REPUBLIC OF THE PHILIPPINES
METROPOLITAN WATERWORKS AND SEWERAGE SYSTEM

STUDY FOR THE GROUNDWATER DEVELOPMENT
IN
METRO MANILA

VOLUME 2
MAIN REPORT

①

JUNE 1992

JAPAN INTERNATIONAL COOPERATION AGENCY

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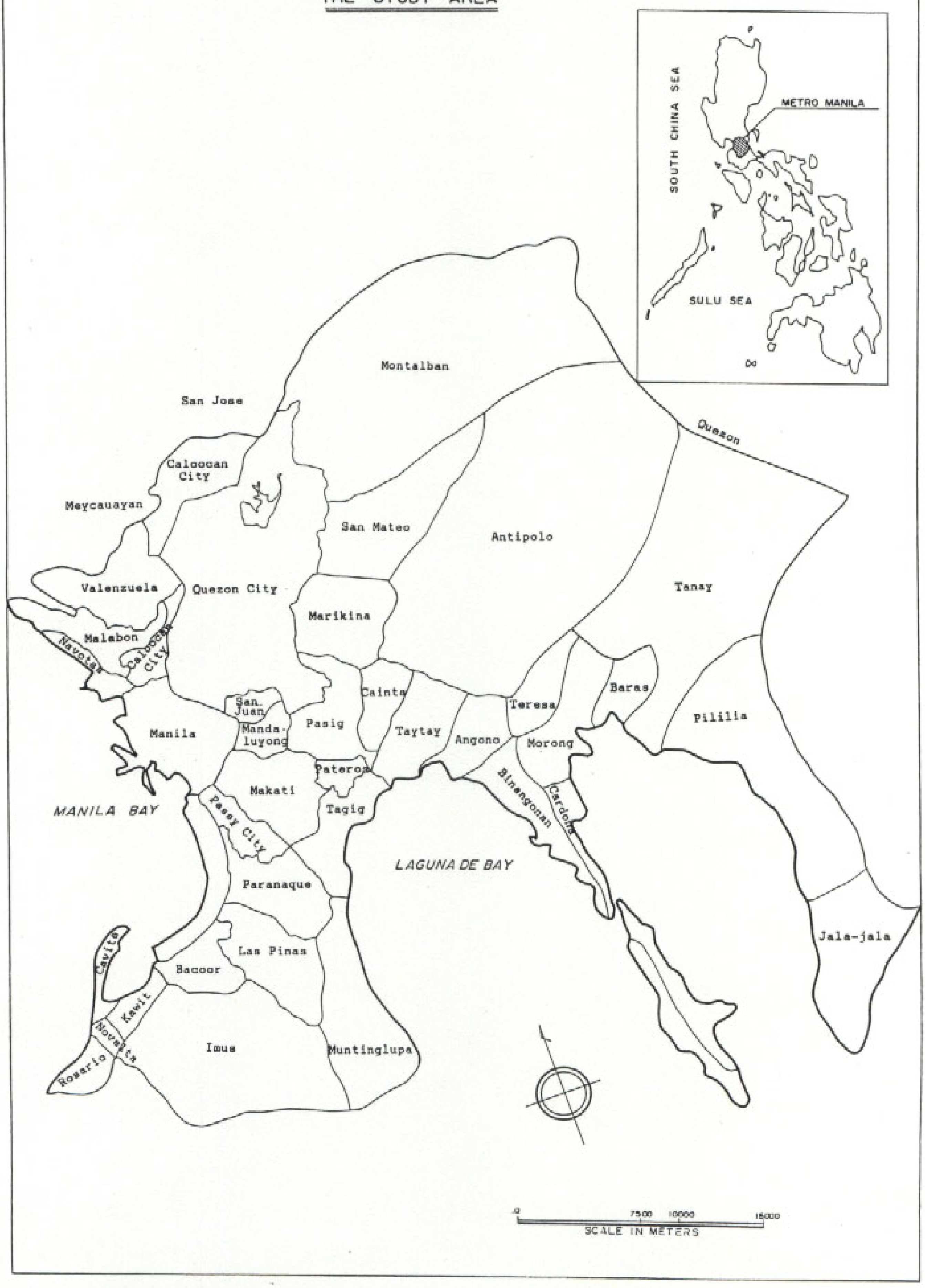

THE STUDY AREA

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STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

MAIN 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

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CHAPTER 1 INTRODUCTION

1.1 STUDY BACKGROUND

The National Capital Region or NCR, better known as Metro Manila, lies on an alluvial plain and terrace along Manila Bay, south of the island of Luzon. Containing a land area which is less than one percent (0.21 percent) of the country's total and having thirteen percent (7.9 million) of the country's total population, the area is characterized by rapid urbanization posing serious problems in water supply, sewerage, transportation, housing, garbage disposal and other related issues.

The problem of water supply shortage in particular is of such seriousness as to spur the Metropolitan Waterworks and Sewerage System (MWSS), which has jurisdiction over Metro Manila's water supply services, to embark on implementing several projects to meet the increasing demand and to have under wraps plans for some more. Notwithstanding the amount of effort the MWSS is exerting to solve the problem, the water shortage in the metropolis remains as grave, even appearing as if it has been further compounded, considering the superannuation and leakage in the distribution pipes of the MWSS.

Metro Manila's water supply, historically, has depended on groundwater as an important source. The deep and shallow wells that were drilled provide water for industry and commerce and for the domestic supply of areas outside the coverage of the central distribution system (CDS) of the MWSS as well. Another source is the surface water of the Angat River in the Province of Bulacan.

The uncontrolled development and excessive pumping of groundwater, however, had caused the widespread decline of water levels in artesian aquifers, this decline dating back as far as the Sixties. What had thus resulted was the intrusion of salt water in the aquifers of coastal areas. Many wells had to be abandoned, new ones have to be drilled, with this seeking of fresh water in deeper aquifers becoming a vicious cycle and in the process expanding more the area affected by the intrusion of salt water.

The above phenomenon has not spared the MWSS. A considerable number of the deep wells in its service area were affected by the regional salinization and were therefore abandoned. Some of these wells form part of the well network that supplies groundwater through pipelines connected to the CDS.

To compensate for the losses from these salt-intruded wells and increase the water supply in areas covered by its central distribution system, the MWSS is currently implementing the Angat Water Supply Optimization Project (AWSOP). For areas where no future water supply plans using surface water as source exist, two projects using groundwater as source are currently under implementation. These are the Fringe Areas Water Supply Project (FAWSP) and the Rizal Province Water Supply Improvement Project (RPWSIP).

It is still projected, however, that even with the increment in supply brought forth by the above efforts, supply would not meet the increasing water demand as rapid urbanization has already taken place. The rational development and conservation of groundwater and the establishment of a system for its proper management must therefore be given greater and sustained attention.

The Philippine Government's concern, in the context of the above, prompted it to request the Government of Japan for technical assistance, which request the Japanese Government acceded to by sending a preliminary mission for the period 12-22 January 1990 to clarify the background and specifics of the request. An agreement was reached between the MWSS and the Japan International Cooperation Agency (JICA) on the Implementing Arrangement (IA) for a study. The agreement was signed on 18 January 1990 by representatives of both parties. Based on the IA, a Study Team was dispatched to carry out the study.

The Study Team stayed in the Philippines for the periods 26 August to 20 December 1990 (Stage I of the Study), 08 January to 26 March 1991 (Stage II of the Study) and 27 May to 20 December 1991 (from First to Third period of Stage III of the Study). In cooperation with MWSS personnel, the team conducted surveys on the groundwater resources of the MWSS service area (MSA).

1.2. STUDY OBJECTIVES AND SCOPE

1.2.1 Study Objectives

The Study aims at the achievement of the following:

(1) To formulate a plan for the rehabilitation, operation, maintenance and development of MWSS supervised wells in MSA.

(2) To evaluate the groundwater resources potential and formulate a groundwater development plan for the Antipolo area.

(3) To come up with solutions or remedial measures and preventive schemes for areas with heavy saline water intrusion.

(4) To formulate a plan for the establishment of a groundwater monitoring system in Metro Manila.

1.2.2 Study Scope

The Study is being carried out within the stipulations of the Implementing Arrangement (IA) abovementioned and covers the following major subjects:

(1) Rehabilitation program for MWSS wells

All operating and non-operating wells of MWSS are to be investigated. Methods of rehabilitation will be examined and evaluated based on the results of the experimental work on selected wells.

(2) Groundwater development plan in the Antipolo area

The area included in the Study is the Antipolo Plateau that is enclosed by ridges and which is about 30 km^2. A groundwater development plan will be formulated for this plateau.

(3) Elucidation of saline water intrusion mechanism

A hydrogeologic investigation is to be carried out along a survey line perpendicular to the coast of Las Piñas-Parañaque where intrusion of saline water has been observed.

Observation wells will be drilled along said line in order to measure groundwater level and water quality. Countermeasures shall be proposed based on the hydrogeologic analysis.

(4) A plan for the establishment of groundwater monitoring system

A plan will be formulated and proposed. It will be analyzed through computer simulations. The plan covers the MSA except those municipalities included in BP 799.

1.3 STUDY AREA

As shown in Figure 1.1, the Study Area covers the MWSS Service Area which comprises five (5) cities and thirty two (32) municipalities, namely:

Metro Manila: 4 cities and 13 municipalities

The cities of Manila, Pasay, Quezon and Caloocan and the municipalities of Las Pinas, Makati, Malabon, Mandaluyong, Marikina, Muntinlupa, Navotas, Parañaque, Pasig, Pateros, San Juan, Taguig and Valenzuela.

Cavite Province: 1 city and 5 municipalities

The city of Cavite and the municipalities of Bacoor, Imus, Kawit, Noveleta and Rosario.

Rizal Province: 14 municipalities

Antipolo, San Mateo, Taytay, Cainta and Montalban. (The municipalities Batas Pambamsa 799: Angono, Baras, Binangonan, Cardona, Jala-Jala, Morong, Pililla, Tanay and Teresa

1.4 STUDY OUTLINE

1.4.1 Study Framework

The Study commenced in August 1990 and was completed in March 1992. The Study period was divided into three stages: Stage I (Basic Survey), Stage II (Detailed Survey) and Stage III (Analysis and Planning).

The Study procedure is flowcharted as shown in Figure 1.2.

(1) Stage I: Basic Survey

This stage involves the review and analysis of existing studies and data, field geological reconnaissance, arrangement of existing well inventory, questionnaire survey on groundwater utilization, preparation of the database system and appraisal survey on the ability and availability of local drilling contractors.

(2) Stage II: Detailed Survey

The Study at this point includes investigation of MWSS wells, the electric resistivity survey of the Antipolo area, drilling and pumping tests, installation of monitoring equipment, pumping tests of existing wells, simultaneous observation of water levels, survey on groundwater utilization (collection and analysis of questionnaires) and preparation of the database system. Various data obtained throughout Stage II are arranged for their use in Stage III.

(3) Stage III: Analysis and Planning

The Study at Stage III concerns the planning of the rehabilitation program for MWSS wells, the groundwater development and management program, the analysis of saltwater intrusion and the planning for the groundwater monitoring system in MSA.

1.4.2 Study Items

Stage I: Basic Survey

The Basic Survey at Stage I is undertaken to:

- o Overview existing MWSS water supply systems and MWSS's future plan, and to make clear the role and effect of the Study;
- o Reveal the hydrogeologic condition of the Metro Manila groundwater basin by field geological reconnaissance;
- o Confirm and decide on the items for inclusion to those of Stage II.

In order to achieve the targets at Stage I, the following Study Items were undertaken:

(1) Collection and arrangement of data and information related to the Study
(2) Explanation of the Inception Report
(3) Review of existing groundwater reports
(4) Arrangement of existing well inventory
(5) Field geological reconnaissance
(6) Survey on the ability and availability of local drilling companies
(7) Survey on the condition of actual groundwater utilization
(8) Review of the organization and management systems
(9) Review of existing water supply systems
(10) Review of urban planning
(11) Preparation for the establishment of a groundwater database system

Stage II: Detailed Survey

The detailed survey at Stage II is undertaken to obtain the hydrogeologic data necessary for the analysis and planning in Stage III.

In order to achieve the targets at Stage II, the following Study Items were conducted:

(1) Survey on MWSS deep wells for rehabilitation
(2) Test drillings and pumping tests
(3) Pumping test of existing deep wells
(4) Groundwater sampling and analysis
(5) Survey on groundwater use
(6) Arrangement of input data for the database system
(7) Installation of observation equipment

Stage III: Analysis and Planning

The Analysis and Planning at Stage III is undertaken to clarify the hydrogeology of the Metro Manila groundwater basin and to establish groundwater development/management plan based on the survey results obtained in Stages I and II.

In order to achieve the targets at Stage III, the following Study Items were conducted.

(1) Investigation and rehabilitation of MWSS wells
(2) Evaluation of the effects of rehabilitation works
(3) Analysis of hydrogeologic structure and aquifer unit
(4) Preparation of database system
(5) Investigation of water supply systems
(6) Urban development planning
(7) Water demand projections
(8) Groundwater modeling of flow and solute transport
(9) Investigation of organization and management systems
(10) Simultaneous hydrological observations
(11) Analysis of hydrology and water quality
(12) Preparation of water supply systems
(13) Groundwater simulations
(14) Rehabilitation program of MWSS
(15) Groundwater development plan in Antipolo
(16) Groundwater monitoring system in Metro Manila

1.5 ORGANIZATION OF THE STUDY

In carrying out the Study, the Metropolitan Waterworks and Sewerage System (MWSS) of the Republic of the Philippines acted as the counterpart agency and the Japan International Cooperation Agency (JICA), the official agency in behalf of the Government of Japan.

The study period is from August 1990 to March 1992.

The Study was carried out by a joint study team composed of a JICA team and a MWSS team:

<u>JICA Study Team</u>

Toru HAYASHI	Team Leader/Water Supply Engineer
Akira KAMATA	Co-Team Leader/Hydrogeologist
Masaharu KINA	Urban Planner
Shoichi OOMORI	Geologist
Naoaki SHIBASAKI	Hydrogeologist
Kenji TAKAYANAGI	Hydrogeologist
Masuomi HIROYAMA	Water Quality Engineer
Reynaldo R. MEDINA	Hydrologist
Mitsuo TSUTSUMI	Drilling Supervisor
Yu AYUSAWA	Drilling Supervisor
Kakuji SUEMATSU	Well Engineer
Takafumi KIGUCHI	Water Supply Planner

<u>MWSS Team</u>

Rolando E. ROCA	Manager, Planning & Programming Dept.
Victor J. BALAGTAS	Project Manager C, MMGWDP
Ernesto V. ALCANTARA	Asst. Project Manager C, MMGWDP
Renee A. PINGOL	Sr. Statistician
Norma M. SANTIAGO	Sr. Hydrogeologist A
Godofredo C. CARPIO	Hydrogeologist A
Richard G. BURCE	Supervising Engineer
Romeo S. MANLAPIG	Sr. Engineer A
Rogelio G. OTIVAR	Sr. Engineer A

Enrico A. RUIDERA	Sr. Draftsman
Rodulfo M. NOVEDA	Engineering Assistant A
Rodolfo B. VICENTE	Engineering Assistant A
Oliver B. PADRON	Sr. Engineer A
Noel B. ZACARIAS	Engineering Assistant A
Daisy C. ARANAN	Data Encoder/Controller
Juliana F. VELADO	Data Encoder/Controller
Ramon N. MENDOZA	Engineering Assistant A
Lorenzo A. DUMANDAN	Engineering Assistant A
Judith S. CADAPAN	Draftsman A
Gemmalyn S. SANTOS	Administrative Service Assistant A
Olivia M. SANTIAGO	Clerk/Processor B

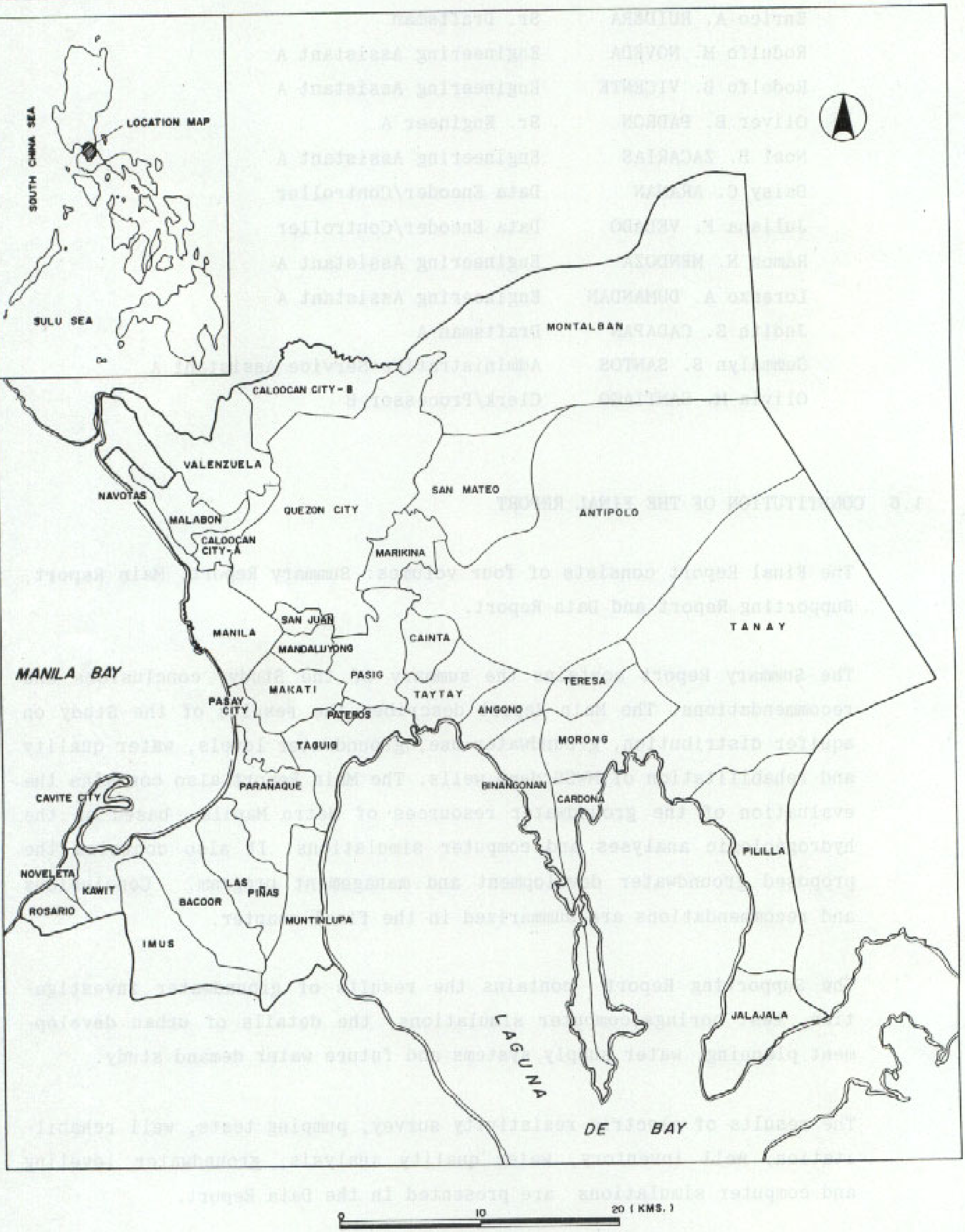
1.6 CONSTITUTION OF THE FINAL REPORT

The Final Report consists of four volumes: Summary Report, Main Report, Supporting Report and Data Report.

The Summary Report contains the summary of the Study, conclusions and recommendations. The Main Report describes the results of the Study on aquifer distribution, groundwater use, groundwater levels, water quality and rehabilitation of MWSS deep wells. The Main Report also contains the evaluation of the groundwater resources of Metro Manila based on the hydrogeologic analyses and computer simulations. It also contains the proposed groundwater development and management program. Conclusions and recommendations are summarized in the final chapter.

The Supporting Report contains the results of groundwater investigation, test borings,computer simulations, the details of urban development planning, water supply systems and future water demand study.

The results of electric resistivity survey, pumping tests, well rehabilitation, well inventory, water quality analysis, groundwater leveling and computer simulations are presented in the Data Report.



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA JAPAN INTERNATIONAL COOPERATION AGENCY	FIGURE 1.1 THE STUDY AREA

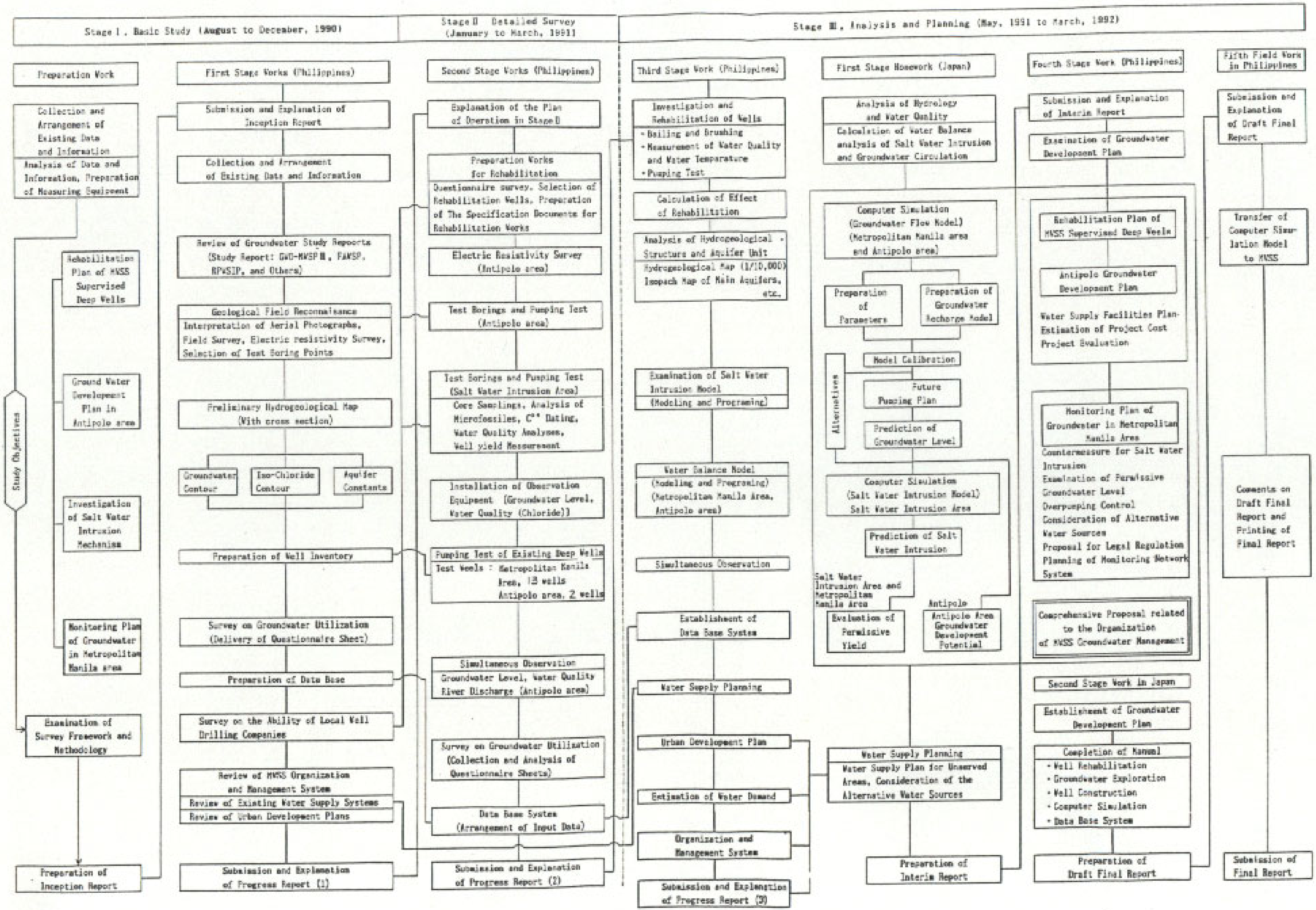


FIGURE 1.2 FLOWCHART OF THE STUDY

CHAPTER 2

SOCIO-ECONOMY AND WATER SUPPLY

CHAPTER 2 SOCIO-ECONOMY AND WATER SUPPLY

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CHAPTER 2 SOCIO-ECONOMY AND WATER SUPPLY

2.1 SOCIO-ECONOMY

2.1.1 General

There are thirteen administrative regions in the Philippines including the National Capital Region (NCR). The Study Area comprises the NCR and the two provinces (Rizal and part of Cavite) of Region IV.

The NCR, better known as Metro Manila, is composed of four (4) cities and thirteen (13) municipalities, namely: the cities of Manila, Quezon, Pasay and Caloocan; and the municipalities of Las Piñas, Makati, Malabon, Mandaluyong, Marikina, Muntinlupa, Navotas, Parañaque, Pasig, Pateros, San Juan, Taguig, and Valenzuela.

Region IV has the most number of provinces, totaling eleven (11): Aurora, Batangas, Cavite, Laguna, Mindoro Oriental, Mindoro Occidental, Marinduque, Palawan, Quezon, Rizal and Romblon. In the MSA, Rizal has fourteen (14) municipalities, while Cavite has one city and five (5) municipalities in the Study Area.

2.1.2 Land Area and Population

(1) Land Area

The Philippines has a total land area of approximately 300,000 km^2. Region IV, among all the regions, has the largest land area (46,924.10 km^2), representing 15.64 percent of the country's total. NCR, on the other hand, has the smallest land area (636 km^2), representing only 0.21 percent of the country's total.

(2) Population and Distribution

The 1990 Philippine Population Census (Preliminary Count by the National Statistics Office as of May 1990) placed the population of the country at 60,685,000. This figure is 12,587,000 more than the population ten years ago (1980) and reflects an annual growth rate of 2.3 percent

(Table 2.1.1 and Figure 2.1.1).

Among the thirteen regions, the NCR and the Southern Tagalog Region (Region IV) account for the bulk (36.7 percent) of the country's total population. The total population of Metro Manila is 7,833,000. Cavite and Rizal have respective populations of 458,771 and 880,608. NCR and Region IV are the most urbanized and economically developed of the 13 regions.

The MSA covers the whole of NCR and 3.2 percent of Region IV. It comprises five (5) cities and thirty-two (32) municipalities whose combined population in 1990 was 9,172,379 (6,805,630 in 1980). This population figure represents 15.17 percent of the country's total and reflects an increase of 34.78 percent over the 1980 figure, or an annual growth rate of 3.03 percent.

The population densities in the MSA are shown in Table 2.1.2 and Figure 2.1.2 and 2.1.3.

2.1.3 Social Profile

(1) Social Development Indicators

The NCR and Region IV as a whole has the major advantage among the regions in terms of social services, physical facilities and those amenities associated with urban life. However, a large portion of its population still bears the brunt of poverty and its attendant ills: unemployment, underemployment, congestion, ill-health and malnutrition, poor delivery of basic services, etc. Table 2.1.3 shows the social profile of the regions using major indicators.

(2) Labor Force

The economically active population within the age range of 15-64 years constitutes the country's labor force (NSO definition). In 1988, the total population of those who are 15 years old and above was 35,865,000 (Table 2.1.4).

For Metro Manila, its labor force in 1989 was estimated to be 3.1 million, representing around 60 percent of the working age population, and which for the last three years increased at an annual average rate of 3.0 percent.

(3) Employment

Total employment in the Philippines was 20,595,000 in the third quarter of 1986 (Table 2.1.4). Employment rate for the same period was 88.9 percent, a reduction from the 95.0 percent registered in 1980. The employment rate, however, improved to 91.7 percent in 1988.

For Metro Manila, the employment rate was estimated at 82.2 percent in 1989, slightly lower than the 84.8 percent registered in the third quarter of 1988 and slightly higher than the 1986 average of 80.6 percent.

2.1.4 Economic Profile

(1) Gross Regional Domestic Product

The National Capital Region (NCR) maintained in 1989 its traditional lead among the regions by producing a hefty ₱33.2 billion worth of Gross Regional Domestic Product (GRDP). The primacy of NCR in setting the trend of the national economy may be gleaned from its performance during the 1980-1986 period when its annual contribution to the total Gross Domestic Product (GDP) averaged as much as 31 percent (Table 2.1.5).

(2) Economic Sectors

In the medium- and long-term periods, the capital region is envisioned to have its industry dominance gradually reduced by the transfer of its major socio-economic activities to the industrial centers of its regional neighbors. It will, however, hold on to its lead as center for trade, finance and commerce, education and as seat of the National Government. In consonance with the limits that its environment and geography can provide, existing levels of industrial activity shall be maintained.

(3) Household Income

According to the Family Income and Expenditures Survey (FIES) conducted by the NSO in 1985, the average annual family income in the Philippines was P31,052, in Region IV P29,985, in NCR P57,193, in Cavite Province P39,759, and in Rizal P38,518 (Table 2.1.6).

With the current economic situation, declining real incomes place increased demands on the government's shelter, health and social infrastructure programs.

(4) Industry and Trade

The industry sector in the Philippines is dominated by manufacturing whose contribution since 1972 to the value added by industry averages to around 75%. The share of construction and utilities has varied between 15% to 20% of total industry value added.

In the Study Area, the industry sector is composed of manufacturing, construction, electricity, gas and water.

2.1.5 Housing

According to the 1990 Census of Population and Housing of the National Statistics Office (NSO), there are about 1,836,564 unit-houses in the MWSS service area. Of this total, Metro Manila accounted for 1,557,000 units (84.8%), Cavite (that part of the Study Area) for 91,435 units (5.0%), and Rizal Province for 188,129 units (10.2%).

Table 2.1.7 presents by type of building the number of families in the country and the NCR. The majority (67.1%) of families in the NCR live in single houses. The remaining 32.9% live in duplex (4.23%), apartment/accesoria/condominium (21.62%), improvised buildings or barong-barong (4.9%), commercial/industrial/agricultural buildings (1.8%) and other dwellings (0.4%) such as natural shelters, boats, etc.

2.1.6 Land Use

(1) Classification of Land Use

The total land area of the Study Area is estimated at 212,555 hectares and is divided as follows:

NCR	63,600 Has.
Cavite (S.A.)	18,572 Has.
Rizal (*)	130,383 Has.

(*) NCSO, Bureau of Lands : 130,383 Has.
BSWM : 130,892 Has.
Office of the Provincial Assessor : 157,345 Has.

The data from the Office of the Provincial Assessor is the latest information (1990). However, the official data of the NCSO is the one adopted for this Study.

Land use is classified into the following six major categories: (a) Built-up area; (b) Agricultural area; (c) Forest; (d) Wetland; (e) Open Space; and (f) Others.

1) Built-up Area

In Metro Manila the built-up area occupies 47 percent of the total area. That of the Rizal province occupies 11.7 percent of the province's total.

The built-up areas of the Rizal Province are sporadically scattered. Major ones are concentrated in Cainta, Taytay and Antipolo because of their contiguity to Metro Manila.

The major built-up areas of Cavite are composed of the municipalities ringing the Metropolitan Area, namely, Bacoor, Kawit, Noveleta and Cavite City. Imus is also rapidly expanding and experiencing the suburbanizing trend of Metro Manila.

2) Agricultural Area

This category includes all areas that are intended for agriculture: rice field, cropland, plantation, etc.

In Rizal, the total agricultural area is about 19,167 hectares or 14.7 percent of the total area of the province. The southern part of Imus constitutes this type of area in Cavite.

3) Forest

Forests are found mainly in the mountainous parts of Montalban, Antipolo and Tanay, and also in the lower hills and along waterways or creeks. They cover about 16,618 hectares or 12.7 percent of the total area of the Rizal province and are the next most extensive natural cover of the Rizal province.

4) Wetland

Wetland areas are found in low-lying coastal plains adjacent to large bodies of water.

5) Open Space

This category consists of those areas associated or mixed-up with built-up areas. Most of the open spaces are found in the NCR.

6) Others

Under this category are areas which could not be classified under the preceeding five categories.

(2) Land Use Development

Responding to the social, economic and political activities in recent years, changes in the land use pattern in Metro Manila may be summarized as follows:

- Increase in the number and density of squatter housing areas.

- The development of middle and upper class residential subdivisions on urban peripheries where land is inexpensive.

- The development in the main urban area of townhouses and high-rise condominiums for the middle and upper income market.

- The conversion of agricultural and fishpond areas for residential and/or commercial use.

- The emergence and intensification of suburban commercial nodes at intersections of major transport routes in response to the need of the growing number of residential subdivisions in the suburbs.

- The location of new and the relocation of existing industries at cheaper sites to the north (Bulacan), east (Rizal) and south (Cavite). These sites are along major transport routes.

2.1.7 Infrastructure

In contrast to the rapid population growth witnessed during the past few decades, the infrastructure situation in the NCR has not kept pace as to be adequate to the basic needs of the inhabitants.

(1) Transportation

The transport system of the country and Study Area remains to be dominated by land transportation facilities. This type of system accounts for 65 percent of the total domestic passenger traffic. The latest technology in land transport is the Light Rail Transit which was opened in Metro Manila to decongest the streets.

The public transportation in Metro Manila, Cavite and Rizal is predominantly road-based, consisting largely of jeepneys and buses for primary and secondary routes, and tricycles and pedicabs for feeder routes.

(2) Sewerage System

Two sewerage systems are working in the NCR. One is the Central Manila

Sewerage System constructed before 1909 with an original overload capacity of 450,000 people. Presently, this system covers 1,850 hectares and serves 530,000 people. It has a total length of 240 km. The other is in Quezon City and Makati, and which is made up of isolated systems in subdivisions and commercial areas serving 350,000 people. Total length is about 140 km. The rest of the NCR populace discharges its wastewater either into storm drains, septic tanks or directly to esteros.

(3) Power Supply

The country's electric power is generated by the state-owned National Power Corporation (NPC). Power generation is done through geothermal means or through the use of oil, coal, hydropower, and other energy resources. The generated power is supplied (at 115 kv or at 230 kv) to the Manila Electric Company (MERALCO) which distributes power over the whole of NCR, Rizal and Cavite.

2.2 WATER SUPPLY SYSTEMS

2.2.1 General Situation in the Country

(1) Present Water Supply Services

As of end-1987, around 63% of the country's total population have access to public water supply systems. The rest of the population, approximately 37%, sourced their water from open dug wells, rainwater cisterns, lakes and streams, a number of which are of doubtful quality. The served population then was 86% for Metro Manila and its contiguous areas, 55% for other urban areas,and 62% for the rural areas. Out of the 86% covered in Metro Manila, however, only 57% were directly served with MWSS water, 16% were served indirectly by MWSS through ambulant vendors, and the rest acquired water through private wells and other undetermined sources. Present water supply coverage in the country is shown in Table 2.2.1. Numbers of families by main water sources and its percentage are shown in Table 2.2.2 and Figure 2.2.1.

In Metro Manila, water supply service consists of individual house connections, private wells, some public standpipes in blighted areas and ambulant vendors. In large urban centers outside Metro Manila, majority of the people is served by Level III systems. In the rural areas, however, the most common water supply facilities are protected wells and developed springs. There are also some Level II and III systems but the latter are generally found only in large poblaciones. Table 2.2.3 shows the condition of existing water supply facilities.

(2) Institutional Aspect

Provision of water supply facilities is under the responsibility of the Department of Public Works and Highways (DPWH) and two of its attached agencies namely: the Metropolitan Waterworks and Sewerage System (MWSS) and the Local Water Utilities Administration (LWUA). The MWSS operates the water supply and sewerage systems in Metro Manila and its contiguous areas, while the LWUA handles the development and improvement of water and sewerage systems in the areas not covered by MWSS.

The DPWH is concerned mainly with the development of Level I systems and is the lead agency in establishing national water supply plans and programs upon which all other agencies involved in the sector base their respective development plans. Other agencies involved in water supply include the National Water Resources Board (NWRB) and the Department of Interior and Local Governments (DILG). DILG's participation is limited to the general administrative/institution building activities, while NWRB's involvement is mainly on policies and regulations concerning the proper utilization and rights thereof of water resources all over the Philippines.

A matrix of responsibility of the concerned agencies in the water supply sector is presented in Table 2.2.4.

(3) Master Plan of the Philippines

To provide direction, establish priorities, and rationalize implementation of projects in the sector, the Philippine Government prepared in 1980 the Integrated Water Supply Program for the period 1980-2000 and the 1982 Philippine Rural Water Supply Master Plan. These were later superseded in 1987 by the Water Supply, Sewerage, and Sanitation Master

Plan for the period 1988-2000. This latest plan contains the sectoral objectives, policies, programs, institutional arrangements, and financial and economic considerations.

The Master Plan calls for a two-stage implementation of projects: the first stage covering the period 1988 to 1992 and the second stage encompassing the period 1993-2000.

As shown in Table 2.2.5, the following activities are envisaged during the first stage (1988-92):

In Metro Manila and its contiguous areas, a package of projects is to be undertaken to improve the existing facilities and expand their coverage. These are the Manila Water Supply Rehabilitation Project I (MWSRP I), the Metro Manila Water Distribution Project (MMWDP), the Angat Water Supply Optimization Project (AWSOP), Manila Water Supply Rehabilitation Project II (MWSRP II), Fringe Areas Water Supply Project (FAWSP) and Rizal Province Water Supply Improvement Project (RPWSIP). These projects are targeted to expand and improve the service coverage of the system to 87% of the metropolitan population.

The second stage (1993-2000) of this Master Plan considers the complete water supply coverage of both urban and rural areas with emphasis on proper operation and maintenance of facilities, and the gradual construction of sewerage systems. Table 2.2.6 reflects the physical targets, investment requirements and service coverage per sector of the second stage.

In Metro Manila, the Manila Water Supply Project III was planned to boost the service coverage to 97%. (This project, however, has been deferred after the commencement of the construction stage due to high cost of construction.)

2.2.2 Present Situation in the MWSS Service Area (MSA)

(1) Service Area

Based on the Republic Act No. 5234, the MWSS has jurisdiction over the following areas (refer to Figure 2.2.2):

- Metropolitan Manila (National Capital Region):

  4 cities: Manila, Pasay, Quezon, and Caloocan

  13 municipalities: Las Piñas, Makati, Malabon, Mandaluyong, Marikina, Muntinlupa, Navotas, Parañaque, Pasig, Pateros, San Juan, Taguig, Valenzuela

- Rizal Province:

  14 municipalities: Angono*, Antipolo, Baras*, Binangonan*, Cainta, Cardona*, Jala-Jala*, Montalban, Morong*, Pililla*, San Mateo, Tanay*, Taytay, Teresa*

  * Merged into MSA by the Batas Pambansa Blg. 799, approved April 27, 1984.

- A Part of Cavite Province:

  1 city: Cavite

  5 municipalities: Bacoor, Imus, Kawit, Noveleta, Rosario

- Lungsod Silangan (Tagalog word, Eastern Cities - not specified)

- Other areas that may come within the development path of the expanding Metropolitan Manila Area, which areas the Board of MWSS may determine and declare as contiguous to its service area and requiring immediate attention, under such terms and conditions that may be agreed upon by the parties concerned. -- Subject to the approval of the President.

The Central Distribution System (CDS) of MWSS, which distributes water from two surface water treatment plants, covers areas within Metro Manila plus some parts of Bacoor and Kawit of Cavite Province. Peripheral areas of Metro Manila such as the northern part of Caloocan City, the northern part of Quezon City, most of Valenzuela, the eastern part of Marikina, a part of Taguig, a part of Parañaque, most of Las Piñas, and most of Muntinlupa, are not covered by the CDS. These areas and other areas in the Rizal and Cavite provinces predominantly rely on isolated groundwater supply systems operated by MWSS and other public entities such as Water Districts, municipalities, and barangays. Figure 2.2.3 presents the areas covered by existing MWSS water supply systems. The meshed area in this figure is covered by the CDS and is mainly supplied with surface water; the striped area (outlying area) is served by the MWSS groundwater supply systems. The groundwater supply is thus very important to places under these latter areas, though representing only a small percentage of the total water supply of MWSS.

AWSOP that is currently under implementation targets an additional 15 m3/sec of surface water. It also aims to expand the area covered by CDS. After completion of this project, the northern part of abovesaid outlying area will be part of the CDS.

In the future, there will be a diminution in the relative importance of groundwater because of the increase in surface water supply. However, the areas that could not be reached by surface water, i.e., areas in the Rizal Province, shall solely rely on groundwater.

(2) Served Population and Water Amount

Table 2.2.7 presents the statistics on MWSS water supply and the size of the population served for the period 1984-1990. Figure 2.2.4 is derived from the said table's data for the year 1990. Based on the 1990 data, total population served is 8.2 million or 90% of total population within MSA. Of this figure, 2.6 million or 29% of total population is estimated as illegal users of the system.

Per capita water consumption from 1984 to 1990, however, has been decreasing. From the per capita water consumption for house connections in the year 1984, a decrease of 22% or 39 lpcd was registered. This fact does not imply a water saving by users, but it results from water shortage caused by inadequate water supply capacity of the MWSS system. In this regards, the development of new water sources for MWSS is an urgent necessity.

(3) Existing Water Supply Facilities

a) Outline of the System

The MWSS's water sources consist of surface water and groundwater. The raw water drawn from surface water facilities, namely, Ipo Dam (Angat River, Ipo River), La Mesa Dam (Novaliches Watershed), and Alat Diversion Dam (Alat River), are conveyed to two (2) treatment plants, namely, the Balara Treatment Plant (Nos. 1 and 2) and the La Mesa Treatment

Plant.

Treated water from the Balara Treatment Plant is sent to the San Juan and the Pasig Reservoirs and the Balara Pumping Station. That from the La Mesa Treatment Plant is sent to the Bagbag Reservoir.

The groundwater drawn from MWSS deepwells are injected directly into the distribution systems after chlorination.

The distribution system serving Metro Manila and Cavite City operates eight booster pumping stations and eight mini-booster pumping stations.

The outline of the system from the surface water sources to the treated water reservoirs is illustrated by Figure 2.2.5.

b) Water Source

Surface water and groundwater sources of MWSS have a total capacity of around 2.495 MCM per day as presented in Table 2.2.8.

The water drawn from these sources are conveyed to treatment plants through two tunnels and four aqueducts.

In 1990, the total volume of raw water drawn from all surface water sources was 916.9 MCM. Average daily supply was 2.512 MCM or about 101% of available water source yield. Table 2.2.9 compares the raw water supply drawn from all surface water source for the period 1986 to 1990.

Average daily raw water supply from surface water sources for the last five years was about 2.436 MCM. Considering the drought during dry season, this amount cannot be expected to answer the water demand. New water sources must be developed.

Table 2.2.10 presents the monthly raw water supply amount. Figure 2.2.6 which was derived from this table shows that the monthly raw water supply withdrawals from Ipo/Alat/La Mesa dams vary widely. During dry season, the supply is extremely low from these dams. As shown in this figure, stable supply of MWSS System relies on Angat Dam. Under AWSOP, an additional 15 m^3/sec (1.296 MCM/day) of water will be supplied to the system from Angat Dam through Ipo Dam and a new conveyance system.

Based on the 1990 MWSS Annual Report, MWSS gained about 33 MCM of groundwater through MWSS-owned deepwells.

c) **Water Production**

MWSS's two treatment plants, namely, the Balara Treatment Plant (Nos. 1 and 2) and the La Mesa Treatment Plant, have a combined treatment capacity of around 2.6 MCM/day (Figure 2.2.7 and 2.2.8). In addition to this output, about 82,000 m3/day of groundwater were produced by MWSS through its 131 operational deepwells scattered within the MSA excluding BP799 coverage. Table 2.2.11 presents the statistics on water production by MWSS from 1985 to 1990. Outlines of the two treatment plants are presented in Table 2.2.12.

As of March 1991, MWSS has 258 deepwells of which 131 wells are in operation. The water from these wells are injected into the distribution pipelines directly or distributed through booster pumping stations. Details on groundwater use are discussed in Section 3.3 of the Main Report.

d) **Water Distribution**

Water from the Balara and the La Mesa treatment plants and groundwater deepwells are distributed to the Central Distribution System (CDS) and other isolated distribution systems directly or through distribution reservoirs and booster pumping stations (Figure 2.2.9).

(4) **Water Quality**

Table 2.2.13 presents the results of physical and chemical analyses conducted in 1989 on raw water, chemically treated water, sedimented water, filtered water and finished water of the Balara and the La Mesa treatment plants. Though values of other water quality parameters are almost passable, the turbidity of the finished water of Balara is relatively high.

Based on the Accomplishment Report for CY 1989 of the MWSS's Central Laboratory Division, the percentage of satisfaction in the bacteriological examination on 1,714 water samples from MWSS house connections was 100%, while 747 samples from MWSS deepwells shows 78.4% satisfaction. (This is shown in Table 2.2.14.) On the other hand, the Process Quality Unit reported less satisfaction percentages for the same kind of examination. The residual chlorine of samples seems to be caused by low pressure in the distribution system, poor construction work of the service connections, and small distribution pipe sizes.

2.2.3 Ongoing and Proposed Projects

(1) Ongoing Projects

MWSS is implementing several rehabilitation and expansion projects with the twin aims of reducing non-revenue water (NRW) and increasing the number of service concessionaires (Table 2.2.15).

(2) Proposed Projects

Table 2.2.16 outlines the MWSS proposed projects. These projects are planned with the principal objectives of expanding the service area and augmenting the water production capacity.

2.2.4 Future Water Source and Production Capacity

(1) Water Source

Based on the implementation plans of ongoing projects, only the AWSOP can be expected to augment the yield of water sources by an annual average of 1.3 MCM/day or 15 m^3/sec. Several projects though are lined up by the MWSS to further augment the water sources yield: RPWSIP, UATP, MWSP III, MNEWSP (Table 2.2.17). However, these projects are still on the feasibility study or detailed design stage and financial sources for them have yet to be finalized. As such, their implementation schedules could only be tentative.

(2) Water Production

Since the completion of the La Mesa Treatment Plant in 1985, water production capacity of MWSS has remained at 2.636 MCM/day. Among MWSS's ongoing projects, only AWSOP is planned for augmenting this capacity through construction of the La Mesa Treatment Plant No. 2 with a capacity of 0.9 MCM/day.

Several courses for increasing supply are being resorted to. One involves the recovery of NRW. Targeted to be recovered by the MWSRP I and II are 0.765 MCM/day of NRW. As more than half of this amount is estimated to be taken up by leakage from the distribution lines, around 0.4 MCM/day of treated water will be available for consumption. Another course of increasing supply involves project proposals to augment water production capacity, but these are still on the feasibility study or detailed engineering stage.

The highest probability of being implemented among the MWSS proposed projects on increasing production capacity appears to fall on the MNEWSP. This project which will use Wawa River as water source is expected to contribute 72 MLD. Other projects propose utilization of Laguna de Bay and groundwater. For reasons of finances and the long construction period required, implementation of MWSP III has been deferred. This project could have been the biggest step yet to be taken in augmenting water production capacity.

TABLE 2.1.1 POPULATION AND GROWTH RATE BY REGION FOR CENSUS YEARS

	POPULATION (THOUSANDS)														GROWTH RATE (%)				
	1960		1970		1975		1980		1985 (Estimate)		1990		1960/ 1970	1970/ 1975	1975/ 1980	1980/ 1985	1985/ 1990
Philippines	27,088	100.0	36,684	100.0	42,071	100.0	48,098	100.0	54,688	100.0	60,685	100.0	3.1	2.8	2.7	2.6	2.4
NCR (National Capital Region)	2,462	9.1	3,697	10.8	4,970	11.8	5,296	12.3	6,942	12.7	7,929	13.1	4.9	4.6	3.6	3.2	3.1
Region																	
1. Ilocos	2,428	9.0	2,991	8.1	3,269	7.8	3,541	7.4	3,903	7.1	3,551	5.9	2.1	1.8	1.6	2.0	1.6
2. Cagayan Valley	1,202	4.4	1,691	4.6	1,933	4.6	2,215	4.6	2,521	4.6	2,341	3.9	3.5	2.7	2.8	2.6	2.0
3. Central Luzon	2,525	9.3	3,615	9.9	4,210	10.0	4,803	10.0	5,456	10.0	6,199	10.2	3.7	3.1	2.7	2.6	2.5
4. Southern Tagalog	3,081	11.4	4,457	12.1	5,214	12.4	6,119	12.7	7,089	13.0	8,266	13.6	3.8	3.2	3.3	3.0	3.0
5. Bicol	2,363	8.7	2,967	8.1	3,194	7.6	3,477	7.2	3,922	7.2	3,910	6.4	2.3	1.5	1.7	2.4	1.3
6. Western Visayas	3,078	11.4	3,618	9.9	4,146	9.8	4,526	9.4	5,092	9.3	5,393	8.9	1.6	2.8	1.8	2.4	1.8
7. Central Visayas	2,523	9.3	3,033	8.3	3,387	7.9	3,787	7.9	4,195	7.7	4,593	7.6	1.9	2.2	2.3	2.1	1.9
8. Eastern Visayas	2,041	7.5	2,381	6.5	2,600	6.2	2,799	5.8	2,073	5.6	3,055	5.0	1.6	1.8	1.5	1.9	0.9
9. Western Visayas	1,351	5.0	1,869	5.1	2,048	4.9	2,528	5.3	2,863	5.2	3,159	5.2	3.3	1.8	4.3	2.1	2.3
10. Northern Mindanao	1,297	4.8	1,953	5.3	2,314	5.5	2,759	5.7	3,718	5.8	3,510	5.8	4.2	3.5	3.6	2.9	2.3
11. Southern Mindanao	1,353	5.0	2,201	6.0	2,715	6.5	3,347	7.0	3,836	7.0	4,457	7.3	5.0	4.3	4.3	2.8	2.9
12. Central Mindanao	1,383	5.1	1,941	5.3	2,070	4.9	2,271	4.7	2,598	4.8	3,171	5.2	3.4	1.3	1.9	2.7	3.5

Source: 1960-1980 Philippine Statistical Yearbook 1989 (NEDA)
1985 Philippine Yearbook 1989 (NSO)
1990 1990 Census of Population and Housing (NSO)

TABLE 2.1.2 POPULATION DENSITY OF THE STUDY AREA

City/Municipality	POPULATION DENSITY (Persons/Ha.)				
	1970	1975	1980	1985	1990
NCR	62.4	78.1	93.2	109.2	123.2
1. Manila	347.5	386.2	425.7	461.1	414.4
2. Pasay	148.4	183.5	207.0	238.7	254.7
3. Quezon	45.4	57.6	70.1	82.9	98.2
4. Caloocan	49.2	71.2	83.8	97.4	133.7
5. Las Pinas	11.0	19.7	32.9	50.1	68.9
6. Makati	88.6	111.9	124.6	140.9	151.2
7. Malabon	60.5	74.7	81.6	94.1	118.4
8. Mandaluyong	57.5	70.1	79.0	89.9	95.0
9. Marikina	29.2	43.3	54.4	66.8	79.2
10. Muntinlupa	13.9	20.2	29.3	39.3	59.5
11. Navotas	320.2	373.5	485.2	566.8	715.4
12. Paranaque	25.4	41.5	54.5	69.6	78.3
13. Pasig	120.4	161.5	206.6	257.5	303.8
14. Pateros	24.5	31.6	38.7	46.5	49.0
15. San Juan	100.5	117.8	125.1	137.0	122.1
16. Taguig	16.4	21.9	39.8	49.3	79.2
17. Valenzuela	20.9	32.0	45.2	61.8	72.3
CAVITE	12.4	14.4	17.5	21.0	24.7
18. Bacoor	9.2	11.9	17.2	22.3	30.6
19. Cavite City	64.0	69.7	74.1	81.7	77.5
20. Imus	4.5	5.0	6.1	7.4	9.5
21. Kawit	21.1	25.2	29.4	35.3	35.6
22. Noveleta	19.5	22.4	26.7	31.6	40.0
23. Rosario	42.0	50.7	58.8	71.5	80.0
RIZAL	2.4	3.2	4.3	5.2	6.8
24. Angono	4.7	6.8	10.2	13.0	17.5
25. Antipolo	0.9	1.3	2.3	3.0	5.7
26. Baras	3.1	4.2	4.8	5.7	7.1
27. Binangonan	7.2	8.7	11.1	12.9	12.8
28. Cainta	20.3	36.3	57.9	81.2	107.5
29. Cardona	5.4	6.8	7.9	8.8	10.5
30. Jala-Jala	1.6	1.9	2.4	2.8	3.3
31. Morong	5.0	5.6	6.6	7.0	8.6
32. Pililla	2.0	2.6	3.1	3.6	4.4
33. Montalban	0.7	1.0	1.3	1.6	2.0
34. San Mateo	4.5	6.0	8.0	9.5	12.6
35. Tanay	1.0	1.4	1.7	2.0	2.0
36. Taytay	13.8	17.3	22.3	25.6	33.3
37. Teresa	5.0	7.2	7.9	8.6	11.1

TABLE 2.1.3 REGIONAL SOCIAL PROFILE

	CBR 1986	CDR 1987	IMR 1986	LITERACY RATE 1989	PREVAL. RATE 1989	UNEMPL. RATE(%) 1985
Philippines	26.70	5.80	35.00	89.90	19.42	7.12
NCR	32.10	7.00	33.40	98.10	9.44	22.11
CAR	-	-	-	86.30	17.07	-
Region I	29.40	7.00	37.70	90.60	19.87	3.65
Region II	27.90	5.80	43.60	88.50	17.41	5.76
Region III	28.50	5.50	29.60	93.60	18.70	6.91
Region IV	28.70	6.30	37.30	93.00	20.15	6.56
Region V	27.40	7.30	41.40	87.60	27.53	2.97
Region VI	20.20	6.20	43.50	88.00	22.77	4.52
Region VII	27.80	6.50	35.20	88.00	17.07	3.38
Region VIII	18.40	5.80	41.00	81.00	28.57	5.53
Region IX	19.10	3.30	32.40	81.70	16.85	6.55
Region X	28.40	4.90	33.20	90.50	19.04	4.20
Region XI	30.10	4.40	23.00	90.40	17.21	5.17
Region XII	18.30	2.70	25.30	78.9	19.46	1.99

Notes:

CBR - Crude Birth Rate per 1,000 population
CDR - Crude Death Rate per 1,000 population
IMR - Infant Mortality Rate per 1,000 population
LITERACY RATE - For the household population 10 years old and above
PREVALENCE RATE -

Sources: 1989 Philippine Statistical Yearbook, NSCB
1989 Functional Literacy, Education and Mass Media Survey, Department of Health

TABLE 2.1.4 HOUSEHOLD POPULATION 15 YEARS OLD AND OVER BY EMPLOYMENT STATUS AND BY REGION

Region	1986				1988			
	Number ('000)	% in Labor Force	Employment Rate %	Unemployment Rate %	Number ('000)	% in Labor Force	Employment Rate %	Unemployment Rate %
Philippines	33,838	63.8	88.9	11.1	35,865	65.4	91.7	8.3
Region IV	4,558	63.8	87.0	13.0	4,729	64.6	91.8	8.2
NCR	4,727	58.6	71.4	28.6	5,005	60.2	82.8	17.2
Cavite (*)	606	54.6	94.3	5.8	657	54.5	96.4	3.6
Rizal	455	62.2	84.8	15.2	480	67.7	91.1	8.9
Total	5,788	58.5	74.8	25.2	6,142	60.2	84.8	15.2

* All Cavite Province. The numbers are not applicable for the Study Area, but may be used as reference however.

Source: National Statistic Office (NSO), Region IV

TABLE 2.1.5 GROSS REGIONAL DOMESTIC PRODUCT, FOR 1987-1988
(at constant 1972 prices)

REGION	Actual (in PM)		Growth Rate	Per Capita GRDP (in P)	Growth Rate (in %)
	1987	1988*	1987-1988	1988	1987-1988
PHIL.	95,948	101,758	6.63	1,733	3.56
NCR	28,502	31,323	9.90	4,143	6.89
I	4,323	4,507	4.25	1,090	2.28
II	2,301	2,432	5.70	897	3.16
III	7,664	8,286	8.12	1,413	5.59
IV	14,221	14,929	4.97	1,941	2.19
V	3,120	3,257	4.41	776	2.09
VI	6,545	6,902	5.44	1,269	3.19
VII	6,905	7,421	7.48	1,669	5.45
VIII	2,323	2,383	2.60	735	0.76
IX	3,350	3,492	4.24	1,141	1.96
X	5,248	5,570	6.13	1,620	3.41
XI	7,082	7,186	1.47	1,739	-0.98
XII	3,844	4,064	5.74	1,451	3.14

(*) As of January 1989

Sources: Economic and Social Statistics Office
National Statistical Coordination Board

TABLE 2.1.6 FAMILY INCOME DISTRIBUTION AND SOURCES

Income Distribution

(Unit: %)

Region/Province	Average Family Income (in Peso)	Below P 10,000	P 10,000 19,999	Below P 19,999 Sub-Total	P 20,000 39,999	Above P40,000
REGION IV	29.985	12.7	33.1	45.8	33.2	21.0
Cavite	39.759	0.0	16.2	16.2	48.3	35.5
Rizal	38.517	4.9	35.5	40.4	30.9	28.7
METRO MANILA	57.193	1.5	11.9	13.4	37.0	49.6
PHILIPPINES	31.052	15.2	33.7	48.9	30.7	20.4

Income Sources

(Unit: %)

Region/Province	Wages and Salaries Agriculture	Wages and Salaries Non-Agriculture	Entrepreneurial Activities Agriculture	Entrepreneurial Activities Non-Agriculture	Other Income Sources
REGION IV	10.30	35.97	24.00	11.21	18.53
Cavite	4.00	67.48	6.20	7.39	14.39
Rizal	8.57	44.89	17.09	13.71	15.73
METRO MANILA	0.50	57.96	0.09	16.60	24.85
PHILIPPINES	9.20	31.24	28.62	12.40	18.54

Source: 1985 Family Income and Expenditures Survey (NSO)

TABLE 2.1.7 NUMBER OF FAMILIES BY TYPE OF BUILDING OCCUPIED, PHILIPPINES, NCR AND REGION IV, 1985

Area/Region	Total Number of families	Type of Building					
		Single House	Duplex	Apartment/ accesoria/ condominium	Improvised (Barong-Barong)	Commercial/ industrial/ agricultural	Other housing units, natural shelter, boat, etc.
Philippines	9,847,340	8,830,688	234,349	409,406	313,960	49,371	9,566
Metro Manila Area (NCR)	1,310,549	879,680	55,408	283,357	63,492	23,662	4,950
IV. Southern Tagalog	1,303,730	1,199,302	42,645	19,894	37,563	2,723	1,603

Source: 1985 Family Income and Expenditures Survey (NSO)

TABLE 2.2.1 PRESENT WATER SUPPLY COVERAGE: 1987

(million)

Area	Total Population	(%)	Population Served: Total	(%)	Wells/Developed Spring	(%)	Piped System	(%)	Underserved/ Unserved Population	(%)
Philippines	57.36	100	36.17	63	17.92	31	18.25	32	21.19	37
Urban	23.53	100	15.39	65	12.52	53	2.87	12	8.14	35
Metro Manila and and its conti- guous area	8.16	100	7.01	86	6.84	84	0.17	2	1.15	14
Others	15.37	100	8.38	55	5.68	37	2.70	18	6.99	45
Rural	33.83	100	20.78	62	5.40	16	15.38	46	13.05	38

* Excluding the 303,433 population of the towns of Rizal province under BP 799.

Source: Department of Public Works and Highways, Water Supply, Sewerage, and Sanitation Master Plan of the Philippines: 1988-2000.

TABLE 2.2.2 NUMBER OF FAMILIES BY MAIN SOURCE OF WATER SUPPLY, BY REGION, URBAN AND RURAL: 1985

Area/Region	Total Number of Families	Faucet inside the house/yard community wtr.system	Faucet, other community water system	Tubed /piped well, own use	Tubed /piped well, others	Dug well	Spring, river, stream, etc.	Rain	Peddler
Philippines	9,847,339	1,853,841	1,723,961	1,678,497	1,631,065	1,702,881	929,892	118,825	208,378
	(100%)	(19)	(13)	(17)	(17)	(17)	(9)	(1)	(2)
Urban	3,726,049	1,462,080	777,429	517,756	478,673	244,330	59,765	14,505	171,511
	(100%)	(39)	(21)	(14)	(13)	(7)	(2)	(0)	(5)
Rural	6,121,290	391,761	946,532	1,160,740	1,152,392	1,458,551	870,126	104,321	36,867
	(100%)	(6)	(15)	(19)	(19)	(24)	(14)	(2)	(1)
Metro Manila Area (NCR)	1,310,549	738,297	292,377	61,783	65,789	32,978	-	-	119,325
	(100%)	(56)	(22)	(5)	(5)	(3)	(-)	(-)	(9)
I. Ilocos	711,232	100,683	90,894	216,201	173,249	94,134	35,529	542	-
II. Cagayan Valley	462,088	18,195	12,915	166,107	127,900	103,281	31,901	1,364	426
III. Central Luzon	956,921	181,438	103,870	380,517	255,389	16,978	14,752	-	3,978
IV. Southern Tagalog	1,303,729	227,001	287,491	256,822	222,193	205,930	100,253	1,294	2,745
	(100%)	(17)	(22)	(20)	(17)	(16)	(8)	(0)	(0)
V. Bicol	668,473	104,311	132,255	88,488	65,793	182,640	86,157	-	8,830
VI. Western Visayas	881,554	70,807	120,490	109,445	119,298	360,119	85,821	9,045	6,530
VII. Central Visayas	783,846	99,975	138,570	60,326	148,001	166,741	116,040	20,760	33,433
VIII. Eastern Visayas	567,496	53,634	157,361	39,594	112,786	137,640	60,793	693	4,996
IX. Western Mindanao	494,818	37,418	72,497	38,272	51,003	174,204	104,750	6,094	10,580
X. Northern Mindanao	565,270	109,462	171,727	23,622	54,236	98,859	99,104	5,778	2,482
XI. Southern Mindanao	705,453	84,995	94,402	160,893	174,835	46,363	64,590	70,553	8,823
XII. Central Mindanao	435,911	27,625	49,111	76,429	60,595	83,015	130,203	2,701	6,231

* Bracketed figures indicate percentages to total number of families.

Source: National Statistics Office, 1985 Family Income and Expenditures Survey.

TABLE 2.2.3 EXISTING WATER SUPPLY FACILITIES: 1987

Area	Type of Facility	Number	Population Served	Total Population	Percent of Population served
Metro Manila and its contiguous areas	Dams	4	7,008,000	8,160,000	86%
	Tunnels	2	-		-
	Aqueducts	7	-		-
	Treatment plants	2	-		-
	Balancing Reservoir	2	-		-
	Pipelines	3,000	-		-
	Pumping stations and reservoir	9	-		-
	Active deepwells	118	-		-
	Fire hydrants	2,350	-		-
	House Service Connection	543,900	-		-
Other urban areas	Waterworks systems (Level III)	214	3,970,000	15,370,000	26%
	Communal faucet systems (Level II)	1,900	1,710,000		11%
	Point sources (Level I)	9,000	2,700,000		18%
Rural areas	Piped systems (Level II & III)	3,232	5,400,000	33,830,000	16%
	Shallow wells	464,678	15,380,000		46%
	Deep wells	193,404			
	Developed springs	9,726			
			36,168,000	57,360,000	63%

Source: Department of Public Works and Highways, Water Supply, Sewerage and Sanitation Master Master Plan of the Philippines: 1988-2000.

TABLE 2.2.4 RESPONSIBILITY OF GOVERNMENTAL AGENCIES

Coverage Area / Responsibility Area / Agency	Metro Manila & its Contiguous Areas			Other Urban and Rural Areas			
	MWSS	DPWH	NWRB	LWUA	DPWH	DLG	NWRB
PLANNING	X (Area Wide)	Sector	C	Other Urban & Rural Areas (Area Wide)	Sector		C
PROGRAMMING	X			L-II/III	L-I Source Dev.	L-I	
FINANCING	X			X	X	X	
INSTITUTIONAL	X			X	Interim	Interim	
ENGINEERING	X			X	X	X	
CONSTRUCTION	X			L-II/III Source Dev.	L-I	L-I	
OPERATION AND MAINTENANCE	X			WD/ RWSA			

X - Directly Responsible
C - Coordination
Source: Department of Public Works and Highways, Water Supply, Sewerage, and Sanitation Master Plan of the Philippines: 1988-2000.

TABLE 2.2.5 PHYSICAL TARGETS, INVESTMENT REQUIREMENTS AND SERVICE COVERAGE, FIRST STAGE (1988-1992)

Particulars (1)	Implementing Agency (2)	Physical Targets (3)	Investment Requirements (million P) (4)	Population Served (million) Additional (5)	Population Served (million) Cumulative (6)	% of Population Served Additional (7)	% of Population Served Cumulative (8)
WATER SUPPLY			21,691.85				87
I. Metro Manila and its Contiguous Areas			9,568.85	1.440	8.448	4	87
1. Manila Water Supply Rehabilitation Project I	MWSS	- Replacement of 131,000 house con. - Removal 28,000 spaghetti con. - Replacement of 200 km. pipelines - Installation of 600 flow rec. stations - Replacement of 108,000 pcs. water mts. - Repair of 22,500 pcs. water meters - Installation of 12,000 pcs. new water meters - Repair of 300 pcs. valves - Replacement of 2.25 pcs. valve	973.57				
2. Metro Manila Water Distribution Project		- Const. of 28 km. new pipelines - Inst. of 100,000 new house con. - Intercon. 72 sub. to serve 15,600 households - Infilling of 24 areas with secondary and tertiary pipelines - Const. of tertiary pipelines for 160 low-income areas - Drilling and equipping of 5 new deep wells	829.51				
3. Manila Water Supply Project II		- Completion of ongoing works	176.08				
4. Angat Water Supply Optimization Project		- Const. of new 6.4 km. tunnel - Const. of new 16.3 km. aqueduct - Expansion of La Mesa Treatment Plant - Const./Inst. of distribution pipelines pumping stations and reservoir - Inst. of additional house service connections	5,363.10				
5. Manila Water Supply Rehabilitation Project II		- Replacement of 104,000 house con. - - Removal of 13,000 spaghetti con. - Replacement of 50 km. pipelines Inst. of 1,040 flow rec. stations connections - Repair of 7,280 pcs. water meters - Installation of 3,120 water meters - Inst. of 1,560 new valves - Replacement of 11,440 water meters Repair or replacement of 1,560 valves	1,043.40				
6. Fringe Areas Water Supply Project		- Construction of deep wells - Const./Inst. of pipelines - Rehab. of existing facilities Inst. of new house service connection	1,021.55				
7. Water Supply Development in Rizal		- Const. of shallow and deep wells - Const./Inst. of pipelines - Development of springs Installation of house service connection	161.64				
II. Other Urban Areas	LWUA, DLG	- Construction of: 450 Piped Systems 450 Piped Systems (L-II/III) Repair/Rehab. of 250 systems	4,367.00 3,943.00 424.00	4.913 4.913	13.766	22	77
III. Rural Areas	DPWH, DLG, LWUA	- Construction of: 933 Piped Systems 933 Piped Systems (L-II/III) 87.46 Point Sources (L-I) Repair/Rehab. of 21,620 systems	7,756.00 1,668.00 5,990.00 98.00	13.723 0.473 13.25	34.030	30	92

Source: Department of Public Works and Highways, Water Supply, Sewerage and Sanitation Master Plan of the Philippines: 1988-2000.

TABLE 2.2.6 PHYSICAL TARGETS, INVESTMENT REQUIREMENTS AND SERVICE COVERAGE, SECOND STAGE (1993-2000)

Particulars	Implementing Agency	Physical Targets	Investment Requirements (million P)	Population Served (million)		% of Population Served	
				Additional	Cumulative	Additional	Cumulative
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
WATER SUPPLY							
I. Metro Manila and its Contiguous Areas			22,689.21				94
1. Manila Water Supply Rehabilitation Project III	MWSS	- Const. of 113 meters rockfilled dam - Const. of 2,400 mld treatment plant - Const. of 14 km tunnel - Const. of 23.2 mega watts hydro-electric plant - Const. of pumping stations and reservoirs - Const. of about 500 km. pipelines - Installation of 170,000 new house service connections	129,000.00	2.705	11.153	10	97
II. Other Urban Areas	LWUA	- Construction of: 654 Piped Systems (L-II/III) Repair/Rehab. of 350 systems	6,915.00 6,321.00 594.00	9.025 9.025	23.506	18	95
III. Rural Areas	DPWH, LWUA	- Construction of: 794 Piped Systems (L-II/III) 13,340 Point Sources (L-I) Repair/Rehab. of 21,000 systems Replacement of 9,500 systems	2,874.21 1,929.00 755.46 161.25 28.50	2.715 0.715 2	36.030	1	93

Source: Department of Public Works and Highways, Water Supply, Sewerage and Sanitation Master Plan of the Philippines: 1988-2000.

TABLE 2.2.7 MWSS WATER SUPPLY STATISTICS, 1984 TO 1990

Year	1984	1985	1986	1987	1988	1989	1990
1) Pop'n under MWSS (million)	7.480	7.712	7.938	8.167	8.405	8.651	9.133
2) Water Production							
a) Surface Water (million m3)	642.24	757.37	874.07	834.75	849.34	859.10	875.80
b) Groundwater (million m3)	25.56	29.45	30.43	27.87	29.48	28.96	33.33
Total	667.80	786.83	904.51	862.62	878.82	888.06	909.13
Increase	-	119.03	117.68	(41.89)	16.20	9.24	21.07
3) Water Consumption							
a) Volume Sold (million m3)	289.90	302.85	310.78	336.51	359.45	375.77	384.67
%	43.4%	38.5%	34.4%	39.0%	40.9%	42.3%	42.3%
b) NRW (million m3)	377.90	483.98	593.73	526.11	519.37	512.29	524.46
%	56.6%	61.5%	65.6%	61.0%	59.1%	57.7%	57.7%
Total	667.80	786.83	904.51	862.62	878.82	888.06	909.13
c) House Connection (mil. m3)	168.55	183.55	195.47	218.48	225.85	235.74	244.97
d) P.F. & Other Conn. (mil. m3)	121.35	119.30	115.31	118.03	133.60	140.03	139.70
e) Illegal Use (mil. m3)	151.16	193.59	237.49	210.44	207.75	204.92	209.78
Sub Total	441.06	496.44	548.27	546.95	567.20	580.69	594.45
%	66.0%	63.1%	60.6%	63.4%	64.5%	65.4%	65.4%
f) Leak, Meter Error (mil. m3)	226.74	290.39	356.24	315.67	311.62	307.37	314.68
%	34.0%	36.9%	39.4%	36.6%	35.5%	34.6%	34.6%
Total	667.80	786.83	904.51	862.62	878.82	888.06	909.13
4) Number of Connections							
a) House Connection	321,512	377,538	442,323	490,223	508,545	543,128	599,754
b) Public Faucet	1,020	1,080	1,160	1,230	1,300	1,420	1,490
c) Others	27,039	27,368	26,919	26,703	44,688	43,910	47,343
Total	349,571	405,986	470,402	518,156	554,533	588,458	648,587
Increase	-	56,415	64,416	47,754	36,377	33,925	60,129
5) Estimated Population Served							
a) House Connection (million)	2.604	3.058	3.583	3.971	4.119	4.399	4.858
b) Public Faucet (million)	0.496	0.525	0.564	0.598	0.632	0.690	0.724
Sub Total	3.100	3.583	4.147	4.569	4.751	5.089	5.582
Increase	-	0.483	0.564	0.422	0.182	0.338	0.493
c) Illegal Use (million)	1.358	1.955	2.738	2.483	2.381	2.399	2.649
Total	4.458	5.538	6.884	7.052	7.132	7.489	8.232
Increase	-	1.080	1.347	0.167	0.080	0.357	0.743
6) Per Capita Water Consumption (lpcd)							
a) for distributed water	410	389	360	335	338	325	303
b) for effective water	271	246	218	212	218	212	198
c) for domestic water	177	164	149	151	150	147	138

Note: 5a = 4a x 8.1, 5b = 4b x 486, 5c = (3b x 0.4 x (3c/3a)) / (3c/4a) x 8.1

6a = (3a+3b) / (5a+5b+5c), 6b = (3c+3d+3e) / (5a+5b+5c), 6c = 3c / 5a

Source: Corporate Planning Group

TABLE 2.2.8 CAPACITY OF WATER SOURCES

Source	Area of Watershed (km^2)	Water Right or Capacity (m^3/day)	Status
Angat Dam (Angat River)	568	1,901,000 1/	Used
Ipo Dam (Angat River, Ipo River) Old	-	(Submerged by New Dam)	
New	70	474,000 2/	Used
La Mesa Dam (Novaliches Watershed)	27	100,000 3/	Used
Alat Diversion Dam (Alat River)	14	20,000 4/	Used
Marikina River Pumping Stations 5/ 1st	-	189,000	Abandoned
2nd	-	189,000	Abandoned
Wawa Dam (Wawa River)	280	57,000	Abandoned
Groundwater		82,000 6/	Used
Total		3,012,000 m^3/day	
Used w/o Groundwater		2,495,000 m^3/day	

1/: Allocated, 22 CMS
2/: AWSOP; derived from catchment area, rainfall, and permeability coefficient
3/: AWSOP; calculated based on water balance
4/: AWSOP; based on measurement
5/: Abandoned due to bad water quality
6/: Annual average pumpage of MWSS-owned deep wells

TABLE 2.2.9 RAW WATER DRAWN FROM SURFACE WATER SOURCES

(thousand m^3)

year	1986	1987	1988	1989	1990
Total	879,956.2	877,733.1	871,413.4	899,157.9	916,875.4
Daily Avg.	2,410.8	2,404.7	2,387.4	2,463.5	2,512.0

Source: MWSS Annual Report 1986, 1987, 1988, 1989, 1990

TABLE 2.2.10 DRAWN RAW WATER BY MONTH: 1990

MONTH 1990	RAW WATER				RECOVERED WASH WATER	TOTAL TREATED WATER
	ANGAT DAM	IPO/ALAT/ LA MESA DAM	MARIKINA PUMP STN.	SUB-TOTAL		
1	65,876,000	8,072,900	0	73,948,900	2,286,000	76,234,900
2	62,673,400	2,017,800	0	64,691,200	2,153,000	66,844,200
3	71,790,700	60,600	0	71,851,300	2,466,800	74,318,100
4	67,951,100	458,900	0	68,410,000	2,299,200	70,709,200
5	71,517,200	(1,688,700)	0	69,828,500	2,794,500	72,623,000
6	51,647,000	17,343,700	0	68,990,700	1,981,500	70,972,200
7	43,104,200	33,127,900	0	76,232,100	2,478,500	78,710,600
8	35,250,800	44,201,900	0	79,452,700	1,405,600	80,858,300
9	74,386,800	5,815,500	0	80,202,300	1,811,700	82,014,000
10	58,703,900	22,451,300	0	81,155,200	2,669,900	83,825,100
11	57,995,300	19,112,600	0	77,107,900	2,398,700	79,506,600
12	67,467,400	10,420,800	0	77,888,200	2,474,400	80,362,600
TOTAL	728,363,800	161,395,200	0	889,759,000	27,219,800	916,978,800
DAILY AVG.	1,995,517	442,179	0	2,437,696	74,575	2,512,271
%	81.9%	18.1%	0	100.0%		-
1989						
TOTAL	703,683,900	170,540,000	0	874,223,900	24,961,000	899,184,900
DAILY AVG.	1,927,901	467,233	0	2,395,134	68,386	2,463,520
%	80.5%	19.5%	0	100.0%	-	-

Source: Weekly Status of Water Production and Elevations, Water Sources and Treatment Dept., MWSS

TABLE 2.2.11 MWSS WATER PRODUCTION: 1985 TO 1990

(unit: m^3)

Year	Treated Surface Water			Groundwater from Wells			Total
	Balara T.P.	La Mesa T.P.	Sub Total	Manila & Suburbs	Cavite Waterworks	Sub-Total	
1985	480,875,282	276,501,100	757,376,382	22,934,495	6,519,749	29,454,244	786,830,626
1986	534,394,436	339,681,600	874,076,036	22,840,692	7,590,881	30,431,573	904,507,519
1987	521,429,600	313,332,400	834,762,000	19,816,742	8,055,750	27,872,492	862,634,492
1988	509,568,000	339,772,700	849,340,700	21,418,094	8,059,931	29,478,025	878,818,725
1989	511,068,700	348,015,800	859,084,500	20,989,504	7,977,002	28,966,506	888,051,066
1990	504,033,800	371,767,600	875,801,400	22,553,080	10,773,164	33,326,244	909,127,644
AVG.	510,228,303	331,511,867	841,740,170	21,758,768	8,162,746	29,921,514	871,661,684
Daily.	1,397,886	908,252	2,306,138	59,613	22,364	81,977	2,388,115

Source: Water Sources & Treatment Dept., MWSS

TABLE 2.2.12 OUTLINE OF TREATMENT PLANTS

	Balara Treatment Plant		La Mesa Treatment Plant
	No.1	NO.2	
Year Completed	: 1935	: 1958	: 1985
Location	: Balara, Quezon City	: same as left	: Novaliches, Quezon City
Design Capacity	: 100 MGD (Normal) = 378,000 m^3/d 125 MGD (Maximum) = 473,000 m^3/d	: 200 MGD (Normal) = 757,000 m^3/d 300 MGD (Maximum) = 1,136,000 m^3/d	: 1,500,000 m^3/d
Chemical Mixing	: Hydraulic Jump	: Rapid Mixing 2 units	: Flush Mixer 6 units
Coagulant Used	: Alum	: Alum	: Ferric Chloride/Alum/Polymer
Flocculation Basin	: 2 units	: 12 units	: 72 units
Volume	: 2,016 m^3	: 20,300 m^3	: 20,736 m^3 (8x8x4.5x72)
Detention Time	: 2,016 / (378,000-132,000) = 11.8 min.	: 20,300 /757,000 = 38.6 min.	: 20,736 / 1,500,000 = 19.9 min.
Sedimentation Basin	: 2 units	: 12 units	: 12 units
Volume	: 4 MG/unit x 2 = 30,000 m^3 (210 x 21 x 3.8 m x 2 units)	: 106,000 m^3 (73.2 x 18.3 x 6.0 x 6) 73.2 x 18.3 x 7.2 x 6)	: 83,800 m^3 (16 x 97 x (4.5 + 1.5) x 12)
Detention Time	: 189 min.	: 201 min.	: 80 min.
Accelator	: 2 units	: -	: -
Capacity	: 17.5 MGD/unit (Normal) = 132,000 m^3/d 25.0 MGD/unit (Maximum) = 189,000 m^3/d	: -	: -
Coagulant Used	: Ferric Chloride/Alum/Polymer	: -	: -
Filter	: 10 units	: 20 units	: 24 units
Type	: Dual Media Rapid Sand Filter	: same as left	: 3 layer RSF
Filtration Area	: 162 m^2/unit	: 162 m^2/unit	: 180 m^2/unit
Capacity	: 12.5 MGD/unit = 47,300 m^3/d/unit	: 10 MGD/unit = 37,800 m^3/d/unit 15 MGD/unit (Maximum)	: 62,640 m^3/d/unit
Filt. Velocity	: 290 m/d	: 233 m/d	: 348 m/d

Source: Water Distribution & Maintenance Dept.

TABLE 2.2.13 PHYSICAL AND CHEMICAL ANALYSES AT MWSS TREATMENT PLANTS (FROM JANUARY 1 TO DECEMBER 31, 1989)

SAMPLE		pH	Turbid-ity units	Acidity mg/l	Free CO2 mg/l	Alka-linity mg/l	Bicar-bonates mg/l	Hard-ness mg/l	Chlo-rides mg/l	Iron mg/l	Residual Chlorine mg/l
Balara Treatment Plant											
Raw Water	Avg.	7.38	19.23	9.10	8.00	54.26	66.20	50.94	7.02	0.15	
	Min.	7.15	6.16	7.15	6.29	51.38	62.68	44.94	5.21	0.09	
	Max.	7.49	49.40	10.33	9.09	58.67	71.58	53.73	8.22	0.25	
Treated	Avg.	7.13	15.38	8.63	7.59	52.06	63.44	50.71	6.93		
	Min.	6.76	5.98	6.80	5.98	48.80	59.53	45.79	5.26		
	Max.	7.36	44.22	10.93	9.61	56.83	69.33	56.50	9.19		
Influent	Avg.	7.10	8.51	8.57	7.54	52.33	63.84	51.00	7.02		
	Min.	6.76	6.07	7.38	6.49	48.26	58.88	45.68	5.68		
	Max.	7.35	15.66	10.48	9.22	57.67	70.36	53.27	9.15		
Filtered Water	Avg.	7.08	3.51	7.91	6.96	51.79	63.18	51.39	7.09		
	Min.	6.86	2.79	7.00	6.16	48.78	59.51	44.78	4.67		
	Max.	7.36	6.39	10.06	8.85	56.33	68.72	56.20	9.41		
Finished Water	Avg.	7.10	3.62	8.13	7.15	51.73	63.11	51.10	7.40	0.07	0.52
	Min.	6.76	2.77	6.76	5.94	49.38	60.24	46.18	5.82	0.05	0.31
	Max.	7.32	6.21	10.23	9.00	57.18	69.76	53.25	11.00	0.08	0.73
La Mesa Treatment Plant											
Raw Water	Avg.	7.22	16.92	11.62	10.23	69.06	84.25	53.08	4.37	0.08	
	Min.	7.16	5.16	10.13	8.91	57.43	70.07	47.94	3.16	0.05	
	Max.	7.30	40.93	13.37	11.76	85.68	104.53	67.00	6.24	0.20	
Treated (Before Settlement)	Avg.	7.06	17.72	11.54	10.18	65.51	79.92	52.80	4.71	0.09	
	Min.	6.97	4.53	10.12	9.08	54.77	66.82	48.97	3.76	0.05	
	Max.	7.19	61.75	13.92	12.55	77.00	93.94	68.25	6.08	0.29	
Influent (Settled)	Avg.	7.05	6.14	11.58	9.25	64.86	79.12	52.71	5.67	0.05	0.96
	Min.	6.96	3.41	10.29	9.06	52.84	64.46	47.71	4.87	0.05	0.90
	Max.	7.15	13.75	13.52	11.37	73.90	90.16	68.00	7.30	0.06	1.07
Filtered Water	Avg.	7.06	1.92	11.21	9.87	63.94	78.00	52.32	5.72	0.05	0.71
	Min.	6.98	1.15	9.26	8.15	53.77	65.60	45.90	4.81	0.05	0.61
	Max.	7.16	3.92	13.15	11.57	72.13	88.00	68.25	7.36	0.05	0.78
Finished Water	Avg.	7.07	2.01	11.07	9.73	64.10	78.44	52.17	5.71	0.05	0.78
	Min.	6.99	1.12	9.59	8.44	53.87	65.72	48.06	4.65	0.05	0.61
	Max.	7.17	4.78	13.17	11.59	71.58	87.33	67.00	7.16	0.05	0.80
Bagbag Reservoir	Avg.	7.09	1.56	11.29	9.94	63.48	78.09	52.48	5.60		0.22
	Min.	7.04	1.09	10.10	8.89	54.00	65.88	47.66	4.85		0.14
	Max.	7.16	2.46	13.03	11.47	71.95	87.78	69.05	6.11		0.32

TABLE 2.2.14 RESULTS OF BACTERIOLOGICAL QUALITY ANALYSIS (FROM JANUARY 1 TO DECEMBER 31, 1989)

Location	Total No.of	No.of Samples of Samples	Percentage of w/ MPN <2.2	Avg. Residual Satisfaction	Chlorine mg/l
Central Labo. Div.	MWSS Tap Water from Manila City	1,026	1,026	100.0%	0.33 range(0.30-0.43)
	MWSS Tap Water from Other Cities and Municipalities	688	688	100.0%	0.34 (0.20-0.61)
	MWSS Deepwells	735	576	78.4%	0.33 (0.20-0.40)
Process Quality Unit	Manila Tap Water	922	861	93.3%	0.32 (0.13-0.44)
	Suburbs Tap Water	629	445	70.7%	0.19 (0.09-0.85)

TABLE 2.2.15 ONGOING PROJECTS OF MWSS

PROJECT	EXPECTED VOL. TO BE INCREASED /RECOVERED	IMPLEMENTATION SCHEDULE START/ COMPLETE	TOTAL PROJECT COST	SOURCES OF FUND	PROJECT COMPONENTS	REMARKS
Manila Water Supply Rehabilitation Project I (MWSRP I)	NRW Recovery 500 MLD	1983/1991	P 1832.91 M	CC =P 794.00 M ADB =$ 29.16 M	- Replacement of 150 kms. tertiary distribution lines - Installation of 280 public faucets - Construction of 50 kms. new tertiary dist. lines - Construction and replacement of 108,000 house service connections - Relocation of 12,000 water meters	completed in 1991
Manila Water Supply Rehabilitation Project II (MWSRP II)	NRW Recovery 265 MLD	1988/1992	P 1376.52 M	ADB 947=$ 26.40 M DBP =P400.00 M CC =P 89.23 M Equity=P 172.15 M	- Replacement of 1,000 kms. tertiary distribution lines - Installation of 285 public faucets - Construction of tertiary dist. lines - Construction and replacement of 87,121 water meters	
Metropolitan Manila Water Distribution Project (MMWDP)	-	1986/1992	P 1,111.76 M	CC =P509.68 M IBRD 2676=$ 24.53 M	- Construction of 280 kms. dist. lines - Construction of 100,000 house service connections (including interconnection of 72 sub-divisions)	
Angat Water Supply Optimization Project (AWSOP)	Increase 1,300 MLD (Angat Riv.)	1989/1994	P 8,400 M	IBRD 3124=$ 40.00 M ADB 986 =$ 103.70 M OECF =$ 80.00 M Bonds =P1,300.00 M CC =P 27.19 M Equity =P2,121.69 M	- Auxiliary Unit Powerhouse - 6.1 kms. tunnel - 900 MLD Water Treatment Plant - 16 kms. Aqueduct - 4 Treated Water Reservoirs - 11 Pumping Stations upgrading work - 4 Pumping Stations construction work - 137 kms. primary dist. lines - 178 kms. secondary dist. lines - 360,000 house service connections - La Mesa By-ass Aqueduct	
Locally Funded Project			P 100 M (annualy)	Local = P 100 M	- normal act. including improvement, expansion, replacement, interconnection, and other miscellaneous works that fall outside of ongoing foreign assisted projects	

SOURCE: 1) FCBD - PCK used in 1991 Budget
(FCBD -Financial control and Budget Department)
(PCK - Project Cost Estimate)
2) PPD - Engineering Area Project Cost Estimates for Total Project Costs
(PPD - Planning and Programming Department)

TABLE 2.2.16 PROPOSED PROJECTS OF MWSS

PROJECT	EXPECTED VOL. TO BE INCREASED /RECOVERED	IMPLEMENTATION SCHEDULE START/COMPLETE	TOTAL PROJECT COST (mil. P)	FUND ALLOCATION Activity	L.C. (mil. P)	F.C. (mil. $)	PROJECT COMPONENTS	REMARKS
Rizal Province Water Supply Improvement Project (RPWSIP)	Increase 48 MLD (37-Laguna de Bay 11-Groundwater)	1991/1998	895.1		667.06	7.93	- Intake structure - Water Treatment Plant - Pumping Station - Reservoir - Distribution Pipeline - Deep Wells - Elevated Tanks - Distribution Tanks	On-going detailed engineering construction '92
Fringe Areas Water Supply Project (FAWSP)	Groundwater	1989/1993	252.4	F/S D/S C	38.00 10.00 204.51		- Deepwells (construction and rehabilitation) - Pump Stations - Distribution Network - 40,000 House Service Connections	On-going test wells construction as part of F.S. Construction April '91
Metro Manila Groundwater Dev't. Project (MMGWDP)	-	1990/1992	90	F/S	14.92	2.7	- Execution of study on groundwater development	On-going development study
Umiray-Angat Transbasin Project (UATP)	Increase 800 MLD (Umiray River)	1991/1995	2,454	F/S D/S C	3.50 7.30 800.00	1.27 8.86 44.73	- Diversion Dam - Tunnel/Aqueduct - Watershed Erosion Control	Technical assistance started February 1991 construction June'93
Manila South Water Distribution Project (MSWDP)		1991/1993	1,707		1,311.50	13.42	- Clean Water Reservoirs - Booster Pumping Stations - 52.8 kms. Primary Dist. Network - 220 kms. Secondary and Tertiary Dist. Network - 99,100 House Service Connections	On-going detailed engineering
Manila Water Supply Project III (MWSP III)	Increase 1,900 MLD (Kaliwa River)	1998/2004	12,923				- Laiban Dam - Tunnel - Power Plant - Treatment Plant - Treated Water Reservoir - Distribution System	Detailed engineering for review Construction deferred

TABLE 2.2.16 PROPOSED PROJECTS OF MWSS (cont'd)

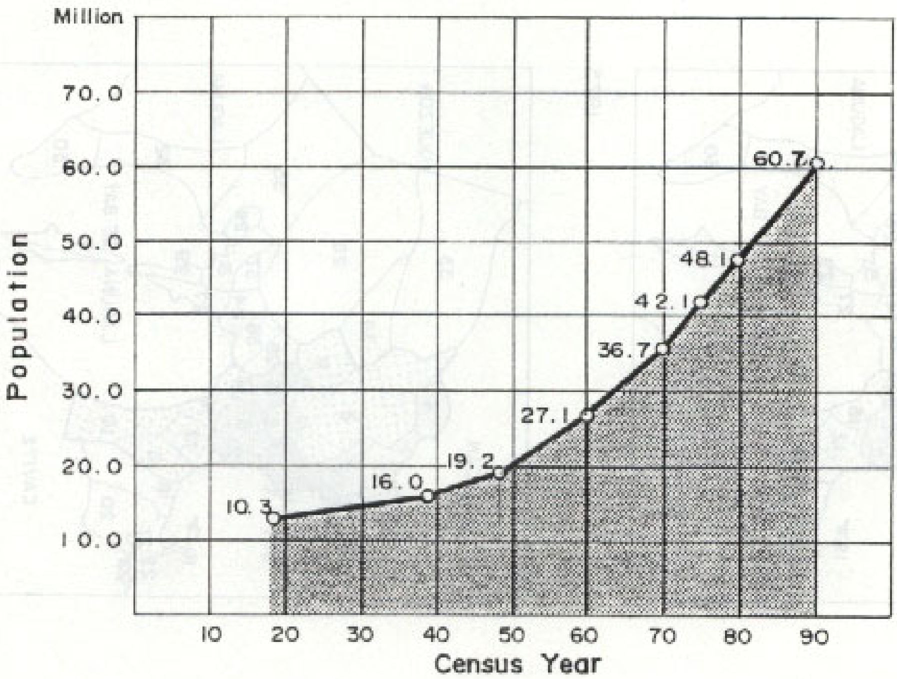
PROJECT	EXPECTED VOL. TO BE INCREASED /RECOVERED	IMPLEMENTATION SCHEDULE START/COMPLETE	TOTAL PROJECT COST (mil. P)	FUND ALLOCATION Activity	L.C. (mil. P)	F.C. (mil. $)	PROJECT COMPONENTS	REMARKS
Manila North-East Water Supply Project (MNEWSP)	Increase 72 MLD (Wawa River)	1991/1995	580	F/S	4.58	1.28	- Rehabilitation of Intake Structure	F.S. to start June 1991 Construction Jan. '94
				D/S	3.00	0.47	- Water Treatment Plant	
				C	245.00	9.2	- Treated Water Reservoirs	
							- Transmission Main/Aqueduct	
							- Distribution System	
							- Wells	
							- 43,000 House Service Connections	
Balara Treatment Plant Rehabilitation Project (BTPRP)	-	1991/1994	486.32	F/S	2.60	0.86	- Rehabilitation of Balara Treatment Plant	Technical assistance to start Aug. 1991 by JICA Construction Dec. '93
				D/S	9.20	1.23		
				C	103.30	10.33		
Cavite Water Supply Project (CWSP)	Increase 300 MLD (Laguna de Bay)	1992/1995	1,489				- Water Treatment Plant	F/S Jan '92-Dec '92 D/S Jan '93-Dec '93 Construction Jan'94 Dec '94
							- Treated Water Reservoir	
							- Booster Pumping Station	
							- 150 kms Dist. Network	
							- 75,000 House Service Connections	

(PPD - Planning and Programming Dept.)

TABLE 2.2.17 PLANNED AUGMENTATION OF WATER SOURCES

YEAR	PROJECT	CAPACITY (m^3/day)
1993	AWSOP	129,600
1995	MNEWSP	72,000
1997	UATP	777,600
2011	MWSP III	1,900,000

GROWTH OF PHILIPPINE POPULATION



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 2.1.1 GROWTH OF PHILIPPINE POPULATION
JAPAN INTERNATIONAL COOPERATION AGENCY	

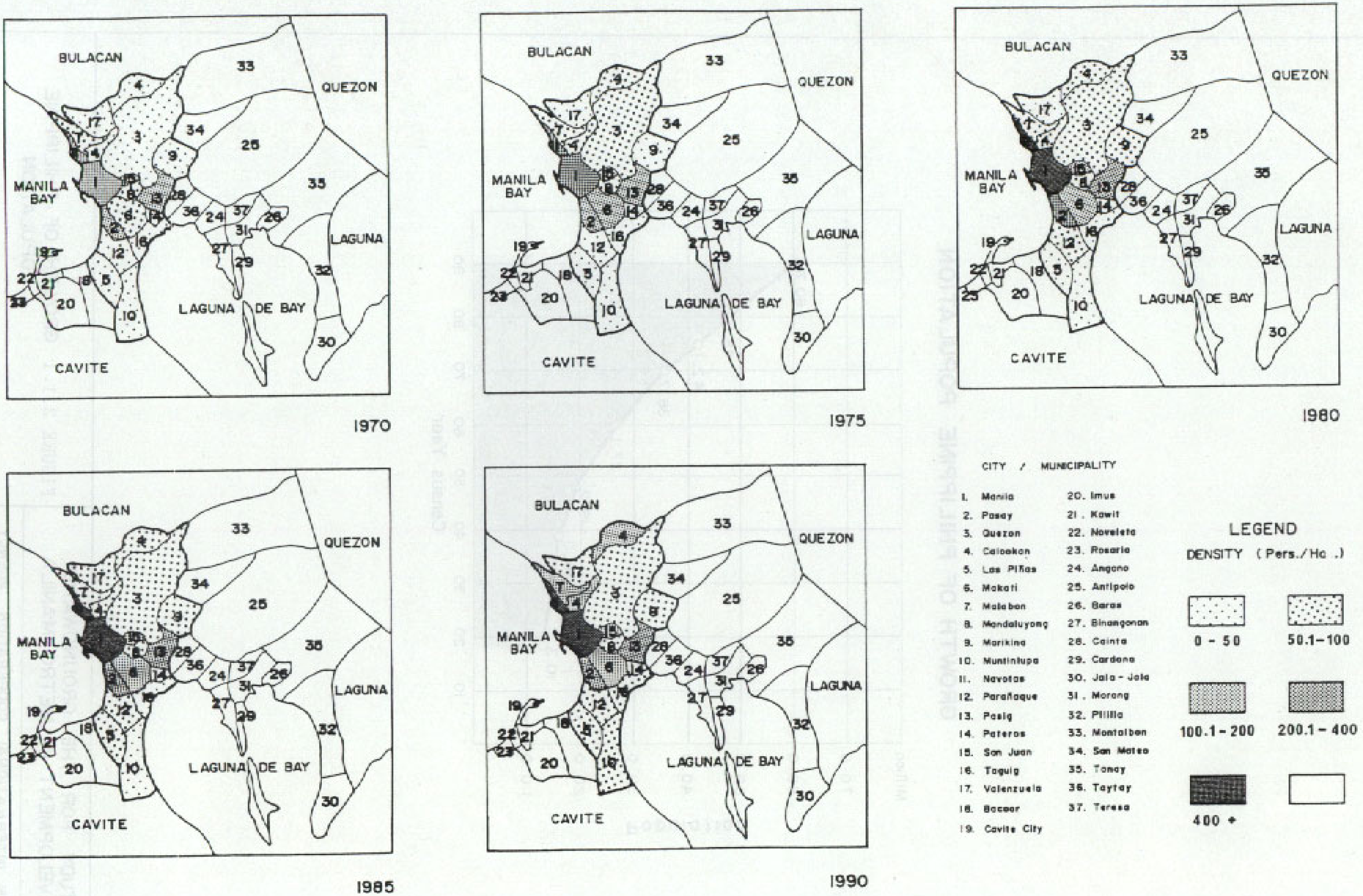


FIGURE 2.1.2 **POPULATION DENSITY OF NCR**

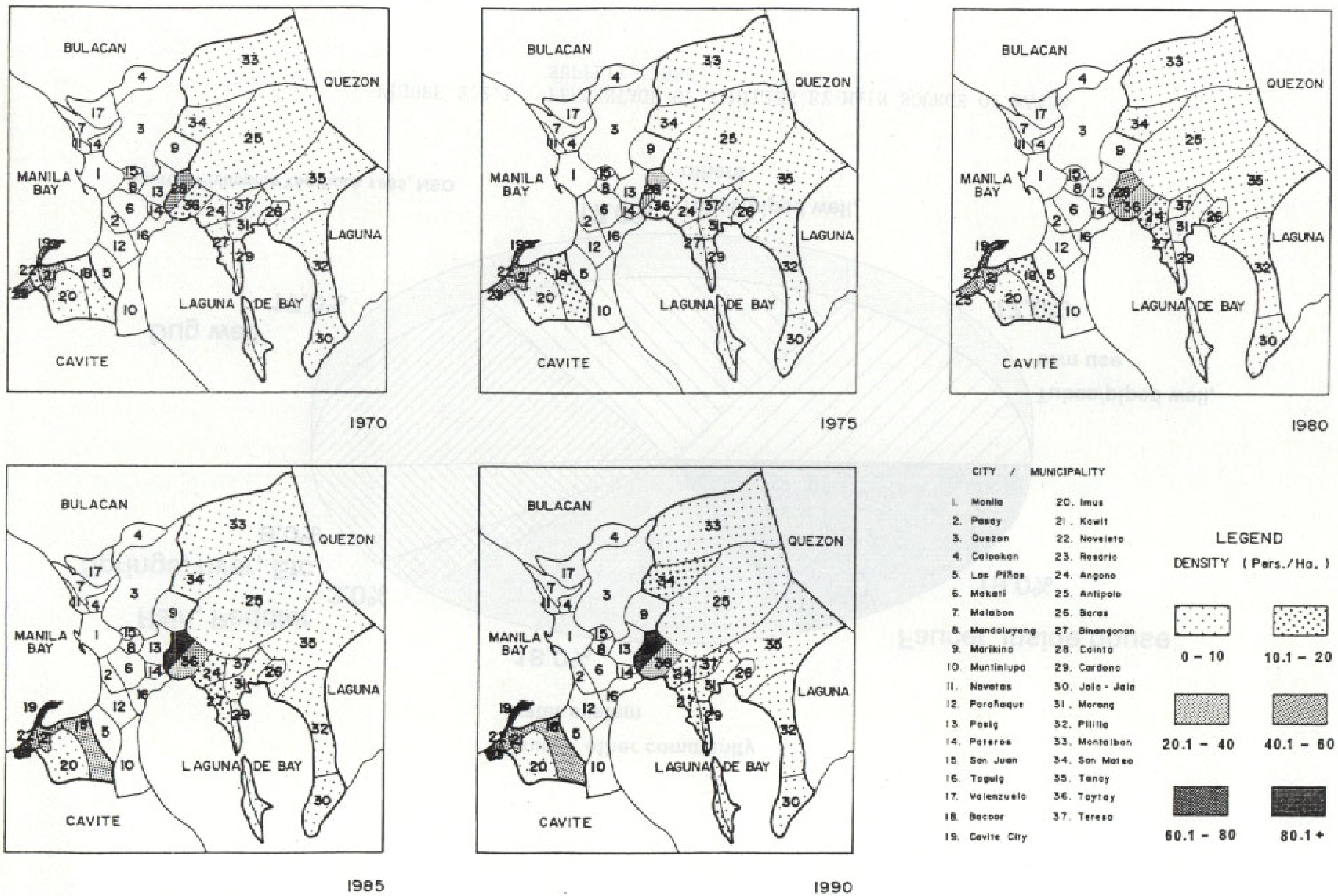
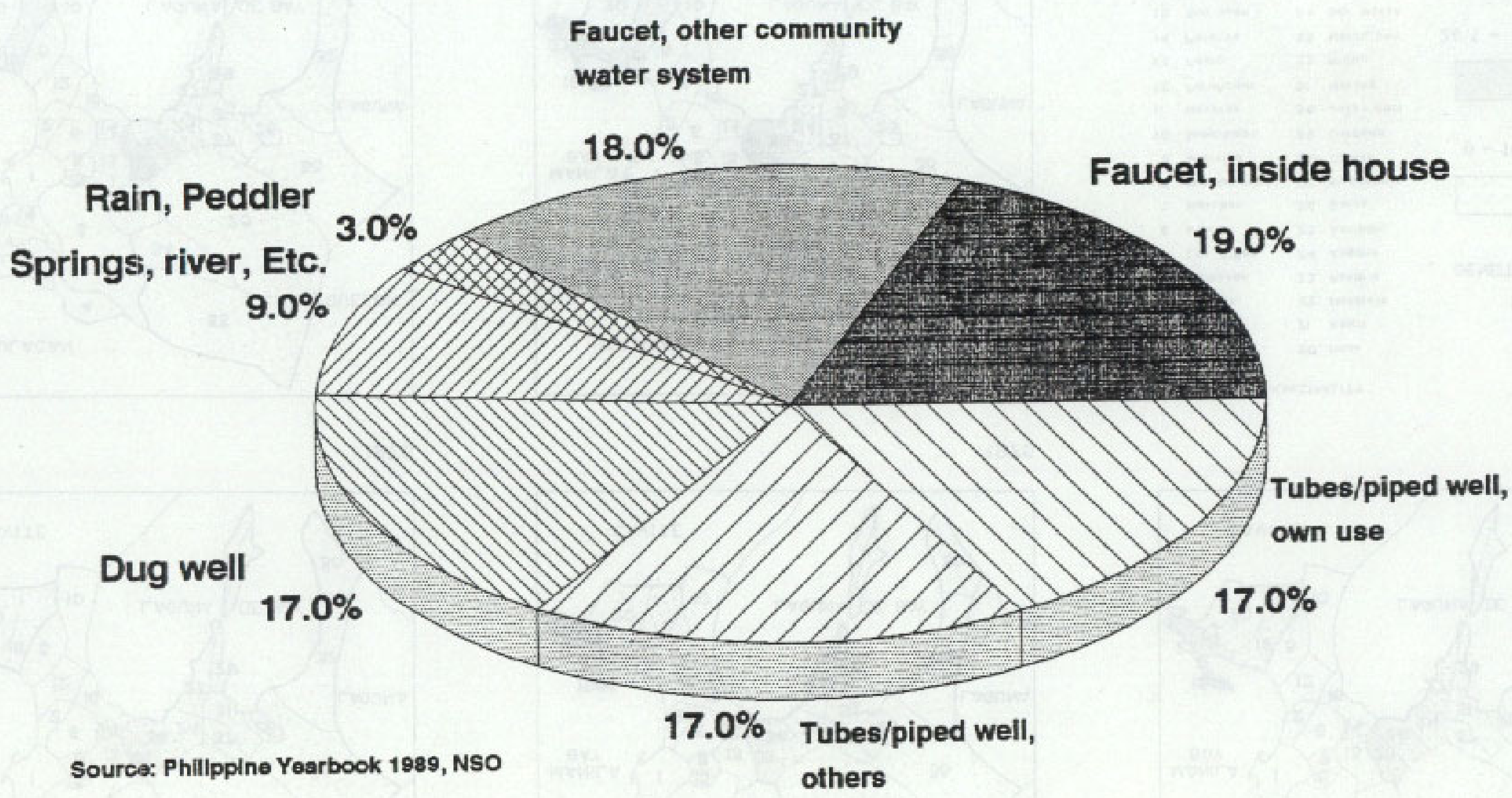
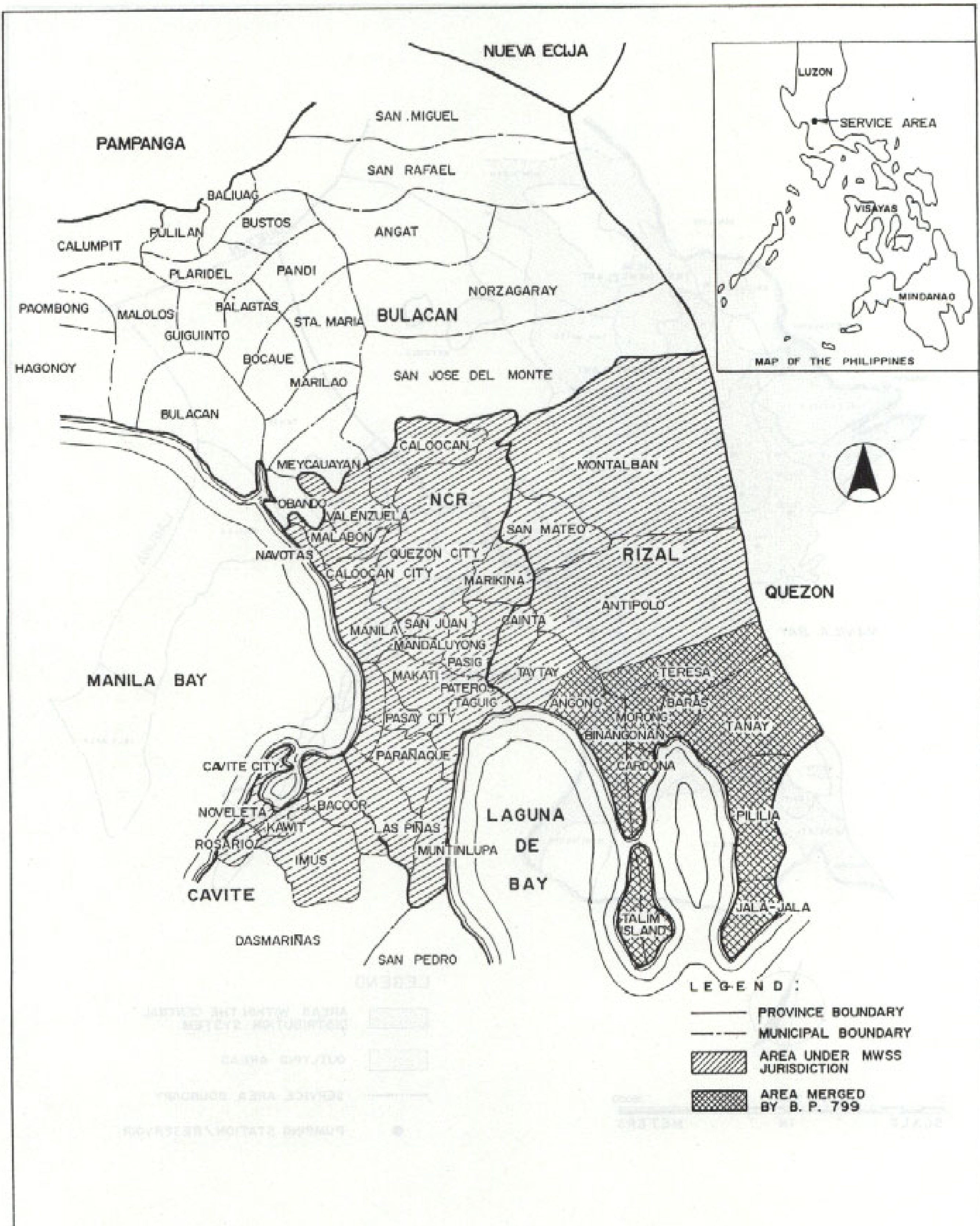


FIGURE 2.1.3 **POPULATION DENSITY OF CAVITE AND RIZAL**

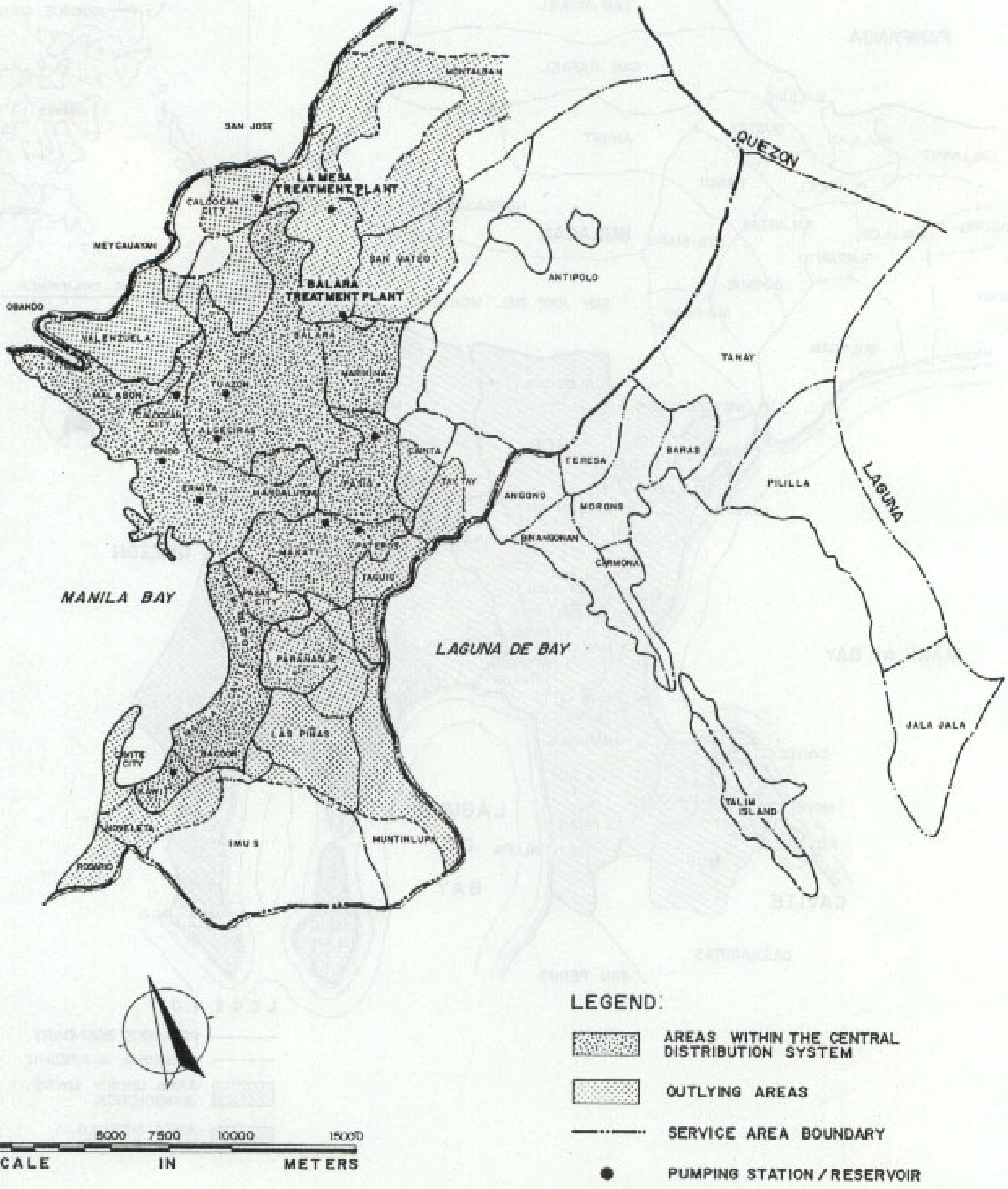


Source: Philippine Yearbook 1989, NSO

FIGURE 2.2.1 PERCENTAGE OF FAMILIES BY MAIN SOURCE OF WATER SUPPLIY, 1985



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 2.2.2
JAPAN INTERNATIONAL COOPERATION AGENCY	MWSS SERVICE AREA



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 2.2.3
JAPAN INTERNATIONAL COOPERATION AGENCY	PRESENT WATER SUPPLY SERVICE AREA BY MWSS

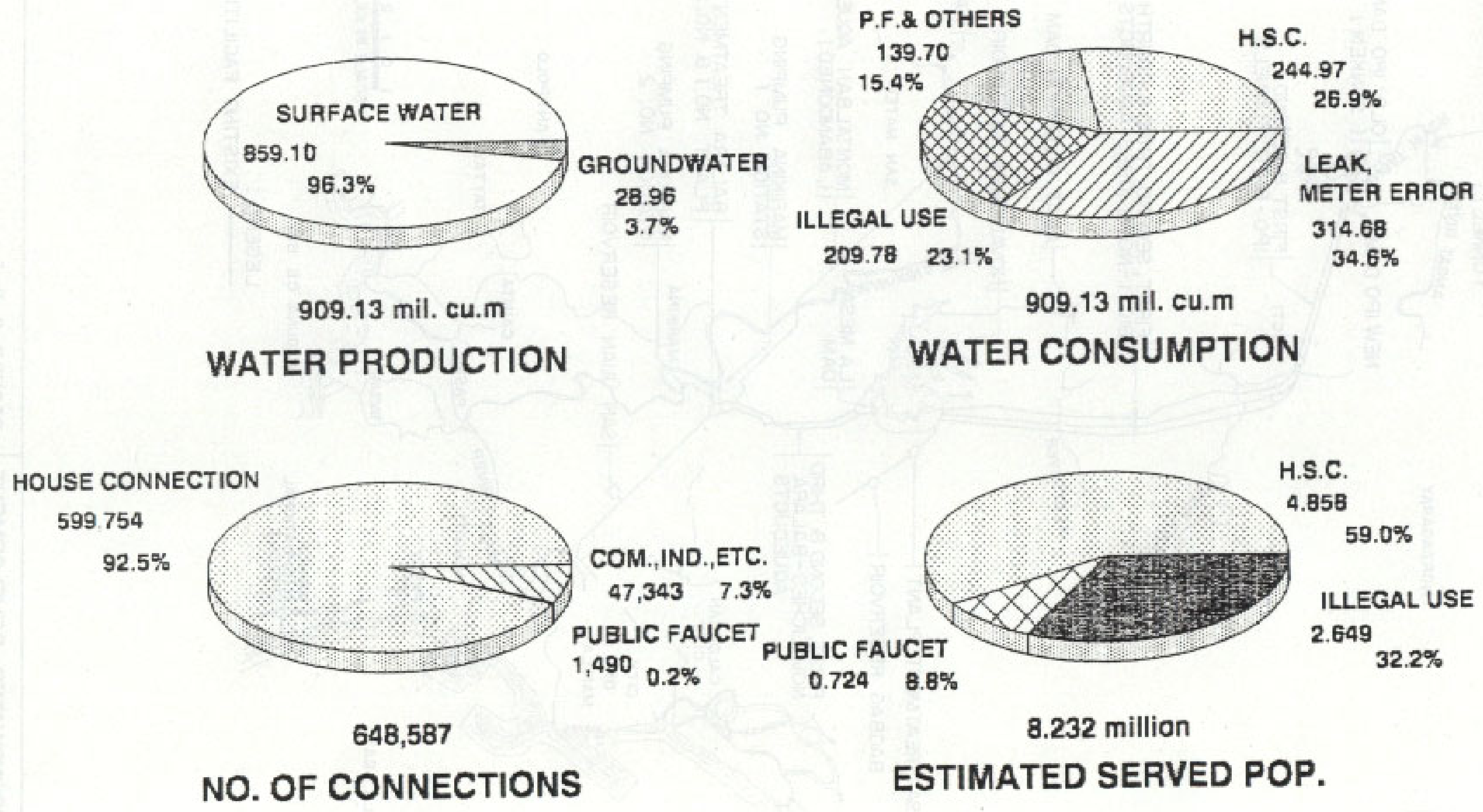
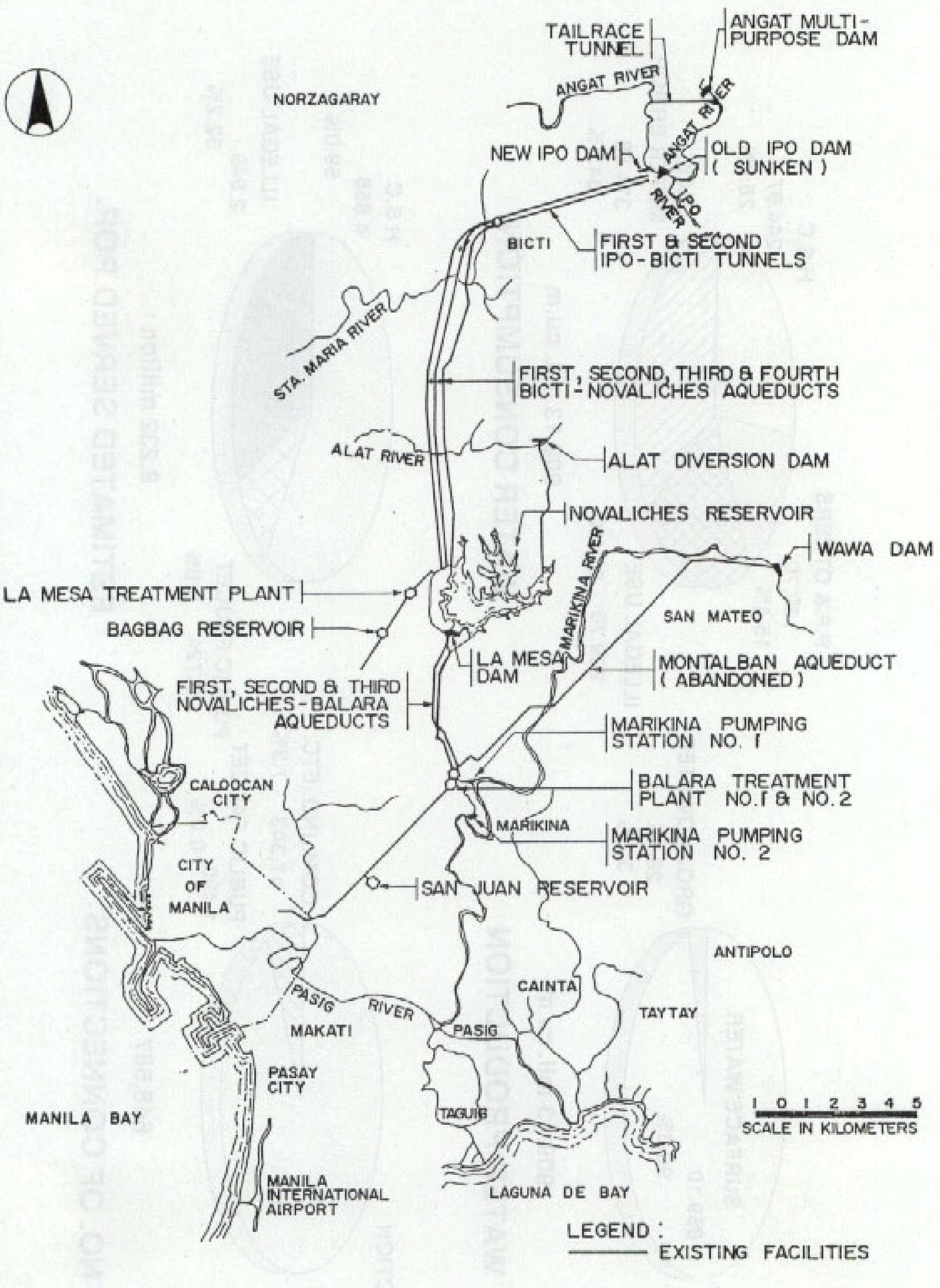


FIGURE 2.2.4 MWSS WATER SUPPLY STATISTICS (1990)



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 2.2.5
JAPAN INTERNATIONAL COOPERATION AGENCY	EXISTING & MAJOR SUPPLY FACILITIES

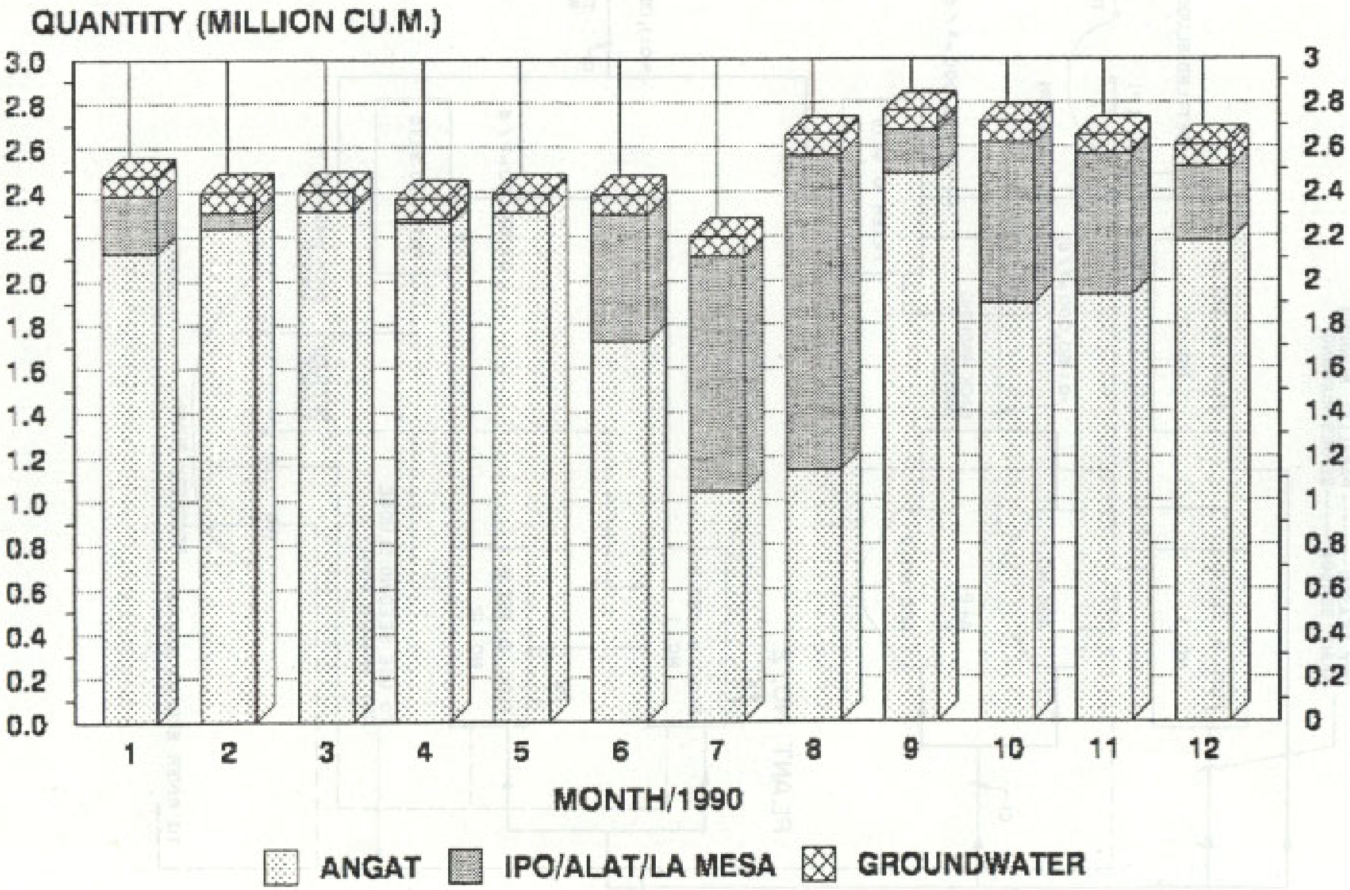
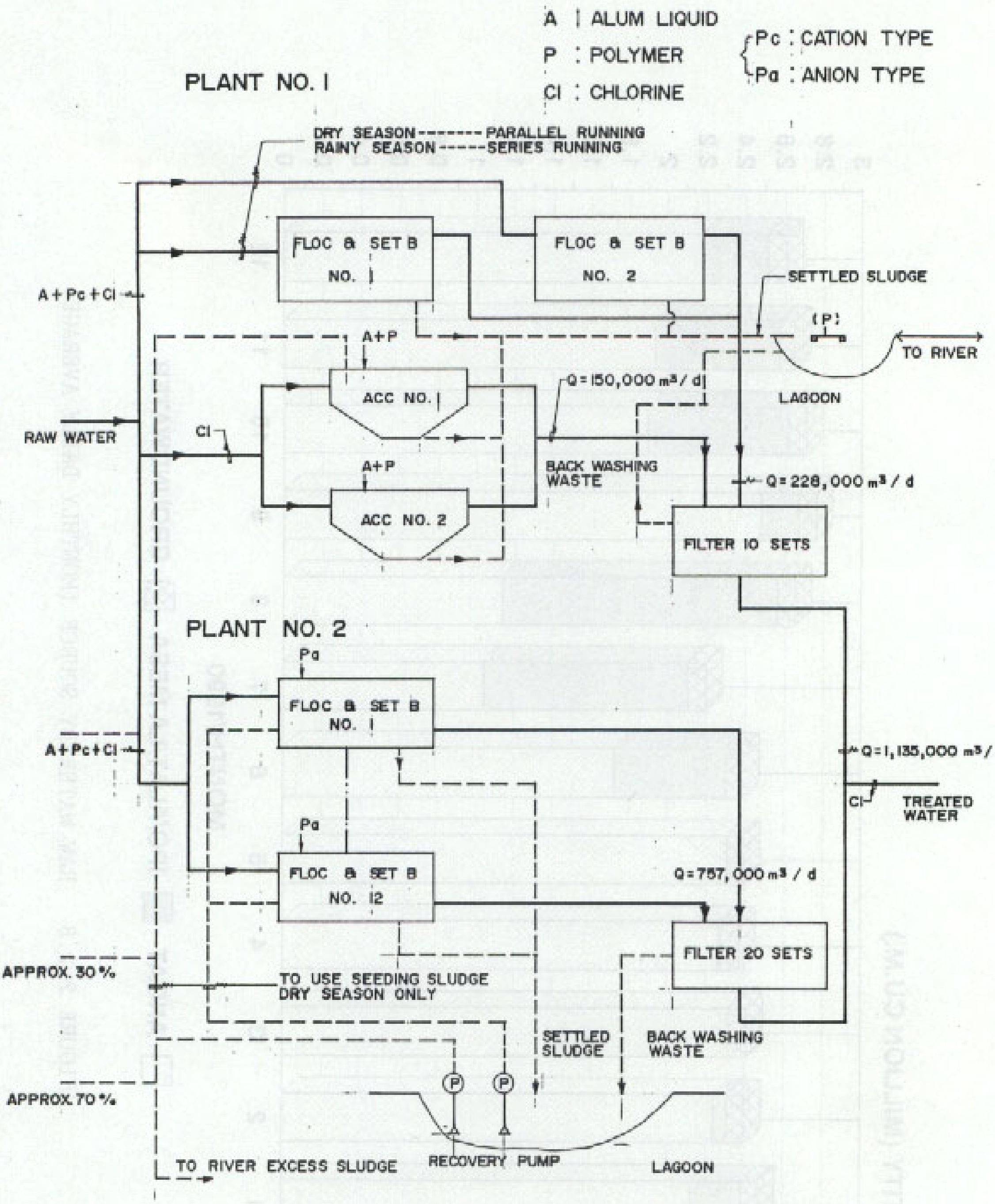


FIGURE 2.2.6 RAW WATER BY SOURCE (MONTHLY DAILY AVERAGE)

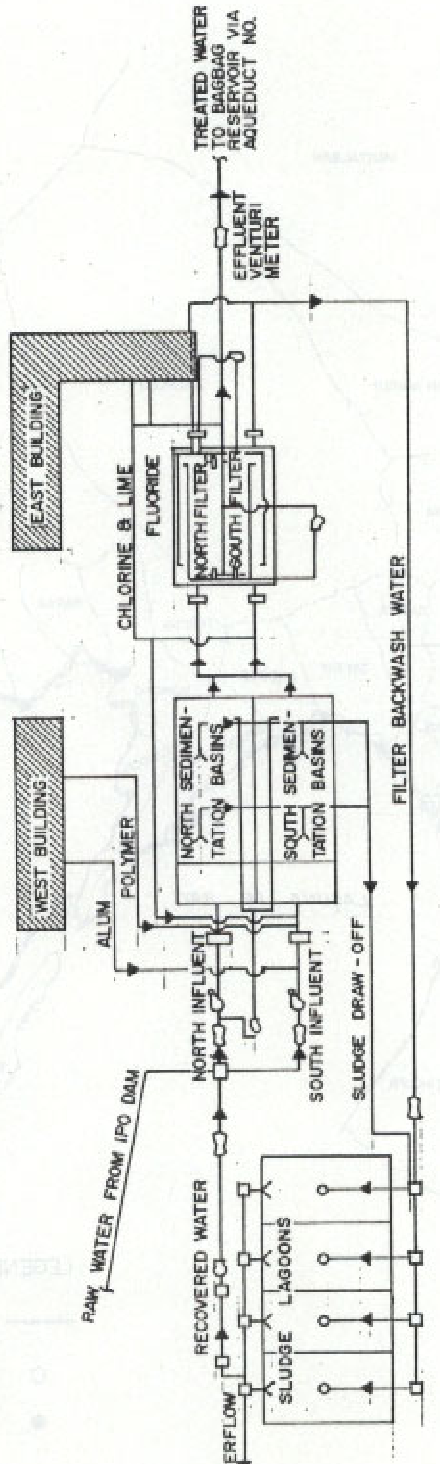


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

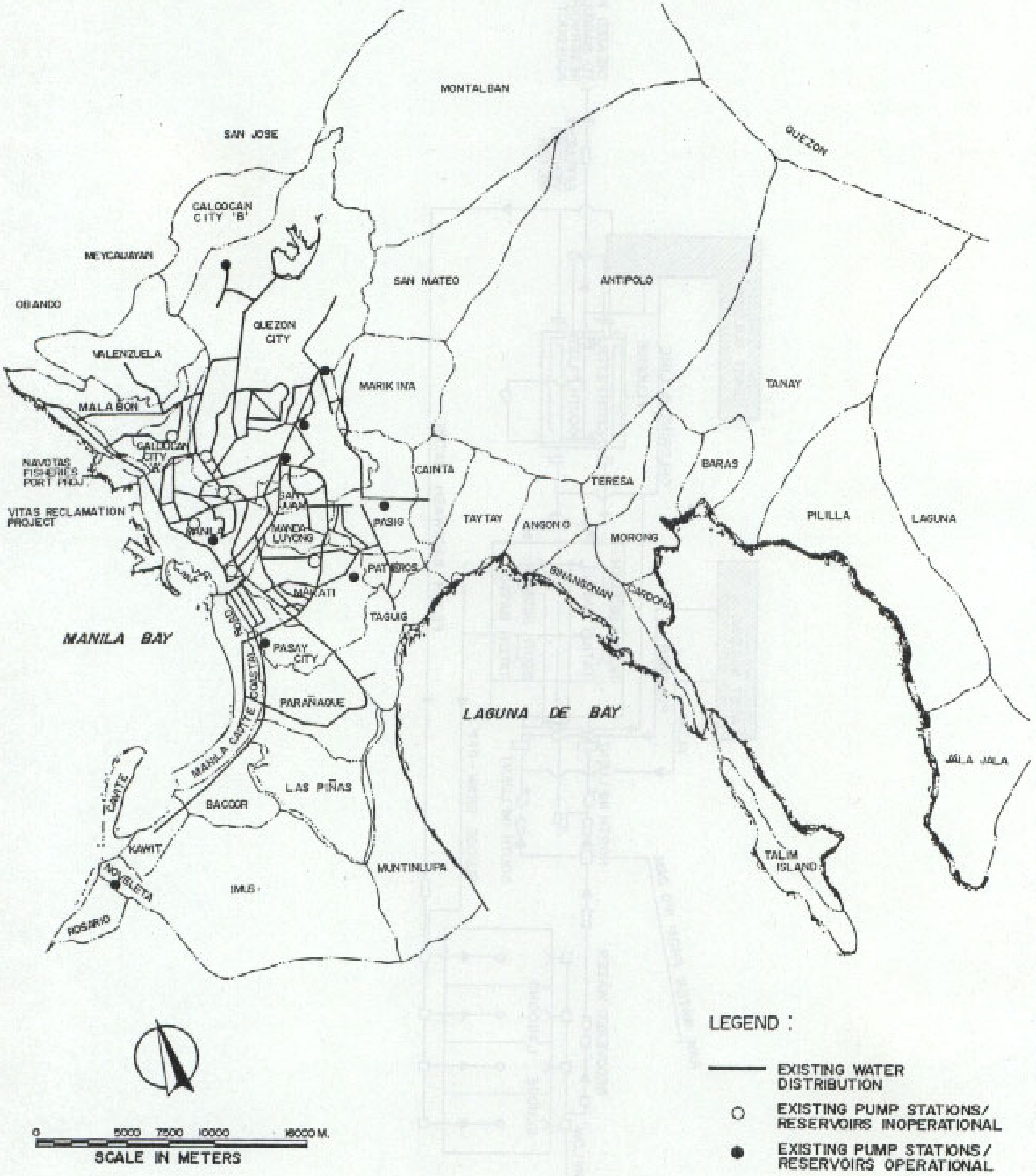
JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 2.2.7

FLOW DIAGRAM OF BALARA TREATMENT PLANT



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 2.2.8
JAPAN INTERNATIONAL COOPERATION AGENCY	FLOW DIAGRAM OF LA MESA TREATMENT PLANT



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 2.2.9 **EXISTING PRIMARY DISTRIBUTION SYSTEM**
JAPAN INTERNATIONAL COOPERATION AGENCY	

CHAPTER 3

GROUNDWATER

CHAPTER 3 GROUNDWATER

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CHAPTER 3 GROUNDWATER

3.1 HYDROLOGICAL ENVIRONMENT

3.1.1 Climate

The climate in the Study Area is divided into two seasons: the rainy season from May to October and the dry season from November to April. About 90 percent of annual rainfall occurs during the rainy season. During the period of the dry season from January to April, rainfall drops to 10-30mm/month.

From the mean annual rainfall map of the Laguna Lake Basin, the Study Area's rainfall ranges from 1900mm to 2200mm. The Cavite and Diliman stations of PAGASA record an annual rainfall range of 1684mm to 2356mm. Rainfall gradually decreases westward as shown in Figures 3.1.1 and 3.1.2.

Monthly temperatures in the Study Area range from 20°C to 35°C. Mean monthly temperature varies from 25°C to 30°C. The coldest months are from December to February while the warmest months are April and May. Mean annual temperature is placed at 27°C. Plots of the minimum, mean and maximum monthly temperatures are shown in Figure 3.1.3.

Monthly pan evaporation at the Diliman station registered a minimum of 62mm in July 1977 and a maximum of 246mm in May 1978. Estimated annual mean is set at 1469mm (Figure 3.1.3).

3.1.2 Topography and Hydrology

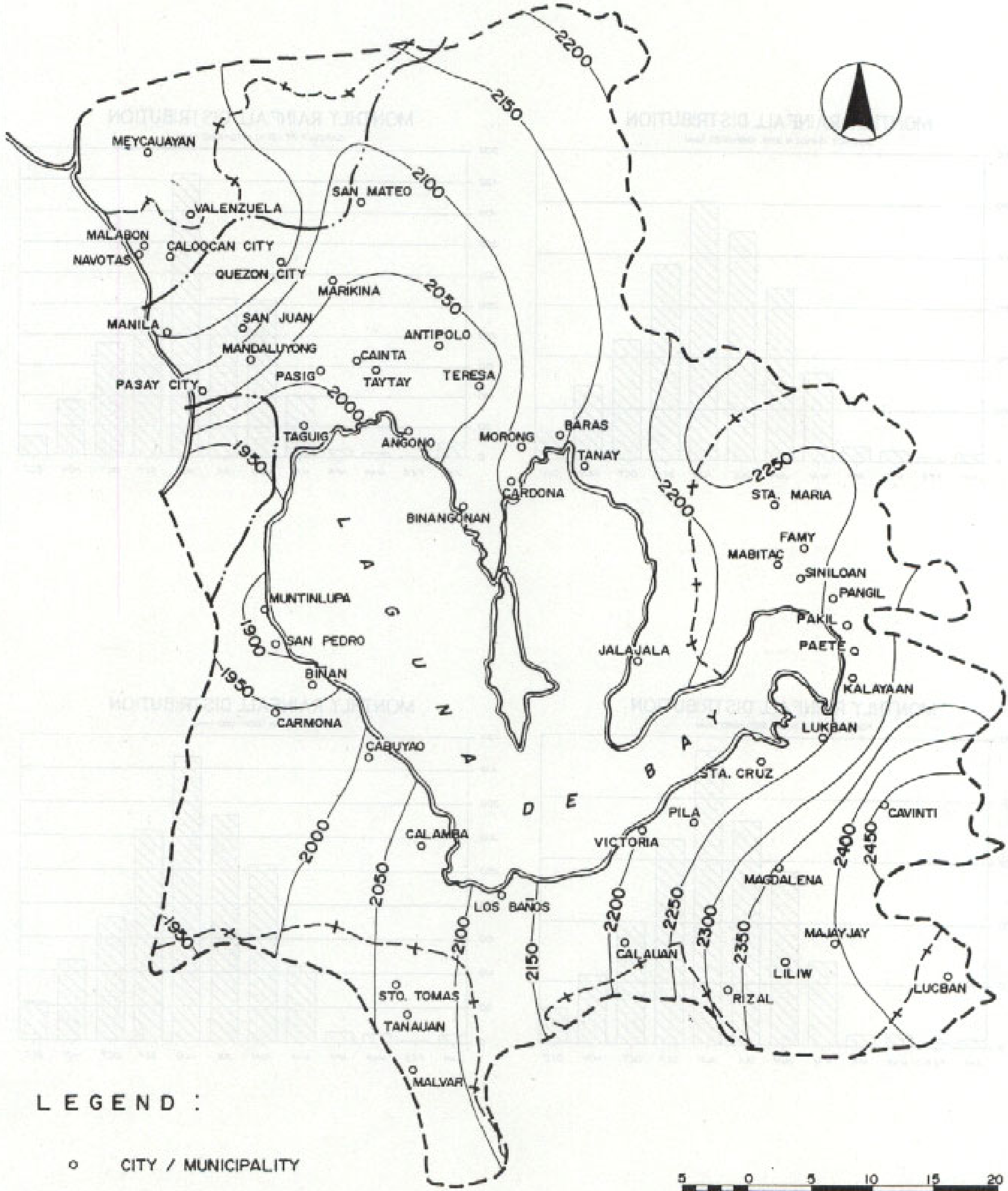
The Study Area faces Manila Bay in the west and the northern coast of Laguna de Bay in the south. This area includes a part of Sierra Madre in the east and the mountainous area of Valenzuela and Montalban in the north.

Surface elevation in the Study Area ranges from 0m at the coast to 1400-1500m at the northeastern mountainous area. Most of the Study Area consists of coastal plains and hilly areas extending in the north-south direction along Manila Bay. Surface elevation ranges from 0m to 10m on the coastal plains and from 20m to 70m on the hills.

Hydrologically, the Study Area is located within the Pasig-Laguna de Bay river basin (4,678 km²; Figure 3.1.4). This basin has an area of 4,678 km² and it drains three (3) distinct and different sub-basins, namely, the Marikina river basin, the Laguna de Bay basin and the urban watershed which includes the Greater Manila urban area, i.e., the Cities of Manila, Pasay, Caloocan, Quezon and the Municipalities of Makati, San Juan, Mandaluyong and Parañaque.

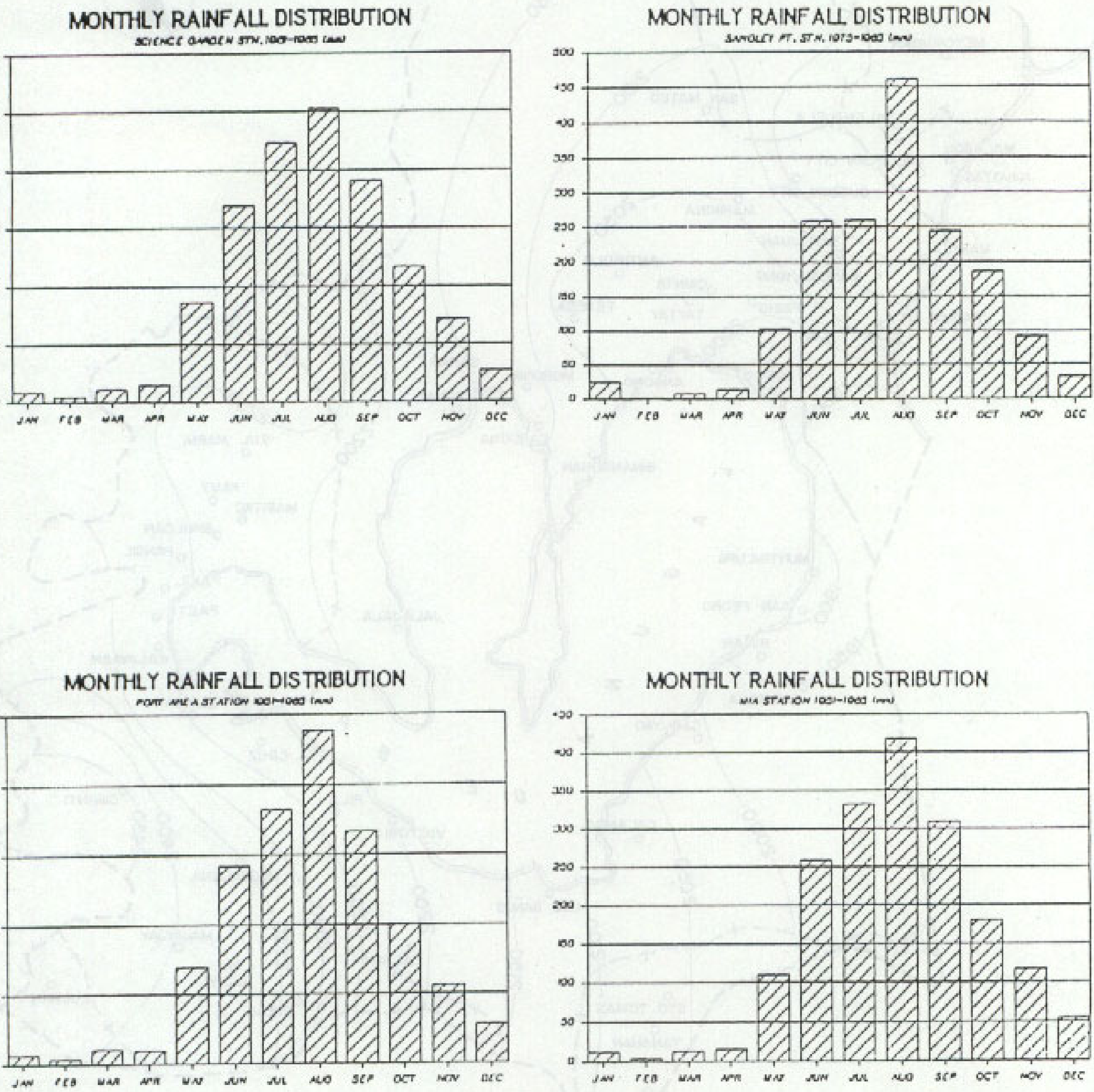
Flowing east to west through central Manila is the Pasig River. It is about 17 kilometers in length from the confluence of the Marikina and Napindan Channel to Manila Bay. One of its principal tributaries is the San Juan River. Its discharge depends upon the elevation of the water surface at the Pasig-Napindan junction, the lake stages of Laguna de Bay, the elevation of tides in Manila Bay, and the discharge from the San Juan River. At certain periods of high tide in the Bay and of low-water lake stage during the dry season, the Pasig River reverses its flow. During high tide conditions and high flows from the San Juan River, a backwater effect slows down the flow of the Pasig River and this causes overbanking.

Immediately inland from the Metro Manila area is Laguna de Bay. It is a shallow lake serving as a natural detention reservoir of discharges from the surrounding tributary streams (Pila-Santa Cruz, San Juan, San Cristobal, Pagsanjan and Romero-Sta. Maria Rivers). The lake's only outlet is via the Napindan Channel and Pasig River. The Napindan River normally flows from Laguna de Bay to Pasig, but it can and does flow in either direction, depending upon river and lake levels. The lake stages of Laguna de Bay depend upon the seasonal variation in rainfall and the yearly inflow of surface water, the interaction between the lake level and tidal stage in Manila Bay, and the annual evaporation from the lake.



SOURCE : LAGUNA LAKE BASINS (1983)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.1.1 MEAN ANNUAL RAINFALL (MM) LAGUNA LAKE BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY	



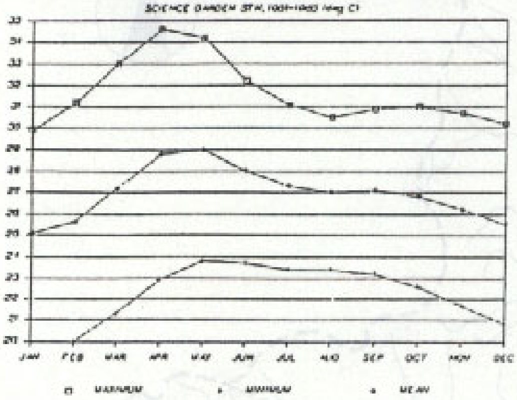
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

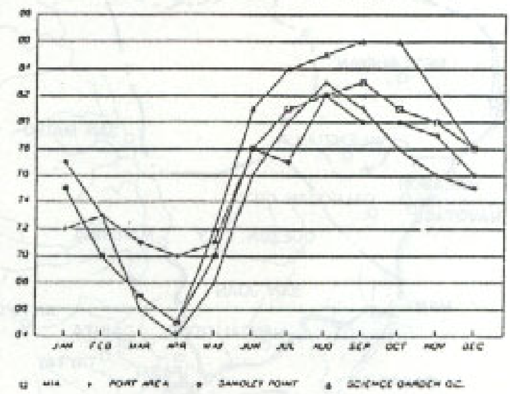
FIGURE 3.1.2

MONTHLY RAINFALL DISTRIBUTION

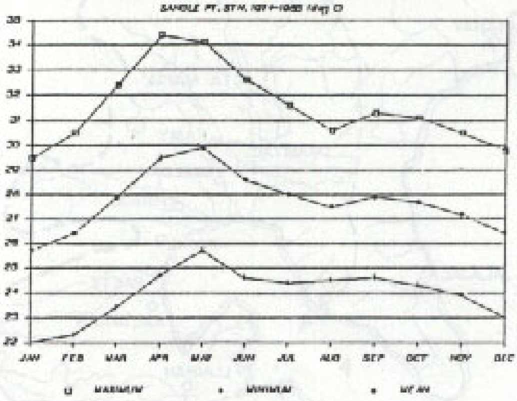
MONTHLY TEMPERATURE DISTRIBUTION



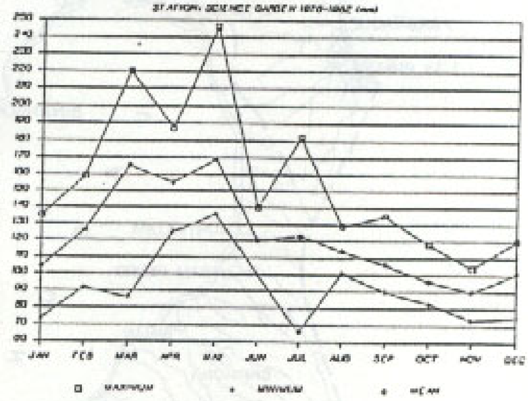
MONTHLY RELATIVE HUMIDITY DISTRIBUTION



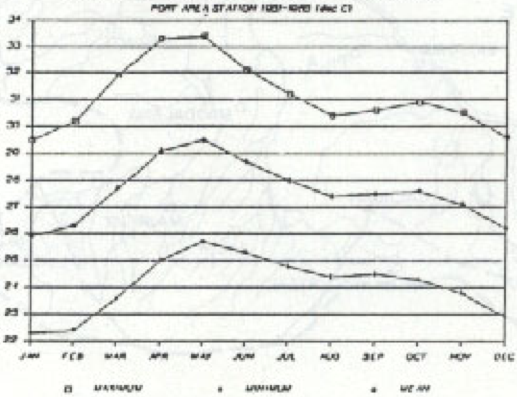
MONTHLY TEMPERATURE DISTRIBUTION



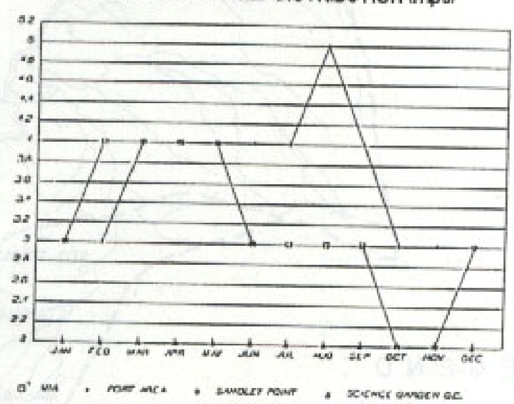
MONTHLY EVAPORATION DISTRIBUTION



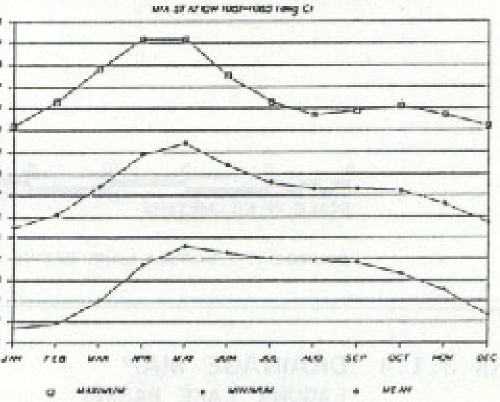
MONTHLY TEMPERATURE DISTRIBUTION



MONTHLY WIND SPEED DISTRIBUTION (mps)



MONTHLY TEMPERATURE DISTRIBUTION

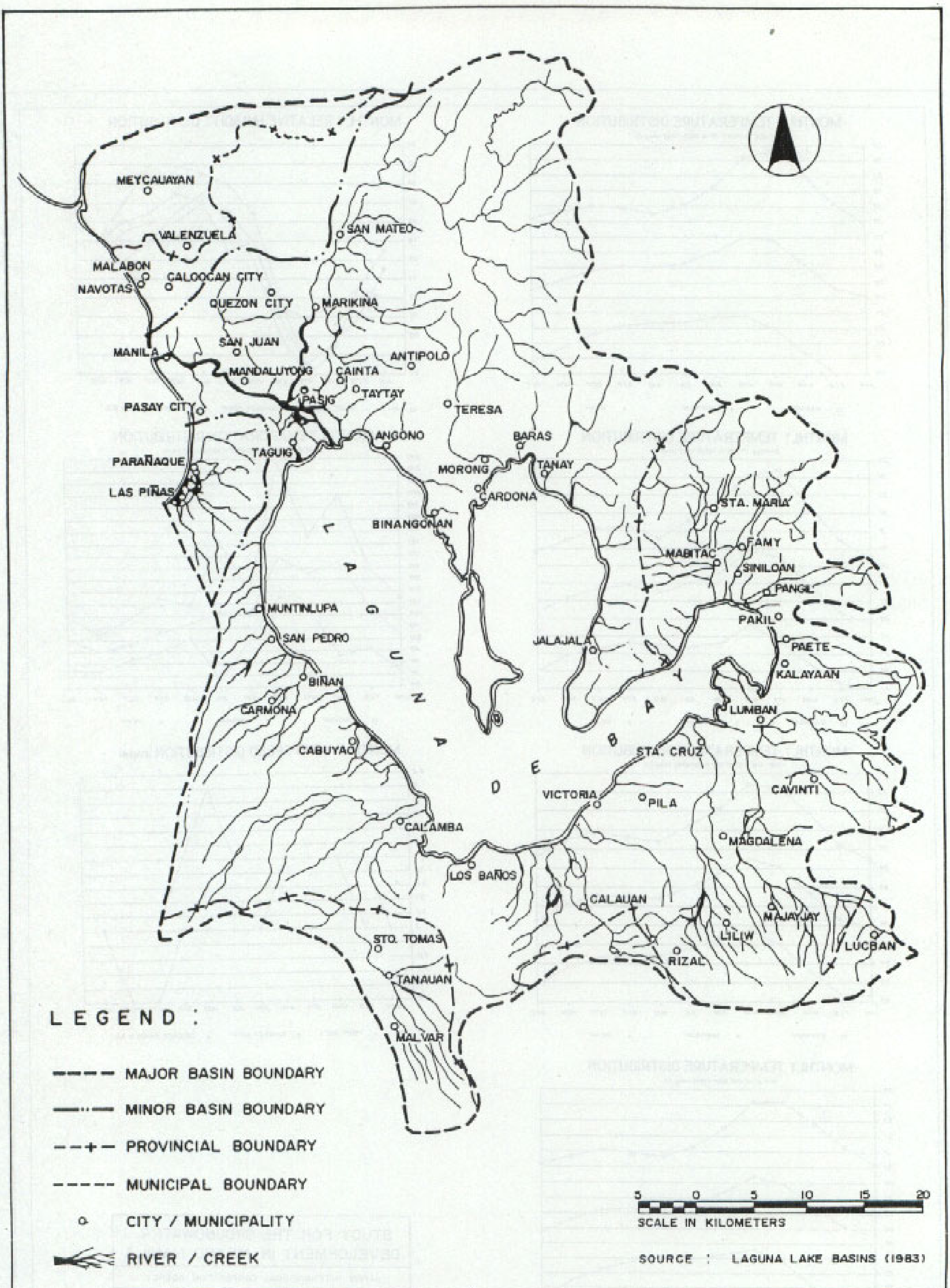


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.1.3

METEOROLOGICAL DATA



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.1.4 DRAINAGE MAP LAGUNA LAKE BASINS
JAPAN INTERNATIONAL COOPERATION AGENCY	

3.2 HYDROGEOLOGY

3.2.1 Metro Manila and Its Environs

3.2.1.1 Outline of Geology

Geographically, the Study area is situated in the southeastern part of the Luzon Central Plain and mainly constitutes the East Side Hill (Figure 3.2.1). It is mountainous east of the Boso-Boso Basin and is contiguous to the South Luzon Upland in the south. East of Manila Bay lies the Zambales Range which extends in the north-south direction.

The Luzon Central Plain extends in the north-south direction and faces Manila Bay in the south and the Lingayen Gulf in the north. The plain has an average length and width of 150km and 60km, respectively. It is bounded by the Philippine Fault on the northeastern part which is contiguous to the Luzon Central Cordillera.

Through the northern part of the plain flows the Agno River which empties into the Lingayen Gulf. The Pampanga and Angat rivers flow through the plain's southern part and both empty into the Manila Bay.

The plain is widely covered by Alluvial deposits. An old inactive volcano (0.53 + 0.05 million years), Mt. Arayat (1,026m), is located prominently in the central part of the plain. The plain is underlain by Alluvium, Guadalupe formation of the Pleistocene to the Pliocene age, and Neogene Tertiary system, in descending order. The thickness of the Guadalupe formation is estimated to be 2,000m in the central part. This sedimentary basin is named as the Luzon Central Valley Basin (Mines and Geosciences Bureau, 1982).

The Study Area is situated southeast of the basin where the Guadalupe formation is exposed. Extending north to south in the marginal zone of the basin are several faults, which indicate tectonic activity up to the Quaternary age (Figures 3.2.2 and 3.2.3). Since volcanoes in the marginal zone were also active during the Quaternary age, most of the sediments have materials of volcanic origin.

The East Side Hill ranges in the north-south direction in the east of the Luzon Central Plain at an elevation of 40-200m. It also extends from Palayan to Laguna de Bay. The hill almost coincides with the area where the Guadalupe formation is exposed.

The Southwest Luzon Upland is situated south of the Study Area. The prominent peaks of Mt. Banahaw (2,177m) and Mt. Makiling (1,109m) of this upland constitute two volcanoes--Taal volcano and Mt. Batulao (811m). The elevation of these mountains decreases towards the north. Accordingly, the southern edges of the piedmont are contiguous to Manila Bay and Laguna de Bay.

The piedmont area is widely covered by thick volcanic materials such as basalt, andesite lava, pyroclastic rocks and mud flows. The area constitutes a recharge zone of the lake water of Laguna de Bay and the groundwater in Imus.

South Sierra Madre presents a landform at the maturity stage with an elevation range of 300m to 1,500m. A steep slope is present and deep valleys are formed. There is no flat plain.

This Sierra Madre area is underlain by pyroclastics, clastic rocks and limestone of Mesozoic to Neogene age. It constitutes a part of the hydrogeologic basement of the Study Area.

West of the Central Plain and extending north to east is the Zambales Range. This range is a mountainous region composed of volcanoes with heights of more than 1,200m. The basement of mountains consists of ultra-basic rocks. These volcanoes, Mt. Pinatubo (1,780m), Mt. Natib (1,287m) and Mt. Mariveles (1,420m) range from north to south and constitute a volcanic row extending to the Corregidor Island, the Luzon Upland and the Mt. Batulao.

Volcanic rocks are composed of lavas of tholeiite basalt, andesite and dacite, and pyroclastics. The volcanic row bounds the western Luzon Central Valley Basin and is considered to be a principal source of materials for the sedimentary basin of the Guadalupe formation in the western part. A previous study (MGB, 1982) considered these volcanoes to have been active for about a million years. One which violently erupted on June 15, 1991 covered parts of Metro Manila with layers of volcanic ash.

3.2.1.2 Lithology and Stratigraphy

The Study Area is underlain by the basement rocks of Pre-Quaternary age and Guadalupe formation and Alluvium of Quaternary age (Table 3.2.1 and Figure 3.2.4).

Marikina Valley is situated at the center of the Study Area and is about 3-7 km wide. It extends in the north-south direction. Bounding the east of the valley, the Binangonan Fault separates the distribution and the structure of geology.

In the west, the Guadalupe formation and Alluvium underlie the area. In the east, the area is underlain by all the formations previously mentioned. However, in the northeastern part, there locates only formations of Pre-Quaternary age.

The Guadalupe formation distributed in the east is lithologically divided into two sections. One is mainly composed of sedimentary rocks; the other, by pyroclastic rocks.

While sedimentary rocks are distributed in the northern part of the Antipolo Plateau, the southern part has a distribution of pyroclastic rocks. These pyroclastic rocks indicate the contemporaneous heterotopic facies and mainly constitute a lower portion of the formation.

The sequence between the Guadalupe formations east and west of the Marikina Valley is not clear as the formations are separated by basaltic rocks that are distributed east of the fault. However, two formations can be identified as sediments from the same period because of the similarity in facies.

The period of sedimentation of the Guadalupe formation is thought to be Quaternary (MGB, 1982). However, a lower part of the sediments might be correlated with the Pliocene age, considering the maximum thickness of 2,000m, the degree of consolidation and alteration of rocks, and the existence of intrusive dyke rocks.

3.2.1.3 Geologic Formations as Aquifers

(1) Basement Rocks

The Madlum formation, Angat formation, Maybangin formation, and Kinabuan formation of Pre-Quaternary age constitute the basement rocks of the Study Area (Figure 3.2.15). Such rocks consist of consolidated clastic and volcanic rocks and are deemed to be relatively impermeable. In some parts where rocks are exposed and weathered, the abovesaid rocks locally form an aquifer. Groundwater can also be found in the fissure zone of rocks which are near faults and limestone caves. However, most of these rocks yield very poor water or form aquifuges.

(2) Guadalupe Formation

Clastic facies such as tuffaceous sandstone, conglomerate, and coarse tuff of Guadalupe formation form good aquifers in the Study Area. The Guadalupe formation distributes separately into three sedimentary basins (Figure 3.2.4), namely, the Guadalupe Sedimentary Basin (GSB), the Antipolo Sedimentary Basin (ASB), and the North Antipolo Sedimentary Basin (NASB). Each basin is surrounded by impermeable base rocks and forms an isolated groundwater basin.

The GSB is situated at a part of the Luzon Central Valley Basin and is composed of thick Guadalupe formation. It is covered by Alluvium in the coastal areas of Manila Bay and the Marikina Valley.

The GSB at the center of Manila Bay has a synclinal axis in the north-south direction. Therefore, the strata in the east of the basin generally dip gently westward. However, there are anticlinal and synclinal axes south of the basin. These folds are affected by the tectonic movement of the Southwest Luzon Upland.

The GSB forms a huge groundwater basin containing several connected and interrelated aquifers composed of tuffaceous sandstone and conglomerate (Figures 3.2.5, 3.2.6 and 3.2.7). Clayey and sandy belts extend in the north-south direction as shown on the facies map of the GSB (Figure 3.2.8).

The thickness of Guadalupe formation is also estimated to range from 1,300 to 2,000m, according to the previously mentioned study (MGB, 1982). In Metro Manila, however, most of the deep wells drilled to exploit fresh groundwater have an average depth of 300 m.

As shown in Figure 3.2.6, the strata of the GSB in Metro Manila tilt monoclinally towards the west. Five to six aquifers can be identified up to a depth of about 300m. The Guadalupe formation is considered to be discontinuous from west to east of the western boundary of the Marikina Valley because the Valley has the features of a graben and is bounded by faults on both sides.

The Guadalupe aquifers strike NW-SE in the northern area of the hill, N-S in the vicinity of the Pasig River, and NNE-SSW in Parañaque. The Guadalupe formation consists of conglomerates in the northern area where non-volcanic sediments are dominant. Secondary volcanic sediments are dominant in the south of Parañaque.

The clay content distribution of the formation is illustrated in Figure 3.2.9. Aquifer transmissivity and productivity may be indicated by this distribution.

Groundwater recharge occurs in the northern area of Novaliches, the northern and eastern areas of Montalban, the western area of the Antipolo plateau, and the southern terrace which is composed of lahar and is contiguous to Tagaytay.

The Guadalupe aquifers in Metro Manila can be considered as the "Metro Manila Groundwater Basin". The Basin constitutes a part of the GSB.

The ASB is a small sedimentary basin surrounded by impermeable base rocks. Its center is in Antipolo and it forms a groundwater basin having an area of about 30km² and contains exploitable water, quantity- and quality-wise. The thickness of the formation is about 230m. Details are explained in Subsection 3.2.2.

The NASB is situated north of Antipolo. It is underlain by thin tuffaceous sandstone and silt stone and the Kinabuan formation. The thickness of Guadalupe formation is estimated to range from several tens of meters to 100m. Its thickness is lower than that of ASB, although the area is bigger. The thin sediments and deep valley in the area suggest that the NASB forms seasonal aquifers because of the presence of a small volume of interspaces in the strata.

Pyroclastics of Guadalupe formation around Laguna de Bay are mainly composed of tuff breccia and partly contains sandstone. These rocks are generally thought to be impermeable, but they contain some exploitable water in the fracture and in the concentrated zone of gravel and sand. Since the sediments were laid down irregularly, the aquifer is locally distributed.

(3) Alluvium

The Alluvium is distributed in the coastal areas of Manila Bay and Laguna de Bay, in the Marikina Valley and the intramountain basins in the eastern mountain area. The Alluvium generally forms a phreatic aquifer in the coastal area of Manila Bay and Marikina Valley. The thickness of Alluvium is estimated to range from 5 to 10m in the coastal areas of Manila Bay and Laguna de Bay, based on drilling data and JICA test well data (Figure 3.2.10).

The Alluvium is mainly composed of soft clay and thin loose sand and overlies Diluvial clay or Guadalupe formation. The sandy layer of the Alluvium forms a phreatic aquifer. Groundwater may be used for domestic purpose; however, water is salinized in the coastal area.

Figure 3.2.11 shows geologic profiles at the Manila South Harbor (JICA, 1987). Based on the N-value, the thickness of Alluvial sediments exceeds 30m at Pier-5. However, and as mentioned previously, the thickness of alluvial sediments in the coastal area from Navotas to Obando is generally small, as shown in Figure 3.2.12 (JICA, 1990). A thick area though is found off-shore.

Diluvial clay consists of clay and silt with N-value range of 5-20 and is partly consolidated. The thickness of the clay layer range from 10-20m in the coastal area. However, the identification of diluvial clay is based only on the foundation drillings at the Manila port and the coastal plain. Further classification is still needed to determine the geologic age, the distribution and thickness of Diluvial clay.

The recent drilling carried out by MWSS indicates the sand and gravel of alluvial fan deposit and the underlying Guadalupe formation to form aquifers in the coastal area of Laguna de Bay from Baras to Jala-Jala. The thickness of Alluvium in the inland basins, such as Teresa and Boso-Boso, is estimated to be minimal as the impermeable basement rock is sporadically exposed. This could suggest that aquifers in these areas yield poor quantities of groundwater.

Based on the geologic data and the above interpretation, the transgression in Alluvium age may be as illustrated in Figure 3.2.13. This figure suggests that the deep erosional valley was not formed in the glacial time that is more than 10,000 years past. The decline of the sea level at the Wurm glacial stage is thought to be a maximum of 140m. But old Manila Bay then might be a huge lake, with its water table level remaining relatively high.

(4) Hydrogeologic Assessment

The groundwater potentials of the Study Area were initially assessed qualitatively, based on the distribution and the facies of rocks, and are illustrated in Figure 3.2.14. Aquifer systems can be classified according to the formations. Six categories were made.

(1) Al/G : Alluvium overlying Guadalupe Formation
(2) G : Guadalupe Formation
(3) G/B : Guadalupe Formation overlying Basement
(4) Al/Gv : Alluvium overlying Guadalupe Formation of volcanic facies
(5) Al/B : Alluvium overlying Basement
(6) B : Basement

Groundwater potential is high at categories 1, 2 and 3, and relatively low at 4 and 5. Category 6 is thought to be the lowest.

3.2.2 Antipolo Plateau

3.2.2.1 Geology

The Antipolo Plateau is located east of Marikina Valley. Its area is about 30km²; elevation, about 200m above mean sea level. The main rivers of the plateau flow into the poblacion of Antipolo and then flow out westward to Marikina Valley or cascade through cliffs. Rivers in the east and north of the plateau originate from springs at piedmont.

The plateau is underlain by the Kinabuan formation and the Antipolo diorite of Cretaceous to Oligocene age, by the Angat formation and Madlum formation of Miocene age, and by the Guadalupe formation and Alluvium of Quaternary age (Table 3.2.2, Figures 3.2.15 and 3.2.16).

The Kinabuan formation is distributed west and north of the plateau and is composed of altered basalt, basaltic andesite lava, pillow lava and pyroclastics. These volcanic rocks are dark greenish in color due to chloritization, indicating them to be products of marine volcanoes.

The Antipolo diorite is distributed in the north-south direction along the eastern edge of the plateau. The rock has a fine- and even-grained texture and is deeply weathered. Recent K-A dating (MGB, 1982) reveals that the rock is of Oligocene age.

The Angat formation is mainly composed of partly crystalline limestone and is distributed in contiguity with the Antipolo diorite in the eastern edge of the plateau. The formation is dated Lower Miocene, based on the occurrence of larger Foraminifera.

The Madlum formation consists of consolidated limey sandstone and silty shale. The formation is distributed in a limited area at the eastern edge of the plateau. Geological age of the formation is considered to be Upper Miocene.

The Guadalupe formation has a total thickness of about 230m, and it may be divided into four members based on logs of existing wells and JICA test wells and field observation of outcrops.

The lowermost member, member I, consists of conglomerate and coarse sandstone and underlies the north of the plateau.

Member II is composed of consolidated medium sandstone and conglomerate in the lower part, and alternating beds of tuffaceous mudstone and sandstone in the upper part. The strike and dip of the formation are N20°W and 6S°W, respectively. The formation gently inclines towards the center of the Antipolo Sedimentary Basin (ASB).

Member III consists of alternating beds of mudstone and tuff. Tuffaceous sandstone is predominant in the member and covers the central area of the plateau. The member intercalates a lappili tuff that is widely distributed south of the ASB and which is considered to be continuous up to the pyroclastics of the Laguna formation.

Member IV consists of deeply weathered tuff breccia and volcanic conglomerate. It overlies the north of the plateau.

Black basalt porphyry intrudes into member III at the western and southern edges of the plateau. The rock is considered to be formed in sheets.

The time stratigraphic classification of the Guadalupe formation is still undetermined by the fossils. It is generally thought that the formation is made up of Quaternary sediments, considering the rock facies. However, judging from the degree of consolidation, the low resistivity and the existence of intrusive basalt porphyry, members I and II are possibly Pliocene. These members are less tuffaceous than upper members III and IV. The rock facies also indicate that the formation was deposited in the bay or the lake environment.

The Antipolo plateau is underlain by the Guadalupe formation with its basement composed by hard rocks of pre-Neogene age. The basin has the shape of a ship-bottom with a depth-range of 180 to 230m at the center (Figure 3.2.15)

The basement rocks are exposed in the east, west, and north of the plateau, in fault contact or unconformity with the Guadalupe formation. Major faults run in the north-south direction on both sides of the plateau, but in the north, a fault in the north-west direction bounds the plateau.

For the southern plateau, a massive lapilli tuff of member III shows a flat landform. Considering the distribution of basement rock, the depth of the sediment is shallow in the southern part.

3.2.2.2 Hydrogeologic Unit and Structure

Pre-Quaternary rocks generally form a hydrogeologic basement of the plateau. The Guadalupe formation overlies the basement. This formation constitutes good aquifers, particularly the coarse sandstone and tuff of its upper member.

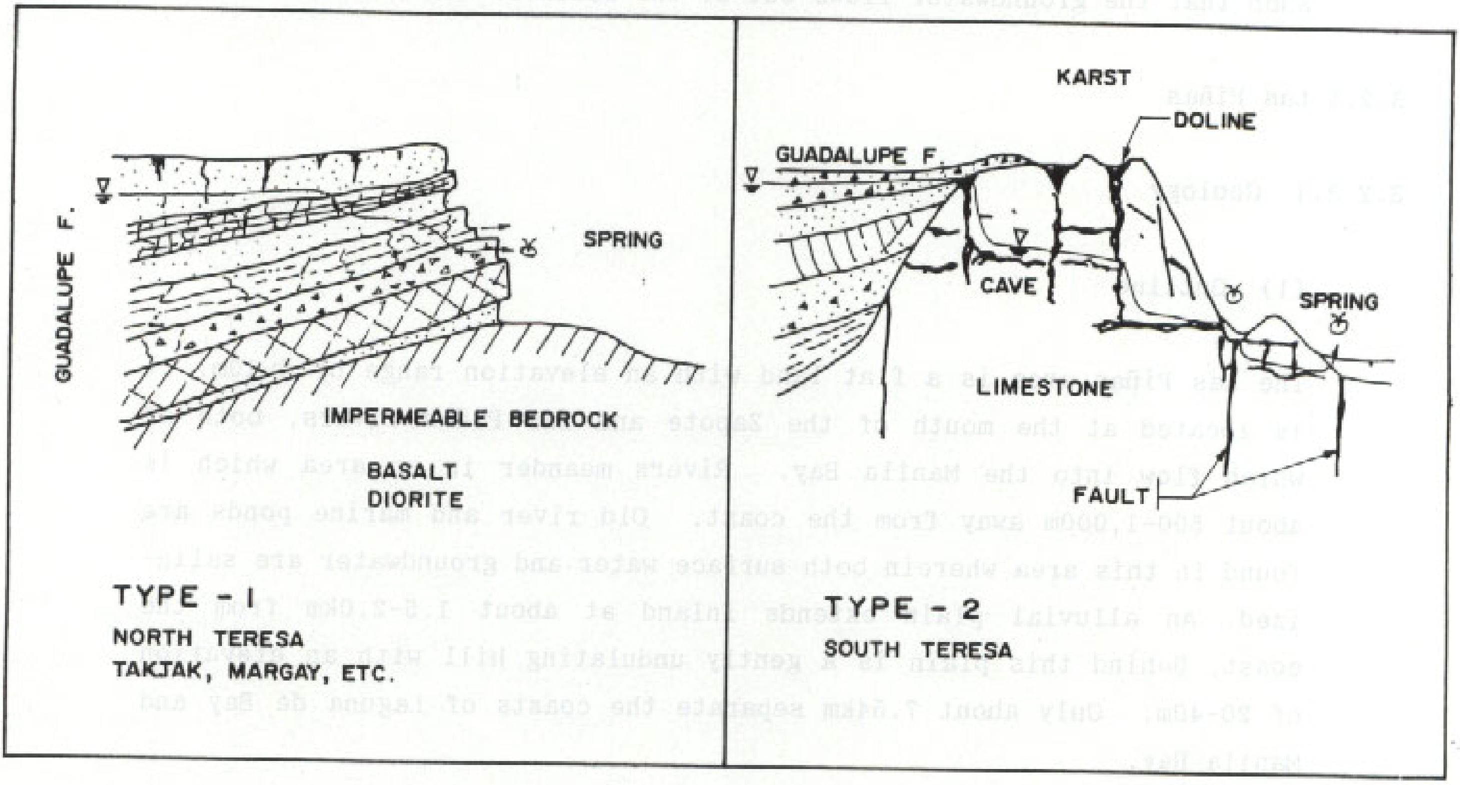
The Guadalupe formation is weathered at a depth of 30-50m from the surface. The weathered section contains unconfined water or perched water especially during the rainy season.

Hydrogeologic units can be defined as upper Gs and lower Gmd in terms of rock facies, resistivity and transmissivity of the formation. Gs is mainly composed of coarse sandstone and tuff of member III and forms a fairly good confined aquifer. Gmd is mainly composed of tuffaceous mudstone of member II and forms an aquitard or aquifuge (Figure 3.2.18).

The type of formation was verified by the pumping test result of JICA 200m test well in Barangay San Jose, Antipolo. Transmissivity of muddy layer (at depths of 152m to 173m and 185m to 194m) was only $9m/d^2$. The discharge rate was 51.6 l/min.

Although the maximum thickness of the Guadalupe formation is estimated to be about 230m, only the upper member of the Guadalupe formation forms an aquifer, with its depth as measured from the surface varying from 100m to 120m (Figure 3.2.17). Some existing wells in Antipolo are tapped at depths of 180m to 245m. However, groundwater is thought to be supplied mainly by Gs aquifer shallower than 120m.

A number of springs are found along the marginal zone of the plateau, with water being discharged from the plateau. Flow systems are categrized into two types and are shown below.



From the flow condition of the spring, the Antipolo Plateau is considered to constitute an isolated groundwater basin.

3.2.2.3 Groundwater Table

The groundwater table as measured in May 1991 is illustrated in Figure 3.2.19. Elevation of the water table at the center of the Antipolo plateau ranges from 160m to 170m, with groundwater level at about 30m to 40m below ground surface. A groundwater mound can be seen in the southern and eastern parts of the plateau. However, the water table becomes rather low at the center of the poblacion where it gradually descends westward.

The hydraulic gradient of the water table is steep where escarpments are formed. These areas are located in the northeastern, the eastern and the southwestern edges of the plateau at a relative height of about 200m. The hydraulic gradient of the water table is steep in these places such that the groundwater flows out of the basin as mentioned in 2.3.2.

3.2.3 Las Piñas

3.2.3.1 Geology

(1) Outline

The Las Piñas area is a flat land with an elevation range of 0-10m. It is located at the mouth of the Zapote and Las Piñas rivers, both of which flow into the Manila Bay. Rivers meander in an area which is about 500-1,000m away from the coast. Old river and marine ponds are found in this area wherein both surface water and groundwater are salinized. An alluvial plain extends inland at about 1.5-2.0km from the coast. Behind this plain is a gently undulating hill with an elevation of 20-40m. Only about 7.54km separate the coasts of Laguna de Bay and Manila Bay.

The Guadalupe formation is exposed in the above undulating hill and it is composed of alternating beds of sandstone, conglomerate, mudstone and tuff. The strata have a strike parallel to the coastal line and dip at 3-5 degrees.

Downstream of the Zapote river, the strata are composed of alternating beds of fine to medium tuffaceous sandstone and mudstone, the tuffaceous sandstone being prominent. The strata intercalate pumice tuff and incline towards Manila Bay at about 3 degrees.

The thickness of the Guadalupe formation possibly reaches to more than 2,000m. The thickness of Alluvium might be 10m to 20m, basing on existing well logs and core boring data at JICA test well sites. The alluvial bed consists of sand and clay with shell fragments (Figures 3.2.20, 3.2.21 and 3.2.23).

(2) Lithologic Description of JICA Test Well Sites

Seven test wells were drilled at three locations in the coastal area of Las Piñas. Prior to the drilling of test wells, two 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 is 300m.

Las Piñas No.1 and No.2 are located inland at a distance of about 500m to 800m from the coast. The distance between the two well sites is about 1,300m. The facies and thickness of the formation are very similar to each other and are briefly described as follows (Figure 3.2.23).

LAS PIÑAS NO.1

The site is near the coastal line where the alluvium is less than seven-meter thick. The rest of the strata 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, namely CL, was traced at depths of 58m to 76m. This clayey layer may be associated with Las Piñas No.2. The formation overlain by this clayey layer consists mainly of alternating beds of 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, thus making the resistivity curves indicate high anomalies.

LAS PIÑAS NO.2

Geology of Las Piñas No.2 can be classified into Alluvium and the Guadalupe formation. The Alluvium which is 11.1-m thick consists of soft clay and loose gravel layers and is underlain by well-consolidated Guadalupe formation.

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 in Las Piñas No.1.

3.2.3.2 Analysis of Core Samples

Core samples taken at Las Piñas No.1 were analyzed from the stratigraphical, chronological and geochemical points of view.

(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 3.2.3. 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 could have been disturbed by water flow during their transport and deposition, judging from the grain shape, lamina, wooden fragment and roundness of conglomerate.

Accordingly, the result of dating may 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.

(2) Diatom Analysis

Most of the diatoms found in the core samples (obtained at depths of 7.7 to 10.5m) are marine or marine to brackish. In contrast, only limnetic diatoms were identified in the core samples taken at depths of 24.8m to 298m (Table 3.2.4).

This finding suggests that the uppermost sediments were laid down in the shallow sea of Holocene age while the 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, was discovered during the 1960s by MGB through a drilling it carried out downstream of the Marikina River. This could indicate that the deeper formation was deposited in a marine environment.

(3) Analysis of Heavy Minerals

The 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 dominant in heavy minerals. Hornblende was found in samples taken at shallow depths reaching up to 165m. The amount of hyperthene was very small--below 265m.

The difference of 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 were found in the samples instead of a small content 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 exceeded 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 can be characterized by the dominance of black volcanic glass and brown volcanic glass, whereas in the upper samples, white volcanic glass and brown volcanic glass are dominant.

The heavy mineral analysis as well as the volcanic glass analysis may be done even with the use of well cuttings. The assemblage of both heavy minerals and volcanic glass could be a good marker and should help future geologic correlation in the Metro Manila.

Results of analysis of heavy mineral are shown in Table 3.2.5.

(4) Analysis of Chloride Content

Chloride content of sandy core samples was analyzed to evaluate the degree of contamination caused by saltwater intrusion.

The findings show that samples from shallow aquifers which were taken at depths of 10m, 27m and 52.5m yield much higher chloride content than those from deep aquifers. This could indicate that the saltwater mainly encroaches on the shallow aquifer from Manila Bay and the surface (Table 3.2.6).

(5) Carbon Dating

The carbon dating was carried out for Las Piñas Site No.2 using two alluvial humic clay samples. Sample No.1 and Sample No.2 were taken from depths of 7.7m and 10.5m, respectively. The measured radiocarbon age before the year 1950 of Sample No.1 is 7040 years, plus or minus 150 years. That of sample No.2 is 7360 years, plus or minus 110 years.

This age shows that the alluvial clay was deposited during the global transgression after Wurm glacial stage (Japanese name "Jomon transgression").

3.2.3.3 Hydrogeologic Unit and Structure

Good aquifers in the area are constituted by tuffaceous sand and gravelly layers of the Guadalupe formation. Groundwater is abstracted by deep wells which tap at a depth of about 300m. A thick clayey layer was 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

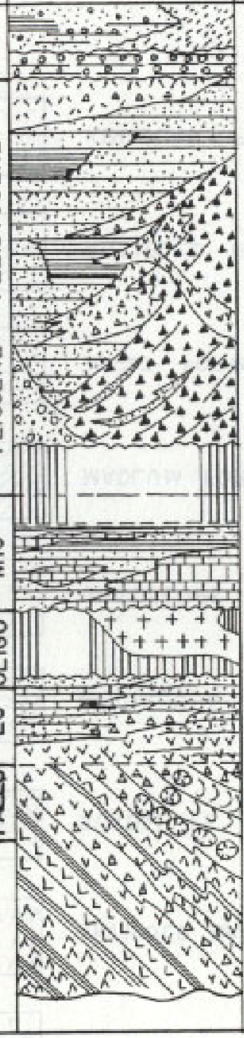
Groundwater level varies from aquifer to aquifer. For instance, water levels of the 100m-test wells at Las Piñas are 4.6m and 3.7m for No.1 and No.2, respectively. In contrast, water levels of the two 200m-test wells are 37.3m for No.1 and 43.4m for No.2. Water levels in the 300m-test wells are 44.5m (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.

TABLE 3.2.1 STRATIGRAPHY OF THE STUDY AREA



GEOLOGIC AGE			SYMBOL	FORMATION NAME	LITHOLOGY	HYDRO-GEOLOGY
CENOZOIC	QUATERNARY	HOLOCENE	Al, Ta, Te	ALLUVIUM	CLAY, SAND GRAVEL TALUS, TERRACE DEPOSITS	AQUIFER
CENOZOIC	QUATERNARY	PLIOCENE ~ PLEISTOCENE	Gf, Gss, Gtb, Gt, G dg, Abp, Gsg, Gg	GUADALUPE FORMATION (LAGUNA F.)	TUFF, TUFFACEOUS SANDSTONE TUFF-BRECCIA MUDSTONE WELDED TUFF, LAPILLI TUFF PYROCLASTIC ROCKS (AGGLOMERATE) SANDSTONE CONGLOMERATE (ANTIPOLO BASALT PORPHYRY	AQUIFER / LOCAL AQUIFER
CENOZOIC	TERTIARY (PALAEOGENE ~ NEOGENE)	MIO	Mc	MADLUM F.	SANDSTONE, SHALE LIMESTONE	IMPERMEABLE BED ROCK
CENOZOIC	TERTIARY (PALAEOGENE ~ NEOGENE)	MIO	ALs	ANGAT F.	LIMESTONE CLASTIC ROCKS	IMPERMEABLE BED ROCK
CENOZOIC	TERTIARY (PALAEOGENE ~ NEOGENE)	OLIGO	Ad	ANTIPOLO DIORITE	DIORITE	IMPERMEABLE BED ROCK
CENOZOIC	TERTIARY (PALAEOGENE ~ NEOGENE)	EO	My	MAYBANGAIN F. (BAYABAS F.)	SANDSTONE, SHALE, PYROCLASTICS LIMESTONE	IMPERMEABLE BED ROCK
CENOZOIC	TERTIARY (PALAEOGENE ~ NEOGENE)	PALEO	Ks	KINABUAN F.	ALTERED ANDESITE, DACITE	IMPERMEABLE BED ROCK
MESOZOIC	CRETACEOUS		Kb, Kd	(BAREMAS-BAITO F.	ALTERED SPILITIC BASALT, PYROCLASTICS CHERT, SANDSTONE SHALE GABBRO	IMPERMEABLE BED ROCK

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GEOLOGIC AGE		Symbol	FORMATION AND LITHOLOGY	FEATURE OF AQUIFERS
QUATERNARY	HOLOCENE	Al	ALLUVIUM : SAND, SILT AND GRAVEL	UNCONFINED AQUIFERS
QUATERNARY	PLEISTOCENE	Gtb	GUADALUPE FORMATION IV : TUFF BRECCIA, AGGLOMERATE AND CONGLOMERATE	UNCONFINED AQUIFERS
QUATERNARY	PLEISTOCENE	Abp	ANTIPOLO BASALT PORPHYRY : PORPHYRITIC BASALT DYKE AND SHEET	
QUATERNARY	PLEISTOCENE	Gs, Gt	GUADALUPE FORMATION III : ALTERNATION OF TUFFACEOUS SANDSTONE, MUD. STONE, FINE TO COARSE TUFF, LAPILLI TUFF	CONFINED AQUIFERS — RICH AQUIFER
QUATERNARY	(PLIOCENE)	Gmd ~Gss	GUADALUPE FORMATION II : TUFFACEOS SANDSTONE, MUDSTONE AND MUDSTONE	CONFINED AQUIFERS — POOR AQUIFER
QUATERNARY	(PLIOCENE)	Gg	GUADALUPE FORMATION I : CONGLOMERATE, COARSE ~ MEDIUM SANDSTONE	CONFINED AQUIFERS — POOR AQUIFER
TERTIARY	NEOGENE	Mc	MADLUM FORMATION : CALCAREOUS SANDSTONE AND SILTY SHALE	IMPERMEABLE BEDROCK
TERTIARY	PALAEOGENE	Als	ANGAT FORMATION : LIMESTONE	LOCAL OR DISCONNECTED AQUIFERS (FISSURE CONTROLED AQUIFER)
TERTIARY	PALAEOGENE	Ad	ANTIPOLO DIORITE : DIORITE	
MESOZOIC CRETACEOUS		Kb	KINABUAN FORMATION : ALTERED SPILITIC BASALT, ANDESITIC BASALT	

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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 $\sigma = \sigma k \times u / k$ (Ma): Mega-annum

σk : thermal neutron dose of standard glass (NBS SRM-913) irradiated at NBS nuclear reactor $= 4.75 \pm 0.05\ (\times 10^{14} cm^{-2})$

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

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

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					
Diploneis 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

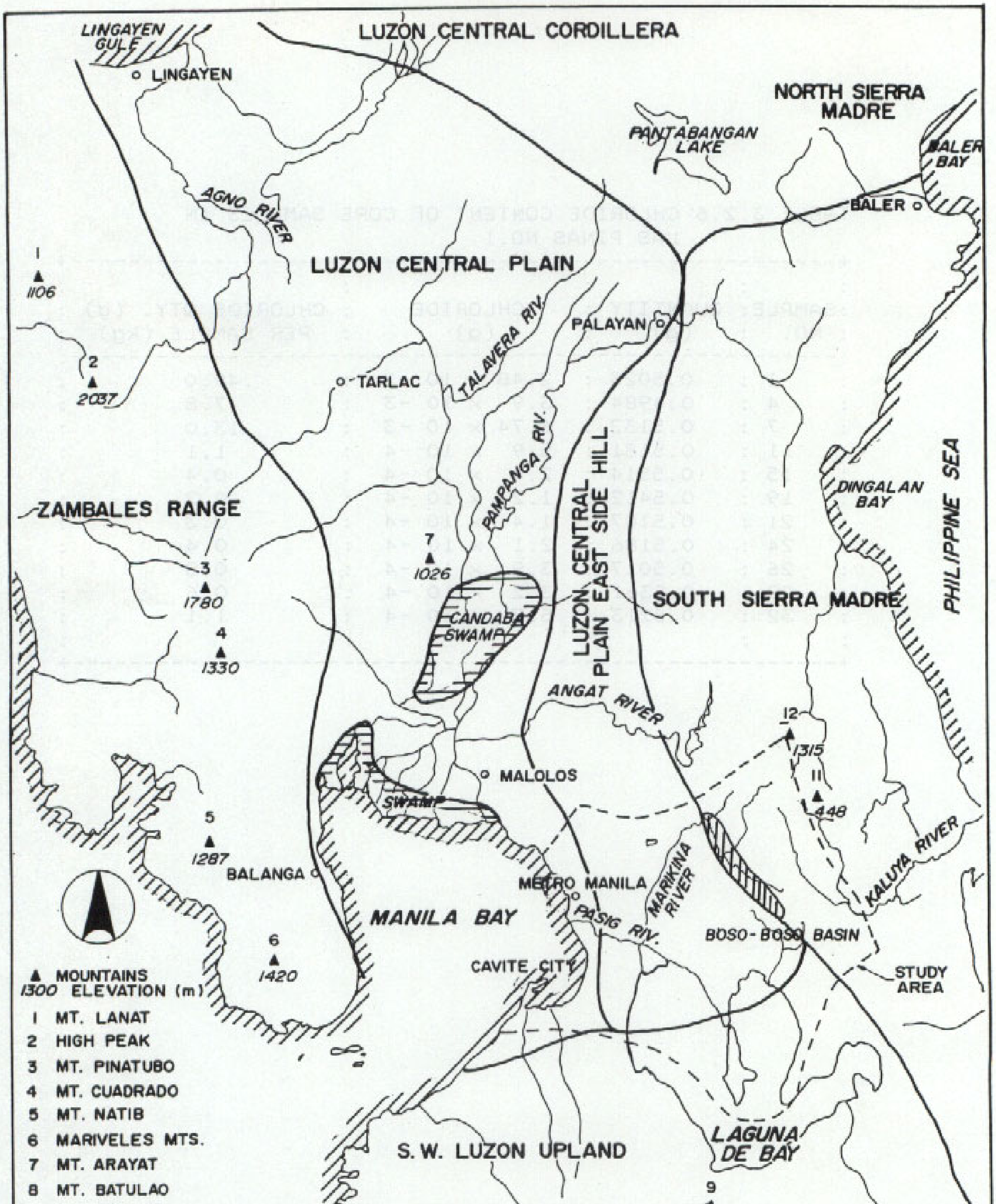
TABLE 3.2.5(2) HEAVY MINERAL COMPOSITION (%)

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

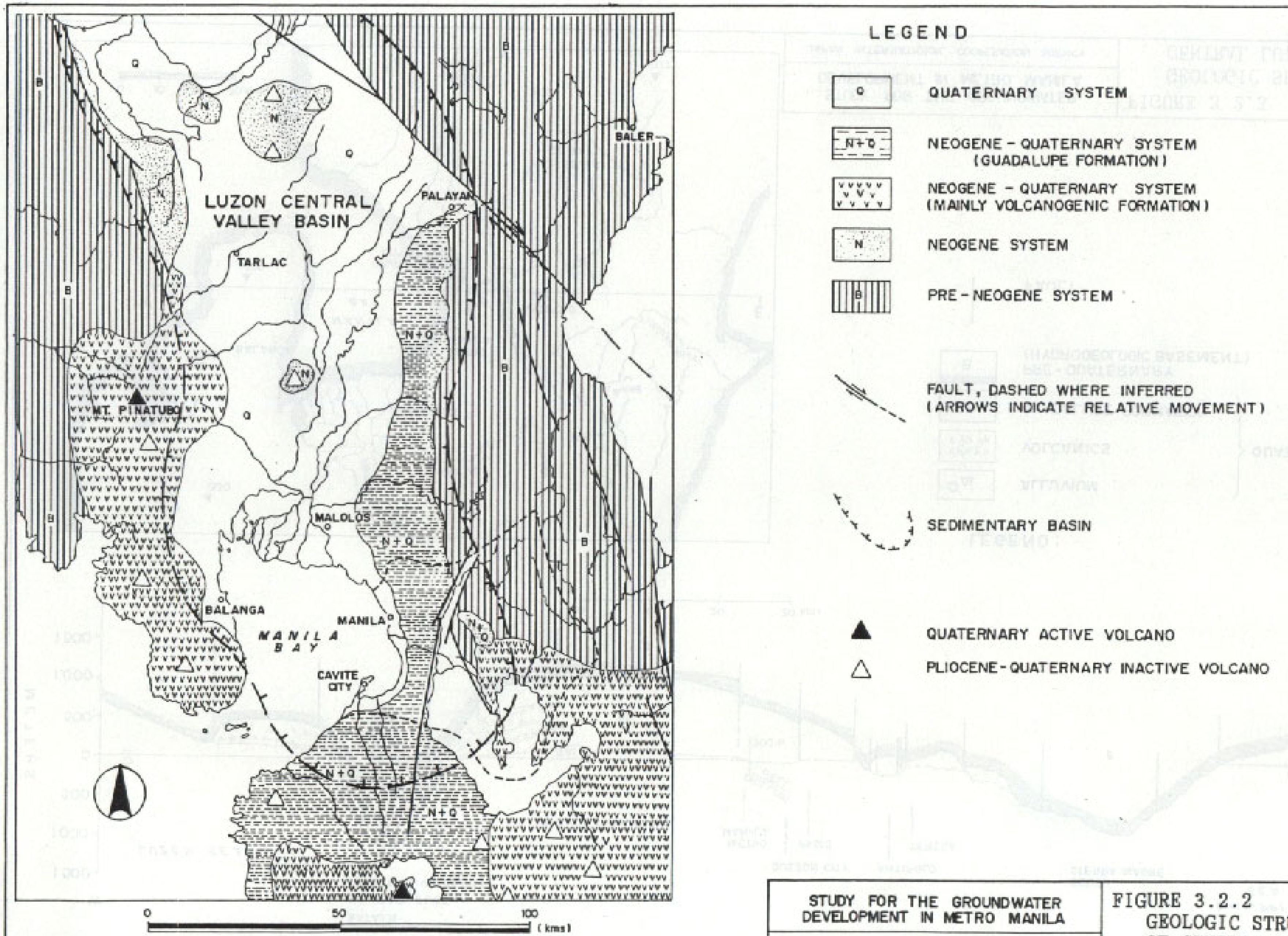
Au: Augite Hy: Hypersthene Ho: Hornblende
Zi: Zircon Mg: Magnetite Py: Pyrite

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



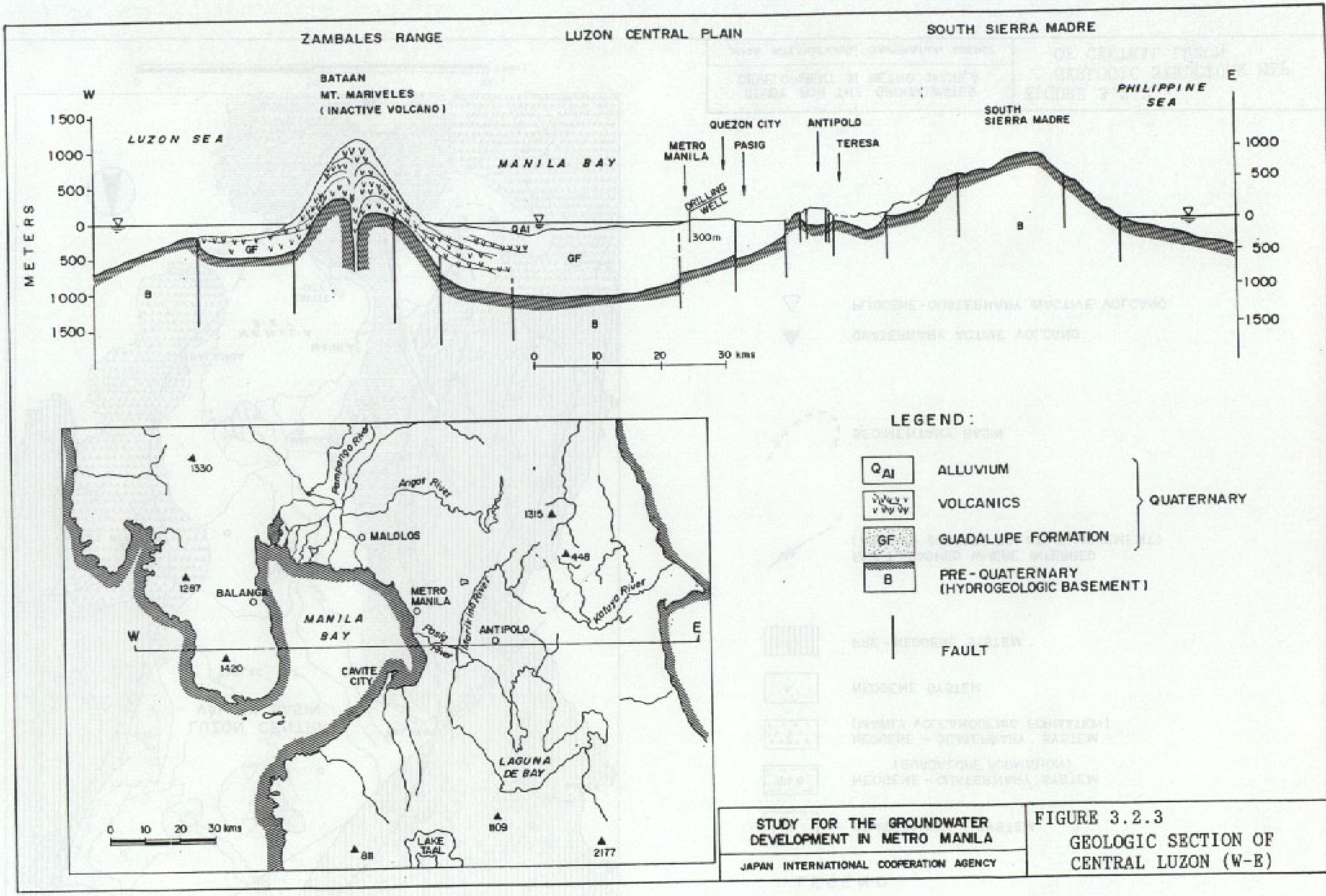
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.1 PHYSIOGRAPHIC PROVINCES OF CENTRAL LUZON
JAPAN INTERNATIONAL COOPERATION AGENCY	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

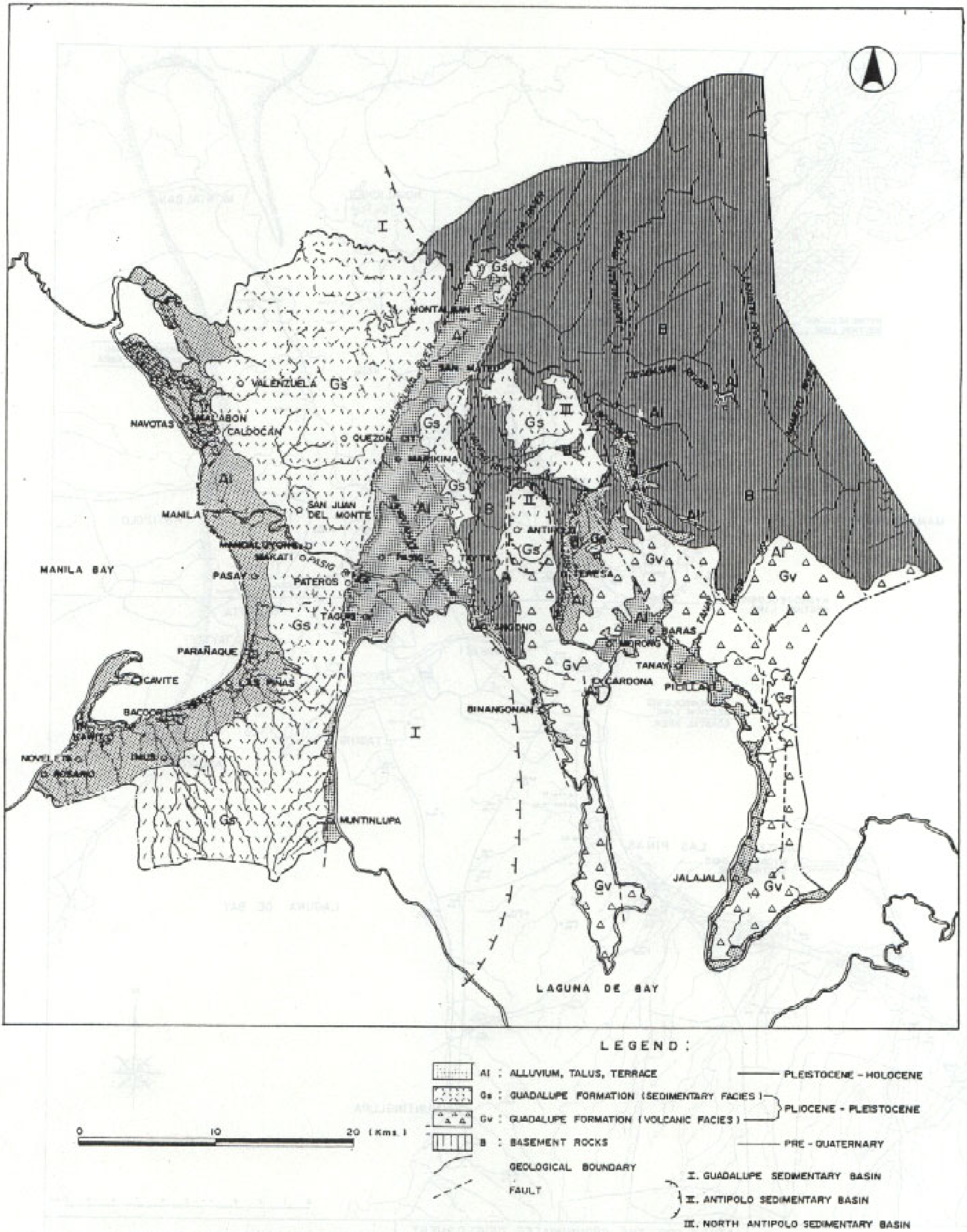
FIGURE 3.2.2
GEOLOGIC STRUCTURE MAP OF CENTRAL LUZON



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

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

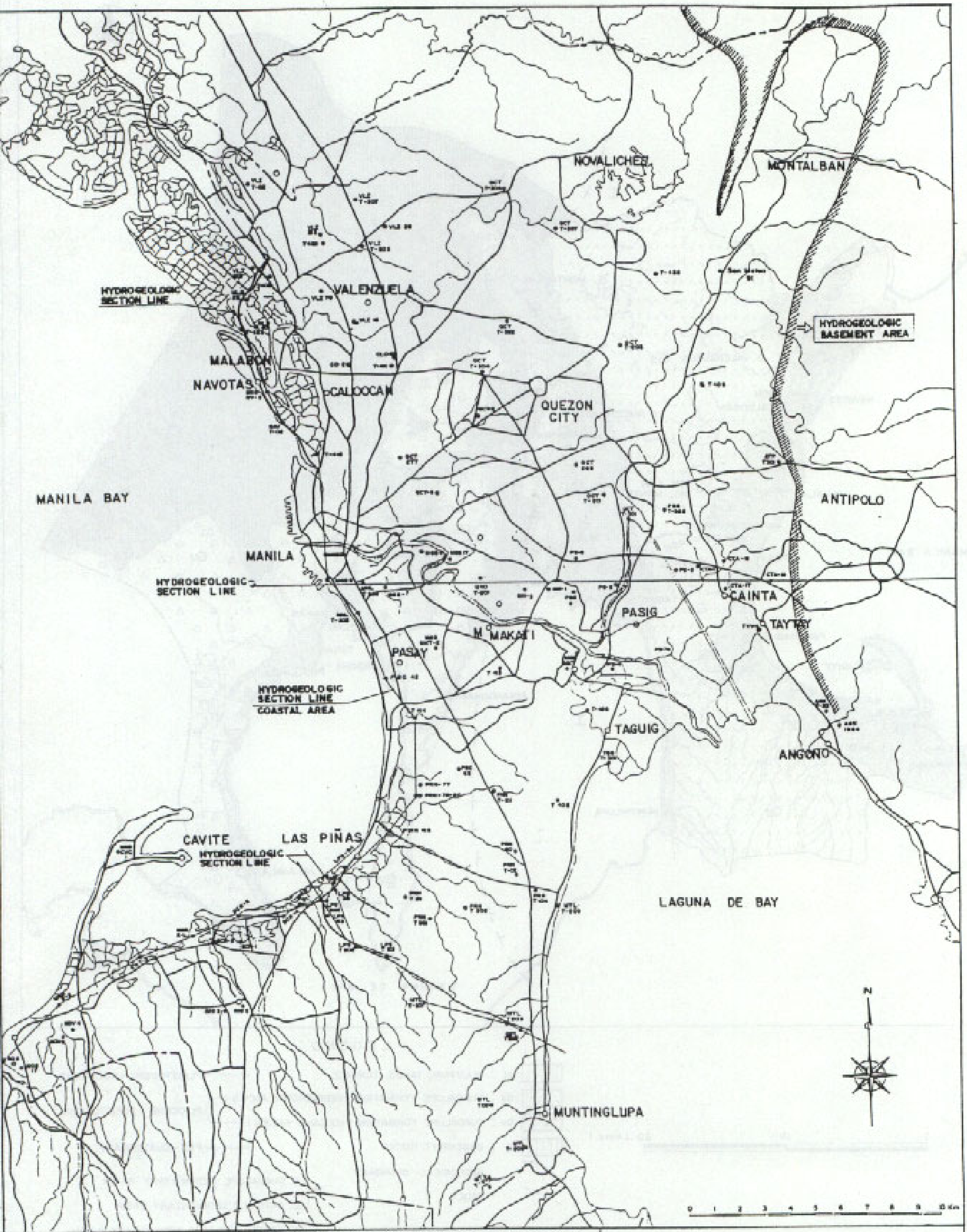


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.2.4

SIMPLIFIED GEOLOGIC MAP - STUDY AREA



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.2.5 LOCATION OF SECTION LINE
JAPAN INTERNATIONAL COOPERATION AGENCY	

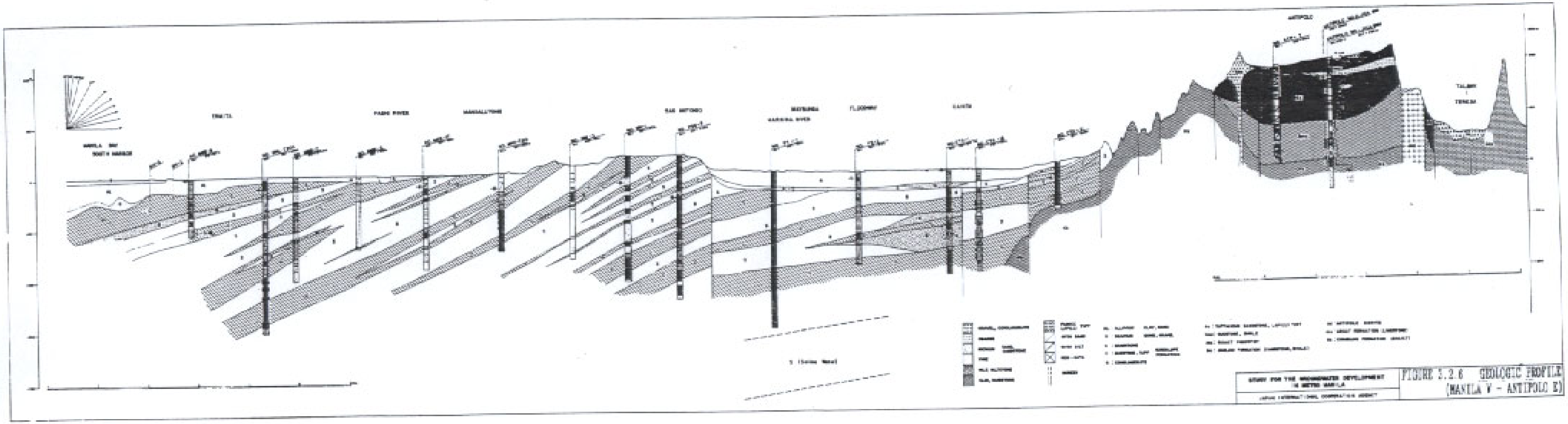
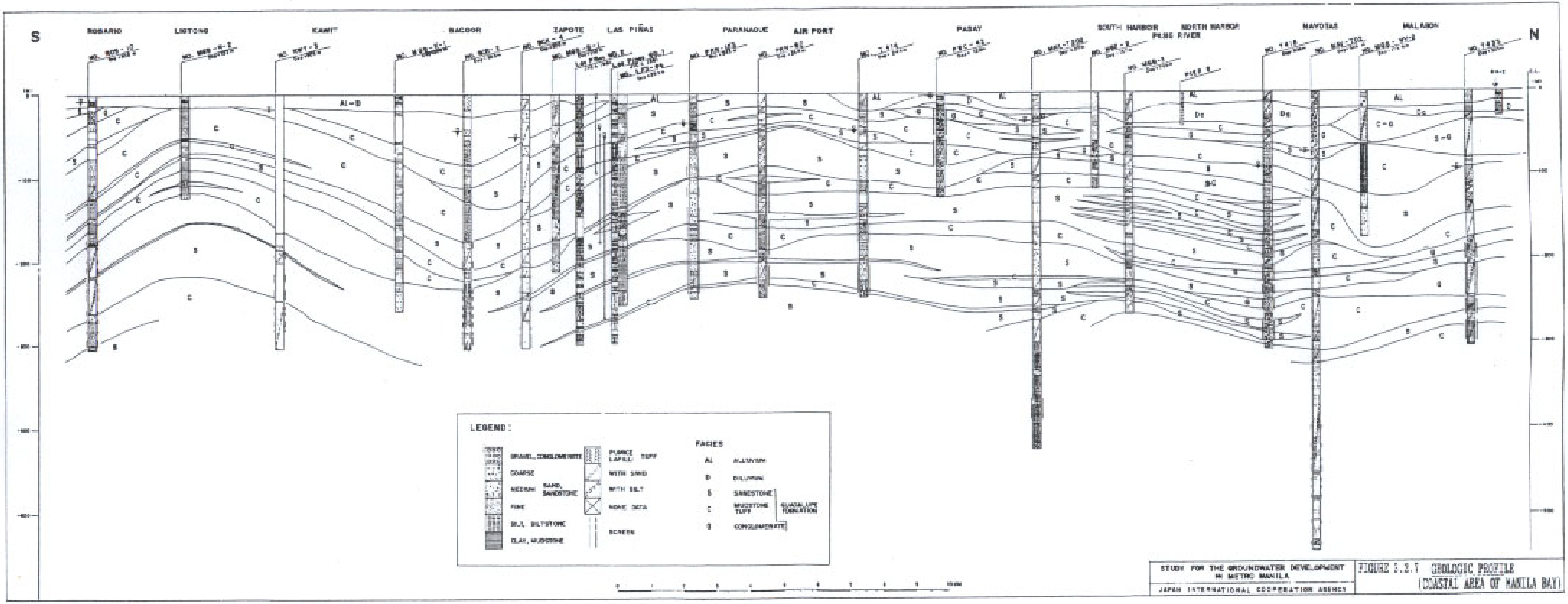


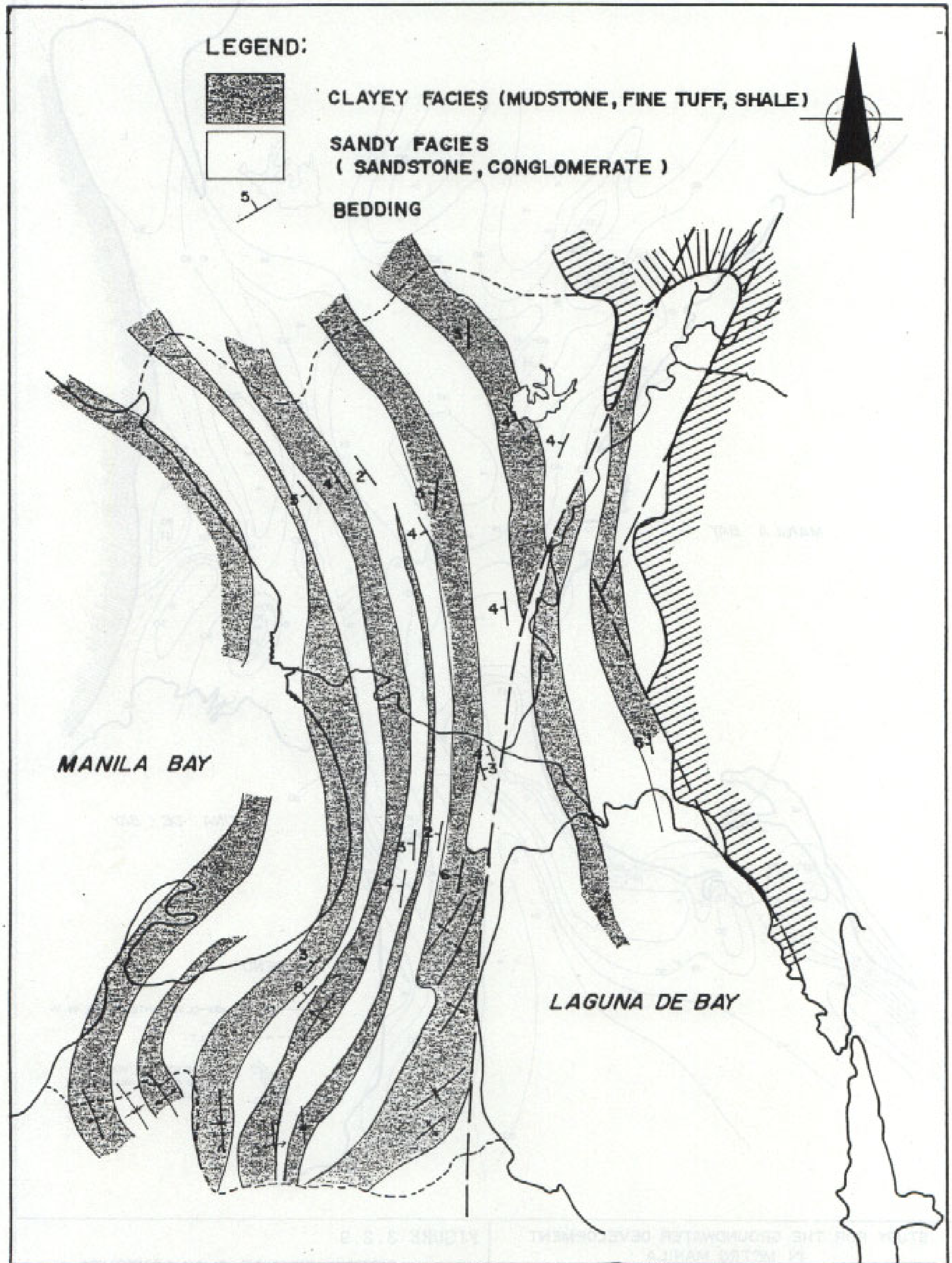
FIGURE 3.2.6 GEOLOGIC PROFILE (MANILA V - ANTIPOLO E)



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

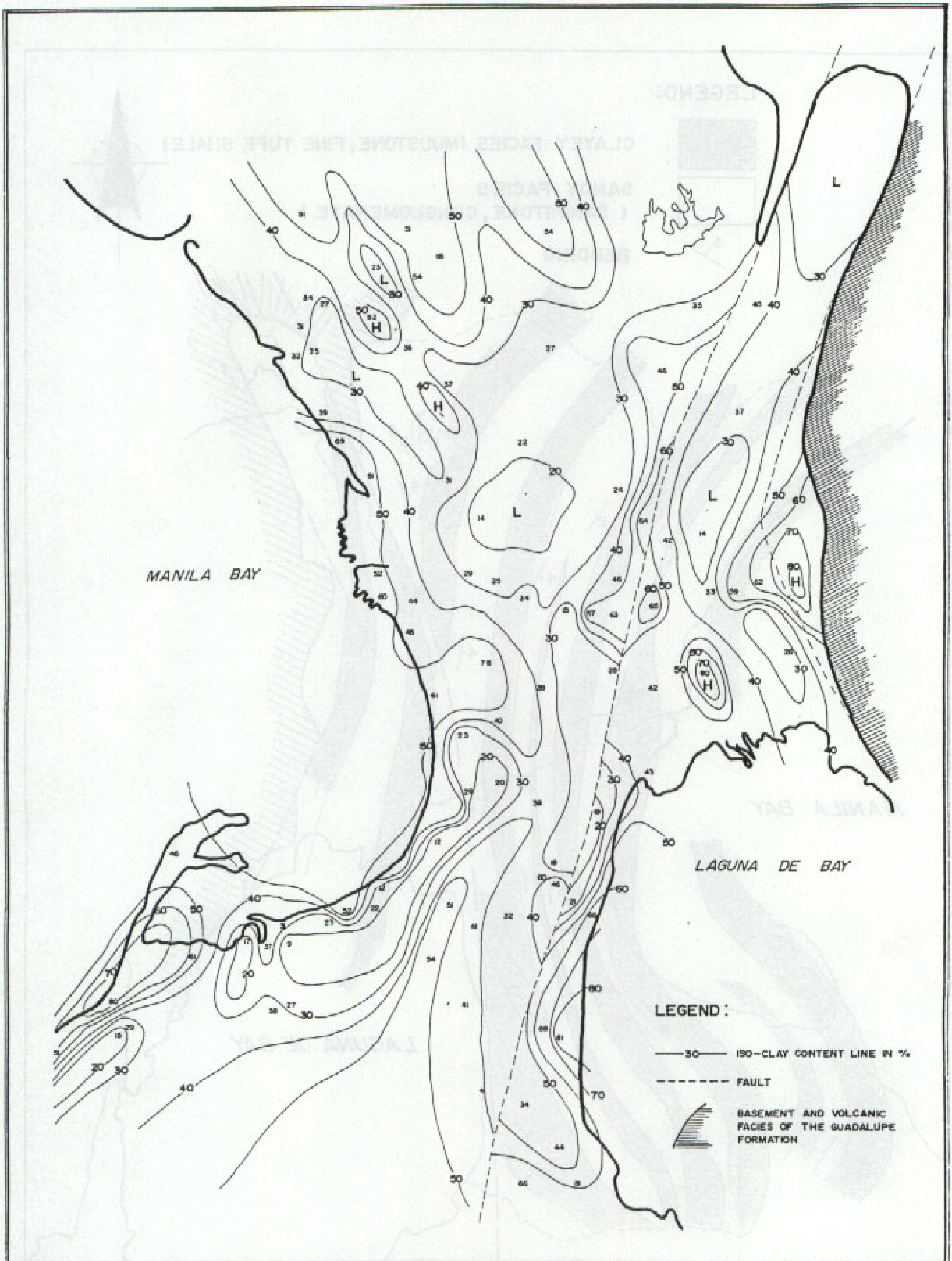
FIGURE 2.2.7 GEOLOGIC PROFILE (COASTAL AREA OF MANILA BAY)



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.2.8 **FACIES MAP OF THE GUADALUPE FORMATION**



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

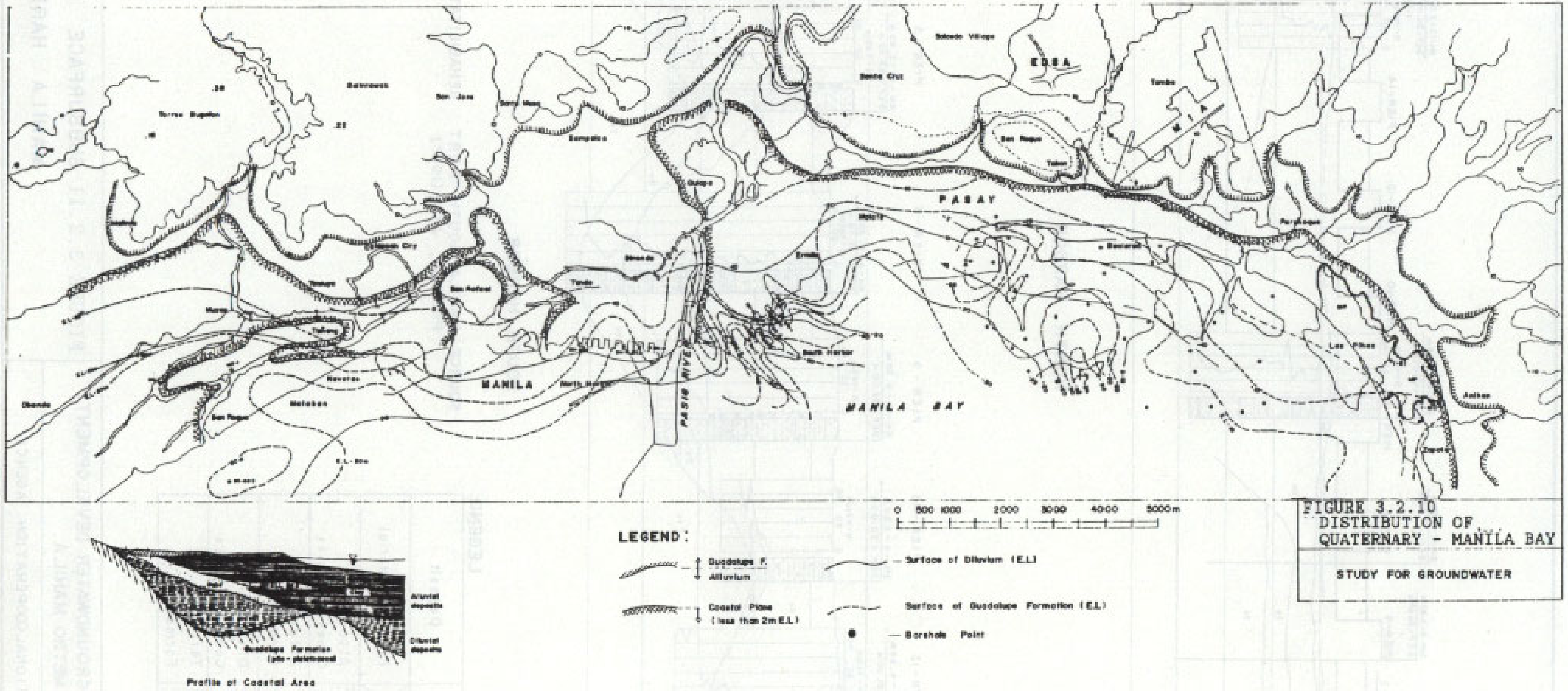
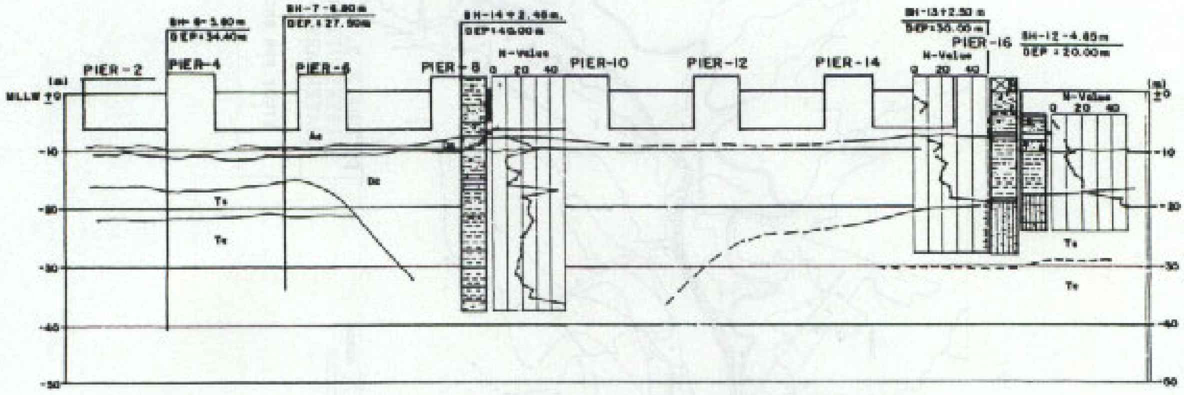
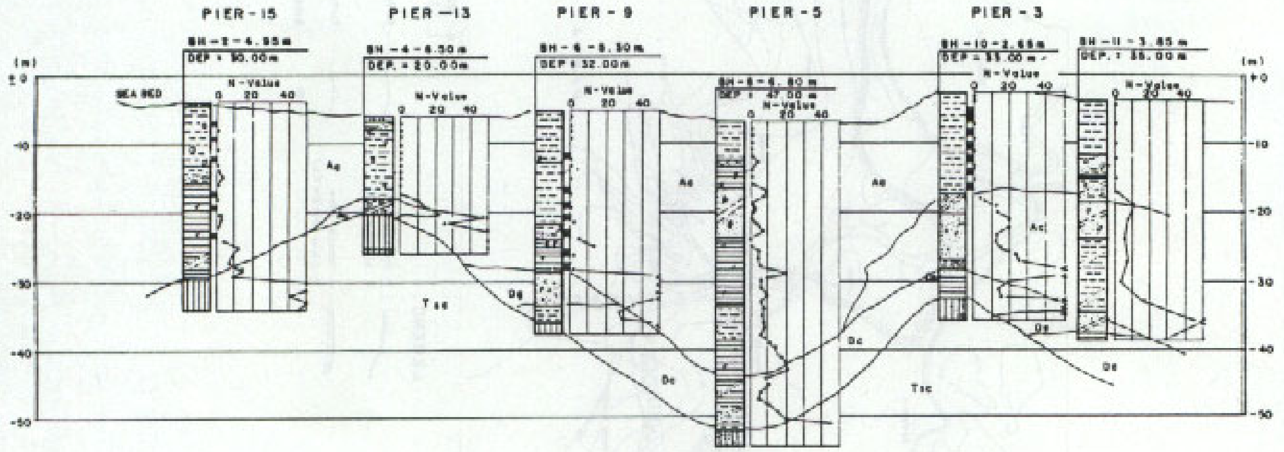


FIGURE 3.2.10
DISTRIBUTION OF QUATERNARY - MANILA BAY

STUDY FOR GROUNDWATER



NORTH HARBOR



SOUTH HARBOR

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

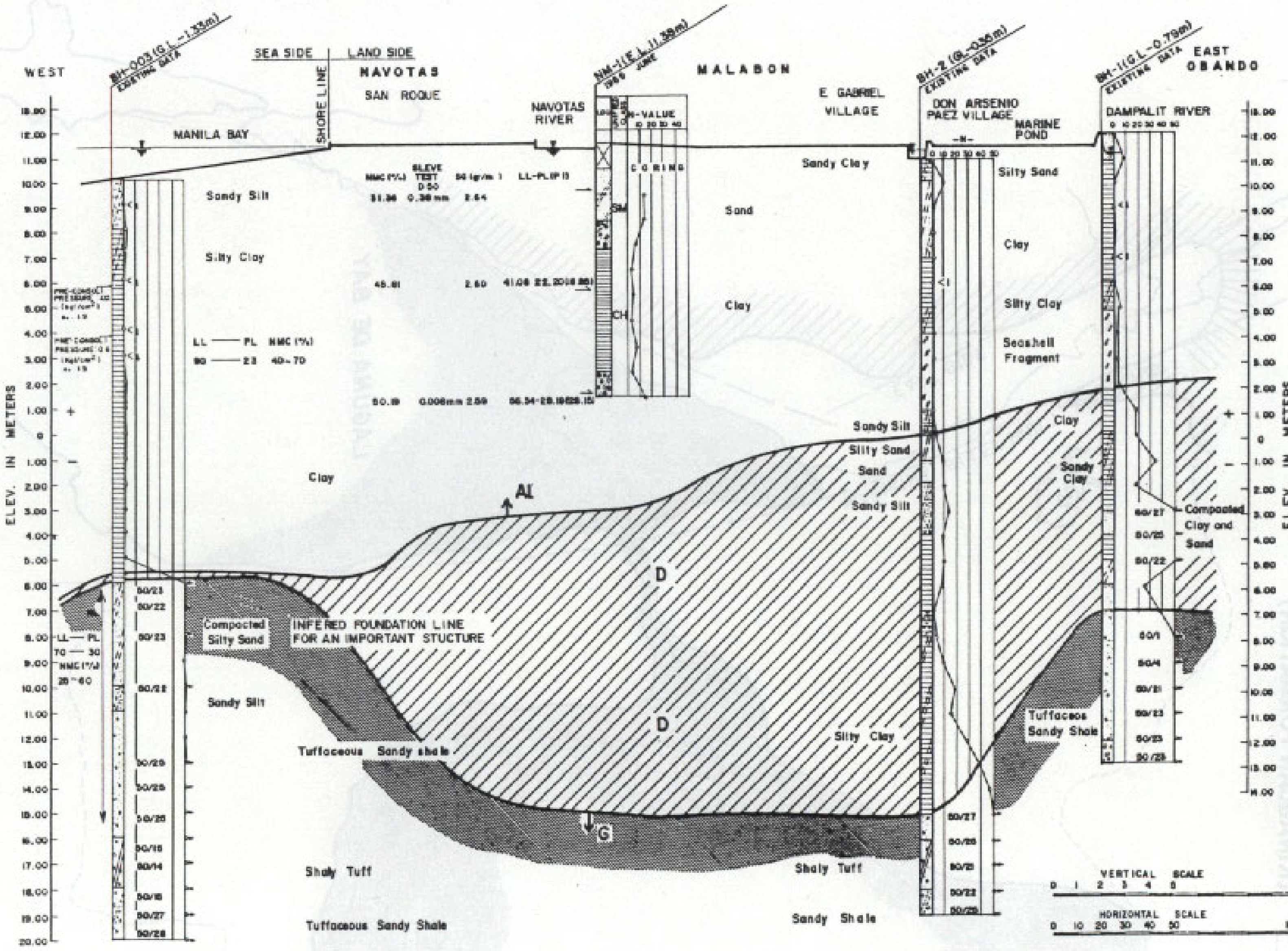
LEGEND

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

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.2.11 SUBSURFACE GEOLOGY OF MANILA HARBOR



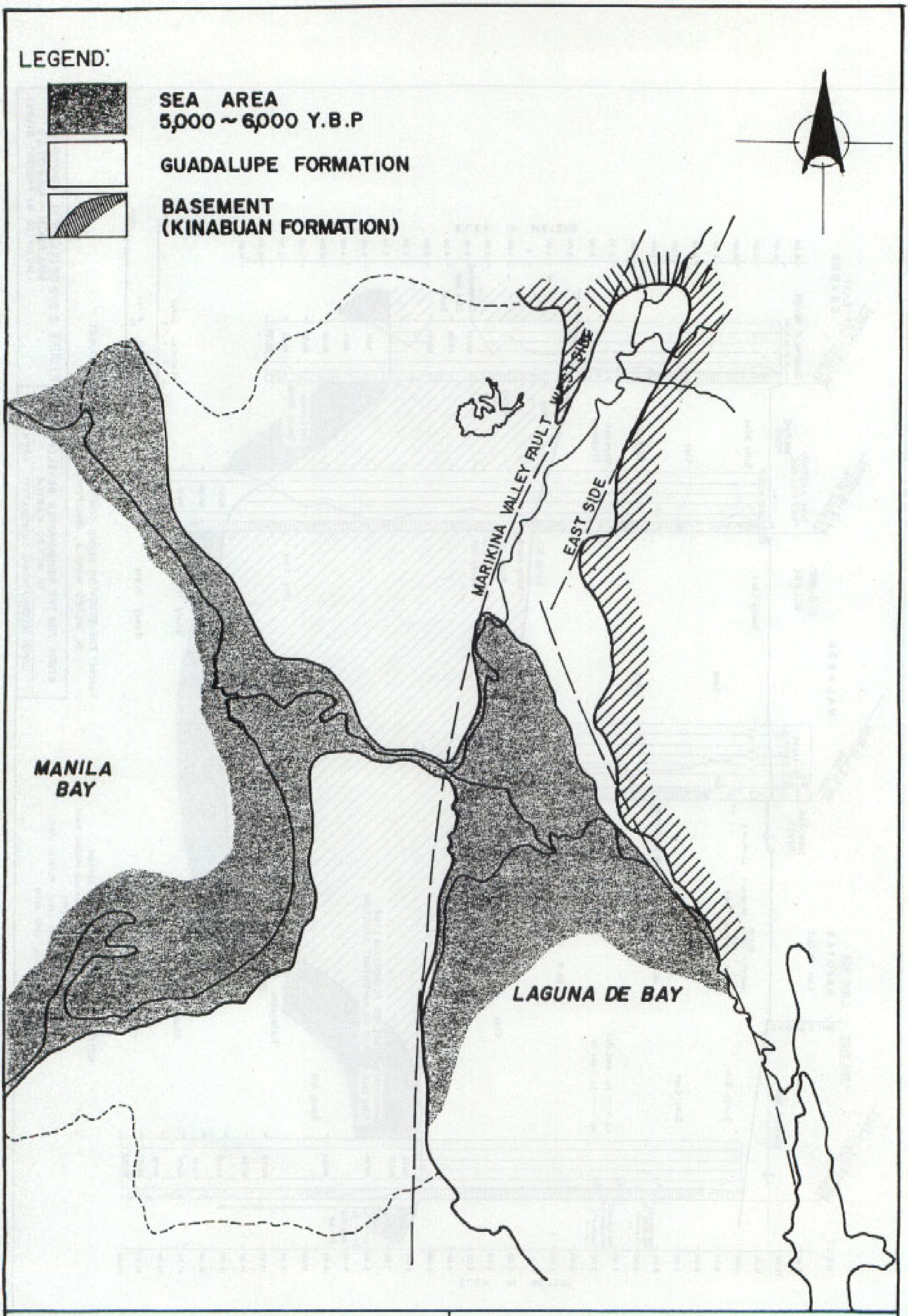
NOTE:
- NMC = NATURAL MOISTURE CONTENT
- D 50 = DIAMETER OF 50 per cent PASSING SIEVE
- SG = SPECIFIC GRAVITY
- LL-PL (PI) = LIQUID LIMIT - PLASTIC LIMIT
- eo = INITIAL VOID RATIO

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

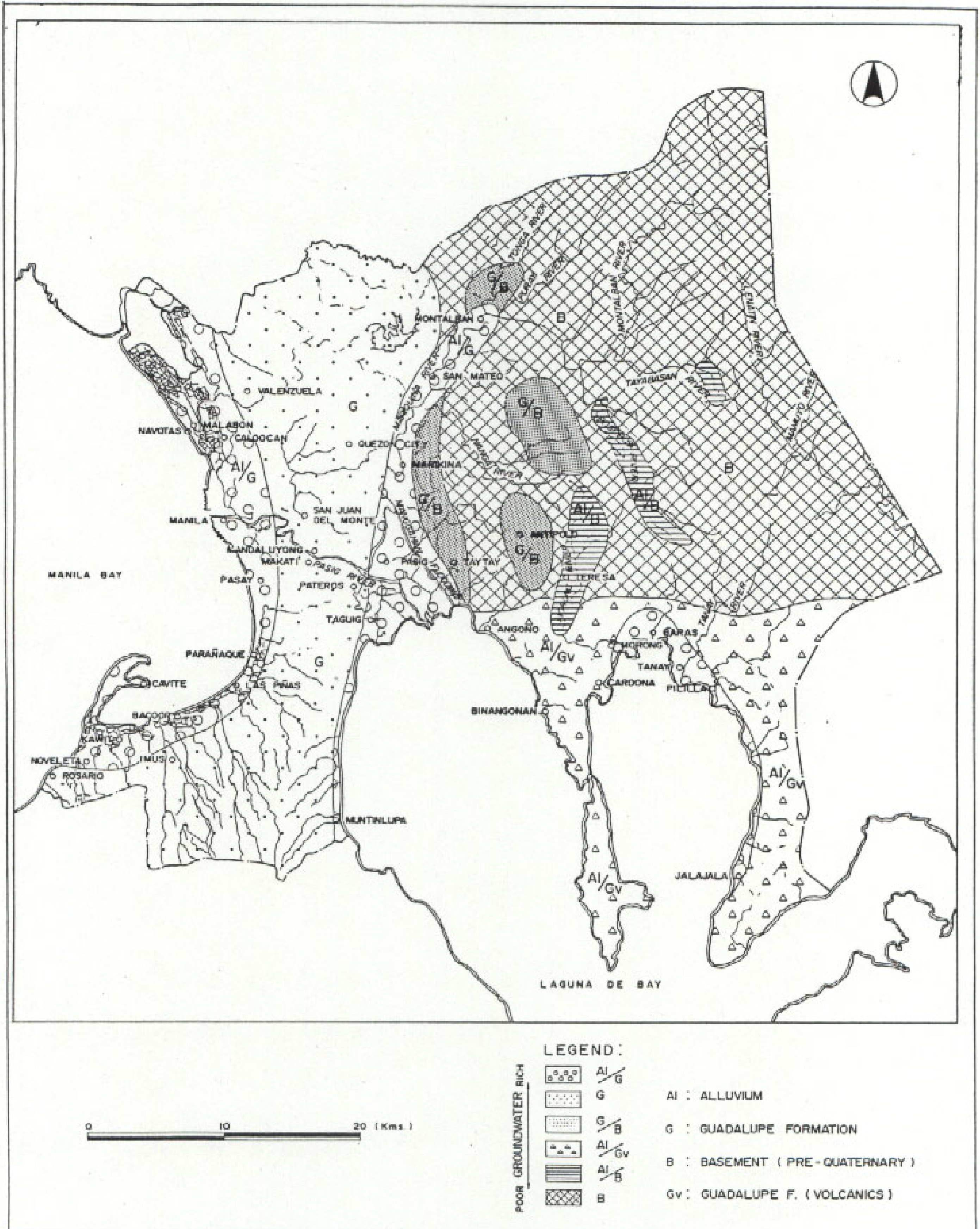
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.2.12 GEOLOGICAL PROFILE OF MALABON - NAVOTAS (MODIFIED BY PRESENT STUDY)



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

HYDROGEOLOGICAL MAP
ANTIPOLO AREA FIGURE 3.2.15

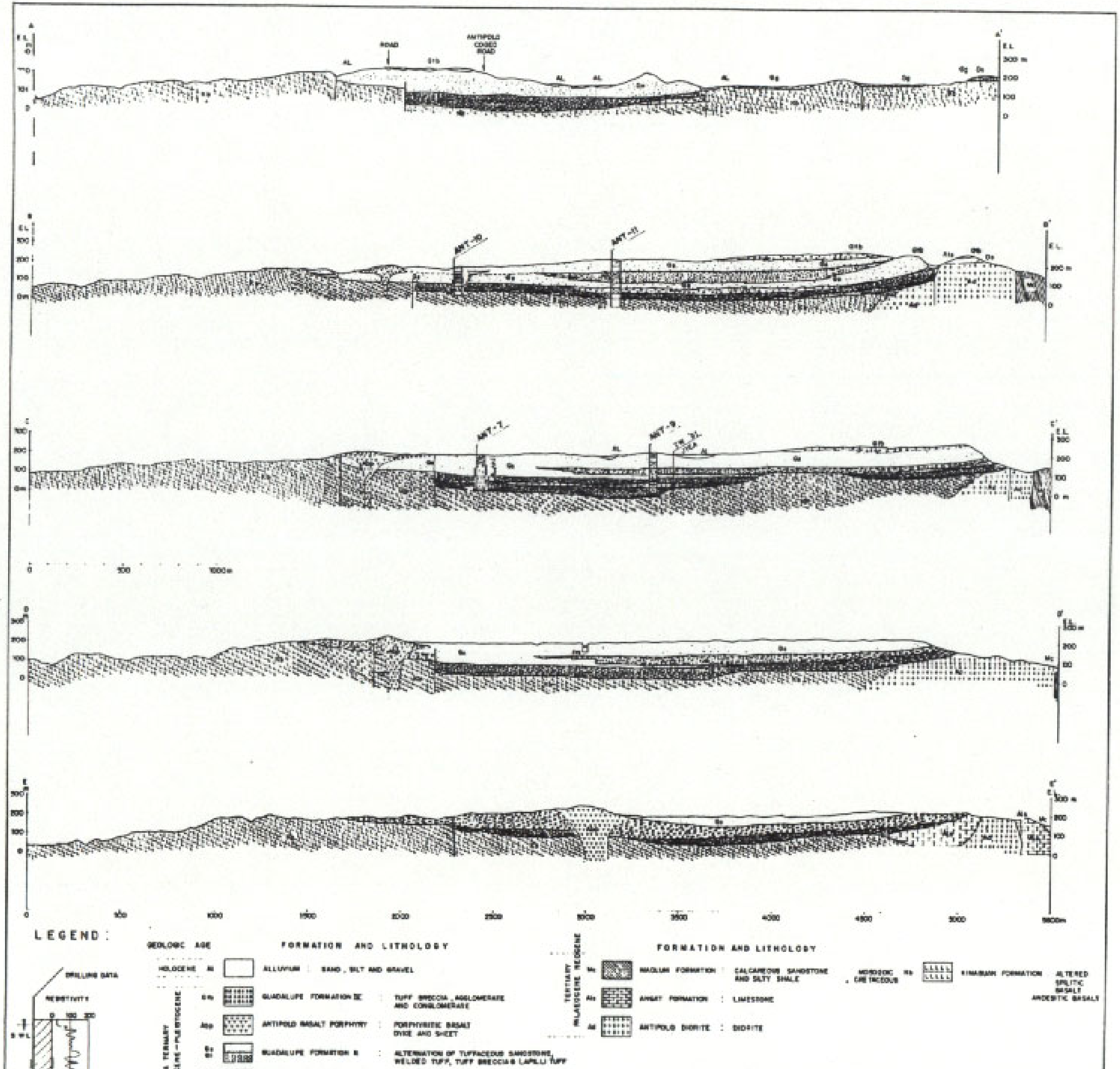
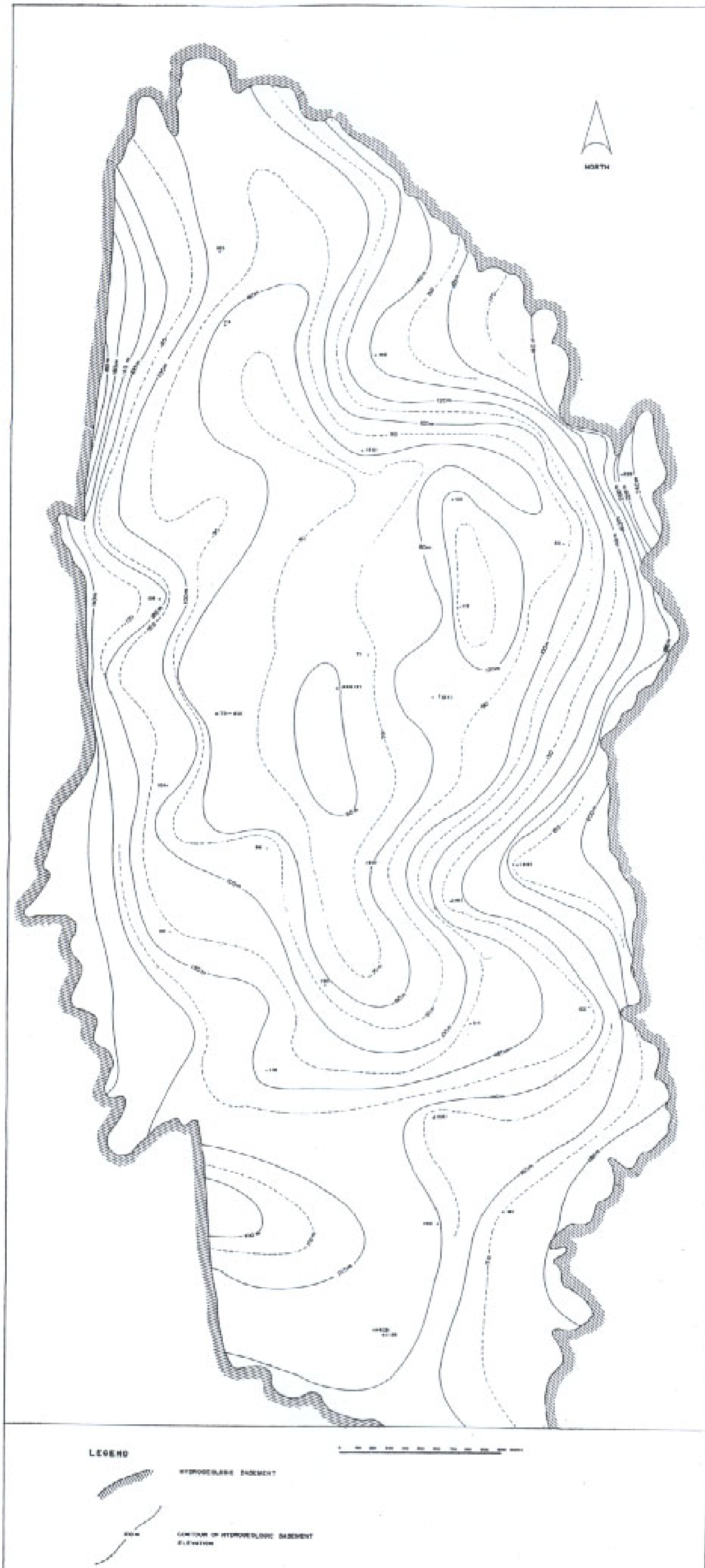


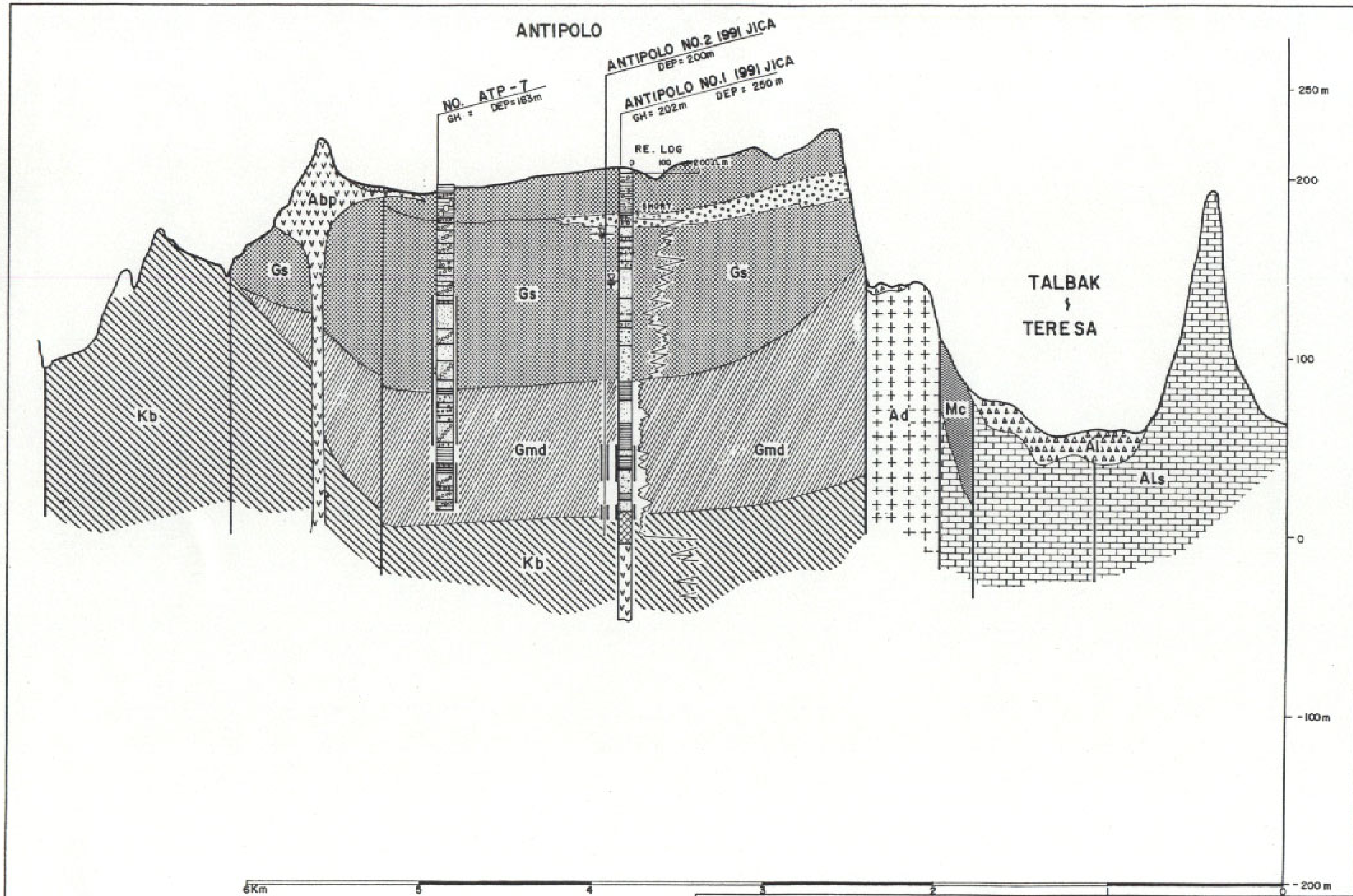
FIGURE 3.2.16

HYDROGEOLOGICAL SECTION - ANTIPOLO AREA -



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

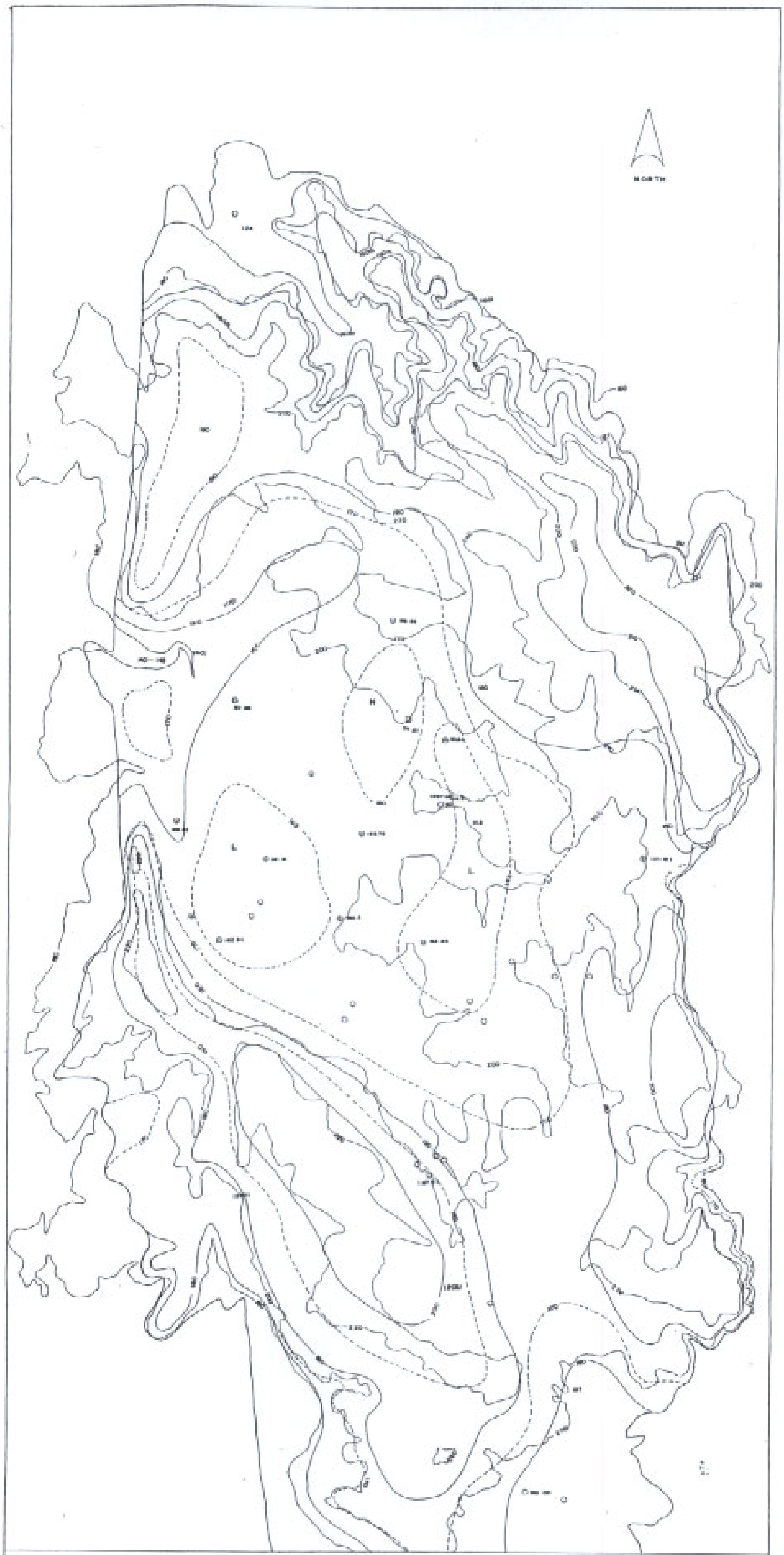
FIGURE 3.2.17
HYDROGEOLOGIC BASEMENT MAP
— ANTIPOLO AREA —



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.2.18 HYDROGEOLOGIC PROFILE - ANTIPOLO AREA



LEGEND

CONTOUR (m)

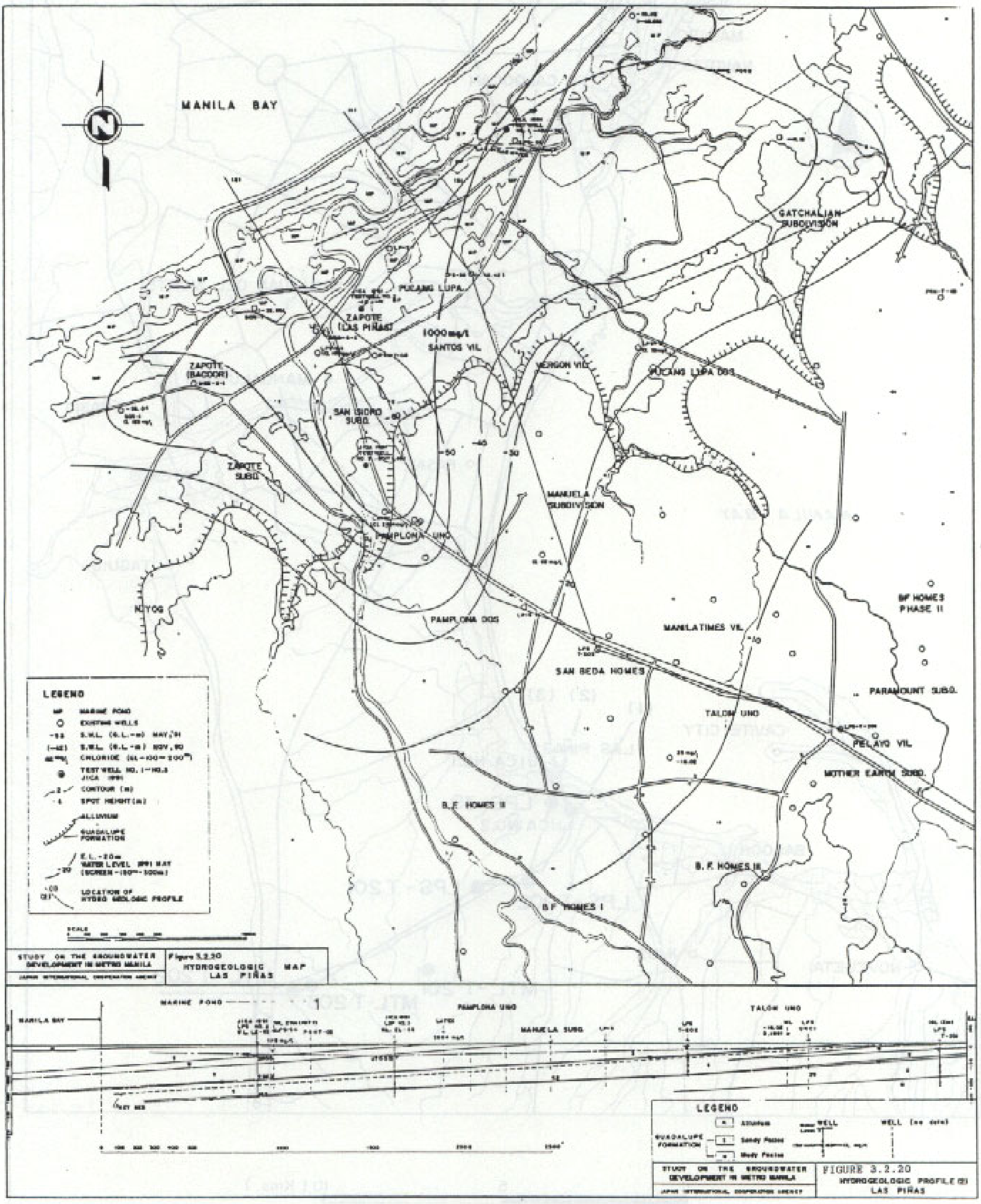
GROUNDWATER LEVEL (m)

WELL POINT

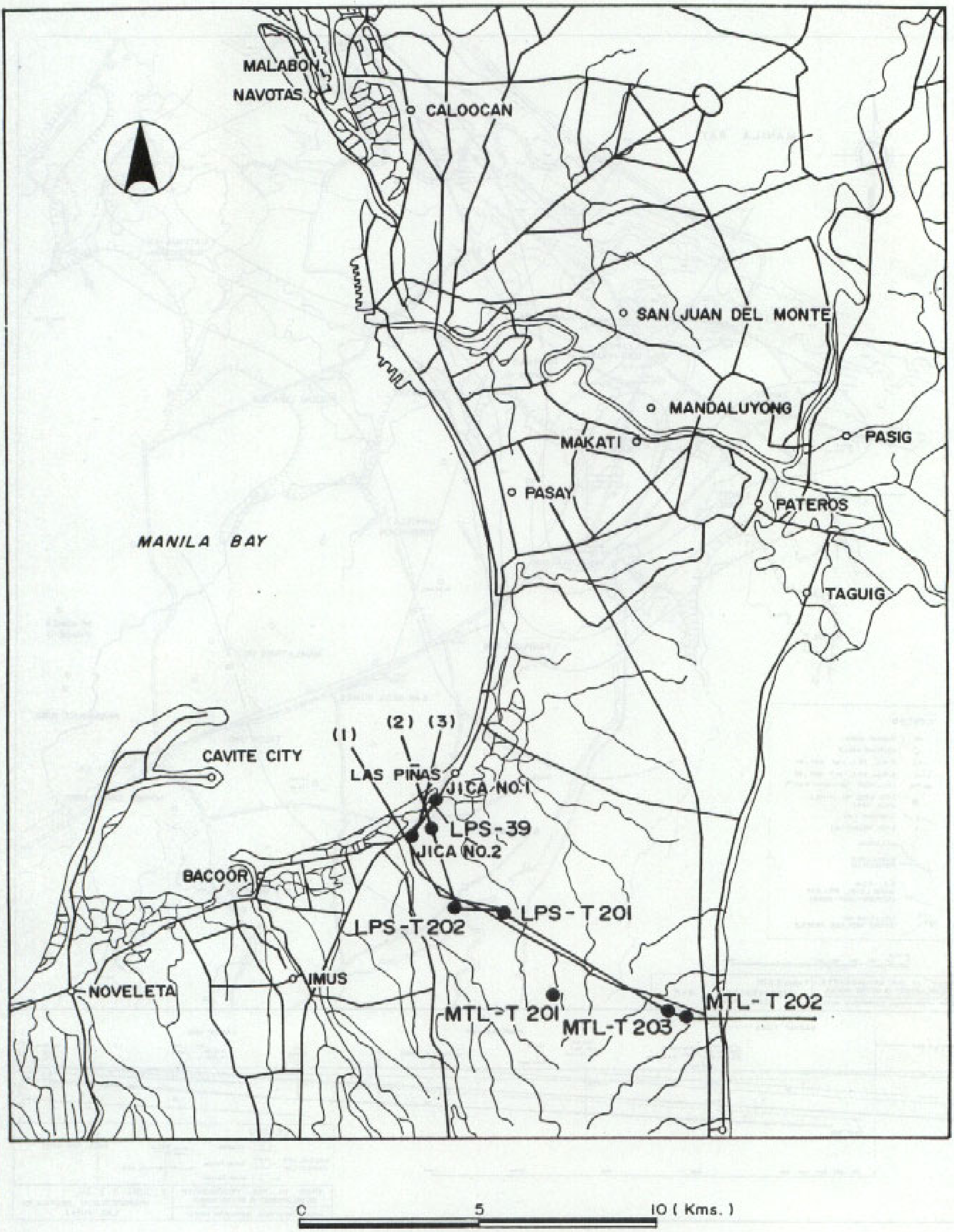
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.2.10
GROUNDWATER LEVEL MAP
MAY 1991
— ANTIPOLO AREA —



MANILA BAY
PULANG LUPA
ZAPOTE (LAS PIÑAS)
1000 mg/l
SANTOS VIL.
ZAPOTE (BACOOR)
SAN ISIDRO SUBD.
VERGON VIL.
PULANG LUPA DOS
GATCHALIAN SUBDIVISION
ZAPOTE SUBD.
MANUELA SUBDIVISION
PAMPLONA UNO
NIYOG
PAMPLONA DOS
MANILATIMES VIL.
BF HOMES PHASE II
SAN BEDA HOMES
TALON UNO
PARAMOUNT SUBD.
PELAYO VIL.
MOTHER EARTH SUBD.
B.F. HOMES II
B.F. HOMES III
B.F HOMES I
LEGEND
MARINE POND
EXISTING WELLS
CONTOUR (m)
SPOT HEIGHT (m)
ALLUVIUM
GUADALUPE FORMATION
LOCATION OF HYDRO GEOLOGIC PROFILE
STUDY ON THE GROUNDWATER DEVELOPMENT IN METRO MANILA
JAPAN INTERNATIONAL COOPERATION AGENCY
Figure 3.2.20
HYDROGEOLOGIC MAP LAS PIÑAS
MANILA BAY
MARINE POND
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
JAPAN INTERNATIONAL COOPERATION AGENCY
FIGURE 3.2.20
HYDROGEOLOGIC PROFILE (2) LAS PIÑAS



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.2.21

LOCATION MAP OF THE CROSS-SECTIONS FOR THE LAS PINAS AREA

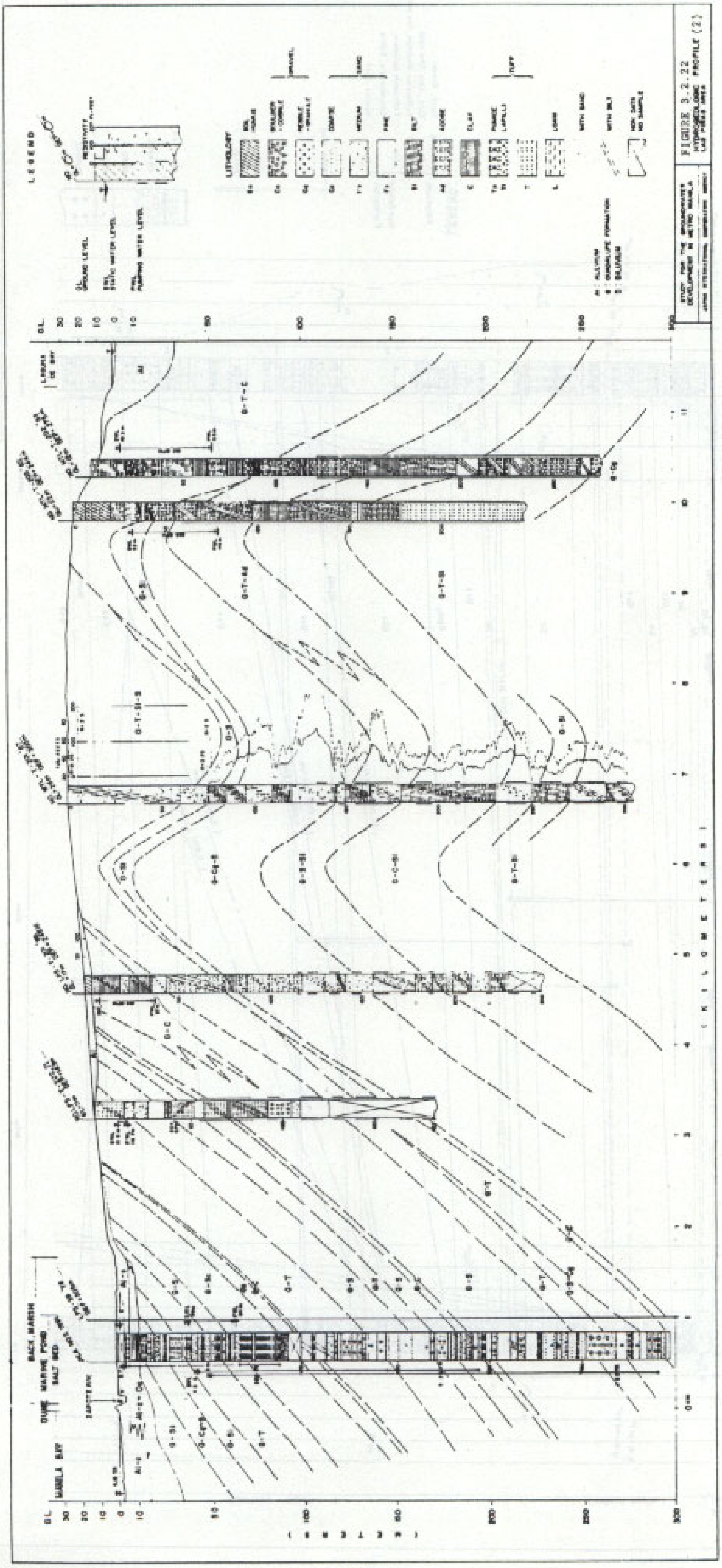


FIGURE 3.2.22
HYDROGEOLOGIC PROFILE (2)
LEGEND

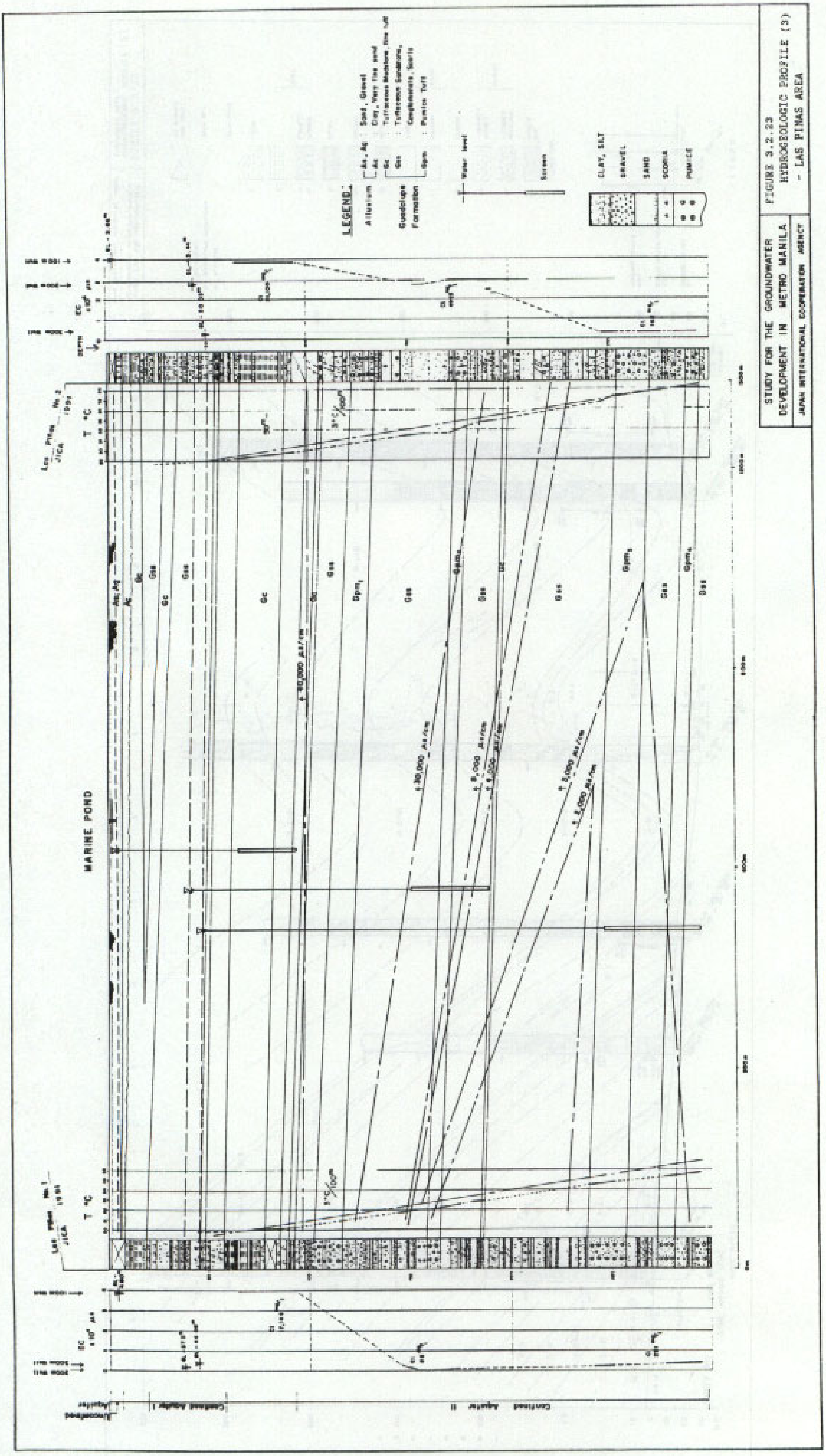


FIGURE 3.2.23 HYDROGEOLOGIC PROFILE (3) - LAS PIÑAS AREA

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	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	RCS	SJN	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											6				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													2															3
Medium																													
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	QCT	ROS	SJN	SMT	T66	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		3							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	MRX	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	RDS	SJN	SKT	TGG	TYY	VL2	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																		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	MDV	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJM	SMT	T66	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		43
Large				12											3				1							6	4		26
-40m to -80m																													
Small													2					5		3		3							13
Medium												2						1				16							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	468
+40m to +0m																													
Small	2																												2
Medium	9		5																										14
Large	14																						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	3.66	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						7.26				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	0.36	1.27	0.24		0.07	0.14	1.73	0.54	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		0.36	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	CVC	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAW	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJN	SMT	T66	TYT	WL2	Total
COMMERCIAL	0.89	0.15	1.01	0.76				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		6.65
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					0.26		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											0.96																	0.30	1.26
Medium			0.36																										0.36
Large																													

TABLE 3.3.3 (CONTINUATION)

	ATP	BCR	CLC	CTA	CVC	IMS	KWT	LPS	MDL	MKT	MLB	MML	MRK	MTB	MTL	MAV	MOV	PRN	PSC	PSG	PTR	QCT	ROS	SJN	SMT	TGG	TYY	VLZ	Total
INDUSTRIAL - CHEMICALS				0.32				0.09	0.10	0.23	0.21	0.09			0.33			0.18		1.05		0.42	0.21			0.29	0.05	0.53	4.08
+40m to +0m																							0.21						0.21
Small																							0.21						0.21
Medium																													
Large																													
-0m to -40m				0.32				0.09	0.10						0.33											0.29	0.05		1.18
Small				0.05					0.10						0.05											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	CVC	IMS	KWT	LPS	MDC	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	RDS	SJN	SMT	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				0.54				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			0.15																	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						0.68				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	MML	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJN	SNT	TGG	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	CVC	IMS	KWT	LPS	MDL	MKT	MLB	MML	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	RDS	SJN	SMT	TGG	TYY	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	IMS	KWT	LPS	MDL	MKT	MLB	MNL	MRK	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	OCT	ROS	SJN	SNT	TGG	TYY	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	MTB	MTL	NAV	NOV	PRN	PSC	PSG	PTR	QCT	ROS	SJN	SMT	TGG	TTY	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				1.3				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				1.8											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		0.3		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	408,910.00	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	115,536.00	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.	211,420.00	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.D.	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	158,983.00	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 Number of Wells	Public	Institutional	Commercial	Industrial	1990 Production	MWSS Number of Wells	1990 Production	TOTAL Number of Wells	1990 Production
ATP	115	10.72	0.12	0.99	4.33	16.16	15	4.34	130	20.50
BCR	47	11.50	0.13	0.13		11.76	6	2.31	53	14.07
CLC	114	6.39	0.33	1.61	1.70	10.03	0		114	10.03
CTA	78	3.38	0.33	0.78	13.20	17.71	5	1.38	83	19.12
CVT	11	0.31	1.27			1.58	15	2.45	26	4.03
IMS	9	1.19	0.24		0.19	1.62	2	0.60	11	2.22
KWT	4	1.33				1.33	4	1.58	8	2.91
LPS	157	20.36	0.27	1.27	7.95	29.85	2	0.56	159	30.41
MDL	31	0.55	0.14	0.64	1.95	3.28	0		31	3.28
MKT	98	3.68	1.73	2.55	1.23	9.19	11	1.37	109	10.56
MLB	67	0.39	0.64	0.09	5.22	6.34	3	0.20	70	6.54
MNL	49	0.81	0.36	1.34	2.11	4.62	0		49	4.62
MRK	36	1.95	0.27	0.24	2.49	4.95	0		36	4.95
MTP	23	1.55	0.19	0.13	1.09	2.96	3	1.15	26	4.11
MTL	182	17.92	1.47	1.53	12.51	33.44	7	2.11	189	35.55
NAV	17	0.62		0.23	0.63	1.48	2	0.04	19	1.52
NOV	9	2.07				2.07	3	2.58	12	4.65
PRN	278	17.35	0.18	1.62	6.46	25.61	5	0.42	283	26.03
PSC	47	2.13	1.66	1.35	1.43	6.57	3	1.63	50	8.20
PSG	197	3.37	0.41	2.02	21.93	27.72	2	0.32	199	27.74
PTR	2				0.64	0.64	0		2	0.64
QCT	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
SMT	11	0.97		0.14	0.22	1.33	5	1.72	16	3.05
TGG	121	7.35	0.65	0.33	15.04	21.22	3	3.23	124	24.45
TYY	62	7.17	0.14	2.29	6.05	15.65	7	2.36	69	18.01
VLZ	127	1.15	0.50	0.75	9.71	12.11	3	0.27	130	12.38
Total	2216	139.39	12.55	26.54	128.54	306.82	131	32.78	2347	339.60

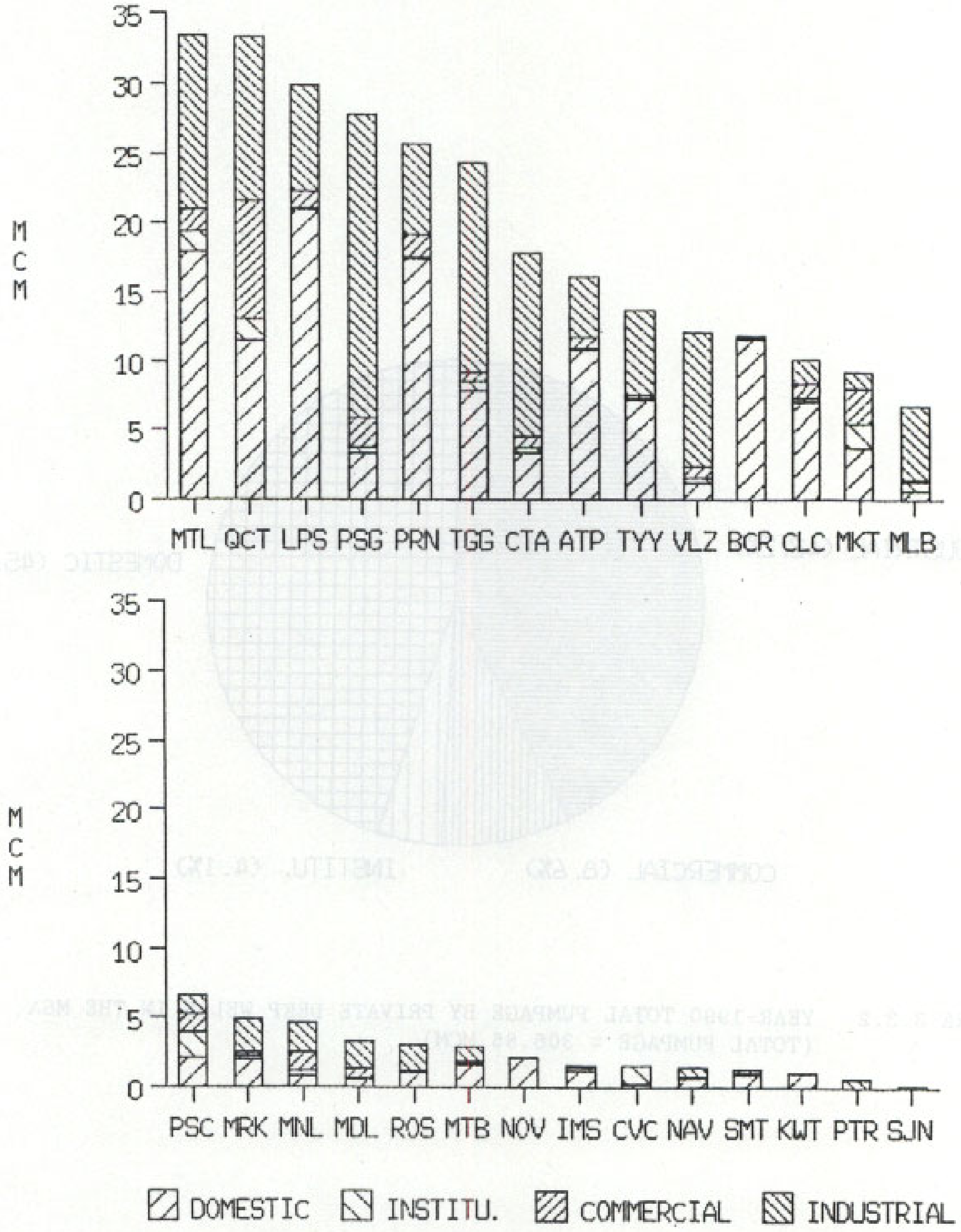


FIGURE 3.3.1 YEAR-1990 TOTAL PUMPAGE BY PRIVATE DEEP WELLS IN THE MSA
(TOTAL PUMPAGE = 306.85 MCM)

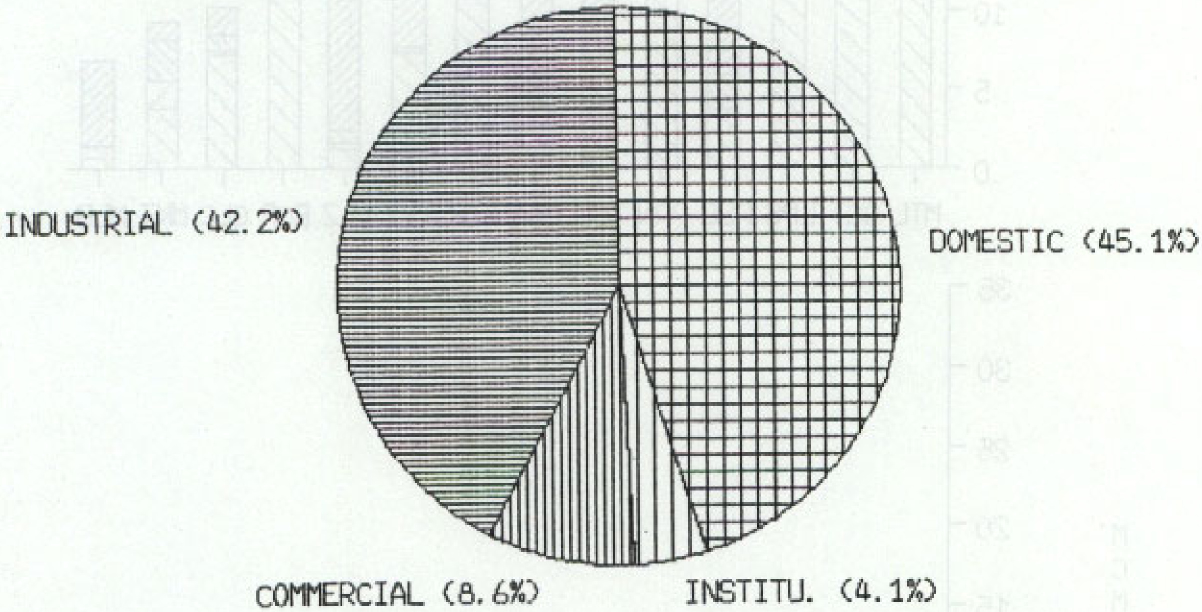
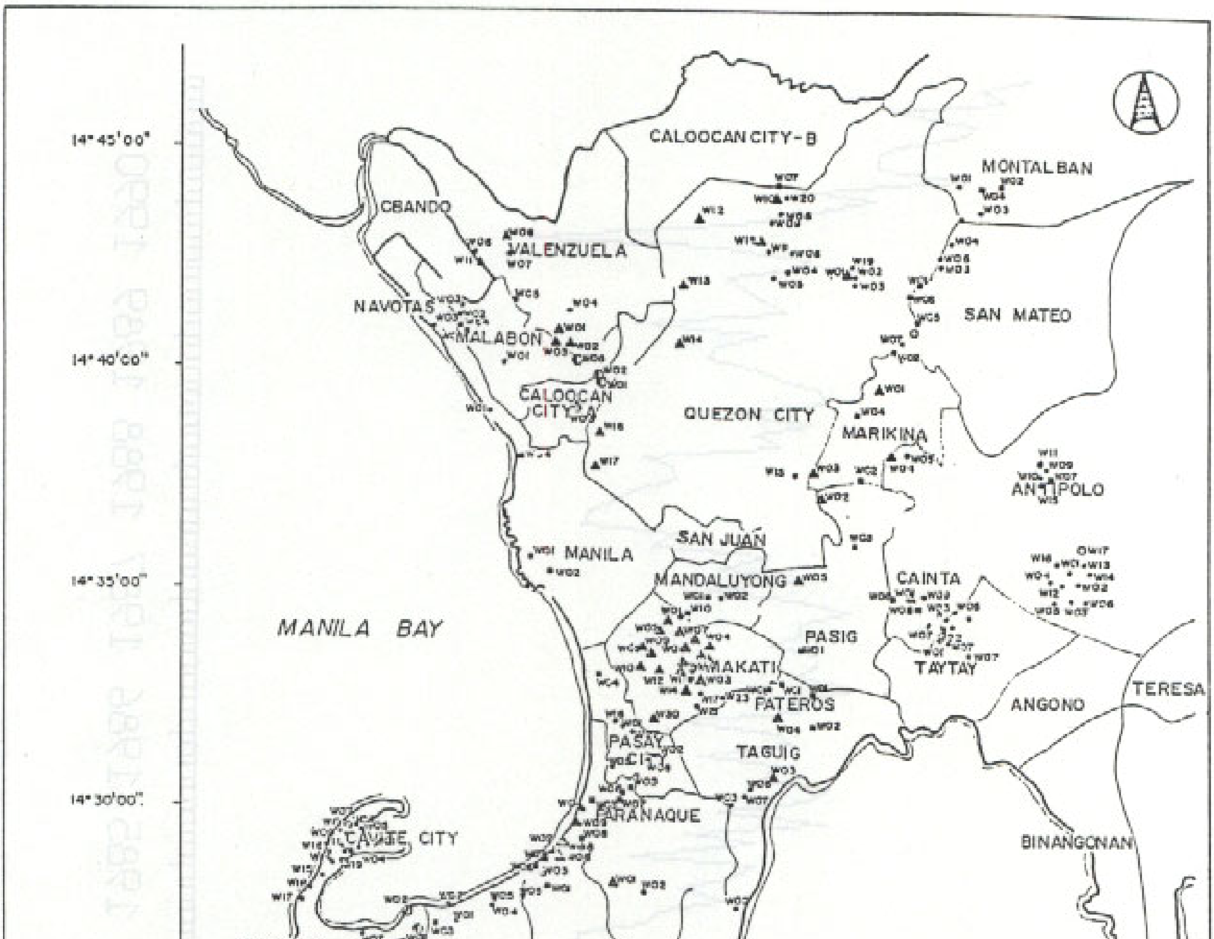


FIGURE 3.3.2 YEAR-1990 TOTAL PUMPAGE BY PRIVATE DEEP WELLS IN THE MSA (TOTAL PUMPAGE = 306.85 MCM)



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

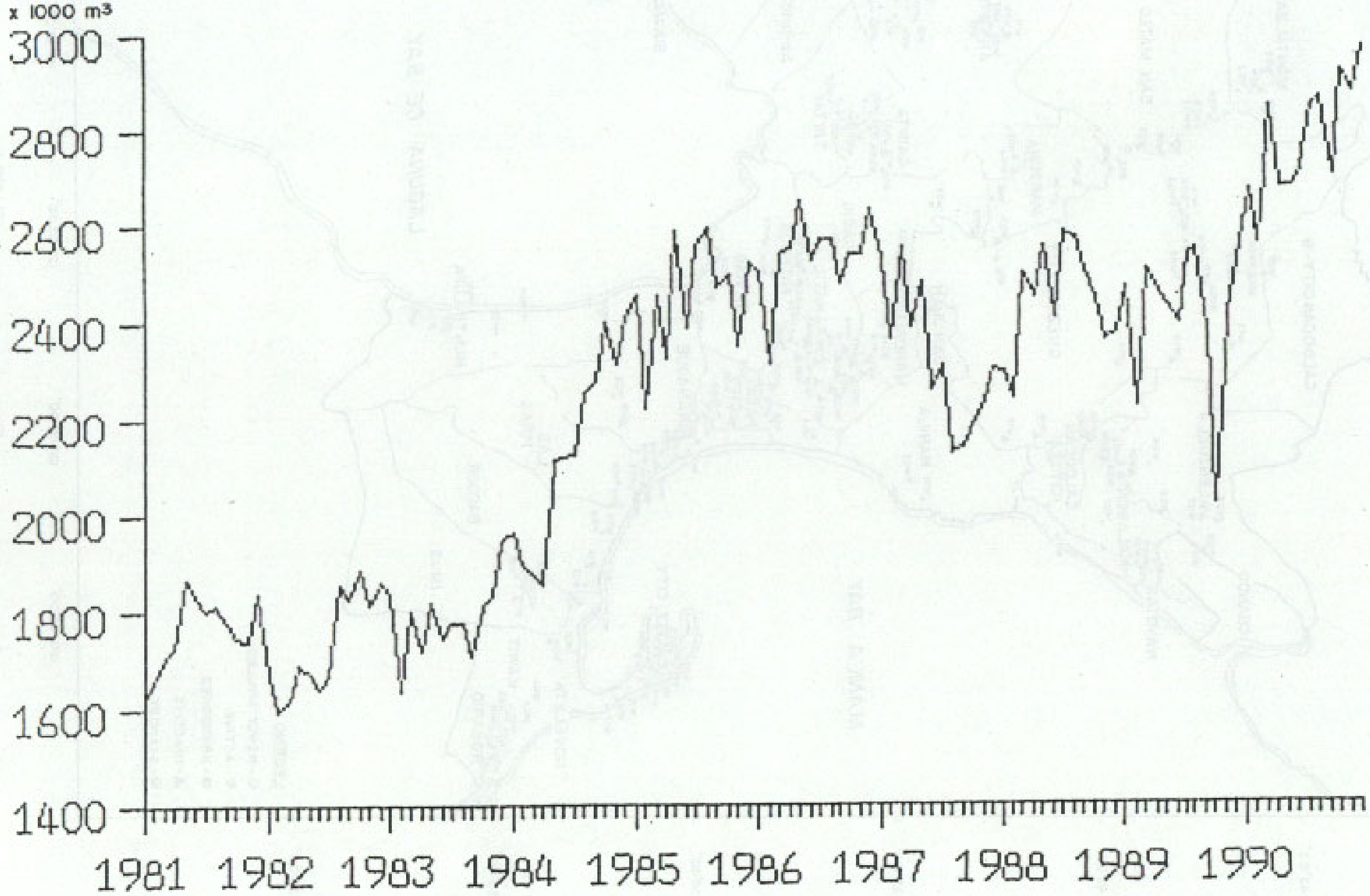


FIGURE 3.3.4 MONTHLY GROUNDWATER PRODUCTION OF MWSS WELLS IN THE MSA

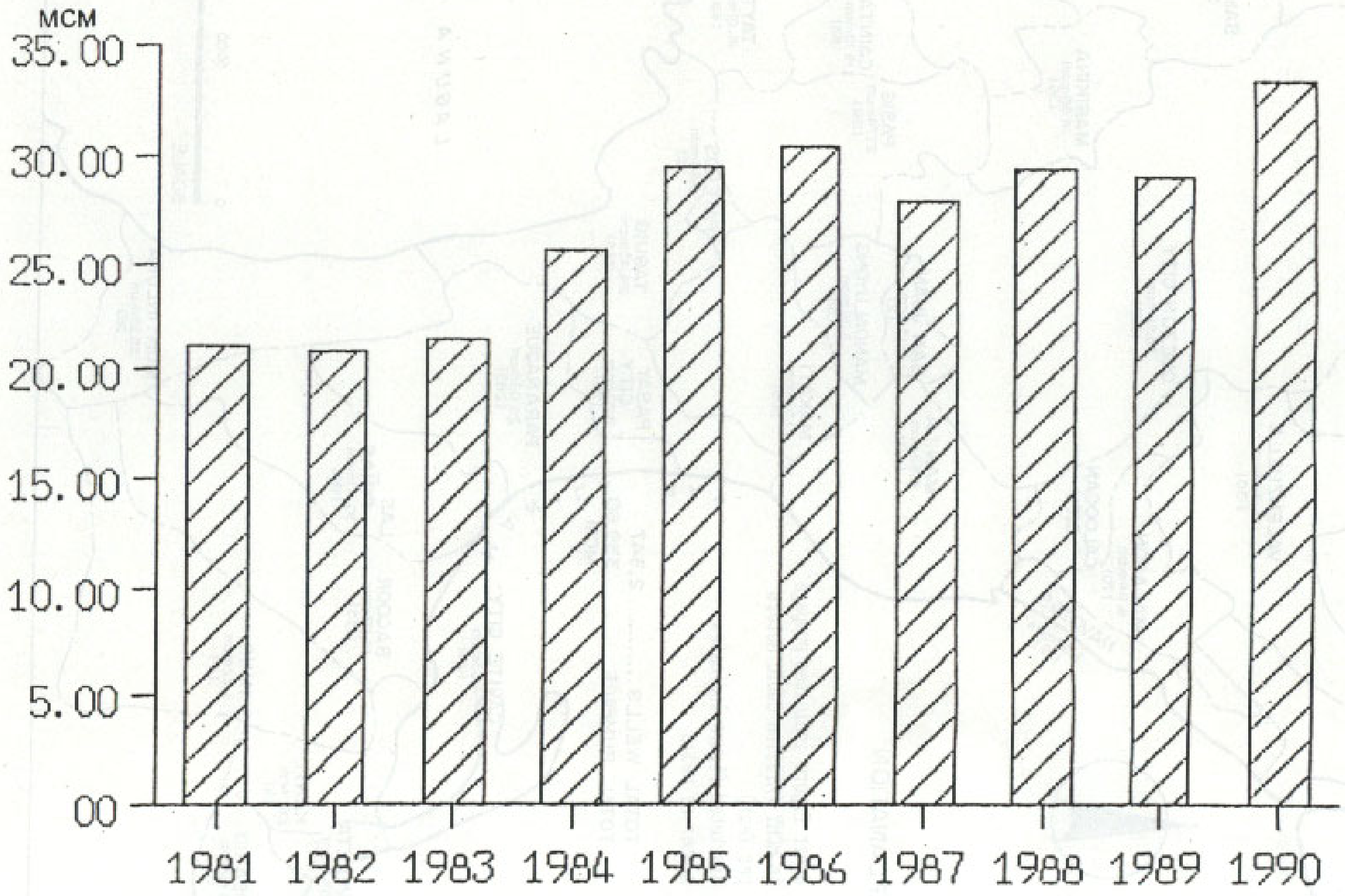
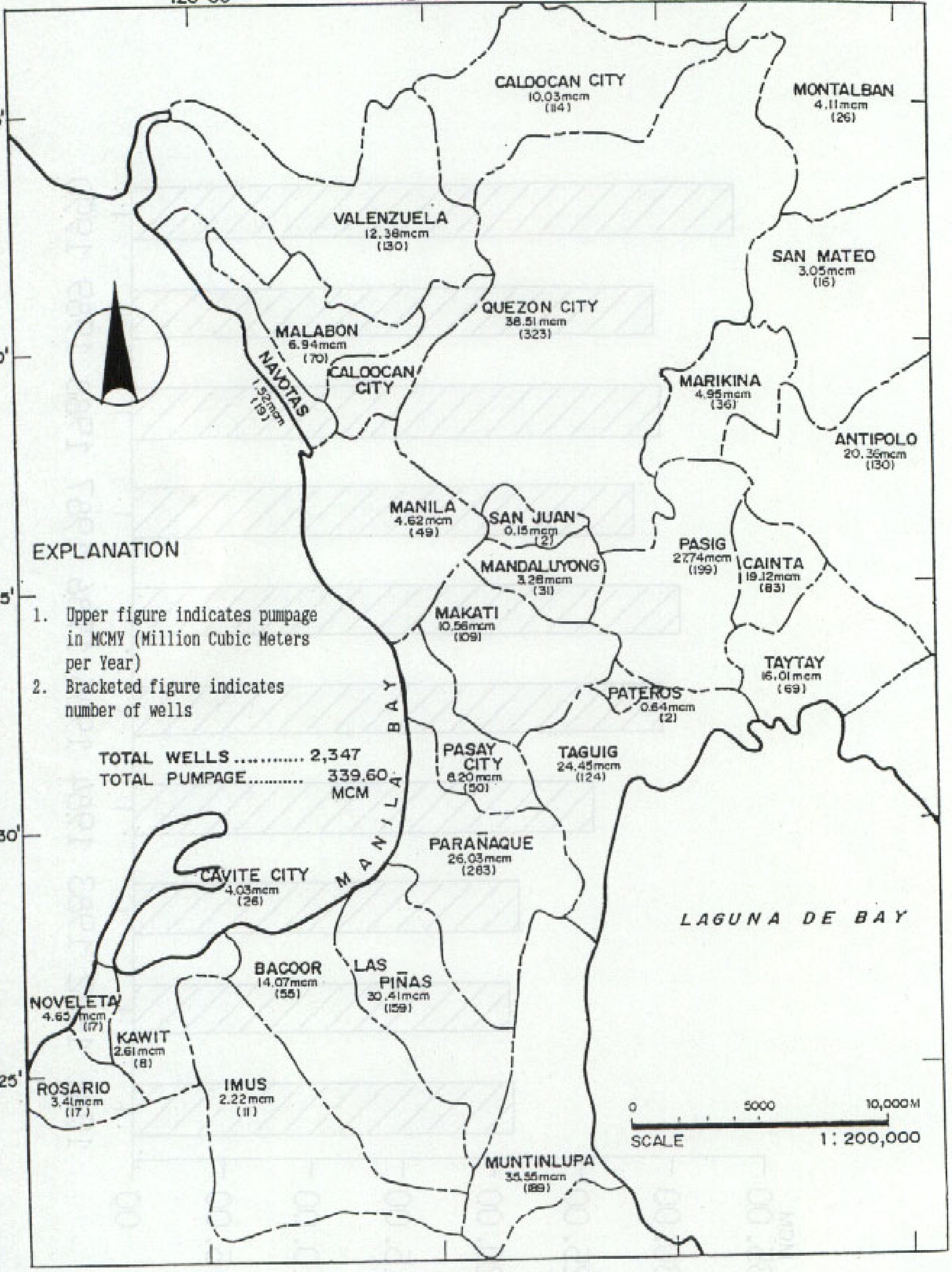


FIGURE 3.3.5 YEARLY GROUNDWATER PRODUCTION OF MWSS WELLS IN THE MSA.



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.3.6 1990 GROUNDWATER PUMPAGE IN THE STUDY AREA
JAPAN INTERNATIONAL COOPERATION AGENCY	

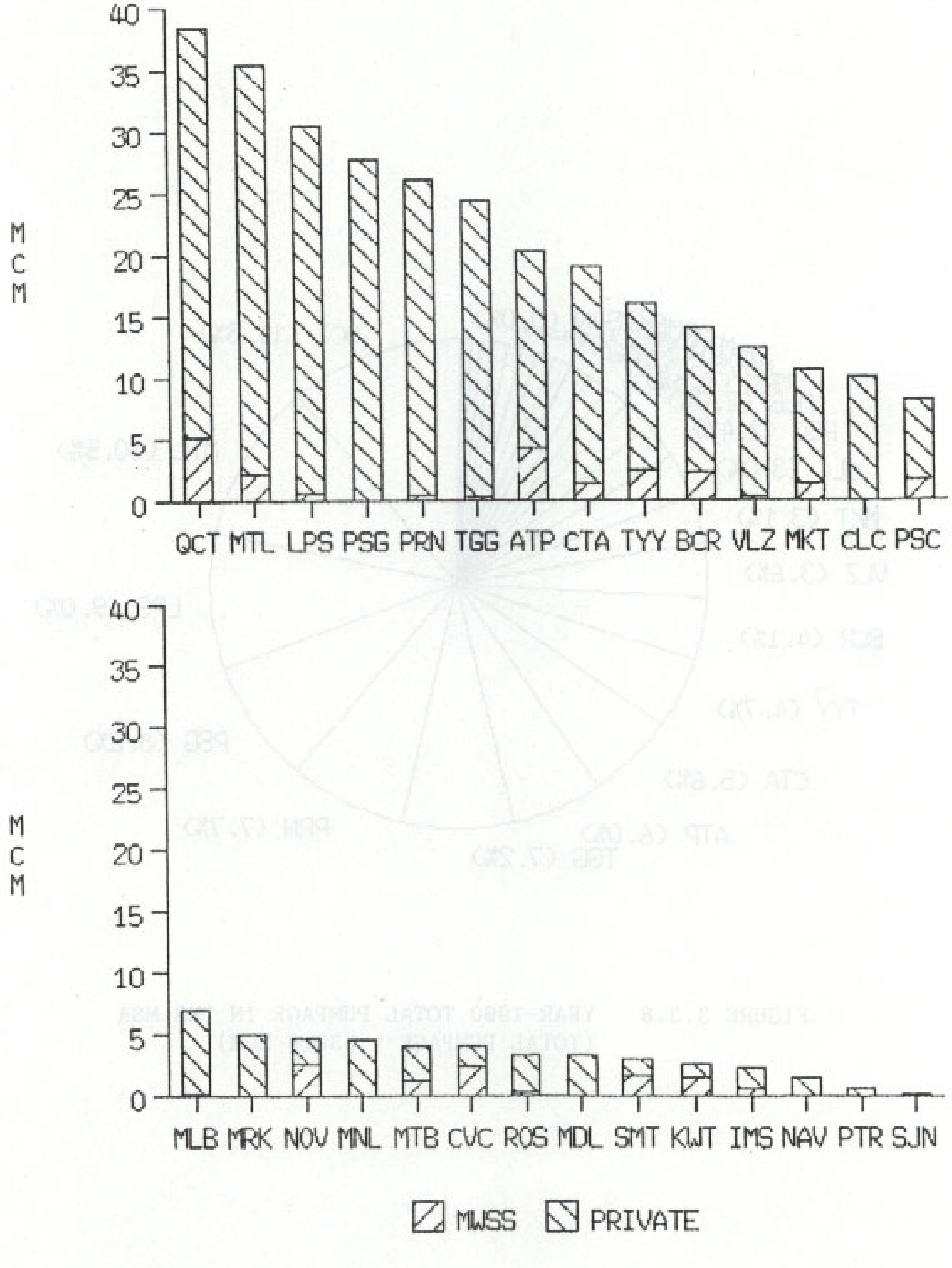


FIGURE 3.3.7 YEAR-1900 TOTAL PUMPAGE IN THE MSA
(TOTAL PUMPAGE = 339.6 MCM)

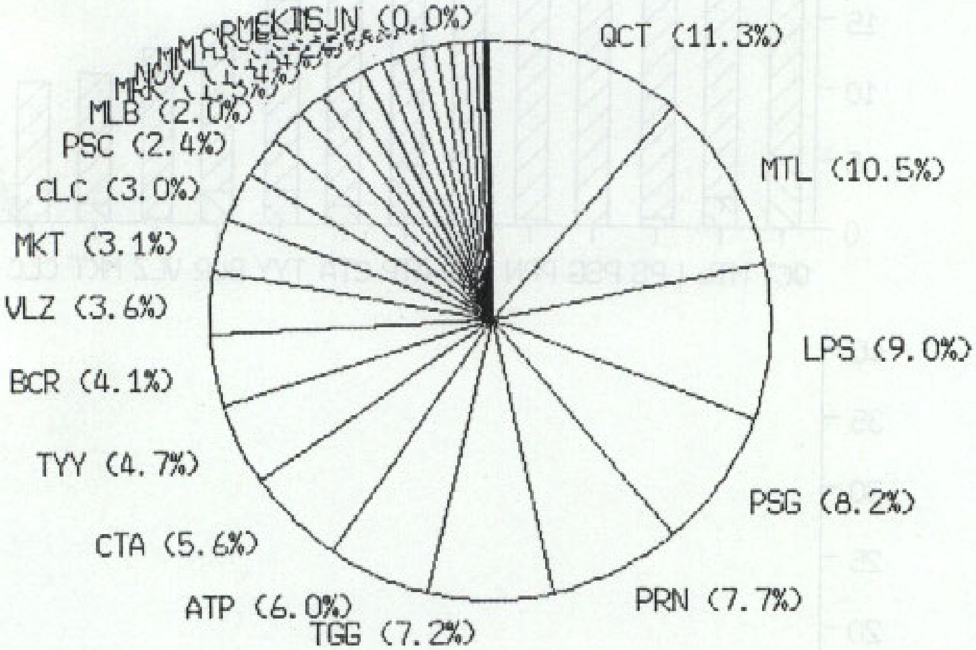


FIGURE 3.3.8 YEAR-1990 TOTAL PUMPAGE IN THE MSA
(TOTAL PUMPAGE = 339.6 MCM)

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 shaded portions indicate the latter exception.

Since 1981, the further decline in piezometric head has been caused by increased heavy pumping in the Study Area. Also, the rapid decline of the piezometric head had occurred due to overdraft. Between 1981 and 1990, the range of annual decline has been from 5 to 7m in the Bacoor-Las Piñas area.

Over the Study Area, the dewatering of aquifers appears to average roughly to 40m, with local minima reaching 120m below sea level. Dewatered volumes of aquifer extend beneath the bed of Manila Bay.

As shown in Figure 3.4.3, the highest recovery of groundwater level is 90mm in Pasig, followed by 80mm on the boundaries of Manila, Quezon City, San Juan, Mandaluyong, and Makati; it is 80m in western Quezon City near Caloocan City, 70mm in Navotas and 40 in Marikina. As mentioned earlier, this recovery of water level was brought about by the completion in 1987 Of MWSP II which almost doubled the supply in the MSA.

Antipolo Groundwater Basin

As discussed in Section 3.2, the Antipolo Plateau forms an independent groundwater basin.

As shown in Figure 3.4.4, groundwater flows northward and southward--from topographically higher grounds to springs along the marginal zone of the plateau where groundwater is discharged from the basin. It moves westward to the depressions in the central part of the basin from the eastern boundary. These depressions are caused by groundwater pumpage over this area.

3.4.3 Seasonal Fluctuations

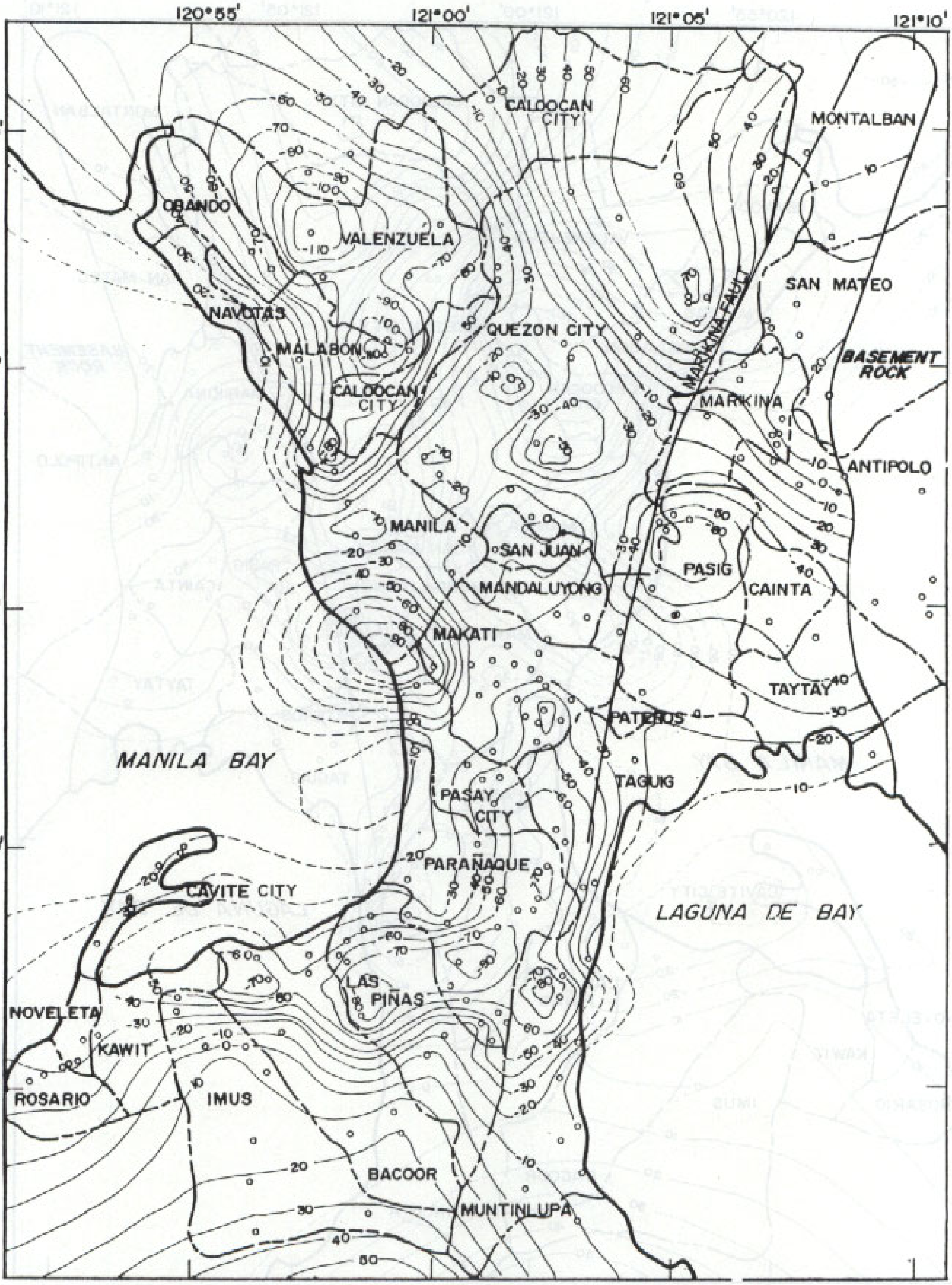
Metro Manila Groundwater Basin

Figures 3.4.5 and 3.4.6 show the seasonal fluctuations in piezometric conditions between May 1990 and November 1990, and between August and May 1991, respectively. As depicted in Figure 3.4.5, the groundwater level declines from the end of the wet season to the end of the dry season. Shaded portions closed by the -2m contour line in this figure reveal areas with more than two-meter lowering of groundwater level. Groundwater level during the dry season could decline up to six meters.

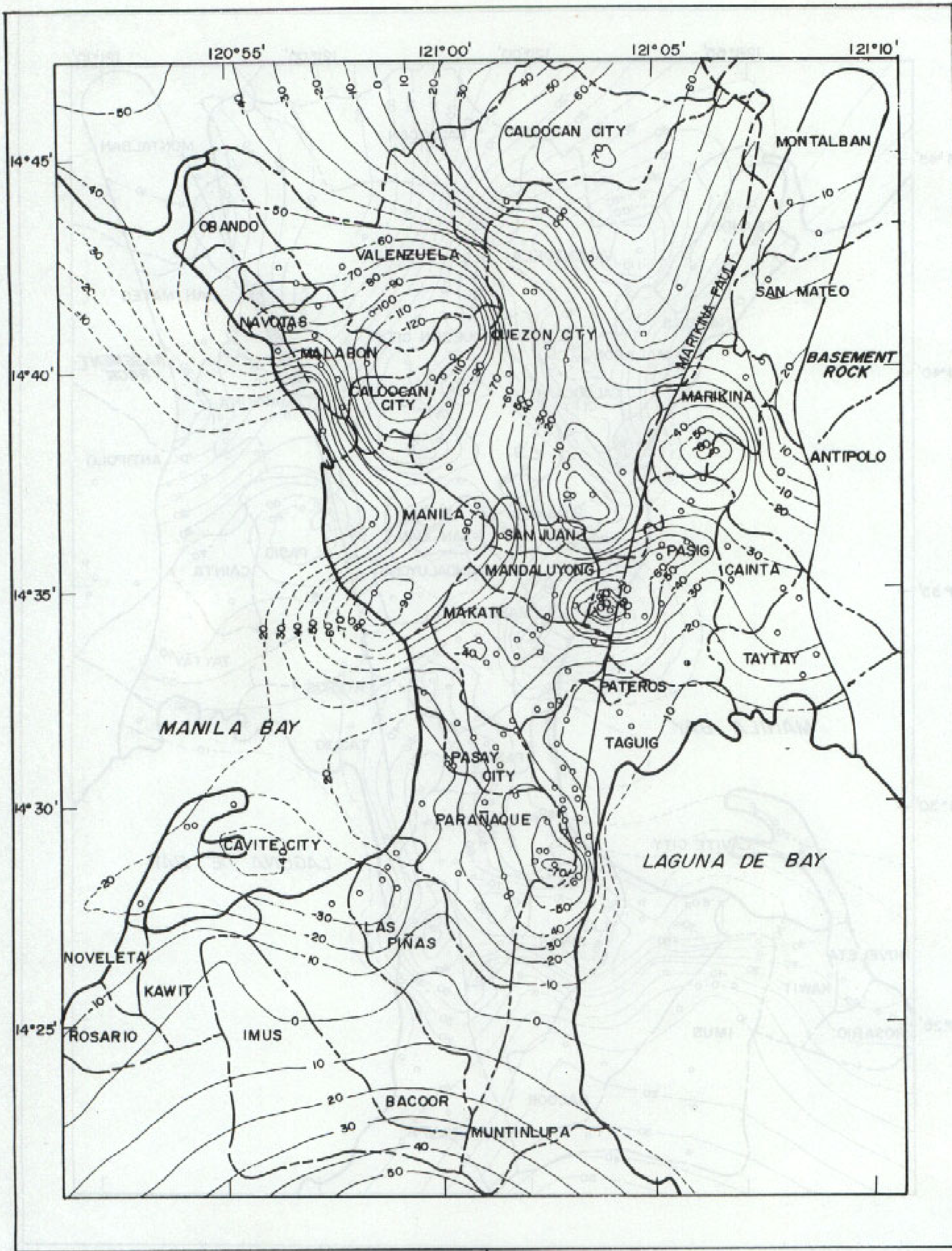
As shown in Figure 3.4.6 (unshaded portions), the fluctuation between May and August 1991 indicates that the groundwater level rose by 1 to 6m in the north and east sectors of the Study Area, and by 2 to 4mm in the south sector. These observations mean that in the north and south recharge areas the rise in the water level is due to recharge from rainfall. In other areas, the rise in water level is perhaps due to decrease in pumpage. The shaded portions indicate areas where water levels have continuously declined since November 1990.

Antipolo Area

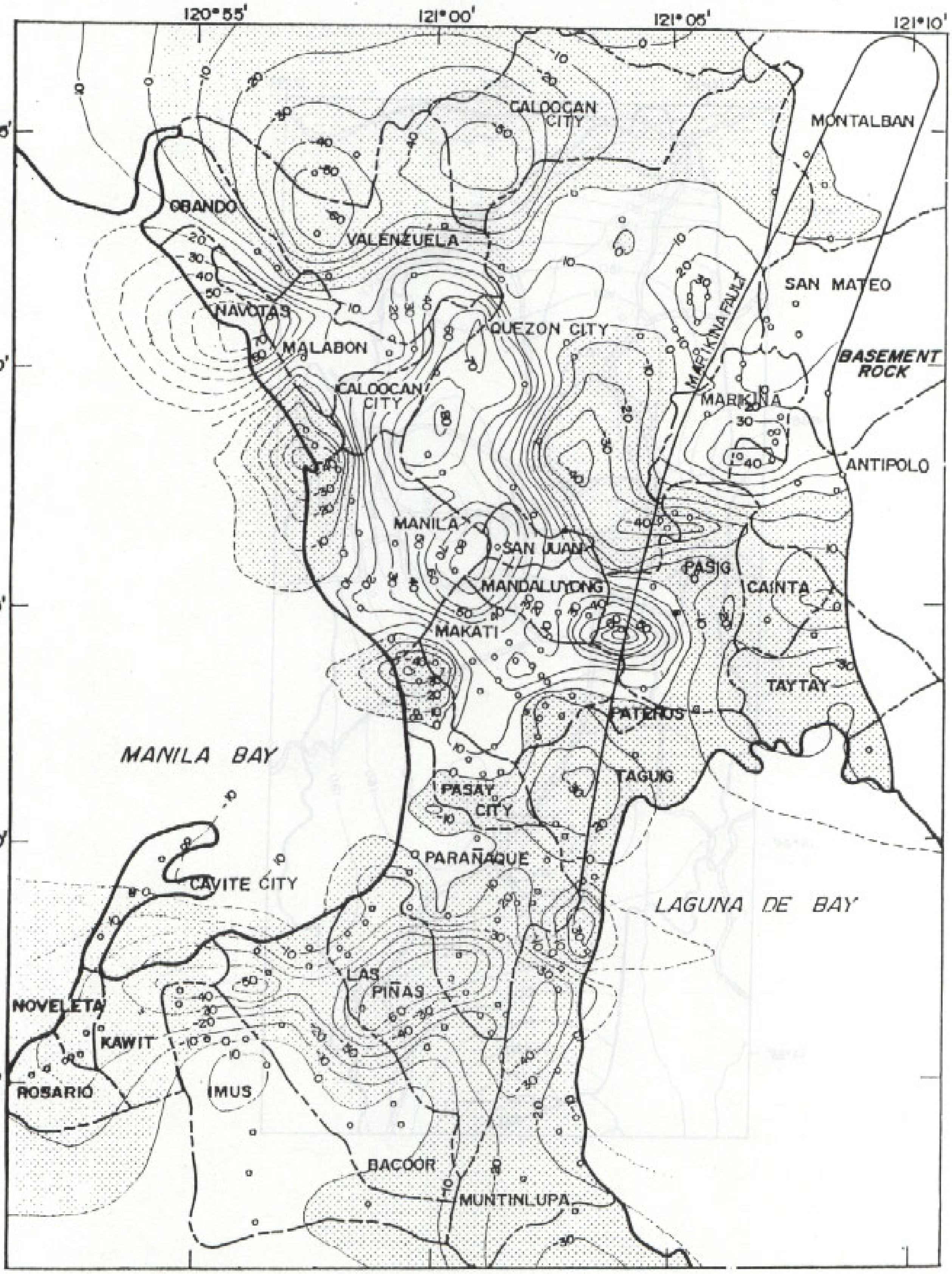
As shown in Figure 3.4.7, the groundwater level in the central part of the basin declined by as much as seven meters in the dry season period between November 1990 and May 1991. Figure 3.4.8 reveals that the piezometric heads rose by 2m from the end of the dry season to the middle of the rainy season due to direct recharge from rainfall.



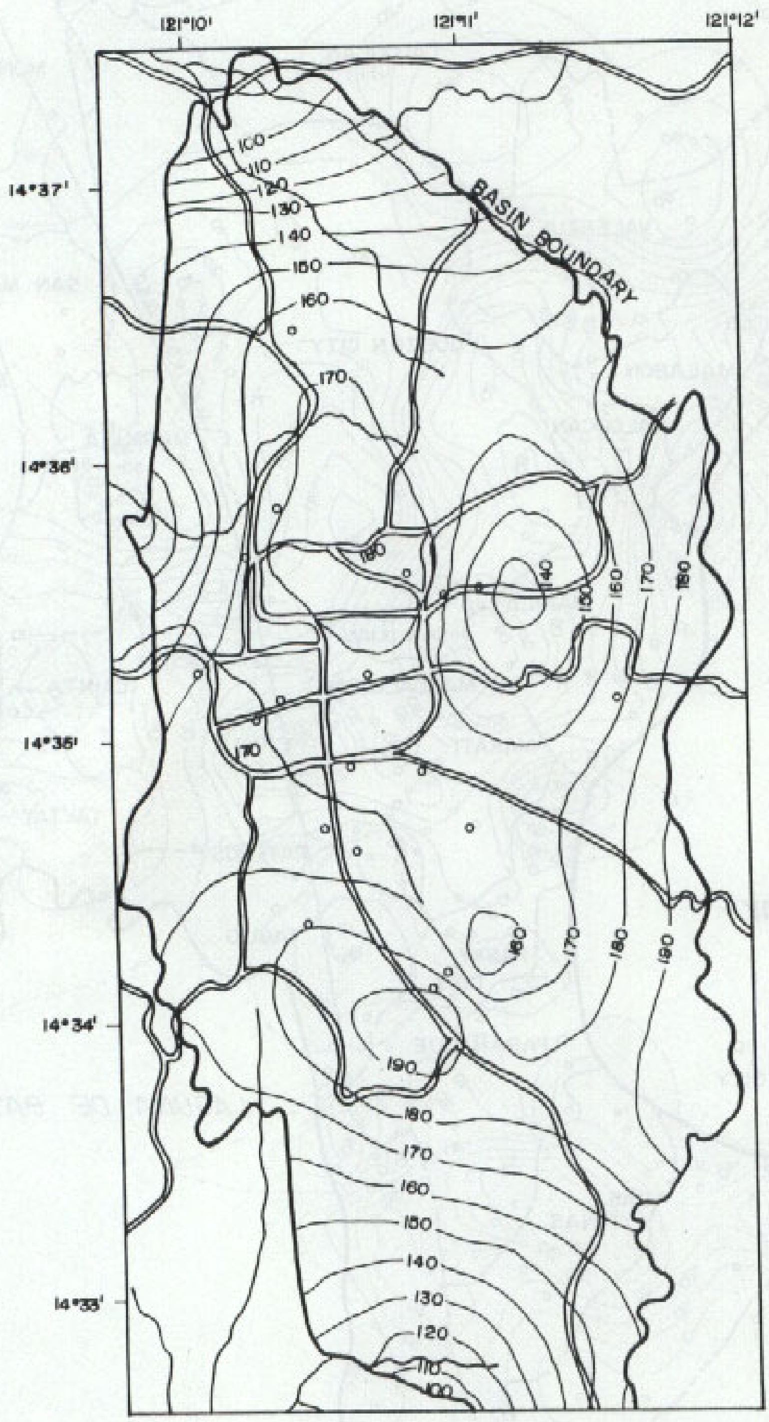
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.4.1 PIEZOMETRIC CONTOUR MAP OF THE STUDY AREA, 1990
JAPAN INTERNATIONAL COOPERATION AGENCY	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.4.2 PIEZOMETRIC CONTOUR MAP OF THE STUDY AREA, 1981
JAPAN INTERNATIONAL COOPERATION AGENCY	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.4.3
JAPAN INTERNATIONAL COOPERATION AGENCY	CHANGE IN PIEZOMETRIC CONTOURS IN THE STUDY AREA FROM 1981 TO 1990

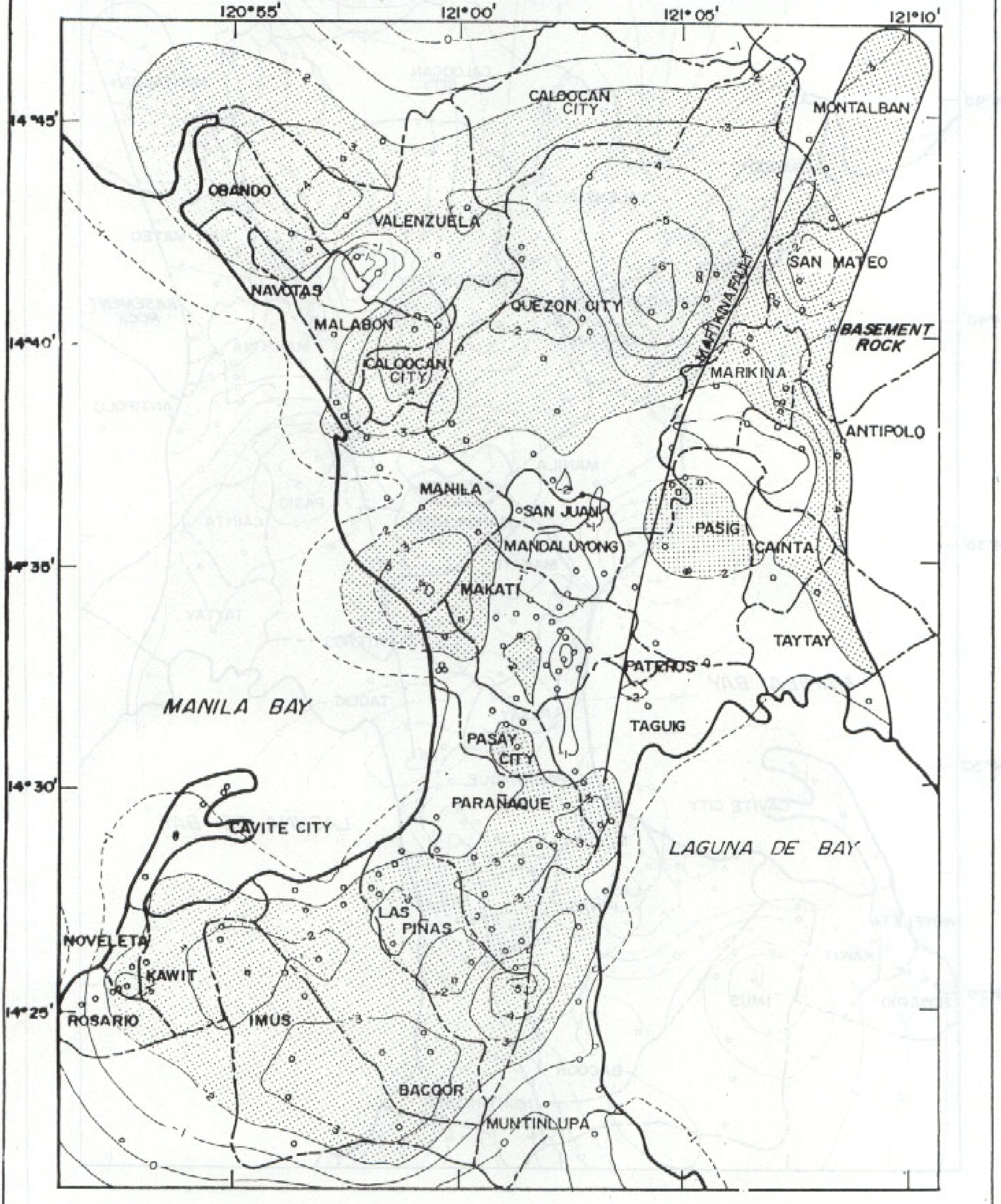


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.4.4

PIEZOMETRIC CONTOUR MAP OF THE ANTIPOLO AREA, 1990

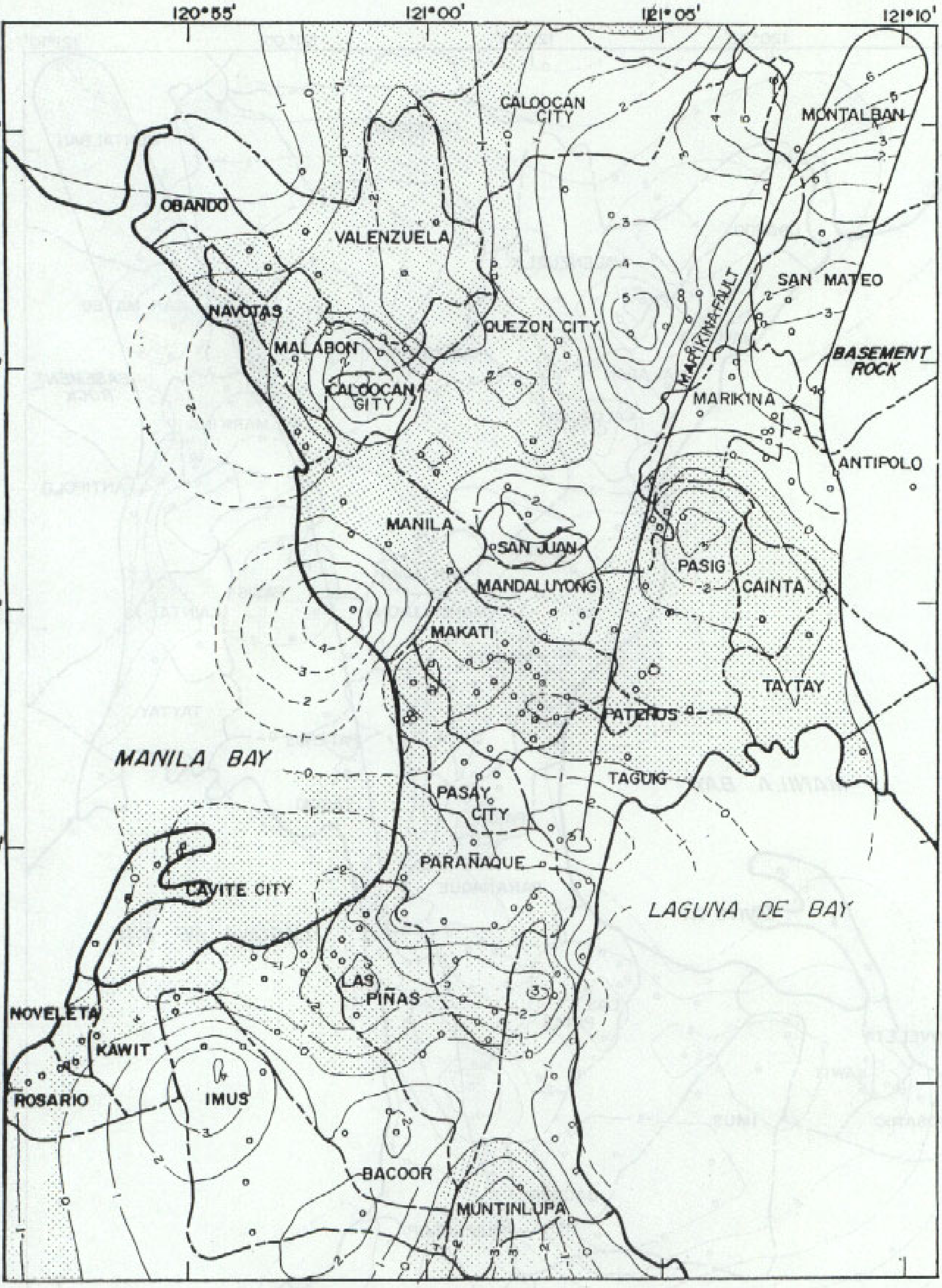


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

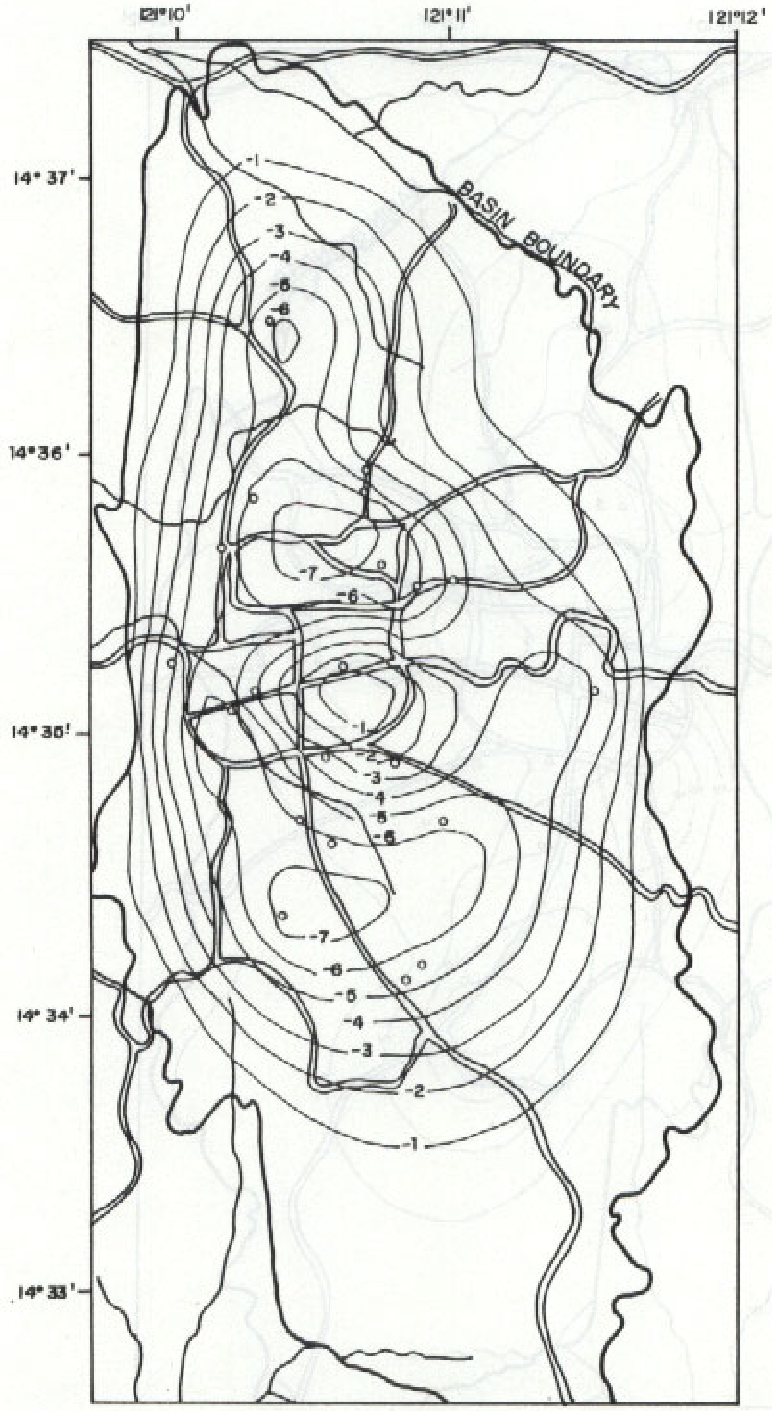
JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.4.5

CHANGE IN PIEZOMETRIC CONTOURS FROM NOV. 1990 TO MAY 1991, STUDY AREA



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.4.6
JAPAN INTERNATIONAL COOPERATION AGENCY	CHANGE IN PIEZOMETRIC CONTOURS FROM MAY 1991 TO AUG. 1991, STUDY AREA

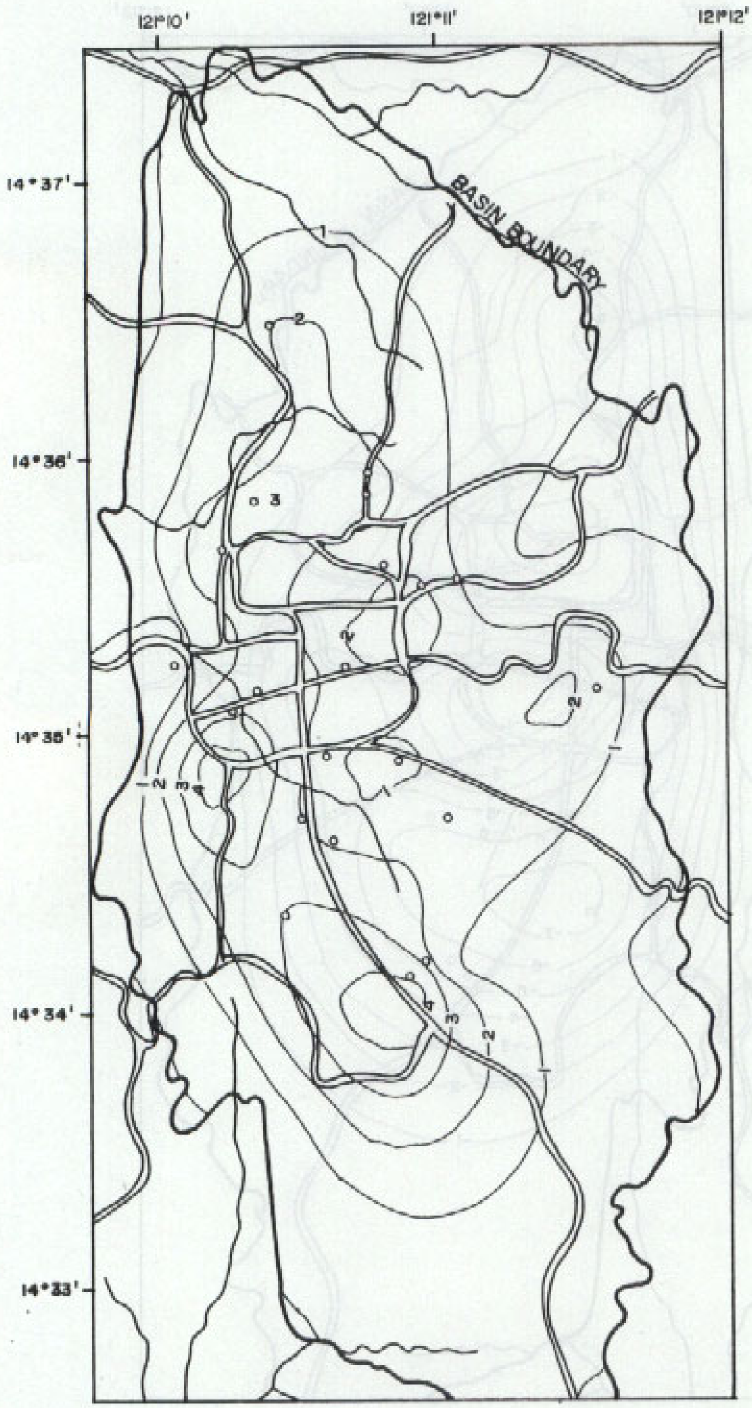


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.4.7

CHANGE IN PIEZOMETRIC CONTOURS FROM NOV. 1990 TO MAY 1991, ANTIPOLO AREA



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.4.8
JAPAN INTERNATIONAL COOPERATION AGENCY	CHANGE IN PIEZOMETRIC CONTOURS FROM MAY 1991 TO AUG. 1991, ANTIPOLO AREA

3.5 RECHARGE ANALYSIS

3.5.1 Water Balance Equation

The water balance equation used in defining recharge is

$$P = R + E + I$$

where, P = mean annual rainfall in mm;
R = runoff in mm;
E = evaporation in mm; and
I = effective infiltration in mm.

Here the direct recharge (effective infiltration) actually includes the infiltration of the precipitation, that from the flow and underflow of the precipitation, that from the flow and underflow of the streams, and that from the percolation of the rice fields.

3.5.2 Estimation of Recharge Components

(1) Rainfall

The isohyetal map of mean annual rainfall for the Study Area is shown in Figure 3.5.1. This map was calculated and plotted using contouring programs which provided nodal values for the isohyets. Areal rainfall was determined using these nodal values.

In the case of Antipolo, the rainfall record (years 1911 to 1990) which was used came from the Sumulong Station, which is located at the center of the groundwater basin. Unreliable portions of the record (1973-90) were reconstructed and missing data from 1911 to 1972 wee estimated using regression analysis, with rainfall data (1865-1990) at Port Area as the independent variable.

(2) Runoff

Previous studies (Bulacan Bulk Water Supply Project, 1984; Philippine Groundwater Salinity Intrusion Control Study, 1987) have used a runoff coefficient of 0.45 for the Guadalupe formation. Considering the present land use condition in Metro Manila, however, a runoff coefficient of 0.60 was instead assumed in this Study. This assumption made use of the results of a previous JICA study (The Study on Flood Control and Drainage Project in Metro Manila, 1990).

(3) Evapotranspiration

For the Study Area and Antipolo, the pan evaporation data from the Science Garden were considered. The actual evapotranspiration was estimated as shown in Table 3.5.1.

3.5.3 Estimated Annual Recharge

Tables 3.5.1 presents the direct recharge estimations for the Study Area. The rainfall over the Study Area is 2,329.7mm; runoff depth is 1,397.9mm; and actual evapotranspiration is 816.6mm. Hence, the direct recharge is estimated at 115.3mm or 4.9% of annual rainfall.

The direct recharge estimates over the northern and southern parts of the Study Area are 153.6mm (or 6.1% of the 2498.8mm-annual rainfall) and 114.7mm (or 5% of the 2308.2mm-annual rainfall), respectively. Over the central area, it is 96.7mm or 4.3% of the 2264.2mm-annual rainfall.

Over the Antipolo groundwater basin, rainfall is 2720.8mm; runoff is 1142,7mm; and actual evapotranspiration is 958.8mm. The recharge depth is estimated at 6193mm or 23% of annual rainfall. Refer to Table 3.5.2.

TABLE 3.5.1 WATER BALANCE CALCULATIONS FOR THE STUDY AREA

(unit, all in mm)

a) Study Area

month	P	PET	AET (E)
jan	18.4	84.9	18.4
feb	7.5	103.6	7.5
mar	15.8	144.7	15.8
apr	30.8	142.0	30.8
may	165.8	140.8	140.8
jun	332.6	99.8	99.8
jul	439.6	90.4	90.4
aug	503.6	95.2	95.2
sep	355.8	88.1	88.1
oct	260.8	76.2	76.2
nov	141.1	74.3	74.3
dec	57.9	79.3	79.3
total	2329.7	1219.3	816.6

I = P - E - R, R = 0.6*P
I = 115.3 (or 4.9% of P)

b) Central Part of the Study Area

month	P	PET	AET (E)
jan	16.7	84.9	16.7
feb	6.4	103.6	6.4
mar	14.3	144.7	14.3
apr	27.3	142.0	27.3
may	160.1	140.8	140.8
jun	329.1	99.8	99.8
jul	422.8	90.4	90.4
aug	491.3	95.2	95.2
sep	346.6	88.1	88.1
oct	260.4	76.2	76.2
nov	136.4	74.3	74.3
dec	52.8	79.3	79.3
total	2264.2	1219.3	808.8

I = P - E - R, R = 0.6*P
I = 96.7 (or 4.3% of P)

c) Northern Part of the Study Area

month	P	PET	AET (E)
jan	26.0	84.9	26.0
feb	11.4	103.6	11.4
mar	20.4	144.7	20.4
apr	44.0	142.0	44.0
may	180.7	140.8	140.8
jun	345.8	99.8	99.8
jul	485.8	90.4	90.4
aug	540.5	95.2	95.2
sep	375.5	88.1	88.1
oct	254.5	76.2	76.2
nov	147.1	74.3	74.3
dec	67.1	79.3	79.3
total	2498.8	1219.3	845.9

I = P - E - R, R = 0.6*P
I = 153.6 (or 6.1% of P)

d) Southern Part of the Study Area

month	P	PET	AET (E)
jan	13.7	84.9	13.7
feb	6.1	103.6	6.1
mar	14.8	144.7	14.8
apr	29.9	142.0	29.9
may	174.1	140.8	140.8
jun	351.4	99.8	99.8
jul	410.1	90.4	90.4
aug	512.5	95.2	95.2
sep	336.9	88.1	88.1
oct	260.9	76.2	76.2
nov	141.7	74.3	74.3
dec	56.1	79.3	79.3
total	2308.2	1219.3	808.6

I = P - E - R, R = 0.6*P
I = 114.7 (or 5.0% of P)

PET, potential evapotranspiration
AET, actual evapotranspiration

TABLE 3.5.2

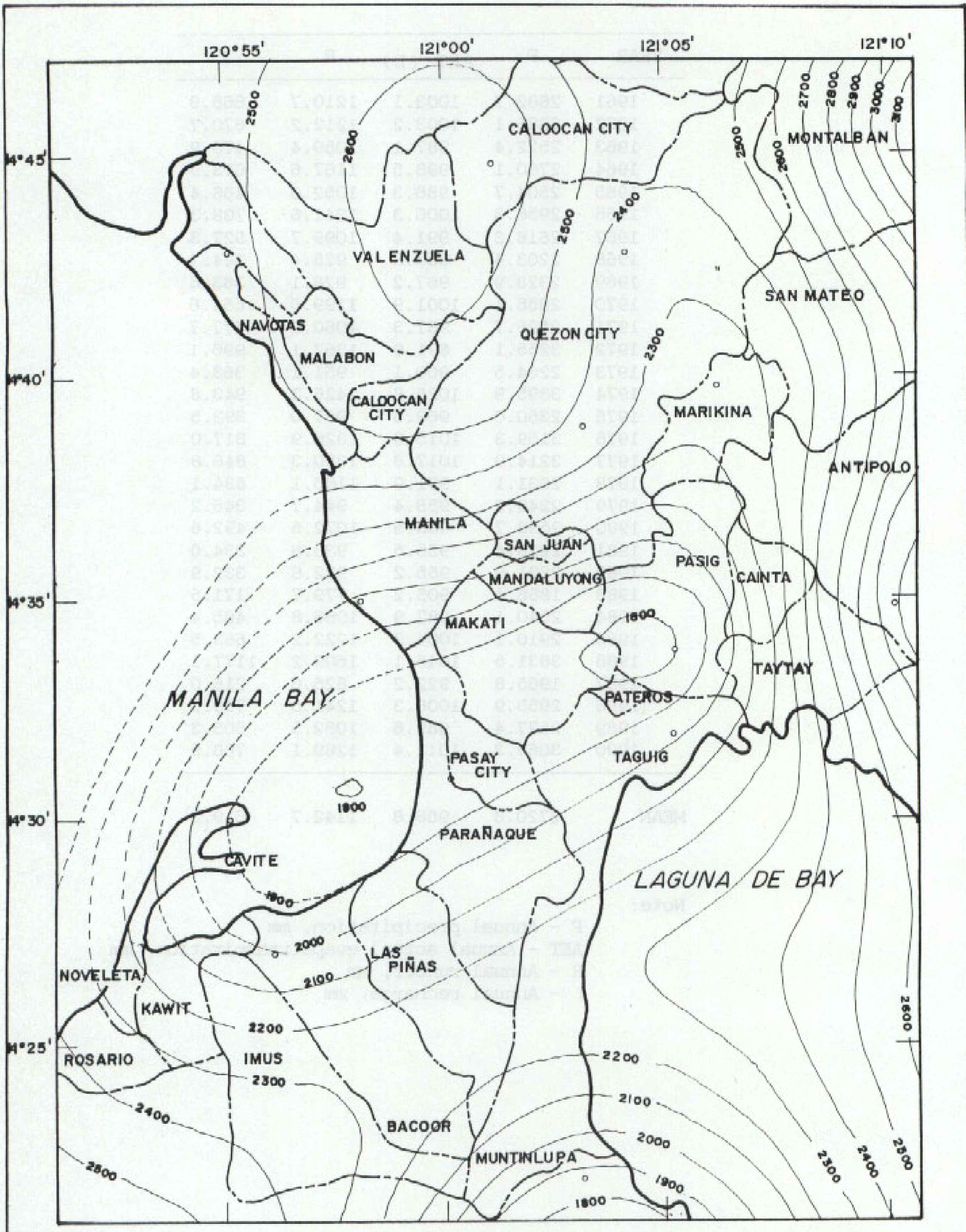
WATER BALANCE CALCULATION FOR ANTIPOLO

YEAR	P	AET (E)	R	I
1911	2968.5	1074.3	1246.8	647.5
1912	2490.2	872.3	1045.9	572.0
1913	2699.9	839.2	1134.0	726.7
1914	3676.3	873.0	1544.0	1259.3
1915	2305.8	812.4	968.4	525.0
1916	2359.4	960.9	990.9	407.6
1917	2576.6	908.0	1082.2	586.4
1918	2945.8	802.8	1237.2	905.8
1919	4402.6	870.9	1849.1	1682.6
1920	2706.2	1004.4	1136.6	565.2
1921	3085.7	824.3	1296.0	965.4
1922	2883.4	916.1	1211.0	756.3
1923	4171.1	1026.7	1751.9	1392.5
1924	2532.3	955.5	1063.6	513.2
1925	2560.0	894.4	1075.2	590.4
1926	2668.8	925.3	1120.9	622.6
1927	2757.5	1050.0	1158.2	549.4
1928	2179.5	907.5	915.4	356.6
1929	2612.0	946.8	1097.0	568.2
1930	2383.1	900.2	1000.9	482.0
1931	3132.8	939.6	1315.8	877.4
1932	2634.9	892.5	1106.7	635.7
1933	2495.6	898.7	1048.2	548.7
1934	4032.0	1051.4	1693.4	1287.2
1935	2879.4	887.0	1209.3	783.1
1936	2475.2	858.3	1039.6	577.3
1937	3639.8	988.3	1528.7	1122.8
1938	2396.8	1087.1	1006.7	303.0
1939	2574.6	922.2	1081.3	571.1
1940	2893.9	968.0	1215.4	710.5
1941	2633.9	992.1	1106.2	535.6
1942	2782.1	998.6	1168.5	615.0
1943	2769.9	998.1	1163.4	608.5
1944	2450.3	980.6	1029.1	440.6
1945	2436.3	979.0	1023.3	434.0
1946	2557.3	988.7	1074.1	494.6
1947	2962.6	1006.6	1244.3	711.7
1948	2664.7	909.4	1119.2	636.1
1949	2020.2	796.9	848.5	374.8
1950	2456.1	981.2	1031.6	443.3
1951	2197.7	848.6	923.0	426.0
1952	2613.1	1045.7	1097.5	469.8
1953	3006.4	1008.6	1262.7	735.1
1954	2281.8	962.0	958.4	361.5
1955	1978.3	924.1	830.9	223.3
1956	2813.5	1000.0	1181.7	631.8
1957	2235.3	956.8	938.8	339.7
1958	3013.1	1008.9	1265.5	738.8
1959	2257.3	959.3	948.1	350.0
1960	3126.6	1013.9	1313.2	799.5

YEAR	P	AET (E)	R	I
1961	2882.7	1003.1	1210.7	668.9
1962	2886.1	1003.2	1212.2	670.7
1963	2522.4	987.1	1059.4	475.9
1964	2780.1	998.5	1167.6	613.9
1965	2504.7	986.3	1052.0	466.4
1966	2956.3	1006.3	1241.6	708.3
1967	2618.3	991.4	1099.7	527.3
1968	2203.4	953.3	925.4	324.7
1969	2328.9	967.2	978.1	383.6
1970	2856.1	1001.9	1199.6	654.6
1971	2525.7	987.3	1060.8	477.7
1972	3255.1	891.9	1367.1	996.1
1973	2264.5	960.1	951.1	353.4
1974	3395.9	1025.8	1426.3	943.8
1975	2350.0	969.5	987.0	393.5
1976	3159.3	1015.3	1326.9	817.0
1977	3214.9	1017.8	1350.3	846.8
1978	2631.1	991.9	1105.1	534.1
1979	2249.2	958.4	944.7	346.2
1980	2553.7	988.5	1072.5	492.6
1981	2223.4	955.5	933.8	334.0
1982	2221.0	955.2	932.8	332.9
1983	1856.4	905.2	779.7	171.5
1984	2540.1	987.9	1066.8	485.4
1985	2910.1	1004.3	1222.2	683.5
1986	3831.5	1045.1	1609.2	1177.1
1987	1965.8	922.2	825.6	218.0
1988	2955.9	1006.3	1241.5	708.1
1989	2577.4	989.6	1082.5	505.3
1990	3069.3	1011.4	1289.1	768.9
MEAN	2720.8	958.8	1142.7	619.3

Note:

P - Annual precipitation, mm
AET - Annual actual evapotranspiration, mm
R - Annual runoff, mm
I - Annual recharge, mm



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA JAPAN INTERNATIONAL COOPERATION AGENCY	FIGURE 3.5.1 MEAN ANNUAL RAINFALL (MM) STUDY AREA

3.6 AQUIFER PARAMETERS

Transmissivity, storativity and leakance are the basic aquifer parameters in the evaluation of groundwater flow, change of storage and leakage. Specific capacity is a measure of the productivity of a well.

Since accurate and reliable data are necessary in the evaluation of groundwater resources, data collection on and pumping tests of existing wells were conducted.

3.6.1 Existing Data

Pumping test and aquifer data obtained during GWD-MWSP II (1983) from 150 wells in Metro Manila were reviewed. Collected data include well depth, static water level, drawdown, test pumping rate, specific capacity and transmissivity.

Results of 123 pumping tests conducted after 1983 were also collected and sifted for data on well depth, static water level, drawdown, test pumping rate and specific capacity. In this collection, a few transmissivity data were included. The Study Team likewise made a list of specific capacities involving 163 MWSS wells.

3.6.2 Pumping Tests of MWSS Wells

The step-drawdown test, the constant rate test and the recovery test were conducted for fifteen (15) wells selected from the active MWSS deep wells. These pumping tests were done to evaluate well efficiency, specific capacity, transmissivity and storativity. Some of the selected wells have pumping test data that were obtained during construction. The tests used are applicable to confined aquifers in unsteady-state conditions.

The location map of the 15 selected MWSS wells is shown in Figure 3.6.1. These wells are detailed in Table 3.6.1.

The 15 selected MWSS deep wells operate twenty four (24) hours a day. This continuity of operation considered, the duration of pumping and recovery tests was shortened. The pumping test program was then set as follows:

(1) Step-drawdown test: five (5) steps at two (2) hours per step
(2) Constant rate test: eight (8) hours pumping at constant discharge
(3) Recovery test : four (4) hours recovery

For five (5) wells, the tests that were conducted are the step-drawdown test, the constant rate test and the recovery test. For the other ten (10) wells, however, the step-drawdown test was omitted because of the need to immediately supply water.

Preparatory works were undertaken prior to the conduct of the pumping tests. These works include the installation of sounding tubes for the measurement of water levels after completion of the pumping test.

3.6.3 Pumping Tests of Test Wells

Step-drawdown pumping tests, continuous pumping tests and recovery tests were performed in the seven (7) test wells drilled by the Study Team. Transmissivity and storativity were calculated from the results of continuous and recovery tests using different methods--Theis method, Cooper-Jacob method and Recovery method. Specific capacity was also computed from the results of continuous pumping tests.

The pumping tests in Las Piñas revealed that the transmissivity of the shallow aquifer is higher than that of the deep aquifer; transmissivities of the 100-m wells vary from 116 m^2/day to 219 m^2/d; transmissivities of the 200-m and 300-m wells vary from 13 m^2/d to 54 m^2/d. Storativities range widely, from $1x10^{-10}$ to $2x10^{-1}$, and do not show clear correlation with depths.

The test wells in Antipolo tapped the deeper aquifer belonging to member IV of the Guadalupe formation (Gmd). The results of the pumping tests show small transmissivity (8.8 m^2/d) and poor productivity of the aquifer.

3.6.4 Transmissivity and Specific Capacity

Figure 3.6.2 shows the distribution of transmissivity values of 196 wells in Metro Manila. The logarithmic average and standard deviation were computed for statistical analyses. The average transmissivity in the Metro Manila area is 77.5 m^2/d, with a 90% reliable range of 21.9 m^2/d to 274.3 m^2/d. Figure 3.6.3 shows the transmissivity map of the Metro Manila area. This map was drawn based on statistical analyses.

As mentioned earlier, the amount of transmissivity data is less than the amount of specific capacity data. Specific capacity values were thus used for the estimation of transmissivity. The empirical relation between transmissivity and specific capacity was given by Logan (1964) in the following equation:

$$T = 1.22Sc$$

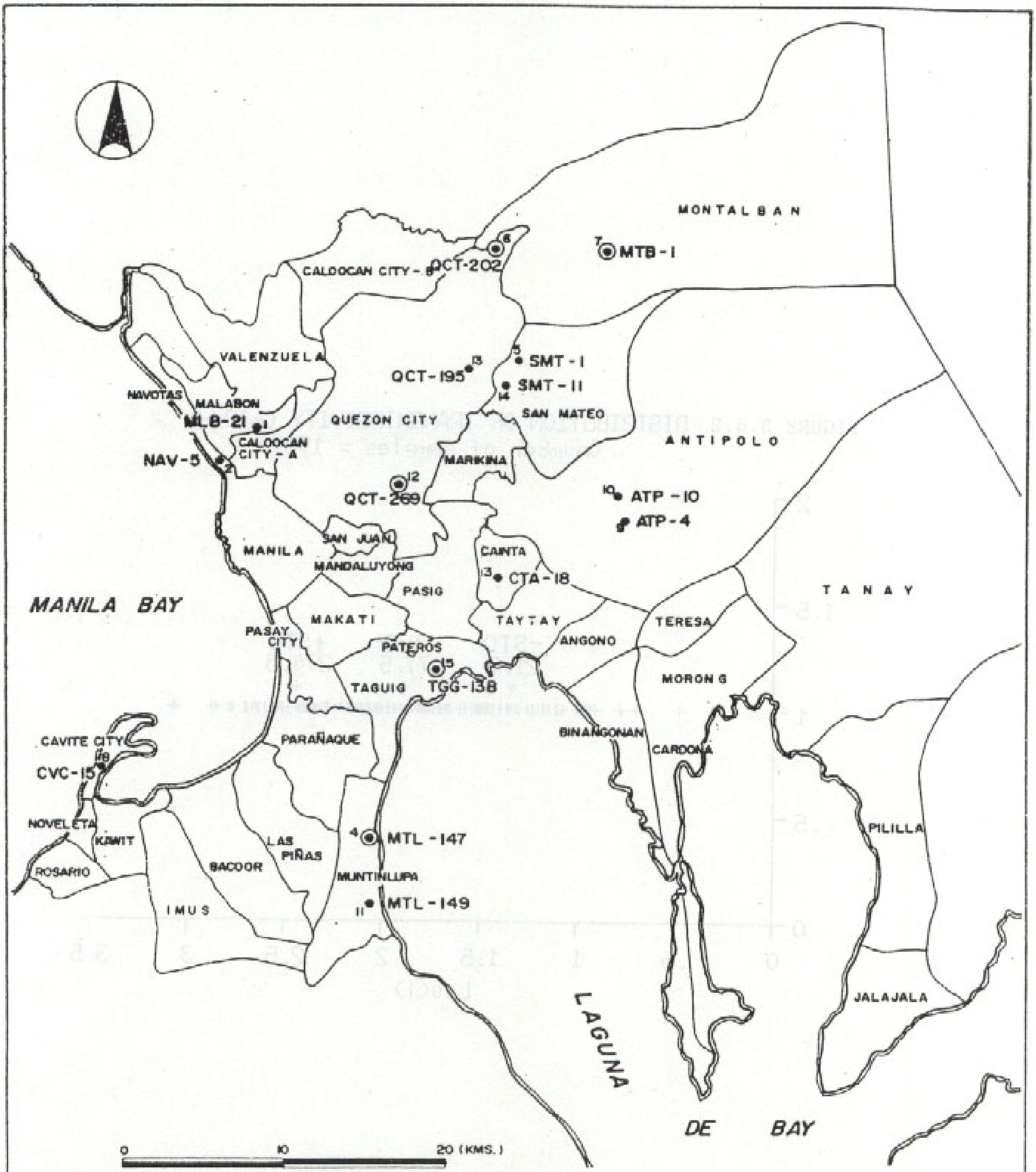
where, T= transmissivity (m^2/d) and Sc= specific capacity (m^2/d). Figure 3.6.4 shows the correlation between the collected/measured transmissivity and specific capacity. It also illustrates the applicability of Logan's equation to the Metro Manila area. The advantages of using specific capacity instead of transmissivity lie not only in increasing the number of data available for analysis but also in making the more reliable data reflect actual aquifer characteristics. Also, even with the most careful conduct of the pumping test, a wide range of transmissivity values is often obtained from such test.

Figure 3.6.5 shows the distribution of transmissivity values of 278 wells, which were estimated from Logan's equation. The logarithmic average is 58.3 m^2/d, with a 90% reliable range of 17.3 m^2/d to 197.1 m^2/d. Figure 3.6.6 shows the estimated transmissivity map of Metro Manila. The input transmissivity data for the Metro Manila groundwater flow model was prepared from the transmissivity map.

TABLE 3.6.1 BRIEF DESCRIPTION OF 15 MWSS WELLS FOR PUMPING TEST

No.	Owner	No.	Locations	Operating Non-Operating	Casing Size (dia.)	Well Depth (m)	Pumping Rate (l/min)	Screen (m)	Remark
1	MWSS	MLB-21	Catmon, Malabon	Operating	(8")	268	-	164-262	(C+R) test
2	MWSS	NAV-5	NHA-1 Dagat-dagatan	Operating	8"-6"	243.8	(206)	140-237	(C+R) test
3	MWSS	CTA-18	Sto. Domingo, Cainta	Operating	12" -10"	200	(240)	60-178	(C+R) test
4	MWSS	MTL-147	Sucat Elem. Sch., Muntinlupa	Operating	10-8"	287	(521)	119-283	(S+C+R) test
5	MWSS	SMT-1	Public Market, San Mateo	Operating	10"	137.19	(937.5)	NA	(C+R) test
6	MWSS	QCT-202	Lagro No. 1, Q.C.	Operating	8"	243.84	(1323)	NA	(S+C+R) test
7	MWSS	MTB-1	San Jose, Montalban	Operating	12"-10"	202.16	(545)	NA	(S+C+R) test
8	MWSS	CVC-I5	Ejercito, Cavite City	Operating	8"-6"	257	(450)	136-298	(C+R) test
9	MWSS	ATP-4	Nursery, Antipolo	Operating	8"-6"	100	(666)	NA	(C+R) test
10	MWSS	ATP-10	Saguinsin, Antipolo	Operating	10"-8"	125	(1304)	51-71 82-88 112-115	(C+R) test
11	MWSS	MTL-149	Tunasan, Muntinlupa	Operating	10"-8"	305	(461)	Multi.	(C+R) test
12	MWSS	QCT-269	Escopa, Proj. 4, Q.C.	Operating	10"-8"	244	(500)	146-244	(S+C+R) test
13	MWSS	QCT-195	IBP No. 2, Q.C.	Operating	10"	274	(375)	115-197	(C+R) test
14	MWSS	SMT-II	Banaba-Ampid, San Mateo	Operating	10-8"	174	(642)	73-140	(C+R) test
15	MWSS	TGG-138	Signal Vill. No. 1, Taguig	Operating	10"-8"	171	-	60-170	(S+C+R) test

C: Continuous Pumping Test, R: Recovery Test,
S: Step Drawdown Test

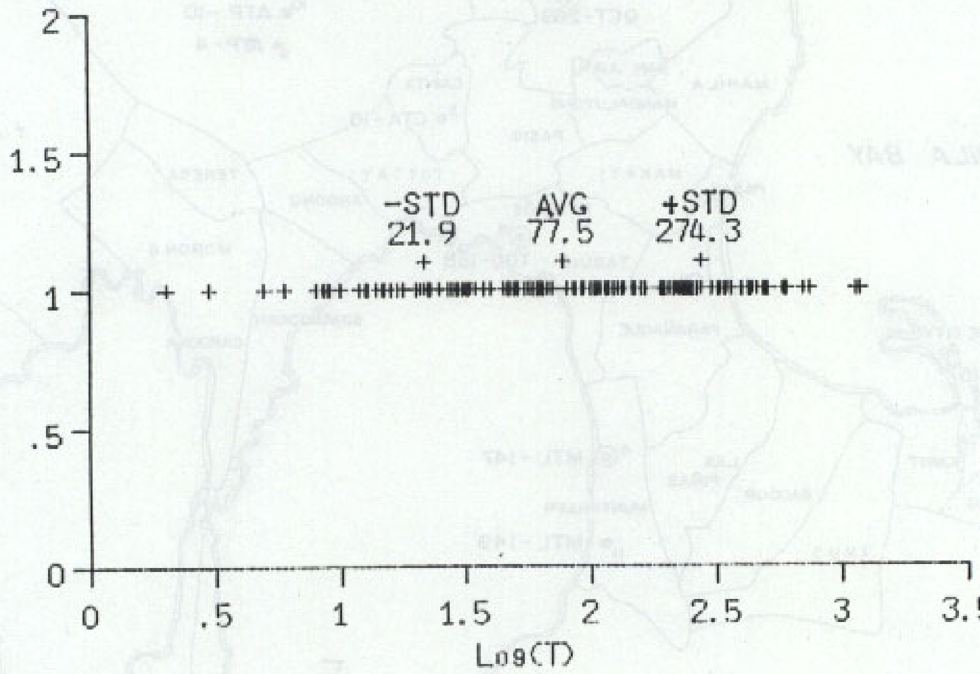


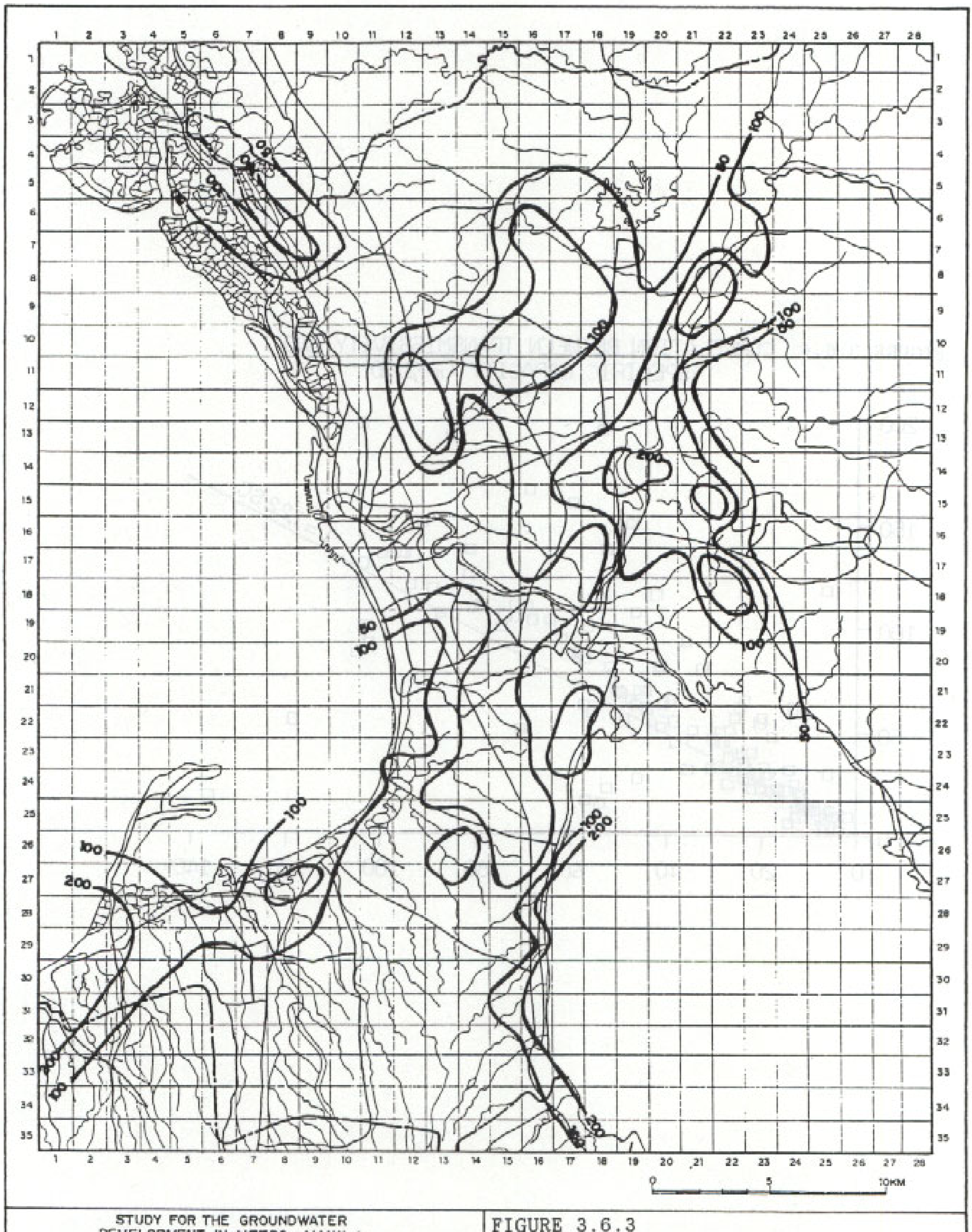
LEGEND:

- • PUMPING TEST SITES (CONTINUOUS DISCHARGE TEST & RECOVERY TEST)
- ◉ PUMPING TEST SITES (STEP-DRAWDOWN, CONTINUOUS DISCHARGE TEST & RECOVERY TEST)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.6.1 FIFTEEN WELLS PUMPING TEST SITES
JAPAN INTERNATIONAL COOPERATION AGENCY	

FIGURE 3.6.2 DISTRIBUTION OF TRANSMISSIVITY (m^2/d)
(number of samples = 196)





STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.6.3
JAPAN INTERNATIONAL COOPERATION AGENCY	TRANSMISSIVITY MAP OF METRO MANILA

FIGURE 3.6.4 CORRELATION BETWEEN TRANSMISSIVITY AND SPECIFIC CAPACITY (m^2/d)

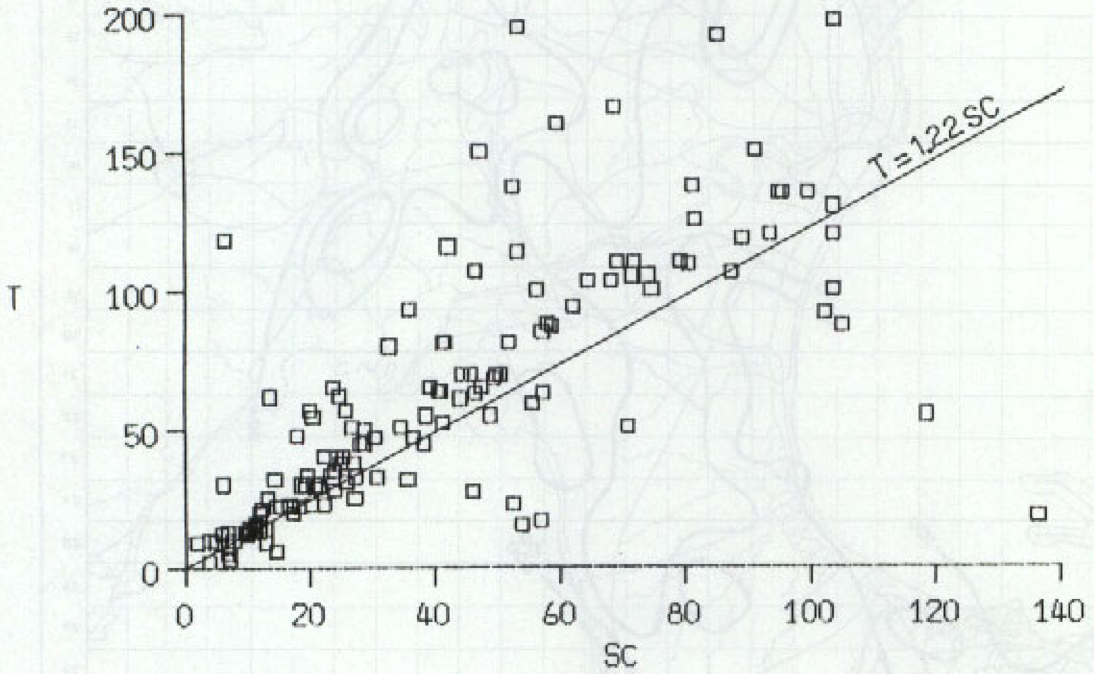
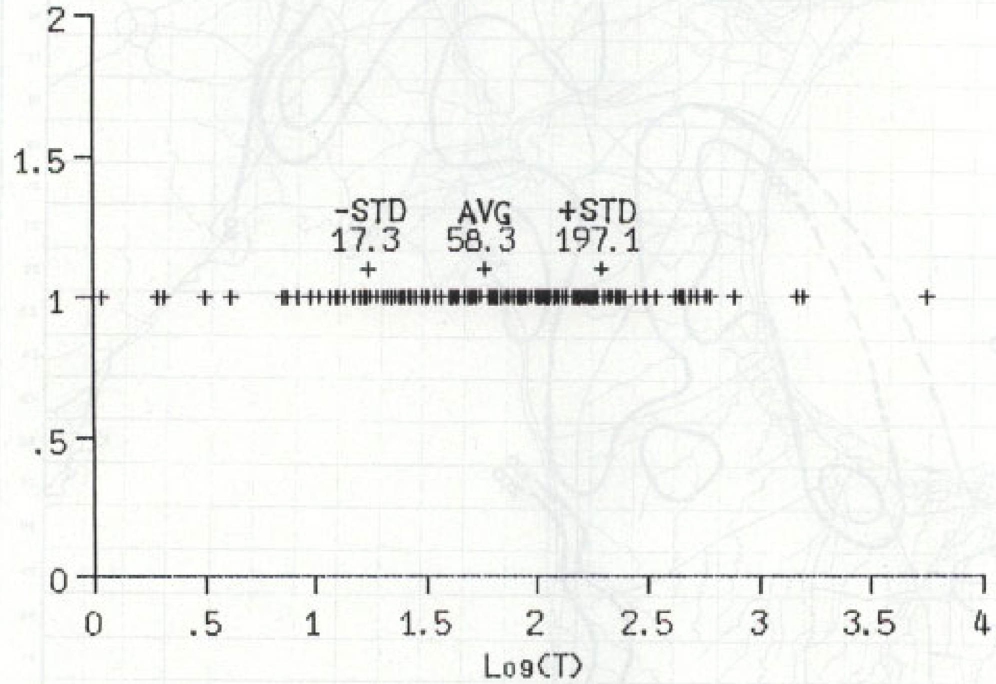
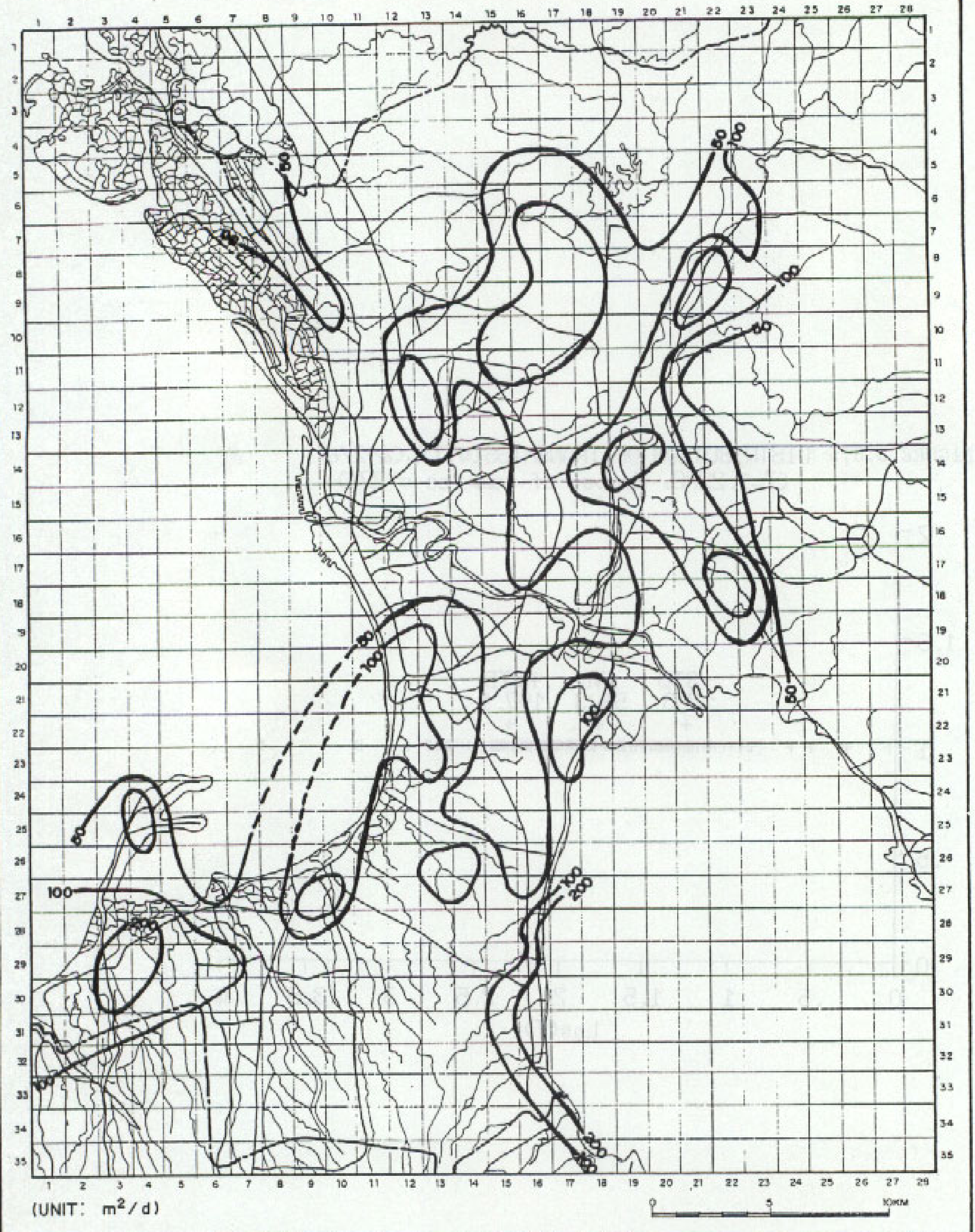


FIGURE 3.6.5 DISTRIBUTION OF TRANSMISSIVITY (m^2/d)
(T=1.22×S, Number of samples = 278)





STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.6.6
ESTIMATED TRANSMISSIVITY MAP FROM SPECIFIC CAPACITY

3.7 GROUNDWATER QUALITY

3.7.1 Groundwater Sampling

Groundwater sampling and water quality analysis were performed in order to characterize the bodies of groundwater in the Metro Manila groundwater basin in terms of their chemical composition, and to clarify the distribution of chloride ion in the area affected by saline water intrusion.

A total of 90 water samples were collected and analyzed. Operational MWSS deep wells were given first priority as sampling points. Where no operating MWSS deep well exists in a locality, sampling points were selected from existing private deep wells. In choosing deep wells as sampling points, the priority is given to those with data on lithologic log, well design, etc.

Water samples were also collected from rivers, from the sea, and from the JICA test wells drilled in Las Piñas and Antipolo. For tritium (^{3}H) analysis, water samples were collected from wells of different depths.

The list of sampling points is shown in Table 3.7.1, and their location is presented in Figure 3.7.1. Results of analyses are summarized in Table 3.7.2.

3.7.2 Hydrochemical Facies

3.7.2.1 Trilinear Diagram Representation

In terms of topography and geology, location of groundwater sampling points can be clustered into four sections, namely, the coastal plain of Manila Bay, the Guadalupe Hill, the Marikina Valley and the Antipolo Plateau (Figure 3.7.1). The results of chemical analysis were separately plotted on the trilinear diagram of each section (Figure 3.7.2).

(1) The Coastal Plain

Most of the samples are plotted on domains III and IV of the diagram. The water in domain III is of the carbonate alkali type, while that in domain IV is of the noncarbonate alkali type. A few samples are plotted on domain II (carbonate hardness type). These samples are located close to the Guadalupe Hill.

Samples plotted on domain IV are salinized and contain more than 200 mg/l of chloride. In JICA's two 100-m test wells in Las Piñas, the chloride concentration is extremely high and reaches more than 17,000 mg/l. In addition, their calcium-magnesium content is higher than that of seawater.

Samples plotted on domain III are not salinized. Their chemical composition is thought to change from II to III along the flow paths, and such composition may be altered to the noncarbonate alkali (domain IV) due to saline water intrusion.

Most samples belong to the sodium-potassium type in terms of cation, except for salinized water which shifts to the calcium type. In terms of anion, the samples have a wide range of distribution. They are classified into bicarbonate, chloride and nondominant types in accordance with the degree of salinization.

(2) Guadalupe Hill

Samples of the Guadalupe Hill are plotted on domains II and III. They are of the sodium-potassium type in terms of anion and of the bicarbonate type in terms of cation. Alteration in the chemistry of groundwater commonly occurs when it moves along flowlines from the recharge area to the discharge area. From this point of view, samples plotted on domain III may have evolved geochemically from domain II. Chloride and sulfate concentrations of these samples are low and amount to less than 50 mg/l, suggesting that groundwater of the Guadalupe aquifer in the hill is not contaminated yet by saline water.

(3) Marikina Valley

Samples are plotted on all the domains from I to IV. Two samples plotted on domain I are remarkable. These samples came from deep wells in Cainta. Another two samples plotted on domain IV are also remarkable. These samples came from deep wells in Taguig and Taytay, which are located downstream of the Marikina River. Chloride concentration of these latter samples show more than 140 mg/l. The sample from Taguig in particular reached 457 mg/l.

According to MGB which drilled a test well (PS-4) downstream of the Marikina River, the Guadalupe aquifer contains connate water in deeper formations. The Electrowatt Study also mentioned the existence of connate water in this valley.

Since water samples taken at the shallow Guadalupe aquifer belong to domains II or III, samples plotted on domains I and IV are possibly contaminated by connate saline water.

(4) Antipolo Plateau

All samples are plotted on domain II. Surface water samples taken from Wawa Dam also belong to domain II. It therefore follows that the chemical component of the groundwater in the plateau is similar to that of surface water.

Groundwater belongs to the bicarbonate type in terms of anion. In terms of cation, it belongs to either calcium type or to no dominant type.

These characteristics of groundwater suggest that it has not been long since rainwater infiltrated through the soil into the aquifer system.

3.7.2.2 Hydrochemical Profile

Hydrochemical facies are represented on the west-east cross section of Metro Manila as shown in Figure 3.7.3.

Hydrochemical facies in the coastal plain are of the noncarbonate alkali type ($NaSO_4$-$NaCl$) of domain IV. Groundwater is obviously being salinized. Water quality in the Guadalupe Hill and Antipolo Plateau belongs to the carbonate hardness type ($Ca(HCO_3)_2$) of domain II. The carbonate alkali type ($NaHCO_3$) of domain III is distributed in a limited area in the coastal plain and Marikina Valley.

The groundwater quality of the Guadalupe aquifer is considered as originally belonging to domain II, but which has been altered along the flow paths. In the coastal area, it has shifted to the noncarbonate alkali type due to saline water intrusion. In Marikina Valley, connate water migrates upward into the shallow aquifer due to upconing.

3.7.2.3 Pattern Diagram

A distribution of pattern diagrams is shown in Figure 3.7.4. The larger the area of the polygonal shape, the greater the concentration of the various ions. The diagrams distributed north of the Guadalupe Hill and the Antipolo Plateau are small and have disc-like or fish-like shapes.

On the other hand, in the coastal plain and the south of the Guadalupe Hill, the diagrams are large because of the high concentration of dissolved ions. Particularly, as groundwater is highly salinized and contains high concentrations of sodium, potassium and chloride, the pattern diagrams show their upper part to be larger and both of their sides longer.

3.7.3 Chemical Evolution and Hydrologic Cycle of Groundwater

3.7.3.1 Chemical Evolution

As groundwater moves along its flow paths in the saturated zone, what normally occurs is an increase of total dissolved solids and of most major ions. In addition, alteration of the chemical composition of groundwater occurs systematically due to:

1) Dissolution from the formation
2) Change in environment from oxidization to reduction
3) Ion exchange between the ions contained in water and those in clay minerals

From these considerations follow the conclusion that shallow groundwater in recharge areas is lower in dissolved solids than water which is located deeper in the same system. The latter type of groundwater has the same characteristic as the water in shallow zones of discharge areas.

The alteration process is generally termed as the chemical evolution of groundwater. Sugisaki and Shibata (1961) explained this process on a key diagram like the one shown in Figure 3.7.5. Groundwater evolves geochemically along the line indicated by the arrow.

Carbonate minerals are first dissolved when rain infiltrates through the unsaturated zone into the aquifer system. Groundwater quality is denoted (1) in domain II of the diagram. As groundwater moves, it chemically evolves and changes to (2) and (3) in domain II due to solution from rock minerals and organic decomposition. Ion exchange between Ca^{++} and Mg^{++} in water and Na^{+} in clay minerals occurs in the process. Chemical composition thereby changes to (4), and then (5) in domain III.

Applying the chemical evolution process to the Study Area, the groundwater in the Guadalupe aquifer system on the northern Guadalupe Hill and Antipolo Plateau is in process (1) and (2). It is in process (3) to (5) in the southern Guadalupe Hill, the Marikina Valley and the coastal plain.

The chemical characteristics of groundwater are related to the minerals of the soils and rocks in contact with it; that is, to the facies of the formation and their geological age.

The Guadalupe formation is covered by the younger Diliman formation in the northern Guadalupe Hill. The Guadalupe formation is also thought to be younger in Antipolo than in Guadalupe Hill. So considered, it can be concluded that it has not been so long since rain reached the aquifer system in these areas.

The evolution of the quality of groundwater in the southern Guadalupe Hill, the coastal plain and Marikina Valley is so long in time due to long travel or stagnancy along its flow paths.

3.7.3.2 Tritium Dating and Hydrologic Cycle

In order to estimate the groundwater cycle, four (4) groundwater samples from JICA test well sites and one (1) seawater sample from Manila Bay were taken to Japan for tritium analysis.

Tritium is a radioactive isotope of hydrogen with a half life of 12.4 years. The presence of tritium in water of the hydrologic cycle arises from both natural and manmade sources. Tritium is produced naturally in the earth's atmosphere by the interaction of cosmic ray-produced neutrons and nitrogen. Until 1952 the average natural tritium content of precipitation worldwide is in the range of about 5 to 20 TU. With the beginning of large scale atmospheric testing of thermonuclear bombs in 1952, the tritium contents of precipitation rose sharply.

From 1962 to 1963, tritium content of the atmosphere reached a maximum of about 80,000 TU in some localities, over a thousand times greater than that for the period prior to nuclear bomb testing. With the restriction of atmospheric testing, tritium contents have been declining, but still in larger concentrations than those naturally produced.

The longest continuous record of ^3H concentration in precipitations came from Ottawa, Canada, where sampling had begun in 1952. ^3H versus time record for this location is shown in Figure 3.7.6. The trends displayed are representative of the ^3H trends recorded elsewhere in the northern hemisphere.

Tritium is widely used for groundwater dating in this context: Very low tritium concentrations, around the level of detectability, indicate that the water is principally from the pre-nuclear period. If a sample of groundwater contains tritium at concentration levels of hundreds or thousands of TU, it is evident that the water, or at least a large fraction of it, originally entered the groundwater zone sometime after 1953. If the water has less than 5-10 TU, it must have originated prior to 1953 (Freeze and Cherry, 1979).

Results of analysis are shown below:

Locality	TU
Las Piñas No.2 300m well	4.63
Las Piñas No.2 200m well	3.25
Las Piñas No.2 100m well	2.58
Antipolo 200m well	1.60
Sea Water (Matabungkay Beach)	4.16

Tritium concentrations indicate that the water may have originated prior to 1953 or may have mixed with post-1953 water. Tritium concentrations in shallow aquifers are lower than those in deep aquifers. This may be explained as follows:

> Significant amounts of the post-1953 water with high tritium con tent are still present in deep aquifers although tritium has de cayed. On the other hand, the shallow aquifer has been replenished with more recent low tritium water. However, the result that tritium content of the seawater is almost the same as that of the groundwater in the deep aquifers could not be explained at present. Further studies using various kinds of environmental isotopes are necessary to clarify the flow mechanism in the Guadalupe aquifers.

3.7.4 Groundwater Salinization

Analysis of groundwater samples collected in the coastal area shows a chemical composition different from a simple proportional mixing of seawater and groundwater (Figure 3.7.2). The samples are located in the lower area of domain IV or the Na+K dominant area of domains III and IV. The highly salinized water samples are located in the Cl+SO_4 area of domain IV.

Chloride concentrations of JICA's 100-m test wells in Las Piñas show 17,144 mg/l at LPS-1 and 21,100 mg/l at LPS-2. In addition, concentrations of Na and Ca are higher than those of seawater (Table 3.7.2).

Shifts in the chemical composition of seawater entering an aquifer may occur under three processes (Revelle, 1941):

(1) Base exchange between water and minerals of the aquifer;
(2) Sulfate reduction and substitution of carbonic or other weak acid radicals; and
(3) Solution and precipitation.

Only the last process can change the total salt concentration; however, the first two processes which require maintenance of ionic balance can alter the percentage by weight of the different salt components and thereby the total dissolved solids in mg/l (Todd,1980).

Clay minerals in the formation generally adsorbs Na. Chemical equilibrium is achieved when these minerals come in contact with water containing Ca as shown below.

$$2NaX+Ca^{2+} \quad CaX_2+2Na^+$$

Reaction occurs from right to left in the above equation if the concen tration of Na is abnormally high.

The Ca/Mg, Ca/Cl and Mg/Cl ratios of samples which denote more than 100 mg/l of chloride concentration are presented in Table 3.7.5. Ca/Mg ratio of all samples are higher than that of seawater. This ratio ranges from 1 to 10, even in the samples which show lower than 200 mg/l of chloride concentration. The Ca/Mg ratio of seawater is only 0.0379.

Ca/Cl ratios of all samples are higher than the Ca/Cl ratio (0.0211) of seawater, suggesting the chemical composition of groundwater to have been changed by seawater intrusion. On the other hand, Mg/Cl ratios of almost all samples are lower than that (0.0684) of seawater, which is still valid (Tables 3.7.3 and 3.7.4).

Revelle (1941) proposed the Cl/HCO_3 ratio as a criterion for evaluating intrusion. Chloride is the dominant anion of ocean water and is not affected by the earlier said processes. It normally occurs in groundwater in only small amounts. On the other hand, bicarbonate is usually the most abundant anion in groundwater and occurs in only minor amounts in seawater.

Groundwater samples in the Study Area show the Cl/HCO_3 ratio to be increasing linearly (Figure 3.7.7), clearly indicating the intrusion of seawater into the aquifer system.

TABLE 3.7.1 LOCATIONS AND NAMES OF WELLS FOR GROUNDWATER SAMPLING

ID NO.	NAME	WELL NO.	LOCATION
1	LPS-1 Well # 2		Quirino Avenue, Las Piñas, M.M.
2	LPS-1 Well # 3		Quirino Avenue, Las Piñas. M.M.
3	LPS-2 Well # 3		Beside Public Market Zapote, Las Piñas
4	URIC Sub. Div.		Alabang Zapote Rd., Las Piñas
5	Manuela Sub. Div.	LPS-117	Alabang Zapote Rd., Las Piñas
6	LPS-2 Well # 2		Beside Public Market, Zapote, Las Piñas
7	Samonte Park # 1	CVC-1	Samonte Park Compound, Cavite City
8	Ejercito P/S	CVC-15	Ejercito St., Cavite City
9	Noveleta Elem. Sch.	NOV-7	Noveleta Elem. Sch., Noveleta, Cavite
10	Noveleta Well # 2	NOV-2	San Antonio, Noveleta, Cavite
11	Noveleta Well # 5	NOV-5	Abandoned Rail Road, Noveleta, Cavite
12	Noveleta Well # 8	NOV-8	Abandoned Rail Road, Noveleta, Cavite
13	Nursery Well # 4	ATP-4	Nursery, Antipolo, Rizal
14	Saguinsin Well # 10	ATP-0	Along Circumferential Rd., Antipolo, Rizal
15	Cogeo Pump # 2	ATP-30	Cogeo Village, Antipolo, Rizal
16	San Juan Pump # 3	CTA-19	San Juan Cainta, Rizal
17	Bangiad Pump Station	TYY-0	Bangiad, Taytay, Rizal
18	Sto. domingo	CTA-18	Sto. Domingo. Cainta, Rizal
19	LPS-1 Well # 1		Quirino Avenue, Las Piñas, M.M.
20	Manila Japanese School		Levitown, Parañaque, M.M.
21	Aguinaldo	KWT-4	Aguinaldo Elem. Sch., Kawit, Cavite
22	IBP # 2	QCT-196	Batasang Pambansa, Q.C.
23	Fairview Pump # 3	QCT-208	Pearl St., Fairview, Q.C.
24	Lagro # 1	QCT-202	Lagro, Quezon City
25	Wawa Dam		Wawa, Montalban, Rizal
26	San Jose Pumping Station	MTB-1	San Jose, Montalban, Rizal
27	Public Market	SMT-1	San Mateo Public Market, San Mateo, Rizal
28	LPS-2 Well # 1		Beside Public Market, Zapote, Las Piñas
29	Combalay		Combalay, Kawit, Cavite
30	Plaza Garcia	IMS-21	Plaza Garcia, Imus, Cavite
31	Green Meadow # 3	QCT-34	Green Meadow, Q.C.
32	Kapitolyo	PSG-97	Bgy. Capitolyo, Pasig, M.M.
33	Escopa	QCT-269	Escopa, Proj. 4, Q.C.
34	Catmon Deepwell	MLB-21	Catmon, Malabon, M.M.
35	Pasolo Elem. School	VLZ-214	Pasolo Elem. Sch., Valenzuela, M.M.

TABLE 3.7.1 (CONTINUATION)

ID NO.	NAME	WELL NO.	LOCATION
36	T. de Leon	VLZ-125	Fortune Vill., Valenzuela, M.M.
37	Banaba-Amoid	SMT-0	Amoid, San Mateo, Rizal
38	EEMI		Ever Electrical Mfg. Inc., Malanday, Marikina
39	HPPC		Hanson Paper Phil. Corp., Manggahan, Pasig
40	LPS-3 Well # 1		R. Castillo, Las Piñas, M.M.
41	Talaba	BCK-5	Bo. Talaba, Bacoor, Cavite
42	Naga Well # 2	LPS-39	Naga, Las Piñas, M.M.
43	ATP JICA Test Well		Antipolo, Rizal
44	Sucat Elem. School	MTL-147	Sucat Elem. Sch., Sucat, Muntinlupa
45	MWSS Alabang	MTL-150	Alabang Junction, Muntinlupa, M.M.
46	Muntinlupa Bliss		Muntinlupa Bliss, Muntinlupa, M.M.
47	Merville Subdivision	MLB-101	Tanza Merville Subd., Navotas, M.M.
48	Dagat-Dagatan # 1		Dagat-Dagatan, Navotas, M.M.
49	Forbes Park # 11	MKT-11	Forbes Park, Cambridge Circle, Makati
50	Ecology Village	MKT-145	Ecology Village, Makati
51	Signal Village II # 5	TGG-135	Signal Vill. II, Taguig, M.M.
52	Silver Swan Mfg. Co.		Panghulo Rd., Malabon
53	Vanson Paper Ind.		150 R. Delfin St., Marulas, Valenzuela
54	Quezon Institute		E. Rodriguez Ave., Q.C.
55	World Paper Mills		2 Baler St., Q.C.
56	Farola Ice Cold (ICSC)		Muella Industria Manila
57	Procter & Gamble Phil. Inc.		Velasquez St., Tondo, Manila
58	Sta. Teresita College		P. Tuazon Q.C.
59	INNOTECH		Commonwealth Ave., UP Diliman, Q.C.
60	Sumulong Taytay		MWSS
61	Cardinal Santos Medical Center		Wilson St., Q.C.
62	IBP # 3		MWSS
63	Latex City		Alabang Zapote Rd.
64	Goodyear Steel Pipe		129 Quirino Hi-Way Q.C.
65	Rubber World		328 Quirino Hi-Way Q.C.
66	IBP (July 13/91)		Quezon City
67	Manila Hotel		Roxas Blvd., Manila
68	BF Homes # 22 L.P.		Madrid St., Las Piñas
69	BF Homes # 1		Lalaiana Beth St., Pamplona
70	BF Homes # 9		Salomita St., Las Piñas, M.M.

TABLE 3.7.1 (CONTINUATION)

ID NO.	NAME	WELL NO.	LOCATION
71	BF # 4 CRM		Menche St., Almanza, Las Piñas
72	BF Homes # 7		Back of Chapel, Las Piñas
73	IBP Q.C.		
74	La Perla		Quirino Ave., Parañaque, M.M.
75	Hyatt Regency Hotel		Roxas Blvd., Manila
76	J.C. Aqua Marine		Parañaque, M.M.
77	Olivares Hospital		Sucat Rd. Parañaque, M.M.
78	Malayan Textile Mill		Sta. Ana Drive
79	Ireneville Subd.		South Super Hi-way Sunvalley Parañaque
80	Cogeo # 6 (Step Drawdown)		Cogeo, Antipolo
81	Cogeo ATP # 1		Cogeo, Antipolo
82	Cogeo # 5 (Constant Pump.)		Cogeo, Antipolo
83	La Huerla		MWSS Parañaque, M.M.
84	Maricaban Pump # 1		Pasay City
85	Liberty Flour Mills		Mandaluyong, M.M.
86	International Oil (Baguio Oil)		San Juan, M.M.
87	National Steel Corp.		Calauan Sur Pasig, M.M.
88	Makati Medical Center		Makati M.M.
89	Oscar Rodriguez		Deparo St., Caloocan City
90	Ramitex		Gen. Luis St., Caloocan City

TABLE 3.7.2 MAJOR ION ANALYSIS OF GROUNDWATER SAMPLES IN MSA

NAME	NWSS WELL NO.	DATE OF SAMPLING	T	EC	NA+		K+		Ca++		Mg++		Cations		CO 3 --		HCO 3 --		CL-		SO 4 --		Anions	
			C	KS/cm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm
1. LPS-1 WELL #2		Jan. 29, 91	32	760	128	5.57	17	0.44	14	0.70	9	0.74	-	7.44	0	0.00	251	4.11	56	1.58	23	0.48	-	6.17
2. LPS-1 WELL #3		Jan. 21, 91	30	39100	9700	421.74	232	5.95	1160	58.00	2290	188.48	-	674.17	0	0.00	292	4.79	17144	483.61	4250	88.50	-	576.90
3. LPS-2 WELL #3		Jan. 15, 91	29	37100	8125	353.26	339	8.69	1450	72.50	1409	115.97	-	550.42	0	0.00	365	5.98	21100	595.20	2500	52.10	-	653.28
4. URCI, LAS PIÑAS		Feb. 15, 91	31	880	68	2.96	18	0.46	61	3.05	21	1.73	-	8.20	0	0.00	377	6.18	25	0.71	11	0.23	-	7.11
5. MANUELA SUBD.		Feb. 15, 91	31	1190	100	4.35	15	0.38	75	3.75	18	1.48	-	9.96	0	0.00	411	6.74	62	1.75	31	0.65	-	9.13
6. LPS-2 WELL #2		Jan. 18, 91	32	14050	1595	69.35	164	4.21	951	47.55	268	22.06	-	143.16	0	0.00	239	3.92	4923	138.87	250	5.20	-	147.99
7. SAMONTE PARK WELL NO.1		Feb. 20, 91	25	1803	297	12.91	27	0.69	40	2.00	7	0.58	-	16.18	0	0.00	241	3.95	383	10.80	68	1.42	-	16.17
8. EJERCITO WELL		Feb. 20, 91	25	617	127	5.52	11	0.28	5	0.25	1	0.08	-	6.14	31	1.03	196	3.21	39	1.10	26	0.54	-	5.89
9. NOVELETA ELEM. SCHL.		Feb. 20, 91	25	536	110	4.78	14	0.36	7	0.35	3	0.25	-	5.74	0	0.00	246	4.03	28	0.79	23	0.48	-	5.30
10. NOVELETA, CAVITE NO. 2		Feb. 21, 91	34	680	114	4.96	13	0.33	6	0.32	4	0.33	-	5.92	36	1.20	128	2.10	37	1.04	28	0.58	-	4.93
11. NOVELETA CAVITE NO. 5		Feb. 21, 91	33	690	108	4.70	16	0.41	12	0.60	3	0.25	-	5.95	18	0.60	205	3.36	39	1.10	28	0.58	-	5.64
12. NOVELETA CAVITE NO. 8		Feb. 21, 91	35	710	118	5.13	13	0.33	4	0.20	3	0.25	-	5.91	18	0.60	178	2.92	40	1.13	29	0.60	-	5.25
13. NURSERY WELL NO. 4		Feb. 22, 91	27	361	15	0.65	5	0.13	47	2.35	10	0.82	-	3.95	0	0.00	142	2.33	32	0.90	9	0.19	-	3.42
14. SQUINSIN WELL NO. 10		Feb. 22, 91	27	566	20	0.87	1	0.03	67	3.35	26	2.14	-	6.39	0	0.00	292	4.79	25	0.71	26	0.54	-	6.03
15. COGEO ANTIPOLO		Feb. 20, 91	30	320	12	0.52	4	0.10	32	1.60	9	0.74	-	2.97	0	0.00	146	2.39	5	0.14	1	0.02	-	2.56
16. SAN JUAN PUMP STN		Feb. 25, 91	29	1143	74	3.22	8	0.21	118	5.90	25	2.06	-	11.38	0	0.00	200	3.28	167	4.71	157	3.27	-	11.26
17. BANGIAD PUMP STN.		Feb. 25, 91	30	420	79	3.43	4	0.10	8	0.40	4	0.33	-	4.27	23	0.77	137	2.25	17	0.48	26	0.54	-	4.03
18. STO. DOMINGO		Feb. 25, 91	30	1481	119	5.17	14	0.36	96	4.80	52	4.28	-	14.61	0	0.00	205	3.36	248	7.00	214	4.46	-	14.82
19. LPS-1 WELL #1		Feb. 27, 91	35	1240	182	7.91	0.3	0.01	12	0.60	1	0.08	-	8.60	23	0.77	58	0.95	221	6.23	77	1.60	-	9.56
20. MNL JAP SCHL.		Feb. 27, 91	32	820	139	6.04	17	0.44	12	0.60	4	0.33	-	7.41	27	0.90	321	5.26	32	0.90	12	0.25	-	7.31
21. AGUINALDO E/S WELL		Feb. 27, 91	34	710	115	5.00	14	0.36	7	0.35	5	0.41	-	6.12	31	1.03	160	2.62	40	1.13	33	0.69	-	5.47
22. QUEZON IBP #2		Feb. 28, 91	29	500	104	4.52	0.6	0.02	6	0.30	4	0.33	-	5.17	32	1.07	162	2.66	30	0.85	2	0.04	-	4.61
23. FAIRVIEW PUMP NO. 3		Feb. 28, 91	28	640	123	5.35	0.4	0.01	7	0.35	4	0.33	-	6.04	59	1.97	140	2.30	40	1.13	1	0.02	-	5.41
24. LAGRO #1		Feb. 28, 91	30	580	117	5.09	0.5	0.01	10	0.50	1	0.08	-	5.68	26	0.87	243	3.98	7	0.20	2	0.04	-	5.09
25. WAWA DAM		Mar. 5, 91	27	340	18	0.78	4	0.10	34	1.70	5	0.41	-	3.00	0	0.00	122	2.00	9	0.25	17	0.35	-	2.61
26. SAN JOSE		Mar. 5, 91	29	350	21	0.91	4	0.10	32	1.60	4	0.33	-	2.94	0	0.00	165	2.70	10	0.28	8	0.17	-	3.15
27. SAN MATEO PUBLIC MKT.		Mar. 5, 91	28	460	35	1.57	3.5	0.09	40	2.00	6	0.49	-	4.15	0	0.00	210	3.44	16	0.45	8	0.17	-	4.06
28. LPS-2 WELL #1		Mar. 6, 91	35	1190	166	7.22	9	0.23	5	0.25	1	0.08	-	7.78	8	0.27	85	1.39	162	4.57	80	1.67	-	7.90
29. COMBALAY, KAWIT		Mar. 6, 91	33	690	116	5.04	13	0.33	2	0.10	1	0.08	-	5.56	8	0.27	198	3.25	37	1.04	29	0.60	-	5.16

TABLE 3.7.2 (CONTINUATION)

NAME	MWSS WELL NO.	DATE OF SAMPLING	T	EC	NA+		K+		Ca++		Mg++		Cations		CO 3 --		HCO 3 --		CL-		SO 4 --		Anions	
			C	MS/cm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm
30. PLAZA GARCIA INUS		Mar. 6, 91	34	690	115	5.00	13	0.33	5	0.25	0.7	0.06	-	5.64	23	0.77	182	2.98	35	0.99	19	0.40	-	5.13
31. GREENMEADOW #3		Mar. 7, 91	30	660	83	3.61	9.5	0.24	18	0.90	4	0.33	-	5.08	0	0.00	146	2.39	90	2.54	4	0.08	-	5.02
32. KAPITOLYO PASIG		Mar. 7, 91	30	560	44	1.91	22	0.56	30	1.50	8	0.66	-	4.64	0	0.00	220	3.61	45	1.27	6	0.13	-	5.00
33. ESCOPA PROJ. 4		Mar. 7, 91	31	450	48	2.09	9	0.23	18	0.90	6	0.49	-	3.71	0	0.00	196	3.21	12	0.34	2	0.04	-	3.59
34. CATMON DEEPWELL		Mar. 11, 91	33	460	92	4.00	3	0.08	2	0.10	0.7	0.06	-	4.23	23	0.77	127	2.08	25	0.71	13	0.27	-	3.82
35. POSOLO ELEM SCHL.		Mar. 11, 91	32	420	87	3.78	5	0.13	2	0.10	0.7	0.06	-	4.07	26	0.87	129	2.11	14	0.39	2	0.04	-	3.42
36. T. DE LEON WELL		Mar. 11, 91	32	450	89	3.87	5	0.13	4	0.20	1	0.08	-	4.28	18	0.60	168	2.75	14	0.39	1	0.02	-	3.77
37. BANABA AMPID		Mar. 12, 91	28	440	48	2.09	7	0.18	40	2.00	5	0.41	-	4.68	0	0.00	155	2.54	30	0.85	21	0.44	-	3.82
38. EVER ELCT. MNFG. INC.		Mar. 12, 91	28	604	76	3.30	12	0.31	24	1.20	4	0.33	-	5.14	0	0.00	192	3.15	77	2.17	16	0.33	-	5.65
39. HANSSON PAPER PHIL.		Mar. 12, 91	31	390	25	1.09	6	0.15	38	1.90	8	0.66	-	3.80	0	0.00	168	2.75	19	0.54	9	0.19	-	3.48
40. LPS-3 WELL #1		Mar. 13, 91	34	780	121	5.26	10	0.26	4	0.20	1	0.08	-	5.80	18	0.60	137	2.25	76	2.14	40	0.83	-	5.82
41. BO. TALABA		Mar. 13, 91	32	1030	137	5.96	33	0.85	18	0.90	2	0.16	-	7.87	0	0.00	223	3.66	123	3.47	20	0.42	-	7.54
42. NAGA WELL #2		Mar. 13, 91	31	2000	183	7.96	35	0.90	73	3.65	21	1.73	-	14.23	0	0.00	246	4.03	274	7.73	46	0.96	-	12.72
43. ATP JICA TEST WELL		Mar. 14, 91	28	490	48	2.09	6	0.15	47	2.35	9	0.74	-	5.33	0	0.00	242	3.97	12	0.34	2	0.04	-	4.35
44. SUCAT E/S		Mar. 18, 91	31	1390	180	7.83	15	0.38	52	2.60	14	1.15	-	11.96	0	0.00	342	5.61	144	4.06	65	1.35	-	11.02
45. ALABANG JUNCTION		Mar. 18, 91	30	750	103	4.48	9	0.23	24	1.20	6	0.49	-	6.40	0	0.00	301	4.93	15	0.42	30	0.63	-	5.98
46. MUNTINLUPA BLISS		Mar. 18, 91	29	740	58	2.52	8	0.21	47	2.35	17	1.40	-	6.48	0	0.00	288	4.72	28	0.79	34	0.71	-	6.22
47. MERVILLE SUBDV.		Mar. 20, 91	33	530	88	3.83	1.6	0.04	4	0.20	1	0.02	-	4.15	0	0.00	118	1.93	47	1.33	32	0.67	-	3.93
48. DAGAT-DAGATAN #1		Mar. 20, 91	30	600	106	4.61	4	0.10	5	0.25	5	0.41	-	5.37	0	0.00	73	1.20	72	2.03	25	0.52	-	3.75
49. TALISAY ST. FORBES PARK		Mar. 19, 91	31	610	40	1.74	16	0.41	25	1.25	33	2.72	-	6.12	0	0.00	241	3.95	17	0.48	16	0.33	-	4.76
50. ECOLOGY VILLAGE		Mar. 19, 91	30	610	50	2.17	17	0.44	24	1.20	27	2.22	-	6.03	0	0.00	273	4.48	16	0.45	10	0.21	-	5.14
51. SIGNAL VILLAGE		Mar. 19, 91	29	700	45	1.96	13	0.33	42	2.10	31	2.55	-	6.94	0	0.00	281	4.61	12	0.34	42	0.88	-	5.82
52. SILVER SWAN MA.		Jul. 2, 91	25	861	160	6.96	10	0.26	14	0.70	4	0.33	-	8.24	0	0.00	155	2.54	173	4.88	16	0.33	-	7.75
53. VARSON PAPER IND.		Jul. 2, 91	25	344	60	2.61	6	0.15	8	0.40	1	0.08	-	3.24	8	0.27	143	2.34	20	0.56	5	0.10	-	3.28
54. QUEZON INSTITUTE		Jul. 3, 91	27	343	68	2.96	3	0.08	4	0.20	3	0.25	-	3.48	13	0.43	88	1.44	26	0.73	28	0.58	-	3.19
55. WORLD PAPER MILLS		Jul. 3, 91	27	355	50	2.17	10	0.26	14	0.70	6	0.49	-	3.62	23	0.77	113	1.85	20	0.56	3	0.06	-	3.25
56. FAROLA ICE COLD		Jul. 5, 91	25	1174	180	7.83	14	0.36	29	1.45	3	0.25	-	9.88	13	0.43	46	0.75	221	6.23	97	2.02	-	9.44
57. PROCTER & GAMBLE		Jul. 5, 91	25	736	130	5.65	8	0.21	11	0.55	3	0.25	-	6.65	23	0.77	63	1.03	138	3.89	20	0.42	-	6.11
58. STA. TERESITA COLLEGE		Jul. 8, 91	24	536	38	1.65	16	0.41	34	1.70	22	1.81	-	5.57	0	0.00	228	3.74	39	1.10	19	0.40	-	5.23
59. INNOTECH		Jul. 8, 91	24	404	16	0.70	10	0.26	40	2.00	16	1.32	-	4.27	0	0.00	200	3.28	31	0.87	3	0.06	-	4.22

TABLE 3.7.2 (CONTINUATION)

NAME	MWSS WELL NO.	DATE OF SAMPLING	T	EC	NA+		K+		Ca++		Mg++		Cations		CO 3 --		HCO 3 --		CL-		SO 4 --		Anions	
			C	MS/cm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm
60. SUMULONG TAYTAY		Jul. 8, 91	24	972	155	6.74	1	0.03	39	1.95	5	0.41	-	9.13	0	0.00	96	1.57	140	3.95	149	3.10	-	8.63
61. CARDINAL SANTOS		Jul. 10, 91	24	397	48	2.09	1	0.03	20	1.00	10	0.82	-	3.94	0	0.00	205	3.36	20	0.56	7	0.15	-	4.07
62. IBP NO. 3		Jul. 10, 91	24	202	12	0.52	3	0.08	20	1.00	8	0.65	-	2.26	0	0.00	100	1.64	20	0.56	6	0.13	-	2.33
63. LATEX CITY		Jul. 12, 91	25	16930	1150	50.00	45	1.15	1640	82.00	283	23.29	-	156.45	0	0.00	305	5.00	5672	160.00	456	9.50	-	174.50
64. GOODYEAR STEEL		Jul. 15, 91	25	362	48	2.09	5	0.13	18	0.90	6	0.49	-	3.61	0	0.00	142	2.33	18	0.51	20	0.42	-	3.25
65. RUBBER WORLD		Jul. 15, 91	25	485	54	2.35	6	0.15	26	1.30	14	1.15	-	4.95	13	0.43	201	3.30	24	0.68	11	0.23	-	4.63
66. IBP (JULY 13,91)		Jul. 17, 91	25	182	12	0.52	3	0.08	16	0.80	8	0.66	-	2.06	0	0.00	87	1.43	18	0.51	0	0.00	-	1.93
67. MANILA HOTEL		Jul. 17, 91	25	560	115	5.00	4	0.10	5	0.25	2	0.16	-	5.52	0	0.00	73	1.20	63	1.78	128	2.67	-	5.64
68. BF HOMES # 22		Jul. 19, 91	25	630	93	4.04	17	0.44	9	0.45	8	0.66	-	5.59	0	0.00	255	4.18	55	1.55	23	0.48	-	6.21
69. BF HOMES # 1		Jul. 19, 91	25	576	89	3.87	17	0.44	16	0.80	10	0.82	-	5.93	0	0.00	228	3.74	40	1.13	25	0.52	-	5.39
70. BF HOMES # 9		Jul. 23, 91	25	605	100	4.35	17	0.44	20	1.00	8	0.66	-	6.44	0	0.00	220	3.61	42	1.18	5	0.10	-	4.90
71. BF HOMES # 4		Jul. 23, 91	25	600	100	4.35	15	0.38	10	0.50	2	0.16	-	5.40	0	0.00	215	3.52	53	1.50	6	0.13	-	5.14
72. BF HOMES # 7		Jul. 24, 91	25	575	99	4.30	14	0.36	11	0.55	1	0.08	-	5.30	0	0.00	155	2.54	63	1.78	43	0.90	-	5.21
73. IBP Q.C.		Jul. 18, 91	25	237	19	0.83	2	0.05	26	1.30	4	0.33	-	2.51	0	0.00	132	2.16	15	0.42	3	0.06	-	2.65
74. LA PERLA		Jul. 26, 91	25	2060	315	13.70	30	0.77	32	1.60	17	1.40	-	17.46	0	0.00	237	3.89	418	11.79	58	1.21	-	16.88
75. HYATT REGENCY		Jul. 26, 91	25	1733	200	8.70	40	1.03	53	2.65	20	1.65	-	14.02	0	0.00	268	4.39	201	5.67	91	1.90	-	11.96
76. J.C. AQUA MARINE		Jul. 29, 91	23	1819	260	11.30	20	0.51	15	0.75	11	0.91	-	13.47	40	1.33	92	1.51	343	9.68	48	1.00	-	13.52
77. OLIVAREZ HOSPITAL		Jul. 29, 91	23	1568	210	9.13	21	0.54	47	2.35	37	3.05	-	15.06	31	1.03	365	5.98	135	3.81	184	3.83	-	14.66
78. MALAYAN TEXTILE		Jul. 31, 91	25	635	47	2.04	20	0.51	40	2.00	20	1.65	-	6.20	0	0.00	304	4.98	11	0.31	1	0.02	-	5.31
79. IRENEVILL SUBD.		Jul. 31, 91	25	605	85	3.70	20	0.51	21	1.05	10	0.82	-	6.08	0	0.00	281	4.61	18	0.51	3	0.06	-	5.18
80. COGEO # 6(STEP)		Aug. 6, 91	25	433	10	0.43	3	0.08	41	2.05	25	2.06	-	4.62	0	0.00	155	2.54	33	0.93	4	0.08	-	3.56
81. COGEO II		Aug. 6, 91	25	478	11	0.48	3	0.08	48	2.40	27	2.22	-	5.16	0	0.00	244	4.00	22	0.62	2	0.04	-	4.66
82. COGEO#6(CPT)		Aug. 6, 91	25	448	7	0.30	1	0.03	51	2.55	24	1.98	-	4.86	0	0.00	238	3.90	20	0.56	3	0.06	-	4.53
83. LA HUERTA		Aug. 7, 91	25	848	50	2.17	13	0.33	73	3.65	27	2.22	-	8.38	0	0.00	366	6.00	42	1.18	1	0.02	-	7.21
84. MARICABAN PUMP		Aug. 7, 91	26	960	154	6.70	30	0.77	12	0.60	7	0.58	-	8.64	0	0.00	317	5.20	112	3.16	1	0.01	-	8.37
85. LIBERTY FLOUR MILLS		Aug. 9, 91	26	592	70	3.04	25	0.64	8	0.40	8	0.66	-	4.74	0	0.00	181	2.97	66	1.86	1	0.01	-	4.84
86. INTERNATIONAL OIL		Aug. 9, 91	26	951	90	3.91	13	0.33	47	2.35	33	2.72	-	9.31	0	0.00	268	4.39	147	4.15	1	0.01	-	8.55
87. NATIONAL STEEL		Aug. 12, 91	26	1915	300	13.04	40	1.03	36	1.80	22	1.81	-	17.68	0	0.00	107	1.75	457	12.89	120	2.50	-	17.15
88. MAKATI MED. CENTER		Aug. 12, 91	26	880	100	4.35	30	0.77	28	1.40	11	0.91	-	7.42	0	0.00	244	4.00	88	2.48	45	0.94	-	7.42
89. OSCAR RODRIGUEZ		Aug. 14, 91	26	406	12	0.52	6	0.15	41	2.05	19	1.58	-	4.29	0	0.00	221	3.62	18	0.51	3	0.06	-	4.19

TABLE 3.7.2 (CONTINUATION)

NAME	KWSS WELL NO.	DATE OF SAMPLING	T	EC	NA+		K+		Ca++		Mg++		Cations		CO 3 --		HCO 3 --		CL-		SO 4 --		Anions	
			C	MS/cm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm	ppm	epm
90. RAKITEX		Aug. 14, 91	26	370	40	1.74	5	0.13	24	1.20	7	0.58	-	3.64	0	0.00	184	3.02	18	0.51	6	0.13	-	3.65

TABLE 3.7.3 CHEMICAL COMPOSITION OF SEAWATER

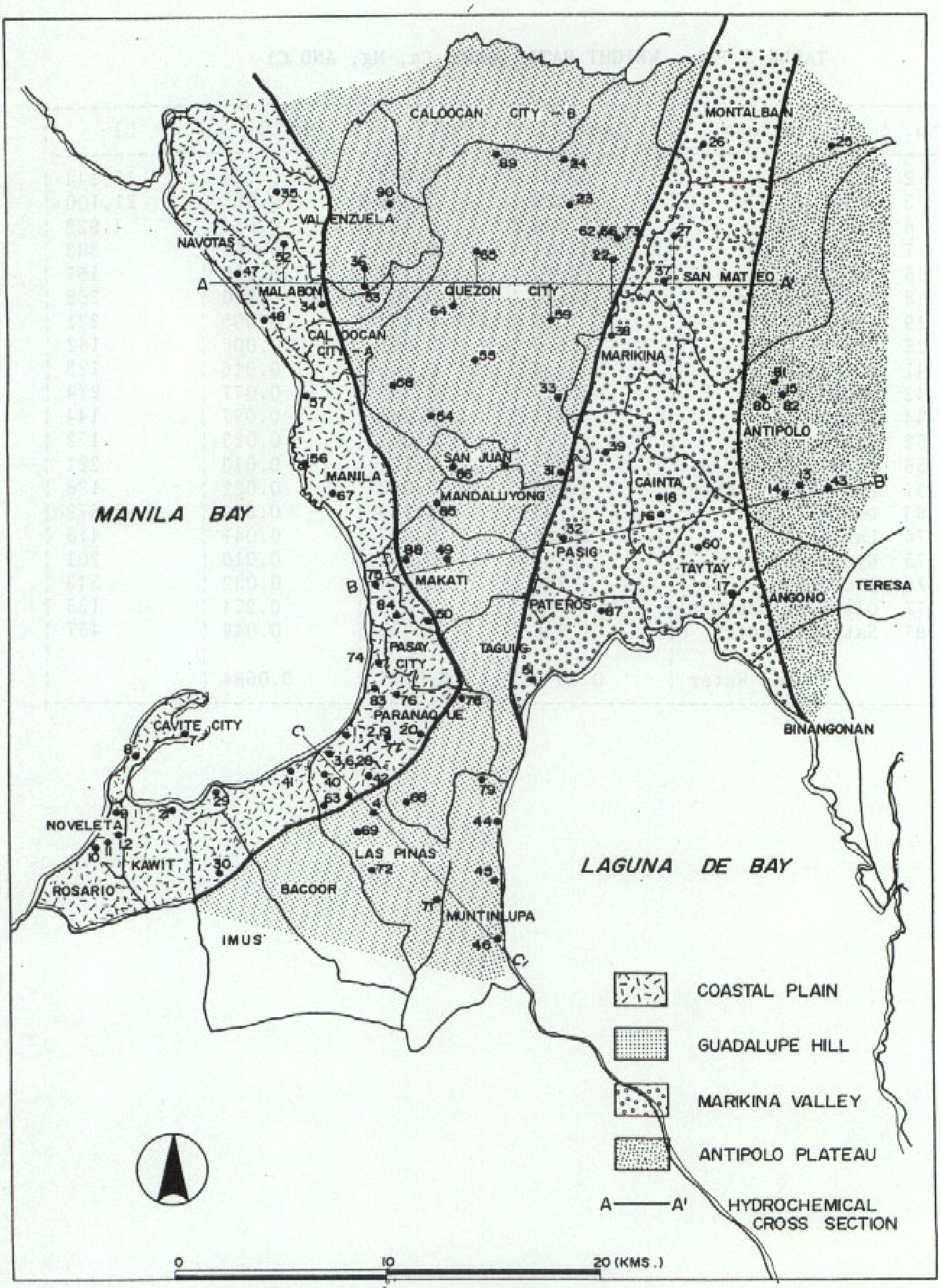
Ion	g/kg	%	Ion	g/kg	%
Cl^-	18.980	55.04	Mg^{2+}	1.272	3.69
Bi-	0.065	0.19	Ca^{2+}	0.400	1.16
SO_4^{2-}	2.469	7.68	Sr^{2+}	0.007	0.02
HCO_3^-	0.140	0.41	K^+	0.380	1.10
F^-	0.001	0.00	Na^+	10.556	30.61
H_3BO_3	0.026	0.07	Total	34.476	99.97

TABLE 3.7.4 DEFINITE WEIGHT AND EQUIVALENT WEIGHT RATIO OF MAJOR CONSTITUENTS VERSUS CHLORIDE OF SEAWATER

	Weight Ratio	Equivalent Weight Ratio
Na:Cl	0.5526	0.85
K:Cl	0.0200	0.18
Mg:Cl	0.0684	0.20
Ca:Cl	0.0211	0.038
Sr:Cl	0.00042	0.036
SO4:Cl	0.1396	0.10
HCO3:Cl	0.00738	0.0043
H3BO3:Cl	0.00137(atomic ratio)	0.00083
Si:Cl	0.0002 (atomic ratio)	0.0002

TABLE 3.7.5 WEIGHT RATIO AMONG Ca, Mg, AND Cl

No.	Locations	Ca/Mg	Ca/Cl	Mg/Cl	Cl
2	LPS-1 No.3	0.507	0.068	0.134	17,144
3	LPS-2 No.3	1.029	0.069	0.067	21,100
6	LPS-2 No.2	3.549	0.193	0.054	4,923
7	Samonte Park	5.714	0.104	0.018	383
16	San Juan Pump	4.72	0.707	0.150	167
18	Sto. Domingo	1.846	0.387	0.210	268
19	LPS-1 No.1	12.0	0.054	0.005	221
28	LPS-2 No.2	5.0	0.031	0.006	162
41	Bo. Talba	9.0	0.146	0.016	123
42	Naga Well No. 2	3.476	0.266	0.077	274
44	Sucat E/S	3.714	0.361	0.097	144
52	Silver Swan	3.5	0.081	0.023	173
56	Farola Ice Cold	9.667	0.131	0.013	221
57	Procter & Gamble	3.667	0.080	0.022	138
63	Latex City	5.795	0.289	0.050	5,672
74	La Perla	1.882	0.077	0.041	418
75	Hyatt Regency	2.65	0.264	0.010	201
76	J.C. Aqua	1.364	0.044	0.032	343
77	Olivares Hospital	1.27	0.348	0.274	135
87	National Steel	1.636	0.079	0.048	457
	Sea Water	0.0379	0.0211	0.0684	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.7.1 LOCATION OF WATER SAMPLING POINTS
JAPAN INTERNATIONAL COOPERATION AGENCY	

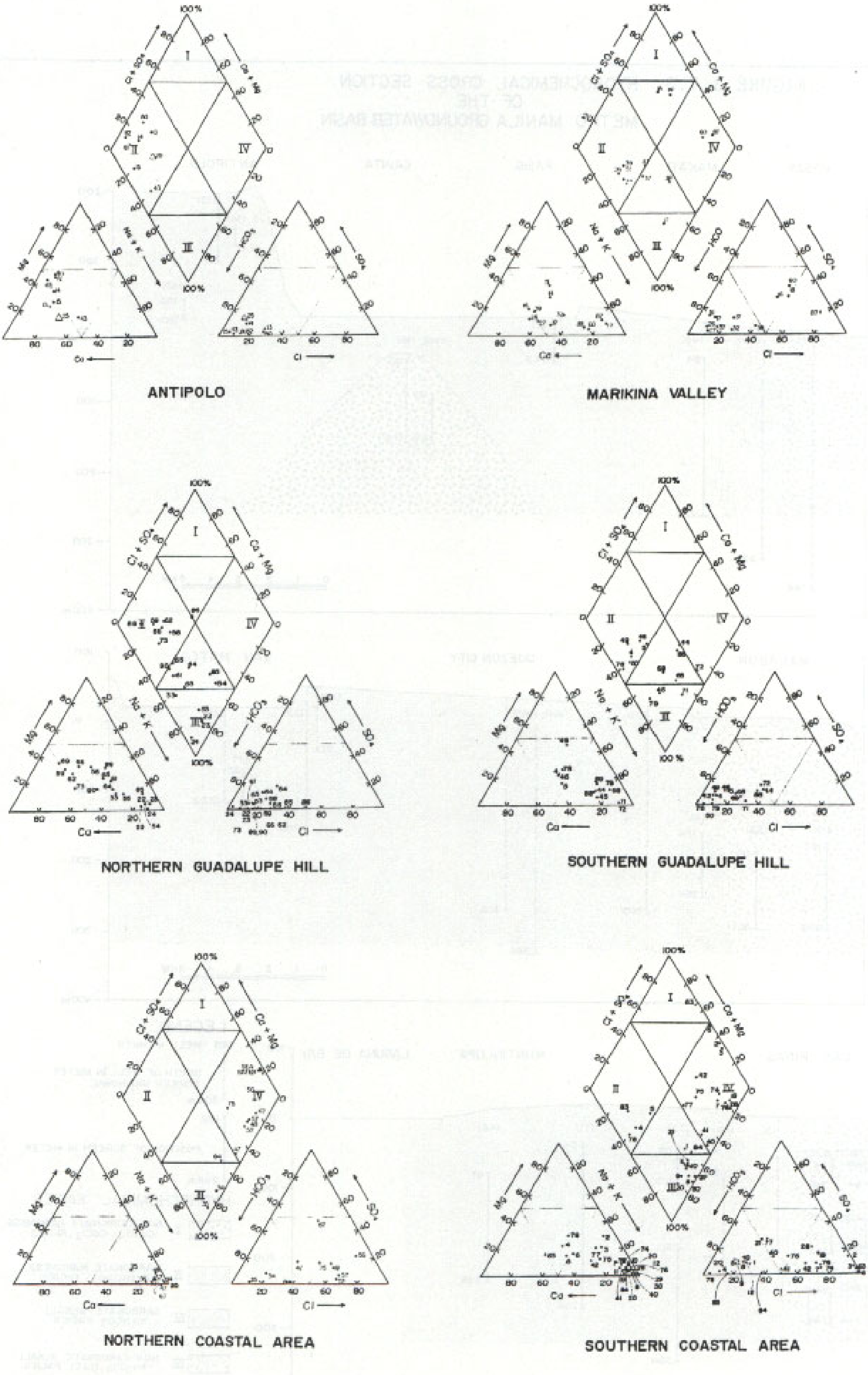
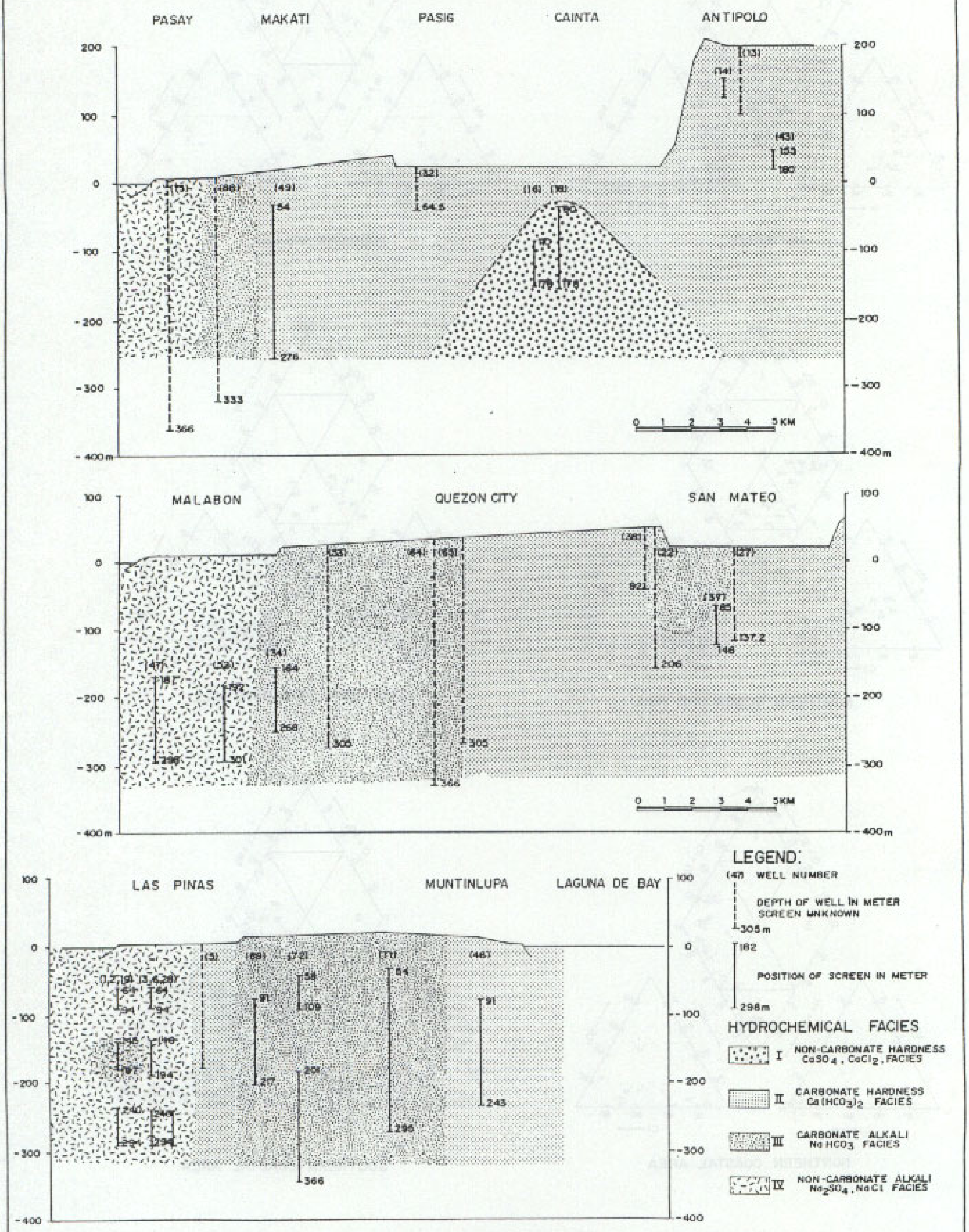
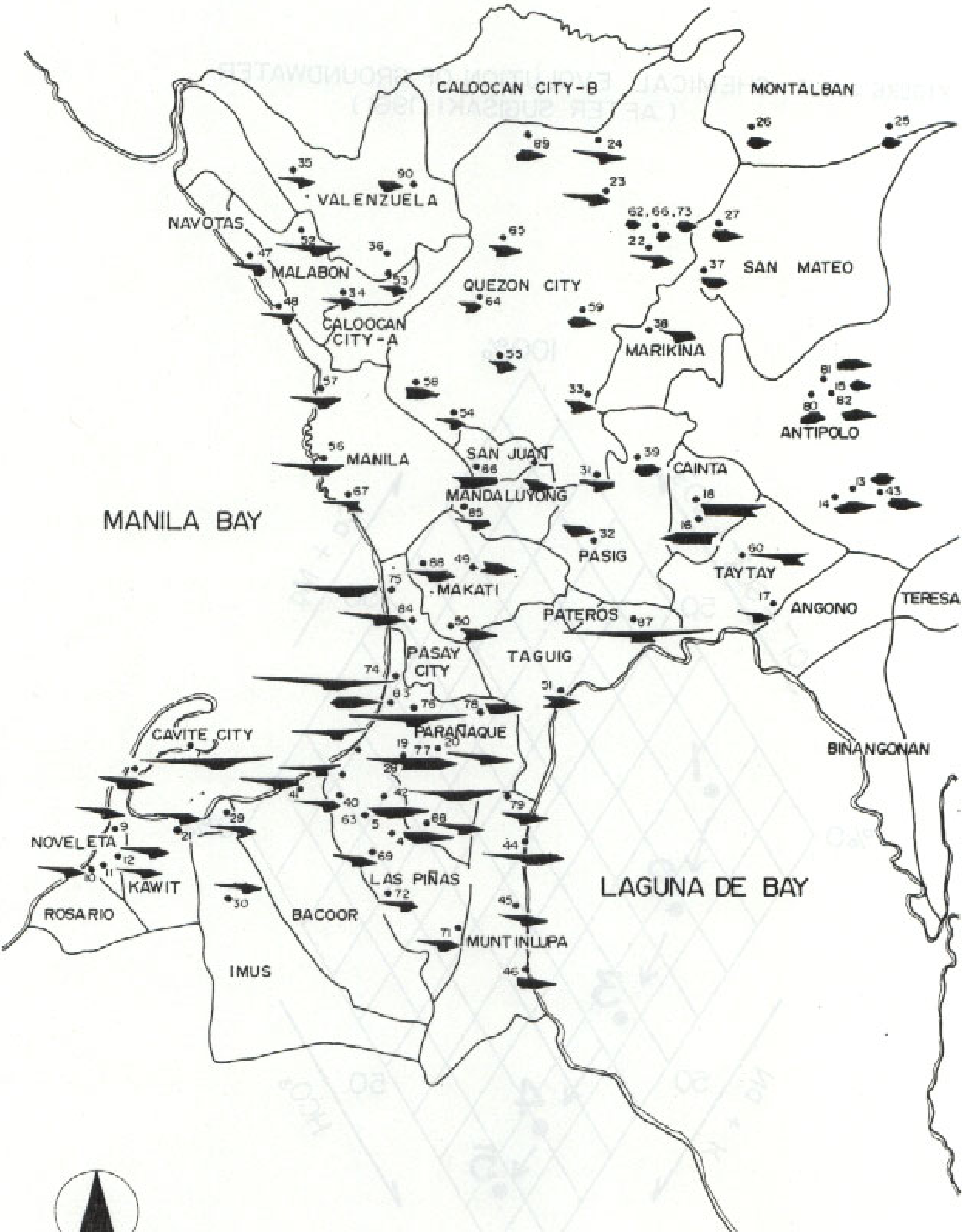


FIGURE 3.7.2 TRILINEAR DIAGRAM REPRESENTATION OF GROUNDWATER SAMPLES IN METRO MANILA

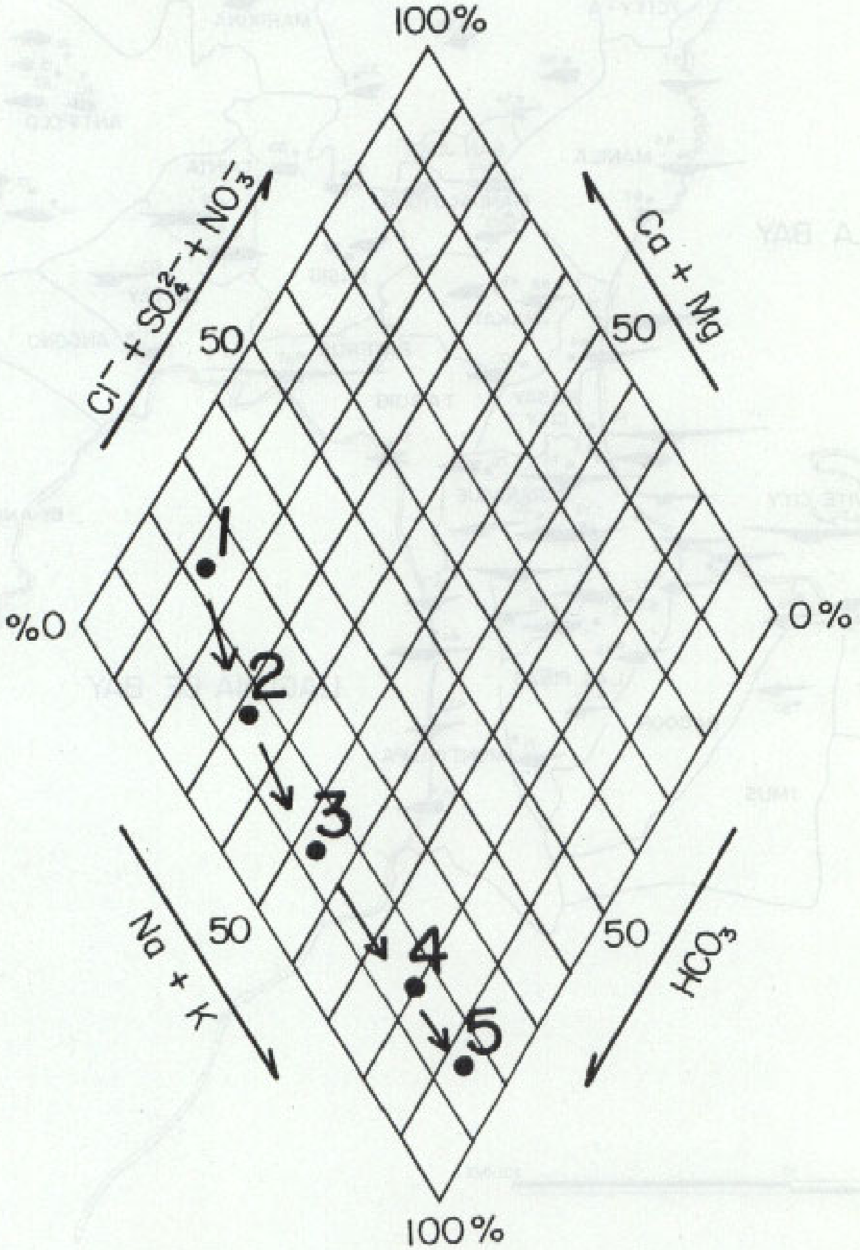
FIGURE 3.7.3 HYDROCHEMICAL CROSS SECTION OF THE METRO MANILA GROUNDWATER BASIN





STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.7.4
JAPAN INTERNATIONAL COOPERATION AGENCY	PATTERN DIAGRAM

FIGURE 3.7.5 CHEMICAL EVOLUTION OF GROUNDWATER
(AFTER SUGISAKI :1961)



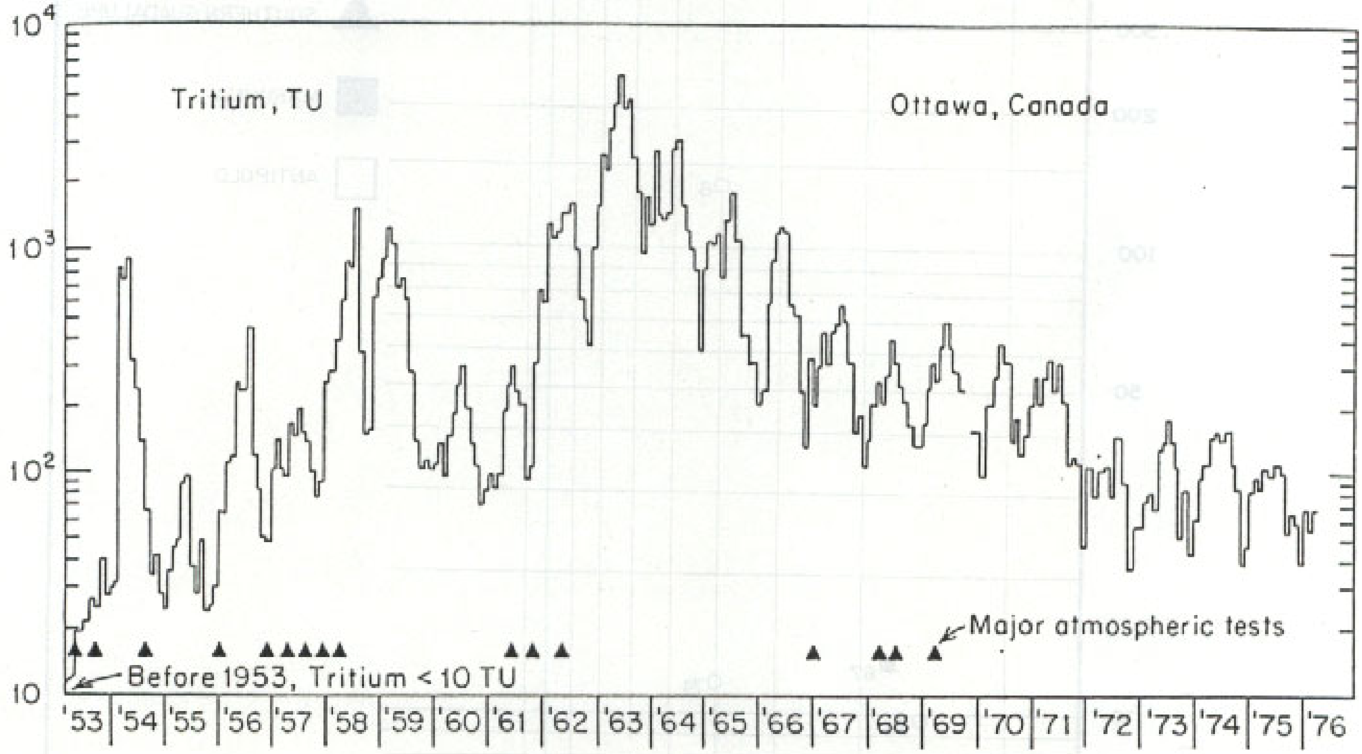
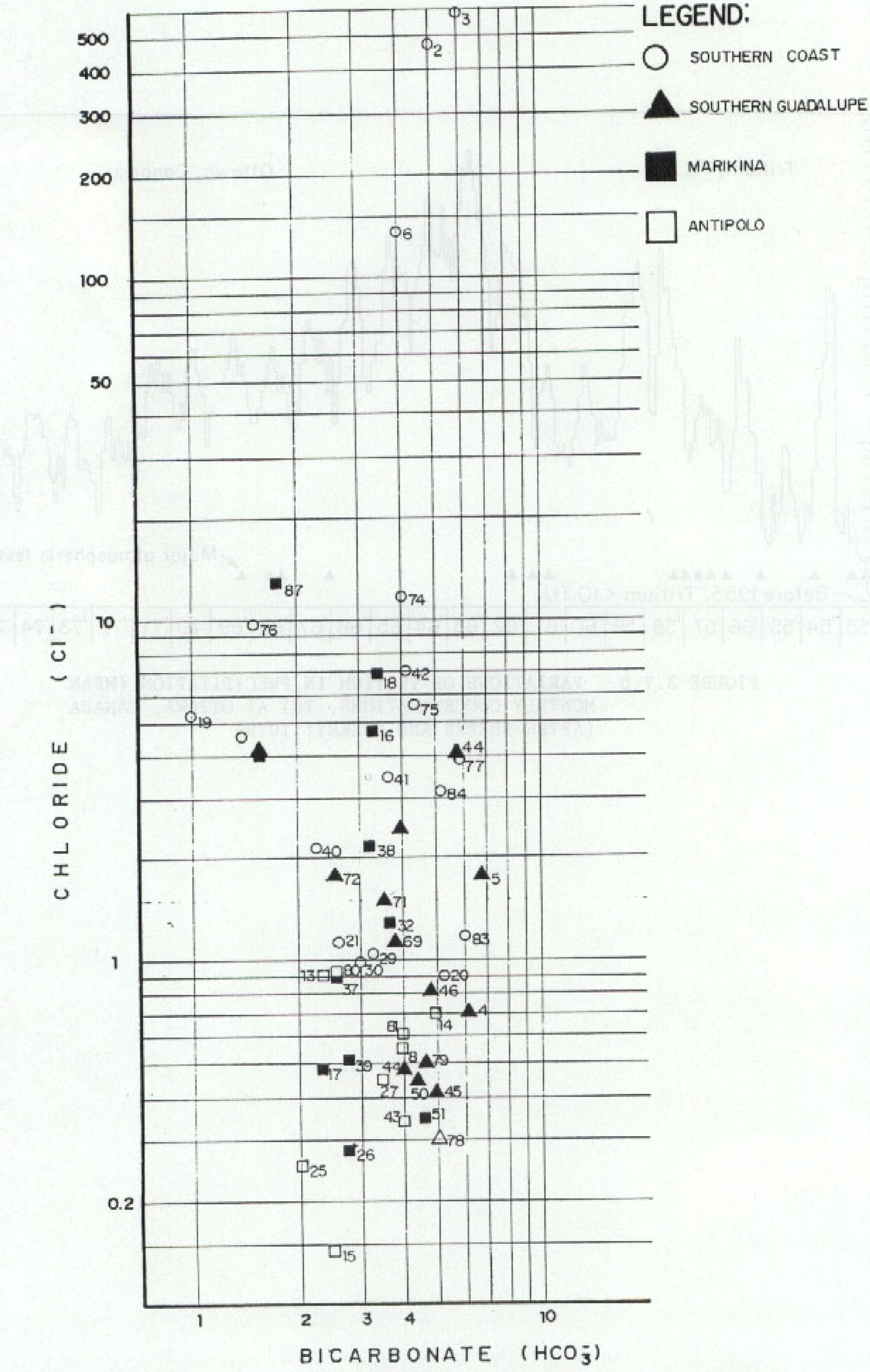


FIGURE 3.7.6 VARIATIONS OF TRITIUM IN PRECIPITATION (MEAN MONTHLY CONCENTRATIONS, TU) AT OTTAWA, CANADA (AFTER FREEZE AND CHERRY: 1979)

FIGURE 3.7.7

RELATIONSHIP BETWEEN Cl^- AND HCO_3^-



3.8 SALINE WATER INTRUSION

3.8.1 Saline Water Intrusion in Metro Manila

Saline water intrusion in the coastal areas of Metro Manila has already been observed in the late 1960s. In 1968, Hernando Quiason reported that (at that time) the groundwater level had dropped to 40 meters below sea level in the Malabon-Navotas-Caloocan area and that, from near-surface to about 100m, saline groundwater was found in the near-shore groundwater zones from Las Piñas to Malabon and in the vicinity of areas away from shore with salty surface water.

In the early 1980s, Electrowatt studied the hydrogeology of Metro Manila as part of the MWSP-II project. This study found out in 1981 that the groundwater level in the Guadalupe aquifer system in Metro Manila had continuously declined since 1955. The rate of decline had reached 5 to 12 m/year, with deep cones of depression appearing in areas with heavy withdrawals of groundwater. This lowering of water level resulted in the saline water intrusion of the Guadalupe aquifer system and has largely affected the quality of groundwater. Figure 3.8.1 shows the distribution of conductivity values of groundwater in Metro Manila. High conductivity zones were observed in the coastal areas along Manila Bay.

Distribution of electric conductivity (EC) values measured in year 1991 is illustrated in Figure 3.8.2. Relation between chloride content and EC is presented in Figure 3.8.3. Pattern of distribution in year 1991 is basically the same as that in year 1981. As samples were taken from operational deep wells with an average depth of about 300m, the number of zones with high conductivity (more than 1,000 microsiemens (µS)/cm) is limited in the area. These zones cannot be seen particularly in Manila, Malabon and Navotas, where measured EC values range from 400 to 800 µS/cm. Groundwater tapped by 300-m deep wells is still unaffected by saline water intrusion even if they are located near the shore.

3.8.2 Saline Water Intrusion Mechanism

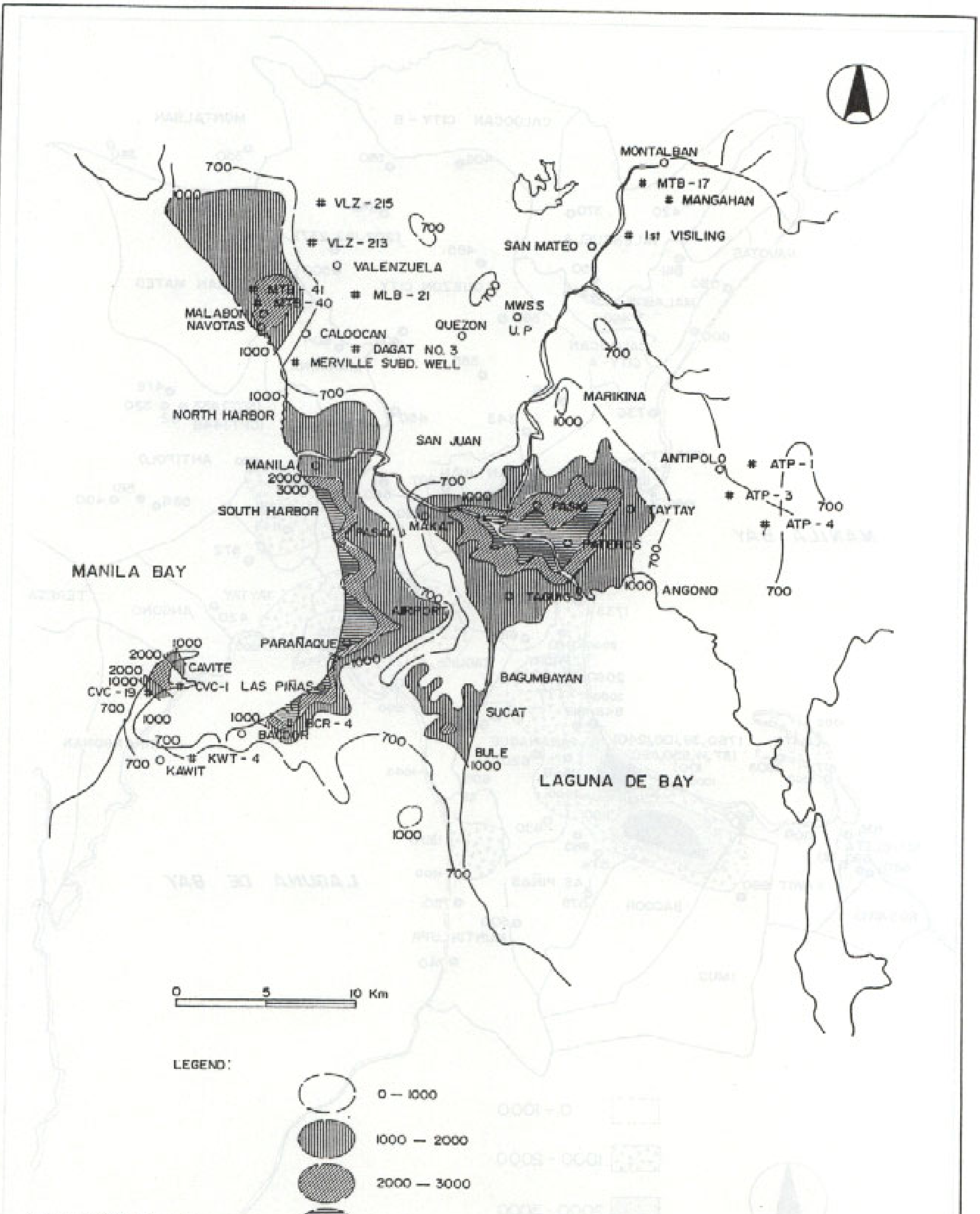
In 1988, MWSS discovered a chloride concentration of 2,884 mg/l at Latex well located 2.0 km from the coast in Pamplona, Las Piñas. In addition, high chloride concentrations of more than 600 mg/l were observed in an area of about 6km2 in Las Piñas. Results of recent measurements show virtually the same salinity distribution as shown in Figure 3.2.20.

Electric conductivity and chloride concentration of groundwater in the Las Piñas test wells differ from aquifer to aquifer (Figure 3.8.4). In the 100-m wells at sites No.1 and No.2, high chloride concentrations of 17,144 mg/l and 21,100 mg/l were found. In the 200-m well at Las Piñas No.2, chloride concentration is 4,923 mg/l. However, groundwater is not salinized in the deep aquifer as observed in the 200-m and 300-m wells at Las Piñas No.1, and in the 300-m wells in No.2 and No.3. Chloride concentration in these wells is less than 200 mg/l.

Considering the different concentration in each aquifer, it is apparent that saline water migrates downward from the first aquifer to the second aquifer by leakage. The first aquifer may be salinized mainly by sea-water encroachment from Manila Bay. Another cause of contamination may be the existence of the marine pond spreading 1.5 to 2.0 km inland from the coast and the tidal inundation of the Zapote river. EC and chloride distributions in other coastal areas, such as those in Manila, Malabon and Navotas give the same observations.

In Marikina Valley, saline water was found in the deeper Guadalupe aquifers, i.e., at the MGB PS-4 well that was drilled in the 1960s. The recorded well depth is 457.2m. Since groundwater was highly salinized, the well was sealed below 243.8m. Water afterwards was taken from shallower aquifers between 100m and 200m. Chloride concentration of the water then became 574 mg/l, which is about 1/10 of that from deep aquifers (Figure 3.8.5). This finding indicates the possible existence of fossil water in the Guadalupe aquifers.

As discussed earlier, some of the water samples from the Marikina Valley were plotted on domain I of the trilinear diagram, unlike most of the samples from Guadalupe Hill and the coastal area. In this case, upconing or upward leakage may be happening in shallow aquifers (100-200m).



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

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FIGURE 3.8.1
ELECTRIC CONDUCTIVITY OF GROUNDWATER IN METRO MANILA

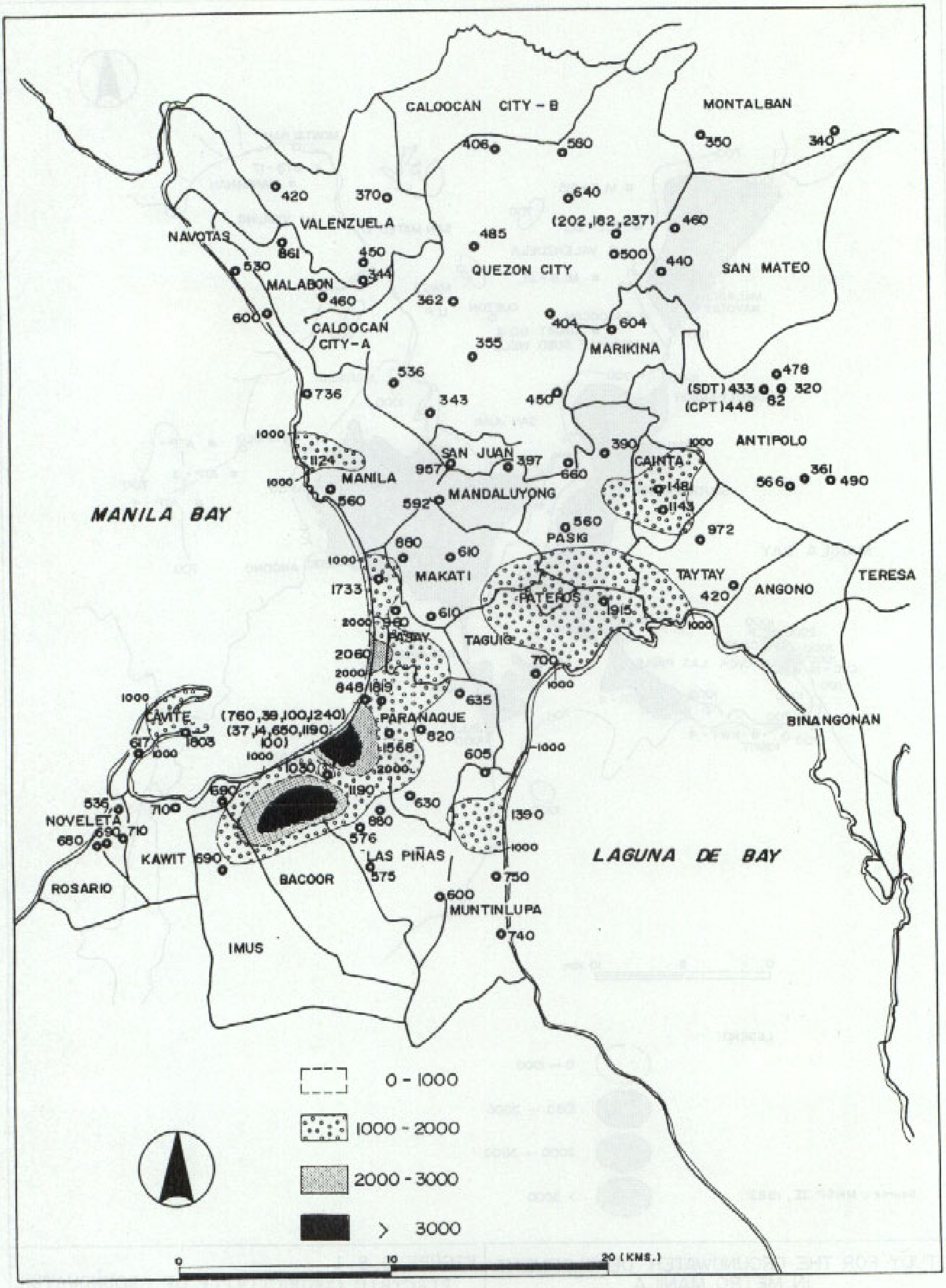

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FIGURE 3.8.2

DISTRIBUTION OF ELECTRIC CONDUCTIVITY

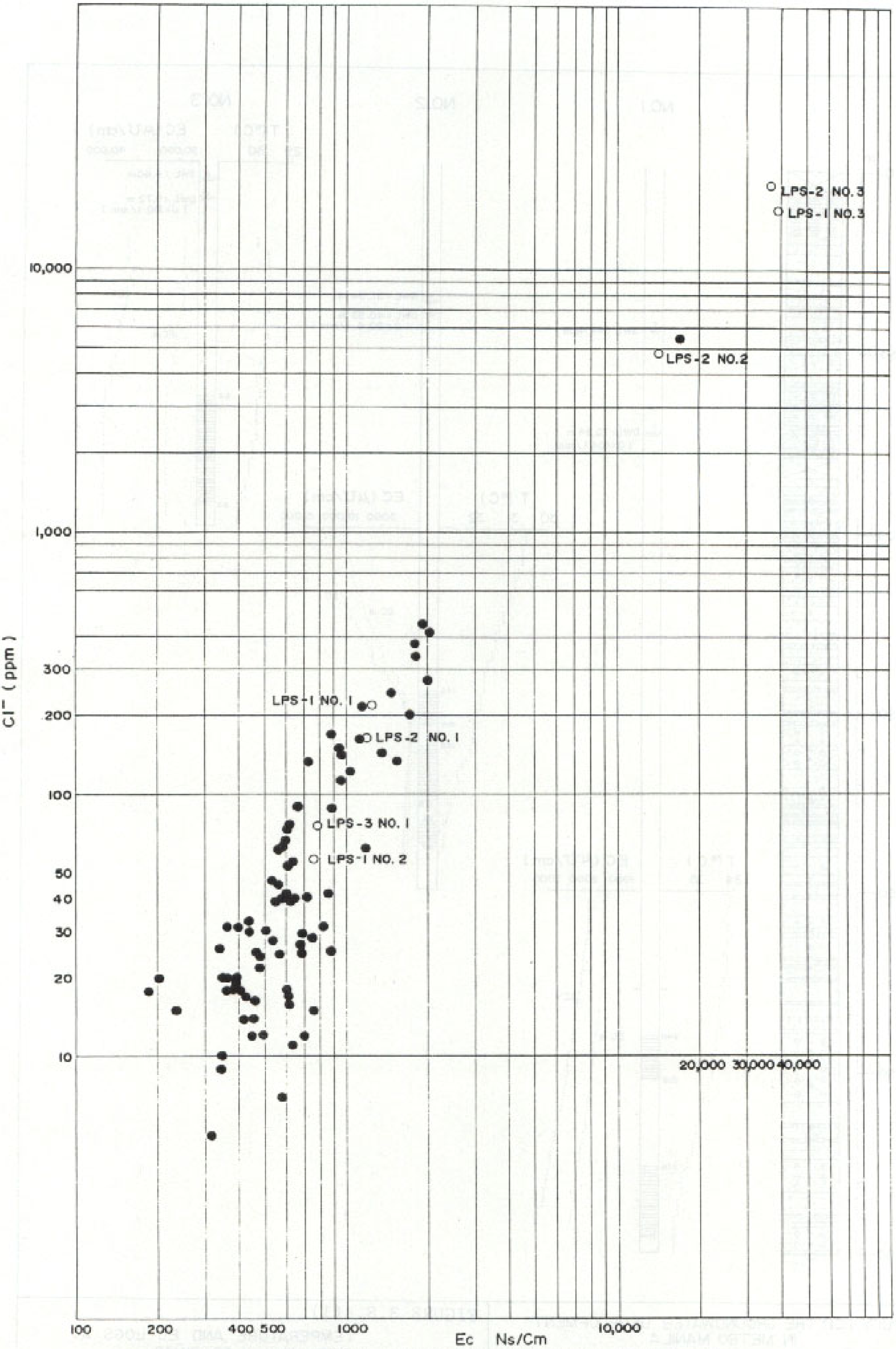

FIGURE 3.8.3 RELATION BETWEEN CHLORIDE CONTENT AND ELECTRIC CONDUCTIVITY

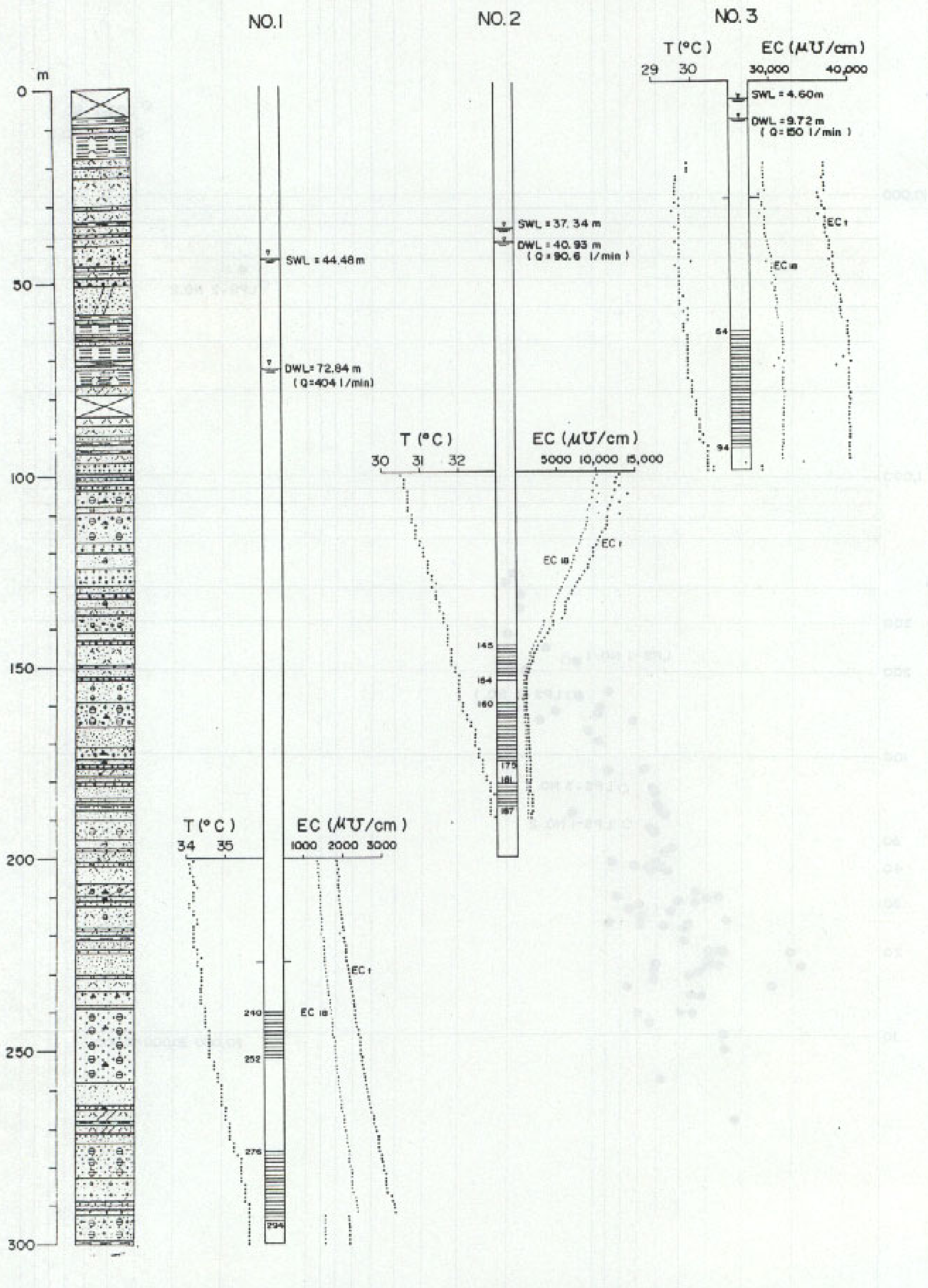

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FIGURE 3.8.4(1)

TEMPERATURE AND EC LOGS AT SITE NO. 1, LAS PIÑAS

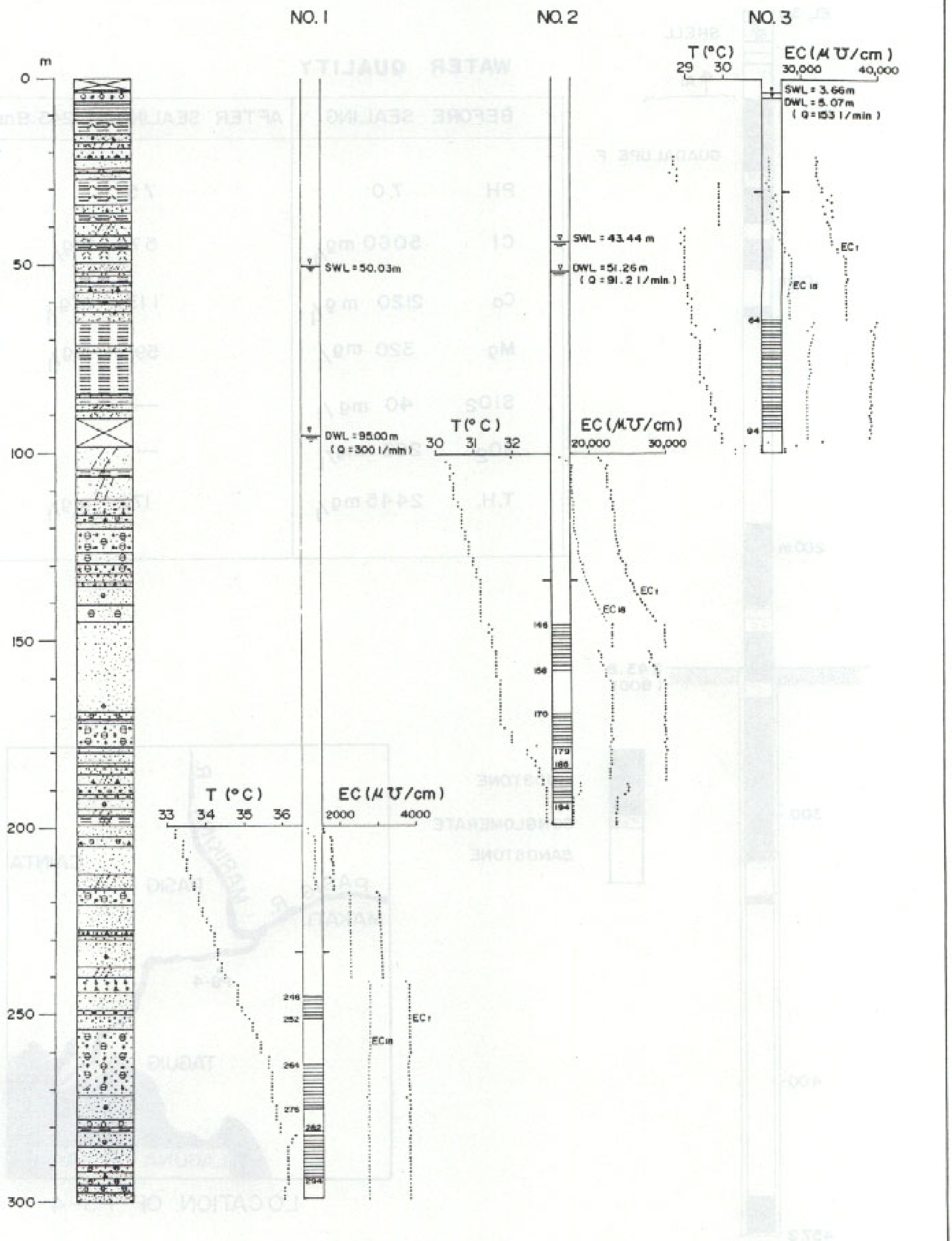

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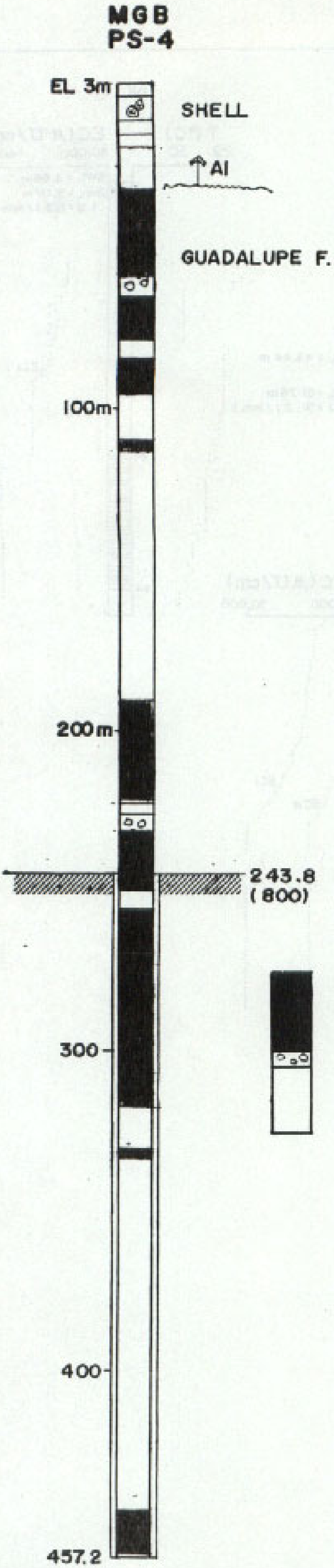
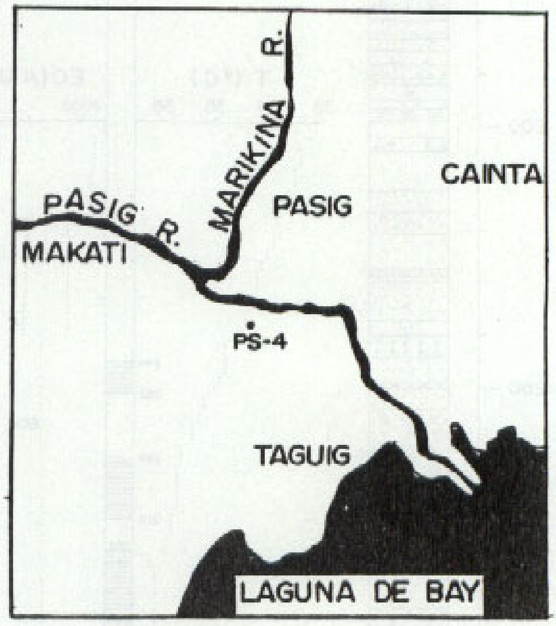
FIGURE 3.8.4(2)

TEMPERATURE AND EC LOGS AT SITE NO. 2, LAS PIÑAS



WATER QUALITY

	BEFORE SEALING	AFTER SEALING AT 243.8m
PH	7.0	7.5
Cl	5060 mg/l	574 mg/l
Ca	2120 mg/l	113 mg/l
Mg	320 mg/l	59 mg/l
SiO_2	40 mg/l	—
SO_2	269 mg/l	—
T.H.	2445 mg/l	172 mg/l



LOCATION OF PS-4

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.8.5 **LITHOLOGY AND WATER QUALITY OF MGB PS-4 WELL**
JAPAN INTERNATIONAL COOPERATION AGENCY	

3.9 POSSIBILITY OF LAND SUBSIDENCE

The rapid and heavy decline of groundwater level in the coastal area throughout the 1960s and 1970s brought forth the belief that land subsidence may have occurred in some areas in Metro Manila.

Land subsidence in general is principally caused by the withdrawal of groundwater, particularly in the alluvial plain. As the coastal areas of Manila Bay and Laguna de Bay and the areas along Marikina River are covered by soft, clayey deposits of Alluvium age, the lowering of the groundwater head of underlying aquifers could cause the consolidation of these clayey deposits. Metro Manila in this sense has the requisite condition for land subsidence.

3.9.1 Field Observation

Indications of land subsidence are generally found at well sites, on roads, dikes, buildings, bridges, etc. Such indications can also be observed on typical foundations such as piles of buildings and bridges. In the latter case, the displacement between ground surface and building can be easily identified. Inclination and cracks on walls of buildings due to unequal at-place subsidence rates can often be observed.

A field observation in the downstream area of the Pasig River and the coastal areas of Manila and Navotas was conducted. Several tall buildings and bridges located along the Pasig River (from Nagtahan Bridge near Malacañang Palace to Del Pan Bridge) were investigated. No clear physical evidence of land subsidence was found by the Study Team. However, this does not mean that land subsidence is not happening in Metro Manila area. What the outcome of the investigation provided was at least a negative evidence of land subsidence. The area's frequent flooding in the rainy season is due to its topographically low elevation and not due to land subsidence.

3.9.2 Soil Properties of Alluvial Clay

According to a previous soil and foundation study carried out by DPWH (1977), the ranges of consolidation characteristics of alluvial clay in the coastal areas of Pasay and Manila are shown in Table 3.9.1. The data indicate that the alluvial clay is in normally consolidated condition. The range of consolidation parameters is basically the same as that of alluvial clays found in the world's coastal plains.

The clay layer can be easily consolidated by overburden or by the decline of pore water pressure. The final settlement is determined by the stress and the thickness of the consolidated layer.

As mentioned earlier, the alluvial clay is generally thin and limited to the coastal areas of Metro Manila. Also, groundwater is mainly pumped from deep Guadalupe aquifers. For these reasons, the probability of land subsidence taking place is nil, even though the area has the soil properties required for land subsidence.

3.9.3 Rise of Mean Sea Level

The mean sea level (MSL) in Manila has markedly risen since the mid-Sixties (Figure 3.9.2). Though not as marked the same rise and fluctuation of the MSL can be observed in Legaspi, Cebu and Davao.

Note that from 1965 to 1989 the MSL in Manila appears to have risen by 0.478m. Assuming the MSL does not change, it can be inferred that land subsidence is occurring in the vicinity of the tidal staff gage.

3.9.4 Elevations of Benchmarks

Though elevation of the reference benchmark differs, NAMRIA's benchmarks were simply compared in order to know the vertical tendency of the displacement of land.

Differences in elevation of benchmarks between years 1966 and 1987 appear to indicate land subsidence. However, several benchmarks are located on a hill composed of consolidated Guadalupe formation (Figure 3.9.3 and Table 3.9.3).

Assuming that one of the benchmarks on the hill is the reference benchmark of the levelings in 1987 and those before 1966, the differences in elevation of other benchmarks become almost negligible errors.

Obtaining clear evidence of land subsidence therefore requires the establishment of immovable points (control points) in the regional leveling in Metro Manila. The control points should be placed in a nearby mountainous area composed of hard rocks to properly evaluate the difference in elevation between two different levelings.

TABLE 3.9.1 RANGES OF CONSOLIDATION CHARACTERISTICS

Area	Py (kg/cm^2)	Cv (cm2/min) Primary consolidation	Cv (cm2/min) 24-hr consolidation	mv.P	Cc
BB-1	h-0.5	0.18 to 0.42	0.1 to 0.2	1.27×10^{-1}	0.58
BB-3	h+0.2	less than 0.43	0.1 to 0.45	8.15×10^{-2}	0.38
BRA-1	h+0.2				0.37
BRA-2	h+0.48				0.28 to 0.58
BRA-3	h+0.06 to 0.27				
BL-1	h-0.73 to -0.35	0.13 to 0.33	3.8×10^{-2} to 1.8×10^{-1}	9×10^{-2} to 2.3×10^{-1}	0.41 to 1.86
BL-2	h-0.07 to +0.25	1.3×10^{-2} to 4.4×10^{-2}	1.1×10 to 2.4×10^{-1}	1.4×10	1.21 to 1.71
BL-4	h-0.68 to +0.33	1.9×10^{-1} to 1.7	4.2×10^{-3} to 6.4×10^{-1}	8.5×10^{-2} to 2.2×10^{-1}	0.66 to 2.36

DATA SOURCE: DPWH, 1977

TABLE 3.9.2 ANNUAL MEAN SEA LEVELS AND VARIATIONS

Page 1 DATA SOURCE: NAMRIA

Year	MANILA OTS (1901) Mean m.	MANILA Divergence m.	LEGASPI OTS (1947) Mean m.	LEGASPI Divergence m.	CEBU OTS (1935) Mean m.	CEBU Divergence m.	DAVAO OTS (1947) Mean m.	DAVAO Divergence m.	JOLO OTS (1947) Mean m.	JOLO Divergence m.	SAN FERNANDO OTS (1947) Mean m.	SAN FERNANDO Divergence m.
1947	2 [2.236]		4 [1.595]		5 [1.806]				10 [1.999]			
1948	2.188	2.188	[1.543]	-0.052	1.728	-0.078	2 [1.833]		1.968	-0.031	1.383	
1949	2.181	-0.007	1.542	-0.001	1.720	-0.008	1.832	-0.001	6 [1.948]	-0.020	1.352	0.031
1950	2.25	0.069	1.545	0.003	1.804	0.082	1.938	0.106	1 [2.079]	0.131		
1951	2.205	-0.045	1.558	0.013	1.733	-0.071	5 [1.820]	-0.118	2.022	-0.057		
1952	2.21	0.005	1 [1.607]	0.049	1.749	0.016	1 [1.912]	4 0.092	4 [2.034]	0.012		
1953	2.252	0.042	1 [1.630]	0.023	1.748	-0.001	1 [1.900]	-0.012	7 [1.994]	-0.040		
1954	2.238	-0.014	1 [1.626]	-0.004	1.773	0.025	1.894	-0.006	2.052	0.058		
1955	2.218	-0.02	1.633	0.007	1.781	0.008	1.928	0.034	2 [2.056]	0.004		
1956	2.234	0.016	1.620	-0.013	1.776	-0.005	2 [1.888]	-0.040	2.042	-0.014		
1957	2.173	-0.061	1.583	-0.037	5 [1.697]	-0.079	1 [1.842]	-0.046	1.988	-0.044		
1958	2.154	-0.019	1.592	0.009	10 [1.670]	-0.027	1.817	-0.025	2 [1.982]	-0.016		
1959	2.18	0.026	1.590	-0.002	1.714	0.044	1.838	0.021	-			
1960	2.245	0.065	1.605	0.015	1.742	0.028	1.912	0.074	2.016			
1961	2.215	-0.03	1.579	-0.026	1.711	-0.031	1.866	-0.046	1 [1.971]	-0.045		
1962	2.234	0.019	1.613	0.034	1.755	0.044	1.932	0.066	2.024	0.053		
1963	2.195	-0.039	1.571	-0.042	1.693	-0.062	1 [1.873]	-0.059	1.962	-0.062		
1964	2.219	0.024	1.594	0.023	1.718	0.025	1.903	0.030	1.975	0.013		
1965	2.238	0.019	1.612	0.018	1 [1.722]	0.004	2 [1.897]	-0.006	1.970	-0.005		
1966	2.262	0.024	1.618	0.006	1.725	0.003	1.912	0.015	1.972	0.002		
1967	2.288	0.026	1.572	-0.046	2 [1.724]	-0.001	1.904	-0.008	1.946	-0.026		
1968	2.283	-0.005	1.548	-0.024	1 [1.697]	-0.027	1.932	0.028	1.952	0.006		

[ ] Number of months due to instrument breakdown.

The integer above the bracket means the number of months.

TABLE 3.9.2 (CONTINUATION)

Page 2

DATA SOURCE: NAMRIA

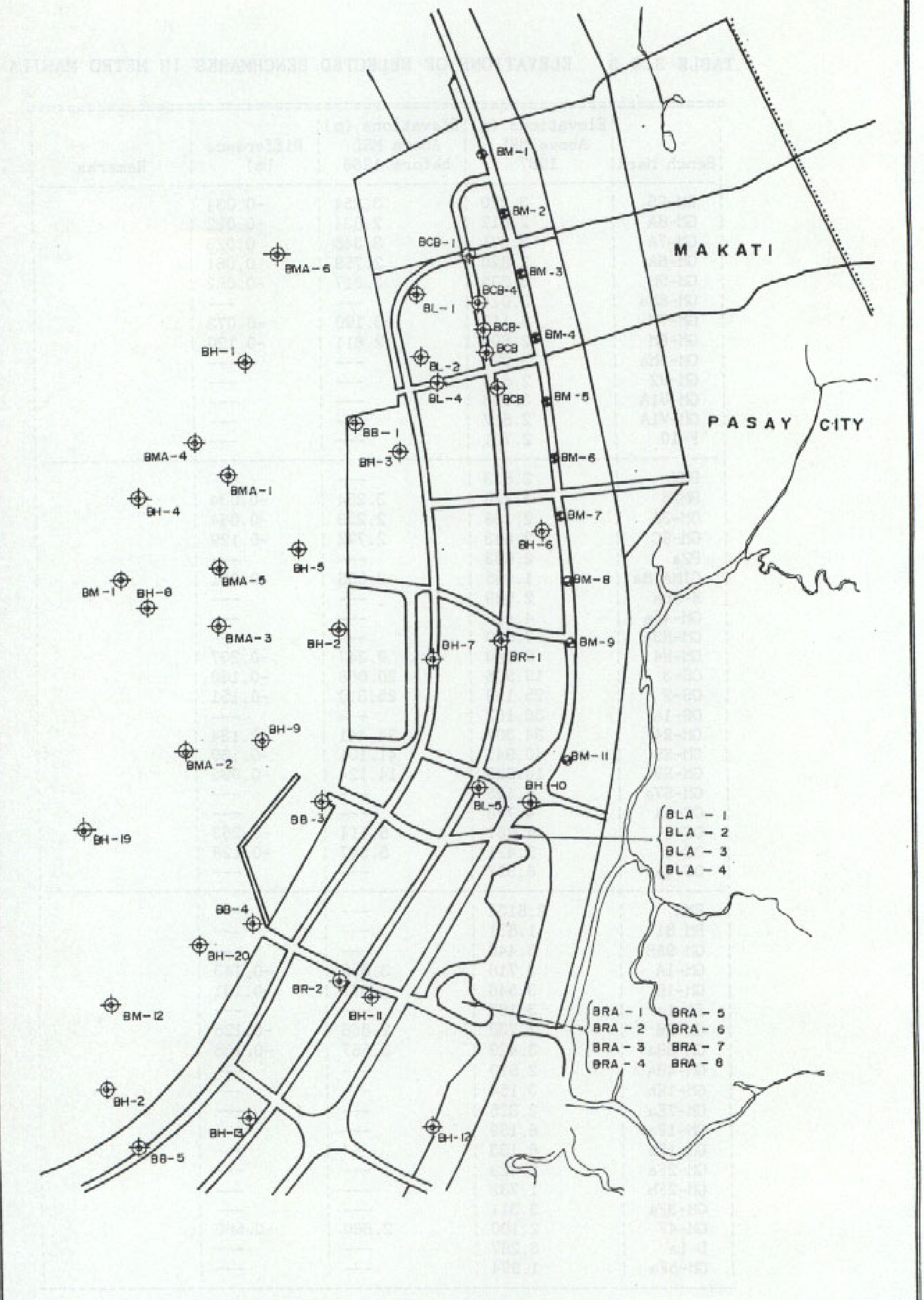
	MANILA OTS (1901)		LEGASPI OTS (1947)		CEBU OTS (1935)		DAVAO OTS (1947)		JOLO OTS (1947)		SAN FERNANDO OTS (1947)	
Year	Mean m.	Divergence m.	Mean m.	Divergence m.	Mean m.	Divergence m.	Mean m.	Divergence m.	Mean m.	Divergence m.	Mean m.	Divergence m.
1969	2.328	0.045	1.533	-0.015	1.657	-0.040	1.888	-0.044	1.938	-0.014		
1970	2.400	0.072	1.593	0.060	4 [1.678]	0.021	1 [1.952]	0.064	2.008	0.070		
1971	2.431	0.031	1 [1.612]	0.019	3 [1.773]	0.095	2.022	0.070	2.019	0.011		
1972	2.441	0.010	1.588	-0.024	1.712	-0.061	6 [1.925]	-0.097	1.932	-0.087		
1973	2.423	-0.018	1.579	-0.009	1.781	0.069	1.998	0.073	1.991	0.059		
1974	2.488	0.065	1.652	0.073	1.871	0.090	1.994	-0.004	2 [2.031]	0.040		
1975	2.514	0.026	1.738	0.086	1 [1.788]	-0.083	2.056	0.062	1 [2.048]	0.017		
1976	1 [2.541]	0.027	1.698	-0.040	1.752	-0.036	1.979	-0.077	1.972	-0.076		
1977	1 [2.538]	-0.003	1.697	-0.001	1.745	-0.007	2.008	0.029	2.008	0.036		
1978	2.561	0.023	1.680	-0.017	7 [1.692]	-0.053	2.051	0.043	2 [2.004]	-0.004		
1979	2 [2.583]	0.022	1.668	-0.012	-		2.021	-0.030	-			
1980	2.536	-0.047	1.653	-0.015	6 [1.663]		1.956	-0.065	1.973			
1981	2.575	0.039	1.675	0.022	1.726	0.063	1.992	0.036	1 [1.991]	0.018		
1982	2.575	0.000	1.692	0.017	1.711	-0.015	1 [1.959]	-0.033	1.929	-0.062		
1983	1 [2.578]	0.003	1.745	0.053	1.668	-0.043	2.017	0.058	1.932	0.003		
1984	2.658	0.080	1.738	-0.008	1.769	0.101	2.130	0.113	1 [2.035]	0.103	1.484	
1985	2.632	-0.024	1.715	-0.022	6 [1.693]	-0.076	2.078	-0.052	4 [1.985]	-0.050	2 [1.461]	-0.023
1986	2.606	-0.026	1.682	-0.033	1 [1.726]	0.033	2.061	-0.017	1.930	-0.005	2 [1.397]	-0.064
1987	2.568	-0.038	1.657	-0.025	4 [1.745]	0.019	2.012	-0.049	3 [1.947]	-0.033	6 [1.433]	0.036
1988	2.647	0.079	1.762	0.105	1.787	0.042	2.113	0.101	2.022	0.075	1 [1.430]	0.057
1989	2.716	0.069	1.818	0.056			2.115	0.002			1.489	-0.001

[ ] Number of months due to instrument breakdown.

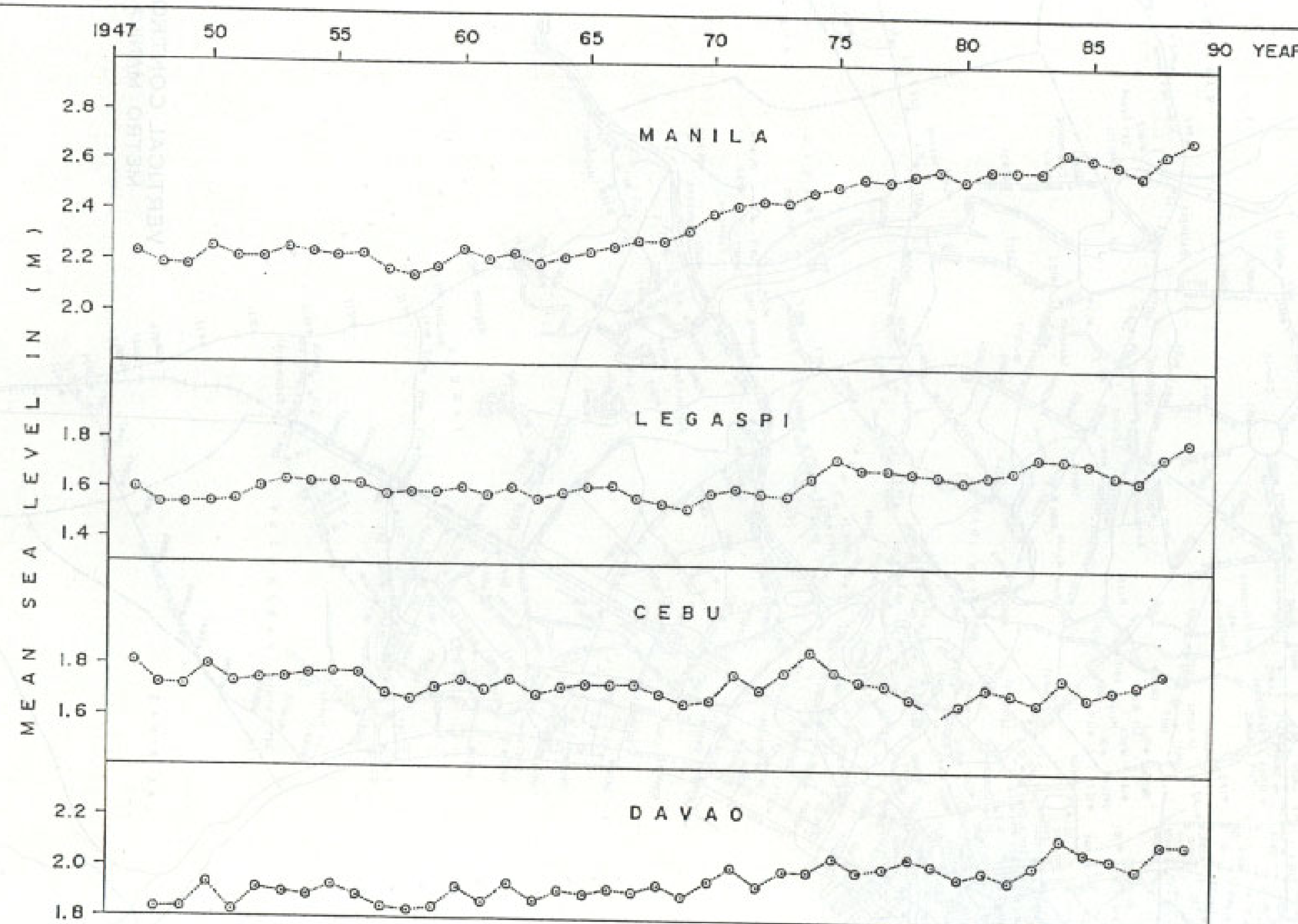
The integer above the bracket means the number of months.

TABLE 3.9.3 ELEVATIONS OF SELECTED BENCHMARKS IN METRO MANILA

Bench Mark	Elevations (m) Above MSL 1987	Elevations (m) Above MSL before 1966	Difference (m)	Remarks
BM-25	3.220	3.254	-0.034	
GM-8A	2.812	2.834	-0.022	
GM-7A	3.371	3.348	0.023	
GM-6A	2.820	2.759	0.061	
GM-9M	3.235	3.317	-0.082	
GM-8Ma	3.014	---	---	
GM-7M	3.117	3.190	-0.073	
GM-6M	2.691	2.811	-0.120	
GM-5Ma	3.226	---	---	
GM-U2	2.645	---	---	
GM-U1A	3.098	---	---	
GM-V1A	2.817	---	---	
F-10	2.721	---	---	
BMX	2.813	---	---	
BM25	3.220	3.254	-0.034	
GM-3A	2.139	2.223	-0.084	
GM-9C	2.643	2.772	-0.129	
P2a	2.833	---	---	
CIMA18a	1.955	2.006	-0.051	
E-36a	2.089	---	---	
GM-4Ja	4.410	---	---	
GM-N3a	7.340	---	---	
GM-N4	9.140	9.347	-0.207	
OS-3	19.906	20.066	-0.160	
OS-2	25.159	25.310	-0.151	
OS-1a	36.162	---	---	
GM-R4	34.307	34.441	-0.134	
GM-S9	40.941	41.101	-0.160	
GM-S8	14.029	14.124	-0.095	
GM-S7a	8.135	---	---	
OC-1a	4.743	---	---	
OC-2	4.861	5.114	-0.253	
OC-3	5.421	5.547	-0.126	
OC-4a	6.697	---	---	
BMX	2.8132	---	---	
BM 81	1.831	---	---	
GM 9AB	3.446	---	---	
GM-1A	3.716	3.859	-0.143	
GM-1B	3.546	3.677	-0.131	
FA-1a	3.187	---	---	
GM-2B	2.738	2.866	-0.128	
GM-3Ba	3.429	3.567	-0.138	
GM-4Ba	2.919	---	---	
GM-1Eb	3.154	---	---	
GM-2Ea	2.325	---	---	
GM-1Fa	6.159	---	---	
GM-1Fb	6.133	---	---	
GM-2Fa	2.420	---	---	
GM-2Fb	1.732	---	---	
GM-3Fa	3.311	---	---	
GM-4F	2.100	2.660	-0.560	
D-1a	3.287	---	---	
GM-5Fa	1.994	---	---	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 3.9.1
JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION OF FOUNDATION DRILLING (DPWH, 1977)

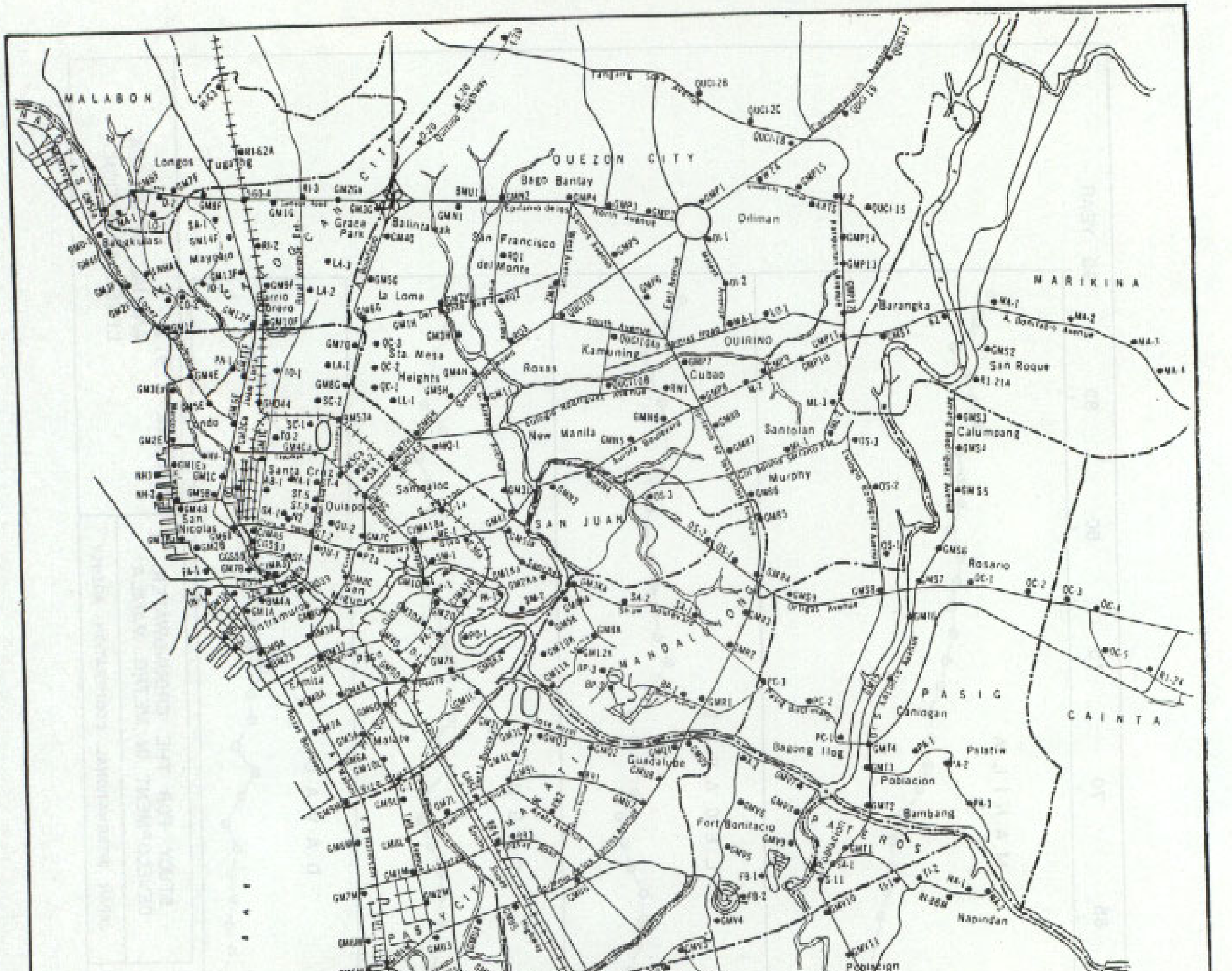


STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.9.2

ANNUAL MEAN SEA LEVEL VARIATIONS



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

FIGURE 3.9.3

VERTICAL CONTROLS METRO MANILA

CHAPTER 4

GROUNDWATER DATABASE

CHAPTER 4 GROUNDWATER DATABASE

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CHAPTER 4 GROUNDWATER DATABASE

4.1 GROUNDWATER DATABASE SYSTEM

The groundwater database system aims to support the groundwater development and conservation program of the Metropolitan Waterworks and Sewerage System (MWSS). The system is designed to facilitate the retrieval of necessary information from the database as well as the inputting of data directly (from the source document) into the computer.

The system is composed of five databases containing the following information:

- o well inventory data
- o meteorological data
- o hydrological data
- o hydrogeological data
- o related literature records

4.2 HARDWARE REQUIREMENT

The system runs on IBM PC/AT or any compatible microcomputer system whose configuration is characterized by the following:

1. A memory size of at least one megabyte (MB)
2. With at least one 3.5" floppy disk drive
3. With hard disk of at least 40 megabytes (MB) storage capacity
4. With DOS 3.0 or higher
5. A printer similar to Epson FX-1000

JICA provided the following hardware components:

a) Computer

TOSHIBA Personal Computer model J3100SGX with 100 MB hard disk drive and 1 MB floppy disk drives; ROM: 96k; RAM: 2 MB; CPU: 386 TM (20MHZ); Operating systems: MS-DOS (Version 3.1)

b) Display: Plazma

c) Printer: TOSHIBA PW5269A

d) Mouse: J33MS001

4.3 SOFTWARE REQUIREMENT

The system is designed to be user-friendly and has a program named WELL which was developed specifically to hide the complexity of its database's internal structures and procedures. WELL was based on DBASE III Plus.

4.4 DATABASE FILE STRUCTURES

4.4.1 Well Inventory Database

Well inventory database includes MWSS-supervised wells and turned-over deep wells, private wells applying for water rights from NWRB, wells inventoried during the Electrowatt project, wells from MGB, wells visited during the groundwater use survey and groundwater leveling, test wells drilled during this JICA study, wells inventoried in NWRB's Philippine Groundwater Summary, and wells from drilling companies.

Data gathered from these are stored in four related data files:

1. Filename: WELLDATA.DBF (Contains Well Casing Data)
2. Filename: WCASING.DBF (Contains Well Casing Schedule)
3. Filename: WSCREEN.DBF (Contains Well Screen Section)
4. Filename: WSTRATUM.DBF (Contains Well Log Record)

4.4.2 Meteorological Database

The meteorological database contains data on meteorological stations including the daily, monthly, and annual records of rainfall, temperature (mean, minimum and maximum), evaporation, humidity, wind velocity and sunshine hours measured from these stations. There are 25 data files comprising this database,contents of which are:

1. Filename: MSTATION.DBF (Data on Meteorological Stations)
2. Filename: RAIN_D.DBF (Daily Rainfall Data)
3. Filename: TMAV_D.DBF (Daily Mean Temperature)
4. Filename: TMIN_D.DBF (Daily Minimum Temperature)
5. Filename: TMAX_D.DBF (Daily Maximum Temperature)
6. Filename: EVAP_D.DBF (Daily Evaporation)
7. Filename: HUMID_D.DBF (Daily Humidity)
8. Filename: SUN_D.DBF (Daily Sunshine Duration)
9. Filename: WIND_D.DBF (Daily Wind Velocity)
10. Filename: RAIN_M.DBF (Monthly Rainfall Data)
11. Filename: TMAV_M.DBF (Monthly Mean Temperature)
12. Filename: TMIN_M.DBF (Monthly Minimum Temperature)
13. Filename: TMAX_M.DBF (Monthly Maximum Temperature)
14. Filename: EVAP_M.DBF (Monthly Evaporation)
15. Filename: HUMID_M.DBF (Monthly Humidity)
16. Filename: SUN_M.DBF (Monthly Sunshine Duration)
17. Filename: WIND_M.DBF (Monthly Wind Velocity)
18. Filename: RAIN_Y.DBF (Yearly Rainfall Data)
19. Filename: TMAV_Y.DBF (Yearly Mean Temperature)
20. Filename: TMIN_Y.DBF (Yearly Minimum Temperature)
21. Filename: TMAX_Y.DBF (Yearly Maximum Temperature)
22. Filename: EVAP_Y.DBF (Yearly Evaporation)
23. Filename: HUMID_Y.DBF (Yearly Humidity)
24. Filename: SUN_Y.DBF (Yearly Sunshine Duration)
25. Filename: WIND_Y.DBF (Yearly Wind Velocity)

4.4.3 Hydrological Database

The hydrological database provides information about the hydrological gaging stations as well as the daily, monthly, and annual continuous observations on the river discharge and gage height measured from the said station. It also contains the simultaneous observations on spring discharge and streamflow in the Antipolo Area. The database comprises nine data files with the following data items:

1. Filename: HSTATION.DBF (Information on Hydrological Station)
2. Filename: RDIS_D.DBF (Daily River Discharge)

3. Filename: GAGE_D.DBF (Daily Gage Height)
4. Filename: RDIS_M.DBF (Monthly River Discharge)
5. Filename: GAGE_M.DBF (Monthly Gage Height)
6. Filename: RDIS_Y.DBF (Yearly River Discharge)
7. Filename: GAGE_Y.DBF (Yearly Gage Height)
8. Filename: SPRING.DBF (Spring Discharge)
9. Filename: STREAM.DBF (Streamflow)

4.4.4 Hydrogeological Database

The hydrogeological database contains data of those wells tested and measured during actual test drillings, rehabilitation studies, pumping test and groundwater quality investigations of wells. The database is composed of six related data files containing the following data items.

1. Filename: HGEO.DBF (Pumping Test Data)
2. Filename: WGWS.DBF (Groundwater Level Simultaneous Observation)
3. Filename: WGWC_D.DBF (Daily Groundwater Level Continuous Observation)
4. Filename: WGWC_M.DBF (Monthly Groundwater Level Continuous Observation)
5. Filename: WGWC_Y.DBF (Annual Groundwater Level Continuous Observation)
6. Filename: WCHEM.DBF (Chemical Quantity of Water)

4.4.5 Literature Database

The literature database provides literature records relevant to the groundwater development study. Data items are the following:

1. Filename: LITR.DBF (Contains Literature Records)

CHAPTER 5

WELL REHABILITATION SURVEY

CHAPTER 5 WELL REHABILITATION SURVEY

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CHAPTER 5 WELL REHABILITATION SURVEY

5.1 OPERATION AND MAINTENANCE OF MWSS WELLS

5.1.1 Organization and Activity

(1) Responsibility on Operation

The operation of MWSS-owned/supervised wells are all being handled by the Water Distribution and Maintenance Department (WDMD) through its Pumping Plants Division down to the Deepwell Pumping Plants Section (Figure 5.1.1). This department is responsible for the operation and monitoring of both operational and non-operational deep wells. The number of personnel assigned to each well station is on rotation basis. Water production of each well are recorded daily.

(2) Responsibility on Maintenance

The repair and maintenance of all wells owned by MWSS is the responsibility of the Central Maintenance Department (CMD) through the General Control and Repair Division (GCRD). This is shown in Figure 5.1.2. Under the GCRD, the Mechanical and Electrical Section implements the on-site repair and maintenance of pumps, motors, electrical controls and other accessories. For works that have to be done at the shop like some fabrication works, welding jobs, rewinding of motors, repair of pumps, etc., the General Workshop Section, also under the GCRD, takes charge.

Repairs and maintenance of these wells' other water supply and distribution facilities, such as piping systems and other appurtenances, are handled by GCRD's Treatment Plant Mechanical-Electrical Section.

The expenses incurred for small damages, repair and minor engine troubles are all borne by CMD as this office has the budget appropriated for such purpose.

(3) Responsibility on Rehabilitation/Construction

The Planning and Programming Department (PPD) through its Groundwater Monitoring Unit under the Hydrology and Research Division (HARD) studies and recommends feasible actions for the rehabilitation of deteriorated MWSS wells and those with very low water discharge. In some cases, the WDMD, or the CMD, or the customers of MWSS request for the rehabilitation of particular MWSS Wells. For the smooth implementation of well rehabilitation works, the support services of the Bidding, Documentation and Estimates Division (BDED) and Locally-Funded Projects Department (LFPD) are required, specifically for the preparation of bidding and contract documents and field supervision of the actual implementation works.

In drilling new wells, PPD does the feasibility studies and undertakes the construction of test wells through its different units and project offices. Such units include the Groundwater Monitoring Unit of HARD, and the offices of the Fringe Areas Water Supply Project (FAWSP), the Rizal Province Water Supply Improvement Project (RPWSIP), the Manila North-East Water Supply Project (MNEWSP), the Metro Manila Groundwater Development Project (MMGWDP) and the other future PPD projects which are groundwater-based.

Support services of the Design Department and BDED are also necessary for the preparation of design/plans and bidding/contract documents for the construction of deepwell pumping stations and their accessories--usually done when test wells are converted into production wells. The supervision of the actual construction of the pumphouse and all its facilities is carried out by the project office involved (FAWSP, RPWSIP, MNEWSP, MMGWDP). LFPD supervises only those projects initiated by HARD's Groundwater Monitoring Unit.

PPD oversees and monitors the implementation progress of the rehabilitation, drilling and pumping station construction works for MWSS deepwells.

(4) Daily Operation and Maintenance

The Deep Well Pumping Plant Section is engaged in the operation and maintenance of MWSS deepwells. Deepwell stations are clustered per area as follows:

1) Antipolo (town proper)
2) Cogeo, Antipolo, Rizal
3) Malabon, Metro Manila
4) Navotas, Metro Manila
5) Pasig, Cainta and Taytay, Rizal
6) Congress (IBP), Quezon City, Metro Manila
7) San Mateo-Montalban, Rizal
8) N.A.I.A.-Pasay City-Las Piñas-Parañaque, Metro Manila
9) Lagro, Quezon City, Metro Manila
10) Fairview, Quezon City, Metro Manila
11) Forbes Park-Valle Verde-Green Meadows, Metro Manila
12) Dasmariñas, Makati, Metro Manila
13) Cavite Area (Imus, Bacoor, Cavite City, Noveleta, Rosario, Kawit)
14) Muntinlupa, Metro Manila
15) Taguig (Signal Village 1 and 2, Upper Bicutan), Metro Manila
16) Escopa, Project 4 & Loyola Grand Villas, Q.C., Metro Manila
17) Valenzuela, Metro Manila

Deep well pumping stations are daily visited. Operating hours, power consumption, discharge rates, etc. are read and reported. Should a defect/trouble like damage to motor occur, a proposal for repair/maintenance is sent to the Central Maintenance Department and a corrective measure is undertaken.

Supervision of wells is not always by cluster. Some are supervised individually.

In the Antipolo area for example, the ten wells of MWSS are operated and maintained by a 19-person team. This manpower complement consists of an officer-in-charge, a pump operator/foreman (assistant of officer-in-charge), four (4) groups, (4 persons/group) and a roving operator. The detailed organization is shown in Fig. 5.1.3

Group 1 consists of two pump operators/foremen and two regular pump operators. It supervises Deepwell Pumping Station (DPS) Nos. 1, 2 and

7. Group 2, which is composed of one senior pump operator and three regular pump operators, supervises DPS Nos. 4 and 5. Group 3 consists of three regular pump operators and one casual pump operator. It supervises DPS Nos. 8, 9 and 10. Group 4, which is made up of one senior pump operator and one regular pump operator and two casual pump operators, supervises DPS Nos. 3 and 6. The relationship between the Groups and the respective wells under their supervision is shown in Fig. 5.1.4.

This group arrangement needs three personnel for operating each pump station. These personnel work five days a week, with pump operators working on eight-hour shifts. An extra operator is assigned to take over the other functions of one who is on rest day or off day. In addition, a roving operator is also assigned as alternate for absent operators. Total number and composition of personnel are shown below.

Table 5.1.1 PERSONNEL COMPLEMENT OF MWSS OPERATION IN ANTIPOLO AREA

Workers' Class	Number of workers
1. Supervising engineer (Officer-in-charge)	1
2. Pump operator foreman	3
3. Sr. pump operator	3
4. Regular pump operator	9
5. Casual pump operator	3
Total	19

5.1.2 Maintenance Capability and Equipment

Maintenance and repairs capability is different in each organization of MWSS. The Deepwell Pumping Station Operators can undertake minor maintenance works as follows:

WDMD DPS Operator's Maintenance Works

1) Replacement of pump head and diaphragm of chemical feeder
2) Replacement or repair of power and control fuses, burnt wires inside control panel, and other related repairs
3) Isolation of defective protective device (control panel)
4) Cleaning of chlorinators and chemical feeder
5) Repair of defective lighting fixtures
6) Maintenance and cleanliness of pump houses and surroundings and motor controls

All the other major maintenance works on deepwell pumping stations which cannot be undertaken by this WDMD DPS Operator are implemented by CMD. The CMD has the following equipment/tools and materials:

Equipment/Tools

a. Hydraulic crane
b. Chain hoist
c. Welding Machine
d. Megger Tester
e. Clamp Ammeter
f. Multi-Tester
g. Assorted hand tools (pliers, wrenches, screwdrivers, etc.)

Materials

a. Chlorine granules
b. Other materials (as per request)

5.1.3 Budget of the CMD

The 1990 Approved Budget of the MWSS for the maintenance of the water supply system is as follows:

Central Maintenance Department	₱170,152,100.00
General Control and Repair Division	60,544,900.00

The ratio of General Control and Repair Division (GCRD) to CMD in the MWSS budget is 35.6%.

5.1.4 Present Rehabilitation Procedure

The rehabilitation of a well is undertaken when the initial discharge rate is decreased by 50% or more. The decrease of the discharge rate may be caused by:

- Regional decline of water level;
- Trouble or superannuation of submersible pump; and,
- Encrustation or clogging of well screen or submersible pump screen.

Figure 5.1.5 shows MWSS's procedure for well rehabilitation. Investigation and analysis is conducted first, followed by detailed engineering work, and then the awarding of the rehabilitation work to contractors which carry them out.

Usual work items are:

- Mobilization and demobilization;
- Pulling out of existing pumping unit;
- Cleaning of well by brushing, bailing and developing by surging for 24 hours; and,
- Developing and pump testing of well for 48 hours.

The effect of rehabilitation work is verified by comparing yield of wells before and after rehabilitation. The static water level, before and after the rehabilitation work, is also measured to verify improvement of well productivity.

5.2 SURVEY AT WELL SITES

5.2.1 Survey Methodology

There are at present two hundred fifty-eight (258) MWSS wells in MSA, about half of which are inactive or abandoned. The total figure is based on the list of active, inactive and abandoned MWSS deep wells which the respective staffs of the MMGWDP and the Deep Well Pumping Plant Section of MWSS prepared (Table 5.2.1). Site survey of these wells was conducted, and the information and data obtained were used to establish a proper rehabilitation program. Investigation items were:

- Site visit of all active and some inactive MWSS deep wells;
- Questionnaire survey at each area-cluster of deep wells;
- Collection and analysis of construction and pumping records of each well;
- Detailed survey of selected wells including the measurements of water levels, discharge rates and water qualities by pumping tests; and
- Preparation of the experimental rehabilitation program.

5.2.2 Present Condition of MWSS Wells

Obtained during the site visits and the interviews with the operators are the data on the present condition of MWSS wells (Tables 5.2.1 and 5.2.2). The well conditions are classified into four: "Good", "Damaged", "Standby" and "Others".

"Good": wells being operated are in good condition.
"Damaged": wells are damaged as indicated by any of the following:

a) Salty water output
b) Dirty water
c) Well caved-in
d) Well is almost dry
e) Defective pump/motor unit

"Standby": wells are on standby, under rehabilitation, or provides adequate water supply.

"Others": wells are abandoned, inactive, have broken distribution pipeline, etc.

Tables 5.2.2 and 5.2.3 show that ninety-nine (99) out of one hundred thirty (131) "active" wells are in good condition. The rest of the wells are practically inactive. However, this number of active wells may increase since some of the "inactive" wells are under rehabilitation and may be activated in the future. In addition, a considerable number of wells have not been operated since turn-over. These wells however could be operated when needed.

Under the active and inactive categories are 28 damaged wells. The causes of damage by municipality are shown in Table 5.2.4.

5.2.3 Detailed Survey of Selected Wells

5.2.3.1 Scope and Specifications

Sixteen (16) out of twenty-eight (28) damaged wells were selected for detailed survey. This survey included pumping tests to obtain the data necessary for the well rehabilitation program. Those wells which were abandoned, or are very shallow, or have no original records were excluded. The scope and technical specifications of the rehabilitation are given as follows.

A. TWO WELLS

1) COGEO No.1, ANTIPOLO (3 days)

- Addition of 2 pieces of riser pipes and lowering of the pump setting by about 12 meters
- Short pumping test (30 minutes)
- Removal of existing pumping facilities
- Measurement of well depth and static water level
- Installation of a pump test unit (pump setting - 78 meters)
- Pumping test (2 hours)
- Water sampling
- Removal of pump test unit
- Re-installation of the existing pumping facilities

2) LAGRO No.5, QUEZON CITY (1 day)

- Measurement of pumping water level and discharge rate
- Addition of 3 pieces of riser pipes and lowering the pump setting by about 18 meters
- Pumping test (2 hours)
- Water sampling

B. TWELVE WELLS

- Removal of threaded-caps of sounding tube
- Measurement of static water level
- Pumping test (2 hours)
- Water sampling and measurement of pumping water level

C. TWO WELLS (Sumulong, Taytay and Forbes Park No. 12)

- Measurement of static water level

5.2.3.2 Results of the Survey

(1) Cogeo No.1, Antipolo

Due to low water output and frequent tripping of pump unit, this well has not been operated since July 1990.

The well and pumping unit have these following characteristics:

Existing pump setting	66m
Well depth	89.40m
Existing pump unit	Franklin Electric Model 2366016010 HP 7 1/2 230 V PH3 MAX A 24.6 3450 R.P.M. Insulation resistivity 1.5 megaohms (Low)

The new pump test unit which was used for the pump testing program has the following characteristics.

Pump Test Unit	RED JACKE 2130 Serial No. DLE 6116 HP 15 230 V 44.5 A, 3450 R.P.M. Insulation resistivity 130 megaohms (Good)

At first, the pump setting was changed to 78 meters by adding twelve

(12) meters of riser pipes. Pumping started afterwards. During the pumping test, the discharge rate is 3.08 lps and the pumping water level (PWL) is more than 67.06 m.

Another pump test unit which was installed at the same depth was also ran. Results show 3.22 lps of discharge and more than 67.06m of PWL and 6.0m of static water level (SWL). Results are almost the same as those on using the existing pump unit.

It is therefore noted that the low output of the well was improved by having the pump setting changed. But even with an increased discharge rate, the existing pump unit must still be repaired because of the low insulation resistance. It is also recommended that the pump setting be lowered by about 12 meters.

(2) Cogeo No. 6, Antipolo

As observed, this well has a reduced discharge rate. Results of the pumping test at Cogeo No.6 are as follows:

Existing pump setting	100.5m
Well depth	107.4m
Discharge rate	2.50 lps
Submersible pump	25 HP
Pumping Water Level	38.0m

It is recommended that the existing pump unit be removed so that pump setting and conditions can be checked. It seems that the pump setting was wrong or the impeller has worn out. Adjustment of pump setting to a more suitable position is recommended.

(3) Lagro No.5, Quezon City

This well was rehabilitated once in July 1990. However, water comes up intermittently.

Present condition of the well is as follows:

Existing pump	30 HP

Existing pump setting	96m
Discharge rate	3.75 lps
Pumping water level	50.60m

The pump setting was changed by adding three (3) pieces of 4" diameter riser pipes. Results of the pumping test are as follows:

Discharge rate	6.50 lps
Pumping water level	54.80m
Static water level	42.00m

The well produced water after the rehabilitation. It seems the existing pump setting was recorded incorrectly.

(4) IBP (Congress) No. 3, Quezon City

The condition of the well is as follows:

Well depth	208.20m
Submersible pump	30 HP
Pump setting	108m
Static water level	39m

This well was inactive since April 1990 because of the presence of iron bacteria. The existing pump should be pulled up and checked. The iron scales adhering to the pump and the riser pipes should be removed.

(5) Alabang Junction, Muntinlupa

The condition of the well is as follows:

Well depth	246.0m
Submersible pump	30 HP
Pump setting	72m
Pumping water level	74.45m
Discharge rate	(Flow meter was broken)

During the site visit made prior to the test, it was learned that the water that comes out from the well is dirty and contains sand. During the pumping test, however, clean water came up without sand. This well seemed to be in good condition. Pump setting was possibly wrong.

(6) Malanday, San Mateo

MWSS rehabilitated this well in 1989, but the well output is low. Results of the pumping test done by the Study Team are as follows:

Submersible pump	30 HP
Pump setting	78m
Flow rate	6.67 lps
Pumping water level	30.50m

Many iron bacteria appear to be present in the groundwater. The iron scales may be inside the riser pipes and the pump unit.

(7) Dulong Bayan, San Mateo

It was reported that the well had caved-in. The pumping test conducted by the Study Team showed that it has not.

Submersible pump	15 HP
Pump setting	57m
Flow rate	10.0 lps
Pumping water level	19.0m

No sandy materials were observed in the groundwater during pumping. Pump operation is good. The groundwater flows directly into the distribution pipeline. Control of pumping rate is done by back pressure and thus could not be increased.

(8) Sumulong, Taytay

This well was inactive from September until the 3rd week of December 1990 due to defective electrical control. A 15-HP submersible pump was pulled out on December 27, 1990 and replaced by a 30-HP submersible pump the next day. The well condition is as follows:

Pump setting	75m
Static water level	58m

Submersible pump insulation resistance 0 ohm

The submersible pump needs repair because of zero (0) insulation resistance. Pump needs to be set deeper by adding three (3) pieces of 4" diameter riser pipes.

(9) Bangiad, Taytay

The well drilling was completed in March 1985. The pumping station was constructed in March 1987 and became operational in 1989.
Results of the pumping test:

Submersible pump	40 HP
Pump setting	90m
Flow rate	22.17 lps
Pumping water level	75.0m
40 HP submersible pump	Installed on Oct.3,1989.

The pump operation is good and groundwater is almost clean, except for some fine sand which sometimes comes out. The discharge rate should therefore be reduced.

(10) Zapote, Las Piñas

The pumping test results are as follows:

Submersible pump	25 HP
Flow rate	10.67 lps
Pumping water level	74.0m
Water quality	2,230 μS/cm; 30.9 deg. C; pH 7.95

Water coming from this well is salty. Considering the data obtained from the test wells drilled by the Study Team, the salty water may have originated from shallow aquifers in this area.

(11) Naga Road No.2, Las Piñas

The results of pumping test conducted by the Study Team are as follows:

Submersible pump	30 HP
Pump setting	132m
Flow rate	7.83 lps
Pumping water level	74.0m

The discharge rate was recorded at 23.03 lps in 1979. No rehabilitation work has been done during the last 12 years. It is therefore recommended that the existing pump unit be pulled out to check the setting and the pump's condition.

(12) Topacio Elementary School, Imus

The results are as follows:

Well depth	252m
Submersible pump	30 HP
Flow rate	14.5 lps
Pumping water level	81.0m

The report that the well had dried up was not true. This well seems to be in good condition. No sand came out during the test and the pump's operation was good.

(13) Dalahican, Cavite City

This well was also reported damaged. But the pumping test showed:

Well depth	189m
Submersible pump	15 HP
Pump setting	78m
Flow rate	6.67 lps
Pumping water level	52.45m

This well seems to be in good condition. No sand come out and the pump is still in good condition.

(14) Forbes Park No.12, Makati

The well characteristics are:

Well depth	304.80m
Static water level	48.50m

The pump unit was installed in September 1990.

(15) Forbes Park No.11, Makati

The well characteristics are:

Well depth	304.80m
Submersible pump	70 HP
Pump setting	210m
Pumping water level	139.0m

The discharge rate could not be measured because there was no flowmeter installed. Clean water came out from this well. The well is in good condition.

(16) Maricaban III, Pasay City

Results of pumping test show:

Well depth	237.74m
Submersible pump	30 HP
Pump setting	109m
Flow rate	11.22 lps
Pumping water level	110.40m
Water quality	1,421 µS/cm; 31.6 deg. C; pH 8.29

The well yields water that is a little salty. No sand came out. This well is still in good condition.

5.2.4 Summary of the Survey

(1) Recommended for well rehabilitation

Cogeo No.1, Antipolo
Cogeo No.6, Antipolo
IBP (Congress) No.3, Quezon City
Malanday, San Mateo
Sumulong, Taytay
Naga Road No.2, Las Piñas
Forbes Park No.12, Makati

(2) Well in good condition

Bangiad, Taytay

(3) Improvement in water quality could not be expected

Zapote, Las Piñas

(4) Increase the power rating of the pump or the total dynamic head

Dulong Bayan, San Mateo
Alabang Junction, Muntinlupa
Topacio Elementary School, Imus
Dalahican, Cavite City
Forbes Park No.11, Makati
Maricaban III, Pasay City

(5) Check and follow up the well condition

Lagro No.5, Quezon City

5.3 EXPERIMENTAL REHABILITATION WORK

5.3.1 Work Outline

The experimental work for rehabilitation was drawn up for five (5) MWSS deepwells in Metro Manila based on the survey results. The location and details of these wells are shown in Figures 5.3.1 to 5.3.6 and Table 5.3.1

The experimental work for rehabilitation involves the following activities:

1) Preparation and mobilization
2) Pulling out of existing pumping unit
3) Measuring of well depth and water level
4) Inspection of existing pumping unit
5) Installation of test pumping unit
6) First pumping test
7) Surging, bailing and airlifting
8) Second pumping test
9) Installation of existing pumping unit
10) Demobilization

After mobilization and preparatory work, the existing pumping unit well depth and static water level are then measured. The accumulation of sand, mud, rust and other materials at the bottom of the well are investigated throughout the measurement.

Electric conductivity and temperature logging are conducted just below the static water level down to the bottom of the well at one meter intervals.

The Study Team had the existing pumping units checked and the slight damages repaired. The scales adhering to the pumping units were removed and the units cleaned up.

A test pumping unit was installed in the well together with a micro-flow meter in order to carry out the following pumping tests.

1) Step-drawdown test

2) Constant discharge test

3) Recovery test

4) Flow measurement at screen sections

Flow measurement was not conducted at Sumulong, Taytay and Cogeo No.1, Antipolo because the diameter of the casings of these wells is 6 inches and the clearance between the test pump and casing was so narrow for the installation of micro-flow meter unit. The flow meter was also not used at Cogeo No.6, Antipolo because the well was cased without screens from the ground surface to the depth of 100m, but was uncased below this depth down to the bottom. Instead of measuring the micro-flow at three wells -- IBP No.3, Cogeo No.6, Antipolo and Naga Road No.2 -- a television camera was lowered inside the wells and photographs were taken.

First Pumping Test

Pumping rate and pumping water level were measured continuously and checked by using a triangle notch weir and electrical sounding wire. The electric conductivity, temperature and pH were measured by using water quality meters.

1) Step-drawdown Test

The step-drawdown test was conducted at five (5) steps with pumping duration of two (2) hours for each step. The pumping rate was decided at the site. The test was not completed at Cogeo No.1, Cogeo No.6, IBP No.3 and Naga Road No.2 wells because of large drawdowns or very low discharges.

2) Constant Discharge Test

This test was continued for forty eight (48) hours. The pumping rate was decided and was directed to the Contractor.

3) Recovery Test

After constant discharge test, the recovery of water level was measured for eight (8) hours.

4) Flow Measurement

The flow rate at each screen section of the well was measured. The depth of setting was at the uppermost part of each screen section.
Measurements were taken at one hour intervals during the conduct of the step drawdown.

Surging and Bailing

After the first pumping test, the wells were surged throughout the screen section. The wells are bailed when any accumulation are observed. Surging and bailing were performed for more than two (2) days, at eight (8) hours per day.

Airlifting

Upon completion of surging and bailing, the wells were discharged by airlifting for more than two (2) days, also at (8) hours per day. The compressor used for pumping by airlifting has a developing pressure of 8 kilograms per square centimeter (114 psi); the delivery rate was 17 cubic meter of air per minute. From time to time, the air flow was stopped to facilitate the loosening of trapped materials.

Airlifting was completed with the eductor pipes almost at the bottom of the well to ensure that all materials are cleaned out of the pipe.

Second Pumping Test

After airlifting, the second pumping test was conducted and flow measurements taken in the same manner as the first pumping test.

After completion of the second pumping test, the existing pumping unit was reinstalled in the well. Sounding tubes of 3/4-inch diameter were installed with the existing pumping unit to facilitate the measurement of water level.

Actually, the existing pumping unit is damaged and therefore was not reinstalled at Sumulong, Cogeo No.6 and IBP No.3. But the riser pipes and submersible pumps for replacement were not available. IBP No.3 is recommended to be abandoned because of its low water output and the presence of many iron bacteria.

5.3.2 Effect of Rehabilitation

The results of experimental works are summarized in Table 5.3.2.

(1) Sumulong, Taytay Deepwell

For the first pumping test, a 30-HP submersible pump was used. It was installed at a depth of 78m below ground level. For the second, a 10-HP submersible pump was used and installed at a depth of 120m below ground level. The diameters of casing are 8 inches from ground level to 80.77m, and 6 inches below 80.77m. The diameter of riser pipes is 3 inches. Static water level before pumping was 58.00m for the first pumping test and 58.50m for the second pumping test.

The pumping tests were conducted at five steps with discharge rates of 60, 108, 144, 168 and 198 l/min for the first test; for the second, 78, 120, 162, 198 and 240 l/min. Each step has a duration of two hours.

From the results, well loss parameters were calculated using Jacob's equation. For the first pumping test, the values of B and C obtained from Q-s/Q graphs are $5.40x10^{-2}$ day/m2 and $1.65x10^{-4}$ day^2/m^5, respectively; and for the second, $2.60x10^{-2}$ day/m^2 and $1.43x10^{-4}$ day^2/m^5, respectively. Well efficiencies were calculated as 51.3% when discharge rate is 198 l/min (285 m^3/day) at the first pumping test and as 34.0% when discharge rate is 240 l/min (328 m^3/day).

In order to determine the transmissivity T and storage coefficient S of the aquifer, the continuous pumping and recovery tests were carried out before and after rehabilitation work. The discharge rate determined from the step-drawdown test was 156 l/min at the first pumping test and 204 l/min at the second pumping test. Duration of pumping was 48 hours. The discharge rates were small because the diameter of the casing pipes was reduced from 8 to 6 inches at depth of 80.77m and only a smaller submersible pump could be installed. The residual drawdown before and after rehabilitation work was measured for 8 hours after pumping has stopped.

The specific capacity was noted to have improved from 9.50 m^2/day to 13.07 m^2/day. Aquifer loss coefficient and well loss coefficient have also improved. This may indicate that the clogging of the well screen and aquifer were removed by rehabilitation work. EC values during pumping tests also support this idea.

(2) Cogeo No. 1, Antipolo

A 10-HP submersible pump was installed at a depth of 78m below ground level. The diameter of casing and riser pipes were 6 and 3 inches, respectively. The static water level before pumping was 8.10m at the first pumping test and 6.55m at the second.

Step-drawdown tests were conducted at discharge rates of 42, 78, 120, 156 and 198 l/min before and after rehabilitation work. The duration of each step was two hours.

From the results, well loss parameters were calculated using Jacob's equation. For the first pumping test, the values of B and C obtained from Q-s/Q graphs are 8.00×10^{-3} day/m^2 and 2.55×10^{-4} day^2/m^5, respectively; and for the second, 2.00×10^{-3} day/m^2 and 2.10×10^{-4} day^2/m^5, respectively. Well efficiencies are calculated as 13.6% at the first pumping test and as 4.70% at the second pumping test. Discharge rate is 156 l/min (225 m^3/day).

The continuous pumping test was conducted at a discharge rate of 198 l/min. Duration of pumping at the first pumping test was 10 hours because the pumping water level declined to near the level of pump setting. Duration of the second pumping test was 48 hours. The discharge rate was small because the pumping water level declined rapidly to the level of pump setting.

The residual drawdown was measured for eight hours after the pumping has stopped.

The specific capacity was noted to have improved from 17.0 m^2/day. Aquifer loss coefficient and well loss coefficient have also improved.

This may indicate that the clogging of the well screen and aquifer were removed by rehabilitation work.

It was also observed that the pumping water level declined rapidly and did not become stable at the discharge rate of 198 l/min. This may indicate that the groundwater of this well come from the fissure of basalt and is unconfined. Storage coefficient S values and aquifer loss coefficient values B obtained from the pumping tests also support this idea.

(3) Cogeo No. 6, Antipolo

A 20-HP submersible pump was installed at a depth of 90m below ground level. The diameter of casing pipes and riser pipes were 8 and 3 inches, respectively. The 8" blank casing pipes were installed up to 91.44m below ground level and a 14" borehole was uncased from a depth of 91.44 to 117.35 meters. The static water level was 11.50m at the first pumping test and 10.49m at the second.

Step-drawdown test was performed at discharge rates of 49.2, 102, 150, 204 and 252 l/min. Although the planned duration of each step was two hours, the final step had only a duration of twenty (20) minutes, because the pumping water level had declined to the level of the pump setting.

For the first pumping test, the values of well loss parameters B and C obtained from Q-s/Q graphs are 0.00 day/m^2 and 8.00x10^{-4} day^2/m^5, respectively; and for the second, 0.00 day/m^2 and 7.35x10^{-4} day^2/m^5 respectively. Well efficiencies are calculated as 0.00% at the first pumping test and also as 0.00% at the second. Discharge rate was 204 l/min (294 m^3/day).

The continuous pumping test was conducted at a discharge rate of 150 l/min. Duration of pumping for the first pumping test was 22 hours. Although it was planned for forty eight (48) hours, pumping was aborted due to power failure (brown out). Duration of the second pumping test was 48 hours. The discharge rate was small because the pumping water level declined rapidly and reached the pump setting position.

The specific capacity was noted to have improved a little from 4.30 m^2/day to 4.58 m^2/day. Well loss coefficient has also improved a little. This may indicate that the clogging of the well screen and aquifer were originally small.

It was also noted that the pumping water level declined continuously and was unstable when the discharge was 252 l/min. This may indicate that the groundwater of this well come from the fissure of basalt rocks, like that in Cogeo Deepwell No.1.

(4) IBP (Congress) No.3

The discharge from IBP No.3 was so small that the pumping test could not be carried out.

According to the lithologic log that was obtained at the time the well was completed on 23 May 1978, the geologic formation mainly consists of clayey layers and the screen section was set at very thin gravel beds. EC values at 18 degrees range from 136 to 156 µS/cm. Considering such low conductivities, this may indicate that water directly enters the well from surface sources such as rain or perched water. Very small amounts of groundwater may flow into the well through the screen section.

(5) Naga Road No.2

A 30-HP submersible pump was installed at a depth of 102m below ground level. The diameters of casing and riser pipes were 10 and 4 inches respectively. The static water level before pumping was 55.84m at the first pumping test and 55.42m at the second.

The step-drawdown test was conducted at discharge rates of 102, 204, 300 and 360 l/min. Although planned for five steps, testing was stopped at the final step because of the small dynamic head.

For the first pumping test, the values of well loss parameters B and C obtained from Q-s/Q graphs were 3.20×10^{-2} day/m^2 and 6.20×10^{-6} day^{-2}/m^5, respectively; for the second, 2.95×10^{-2} day/m^{-2} and 6.20×10^{-6} day^{-2}/m^5, respectively. Well efficiencies were calculated at 92.3% at the first pumping test and at 90.2% at the second. Discharge rate was 300 l/min

($432 m^3/day$).

The discharge rate determined from the step-drawdown test was 354 l/min.

The continuous pumping test duration was 48 hours.

The discharge rate was not so high at the first pumping test because the existing 6-stage submersible pump that was used, after dismantling and removing the scales from the pump impeller, does not have high dynamic head. At the second pumping test, the discharge rate was also not so high because the existing pump was again used. A new 30-HP, 12-stage, submersible pump was then installed, but the motor conked out during the 20-minute test operation due to the intrusion of sand. Such being the case.

The residual drawdown was measured for eight hours after the pumping has stopped.

The specific capacity was noted to have improved from 28.9 m^2/day to 30.6 m^2/day at a discharge rate of 378 l/min. It was also noted that after rehabilitation the groundwater flowed into the well through lower screen sections. Well loss coefficient was the same. This may indicate that the clogging of the well screen and aquifer was very few.

5.3.3 Recommendation

Based on the result of the experimental work for rehabilitation of five (5) MWSS deepwells, the recommendation on the operation and maintenance of these wells are as follows.

(1) Sumulong, Taytay

The control panel of the submersible electric motor and all columns of riser pipes should be replaced. The submersible pump should have a smaller diameter and capacity than the existing one has. Pump should be set deeper because the diameter of the well casing pipes was reduced from 8" to 6" at a depth of 80.77m, and the pumping water level is below this depth when the well was pumped at a discharge rate of 240 l/min. Submersible cable should be replaced because its insulation resistance reading is only 10 megaohms.

The submersible pump that should be installed must be 10 HP, 133mm in diameter, and it should have 115 meters of total dynamic head at 216 l/min of discharge. Twenty (20) columns of 3" x 20' riser pipes should also be installed.

(2) Cogeo No.1, Antipolo

Submersible pump should be replaced because its insulation resistance reading is only 0.5 megaohms, despite Contractor's not finding of any damage during inspection of the dismantled pump assembly.

In the course of the rehabilitation work, the pump setting has been changed from 66m to 78m by using two additional columns of 3" riser pipes and 12m additional submersible cable. The pumping water level was not stable and was still declining when the discharge was 198 l/min.

It is therefore recommended that this well should be operated on a half-day basis, at about 150 l/min of discharge and stopped for the rest of the day.

The pumping water level should always be monitored. Pump condition, especially the bolts, should be carefully maintained.

(3) Cogeo No.6, Antipolo

Submersible pump should be replaced because its insulation resistance reading is only 8 kiloohms and it has a 1x1 cm-size hole at the pump bowl. Two (2) pieces of 3"x20' riser pipes are usable, but 14 pieces of 3"x20' riser pipes and one 1 piece of 3"x20' riser pipe should be re placed. One hundred and one (101) meters of submersible cable are still usable. The pumping water level was not stable and still declining when the discharge was 204 l/min.

Submersible pump which has a capacity of 7.5 HP and 97 meters of total dynamic head at 200 l/min discharge rate should be installed with 16 pieces of 3"x20' riser pipes.

This well should be operated on a half-day basis at a discharge rate of about 150 l/min and be similarly maintained as the Cogeo Antipolo Deepwell No.1.

(4) IBP (Congress) No.3

This well should be abandoned after it has been plugged with cement.This well produces very low water output and has many iron bacteria inside the well. In order to avoid the spread of iron bacteria, and obviate the possibility of infection of another active well through the aquifer, the well should be completely plugged.

(5) Naga Road No.2

Seventeen (17) pcs. of 3"x20' riser pipes formerly used at Tuazon deepwell were installed to replace those of Naga Road Deepwell No.2. It is recommended that the pumping unit be pulled out and checked within two to three years. The pumping water level and discharge rate should be monitored regularly. Pumping facilities should be properly maintained.

TABLE 5.2.1a LIST OF ACTIVE MWSS DEEP WELLS

(as of March 1991)

Well Name Municipality	Actual Condition	Group
ANTIPOLO		
1. M.L. Quezon (Pump £1)		
2. Sto. Nino (Pump £2)		
3. P. Burgos (Pump £3)		
4. Nursery (Pump £4)		
5. Circumferential Road (Pump £5)		
6. Road to Teresa (Pump £6)		
7. Sumulong Elementary School (Pump £7)		
8. San Isidro Elementary School (pump £8)		
9. Ang Tahanan (Pump £9)		
10. Saguinsin (Pump £10)		
11. Cogeo £ 1	Defective pump unit	D-Pump
12. Cogeo £ 2	Defective pump unit	D-Pump
13. Cogeo £ 4		
14. Cogeo £ 5	Defective pump unit	D-Pump
15. Cogeo £ 6	Defective pump unit	D-Pump
CAINTA		
16. San Juan		
17. Gloria-Marick		
18. San Fabian		
19. Mapandan	Abandoned	Others
20. Sto. Domingo	Defective pump unit	D-Pump
TAYTAY		
21. Sumulong	Defective pump unit	D-Pump
22. San Isidro		
23. Sta. Ana Elementary School		
24. Taytay Elementary School		
25. San Victores		
26. Rosario		
27. Bangiad		
SAN MATEO		
28. San Mateo Public Market		
29. Banaba, Ampid		
30. Malanday	Abandoned	Dirty
31. Maly		
32. Dulong Bayan 11	Well caved-in	Caved

TABLE 5.2.1a (CONTINUATION)

Well Name Municipality	Actual Condition	Group
MONTALBAN		
33. San Jose		
34. Manggahan		
35. Aranzazu		
VALENZUELA		
36. T. De Leon		
37. Pasolo Elementary School		
38. Arkong Bato	No operator	Others
MALABON		
39. Catmon	No operator	Others
40. Dampalit	No operation	Others
41. Dona Juana		
NAVOTAS		
42. Merville Subdivision		
43. Dagat Dagatan £ 1	No operation	Others
MUNTINLUPA		
44. Muntinlupa Bliss		
45. Poblacion	Defective Pump unit	D-Pump
46. Tunasan		
47. Putatan		
48. Cupang Elementary School		
49. Alabang Junction	Dirty water yields	Dirty
50. Sucat Elementary School		
PARANAQUE		
51. MIA £ 1		
52. mia £ 3		
53. MIA £ 4		
54. Sucat £ 2		
55. La Huerta		
TAGUIG		
56. Signal Village 11		
57. Upper Bicutan	No operation	Others
58. Signal Village 1	No operation	Others

TABLE 5.2.1a (CONTINUATION)

Well Name Municipality	Actual Condition	Group
LAS PINAS		
59. Naga £ 2	Defective Pump Unit	D-pump
60. Zapote, Las Pinas (under the supervision of Cavite pumping station)	Salty water yields	Salty
PASAY CITY		
61. Maricaban 1	Defective Pump Unit	D-pump
62. Maricaban 11		
63. Maricaban 111	Defective Pump Unit	D-pump
MAKATI		
64. Poblacion		
65. Ecology Village		
66. Ayala £ 1	No operation	Others
67. Forbes Park £ 2		
68. Forbes Park £ 6	Defective Pump Unit	D-pump
69. Forbes park £ 8		
70. Forbes Park £ 9		
71. Forbes Park £ 11	Defective Pump Unit	D-pump
72. Forbes Park £ 12	Defective Pump Unit	D-pump
73. Dasmarinas £ 39		
74. Dasmarinas £ 17	Not yet in operation	Others
PASIG		
75. Barrio Capitolyo		
76. Valle Verde Phase 5	Not yet in operation	Others
QUEZON CITY		
77. Greenmeadows £ 3		
78. Greenmeadows £ 4		
79. Fairview £ 1		
80. Fairview £ 2		
81. Fairview £ 3		
82. Fairview £ 4		
83. Fairview £ 5		
84. IBP Congress £ 2		
85. IBP Cognress £ 3	Recommended for abandon	Dirty
86. IBP Cognress £ 4		
87. Lagro £ 1		
88. Lagro £ 2		
89. Lagro £ 3		
90. Lagro £ 5		
91. Escopa, Project 4		
92. Loyola Grand Villas	No operation	Others

TABLE 5.2.1a (CONTINUATION)

Well Name Municipality	Actual Condition	Group
CAVITE CITY		
93. Samonte Park	Salty water yields	Salty
94. Garita		
95. San Roque		
96. Manalac		
97. Calle Marino		
98. San Nicolas		
99. Bagong Pook	No operator	Others
100. Garcia Extension	No operation	Others
101. Crescini		
102. Rivero		
103. Magcauas		
104. Ejercito		
105. Militar		
106. Antonio		
107. J. Felipe		
BACOOR		
108. Daang Bukid		
109. Poblacion		
110. Balsahan		
111. Combalay		
112. Talaba		
113. Niog		
114. Bacoor Central School		
115. Dulong Bayan		
IMUS		
116. Plaza Garcia		
117. Yengco		
KAWIT		
118. Malamok		
119. Aguinaldo		
120. Josephine Resort		
121. Putol-Sta. Isabel		
ROSARIO		
122. Poblacion		
NOVELETA		
123. Noveleta Elementary School		
124. Noveleta Well Field £ 1		
125. Noveleta Well Field £ 2		
126. Noveleta Well Field £ 3		
127. Noveleta Well Field £ 4		
128. Noveleta Well Field £ 5		
129. Noveleta Well Field £ 6		
130. Noveleta Well Field £ 7		
131. Noveleta Well Field £ 8		

Notes: Blank of actual condition is good condition.

TABLE 5.2.1b LIST OF INACTIVE MWSS DEEP WELLS

(as of March 1991)

Well Name Municipality	Actual Condition	Group
CAINTA		
1. Sumulong Highway	For rehab	Rehab
2. Poblacion	Frequent tripping of unit	D-pump
MARIKINA		
3. SSS Vill £ 1	Test tun	Stand-by
4. SSS Vill £ 2	Under rehabilitation program	Rehab
5. SSS Vill £ 3	Test run	Stand-by
6. SSS Vill £ 4	Test run	Stand-by
7. SSS Vill £ 5.	Test run	Stand-by
8. SSS Vill £ 6	Under rehabilitation program	Rehab
9. SSS Vill £ 7	Under rehabilitation program	Rehab
10. SSS Vill £ 8	Test run	Stand-by
11. SSS Vill £ 9	Test run	Stand-by
12. SSS Vill £ 10	Test run	Stand-by
13. East Drive, SSS Village	Test run	Stand-by
14. Industrial Valley	Insufficient water pressure	Adequate
15. Concepcion -	- do -	Adequate
MALABON		
16. Santolan	Adequate water supply	Adequate
17. Niogan	Stand-by	Stand-by
18. Panghulo	Stand-by	Stand-by
VALENZUELA		
19. Kadiwa Center	Sufficient surface water	Adequate
20. Tamaraw Hills	- do -	Adequate
21. Constantino	- do -	Adequate
22. Marulas Elem. School	- do -	Adequate
CALOOCAN CITY		
23. Banal St., Bagong Barrio	Stand-by	Stand-by
24. katarungan St., Bagong Barrio	Stand-by	Stand-by
NAVOTAS		
25. D. Dagatan £ 2	Sufficient surface water	Adequate
26. D. Dagatan £ 3	- do -	Adequate
27. D. Dagatan £ 4	- do -	Adequate
28. D. Dagatan £ 5	- do -	Adequate
29. D. Dagatan £ 6	- do -	Adequate
30. D. Dagatan £ 7	- do -	Adequate
31. D. Dagatan £ 8	- do -	Adequate

TABLE 5.2.1b (CONTINUATION)

Well Name Municipality	Actual Condition	Group
PARANAQUE		
32. San Dionisio	Sufficient water pressure	Adequate
33. Sucat £1	Sufficient water pressure	Adequate
TAGUIG		
34. Maharlika	operated by Muslim	Others
LAS PINAS		
35. Poblacion	defective pumping unit since 8/19/86	D-pump
36. Manuyo	For Rehab	Rehab
37. Ilaya	For Rehab	Rehab
PASAY CITY		
38. Henares Cpd.	Sufficient surface water	Adequate
MAKATI		
39. Ayala £ 8	defective unit	D-pump
40. Ayala £ 10A	Under rehabilitation program	Rehab
41. Ayala £ 11	Under rehabilitation program	Rehab
42. Ayala £ 19	Under rehabilitation program	Rehab
43. Ayala £ 20	Under rehabilitation program	Rehab
44. Ayala £ 22	Under rehabilitation program	Rehab
45. Ayala £ 25	Under rehabilitation program	Rehab
46. Ayala £ 28	Under rehabilitation program	Rehab
47. Ayala £ 29	Under rehabilitation program	Rehab
48. Ayala £ 31	Under rehabilitation program	Rehab
49. Ayala £ 33	Under rehabilitation program	Rehab
50. Ayala £ 35	Under rehabilitation program	Rehab
51. Magallanes £ 5	Under rehabilitation program	Rehab
52. Magallanes £ 15	Under rehabilitation program	Rehab
53. Magallanes £ 41	Under rehabilitation program	Rehab
54. Magallanes £ 42	Under rehabilitation program	Rehab
55. Dasmarinas £ 9	Under rehabilitation program	Rehab
56. Dasmarinas £ 14	Under rehabilitation program	Rehab
57. Dasmarinas £ 40	Under rehabilitation program	Rehab
58. Forbes Park £ 3	Defective unit & Sufficient water pressure	D-pump
59. Forbes Park £ 10	- do -	D-pump
60. Forbes Park £ 13	- do -	D-pump
61. Forbes Park £ 14	- do -	D-pump

TABLE 5.2.1b (CONTINUATION)

Well Name Municipality	Actual Condition	Group
PASIG		
62. Santolan	Sufficient surface water	Adequate
QUEZON CITY		
63. IBP £ 1	Defective motor	D-pump
64. Congressional Village £8	For Rehab	Rehab
65. D. Tuazon Pumping Station	Sufficient water	Adequate
66. D. Tuazon Elem. School	Sufficient water	Adequate
67. Lagro £4	Defective motor	D-pump
68. GSIS Village	Sufficient water pressure	Adequate
69. Bagbag, Novaliches	- do -	Adequate
70. Poblacion, Novaliches	- do -	Adequate
71. North Fairview £ 8		Others
KAWIT		
72. Binakayan, Kawit	Stand-by unit	Stand-by
73. Bo. Wawa	Stand-by unit	Stand-by
PASIG		
74. Wawa, Rosario, Cavite	Stand-by-unit	Stand-by
75. Bo. Sapa	- do -	Stand-by

TABLE 5.2.1c LIST OF ABANDONED MWSS DEEP WELLS

(as of March 1991)

Well Name Municipality	Actual Condition	Group
ANTIPOLO		
1. Cogeo £ 3	Well caved in	Caved-in
CAINTA		
2. Irma	Non potable water yields	Dirty
3. Felix	Non potable water yields	Dirty
TAYTAY		
4. Isagani	Very low water output	D-pump
MARIKINA		
5. San Roque	Adequate Water Supply	Adequate
6. Malanday	Availability of surface water	Adequate
SAN MATEO		
7. Ampid 1	Non potability water yields	Dirty
8. Sta. Ana	Now operational	Others
9. Ampid 11	Non potability water yields	Dirty
MONTALBAN		
10. Geronimo	Pumping unit was not installed	D-pump
11. Poblacion	Pumping unit was not installed	D-pump
VALENZUELA		
12. Malinta	No available data	Others
MALABON		
13. Bo. Hulong Duhat 1	No more existing well	Others
14. Bo. Hulong Duhat 11	No more existing well	Others
15. Dampalit, old well	Cemented, Salty	Salty
CALOOCAN CITY		
16. Pasmon Tala	Clogged	Caved-in
MANILA		
17. Baluto, Tondo	Salty water yields	Salty
18. Aduana, Intramuros	Old well/clogged	Caved-in
19. Muralla, Intramuros	Old well/clogged	Caved-in

TABLE 5.2.1c (CONTINUATION)

Well Name Municipality	Actual Condition	Group
PARANAQUE		
20. Sto. Nino	Salty water yields	Salty
21. Sukat £ 3	Salty water yields	Salty
22. MIA £ 2	Salty water yields	Salty
23. MIA £ 3	Salty water yields	Salty
24. MIA £ 4	Salty water yields	Salty
LAS PINAS		
25. Naga £ 1	Salty water yields	Salty
26. Las Pinas Elem. School	Salty water yields	Salty
27. Pulang Lupa £ 2	Salty water yields	Salty
PATEROS		
28. Fort Bonifacio	Salty water yields	Salty
29. San Pedro	Old well/cemented	Salty
TAGUIG		
30. Tipas	Salty water yields	Salty
31. Tuktukan	Salty water yields	Salty
32. Ususan	Salty water yields	Salty
PASAY CITY		
33. School of Deaf	Availability of surface water	Adequate
MAKATI		
34. Forbes Park £ 15	Non potable water yields	Dirty
PASIG		
35. Pasig Market	Clogged/cemented	Caved-in
36. dela Paz	Clogged	Caved-in
MANDALUYONG		
37. National Mental Hospital £ 1	Old well/ Availability of surface water	Adequate
38. National Mental Hospital £ 2	Old well/ Availability of surface water	Adequate
39. MWSS Bliss, Bgy. Hulo	Availability of surface water	Adequate
CAVITE CITY		
40. R. Palma	Well caved-in	Caved-in
41. M. Castro	Salty water yields	Salty
42. Dalahican	Well is almost dry	Dry
43. Del Trabajo	Well caved-in	Caved-in
44. Paterno St.	Well caved-in	Caved-in
45. Public Market	Well caved-in	Caved-in
46. Hermanos St.	Well caved-in	Caved-in

TABLE 5.2.1c (CONTINUATION)

Well Name Municipality	Actual Condition	Group
BACOOR		
47. Banalo	Salty water yields	Salty
48. Wawa	Well is almost dry	Dry
IMUS		
49. Nueno	Well caved-in	Caved-in
50. Topacio Elem. School	Well is almost dry	Dry
51. Satorre St.	Clogged/Well caved-in	Caved-in
KAWIT		
52. Tirona	Well caved-in	Caved-in

TABLE 5.2.2 WELL CONDITIONS OF MWSS DEEP WELLS

(NUMBER OF WELLS)

WELL CONDITIONS	STATUS			
	ACTIVE	INACTIVE	ABANDONED	TOTAL
IN GOOD CONDITION	99	0	0	99
DAMAGED WELLS				
Defective unit	13	9	3	25
Yields salty water	2	0	17	19
Well caved-in	1	0	14	15
Yields dirty water	3	0	5	8
Well is almost dry	0	0	3	3
TOTAL	19	9	42	70
STAND BY				
Stand by	0	16	0	16
Under Rehabilitation Program	0	25	0	25
Adequate surface water supply	0	23	6	29
TOTAL	0	64	6	70
OTHERS	13	2	4	19
GRAND TOTAL	131	75	52	258

TABLE 5.2.3 PRESENT STATUS OF MWSS DEEPWELLS (31 MAY 1991)

(UNIT: NUMBER OF WELLS)

MUNICIPALITY	Pumping Rate (l.p.s.)	ACTIVE WELLS			Inactive Wells	Abandoned Wells	EXISTING WELLS		
		Good	Damaged	Total			Good	No Good	Total
ANTIPOLO	153.29	11	4	15	0	1	11	5	16
BACOOR	74.00	8	0	8	0	2	8	2	10
CALOOCAN	0.00	0	0	0	2	1	0	3	3
CAINTA	56.36	3	2	5	2	2	3	6	9
CAVITE	92.59	12	3	15	0	7	12	10	22
IMUS	24.33	2	0	2	0	3	2	3	5
KAWIT	51.62	4	0	4	2	1	4	3	7
LAS PINAS	18.08	0	2	2	3	3	0	8	8
MANDALUYONG	0.00	0	0	0	0	3	0	3	3
MAKATI	95.77	6	5	11	23	1	6	29	35
MALABON	8.67	1	2	3	3	3	1	8	9
MANILA	0.00	0	0	0	0	3	0	3	3
MARIKINA	0.00	0	0	0	13	2	0	15	15
MONTALBAN	48.75	3	0	3	0	2	3	2	5
MUNTINLUPA	72.84	5	2	7	0	0	5	2	7
NAVOTAS	5.05	1	1	2	7	0	1	8	9
NOVELETA	88.38	9	0	9	0	0	9	0	9
PARANAQUE	33.09	5	0	5	2	5	5	7	12
PASAY	39.75	1	2	3	1	1	1	4	5
PASIG	3.25	1	1	2	1	2	1	4	5
PATEROS	0.00	0	0	0	0	2	0	2	2
QUEZON	191.24	14	2	16	9	0	14	11	25
ROSARIO	12.67	1	0	1	2	0	1	2	3
SAN JUAN	0.00	0	0	0	0	0	0	0	0
SAN MATEO	54.33	3	2	5	0	3	3	5	8
TAGUIG	10.00	1	2	3	1	3	1	6	7
TAYTAY	65.19	6	1	7	0	1	6	2	8
VALENZUELA	11.59	2	1	3	4	1	2	6	8
TOTAL	1210.84	99	32	131	75	52	99	159	258

Note: NO GOOD - No operational or no good conditioned wells

TABLE 5.2.4 WELLS UNDER UNSATISFACTORY CONDITIONS

(UNIT: NUMBER OF WELLS)

MUNICIPALITY	TYPE OF CAUSE OF DAMAGE															ANOTHER REASON				OTHERS			TOTAL			GT
	D PUMP			SALTY			CAVED-IN			DIRTY			DRY			STAND	REHAB	ADEQUATE		OTHERS			TOTAL			
	A	I	Ab	A	I	Ab	A	I	Ab	A	I	Ab	A	I	Ab	I	I	I	Ab	A	I	Ab	A	I	Ab	
ANTIPOLO	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	5
BACOOR	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	2
CALOOCAN	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	1	3
CAINTA	1	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	1	0	0	2	2	2	6
CAVITE	0	0	0	1	0	1	0	0	5	0	0	0	0	0	1	0	0	0	0	2	0	0	3	0	7	10
IMUS	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	3
KAWIT	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	1	3
LAS PINAS	1	1	0	1	0	3	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	3	3	8
MANDALUYONG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	3
MAKATI	3	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	18	0	0	2	0	0	5	23	1	29
MALABON	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	1	0	2	0	2	2	3	3	8
MANILA	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
MARIKINA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	3	2	2	0	0	0	0	13	2	15
MONTALBAN	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
MUNTINLUPA	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2
NAVOTAS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	1	0	0	1	7	0	8
NOVELETA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PARANAQUE	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	5	7
PASAY	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	2	1	1	4
PASIG	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	1	0	0	1	1	2	4
PATEROS	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
QUEZON	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	5	0	1	1	0	2	9	0	11
ROSARIO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	2
SAN JUAN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SAN MATEO	0	0	0	0	0	0	1	0	0	1	0	2	0	0	0	0	0	0	0	0	0	1	2	0	3	5
TAGUIG	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	2	1	3	6
TAYTAY	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	2
VALENZUELA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	0	1	1	4	1	6
TOTAL	13	9	3	2	0	17	1	0	14	3	0	5	0	0	3	16	25	23	6	13	2	4	32	75	52	159
G.T.	25			19			15			8			3			16	25	29		19			159			159

Notes:

- D PUMP - Defective pump/ motor unit
- SALTY - Salty water yields
- CAVED-IN - Well caved-in
- DIRTY - Dirty Water yields
- DRY - Well is almost dry
- STAND - Stand-by
- REHAB - Recommended for rehabilitation
- ADEQUATE - Adequate water supply
- A - Active wells
- I - Inactive wells
- Ab- Abandoned wells

TABLE 5.3.1 WELLS FOR EXPERIMENTAL REHABILITATION WORK

Well Name	Municipality	Status	Total Depth	Casing Pipe Position	Size	Well Screen Position	Exist. Pump Set.	Exist. Pump Cap.	Test Pump Set.	Test Pump Spec.	Pump After Rehab. Set.	Pump After Rehab. Spec.
Cogeo Antipolo No.1	Antipolo	In-active	91.44m	0m-9.75m 9.75-91.44	8" 6"	64m-87.78m	66m	7.5 Hp	78m	SP8-21 7.5HP OD 133	3" 78m	Existing Pump Installed
Sumulong	Taytay	In-active	202.69	0-80.77 80.77-202.7	8" 6"	Unknown	75	30	78m 120m	30 HP 10 HP OD 133mm	NO	No Pump Installed
Naga Road No.2	Las Pinas	Active	243.84	0-243.84	10"	103.63-121.91 128.01-158.49 164.59-170.68 182.88-213.36 219.45-237.74	78	30	120m 102m	SP45-12 30HP OD 150	3" 102m	Existing Pump Installed
IBP (Congress) No.3	Quezon City	In-Active	202.69	0-80 80-202.69	10" 8"	87-99 103-122 129-144 151-166 173-197	120	20	108	20 HP 9 stage OD 140	NO	No Pump Installed
Cogeo Antipolo No.6	Antipolo	In-Active	117.35	0-91.44	8"	91.44-177.35 bore hole	99	20	90	20 HP 9 stage OD 140	NO	No Pump installed

TABLE 5.3.2 RESULTS OF EXPERIMENTAL REHABILITATION WORK

	Sumulong Taytay	I B P No. 3	Cogeo ATP No.1	Cogeo ATP No.6	Naga Road No.2
Well Depth (m)	202.68	202.69	91.44	117.35	243.84
Accumulation (m)	5.68	32.69	4.44	11.35	0
Static Water Level (m)	58.00	39.30	7.25	11.50	55.40
EC-T Logging					
ECt (uS/cm)	684-961	92-144	335-390	316-342	517-9585
T (. C)	30.2-30.7	27.7-28.1	25.8-27.10	26.4-27.50	30.0-34.20
Micro Current	*	*	*	*	
1st Pumping Test					
Discharge Rate (m3/d)	285	(25.9)	285	294	544
Drawdown (m)	30.00	(70.7)	48.80	68.40	17.70
Specific Capacity (m2/d)	9.50	(0.37)	5.84	4.30	30.70
Transmissivity (m2/d)					
Continuous - Theis	14.6	-	2.83	1.33	36.9
Continuous - Jacob	15.2	-	5.27	7.19	31.1
Recovery - Jacob	11.4	-	32.6	19.8	29.2
Storage Coeff.	7.65x10-5	-	1.19	2.26	3.18x10-4
Aquifer Loss Coeff. (day/m2)	5.40x10-2	-	8.00x10-3	0.0	3.2x10-2
Well Loss Coeff (day2/m5)	1.65x10-4	-	2.55x10-4	8.0x10-4	6.2x10-6
2nd Pumping Test					
Discharge Rate (m3/d)	328	(54.4)	285	294	518
Drawdown (m)	25.10	(70.70)	19.50	64.20	17.07
Specific Capacity (m2/d)	13.07	(0.77)	14.60	4.58	31.9
Transmissivity (m2/d)					
Continuous - Theis	14.6	-	4.37	1.34	36.6
Continuous - Jacob	4.10	-	11.1	4.88	31.1
Recovery - Jacob	44.8	-	17.4	15.2	31.9
Storage Coeff.	1.03x10-4	-	2.05	3.32	3.90x10-4
Aquifer Loss Coeff. (day/m2)	2.6x10-2	-	2.0x10-3	0.0	2.95x10-2
Well Loss Coeff (day2/m5)	1.43x10-4	-	2.10x10-4	7.35x10-4	6.2x10-6

TABLE 5.3.3 MEASUREMENT OF MICRO-CURRENT AT NAGA ROAD NO. 2, LAS PIÑAS

step		F1	F2	F3	F4	F5	Total
	screen position	103.63m	128.01m	164.59m	182.88m	219.45m	
		-121.91m	-158.49m	-170.68m	-213.36m	-237.74m	
	length	18.28m	30.48m	6.09m	30.48m	18.29m	103.62m
1st step drawdown test							
1	V cm/s	3.36	0.0	0.0	0.0	0.0	3.36
	Q l/m	102	0	0	0	0	102
	%	100	0	0	0	0	100
2	V cm/s	1.12	5.6	0.0	0.0	0.0	6.72
	Q l/m	34.2	169.8	0	0	0	204
	%	16.7	83.3	0	0	0	100
3	V cm/s	1.78	4.8	3.3	0.0	0.0	9.88
	Q l/m	54	145.8	100.2	0	0	300
	%	18.0	48.6	33.4	0	0	100
4	V cm/s	2.95	5.3	4.2	0.0	0.0	12.45
	Q l/m	90	160.8	127.2	0	0	378
	%	23.7	42.6	33.7	0	0	100
2nd step drawdown test							
1	V cm/s	0.56	2.80	0.0	0.0	0.0	3.36
	Q l/m	17	85	0	0	0	102
	%	16.7	83.3	0	0	0	100
2	V cm/s	1.42	2.3	0.9	2.1	0.0	6.72
	Q l/m	43.1	69.8	27.3	63.8	0	204
	%	21.1	34.2	13.4	31.3	0	100
3	V cm/s	0.98	6.0	1.1	1.8	0.0	9.88
	Q l/m	29.8	182.3	33.4	54.6	0	300
	%	9.9	60.8	11.1	18.2	0	100
4	V cm/s	2.15	6.3	3.4	0.0	0.0	11.85
	Q l/m	65.3	191.4	103.3	0	0	360
	%	18.1	53.2	28.7	0	0	100

NOTE: WELL DEPTH : 243.84M
CASING SIZE : 10" (O.D. : 25.4 CM)

TABLE 5.3.4 EXISTING PUMPING FACILITIES AND STATUS

WELL NAME	SUMULONG TAYTAY	IBP NO.3	COGEO ATP NO.1	COGEO ATP NO.6	NAGA ROAD NO.2
Control panel	Defective	Replaced some parts	Good	Good	Good
Submersible Cable	Low Resistance	good	Low Resistance	Good	Good
Riser Pipes	Rusted	Rusted	Good	2 pcs are good another 14.5 pcs were rusted	Rusted
Submersible Pump and	Good	Took out plastics from pump suction	Good	10x10 mm hole observed	Took out soft scales from pump impleller
Motor	Newly	Good	Low resistance	Low resistance	Good
Before Rehab.	Inactive	Inactive	Inactive	Inactive	Active
After Rehab.	No pump	No pump	Active	No pump	

Sumulong Taytay

Grundfos pump model - sp 25-20 (without 2 bowl assembly)
Century submiersible motor 30 Hp
11 pcs 3"0 riser pipes and 1.5 pcs 4"0 riser pipes

IBP NO.3

Gruppo Industriale Ercole pump
motor 20 Hp
20 pcs 3"0 riser pipes

Cogeo Antipolo No.1

Grundfos pump model - sp 16-10
Franklin Electric motor 7.5 Hp
11 pcs 3"0 riser pipes

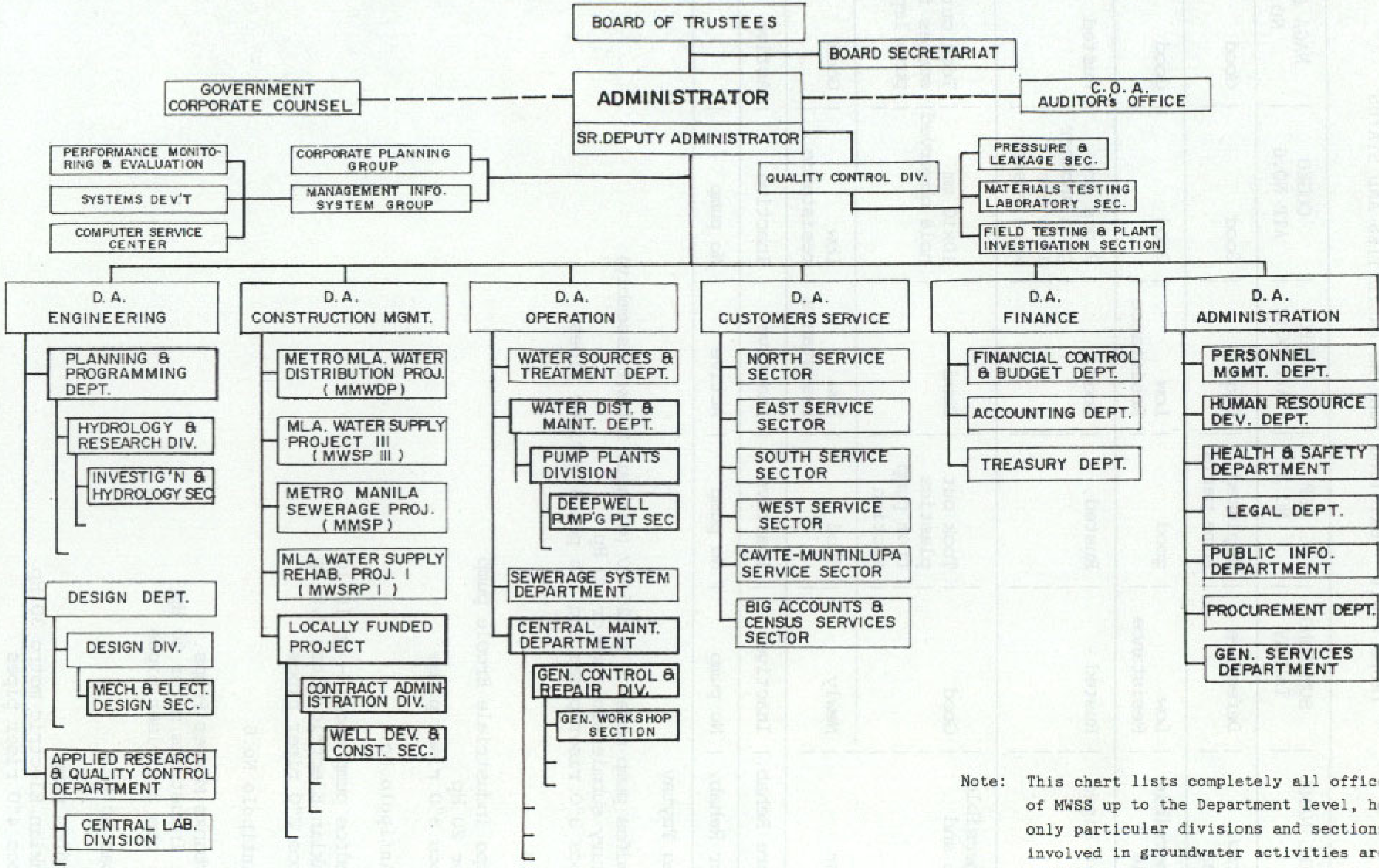
Cogeo Antipolo No.6

Fairbanks Morses Pumps
Colt Industries motor 20 Hp
16.5 pcs 3"0 riser pipes

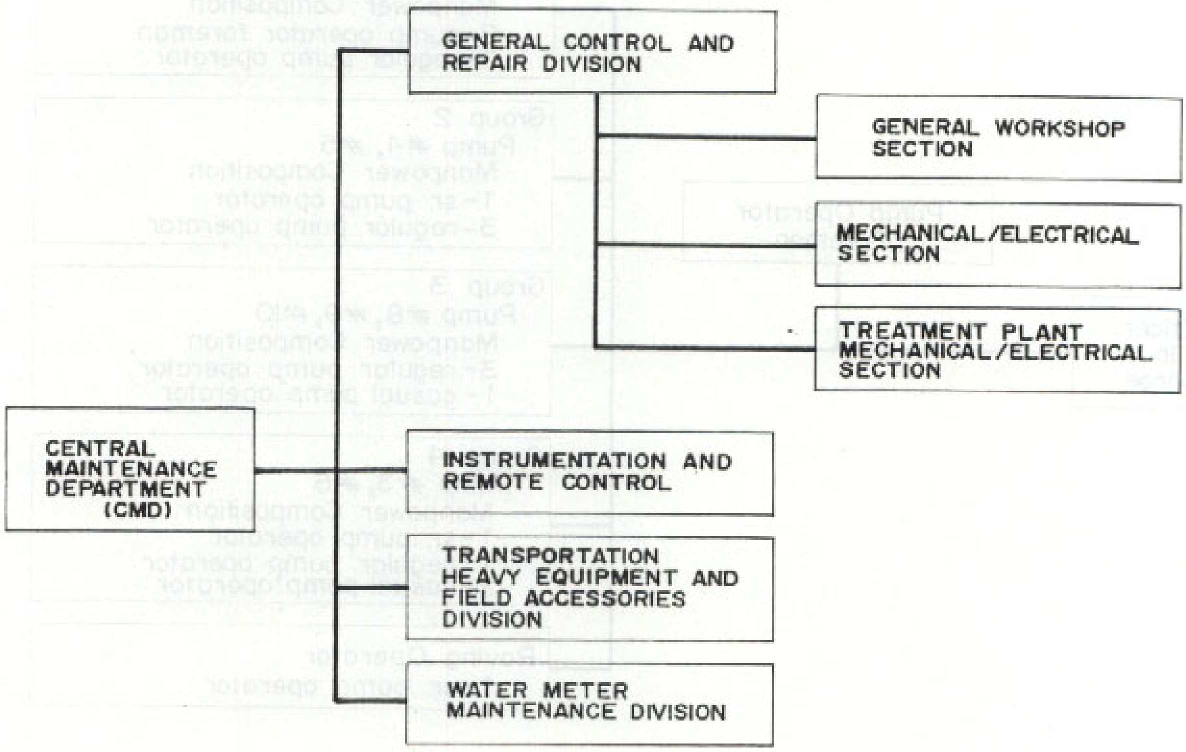
Naga Road No.2

Grundfos pump
Franklin Electric motro 30 Hp
13 pcs 4"0 riser pipes

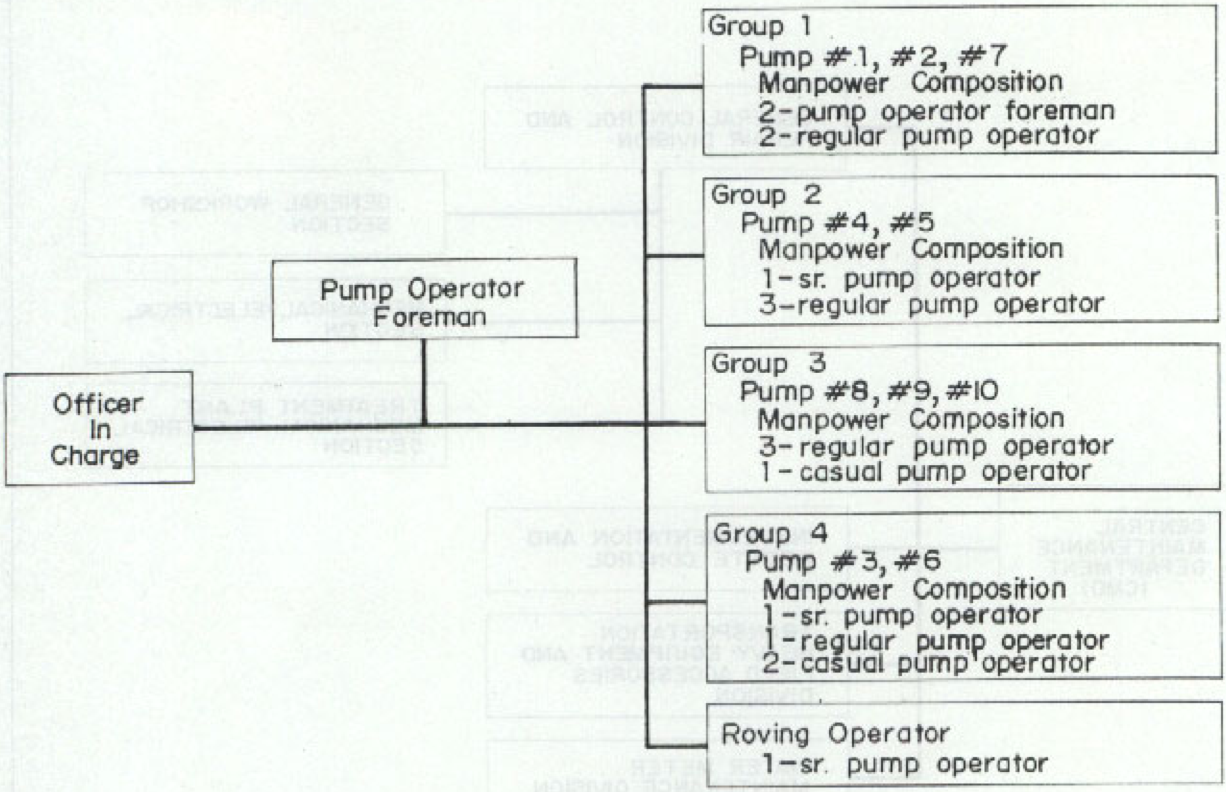
FIG. 5.1.1 MWSS ORGANIZATIONAL CHART



Note: This chart lists completely all offices of MWSS up to the Department level, however, only particular divisions and sections involved in groundwater activities are included in the chart



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 5.1.2 CENTRAL MAINTENANCE DEPARTMENT ORGANIZATION
JAPAN INTERNATIONAL COOPERATION AGENCY	



NOTE : The three (3) pump operator foremen were actually performing pump operational duties.

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 5.1.3 OPERATION AND MAINTENANCE ORGANIZATION FOR ANTIPOLO EXISTING WELLS
JAPAN INTERNATIONAL COOPERATION AGENCY	

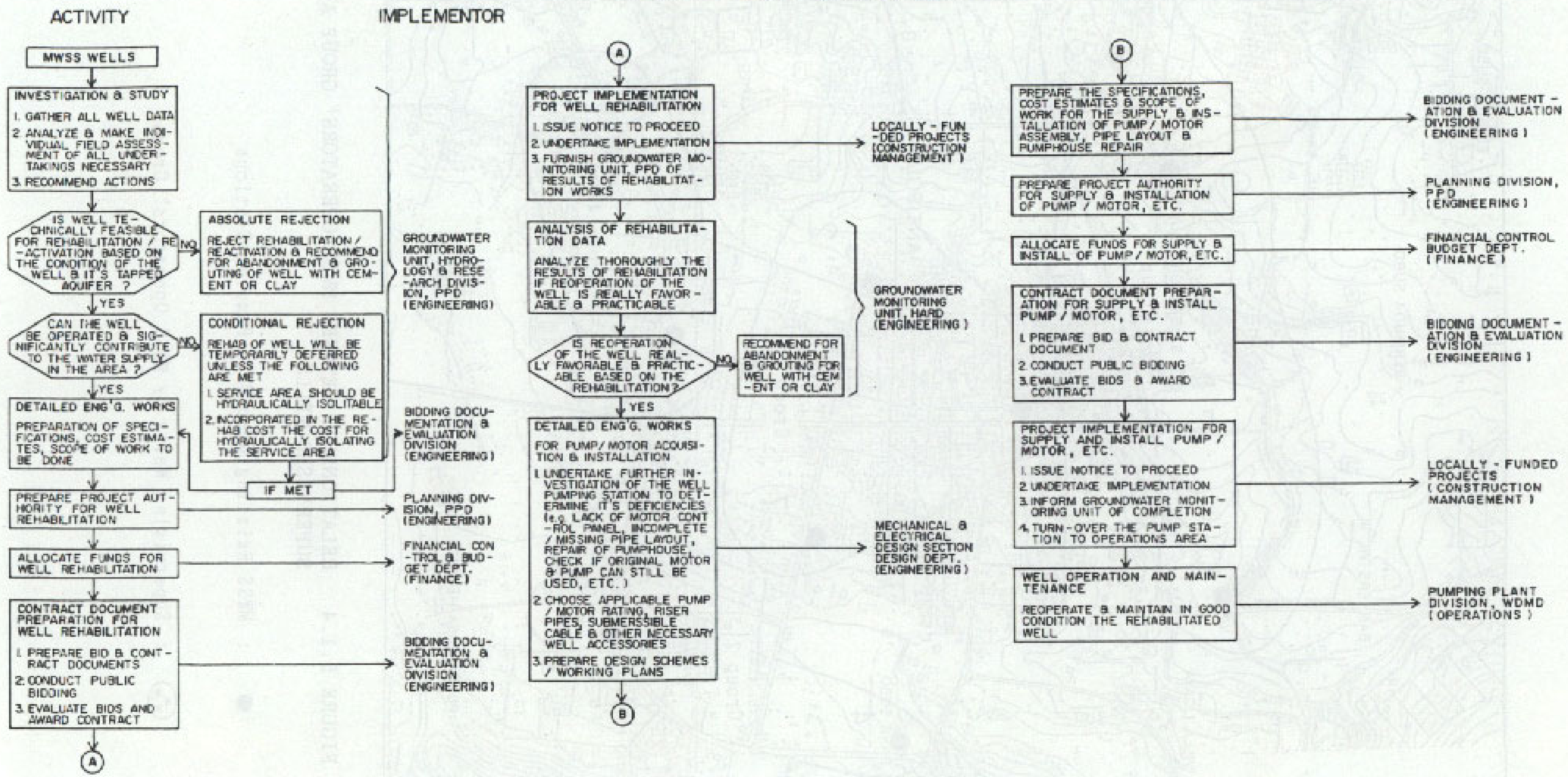
FIGURE 5.1.4 RELATIONSHIP BETWEEN MWSS OPERATORS' GROUP AND SUPERVISED WELLS

● : MWSS Existing Deep Well Pumping Stations

(∴) : Supervising Wells by MWSS Operators' Groups

REHABILITATION OF EXISTING MWSS WELLS

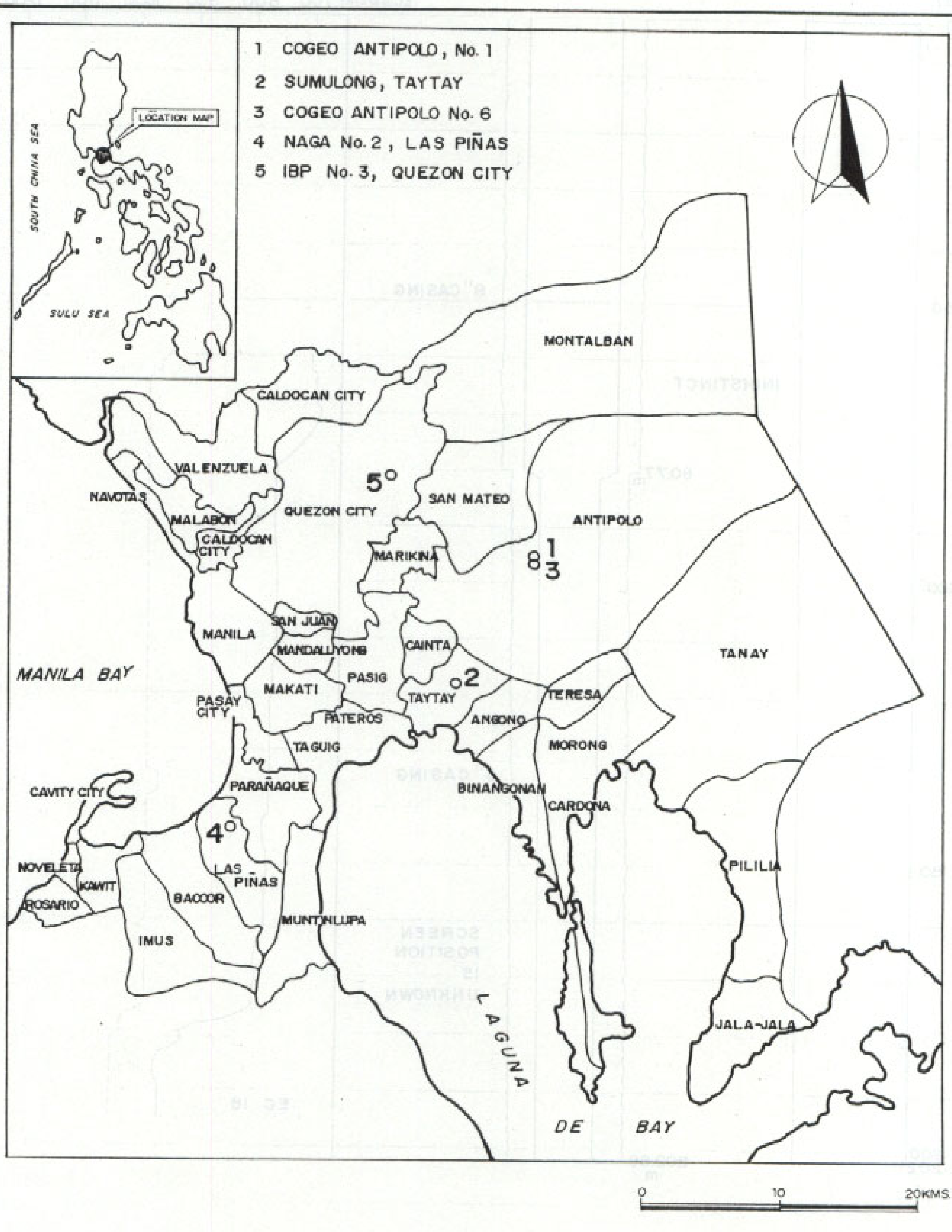
REVISED
WORK FLOW DIAGRAM



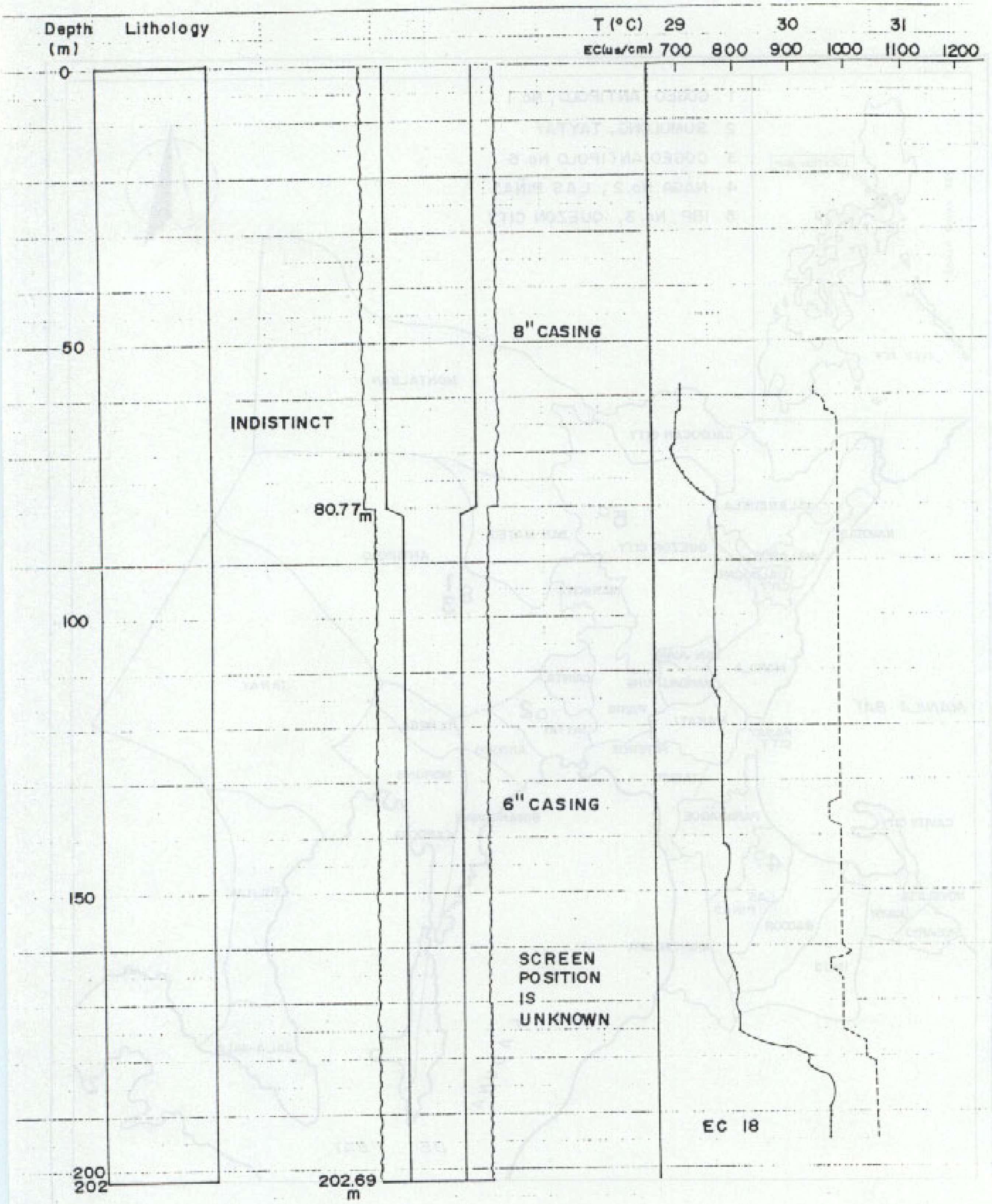
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY

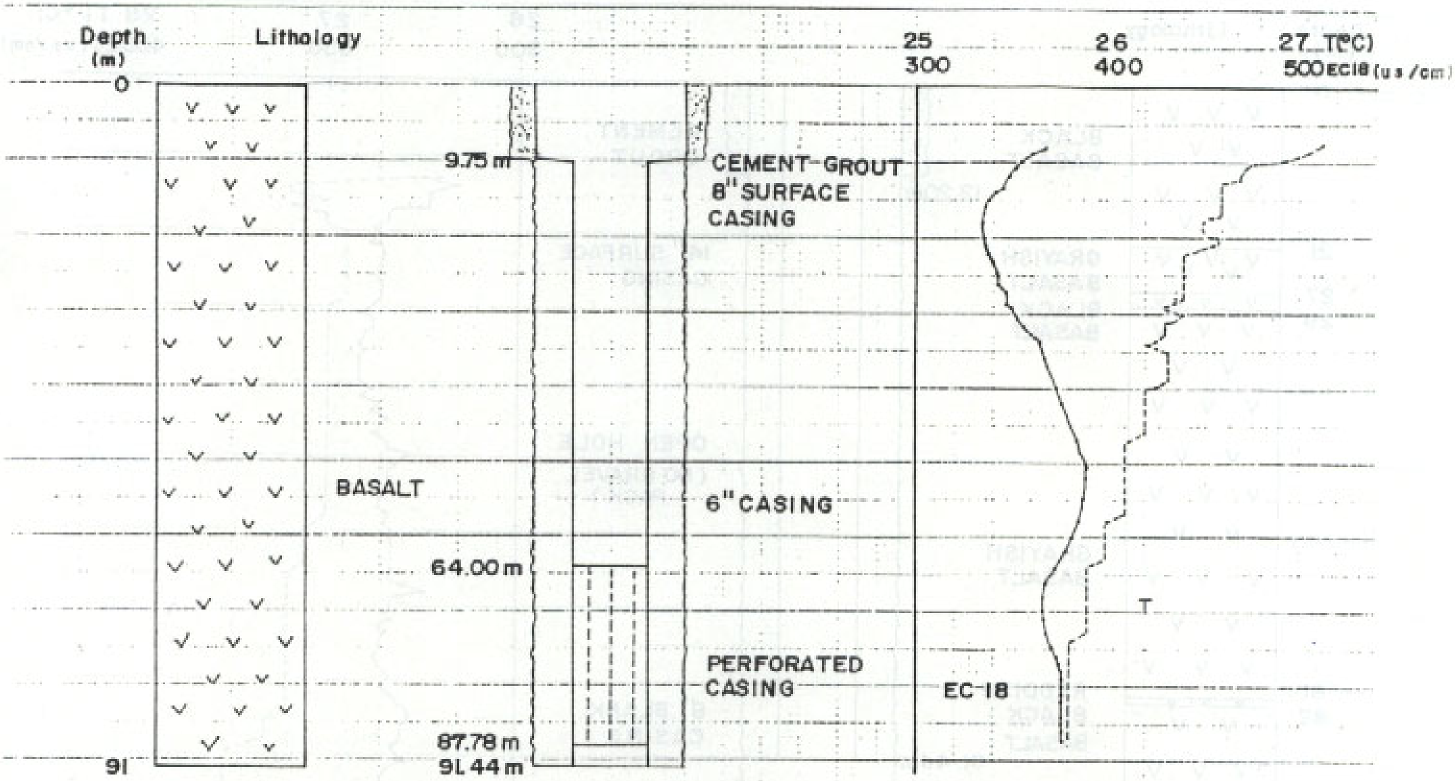
FIGURE 5.1.5
WORK FLOW DIAGRAM



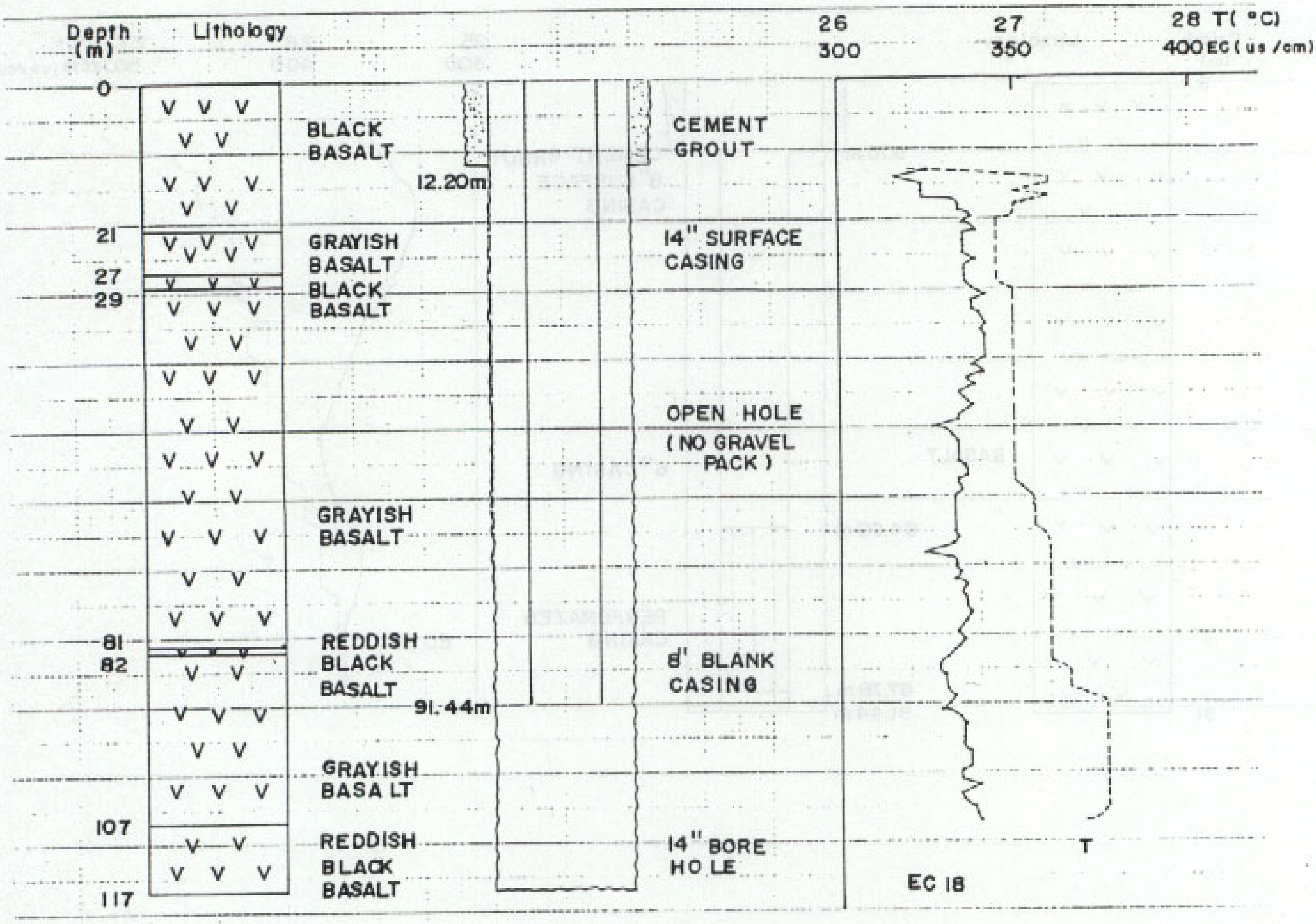
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 5.3.1
JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION MAP OF MWSS WELLS FOR REHABILITATION



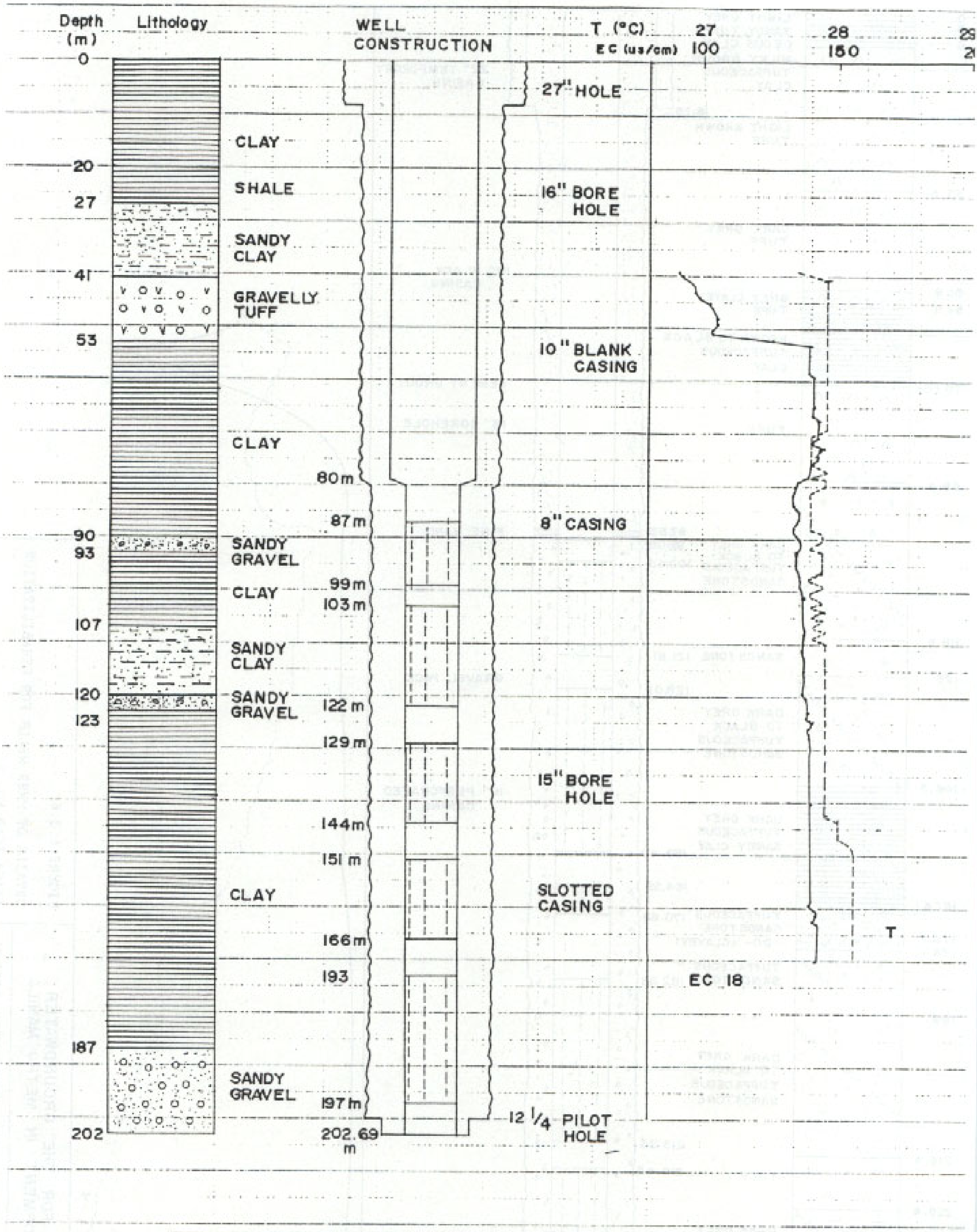
STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA JAPAN INTERNATIONAL COOPERATION AGENCY	FIGURE 5.3.2 DETAILS OF MWSS WELLS FOR REHABILITATION (SUMULONG, TAYTAY)



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 5.3.3
JAPAN INTERNATIONAL COOPERATION AGENCY	DETAILS OF MWSS WELLS FOR REHABILITATION (COGEO, ANTIPOLO NO. 1)



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 5.3.4 DETAILS OF MWSS WELLS FOR REHABILITATION (COGEO, ANTIPOLO NO. 6)
JAPAN INTERNATIONAL COOPERATION AGENCY	



STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA	FIGURE 5.3.5 DETAILS OF MWSS WELLS FOR REHABILITATION (IBP NO. 3)
JAPAN INTERNATIONAL COOPERATION AGENCY	

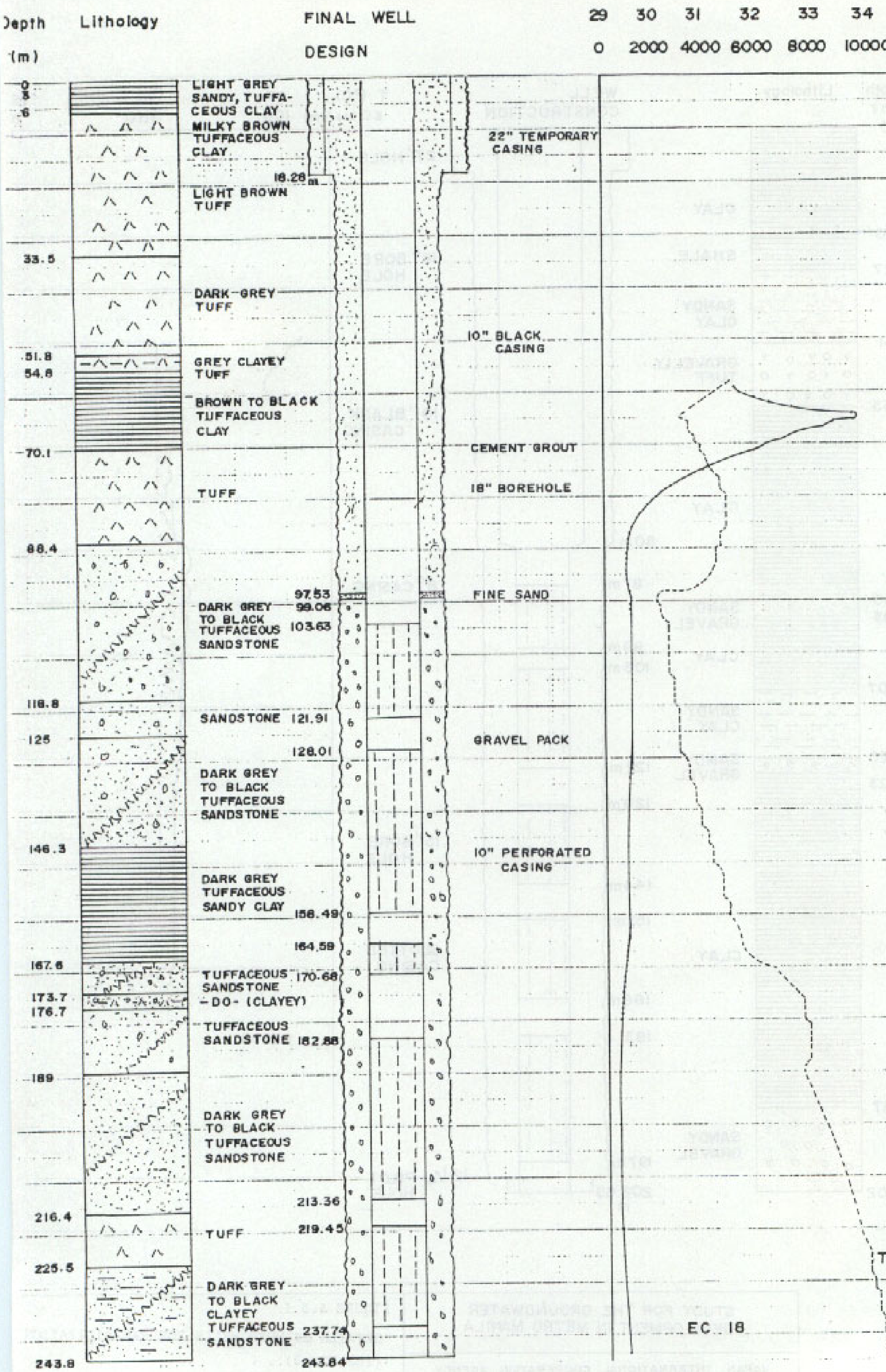


FIGURE 5.3.6 DETAILS OF MWSS WELLS FOR REHABILITATION (NAGA ROAD NO. 2)

STUDY FOR THE GROUNDWATER DEVELOPMENT IN METRO MANILA

JAPAN INTERNATIONAL COOPERATION AGENCY