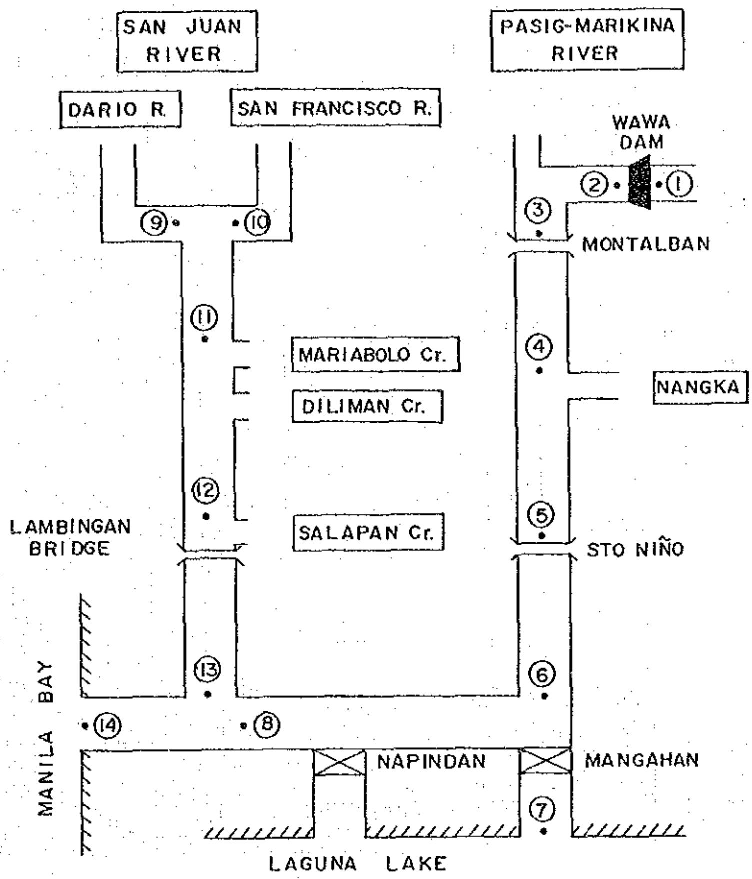

UNIT : m^3/s

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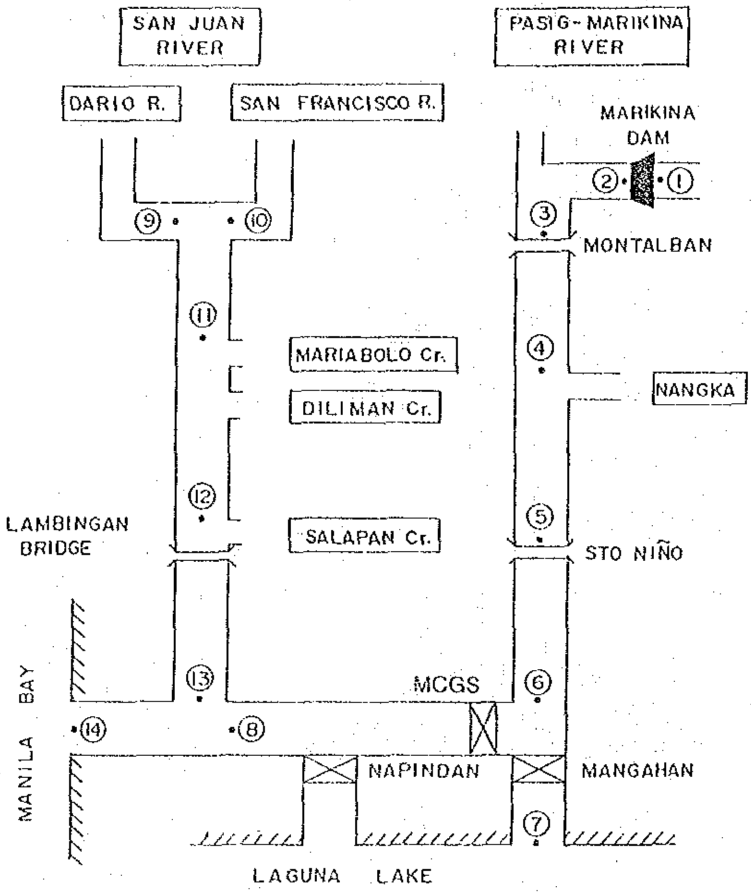
④	3050	2800	2550	2400	2100	1750	1400
⑤	3500	3200	2900	2800	2400	2050	1600
⑥	3500	3200	2900	2800	2400	2050	1600
⑦	2250	2000	1850	1750	1450	1200	900
⑧	1200	1100	1000	950	850	750	600
⑨	250	230	230	220	210	200	190
⑩	390	380	370	350	330	320	310
⑪	630	600	600	570	540	520	490
⑫	820	790	780	750	700	670	610
⑬	900	860	850	810	740	700	630
⑭	1500	1350	1200	1150	1000	900	750

W/O MARIKINA DAM & W/O MCGS

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

PROBABLE DISCHARGE DISTRIBUTION IN 2020 (SAN JUAN AND PASIG-MARIKINA) Fig. 2-6-11 (1/6)



UNIT : m³/s

Point No.	RETURN PERIOD						
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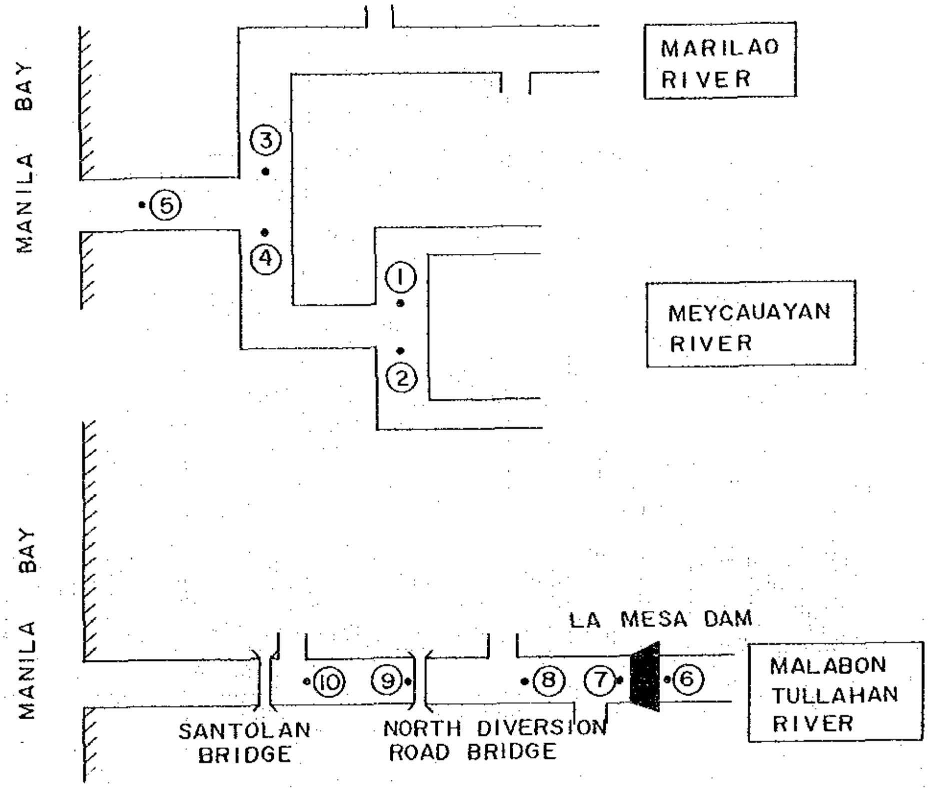
②	1500	1400	1300	1250	1200	1000	900
③	2050	1900	1800	1700	1550	1300	1200
④	2600	2400	2200	2100	1900	1600	1400
⑤	2900	2700	2500	2400	2100	1800	1550
⑥	2900	2700	2500	2400	2100	1800	1550
⑦	2400	2000	2200	1900	1600	1300	1050
⑧	500	290	100	80	65	50	30
⑨	250	230	230	220	210	200	190
⑩	390	380	370	350	330	320	310
⑪	630	600	600	570	540	520	490
⑫	820	790	780	750	700	670	610
⑬	900	860	850	810	740	700	630
⑭	950	860	800	750	660	570	420

W/ MARIKINA DAM & W/ MCGS

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

PROBABLE DISCHARGE DISTRIBUTION IN 2020 (SAN JUAN AND PASIG-MARIKINA) Fig 2-6-11 (2/6)



UNIT : m^3/s

Point No.	RETURN PERIOD						
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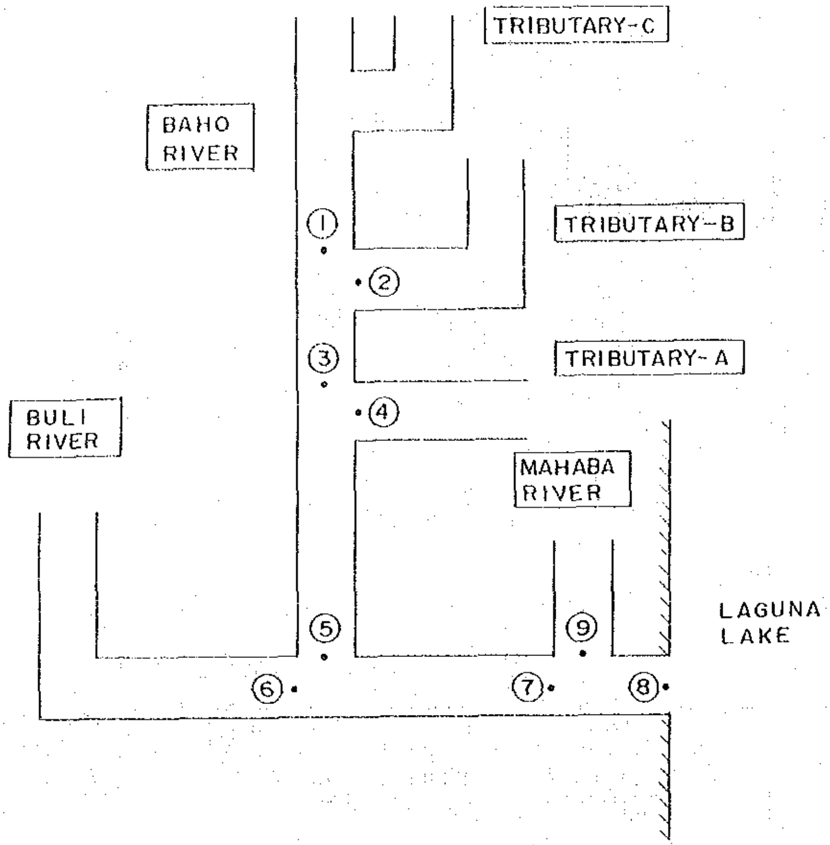
①	320	290	270	250	230	210	180
②	540	500	470	440	400	360	320
③	770	710	640	590	510	430	340
④	600	560	520	490	440	400	350
⑤	1220	1070	1010	940	810	700	560
⑥	400	370	360	340	310	290	250
⑦	240	220	210	200	180	160	140
⑧	330	300	290	270	240	220	190
⑨	480	430	420	390	340	300	240
⑩	520	470	450	420	360	320	250

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

PROBABLE DISCHARGE DISTRIBUTION IN 2020 (MEYCAUAYAN AND MALABON-TULLAHAN) Fig. 2-6-11 (3/6)



UNIT : m³/s

Point No.	RETURN PERIOD						
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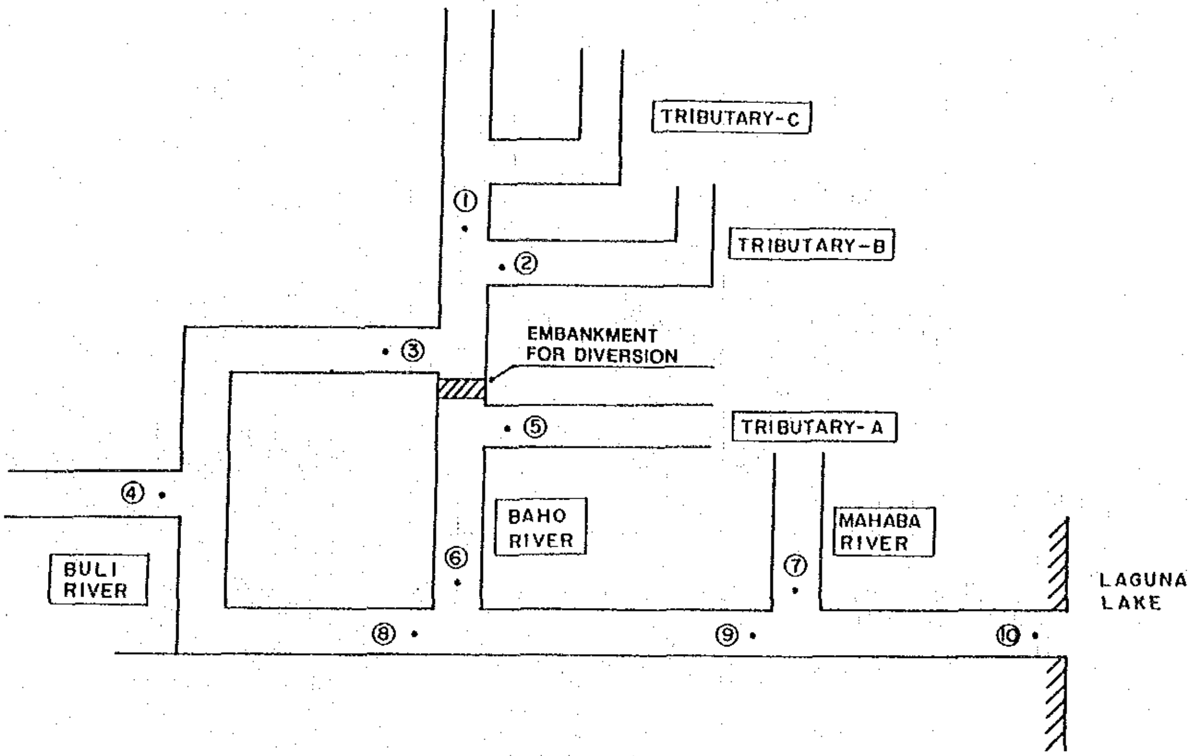
①	280	250	230	225	210	190	170
②	110	100	95	90	85	80	70
③	280	250	230	225	210	190	170
④	280	250	230	225	210	190	170
⑤	520	470	430	420	390	350	290
⑥	120	110	100	95	90	85	80
⑦	530	480	440	420	390	350	290
⑧	570	510	470	450	410	360	290
⑨	190	170	160	150	140	130	120

W/O SHORTCUT

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

PROBABLE DISCHARGE DISTRIBUTION IN 2020 (BAHO-BULI) Fig. 2-6-11 (4/6)

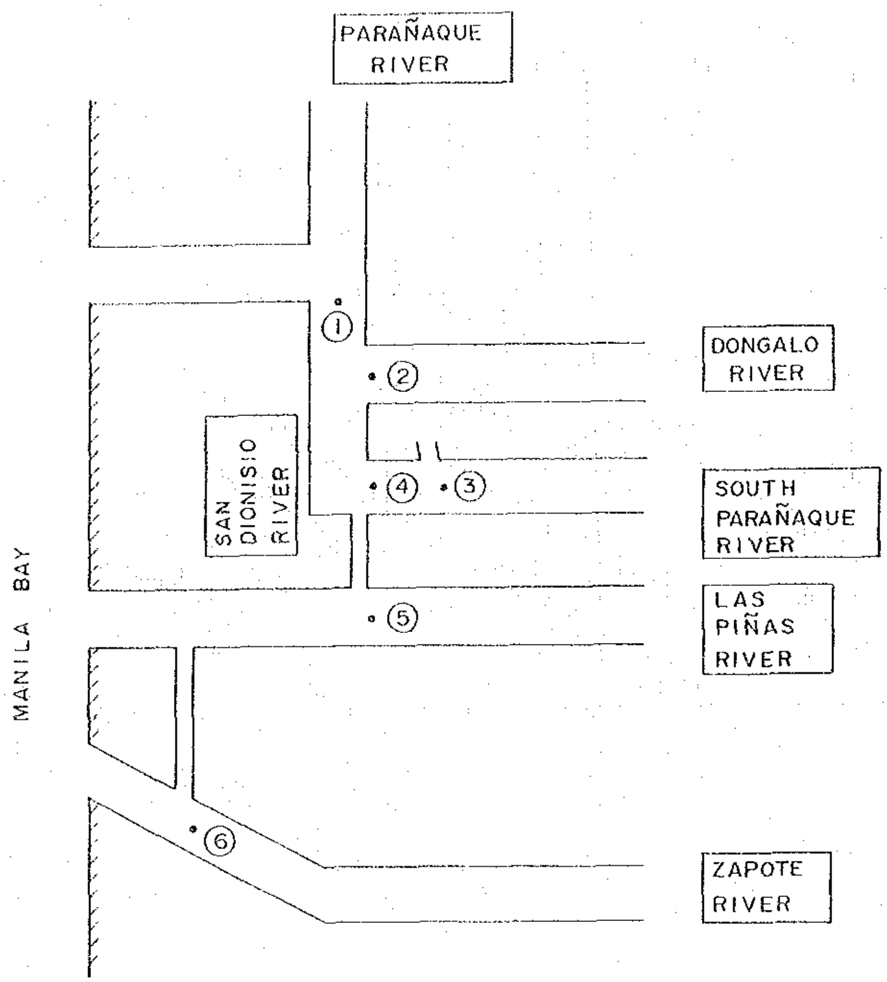


UNIT : m³/s

Point No.	RETURN PERIOD						
	100	50	30	20	10	5	2
①	280	250	230	225	210	190	170
②	110	100	95	90	85	80	70
③	280	250	230	225	210	190	170
④	80	75	70	65	60	55	50
⑤	280	250	230	225	210	190	170
⑥	335	300	275	270	250	230	190
⑦	190	170	160	150	140	130	120
⑧	330	295	270	260	245	210	180
⑨	495	450	410	395	365	320	260
⑩	530	475	430	415	380	330	260

W/ SHORTCUT

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	PROBABLE DISCHARGE DISTRIBUTION IN 2020 (BAHO-BULI)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-6-11(5/6)



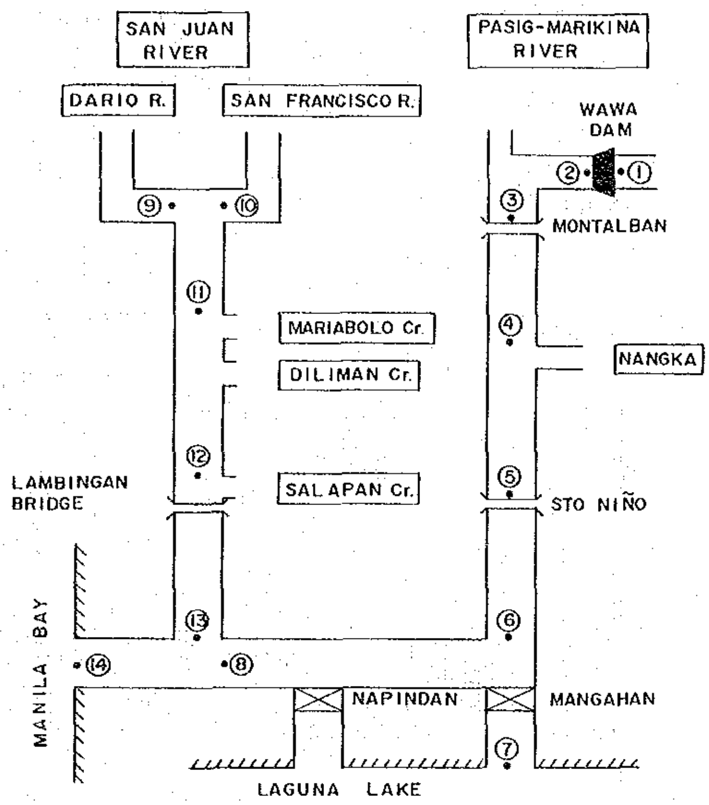
UNIT : m³/s

Point No.	RETURN PERIOD						
	100	50	30	20	10	5	2
①	630	560	520	490	440	380	320
②	200	180	170	160	140	120	100
③	370	330	300	290	260	220	190
④	430	380	350	330	300	260	220
⑤	220	200	180	170	160	140	120
⑥	510	450	410	390	340	280	220

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

PROBABLE DISCHARGE DISTRIBUTION IN 2020 (SOUTH PARAÑAQUE-LAS PIÑAS) Fig. 2-6-11(6/6)



UNIT : m³/s

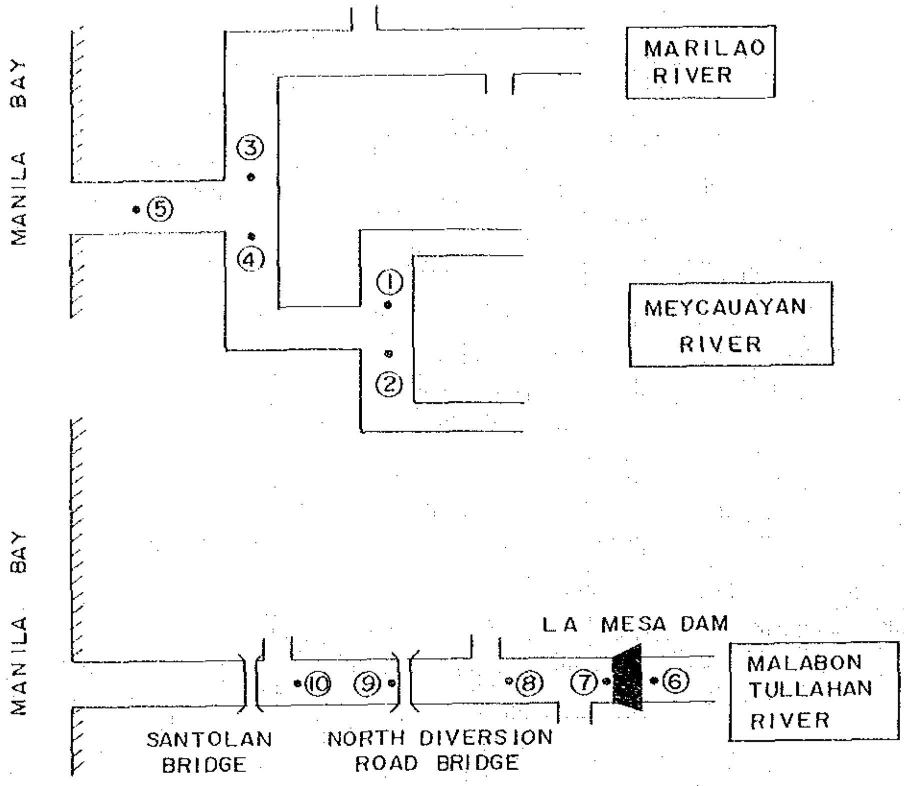
Point No.	RETURN PERIOD						
	100	50	30	20	10	5	2
①	2000	1 800	1 700	1 600	1 400	1 200	1 000
②	2 000	1 800	1 700	1600	1 400	1 200	1000
③	2700	2 450	2 250	2 100	1 900	1 600	1 300
④	3050	2 800	2550	2400	2 100	1 750	1400
⑤	3500	3 200	2 900	2700	2 400	2 050	1600
⑥	3500	3 200	2 900	2800	2 400	2050	1600
⑦	2250	2 000	1 850	1750	1 450	1 200	900
⑧	1200	1 100	1 000	950	850	750	550
⑨	140	130	125	120	115	110	105
⑩	290	280	270	260	250	240	220
⑪	420	400	395	380	360	340	320
⑫	700	670	660	630	580	560	510
⑬	790	750	740	700	650	600	540
⑭	1 450	1 300	1 200	1 150	1000	850	650

Note: Under the present condition.

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

PROBABLE DISCHARGE DISTRIBUTION IN 1986 (SAN JUAN AND PASIG-MARIKINA) Fig. 2-6-12(1/4)



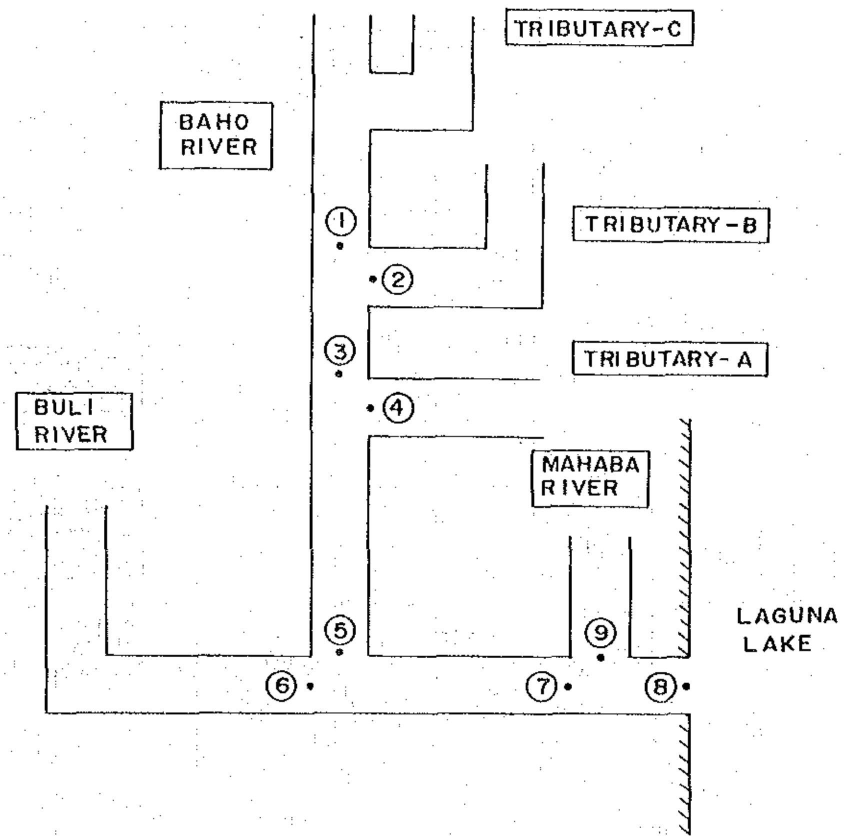
UNIT : m^3/s

Point No.	RETURN PERIOD						
	100	50	30	20	10	5	2
①	210	190	180	160	150	130	120
②	270	250	230	220	200	180	160
③	750	680	610	570	490	410	320
④	340	320	290	280	250	220	190
⑤	970	880	790	730	630	520	400
⑥	400	370	365	340	310	290	250
⑦	240	220	210	200	180	160	140
⑧	330	300	290	270	240	220	180
⑨	480	430	420	390	340	300	190
⑩	520	470	450	420	360	320	200

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

PROBABLE DISCHARGE DISTRIBUTION IN 1986 (MEYCAUAYAN AND MALABON-TULLAHAN) Fig. 2-6-12 (2/4)



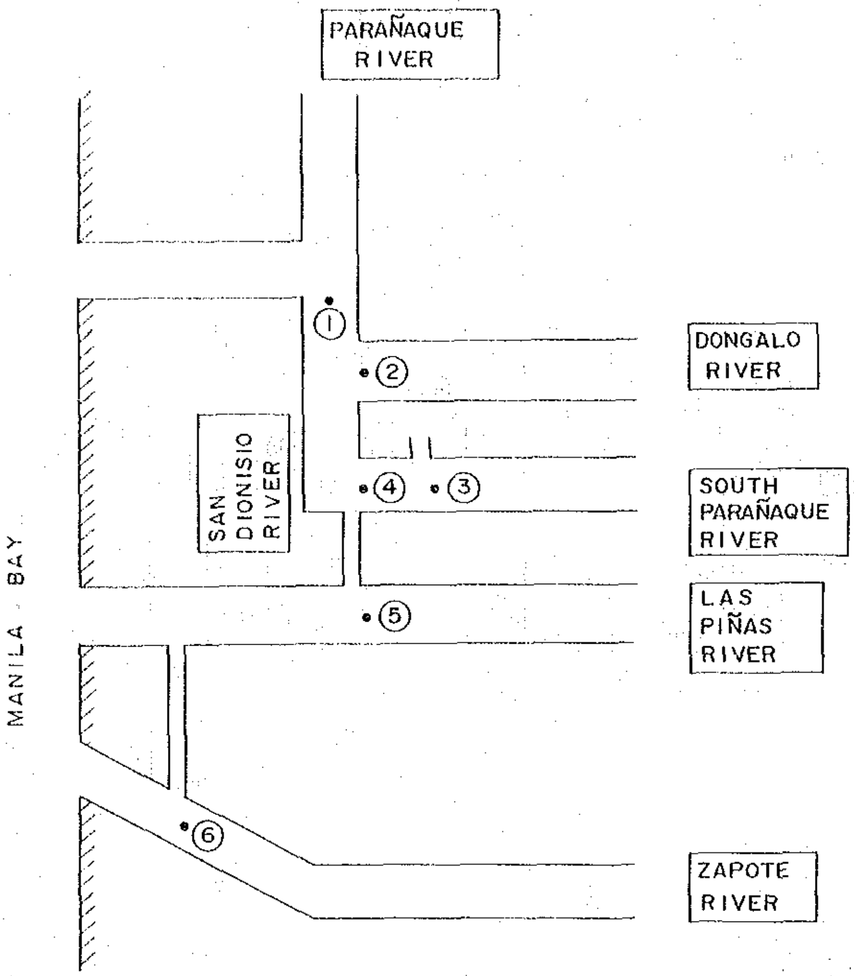
UNIT : m^3/s

Point No.	RETURN PERIOD						
	100	50	30	20	10	5	2
①	260	230	210	205	200	180	160
②	70	65	60	60	55	50	45
③	240	220	200	190	180	160	140
④	210	190	170	165	160	140	120
⑤	430	390	350	340	310	280	230
⑥	80	75	70	65	65	60	50
⑦	450	400	360	350	320	280	230
⑧	480	430	390	370	340	290	230
⑨	150	130	120	115	110	100	90

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

PROBABLE DISCHARGE DISTRIBUTION IN 1986 (BAHO-BULI) Fig. 2-6-12 (3/4)



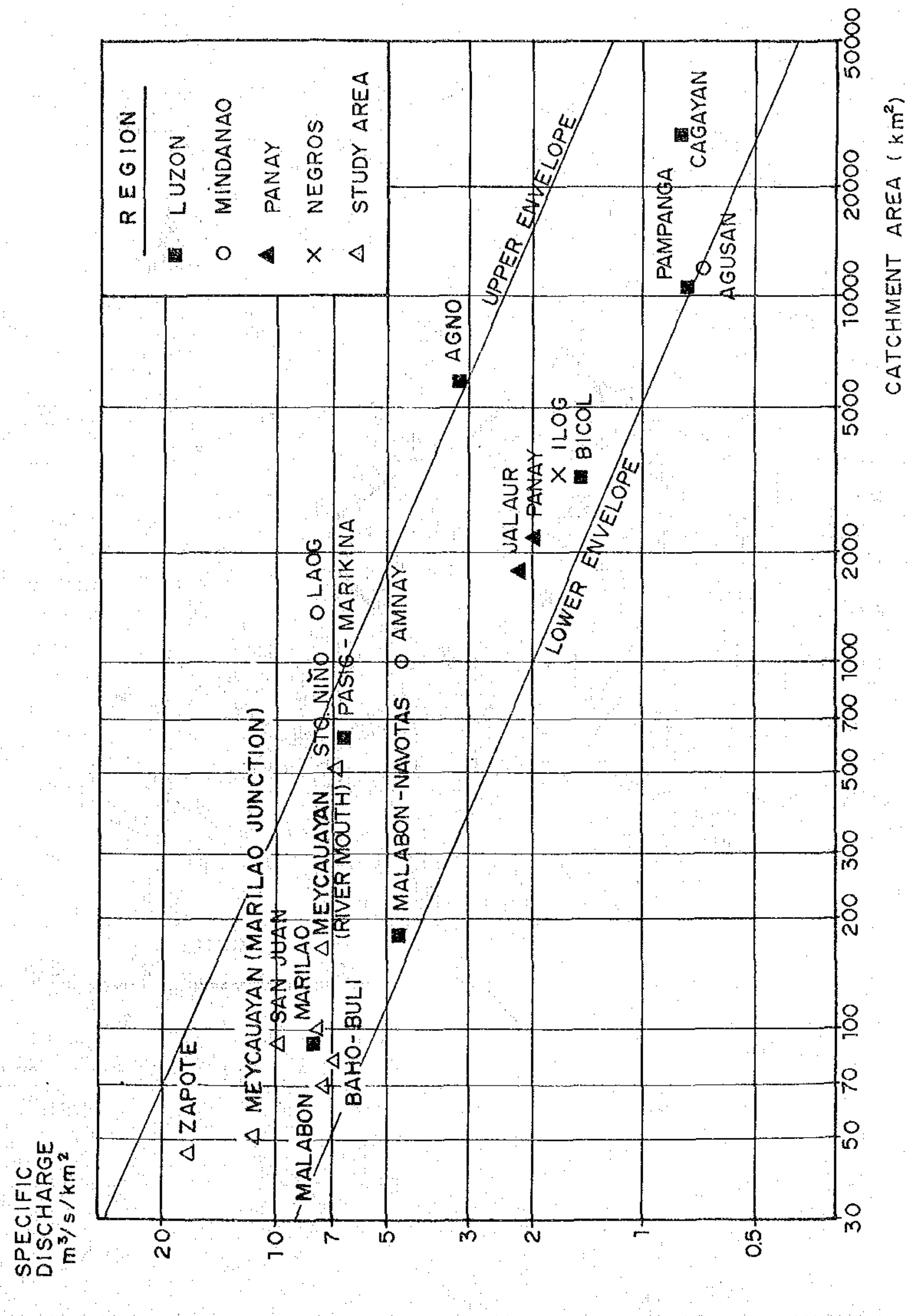
UNIT : m^3/s

Point No.	RETURN PERIOD						
	100	50	30	20	10	5	2
①	510	460	420	400	350	310	260
②	180	160	150	140	130	110	100
③	300	260	240	230	210	180	150
④	330	300	280	260	230	200	170
⑤	180	160	150	140	130	110	90
⑥	510	450	410	390	340	280	220

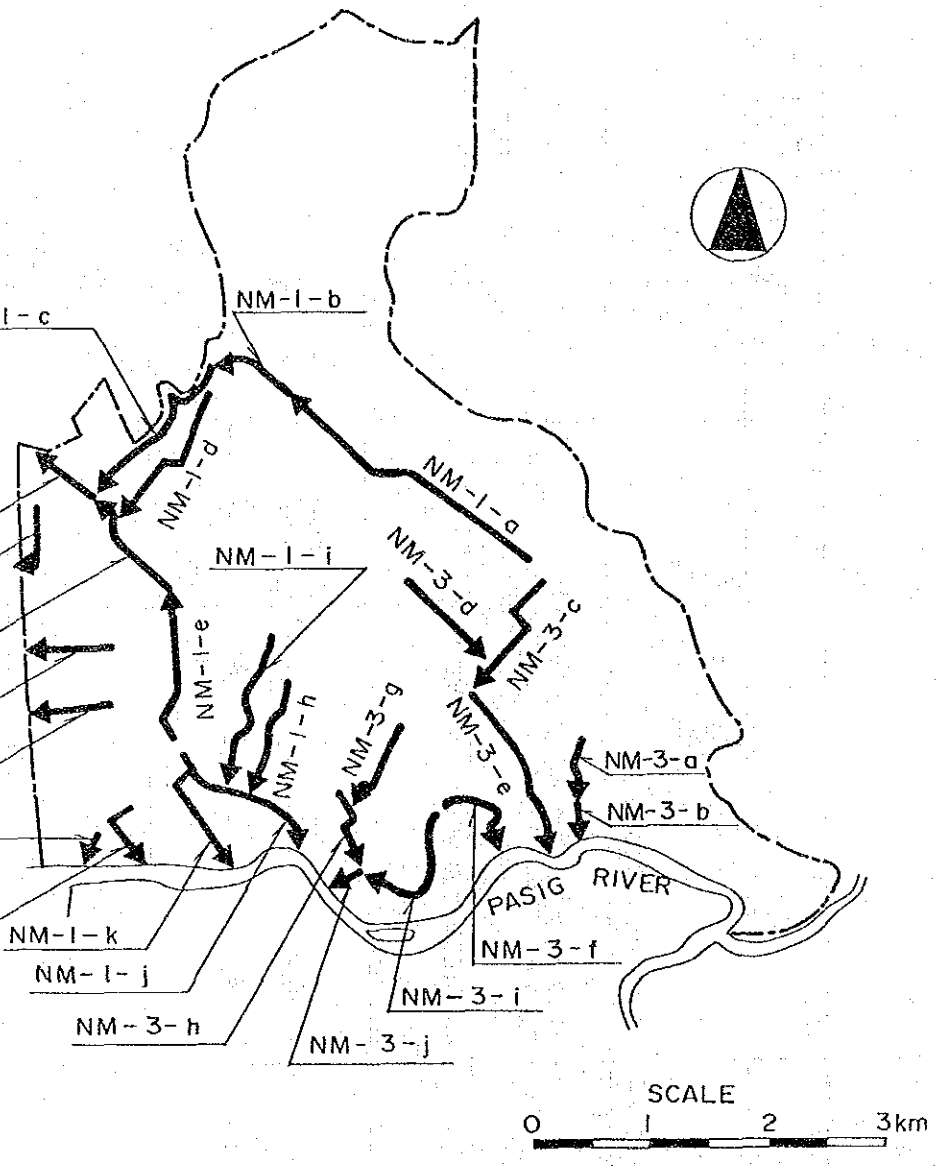
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

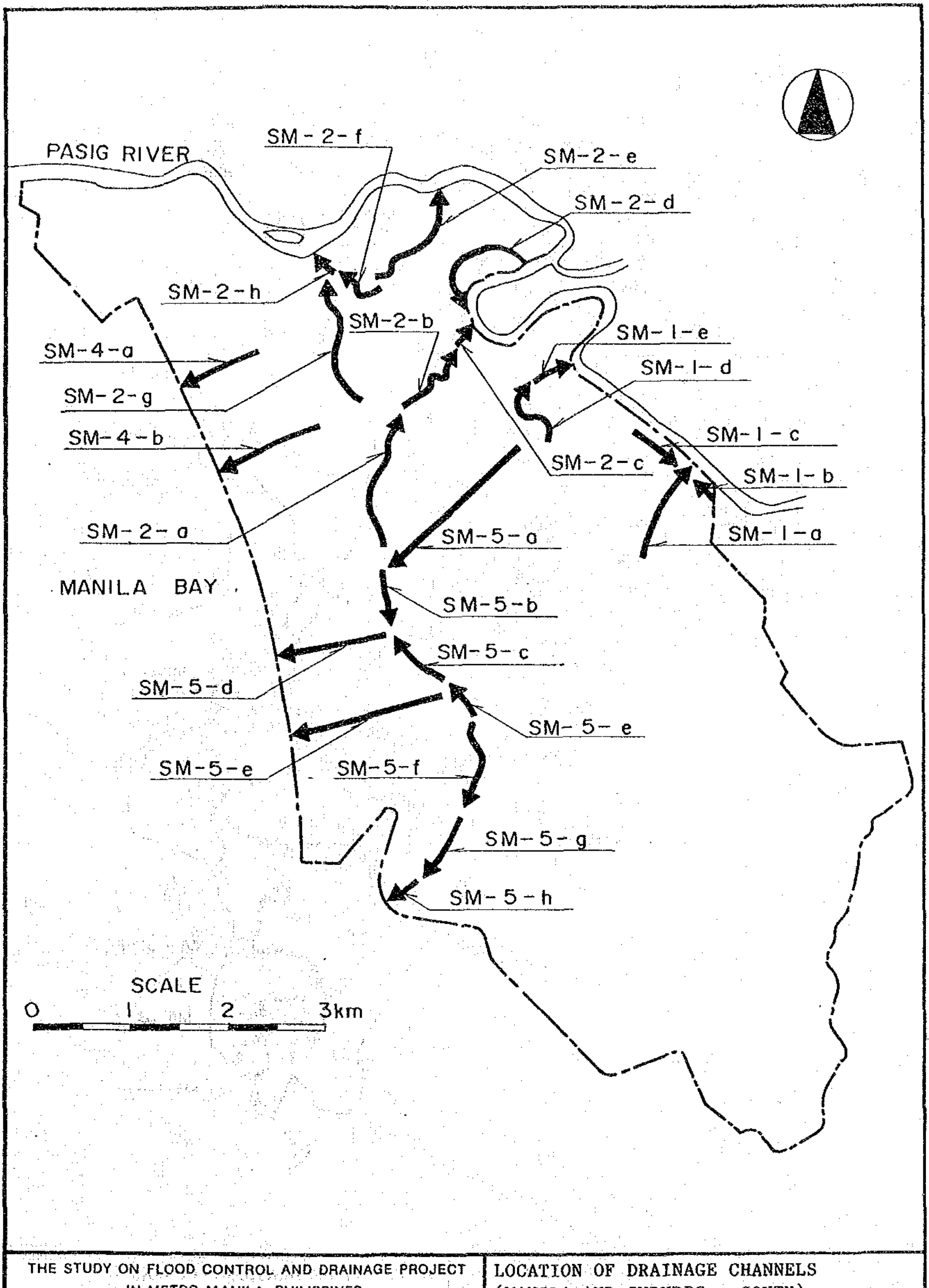
PROBABLE DISCHARGE DISTRIBUTION IN 1986 (SOUTH PARAÑAQUE-LAS PIÑAS) Fig. 2-6-12 (4/4)



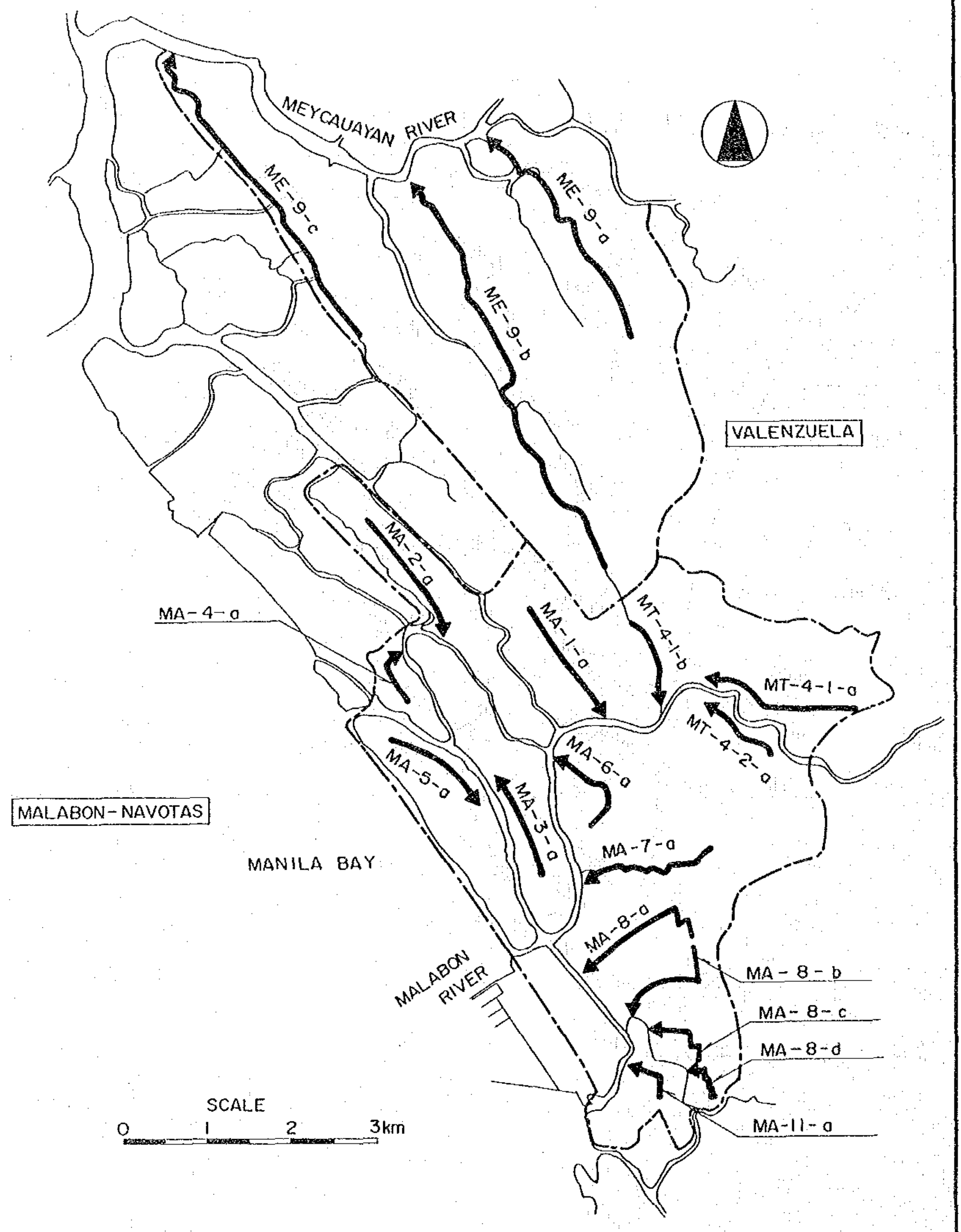
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	COMPARISON OF SPECIFIC DISCHARGE OF 100-YEAR FLOOD WITH OTHER RIVERS IN THE PHILIPPINES Fig. 2-6-13
JAPAN INTERNATIONAL COOPERATION AGENCY	



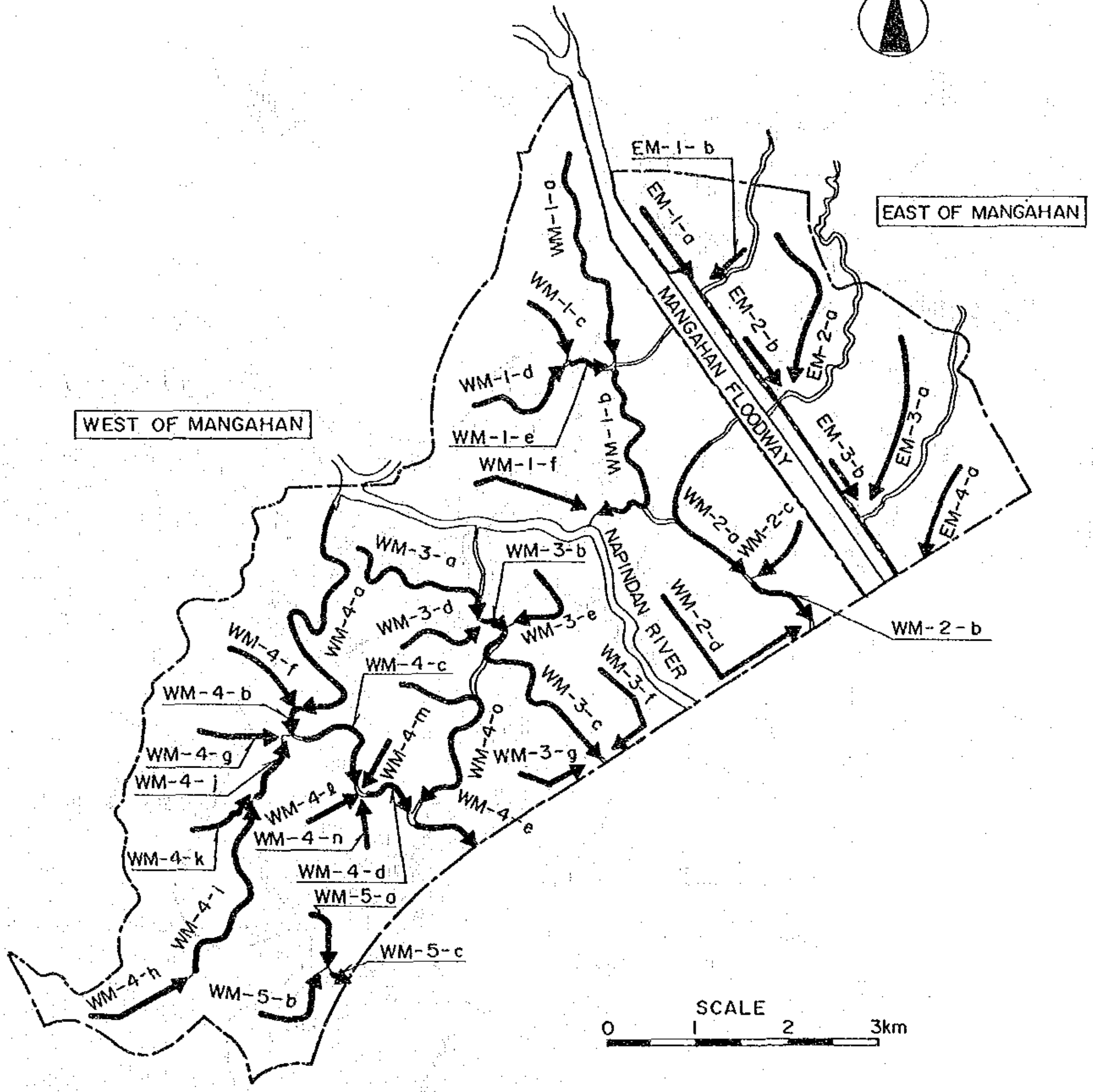
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	LOCATION OF DRAINAGE CHANNELS (MANILA AND SUBURBS : NORTH)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-6-14(1/8)



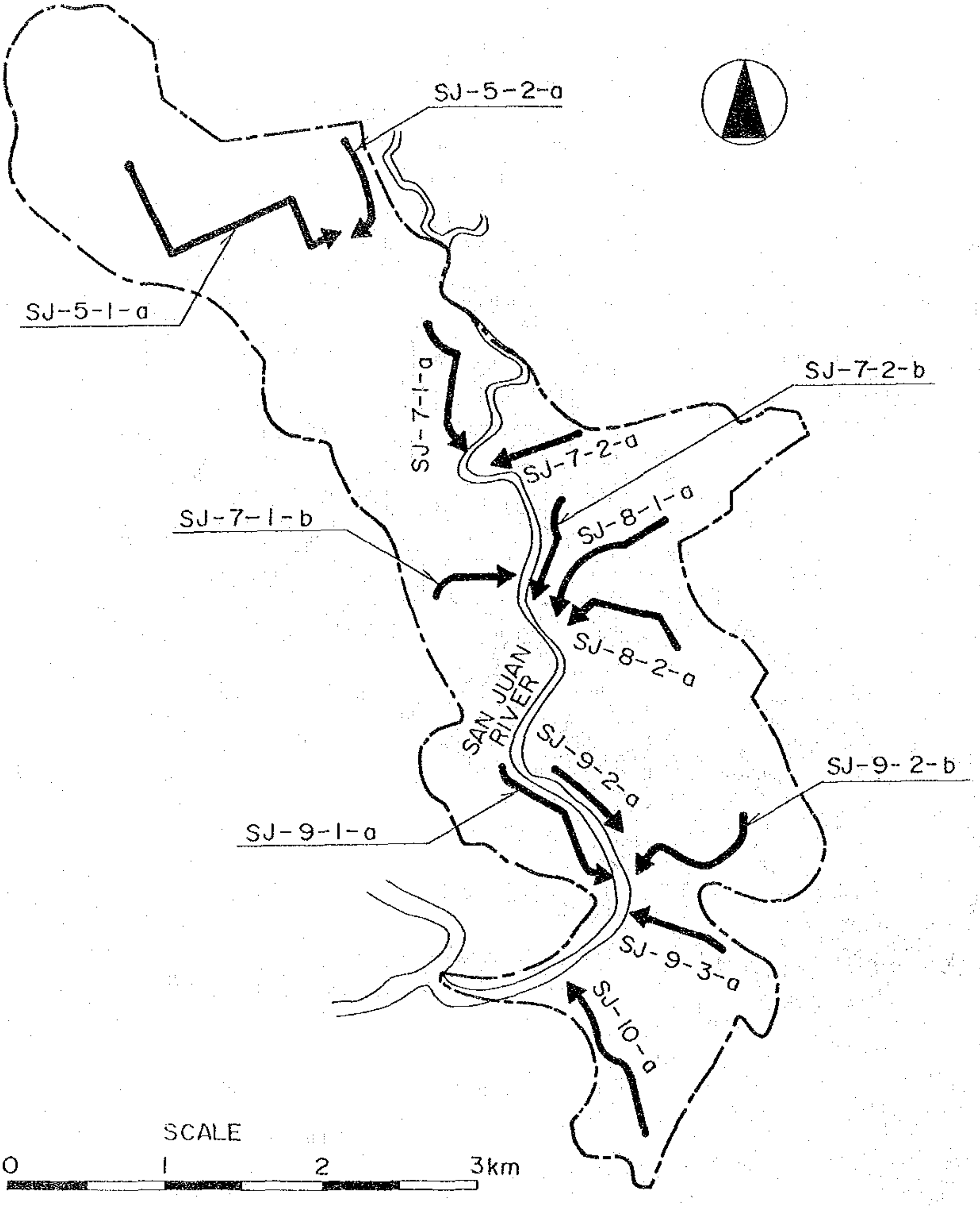
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES JAPAN INTERNATIONAL COOPERATION AGENCY	LOCATION OF DRAINAGE CHANNELS (MANILA AND SUBURBS : SOUTH) Fig. 2-6-14(2/8)



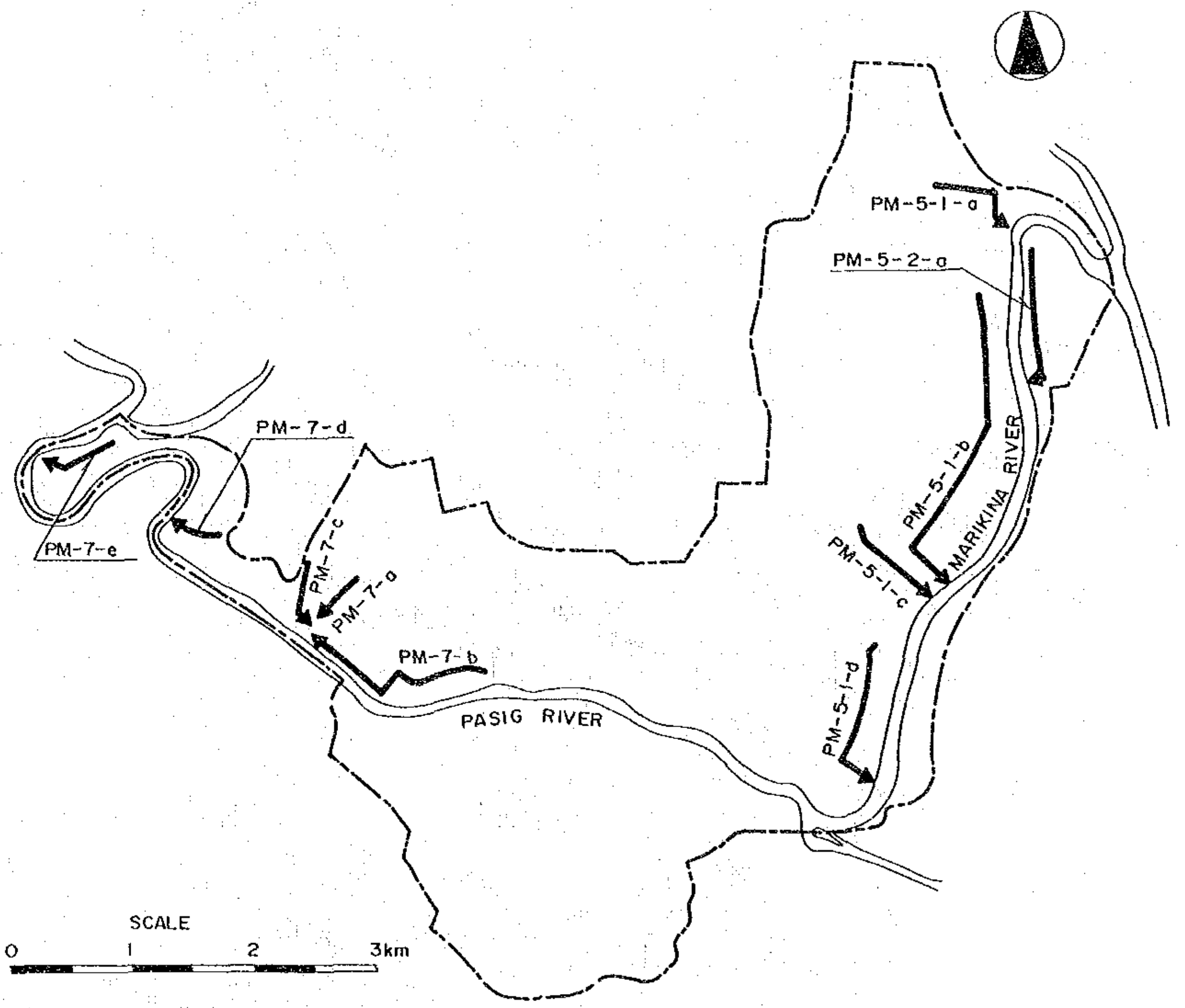
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	LOCATION OF DRAINAGE CHANNELS (MALABON NAVOTAS AND VALENZUELA)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-6-14(3/8)



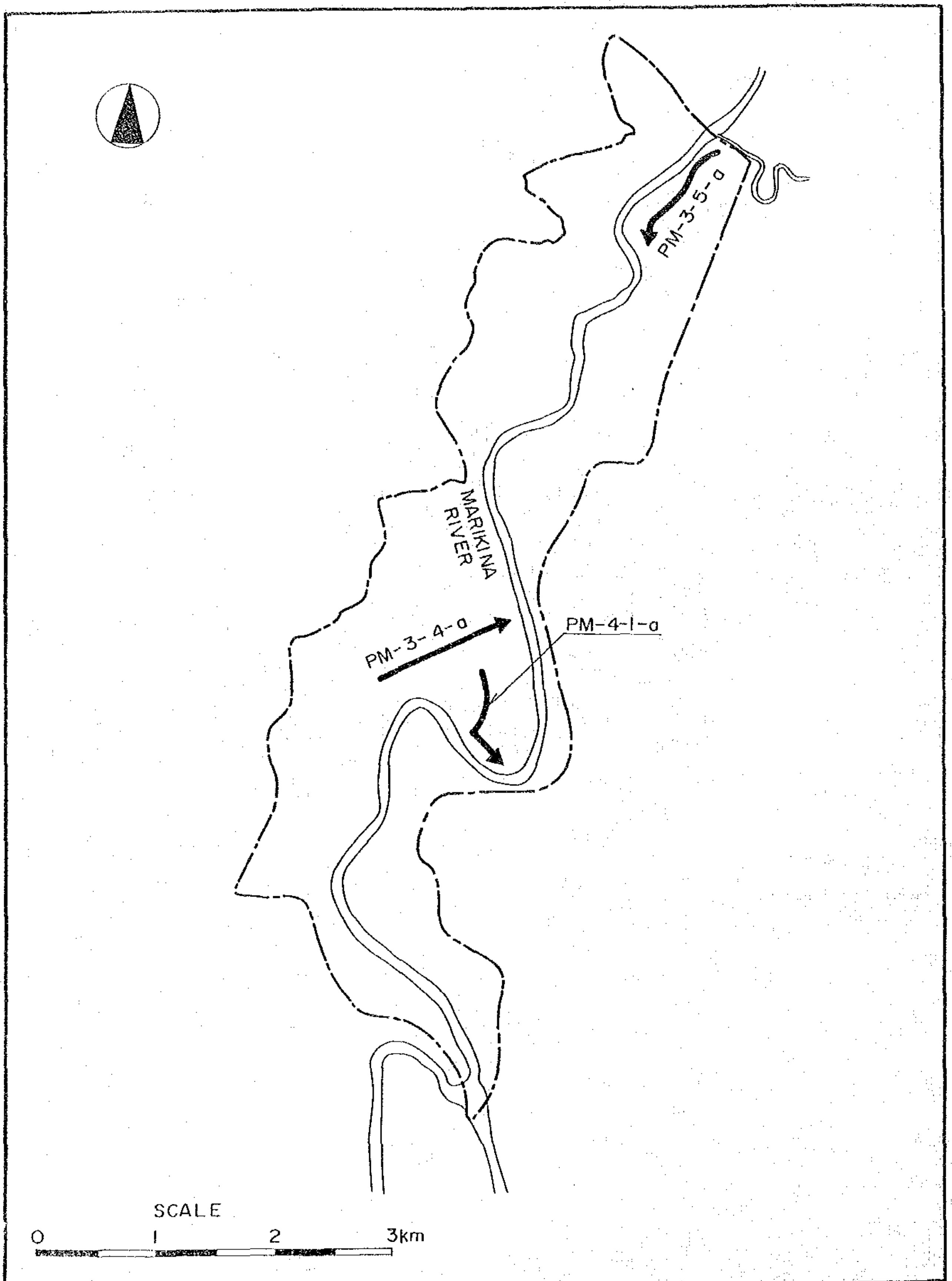
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	LOCATION OF DRAINAGE CHANNELS (EAST AND WEST MANGAHAN)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-6-14(4/8)



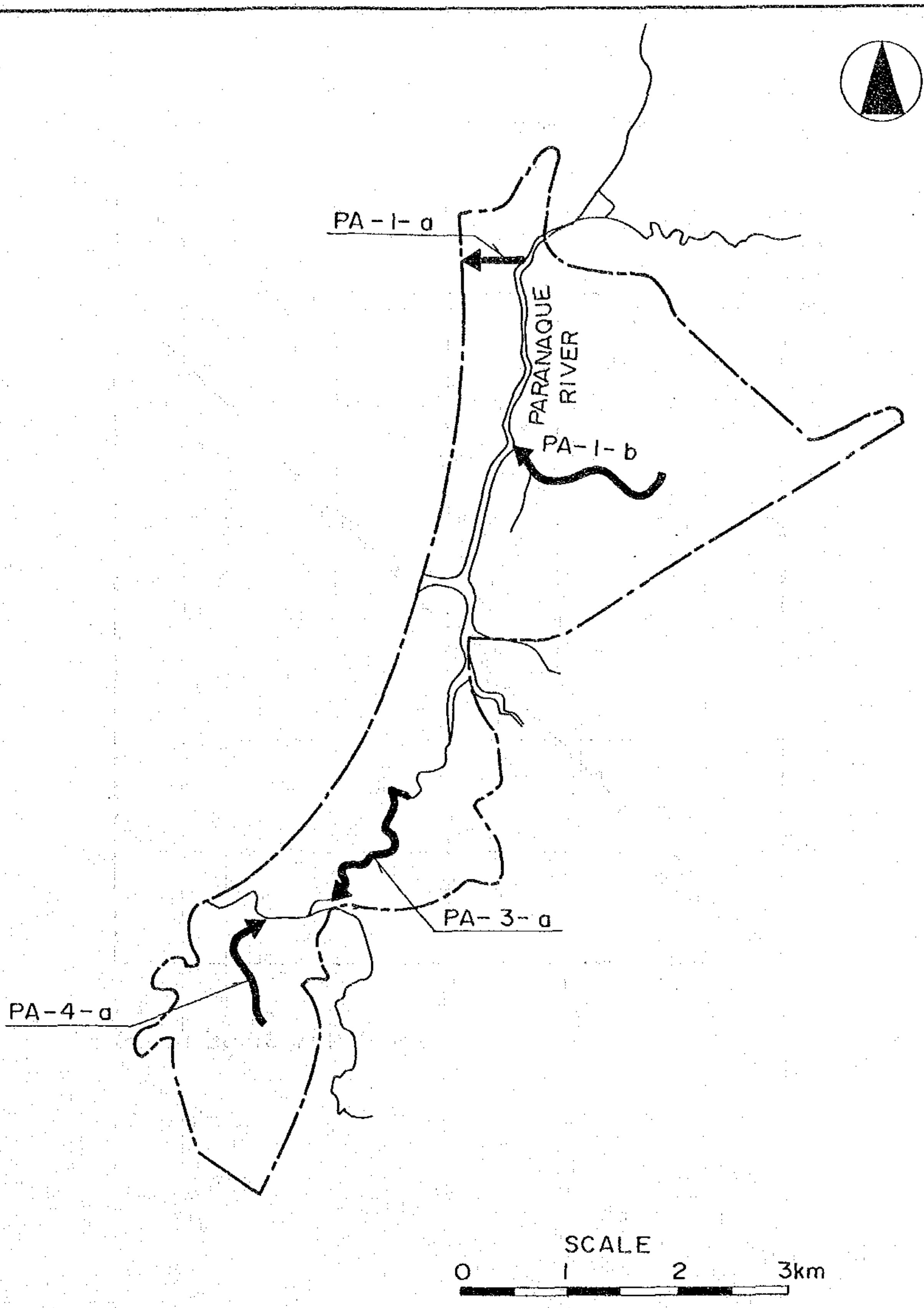
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	LOCATION OF DRAINAGE CHANNELS (SAN JUAN)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-6-14(5/8)



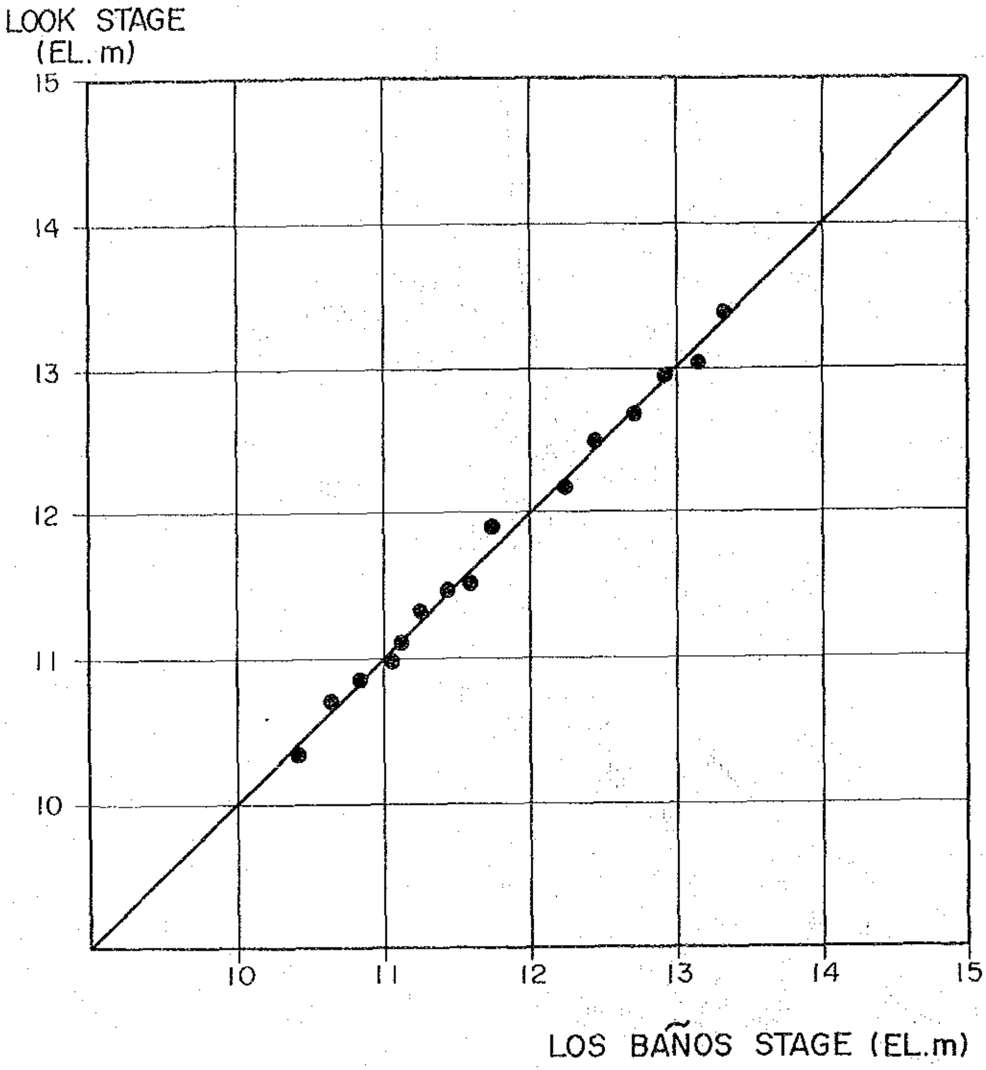
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	LOCATION OF DRAINAGE CHANNELS (MANDALUYONG-PASIG)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-6-14(6/8)



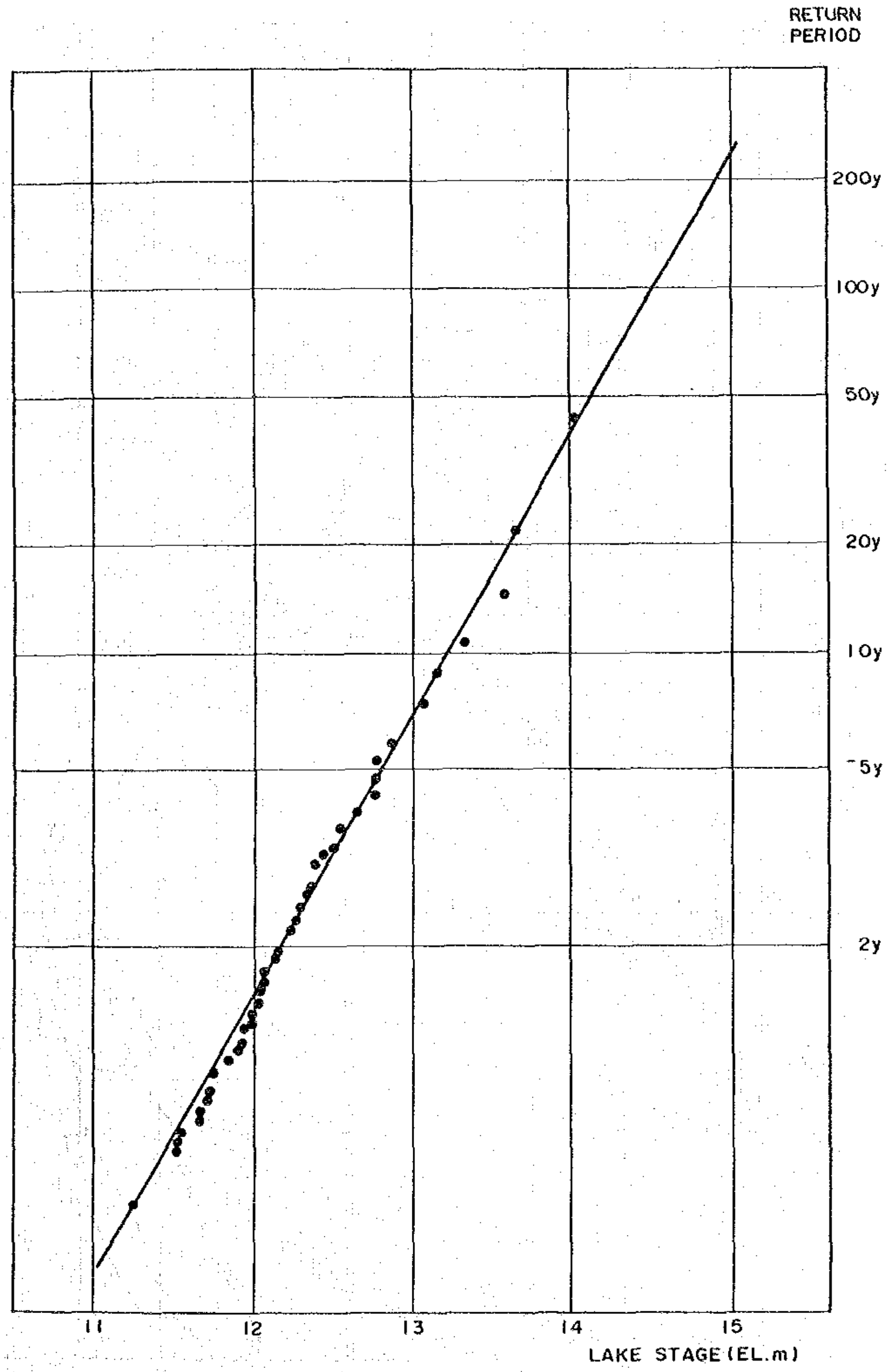
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	LOCATION OF DRAINAGE CHANNELS (MARIKINA)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-6-14(7/8)



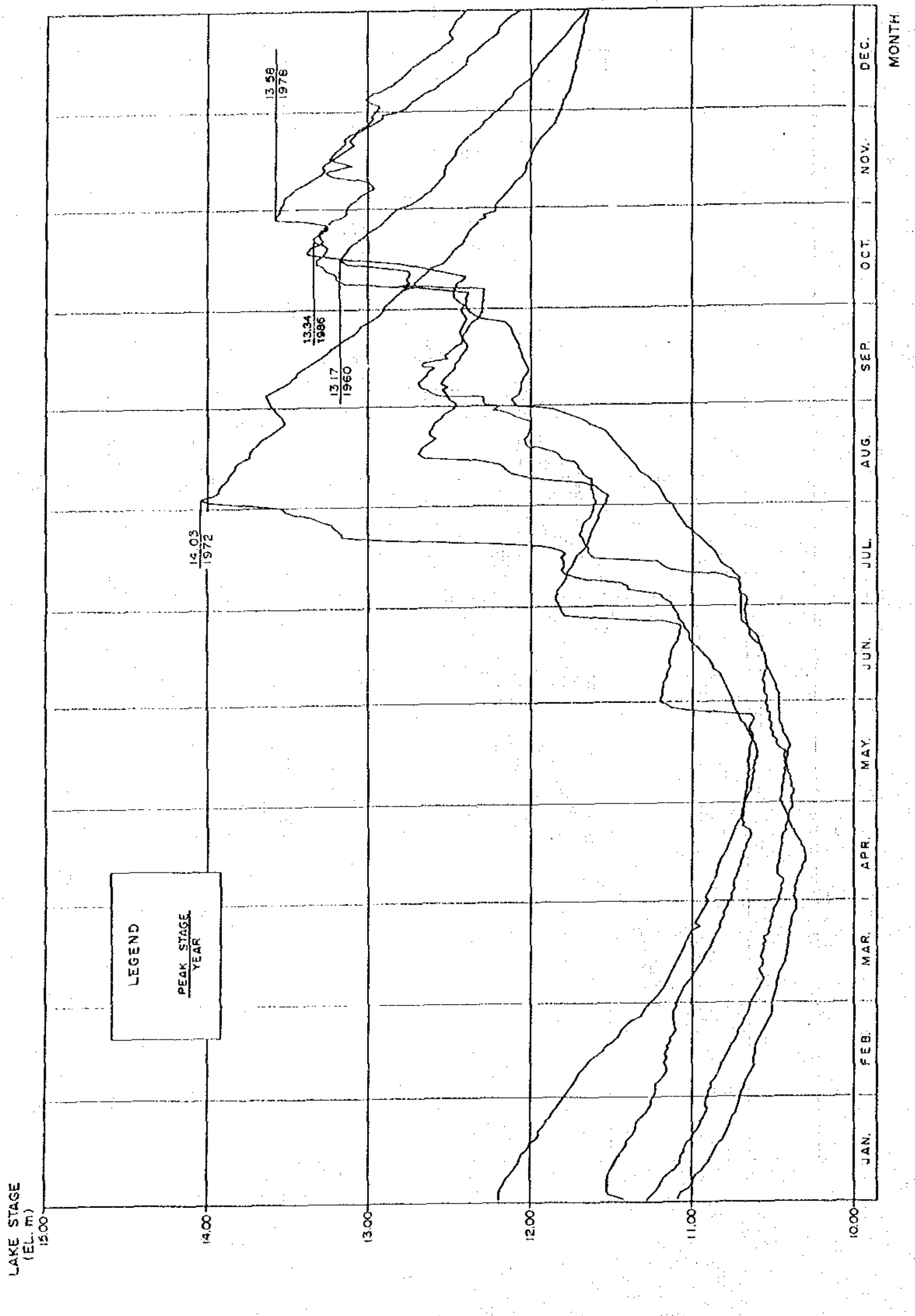
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	LOCATION OF DRAINAGE CHANNELS (PARANAQUE-LAS PINAS)
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-6-14(8/8)



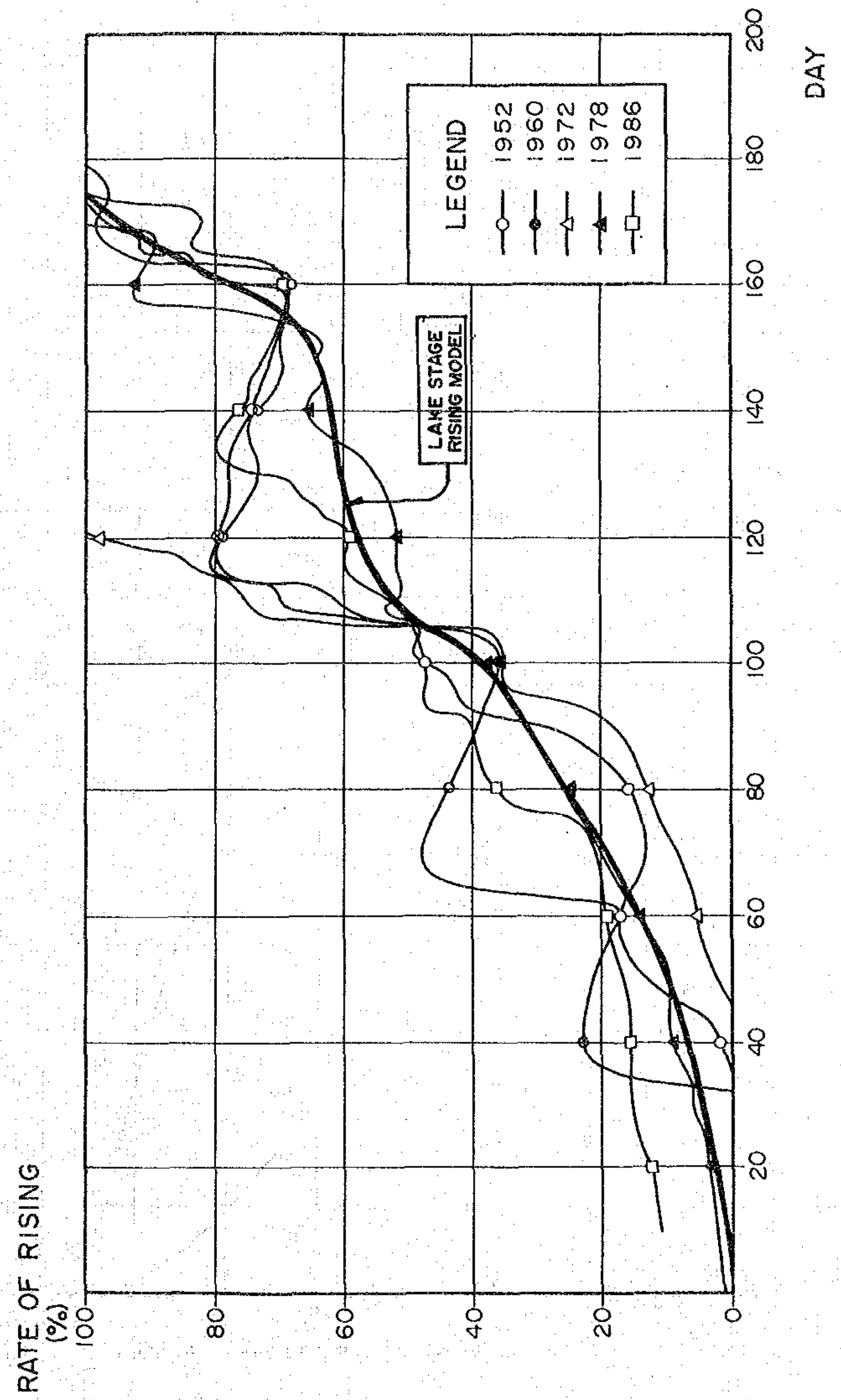
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	LAGUNA LAKE STAGE CORRELATION BETWEEN LOS BAÑOS AND LOOC GAUGE
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-7-1



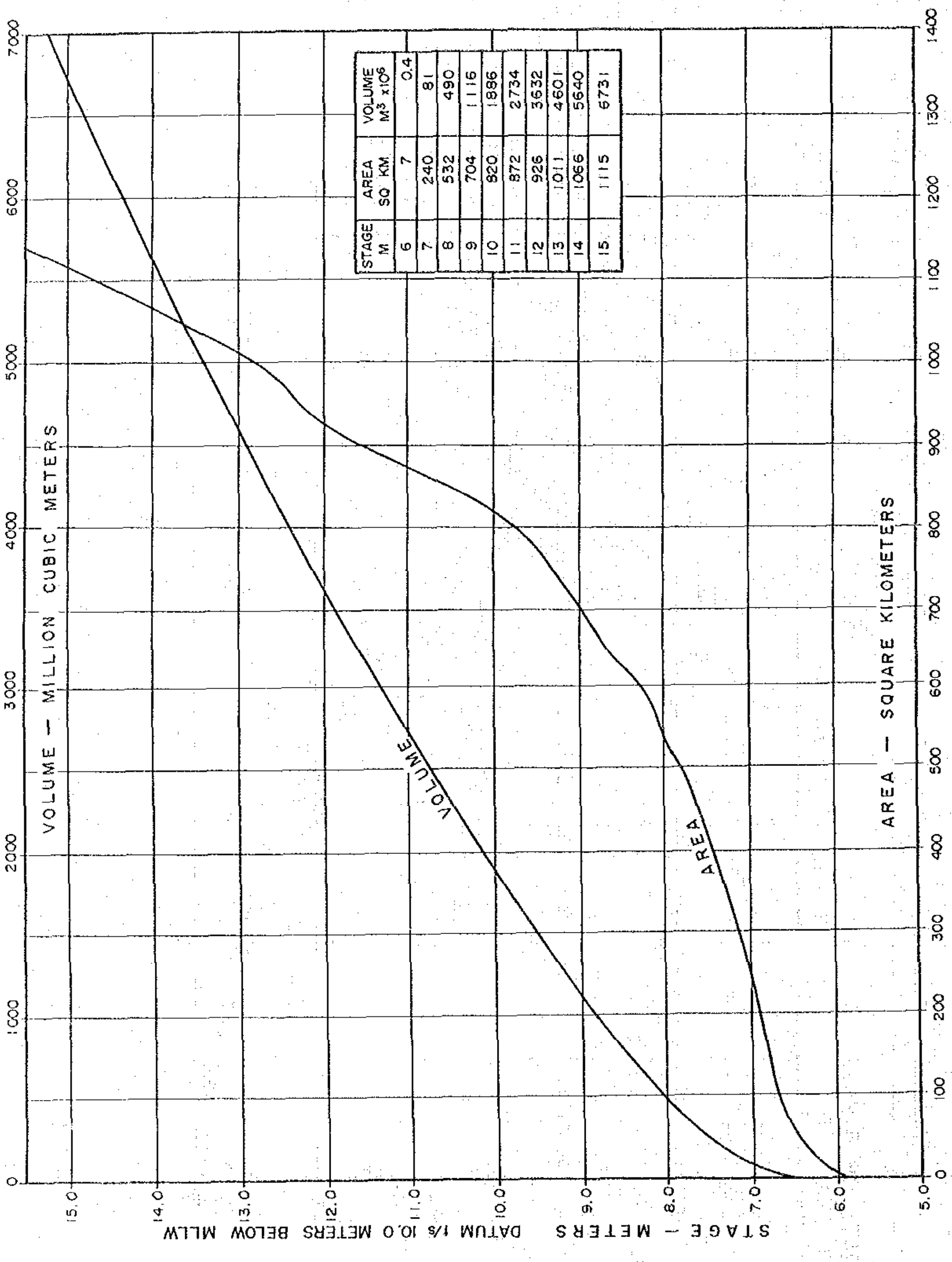
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	PROBABLE LAGUNA LAKE STAGE
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-7-2



THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	LAGUNA LAKE STAGE RECORDS
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig. 2-7-3



THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES JAPAN INTERNATIONAL COOPERATION AGENCY	NON-DIMENSIONAL LAGUNA LAKE STAGE (RISING PATTERNS) Fig. 2-7-4



STAGE M	AREA SQ KM	VOLUME M³ x10⁶
6	7	0.4
7	240	81
8	532	490
9	704	1116
10	820	1886
11	872	2734
12	926	3632
13	1011	4601
14	1066	5640
15	1115	6731

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

LAGUNA LAKE AREA VOLUME CURVE

Fig. 2-7-5

III. GEOLOGICAL ENGINEERING

SUPPORTING REPORT

III. GEOLOGICAL ENGINEERING

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1. GENERAL

The geological study was carried out firstly, by collecting data on groundwater to know the condition of land subsidence; secondly, by collecting the general geological data over Metro Manila, as well as data related to structural measures for flood control and drainage improvement; and finally, by conducting detailed geotechnical investigations consisting of drilling and soil laboratory tests for the two priority areas in the east and west of Mangahan and in Malabon-Navotas. The results are presented in this report in the following order:

- Land subsidence
- Geological investigation in East and West of Mangahan, and in the Malabon-Navotas area
- Geotechnical condition at major structure sites

2. LAND SUBSIDENCE

The main causes of land subsidence seem to be the settlement of soil due to added load and excessive groundwater utilization, and the latter appears to be the more general factor. Since local land subsidence can be closely related with the drawdown of groundwater table, the records on groundwater, as well as the ground elevation survey record, were utilized in this study to evaluate the occurrence of land subsidence.

2.1 General Conditions

<u>Geological Aspect</u>

The geological setting concerning land subsidence is the alluvial deposit and the underlying Quaternary pyroclastic rocks. The geology of the Manila Deltaic Plain, the Guadalupe Formation and the Marikina Valley Alluvial Plain has been described as follows. (Refer to Fig. 3-2-1.)

(1) Manila Deltaic Plain

The area is almost flat and the elevation ranges from zero on Manila Bay to five meters in Sta. Mesa and Makati. The thickness of the deltaic sediments which consist of sand, pebbly gravel, silt and clay of various colors and plasticity is over 70 meters near the coast and thins out eastward in the Sta. Mesa and Marikina area.

(2) Guadalupe Formation

The Guadalupe Formation, known as a thick sequence of tuff and tuffaceous clastics, is the base rock of the Manila Deltaic Plain and the Marikina Valley Alluvial Plain and it exposes in a low hill zone between the two plains. The elevation of the hill is 5 to 30 meters at Parañaque, around 40 meters between Guadalupe and Camp General Emilio Aguinaldo, and 50 to 70 meters in the area from Quezon City to Novaliches.

(3) Marikina Valley Alluvial Plain

The Marikina Valley Alluvial Plain occupies the area between the hills of the Guadalupe Formation and the Sierra Madre Range, and it widens southward to the Laguna Lake. The thickness of the alluvial deposits which have similar components as the Manila deltaic materials, varies irregularly. It is 120 meters in the northern portion of Montalban, around 15 meters at Marikina, between 30 and 40 meters at Pasig, and more than 130 meters at the southernmost part.

Hydrological Aspect

The Quaternary Alluvium and Guadalupe Formation, from especially hydrogeological points of view, are as follows.

(1) Quaternary Alluvium

The thickness of the alluvium is unclear because of the difficulty in distinguishing it from the underlying Gaudalupe Formation. Deltaic deposition resulted in frequent vertical and horizontal variations of deposit features and the nature of such deposition produced locally confined aquifers of pervious sediments which, however, do not have any outstandingly high pressure. Some of the isolated aquifers were exploited and the others were possibly left intact.

(2) Guadalupe Formation

The Quaternary Guadalupe Formation consists of pyroclastics and sedimentary units and includes a basal member named the Alat Conglomerate. The pyroclastic member has little potential for bearing ground water in general, while some layers of the sedimentary units have highly productive water bearing potentials. The Guadalupe Formation consists of waterlain depositions and such sedimentary units of formation have the most productive water bearing potential.

2.2 Evaluation of Land Subsidence

Ground Water Level Survey

The ground water level records of 1955, 1967 and 1981 and the measurements of ground water level in June 1988 were studied. According to the available ground water level data of the Manila Bay Aquifer System given by H. P. Quiazon of the Bureau of Mines, as well as those from the MWSS (1981), the ground water level in the project area had continued to subside since 1955, except in Manila where the ground water level recovered between 1967 and 1981 as a result of the reduced pumpage and abandonment of wells due to saline water intrusion. By 1981, new centers of the pumpage were Sucat, Parañaque, Makati and Quezon City.

Measurement of the ground water level was carried out at six wells in June, 1988. The water level of the wells had been almost unchanged or recovering since 1981 (refer to Fig. 3-2-2).

Ground Elevation Survey

The existing data obtained in 1979 and results of the topographic survey carried out in 1988 were studied. Since the primary bench mark level of 1979's survey is unknown, the results of the survey carried out in 1979 and 1988 are incomparable in the same level.

Considering the consolidated condition of the Guadalupe Formation as mentioned above, and the recovering ground water level in the formation since 1981, the ground level of the hill consisting the Guadalupe Formation appears to be stable and able to be regarded as the primary bench mark during the time between 1981 and 1988. Based on this concept, the results of the topographic survey show that the ground level in the alluvial deposits is almost unchanged or has somewhat risen since 1979.

Findings on Land Subsidence

As shown in Table 3-2-1, Ground Water and Land Subsidence, which summarizes the above conditions, all the data appear to indicate that the land subsidence of the alluvial deposit area is presumed to have ceased since 1981. No more subsidence is expected, when the ground water utilization continues to decline in the future.

3. GEOLOGICAL INVESTIGATION

Geological investigations were made for the drainage areas of East and West of Mangahan and Malabon-Navotas which are designated as priority areas.

3.1 East and West of Mangahan Floodway

General Aspects

(1) Geomorphology

This area is located at the northern shore of the lake, covering Taguig and Taytay, with a shoreline of approx. 10 km long, and at the southern end of the Marikina Valley with a north-south trend. The Marikina River runs through the valley in the middle reaches, but flows out of the valley toward the sea in its lower reaches.

According to the past geomorphological/geological studies in the area, the Marikina Valley is a graben valley which was caused by fault movements (A.D. Alvir, 1929). It is reported that the Marikina Valley Fault runs from north to south along the western margin of the valley and the western rim of the lake. A fault (called Binangonan Fault) trending from northwest to southeast is assumed to be running through

Taytay and Angono on the eastern margin of the valley (Froilan C. Gervasio). The locations of these faults are shown in Fig. 3-2-1.

(2) Geology

The floor of the Marikina Valley in this study area is entirely covered with clay and sand layers of alluvial deposits of the Marikina River and its tributaries. These alluvial deposits dip gently towards the south with an inclination of 1 or 2 vertical by 5,000 horizontal.

Tuffaceous bedrock of the Plio-Pleistocene Guadalupe Formation, which is locally called adobe, exposes in the hilly zones on both the west side (Quezon City and Parañaque) and the east side (Antipolo and Angono) of the Marikina graben.

Geological Condition

(1) Field Investigation

(a) Previous Investigations

Some geotechnical investigations in and around the area have previously been carried out for various projects as follows.

- Mangahan Floodway Project Study; DPWH, February 1975.
- Feasibility Study on the Parañaque Spillway Project; DPWH, 1975.
- Feasibility Study on C-3 and R-4 and Related Roads Project; DPWH, March 1978.
- Napindan Hydraulic Control Structure Project; DPWH, October 1978.
- Soil Investigation for the Proposed Laguna Lake Reclamation and Development Project, Technotest, Inc., March 1981.

(b) Investigation in this Study

In this Study, drilling was conducted at 10 locations along the lakeshore as follows.

Drillhole	Depth (m)	Ground Elevation (m)	S.P.T.	Undisturbed Sampling from Test Pits
JB-1	15	11.614	13	-
JB-2	20	12.966	16	-
JB-3	20	11.508	18	1
JB-4	20	12.157	18	1
JB-5	20	13.279	18	-
JB-6	25	12.544	23	-
JB-7	20	12.716	18	1
JB-8	20	11.978	19	1
JB-9	20	12.375	19	1
JB-10	20	13.914	18	-
10 holes	200		180	5

The locations of the above drillholes are shown in Fig. 3-3-1, together with the previously drilled holes in the vicinity.

(2) Laboratory Tests

The following laboratory tests were carried out for the samples taken from the drillholes and the test pits.

- Natural Moisture Content (NMC)
- Gradation Analysis with the Hydrometer (Hydro)
- Gradation Analysis (Sieve)
- Atterberg Limits (LL-PL)
- Specific Gravity (Gs)
- Unit Weight (UWT)
- Unconfined Compression Test (UCT)

- Triaxial Test, Consolidated-Undrained with Pore Pressure Measurement (Triax)
- One Dimensional Consolidation Test (Conso)
- Compaction Test (CT)
- Penetration Resistance Test (PRT)
- Organic Content (Org)
- Shrinkage Limit (SL)

The results of the laboratory tests are summarized in Table 3-3-1, and the typical soil features along the lakeshore dike was determined on each soil layer based on the laboratory tests and the existing available data (refer to Table 3-3-2).

(3) Soil Profile

As shown in Fig. 3-3-2, Geological Profiles on Lines A, B, C and D, all subsurface soil layers in this area develop continuously in all the directions, except for the fill layer and sand layer near the surface.

The description of each soil layer in descending order is as follows.

(a) Fill Layer (Top Layer)

This layer extends in the restricted zones such as the embankments of the Mangahan Floodway and the road linking Bicutan and Pasig. The thickness of this layer is 2 to 5 m above the original ground.

(b) Sand Layer

This layer develops at the western rim of the lake at the maximum thickness of 2 m. It comprises yellowish brown, medium to coarse sand which falls under SP or SM in the unified soil classification as shown in Table 3-3-3. This layer is a part of the alluvial deposit reflecting a localized sedimentary environment on the western margin of the lake.

(c) Clay Layer C1

This layer develops widely with the thickness of 2 to 3 m. It is composed of yellowish or grayish brown soft clay of high plasticity (CH) as a part of the alluvial deposits of the Marikina River and its tributaries.

(d) Sand Layer S1

This layer is composed of two strata. The first stratum underlies the C1 layer (thickness of 2 to 6 m, ave. 2.5 m). The second stratum is intercalated in the following thick clay layer of C2 (max. thickness of 2 m). Both strata comprise dark gray or dark yellowish to greenish gray, fine to coarse sand with much marine fauna (SP or SM). Fine to medium sand is dominant, but coarse sand is occasionally located in the eastern parts (Mangahan Floodway to Taytay), and the north of Napindan and Taytay (JB-6 to JB-10).

(e) Clay Layer C2

This layer comprises bluish to greenish gray clay occasionally including marine fauna (CH-CM). The thickness is 4 m at the eastern end of Profile A, and 14 m at the hole JB-6 at Napindan along the Pasig River. The variety in thickness of the C2 layer suggests that the bottom of the old Marikina Valley, before the C2 layer was formed, had simply descended from north (Taytay) to south (Laguna de Bay).

(f) Clay Layer C3

This layer comprises dark gray to black, stiff or hard, tuffaceous clay to silt (CH-MH). The thickness is 4 m or more.

(g) Sand Layer S2

This layer is distinguished as the last layer by the holes JB-8 and JB-9 drilled in the east of Taytay. The layer comprises light brown, hard, silt to clayey silt (SM-MH). It appears that the layer belongs to the weathered zone of the Guadalupe Formation (adobe) for its color and soil characteristics.

Geotechnical Considerations for the Lakeshore Dike

The lakeshore dike will be designed as earth embankment of 2 to 4 m in height and about 9 m in crest width with gates and pump stations at the crossing points of the rivers.

(1) Alignment of Lakeshore Dike

As shown in Fig. 3-3-1, three alternative layouts were contemplated for the lakeshore dike in the course of this study. The geotechnical conditions of these alternatives are as follows.

(a) Alternative No. 1 and No. 2

From the geotechnical viewpoint, there is no difference between the alignments of No. 1 and No. 2, although the alignment of No. 1 may be more suitable than that of No. 2 in terms of the stiffness of the soil layers and the higher elevation.

(b) Alternative No. 3

As clearly shown in Profile D of Fig. 3-3-2, the soil layers along the alignment of No. 3 have a tendency to decrease the N-value in the C1, S1 and C2 layers. This means that soil on the alignment of No. 3 is finer and/or softer even in the same layer as the alignments of No. 1 and No. 2.

(2) Bearing Capacity of Foundation for Important Structures

The foundation for important structures in the area will be the C3 layer of clay with the average N-value of 20-50. The ultimate bearing capacity of this layer is calculated as follows, based upon the design shear strength and unit weight mentioned in Table 3-3-2.

(a) For Direct Foundation

Foundation Type	Ultimate Bearing Capacity
Circular Footing	$qu = 1.3\ C\ Nc + 0.6\ r_2\ R\ Nr + r_1\ Df\ Nq$
Square Footing	$qu = 1.3\ C\ Nc + 0.4\ r_2\ B\ Nr + r_1\ Df\ Nq$
Rectangular Footing	$qu = (1+0.3\ B/L)CNc+(0.5-0.1B/L)r_1\ BNr + r_1\ Df\ Nq$
Continuous Foundation	$qu = C\ Nc + 0.5\ r_1\ B\ Nr + r_1\ Df\ Nq$

where; qu: ultimate bearing capacity: C: cohesion; Nc, Nr, Nq: Terzaghi's bearing capacity factor; R: radius of foundation; B: width of foundation; L: length of foundation; R_1: unit weight of soil from ground surface to foundation bottom; r_2: unit weight of soil from foundation bottom to 2B below the bottom.

(b) For Pile Foundation

$$Ra = 1/3 \bullet \{30\ N \bullet Ap + [(Ns \bullet Ls)\ /\ 5 + (Nc \bullet Lc)\ /\ 2]\}$$

where; Ra: long-term bearing capacity; N: N-value at the pile end; Ap: section of the pile end (m^2); Ns: average N-value of sand in the section of pile; Nc: average N-value of clay in the section of pile.

(3) Settlement

Based upon the design loads by embankment heights of 3 and 4 m and the design values shown below, settlement was calculated.

Consolidation Coefficient	:	2.1×10^{-3} cm^3/s in C1 layer
		1.7×10^{-3} cm^3/s in C2 layer
Drainage Length	:	100 cm in C1 layer
	:	300 cm in C2 layer
Embankment Height	:	4 m

Note: Drainage length of the layer is assumed at 100 cm in C1 layer and 300 cm in C2 layer due to the existing intercalated thin sand layers.

According to the calculated results based on the above conditions, the total of the 80% settlement under an embankment of 4 m in height is estimated at about 52 cm in a period of about 24 months. Therefore, an extra embankment of 20% of the embankment height is required for permanent structures.

(4) Embankment Methods

The embankment of the lakeshore dike is planned to be of earthfill with the height of approx. 4 m. Five alternative embankment methods are considered as follows.

- Embankment by dredged/excavated material from the vicinity of the dike alignment.
- Embankment by mixed soil of dredged/excavated material with borrowed sandy material.
- Embankment by borrowed material for the outer part and dredged/excavated material for the center part.
- Embankment by borrowed material.
- Embankment by dredged/excavated material with the addition of quicklime or cement powder.

The most suitable method for the construction of the lakeshore dike shall be selected from the economical and practical viewpoints.

Material Sources for Construction of Lakeshore Dike

If the lakeshore dike is constructed with dredged/excavated material from the vicinity of the dike alignment, soils of the C1 and S1 layers are practically obtainable. If borrowed material is necessary to be used, it can be taken from Angono, Antipolo or Muntinlupa.

According to the information gathered from the inhabitants and the report of the Feasibility Study for the Metro Manila Outer Major Roads

Project (Northern Package, June 1983), the quantity of available borrow materials in Antipolo may be unlimited, while the quantity in Muntinlupa may be very limited. The up-to-date condition of each site should be confirmed in detail at the detailed design stage.

Sand/gravel materials for embankment and the concrete aggregates will have to be transported from the upper reaches of the Marikina River and from Angono about 10 km east of Taytay. The properties of sand and gravel deposits at Angono for concrete aggregates were reported by the producer as follows.

Material	Wash Loss	Absorption	Abrasion Loss	Specific Gravity
Concrete Aggregate	0.05%	1.03%	17.0%	2.89

Source: Concrete Aggregates Corporation

3.2 Malabon-Navotas Area

General Aspects

(1) Geomorphology

The Malabon-Navotas area is on the coastal alluvial plain with a ground elevation of zero to 2 m above sea level. The general topography of the area is characterized by flat and low-lying plains with the Navotas and the Malabon-Tullahan rivers flowing in a southwesterly direction associated with deserted loops.

(2) Geology

The whole surface of the alluvial deposit is covered with sand, silt and clay. These soils are of the deltaic deposits formed by the Navotas and the Malabon-Tullahan rivers and mixed with marine faunas and corals.

According to the existing drilling data of the road project (C-5, C-6 and R-10), the thickness of the alluvial deposits is in the range from 15 m to 27 m, below which lie Plio-Pleistocene tuffaceous rocks (tuff and pyroclastic rocks) of the Guadalupe Formation, cemented in varied degrees and with undulating surface.

Geological Condition

(1) Field Investigation

(a) Previous Investigations

In the Malabon and Navotas areas, geotechnical investigations were previously made for a few projects of the DPWH such as the Feasibility Study for Manila-Bataan Coastal Road and Its Related Roads (C-5 & C-6) Project, March 1980; and, the Metro Manila Integrated Urban Drainage and Flood Control Project, Malabon-Tullahan River, July 1983.

(b) Investigations in this Study

To study and confirm the geological conditions in the area, one drilling (MN-1) 10 m deep was additionally conducted at the ground elevation of EL 11.380 m and nine standard penetration tests were carried out. The location of MN-1 is shown in Fig. 3-3-3, together with those of the previously drilled holes.

(2) Laboratory Test

Samples were taken from drillhole MN-1 for the laboratory test with the following results.

Layer	Depth (m)	NMC (%)	Sieve (D50, Uc)	S.G.	LL-PL (%)
Sand	1.55-2.00	31.36	0.38, 12	2.64	---
Clay	5.55-6.00	48.81	Clay	2.60	41.08-22.2
Clay Containing Shell Fragments	9.55-10.00	50.19	0.008, 150	2.59	56.34-28.1

[Note] NMC: Natural Moisture Content; Uc: Uniformity Coefficient;
S.G.: Specific Gravity; LL-PL: Liquid-Plastic Limit

The above figures reveal well the characteristics of each soil layer, as well as the existing test results of BH-003 samples as shown in Fig. 3-3-4.

(3) Soil Profile

The geological profile was prepared on the basis of the data on the previously drilled holes of BH-003, BH-2 and BH-1, and the latest hole of MN-1 in this study (see Fig. 3-3-4).

The profile shows a general picture of the subsurface geology, mainly consisting of thick clayey deposits with intercalations of sandy-shally layers, which cover the tuffaceous bed and is covered with a few meter thick sandy layer.

The layers having the N-value of more than 50 which indicates enough bearing capacity are reached at the depth of 15 to 27 m below the ground surface. It is conceivable that the layer having such a high N-value is the tuffaceous rocks of the Guadalupe Formation.

(4) Geotechnical Considerations for Foundation

At the Malabon-Navotas area, various types of structures such as ring dike, pump stations and gates are required to be constructed. Their foundations such as pump stations and gates have to rest on the layer having adequate bearing capacities of N-value over 50, i.e., the Guadalupe Formation. Reinforced concrete piles to reach the Guadalupe Formation will be a practical solution to be examined in the future.

4. GEOTECHNICAL CONDITION AT MAJOR STRUCTURE SITES

Marikina Control Gate Structure

The Marikina Control Gate Structure (MCGS) is proposed on the Marikina River around one (1) kilometer west of the Rosario Weir of the Mangahan Floodway.

According to the geological data obtained in investigations for the Marikina Control Structure and Upper Marikina River Improvement Project, a sup-horizontally bedding Guadalupe Tuff Formation is the bedrock of the site. (Refer to Fig. 3-4-1.)

Alluvial deposits of less than two (2) meters in thickness and five to six (5-6) meters in thickness are distributed in the riverbed and both banks respectively. Sandy layers of the alluvium show N-value around ten (10) and silty layers show more than twenty (20) in the penetration test to the USBR specification.

San Juan River Improvement Works

San Juan River is a major tributary of the Pasig River, joining from north at the confluence around 8.7 km upstream from the primary benchmark located at the river mouth. The river gradient in the upper and middle reaches is relatively steep reflecting the topographic condition of the area.

According to the existing record or core drilling in the subsoil investigation for the San Juan River and Talayan Creek carried out in 1983, the area along the river is composed of tuffaceous bedrocks of Guadalupe Formation and overlying dense soil with thickness less than 2 m. The bedrock is covered by clayey to sandy oberburden with thickness of less than 3 m in the upper stretch of the river. The recent river deposits in the lower stretch of the river within 2.5 km from the river mouth is around 7 m.

Cut-off from Parañaque River

The cut-off of the Parañaque River, about five hundred (500) meters long, is proposed to divert the river water from the vicinity of the Airport Road Bridge to Manila Bay.

The cut-off stretches in the Manila Alluvial Plain which consists of silty to sandy layers. Thickness of this unconsolidated layer is unknown, but presumed to be between five and twenty meters from the existing record of core boring in this area.

Marikina Dam

Proposed site of the Marikina Dam is located approximately 30 m downstream from the existing Wawa Dam which is situated around 3.5 km upstream from the border between the Marikina Valley Plain and the mountain zone.

The riverbed at the dam site is around 50 m in elevation and about 40 m wide and steep slopes rise abruptly up to 400 m in elevation on both banks.

The bedrock of the site is a member of Angat formation of early Miocene, which consists of well bedded to massive limestone associated with thin siliceous and calcareous sandstone and alternations of thinly bedded sequence of calcareous shale, clayey sandstone, sandy limestone and coglomerate. This formation is highly weathered under coglomerate. This formation is highly weathered under tropical climate and forms Karst caves of underground erosion at places. The bedrock at the dam site is a massive limestone with cavities. Some of the cavities stretch deep under the hills, occasionally developing into large caverns.

The topographical and geological conditions seem to suit construction of a concrete gravity dam from the mechanical point of view. However, it is highly probable that the intensive Karst features, or development of solution cavities, in the limestone bedrock will cause much difficulties and, thereby, extra cost in foundation treatment for seepage cut-off.

Further detailed geotechnical investigations are required.

TABLES

Table 3-2-1 GROUND WATER LEVEL AND LAND SUBSIDENCE

PERIOD	OBSERVATION YEAR	ALLUVIAL DEPOSIT		GUADALUPE FORMATION	
		GROUND LEVEL	G.W. LEVEL	GROUND LEVEL	G.W. LEVEL
- 1950					
	1955		----------------		----------------
- 1960			DOWN		DOWN
	1967	DOWN	----------------		----------------
- 1970					
			UP		DOWN
	1979	----------------		----------------	
- 1980		ALMOST			
	1981	UNCHANGED	----------------	UNCHANGED	----------------
	1988	----------------	UNCHANGED	----------------	UNCHANGED
- 1990			OR UP		OR UP

Table 3-3-1(1/2) SUMMARY OF LABORATORY TEST RESULTS

			JB-1		JB-2	JB-3				JB-4			JB-5		JB-6			
SAMPLE No.			UDS-1	UDS-2	UDS-1	TP-UDS	UDS-1	UDS-2	S-16	TP-UDS	UDS-1	UDS-2	UDS-1	S-12	S-5	UDS-1	UDS-2	S-23
SAMPLE DEPTH (m)			7.55-8.00	14.55-15.00	17.55-18.00	0.55-1.00	5.55-6.00	14.55-15.00	17.55-18.00	0.50-1.00	8.55-9.00	14.55-15.00	4.55-5.00	13.55-14.00	4.55-5.00	6.55-7.00	14.55-15.00	24.55-25.00
GRAIN SIZE ANALYSIS	% PASSING SIEVE 3/8"		100	100	100	100	100		100	100	100	100	100	100	100	92		100
	# 4		99	99	99	100	100		100	100	99	100	100	98	100	88		100
	# 10		99	95	97	100	97		99	100	98	99	100	89	99	87		97
	# 40		98	92	95	99	97		99	99	97	97	99	78	99	85		95
	# 100		96	91	95	99	97		97	99	95	96	95	41	89	68		94
	# 200		93	87	95	99	95		93	99	86	80	63	26	64	50		92
CONSISTENCY	Liquid Limit, Wl (%)		40	78	91	62	67	103		65	34	44	50			34	63	
	Plastic Limit, Wp (%)		21	40	47	33	34	54		35	17	22	27			18	32	
	Plasticity Index, Ip		19	39	44	29	32	49		30	16	22	23			16	30	
	*Shrinkage Limit, Sl, %					34		43		24						35		
Soil Classification (ASTM)			MH	MH	CH	CH	MH	CH	CH	OH	MH	MH	ML	SP	SM	CH	SP	MH
Specific Gravity, Gs			2.60	2.61	2.61	2.63	2.60	2.61	2.57	2.62	2.63	2.60	2.60	2.60	2.53	2.59		2.60
Natural Moisture Content, Wn (%)			93	92	83	43	72	122	103	45	42	49	42	44	37	39	68	52
Organic Content																		
Wet Unit Weight, γt (g/cm³)			1.76		(1.39)	(1.60)	(1.52)	(1.42)		(1.63)	(1.64)		(1.75)			1.78	(1.57)	
Dry Unit Weight, γd (g/cm³)			1.76	1.34	0.67	1.12	0.88	0.64		1.12	1.15		1.23				0.94	
Natural Void Ratio, e_o			1.13	0.70		1.353	1.941	3.082		1.273			1.105					
Degree of Saturation, Sr (%)						84	97	95		93			98					
CONSOLIDATION TEST	Preconsolidation Pressure, Pc (kg/cm²)					0.78	0.92	0.77		0.99			2.80					
	Compression Index, Cc					0.377	1.01	1.395		0.408			0.488					
UNCONFINED COMPRESSION TEST	Unconfined Compressive Strength, qu (kg/cm²)	1		0.105	0.175		0.097	0.121			0.182		0.629				0.799	
		2																
	Strain, ε (%)	1		8.81	3.297		5.714	11.152			2.747		3.608				5.051	
		2																
TRIAXIAL COMPRESSION TEST (Cu)	Cohesion, Cu (kg/cm²) (C')		0.07		0.18		0.06				0.32		0.18				0.30	
	Angle of Internal Friction, φu (deg) (φ')		29 (44)		13.5 (18.5)		15 (20.4)				8 (11.4)		23 (36.2)				13 (15.9)	
COMPACTION TEST	Maximum Dry Density, g/cc					1.48				1.43								
	Optimum Moisture Content, %					25				29								
Dia 50			0.009	0.03	0.0036	0.0068	0.03		0.005	0.0068	0.045	0.03	0.065	0.15	0.064	0.075		0.007
$Uc = D_{60}/D_{10}$			14	58	3	35	43		.14	20	27	23	35	3	13	4		33
ASSUMED PERMEABILITY (From D_{10}) K(cm/sec)			3×10^{-8}	3×10^{-8}	3×10^{-8}	3×10^{-6}	3×10^{-6}		3×10^{-6}	3×10^{-6}	3×10^{-6}	3×10^{-8}	3×10^{-6}	3.5×10^{-3}	3×10^{-6}	4.5×10^{-4}		3×10^{-6}

Note : The value of shrinkage test were obtained from the sample passing the sieve No. 40

C' and φ' mean an effective cohesion and an effective angle of internal friction respectively

Table 3-3-1(2/2) SUMMARY OF LABORATORY TEST RESULTS

DRILLING No.		JB-7				JB-8				JB-9			JB-10			NM-1		
SAMPLE No.		TP-UDS	UDS-1	UDS-2	S-15	TP-UDS	UDS-1	S-14	S-17	TP-UDS	UDS-1	S-16	S-1	UDS-2	S-14			
SAMPLE DEPTH (m)		0.50-1.00	5.50-6.00	11.50-12.00	16.55-17.00	0.55-1.00	5.55-6.00	14.55-15.00	17.55-18.00	0.50-1.00	7.55-8.00	16.55-17.00	0.55-1.00	11.55-12.00	15.55-16.00	1.55-2.00	5.55-6.00	9.55-10.00
GRAIN SIZE ANALYSIS	% PASSING SIEVE 3/8"	100	100		100	100	100	100	100	100	100	100	94	89	100	99	100	99
	# 4	99	99		100	100	100	98	100	100	100	100	93	83	97	82	100	97
	# 10	99	95		99	100	99	98	100	100	95	99	90	82	89	74	100	90
	# 40	99	66		99	99	75	98	91	100	82	99	88	80	85	52	100	66
	# 100	99	34		99	99	16	97	60	99	79	98	87	75	85	26	99	60
	# 200	97	27		97	99	8	95	45	99	77	94	85	67	85	12	94	57
CONSISTENCY	Liquid Limit, Wl (%)	56		53		59				57	63			56			41	56
	Plastic Limit, Wp (%)	30		30		27				28	34			28			22	28
	Plasticity Index, Ip	26		23		32				29	29			28			19	28
	Shrinkage Limit, Sl, %	23		43		38				19	19			33				
Soil Classification (ASTM)		CH	SM	CH	CH	CH	SM	CH	SM	CH	CH	MH	CH	MH	CH	SM	CH	CH
Specific Gravity, Gs		2.61	2.62	2.61	2.57	2.61	2.59	2.61	2.64	2.62	2.62	2.62	2.66	2.60	2.65	2.64	2.60	2.59
Natural Moisture Content, Wn (%)		33	31	70	47	46	32	39	26	47	43	30	34	65	71	31.36	49	50
Organic Content				-														
Wet Unit Weight, γt (g/cm³)		(1.59)	1.65	(1.58)		(1.69)				(1.72)	(1.75)		(1.86)	(1.59)				
Dry Unit Weight, γd (g/cm³)		1.19		0.93		1.16				1.17	1.22		1.39	0.96				
Natural Void Ratio, e_o		1.174		1.817		1.247				1.247			0.905	1.703				
Degree of Saturation, Sr (%)		74		100		96				99			99	99				
CONSOLIDATION TEST	Preconsolidation Pressure, Pc (kg/cm²)	0.76		0.890		1.102				0.83			1.440	1.99				
	Compression Index, Cc	0.380		0.682		0.383				0.368			0.168	0.367				
UNCONFINED COMPRESSION TEST	Unconfined Compressive Strength, qu (kg/cm²) 1	1.663				0.955				0.838	0.632		0.089					
	2																	
	Strain, ε (%) 1	4.571				4.00				5.58	8.515		1.378					
	2																	
TRIAXIAL COMPRESSION TEST (Cu)	Cohesion, Cu (kg/cm²) (C')			0.18 (0.21)		0.10				0.05				0.20				
	Angle of Internal Friction φu (deg) (φ')			17.5 (26.8)		13.5 (18)				16.2 (21.8)				12.3 (15.6)				
COMPACTION TEST	Maximum Dry Density, g/cc	1.43		0.18		1.45	-			1.37								
	Optimum Moisture Content, %	29		17.5		26				30								
Dia 50		0.0033	0.3		0.006	0.001	0.3	0.0065	0.09	0.058	0.06	0.03	0.03	0.066		0.38		0.008
$Uc = D_{60}/D_{10}$		20	400		—	—	4	50	7	59	60	30	50	23		12		150
ASSUMED PERMEABILITY (From D_{10}) K (cm/sec)		3×10^{-6}	3×10^{-6}		3×10^{-4}	3×10^{-6}	1.5×10^{-3}	4.5×10^{-4}	4.5×10^{-4}	3×10^{-6}	3×10^{-6}	3×10^{-6}	3×10^{-6}	3×10^{-6}		3.5×10^{-3}		3×10^{-6}

Note : The value of shrinkage test were obtained from the sample passing the sieve No.40

C' and φ' mean an effective cohesion and an effective angle of internal friction respectively

Table 3-3-2 TYPICAL SOIL PROFILE AND ITS PROPERTIES
(TAGIG AND TAYTAY AREA)

DEPTH (m)	LAYER (SOIL SYMBOL)	N-VALUE (AVERAGE)	PHYSICAL PROPERTY	ENGINEERING PROPERTY
	F I L L	———	———	———
0 m	S A N D(SM) (SM)	20-30	γt = 1.7, Gs = 2.60 Wn = 30 - 40% *	Partly located at western rim of lake
	C l a y C_1 (CH)	10	γt = 1.64 gr/cm^3** Wn = 42% (34-47) LL = 58% (56-65) PL = 30% (27-35) PI = 28% Gs = 2.62 gr/cm^3**	C' = 0.11kgf/cm^2 (0.06 0.18) ϕ = 14.0° (14° - 23°) ϕ' = 22.0° (18° - 36°) ** Cv = 2.1x10^{-3}cm^3/sec Cc = 0.37 (0.37-0.49) qu = 0.81kgf/cm^2 (0.63-0.96) eo = 1.19 (0.91-1.34)
3.0m	S A N D S_1 (SP-SM)	5	γt = 1.75 gr/cm^3** Wn = 52% (32 - 72) Gs = 2.64 gr/cm^3**	C' = 0.18kgf/cm^2 (0.06 0.30) ϕ = 14° (13° - 15°) ϕ' = 36° ** (16° - 20°) Cc = 0.20 ** (1.01) qu = 0.80kgf/cm^2 (0.8) eo = 0.90 ** (1.941)
5.5m	C l a y C_2 (CH-CM)	2	γt = 1.50 gr/cm^3** Wn = 68% (39-122) LL = 61% (34-103) PL = 32% (18-54) PI = 29% Gs = 2.61 gr/cm^3**	C' = 0.19kgf/cm^2 (0.18-0.32) ϕ = 16.8° (8° - 29°) ϕ' = 20° ** Cv = 1.7x10^{-3}cm^3/sec Cc = 0.80 (0.682-1.340) qu = 0.39kgf/cm^2 (0.11-0.89) eo = 1.34 (0.70-1.82)
17.5m	C l a y C_3 (CH)	20-50	γt = 1.70 gr/cm^3** Wn = 75% (39-103) LL = 63% (34-91) PL = 32% (16-44)	Gs = 2.61 gr/cm^3 ** C (Su) = 0.32kgf/cm^2 ** qu = 0.18kgf/cm^2 ϕ' = 18.5°
22.5m or deeper	S A N D S_2 (MH-SM)	50 or more	γt = 1.75 gr/cm^3** Wn = 28% ** Gs = 2.62 gr/cm^3**	C' = 0kgf/cm^2 ** ϕ' = 36° **

[Note]

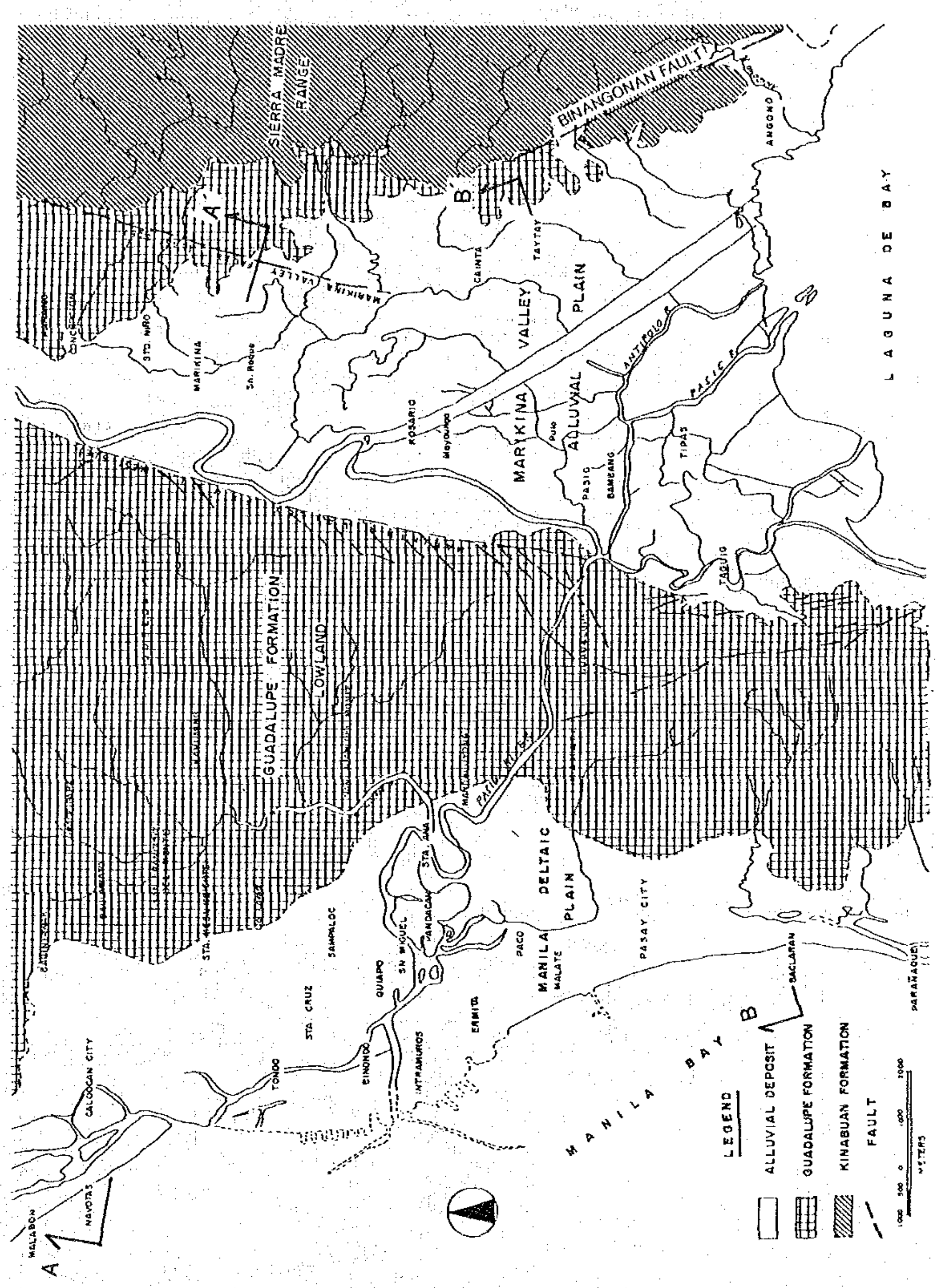
Figures in parentheses are the minimum and the maximum values of the tests.

* Data taken from the Report of the Parañague Spillway Project.
** Data used by Technotest, Inc.

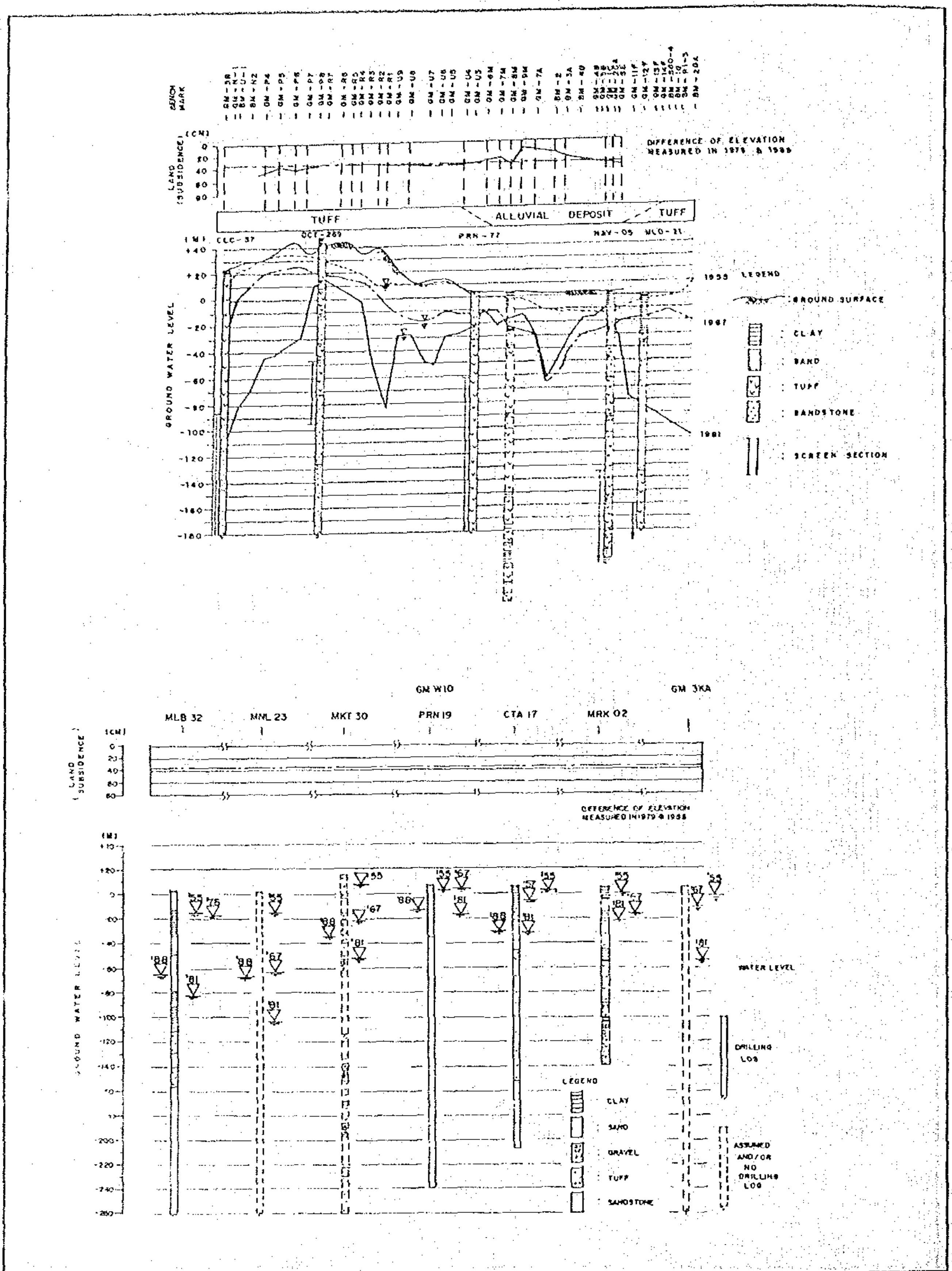
Table 3-3-3 UNIFIED SOIL CLASSIFICATION SYSTEM

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 3 inches and basing fractions on estimated weights)						GROUP SYMBOLS a	TYPICAL NAMES
COARSE GRAINED SOILS More than half of material is <u>larger</u> than No. 200 sieve size 12. (The No. 200 sieve size is about the smallest particle visible to the naked eye)	GRAVELS More than half of coarse fraction is larger than No. 4 sieve size. (For visual classifications, the ¼" size may be used as equivalent to the No. 4 sieve size.)	CLEAN GRAVELS (Little or no fines)	Wide range in grain size and substantial amounts of all intermediate particle sizes.			GW	Well graded gravels, gravel-sand mixtures, little or no fines.
			Predominantly one size or a range of sizes with some intermediate sizes missing.			GP	Poorly graded gravels, gravel-sand mixtures, little or no fines.
		GRAVELS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).			GM	Silty gravels, poorly graded gravel-sand-silt mixtures.
			Plastic fines (for identification procedures see CL below).			GC	Clayey gravels, poorly graded gravel-sand-clay mixtures.
	SANDS More than half of coarse fraction is smaller than No. 4 sieve size. (For visual classifications, the ¼" size may be used as equivalent to the No. 4 sieve size.)	CLEAN SANDS (Little or no fines)	Wide range in grain sizes and substantial amounts of all intermediate particle sizes.			SW	Well graded sands, gravelly sands, little or no fines.
			Predominantly one size or a range of sizes with some intermediate sizes missing.			SP	Poorly graded sands, gravelly sands, little or no fines.
		SANDS WITH FINES (Appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below).			SM	Silty sands, poorly graded sand-silt mixtures.
			Plastic fines (for identification procedures see CL below).			SC	Clayey sands, poorly graded sand-clay mixtures.
FINE GRAINED SOILS More than half of material is <u>smaller</u> than No. 200 sieve size. (The No. 200 sieve size is about the smallest particle visible to the naked eye)	IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN No. 40 SIEVE SIZE						
			DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATANCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)		
	SILTS AND CLAYS Liquid limit less than 50		None to slight	Quick to slow	None	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands with slight plasticity.
			Medium to high	None to very slow	Medium	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			Slight to medium	Slow	Slight	OL	Organic silts and organic silt-clays of low plasticity.
	SILTS AND CLAYS Liquid limit greater than 50		Slight to medium	Slow to none	Slight to medium	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			High to very high	None	High	CH	Inorganic clays of high plasticity, fat clays.
			Medium to high	None to very slow	Slight to medium	OH	Organic clays of medium to high plasticity.
HIGHLY ORGANIC SOILS			Readily identified by color, odor, spongy feel and frequently by fibrous texture.			Pt	Peat and other highly organic soils.

FIGURES



THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	GEOLOGICAL MAP OF THE STUDY AREA
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.3-2-1

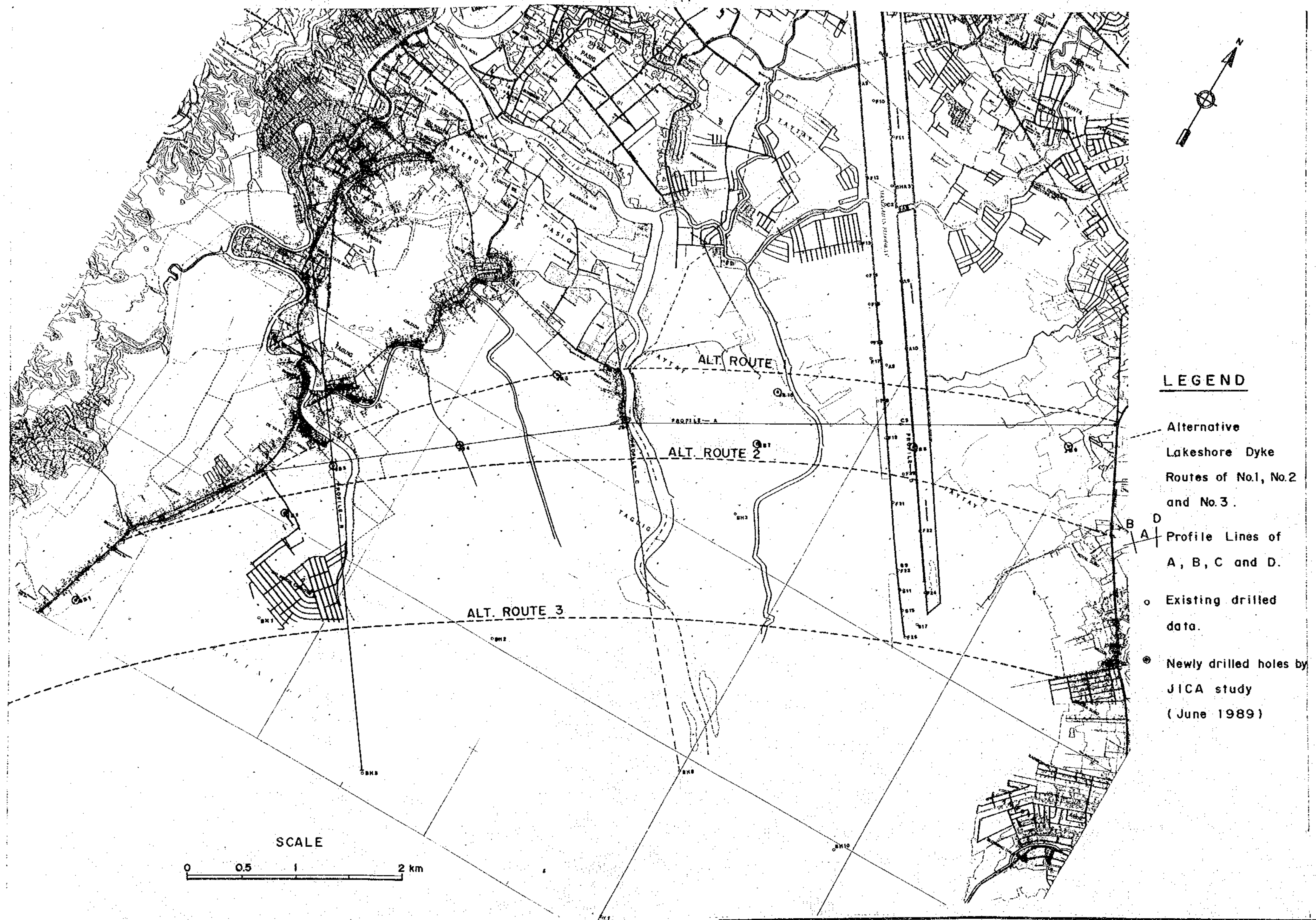


THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

SURVEY RESULS AND FLUCTUATION OF GROUNDWATER

Fig.3-2-2



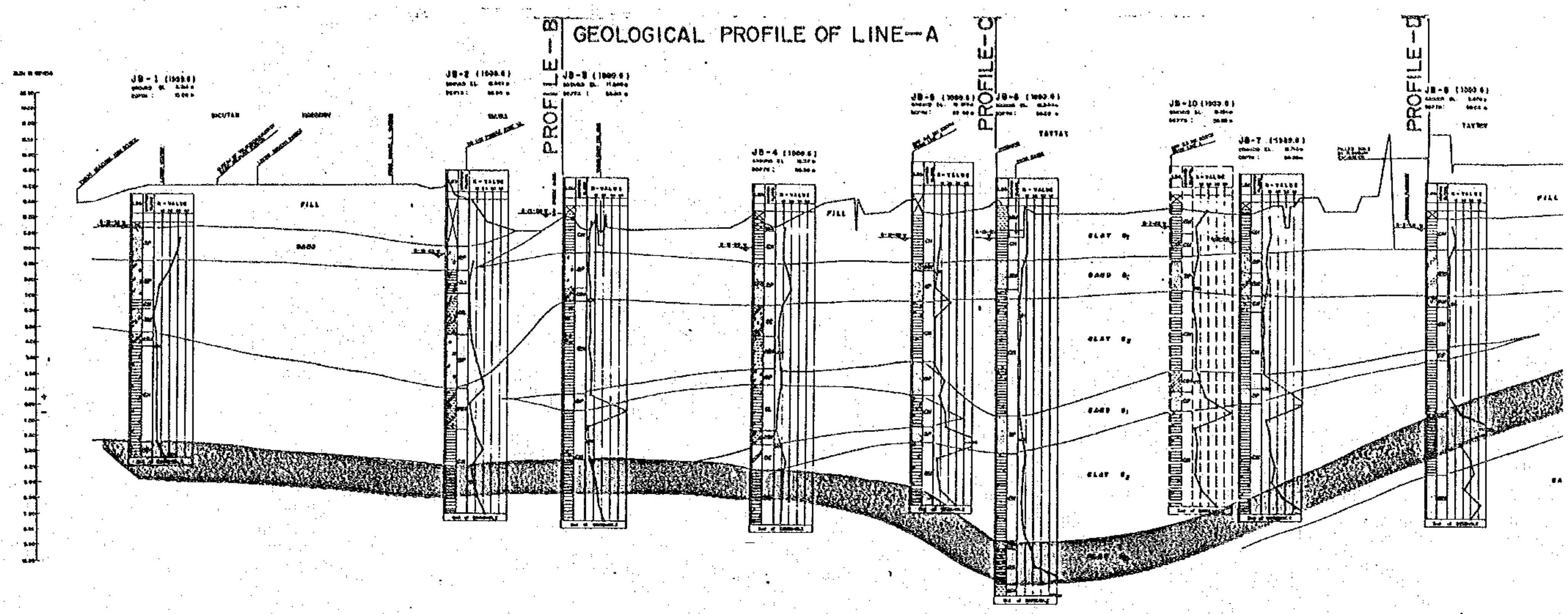
THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

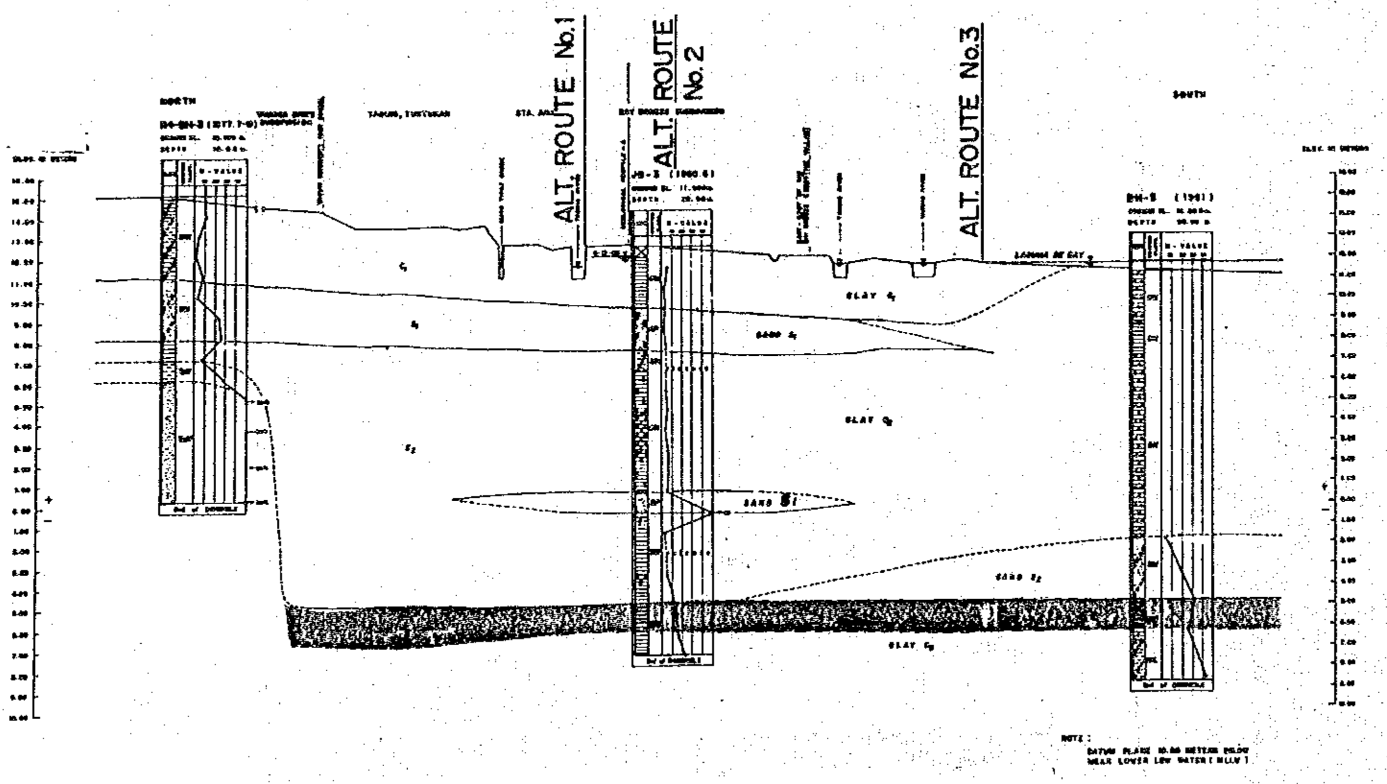
DRILLING HOLES IN THE LAKESHORE DIKE AREA

Fig.3-3-1

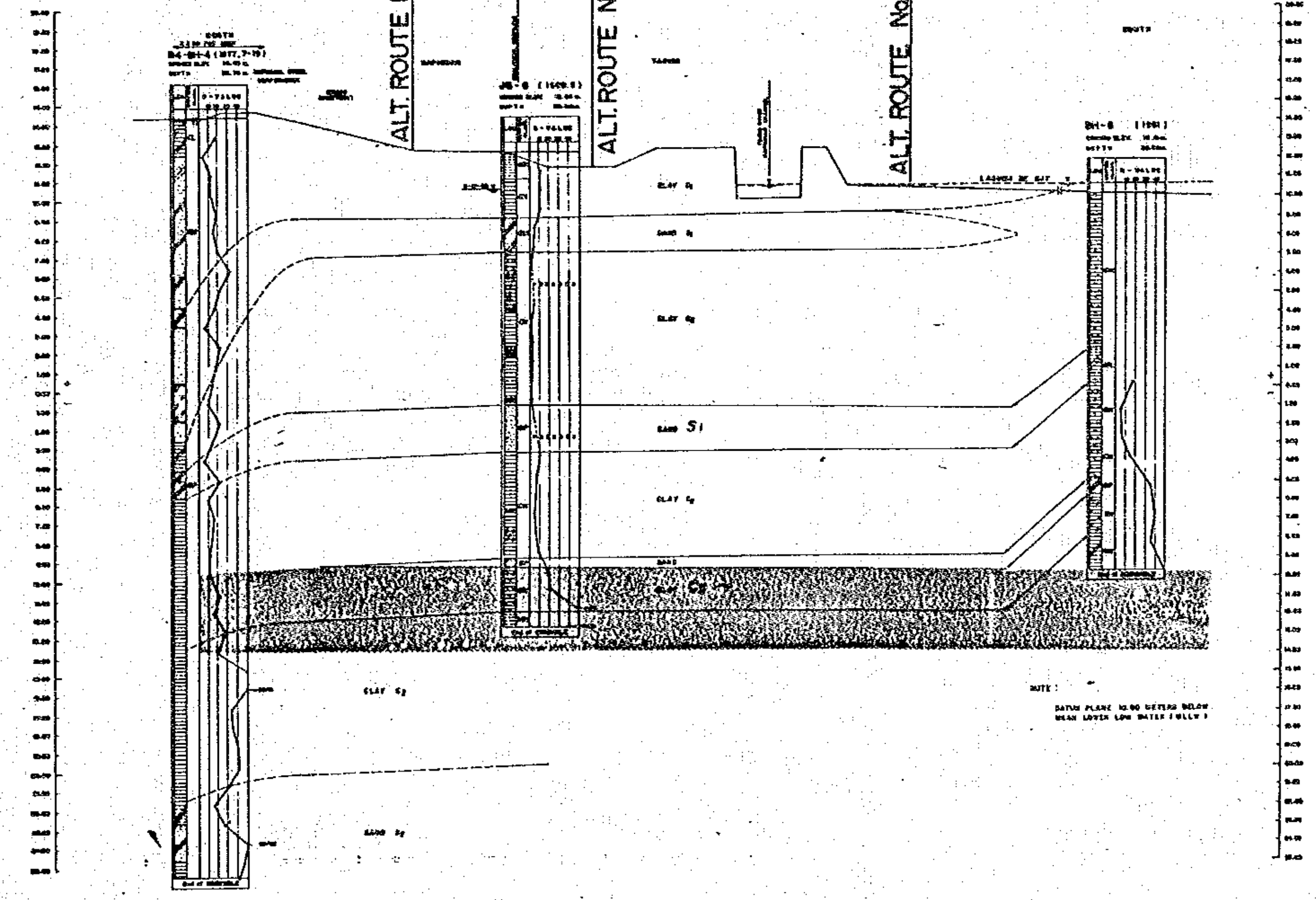
GEOLOGICAL PROFILE OF LINE—A



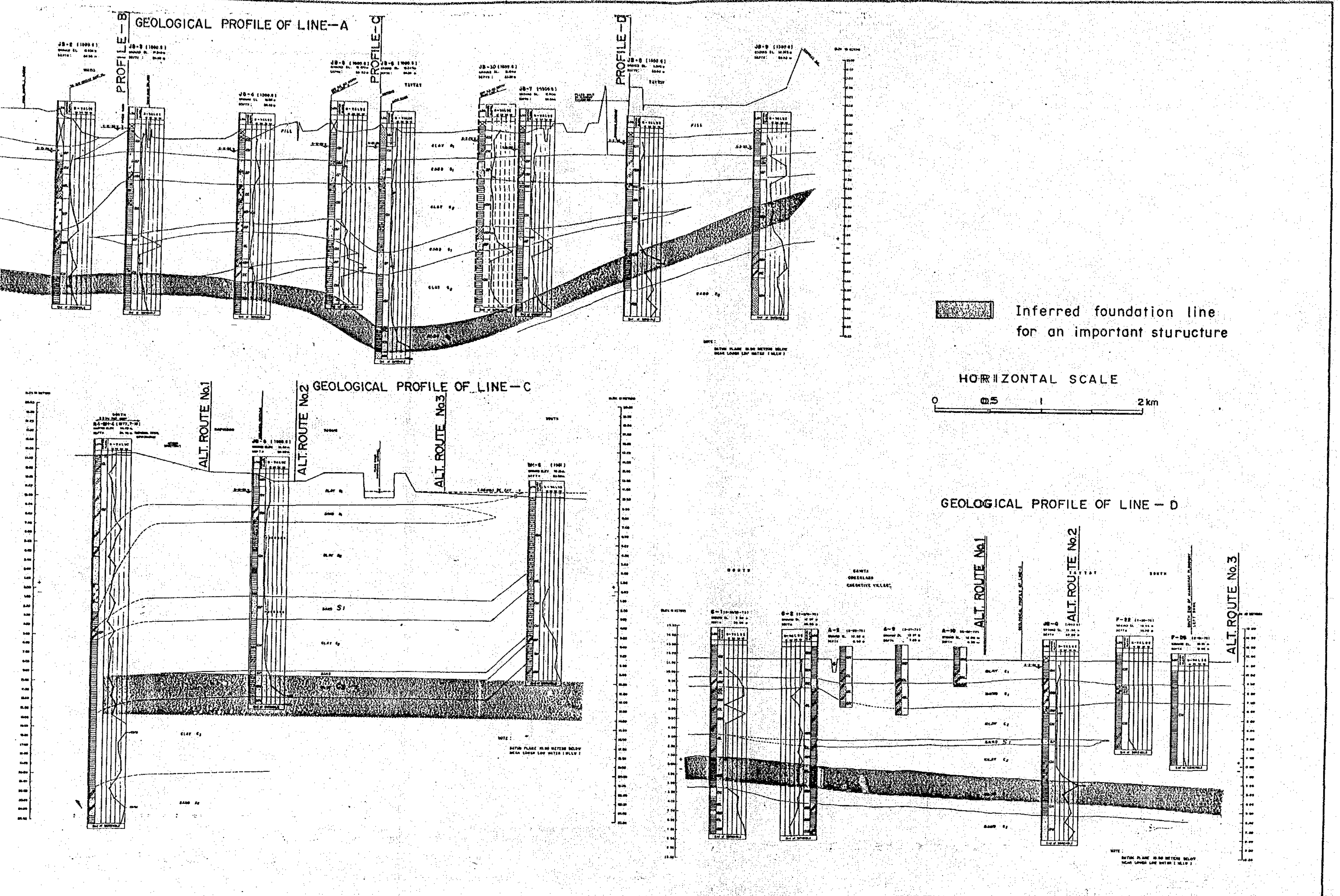
GEOLOGICAL PROFILE OF LINE—B



GEOLOGICAL PROFILE OF LINE—C



THE S

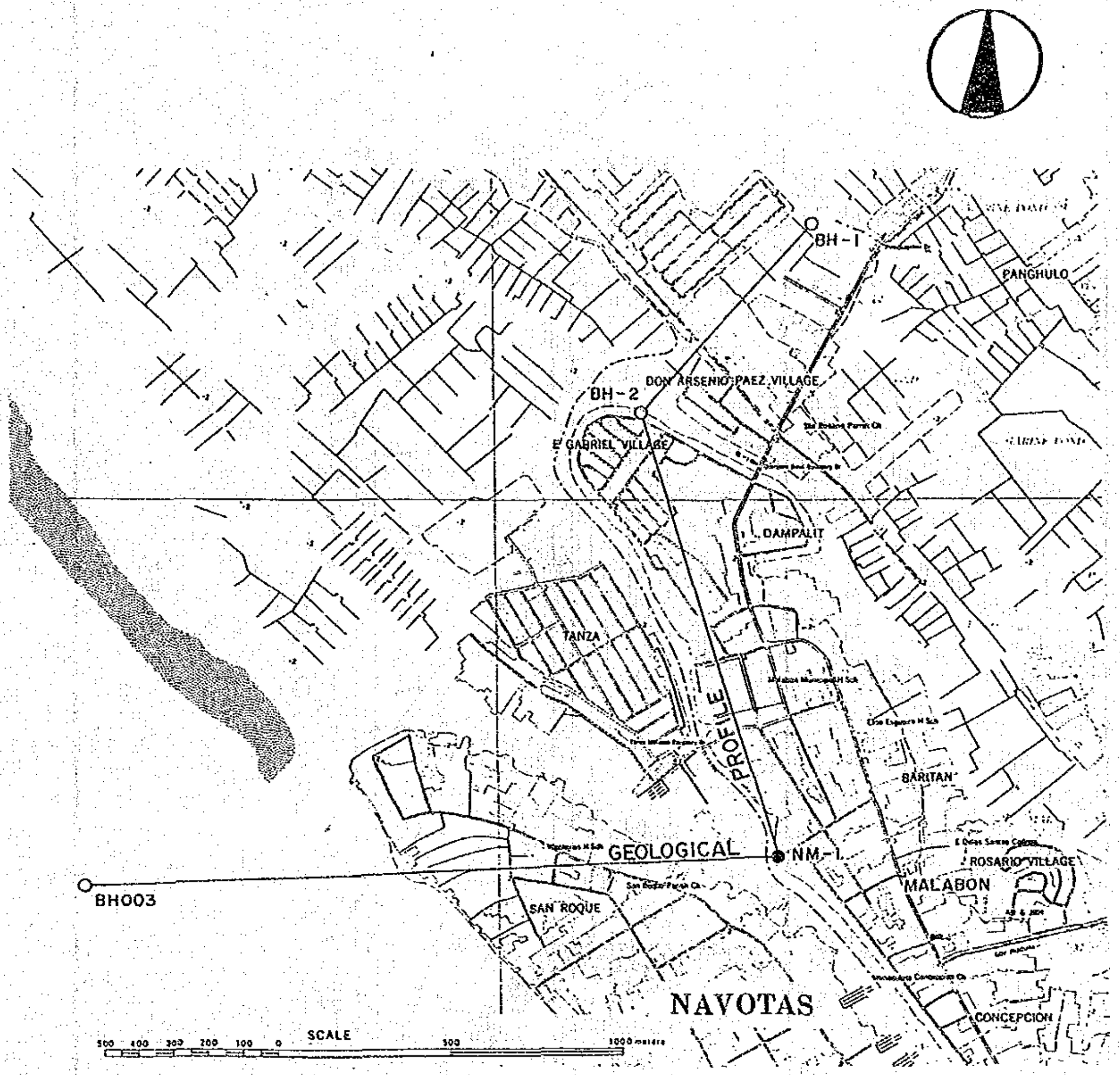


THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES

JAPAN INTERNATIONAL COOPERATION AGENCY

GEOLOGICAL PROFILES (A,B,C & D) IN AND AROUND THE LAKESHORE DIKE

Fig.3-3-2

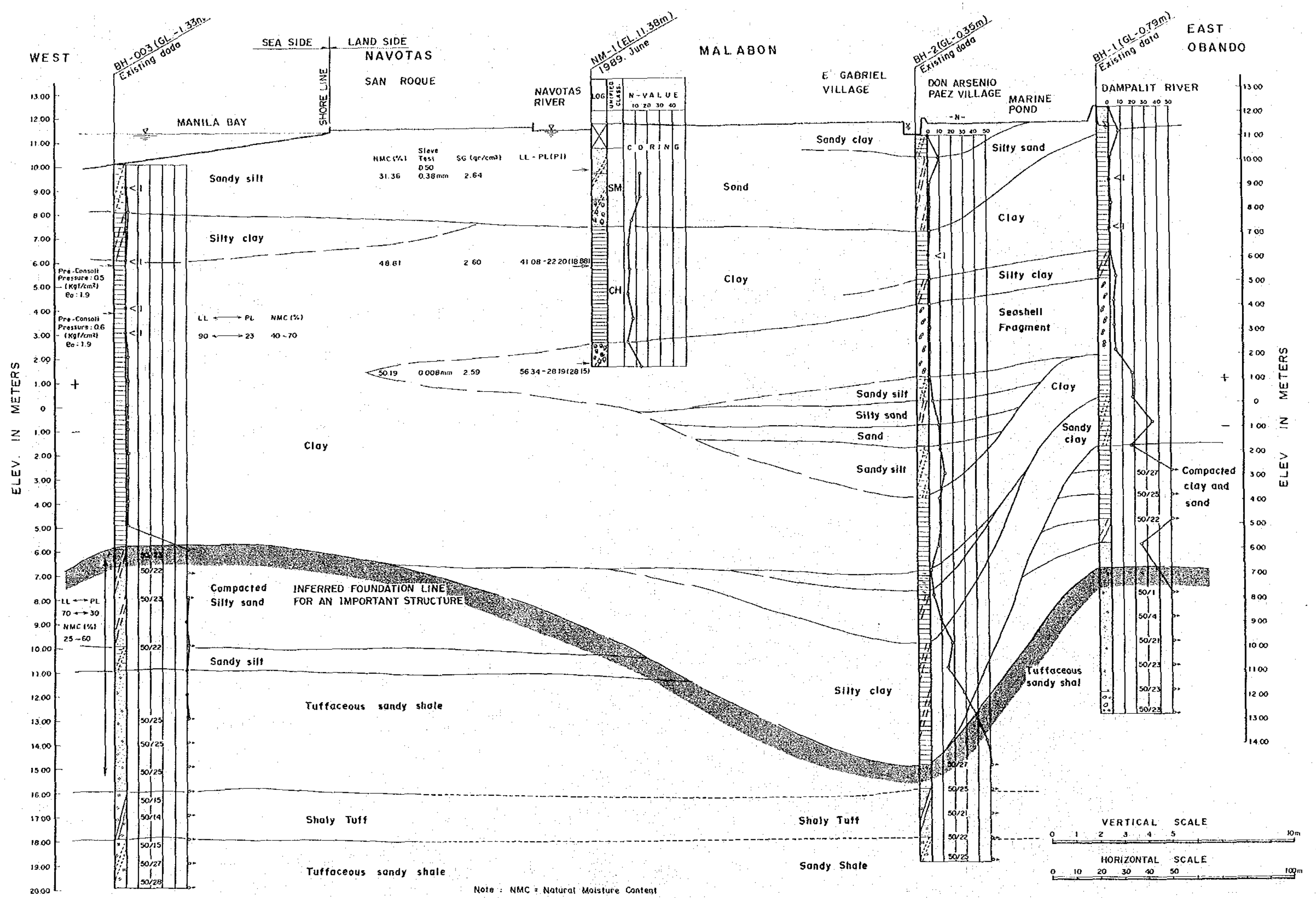


LEGEND

○ Existing data

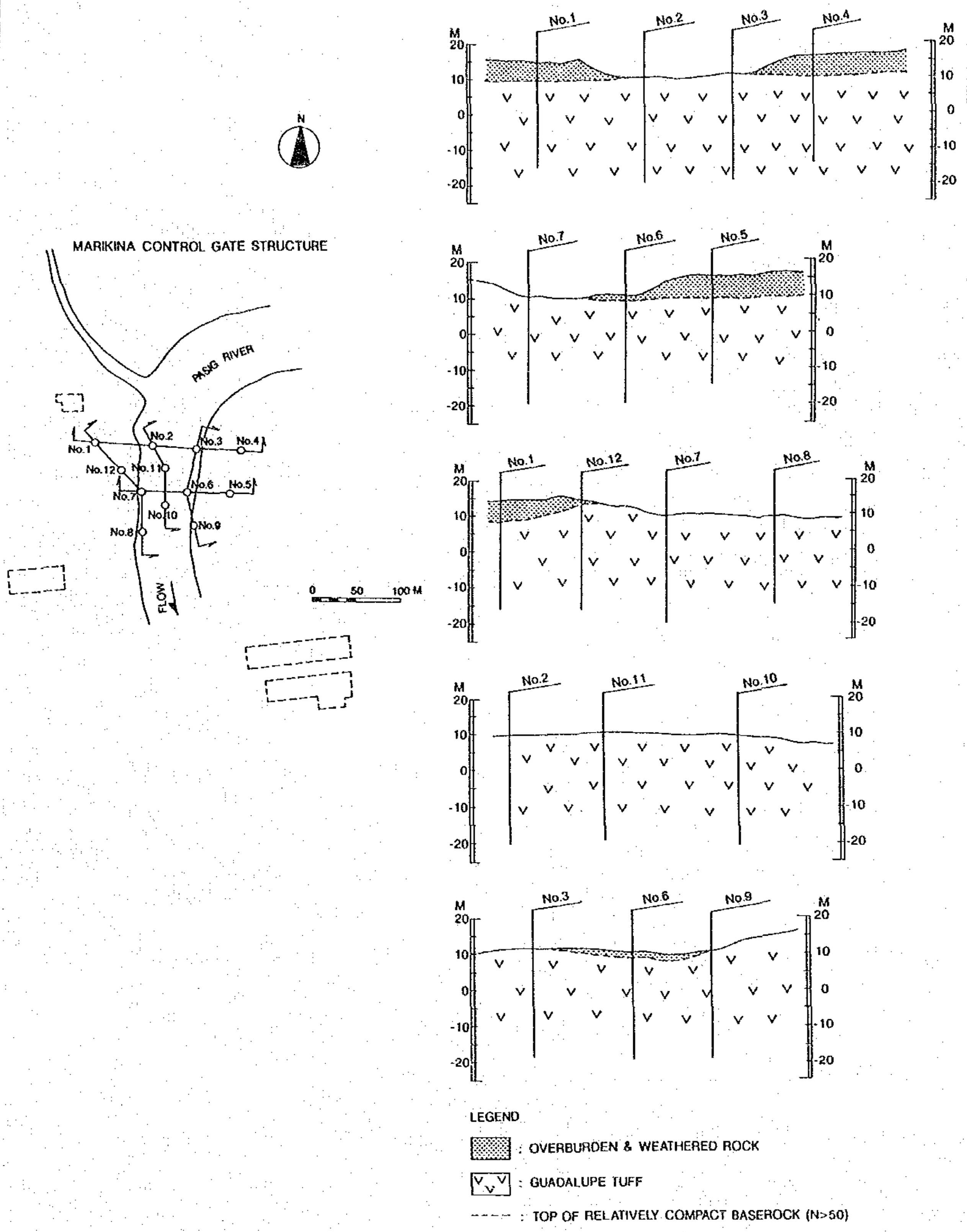
● NM-1
Newly drilled by
JICA study
(June 1989)

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES	DRILLING HOLES IN MALABON-NAVOTAS
JAPAN INTERNATIONAL COOPERATION AGENCY	Fig.3-3-3



Note : NMC = Natural Moisture Content
D_{50} = Diameter of 50 per cent passing sieve
SG = Specific Gravity
LL-PL(PI) = Liquid Limit - Plastic Limit (Plasticity Index)
e_0 = Initial Void Ratio

THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES JAPAN INTERNATIONAL COOPERATION AGENCY	GEOLOGICAL PROFILE OF MALABON-NAVOTAS Fig.3-3-4



THE STUDY ON FLOOD CONTROL AND DRAINAGE PROJECT IN METRO MANILA, PHILIPPINES JAPAN INTERNATIONAL COOPERATION AGENCY	GEOLOGICAL CONDITION OF THE PROPOSED SITE FOR MARIKINA CONTROL GATE STRUCTURE Fig.3-4-1

IV. FLOOD CONTROL

SUPPORTING REPORT

IV. FLOOD CONTROL

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1. GENERAL

This supporting report presents the flood control of river systems under The Study on Flood Control and Drainage Project in Metro Manila.

2. PRESENT CONDITION

2.1 Watersheds

The objective area is divided into the following basins in accordance with the topographic characteristics and the river and channel system.

- Pasig-Marikina River Basin
  (Including San Juan River)
- Meycauayan River Basin
- Malabon-Tullahan River Basin
- Buli-Baho-Mahaba River Basin
- South Parañaque-Las Piñas River Basin
- Other Remaining Areas

The areal divisions and catchment areas are shown in Fig. 4-2-1. Laguna Lake Basin with the total catchment area of about 3,160 km^2 is not included, and other remaining areas means the inland drainage area which do not belong to the river basin such as the coastal lowland areas and the lowland area in the north shoreline of the Laguna Lake.

2.2 River System

Pasig-Marikina River System

The Pasig-Marikina River flows through the City of Manila to the Manila Bay. Its total catchment area is estimated at about 635 km^2, as shown in Table 4-2-1, about 10% of which is situated in Metro Manila. The Mangahan Floodway has been constructed to divert the Marikina floodwater into the Laguna Lake at the design discharge of 2,400 m^3/s with the Marikina Control Gate Structure (MCGS) which is not yet completed. In this situation, a discharge of 1,100 m^3/s is designed to flow down into the lake when the Marikina River has a discharge of 2,000 m^3/s according to the model test conducted in 1983. At the confluence with the Napindan Channel, the river is known as the Marikina River in the upper reaches and the Pasig River in the lower reaches. The San Juan River, one of the tributaries with a catchment area of 91 km^2, joins the Pasig River at its meandering section in the central city area.

The boundary between the Pasig-Marikina River System and the Laguna Lake System is at the confluence point with the Napindan Channel which links the two river systems. The Pasig-Marikina River System is also adjoining to the Malabon-Tullahan River System and the South Parañaque-Las Piñas River System on the north and south boundaries, respectively.

Meycauayan River System

The Meycauayan River System consists of several rivers such as Meycauayan, Marilao, Bulacan, Bocaue, Polo, Caloocan and others. The Meycauayan and Marilao Rivers, two main streams of the river system, flow from east to west mostly along the northern boundary of Metro Manila. The catchment area of these two main streams is estimated at about 169 km^2, about 45% of which belongs to two municipalities, i.e., Caloocan (North) and Valenzuela. In the vicinity of its estuary, the river system links with the Malabon-Tullahan River System through the tributaries of the Polo River and others.

Malabon-Tullahan River System

The Malabon-Tullahan River System originates in the northeastern boundary of Metro Manila and flows into the Manila Bay. The main stream of this river system is called by different names such as Tullahan, Tenejeros, Malabon and Navotas depending on the location from the upstream to the downstream. The Novaliches Reservoir, the municipal and industrial water source for Metro Manila, is located in the upper reaches of this river system.

Buli-Baho-Mahaba River System

The area is located in the eastern side of the Mangahan Floodway and includes the small rivers and/or creeks such as Baho, Buli and Mahaba. All of the rivers have a rather steep riverbed gradient and they collect the runoff from the mountainous and hilly land area. The lower stretches do not have enough flow capacities; thus, runoff water inundates the flat lowland area, together with the high water stage of the Laguna Lake.

South Parañaque-Las Piñas River System

This river system is situated in the southern part of Metro Manila. the Paranaque River flows for about 3.0 km along the seashore from the southern end of Estero Tripa de Gallina to Manila Bay. At the vicinity of the estuary two tributaries, the Dongalo and the San Dioniso Rivers, join the Parañaque River. The Las Piñas River joins the South Parañaque River and the Zapote River in the low-lying area adjacent to the seashore.

Most of the southern boundary of Metro Manila runs along the Zapote River from the south to the north. The whole catchment area of this river system is 95 km^2, most of which administratively belongs to Metro Manila.

Other Remaining Areas

Other remaining areas which are not included in the river basin, are mostly located in the lowland area along the coastal line of the Manila Bay and the north shoreline of the Laguna Lake such as Manila and suburbs, Marabon-Navotas, East of Mangahan and West of Mangahan. In the area, esteros, creeks and other small channels are complicated, and those present systems are as explained in Supporting Report V, Drainage Improvement.

2.3 Major Facilities

Pasig-Marikina River System

(1) Mangahan Floodway

The Mangahan Floodway consists of the several components namely; the floodway channel, the roadways on both sides of the floodway, the gated weir, and a bridge along Ortigas Avenue Extension crossing the floodway channel, as follows. (Refer to Fig. 4-2-2.)

Total Channel Length	:	8.950 km
Concrete Lined Channel	:	1.1 km x 80 m bottom width
Rock-Lined Channel	:	1.0 km in transition portion
Unlined Portion	:	6.85 km x 118 m bottom width
Rosario Weir	:	8 roller gates (18.75 m x 3.5 m); Total length of 174 m
New Ortigas Bridge	:	161.14 m span length; 6 lanes
Roadways	:	1.3 km in total, on both banks
Excavation Volume	:	585,000 m^3
Embankment	:	7.1 km on both sides with 2:1 slope

(2) Napindan Hydraulic Control Structure

The Napindan Hydraulic Control Structure (Napindan HCS) is located at the site where Napindan Channel joins with the Pasig River. It is designed to prevent contaminated water from the Pasig River and saltwater from the Manila Bay from proceeding to the Laguna de Bay by closing the gated spillway having four (4) movable gates, and to serve as passage of watercrafts for commerce between Manila and the Laguna area through the nagivation lock. The main components of the project are as follows. (Refer to Fig. 4-2-3.)

Gated Control Structure	:	4 units of steel roller gates, clear span of gate is 15 m
Navigation Lock	:	110 m long lock chamber, 180 m long navigation lock 2 units submergible radial gate with 18 m clear span and 9.59 m gate height

(3) Pasig River Improvement Works

The riverine area of the Pasig River is protected from floods by two measures. One is the channel improvement such as the river wall on both banks and the dredging of the channel bed, and the other is the drainage improvement by construction of pumping stations.

The most recent feature of the river including the riverwall condition is shown in Fig. 4-2-4, based on the survey results in 1988.

As for the pumping station, ten stations were constructed as follows. (Detailed features are referred to in the Supporting Report V, Drainage Improvement.)

Pump Station	No. of Pumps	Drainage Capacity (m^3/s)	Discharge Into
North:			
Binondo	4	11.4	Pasig River
Quiapo	4	9.5	Pasig River
Aviles Sampaloc	4	14.1	Pasig River
Valencia	4	10.5	Pasig River

Pump Station	No. of Pumps	Drainage Capacity (m^3/s)	Discharge Into
South:			
Paco	3	7.6	Pasig River
Pandacan	2	4.4	Pasig River
Sta. Clara	2	5.3	Pasig River
Makati	2	7.0	Pasig River
Libertad	6	42.0	Libertad Channel
Tripa de Gallina	8/1	56.0	Estero Tripa de Gallina

Note: /1 Six (6) units are in operation and two (2) additional units are under construction.

Meycauayan River System

To protect the Valenzuela and Obando area from flood inundation of the Meycauayan River, the earth dike with an elevation of 12.0 - 12.5 m is provided in the left bank side in the 5 km length approximately.

This earth dike consists of a part of the ring dike constructed along the western coastal lowland of the Manava area, and connected to the river dike at the right bank of the Malabon River. (Refer to Fig. 4-5-6.)

The dike is, from a structural viewpoint, not appropriate, and the leakage is observed at several sections, according to the site reconnaissance.

Malabon-Tullahan River System

Except a part of the right bank, the parapet wall with a grouted riprap is constructed on both banks of the Malabon River, in the lower reach of the Tenejeros Bridge. The wall is about 11.5 - 12.5 m in the elevation, and constructed in total length about 10 km along the riverine.

In the upper reach of the Tullahan River, the Navaliches reservoir to supply the drinking water exists. The catchment area in the upper reach of the La Mesa Dam site is 52.8 km^2 which is equivalent to about 50% of the total catchment area of the Malabon-Tullahan River.

Buli-Baho-Mahaba River System

These rivers are passing through the urbanizing area, but riparian structure is, at present, in poor condition. Partially, the revetment with concrete lining and riprap and the parapet wall are observed in the middle or upper reaches. At connecting section with the Mangahan Floodway, the revetment with riprap is provided.

South Parañaque-Las Piñas River System

In the middle and upper reaches of the South Parañaque River and the Las Piñas River, urbanization is in progress, and the concrete lining revetment or riprap revetment is partially provided to prevent the collapse of the channel slope. In the lower reaches, the channel is in the natural condition.

In the upper reach of the Zapote River which is located in the southern boundary of the Metro Manila, the Molino Dam is provided for the irrigation purposes but the river is in a natural condition.

3. BASIC STUDY AND ANALYSIS

3.1 Existing Flow Capacity of Rivers

Calculation Conditions

(1) Equation for Flow Capacity Estimate

The existing flow capacity of the main river channel was checked by non-uniform flow calculation, based on the cross sectional survey drawings prepared in 1988.

(2) Roughness Coefficient

Manning's roughness coefficient, one of the key factors in the calculation, has been noticed by experience to change approximately in the range of 0.025 to 0.033 in common alluvial river channel. In accordance with the feasibility study for the Managahan Floodway, the roughness coefficient has been checked precisely and was concluded in this present study that 0.030 is the approprioate average value for all the stretches of the Pasig-Marikina River. This value is also adopted for the other rivers different from the Pasig-Marikina River as verified from the site survey.

(3) Hydraulic Boundary Condition

The following water stages of Manila Bay and Laguna Lake was adopted as the initial water stage (HO) for the calculation.

Manila Bay Tide : 11.30 m (Mean spring high tide)
10.47 m (Mean sea level)

Laguna Lake Level: 14.00 m (Recent recorded highest)
12.50 m (Mean annual highest)

Estimated Flow Capacity

(1) Pasig-Marikina River System

(a) Pasig River (Refer to Fig. 4-3-1(1/3)

Pasig River is divided into two stretches, the stretch from the river mouth to the confluence with San Juan River and the stretch from the confluence to the Napindan junction. The bankfull discharge capacity is summarized below.

Stretch	Bankfull Discharge	
	HO=11.30	HO=10.47
River Mouth to San Juan River	700 m^3/s	800 m^3/s
San Juan River to Napindan junction	500 m^3/s	600 m^3/s

(b) Marikina River (Refer to Fig. 4-3-1(2/3)

Marikina River is divided into two stretches, the Lower Marikina River from the Napindan junction to the diversion point of the Mangahan Floodway, and the Upper Marikina River in the upper reach from the diversion point of the floodway. The bankfull discharge is summarized below.

Stretch	Bankfull Discharge	
	HO=13.15	HO=12.97
Lower Marikina River	500 m^3/s	600 m^3/s
Upper Marikina River		
- From Rosario to Sto. Nĩno	1,100 m^3/s	1,300 m^3/s
- From Sto. Niño to Montalban	1,500 m^3/s	1,800 m^3/s

In the above table, the water level of 13.15 m and 12.97 m are set at the Napindan junction, assuming that the flow condition of the Pasig River is 500 m^3/s which is estimated at the tidal levels of 11.30 m and 10.47 m, respectively.

(c) San Juan River (Refer to Fig. 4-3-1(3/3))

In addition to the above, there exist the San Juan River, which is the biggest tributary of the Pasig-Marikina River, the Napindan River and the Mangahan Floodway. Their bankfull discharges are summarized as follows:

Stretch	Bankfull Discharge *	
	HO=11.88	HO=11.48
About 8 km from Pasig River	50 m^3/s	100 m^3/s

Note *: Except 1 km with a low bank along the river mouth.

The water levels of 11.88 m and 11.48 m were obtained from non-uniform flow calculation for Pasig River at the discharge of 500 m^3/s, setting the Manila Bay Tide Level at 11.30 m and 10.47 m, respectively. The results show that when Pasig River is flooded, the downstream area of San Juan River will always be flooded.

(d) Napindan River

The bankful discharge of the Napindan River from the Laguna lake to the Pasig River is only about 50 m^3/s because the bank height in the stretch of about 4 km from the lake is very low.

(2) Meycauayan River

In the Meycauayan River, the estimation of flow capacity was made within the middle stretch which belongs to Metro Manila and has a strong influence on the flood in the MANAVA area. The middle river stretch will hardly have a flow capacity during high tide (11.30 m) but will have a capacity of about 200 m^3/s at the mean sea level (10.47 m).

(3) Malabon-Tullahan River

The stretch of Malabon-Tullahan River about 5 km upstream from its river mouth is affected by the tidal fluctuation, and its bankfull flow capacity is almost nil at the mean spring tide. The middle stretch of the Malabon River which is called the Tullahan River, has a rather steep riverbed gradient of about 1/100 which provides a flow capacity of about 100 m^3/s only at the mean sea level.

The Navotas River runs along the seashore; therefore, the whole river stretch is affected by tidal fluctuation and the bankfull flow capacity is almost nil at the mean spring tide. The Malabon River is under the same condition.

(4) Buli-Baho-Mahaba River

The flow capacity of the rivers are fairly influenced by the water stage of the Laguna Lake. Subject to the lake stage of 12.5 m which corresponds to the annual mean highest stage, the estimated flow capacities of the rivers are 30 m^3/s along the Buli River, 50 m^3/s along the lower reaches of Baho River, 20 m^3/s along the upper reaches of Baho River, and 5 m^3/s along the Mahaba River.

(5) South Parañaque-Las Piñas River

There are three major rivers; namely, South Parañaque, Las Piñas and Zapote, which cause serious flooding by river channel overflow. In the South Parañaque River and its major tributary, the Dongalo River, the lower and middle reaches are affected by the tidal fluctuation. Thus, the bankfull flow capacity is almost nil when the tidal level of the Manila Bay rises to around its mean high spring of 11.30 m.

In the Las Piñas and Zapote rivers, the stretch of about 5 km from the river mouth is affected by the tidal fluctuation. During high tide in Manila Bay, the bankfull flow capacity in the downstream of Las Piñas River is almost nil and the middle stream will have about 10 m^3/s of bankfull flow capacity.

San Dionisio and Parañaque rivers interconnect the aforementioned three rivers. Since the rivers run on flat and low land, the flow capacity is almost nil when the tidal level is high.