalt
VI	350+	Antipolo Basalt Porphyry	Pleistocene ~ Pliocene	Basalt Porphyry dyke and sheet

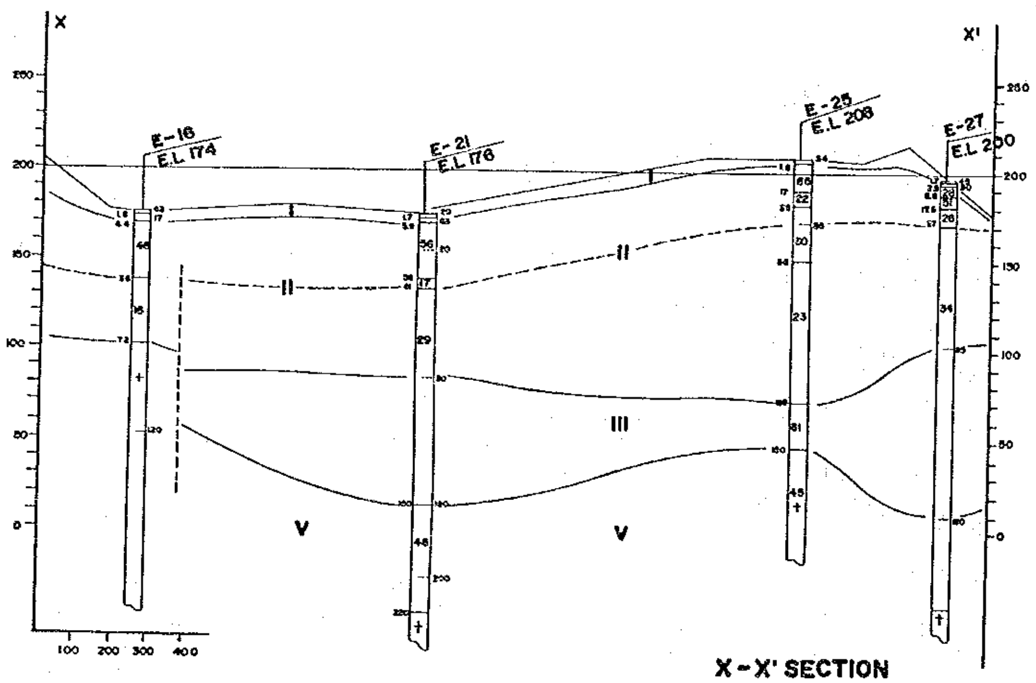


E – E' SECTION

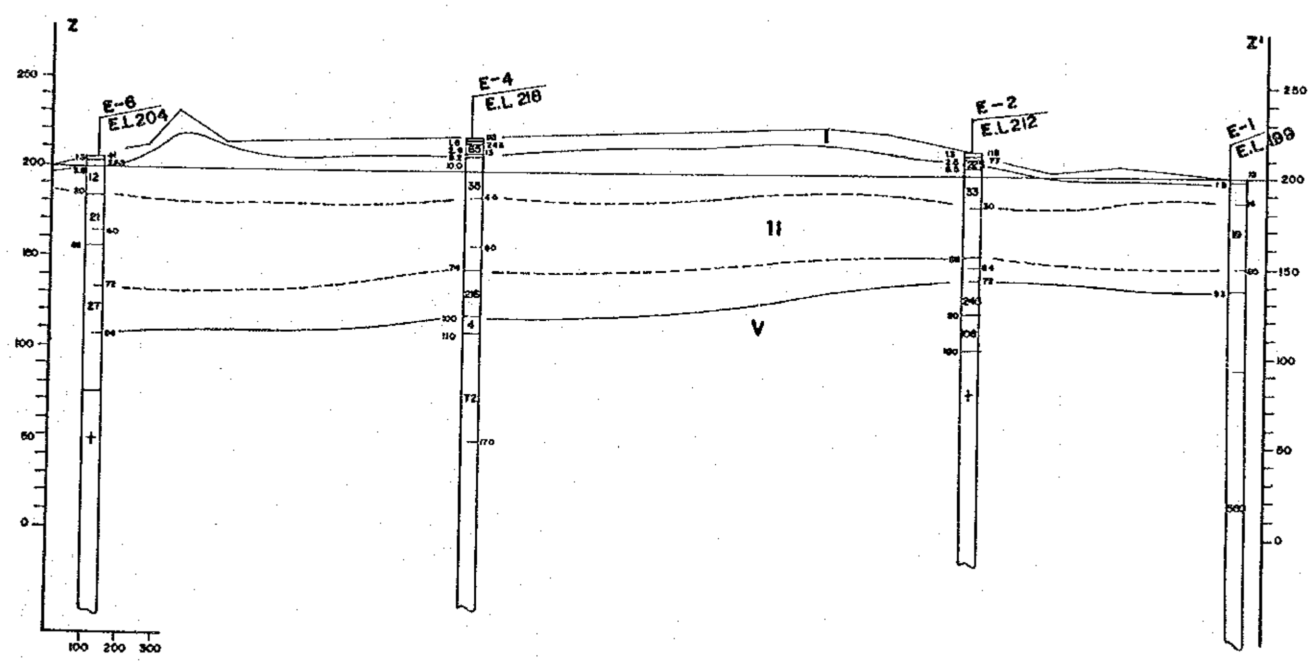


F – F' SECTION

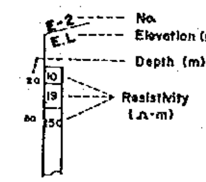
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	Figure ELECTRIC RESISTIVITY SURVEY Profile (2)
JAPAN INTERNATIONAL COOPERATION AGENCY	



X - X' SECTION

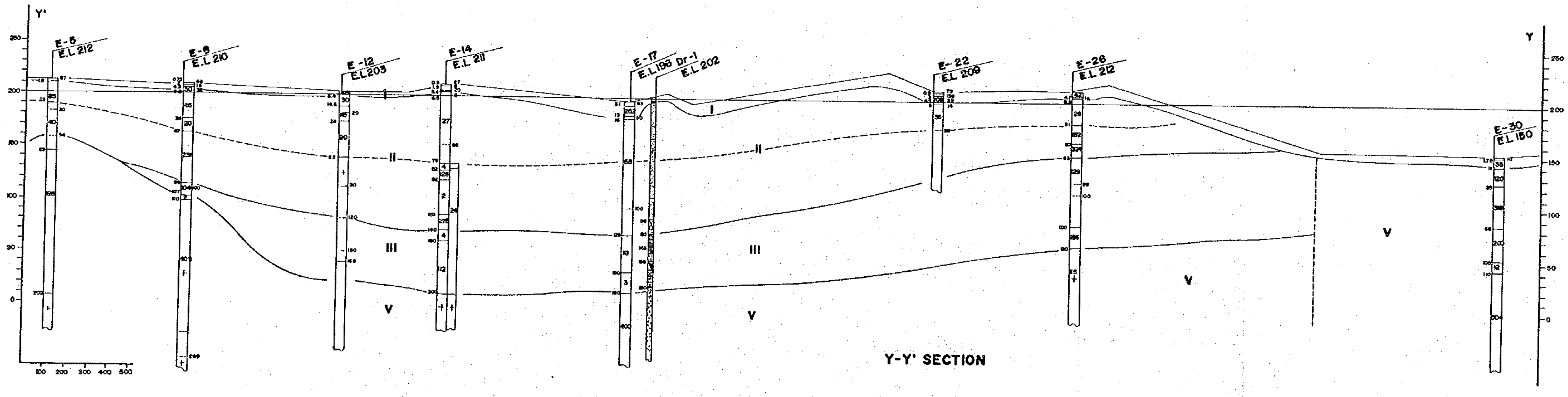


Z-Z' SECTION



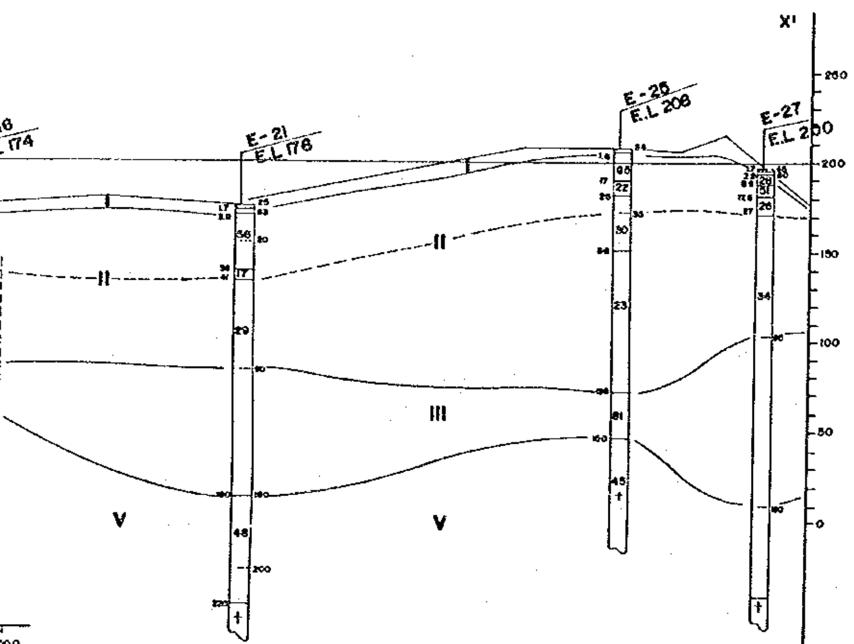
LEGEND

Strata Classification	Resistivity (Ω-m)	Correspon-	
		Formation	Geo
I	20~250	Surface layer	Qua Hol
II	20~100	Guadalupe Formation	Ple
III	20~190		Pli
IV		Angat Formation	Neo Mio
V	50~400+	Antipolo Diorite Kinabuan F.	Pal CRE
VI		Antipolo Basalt Porphyry	Plei Plio

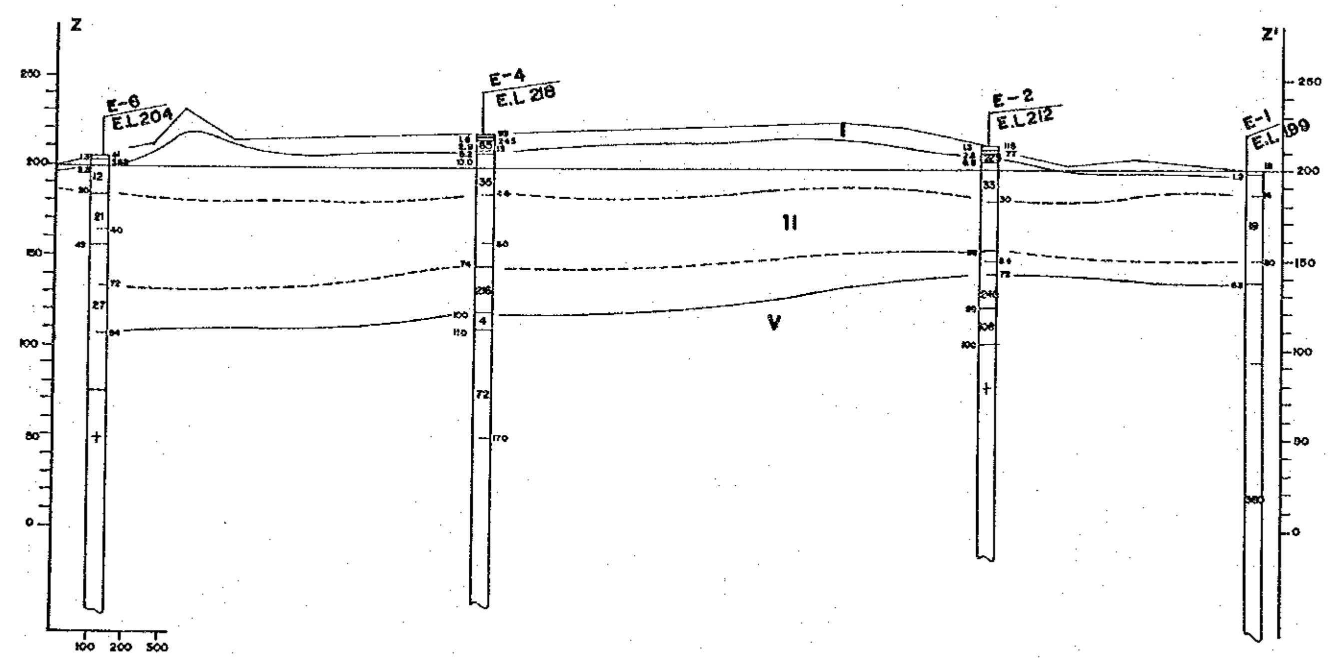


Y-Y' SECTION

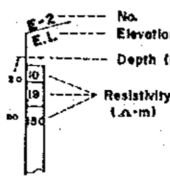
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	Figure
JAPAN INTERNATIONAL COOPERATION AGENCY	ELECTR



X - X' SECTION

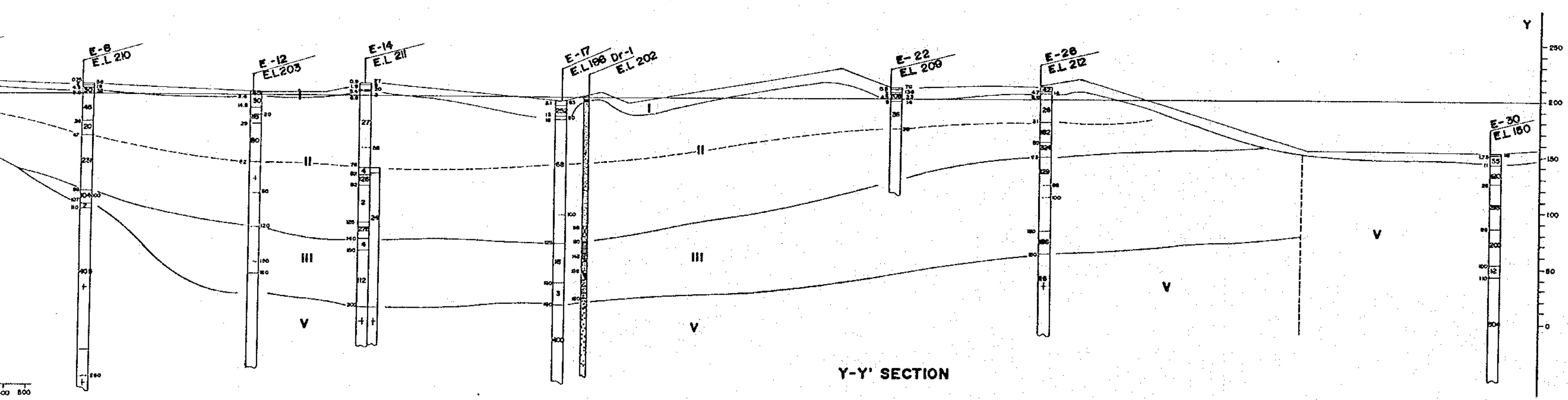


Z-Z' SECTION



LEGEND

Strata Classification	Resistivity (Ω-m)	Corresponding Formation		
		Formation	Geologic Age	Lithology
I	20~250	Surface layer	Quaternary Holocene	Soil humus Weatheredrock
II	20~100	Guadalupe Formation	Pleistocene ~	Tuffbreccia Welded tuff Lapilli tuff Tuffacious Sandstone
III	20~180		Pliocene	Mudstone Sandstone Conglomerate
IV		Angat Formation	Neogene Miocene	Limestone
V	60~400+	Antipolo Diorite Kinabuan F.	Palaeogene ~ CRETACEOUS	Diorite Propyrite Altered Spilitic Basalt
VI		Antipolo Basalt Porphyry	Pleistocene ~ Pliocene	Basalt Porphyry dyke and basalt



Y-Y' SECTION

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	Figure ELECTRIC RESISTIVITY SURVEY Profile (3)
JAPAN INTERNATIONAL COOPERATION AGENCY	

CHAPTER 3

DRILLING AND PUMPING TEST

CHAPTER 3 DRILLING AND PUMPING TEST

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CHAPTER 3 DRILLING AND PUMPING TEST

3.1 GENERAL

The work done during Stage I of the Study showed that there was insufficient data for evaluating the hydrogeologic condition in the Antipolo Area and the Las Piñas-Parañaque Area. This was particularly true in the Las Piñas-Parañaque Area where saltwater intrusion had widely occurred. It was therefore planned that deep test wells be drilled in each area for evaluating the geology, aquifer parameters and water quality, with adjacent core borings (in Las Piñas only) for observation and sampling purposes.

Data obtained from the above activities will be used for evaluating the groundwater conditions in the two areas. This in turn will assist in the planning of groundwater development and management in Metro Manila.

3.2 TEST WELLS AND LOCATIONS

Two (2) test wells of 250m and 200m depth were drilled in Barangay San Jose, Antipolo to evaluate geological and hydrogeological conditions of aquifers throughout their total depth and to confirm the depth of Pre-Quaternary basement. The 250-m well was used as a pumping well, the 200-m well for observation. Screen sections of the two (2) wells were set at the same aquifers. Test well locations are shown in Figure 3.2.1.

As shown in Figure 3.2.2, seven (7) test wells were drilled at three (3) locations in the coastal area of Las Piñas. Prior to the drilling of test wells, two (2) core borings were carried out in Las Piñas (No. 1 and No. 2) to evaluate the geological conditions and to take core samples for observation and laboratory analysis. Depth of each hole was 300m.

For evaluating the hydrogeological condition and water quality of aquifers, test wells of different depths were drilled in each location.

- Las Piñas No.1: Three wells of 300m, 200m and 100m depths
- Las Piñas No.2: Three wells of 300m, 200m and 100m depths
- Las Piñas No.3: One well of 300m depth

3.3 GEOLOGICAL DESCRIPTION

Test wells in Antipolo and Las Piñas were drilled using the rotary method. During the drilling operation, samples of cuttings were collected at one (1) meter intervals and penetration rates were recorded for geological interpretation. After completion of each drilling, spontaneous potential logging and resistivity logging were conducted within an uncased hole. After interpretation of all these data in terms of formation characteristics, the depth and length of the screen sections were fixed and test holes were cased and developed.

In Las Piñas, two series of core samples up to the depth of 300m were continuously taken, for geological observation and description by means of the wire-line drilling method. Lithologic data as well as geophysical logging data were interpreted for determination of screen section in test wells.

3.3.1 Antipolo

The lithologic log of a 250m well in San Jose, Antipolo is described as follows (Figure 3.3.1):

The upper part of the formation which is continuous up to a depth of 25m consists of reddish brown clay with gravels. This formation is underlain by boulder formation with a thickness of 8m. Thick, dark-brownish sand formation can be observed at depths of 32m to 118m where resistivity values are relatively higher. Sand grains are fine to coarse in size and are supposed to be derived from volcanic rocks. This sand formation could be a good aquifer.

Finer formations consist of clay and fine sand with clay. They occur consistently at a thickness of 50m beneath the shallow aquifer. The resistivity values are also lower than those of the overlying formation. The clay is sometimes consolidated and could be an aquiclude. Such finer formations are underlain by medium sand formations which occur at depths of 170m to 188m. One clayey formation is intercalated in the sand formations. The sand formations also contain clay, but the grain sizes are larger and the resistivity values slightly higher than clayey formations. The formations therefore could be confined aquifers.

The drilling activities verified the presence of basement rock, encountered 189m below ground level. The basement rock consists of greenish meta-basalt with its surface portion at depths of 189m to 200m being a weathered and fractured zone so that the penetration rates and resistivity values are small, for all the spontaneous potentials indicate negative values. The fresh portion of the basement rock below 200m is so hard that the penetration rates range from 0.3cm/min to 2cm/min and the resistivity values exceed 150ohm-m.

In order to evaluate the productivity of deeper aquifers that are overlain by confined layers, screens were set at depths of 152m to 173m and 185m to 194m. Aquifers above 118m were not considered since most of the existing wells set screens in shallow aquifer, and the productivity can be evaluated from existing pumping test data.

3.3.2 Las Piñas No.1

The lithology at Las Piñas No.1 up to a depth of 300m is described as follows (Figure 3.3.2):

The site is located near the coastal line, but the alluvium is less than 7m in thickness. The rest of the formations belong to the Guadalupe formation. Generally, the cores of the Guadalupe formation are well-consolidated and tuffaceous.

The upper portion of the formation up to a depth of 76m consists of tuffaceous silt, fine sand and medium to coarse sand. Significant thickness of clayey sediments that form the confining layer (CL) has been identified at depths of 58m to 76m. This clayey layer can be traced to Las Piñas No.2. The formation overlain by this clayey layer consists mainly of alternated tuffaceous, fine to coarse, sand layers. Four characteristic pumice-bearing layers which can be treated as key beds, namely PM1, PM2, PM3 and PM4, occur at depths of 105m to 117m, 159m to 165m, 240m to 257m and 274m to 283m, respectively. These pumice- bearing layers contain coarse materials such as coarse sand, granules and pebbles so that the resistivity curves indicate high anomalies.

After the observation of core samples and the interpretation of geophysical loggings, the casing program of each well was fixed. In Well No.1 (300m depth), screens were set at depths of 240m to 252m and 276m to 294m in order to investigate deeper aquifers. In Well No.2 (200m depth), screens were set at depths of 145m to 154m, 160m to 175m and 181m to 187m. In Well No.3 (100m depth), screens were set at depths of 64m to 94m to evaluate the characteristics of shallow aquifer.

3.3.3 Las Piñas No.2

Geology of LAS PIÑAS NO. 2 can be classified into Alluvium and Guadalupe Formation. The Alluvium (11.1m thickness) consists of soft clay and loose gravel layers and is underlain by well-consolidated Guadalupe Formation (Figure 3.3.3).

The upper portion of the Guadalupe formation up to a depth of 89m consists of tuffaceous silt, fine sand and medium to coarse sand. Significant thickness of clayey sediments (CL), which was found in LAS PIÑAS NO. 1, can be traced at depths of 65m to 89m. Alternated tuffaceous, fine to coarse, sand layers which are geologically well-correlated with LAS PIÑAS NO. 1 by four characteristic pumice-bearing layers are overlain by CL. The occurrence of PM1, PM2, PM3, and PM4 are at depths of 120m to 132m, 169m to 179m, 254m to 271m and 291m to 297m, respectively. The characteristics of pumice-bearing layers as well as the facies and thickness of the rest of the formations are very similar to those of LAS PIÑAS NO. 1 (Figure 3.3.4).

After the observation of core samples and the interpretation of geophysical loggings, the casing program of each well was fixed. In Well No. 1 (300m depth), screens were set at depths of 246m to 252m, 264m to 276m and 282m to 294m in order to investigate the deeper aquifers. In Well No. 2 (200m depth), screens were set at depths of 146m to 158m, 170m to 179m and 185m to 194m. In Well No. 3, screens were set at depths of 64m to 94m to evaluate the characteristics of shallow aquifer.

3.4 RESULTS OF PUMPING TEST

The step-drawdown, constant rate and recovery tests were conducted in the three 300-m wells in Las Piñas and the 250-m well in Antipolo. In other wells, the constant rate and recovery tests were conducted. Prior to the pumping tests, electric conductivity (EC) and temperature were measured at different depths in each test well. EC and temperature were also measured at every time-step during pumping tests. Water samples were taken during the constant rate test.

Time-drawdown measurements and semi-log plot of the step-drawdown tests are included in Chapter 2 of this study's Data Report. Well loss parameters were calculated using Jacob's formula.

3.4.1 Antipolo

The well development performed prior to the pumping test revealed that the static water level (SWL) of the 250-m well was deeper than 60m and the discharge rate during airlifting showed a poor water output of 5 to 10 l/min.

On the other hand, the SWL of the 200-m well was about 35m, and this well was anticipated to be more productive than the 250-m well, despite its having the same screen positions and being only eight (8) meters away from the other well. The difference may be caused by the non-homogeneity of aquifers in terms of materials contained in the formation.

Observation of drill cuttings shows the lower part of the formation in the 250-m well to contain more silty materials than the 200-m well, though the resistivity curves of these two wells look the same.

It was therefore decided that the 200-m well be used as the pumping well instead of the 250-m well. The 250-m well was used for observation purposes.

A constant rate pumping test was performed on 12 March 1991. It was begun at 10:30am and was planned to run for forty eight (48) hours at 51.6 l/min, but it was aborted at 11:30pm due to power failure (brown out). The test was restarted at 10:30am on 13 March and it lasted for twenty four (24) hours. Discharge was 51.6 l/min. During the test, the water level of the 250m well was stable and unaffected by the adjacent pumping. After the pumping test was completed, a recovery test was carried out and water level was measured for eight (8) hours.

The electric conductivity (EC), pH and temperature were frequently checked during the test. EC ranged from 480 to 490 µs/cm, pH was 7.6, and temperature was 27°C.

Drawdown and recovery measurements are included in Chapter 2 of the Data Report. Time-drawdown on semi-log and log-log graph papers are also included in the Data Report.

Analysis results show that, transmissivity was 8.8m^2/day and specific capacity was 1.67m^3/day/m. These figures indicate that the lower Guadalupe aquifers are less permeable and poorly productive.

3.4.2 Las Piñas No.1

Continuous pumping and recovery tests were carried out in three test wells, viz., Well No.1 (300m), Well No.2 (200m) and Well No.3 (100m) in Las Piñas No.1. In Well No.1, the step-drawdown test was conducted ahead of the continuous pumping test.

In Well No.1, a 30-HP submersible pump was installed at a depth of 120m below ground level. The diameters of casing and riser pipes were 8 in. and 2.5 in., respectively. The static water level before pumping was 44.48m.

Five steps of discharge rate were intended to be employed before conducting the pumping tests. Because of the unexpected small discharge due to the small diameter of the riser pipe, only four steps of discharge rate, viz., 198 l/min, 402 l/min, 606 l/min and 648 l/min were performed. The duration of each step was two hours. The time-drawdown graph of the step-drawdown test is shown in Chapter 2 of the Data Report. The results of step-drawdown test are given in Table 3.4.1.

From the results, well loss parameters were calculated using Jacob's equation. The values of B and C obtained from Q-s/Q graph were

$0.2949 d/m^2$ and $2.60 \times 10^{-6} d^2/m^5$, respectively. Well efficiency was calculated at 98.6% when the discharge rate was 606 l/min ($872.6 m^3$/day).

In order to determine the transmissivity T and storage coefficient S of the aquifer, the continuous pumping test and recovery test were carried out in each well. In Well No.1, the discharge rate determined from the step-drawdown test was 402 l/min. Duration of pumping was 48 hours. In Well No.2 and Well No.3, the duration of continuous pumping was 12 hours. The discharge rate of Well No.2 and Well No.3 was small because the diameter of the casing pipe was only 4 in., and only a smaller submersible pump could be installed. The residual drawdown in each well was measured for at least eight hours after the pumping has stopped. Time-drawdown graphs were plotted on logarithmic and semi-logarithmic papers. Time ratio (t/t')-residual drawdown graphs were plotted on semi-logarithmic paper. Both types of graphs are shown in the Data Report.

The results of continuous pumping and recovery tests, as well as EC and temperature measurements, are summarized in Table 3.4.2 and Figure 3.4.1.

It is noted that the static water level of Well No.3 (100m) is only 4.60m, whereas the static water levels of Well No. 2 (200m) and Well No.1 (300m) are 37.34m and 44.48m, respectively. This could indicate the separation of the shallow aquifer of Well No.3 from deeper aquifers.

During the continuous pumping in Well No.1, water levels in Well No.2 and Well No.3 remained stable and were unaffected by the pumping. EC values during the pumping tests and the difference in T values also support this idea. Based on the geological investigation mentioned before, significant thicknesses of clayey formations that could form a confining layer have been identified at depths of 58m to 76m. It can be said that the clayey layer separates the shallow aquifer from the deeper aquifers, and with it acting as a significant aquiclude.

3.4.3 Las Piñas No.2

Continuous pumping and recovery tests were carried out in three test wells in Las Piñas No.2, viz., Well No.1 (300m), Well No.2 (200m) and Well No.3 (100m). In Well No.1, the step-drawdown test was conducted prior to the continuous pumping test.

In Well No.1, a 30-HP submersible pump was installed at a depth of 120m below ground level. The diameters of casing and riser pipes were 8 in. and 2.5 in., respectively. The static water level before pumping was 50.03m.

Five steps of discharge rate, viz., 101.4 l/min, 198.6 l/min, 300.0 l/min, 402.0 l/min and 445.8 l/min were employed for the step-drawdown test. The duration of each step was two hours. The time-drawdown graph is shown in Chapter 2 of the Data Report. Results of the step drawdown test are given in Table 3.4.3.

From the results, well loss parameters were calculated using Jacob's equation. The values of B and C obtained from Q-s/Q graph were $0.07612 d/m^2$ and $2.40 \times 10^{-5} d^2/m^5$, respectively. Well efficiency was calculated at 84.6% when the discharge rate was 402.0 l/min ($578.9 m^3/day$).

In order to determine the transmissivity T and storage coefficient S of the aquifer, continuous pumping and recovery tests were carried out in each well. In Well No.1, the discharge rate determined from the step-drawdown test was 300 l/min. Duration of pumping was 48 hours. In Well No.2 and Well No.3, the duration of continuous pumping was 12 hours. The discharge rate of Well No.2 and Well No.3 was small because the diameter of the casing pipe was only 4 in., and only a smaller submersible pump could be installed. The residual drawdown in each well was measured for at least 8 hours. Time-drawdown graphs were plotted on logarithmic and semi-logarithmic papers. Time ratio (t/t')-residual drawdown graphs were plotted on semi-logarithmic paper. Both types of graphs are shown in the Data Report.

The results of continuous pumping tests and recovery tests, as well as EC and temperature measurements, are summarized in Table 3.4.4 and Figure 3.4.2.

The static water table of Well No. 3 (100m) is shallow whereas the static water levels of Well No. 2 (200m) and Well No. 1 (300m) are deep. This is similar to Las Piñas No.1. The EC values of Well No.2 are higher than those of Las Piñas No. 1. It is noted as an interesting phenomenon that the EC_{18} value before pumping in Well No.2 was 22783 µs/cm, which after pumping became 9483 µs/cm. The transmissivity of Well No.3 is higher than those of Well No.2 and Well No.1.

3.4.4 Las Piñas No.3

The step-drawdown test, continuous pumping and recovery tests were carried out in Well No.1 (300m), Las Piñas No.3.

A 30-HP submersible pump was installed at a depth of 120m below ground level. The diameters of casing and riser pipes were 8 in. and 2.5 in., respectively. The static water level before pumping was 64.90m.

Four steps of discharge rate, viz., 102 l/min, 198 l/min, 300 l/min, 402 l/min were employed for the step-drawdown test. The duration of each step was two hours. The time-drawdown graph is shown in the Data Report. The results of the step-drawdown test are given in Table 3.4.5.

From the results, well loss parameters were calculated using Jacob's equation. The values of B and C obtained from Q-s/Q graph are $0.04807 d/m^2$ and $1.57 x 10^{-5} d^2/m^5$, respectively. Well efficiency is calculated as 87.6% when discharge rate is 300 l/min ($432 m^3/day$).

In order to determine the transmissivity T and storage coefficient S of the aquifer, continuous pumping and recovery tests were carried out. The discharge rates determined from the step-drawdown test was 300 l/min. Duration of pumping was 48 hours. Time-drawdown graphs were plotted on logarithmic and semi-logarithmic papers. The time ratio (t/t')-residual drawdown graph was plotted on logarithmic paper. Both types of graphs are shown in Chapter 2 of the Data Report.

The results of continuous pumping tests and recovery tests, as well as EC and temperature measurements, are summarized in Table 3.4.6.

The static water level of this well is the lowest among the test wells in Las Piñas. The values for maximum and minimum EC_{18} before and after pumping are also the lowest. Transmissivity values range from $28.7 m^2/day$ to $38.8 m^2/day$. Storage coefficient ranges from $9.73 x 10^{-5}$ to

$6.18x10^{-6}$.

3.5 ANALYSIS OF CORE SAMPLES

In order to clarify the stratigraphy and geological environment of Alluvium and Guadalupe formation, various geological methods of analysis were employed.

Laboratory analysis of core samples taken at Las Piñas sites include:

1) Carbon 14 dating	2 samples
2) Fission track dating	5 samples
3) Micro-fossils (Foraminifera and Diatom)	6 samples
4) Heavy minerals	20 samples
5) Chloride content	10 samples

Samples were sent to Japan for laboratory analysis.

3.5.1 Fission Track Dating

The age of zircon grains contained in PM1 to PM5 layers were analyzed by the fission track method. Absolute age of all samples ranged from 80.0 to 139.5 million years as shown in Table 3.5.1. While the result shows very old age, the Guadalupe formation is believed to be younger, i.e., Plio-Pleistocene.

Very few zircon grains were found in the core samples. Also, heavy minerals were affected by diagenesis and weathering due to their deposition in the lake environment near volcanoes. Therefore, these sediments may not be original and may have been disturbed by water flow during their transport and deposition in view of the grain shape, lamina, wooden fragment and roundness of conglomerate.

Accordingly, the result of dating could indicate similarity in the absolute age of the Kinabuan formation (basalt) and that of another formation. These formations underlie the volcanoes in Bataan, Corregidor, Taal and Laguna.

3.5.2 Diatom Analysis

Most of the diatoms found in the core samples (obtained at depths of 7.7 to 10.5m) were marine or marine to brackish. In contrast, only limnetic diatoms were identified in the core samples taken at depths of 24.8 to 298m (Table 3.5.2).

This finding suggests that the uppermost sediments were laid down in the shallow sea of Holocene age while lower sediments, i.e., below 10.5 to 300m, were deposited in the lake environment of Pleistocene age.

The environment of deposition of the Guadalupe formation up to a depth of about 2,000m is yet to be clarified. However, the presence of saline water in the deeper part of the formation, i.e., at depths below 300m, which was discovered during the 1960s by GMB through a drilling it carried out downstream of the Marikina River, could indicate that the deeper formation was deposited in a marine environment.

3.5.3 Analysis of Heavy Minerals

A heavy mineral assemblage analysis was carried out to obtain basic data for the stratigraphic correlation. The content of heavy minerals was less than 10% of total grains in each sample. Augite, hyperthene and magnetite were the dominant heavy minerals. Hornblende can be found in samples taken at shallow depths reaching up to 165m. The amount of Hyperthene at depths below 265m was very small.

The difference in heavy mineral assemblage may be caused by change of volcanic activities and/or environment during the deposition. Therefore, the Guadalupe formation within a depth of 300m at this location can be divided into at least three units by heavy mineral assemblage.

Many volcanic glasses, rock fragments and weathered rock particles are found in the samples instead of small contents of heavy minerals. From the content and type of volcanic glasses that are indicative of neighboring volcanic activities, it is possible to classify the formation. The content of volcanic glass exceeds 50% of total grains in the samples taken at depths of 99m to 105m, 134m to 144m, 184m to 197m, 231m to 142m, and 281m. The assemblage of volcanic glass below the 281m depth