REPUBLIC OF VIETNAM

WATER SUPPLY PROJECT IN SAIGON

PREFEASIBILITY STUDY

Nov. 1972

Prepared for

OVERSEAS TECHNICAL COOPERATION AGENCY

GOVERNMENT OF JAPAN

by

JAPANESE SURVEY TEAM FOR WATER SUPPLY PROJECT

Preface

The Government of Japan, in response to the request of the Government of the Republic of Vietnam, undertook to conduct a feasibility survey for the water supply project in the Saigon Metropolitan Area and entrusted the execution of the survey to the Overseas Technical Cooperation Agency (O. T. C. A.).

Being congnizant of the importance of water supply works for the improvement of the living environment of the people and the stabilization of livelihood in the area, the O. T. C. A. organized a survey team comprising seven members, headed by Dr. Iwao Tatsumi, Professor of Osaka Industrial University, for the purpose of electric prospecting for underground water in the northern part of Saigon and dispatched it to Veitnam for a period of 45 days from March 23 to May 6, 1972.

Thanks to the kind cooperation of the Government of Vietnam, the survey was carried out satisfactorily.

Upon completion of the survey for the water supply expansion project, the team came to the conclusion that water supply utilizing ground water source, as an urgent countermeasure, would be generally promising although its possible amount should be checked by the future survey. It is my firm belief that this report covers process of the analysis which leads to this conclusion and will be important materials for the Government of Vietnam.

On behalf of O. T. C. A., I would like to take this opportunity to express my deep gratitude to the authorities of various agencies of the Government of Vietnam concerned, for their wholehearted cooperation and support extended to the team in the execution of the survey.

Keiichi Tatsuke
Director General

Overseas Technical Cooperation Agency

1. ORGANIZATION OF SURVEY TEAM

Chief:	Iwao Tatsumi	Doctor of Engineering, Proffessor of Osaka Industrial University
Member:	Hiroshi Shinohe	Consulting Engineer Registered, Deputy Chief, Waterworks Department, Nihon Suido Consultants Co., Ltd.
Member:	Katsuyoshi Tomono	Consulting Engineer Registered, Waterworks Department, Nihon Suido Consultants Co., Ltd.
Member:	Yuji Fujii	Assistant Engineer, - do -
Member:	Masato Fujinami	Assistant Engineer, - do -
Member:	Takeshi Sakai	Assistant Engineer, - do -
Member:	Jiro Kuroda	Coordinator, Development Survey Division, OTCA

2. SAMMARY OF SURVEY

2-1 DAILY PROGRAM AND PERFORMANCE

MARCH 23, 1972	Travel from Tokyo to Saigon
MARCH 24	Meeting with officials of Embassy of Japan, Meeting with officials of Ministry of Public Works.
MARCH 25	Discussion of schedule with officials of SMWO.
MARCH 27	Visit to Hoa An Intake station and Thu Duc Plant.
MARCH 28, 29	Field survey of Electrical prospecting area, Decision of prospecting points and Investigation of existing wells.
MARCH 30	Discussion of preparation for works with SMWO.
MARCH 31	Start of Electrical prospection.
APRIL 6, 1972	Mr. Kuroda leaves for Tokyo.
APRIL 14	Dr. Tatsumi leaves for Tokyo.
APRIL 22	Electrical prospection ends.
APRIL 24-27	Make-up of data by Electrical prospection.
APRIL 28	Meeting with officials of Ministry of Public Works.
APRIL 30	Mr. Kuroda returns.
MAY 2, 3, 1972	Final meeting with officials of SMWO.
MAY 4	Meeting with Embassy of Japan.
MAY 6	Leave Saigon for Tokyo.

2-2 THE PERSONS CONCERNED IN SAIGON

People who gave various cooperation and support to the team and whom we negotiated and discussed with during the survey are as follows.

(1) Ministry of Public Works

Minister of Public Works	Mr. Buu Don Han
Vice-Minister of Public Works	Mr. Bui Huu Tuan
Director of National Water Supply Agency	Mr. Vo Dinh Han
Assistant Director of National Water Supply Agency	Mr. Tran Phuoc Tho
Chief of Urban Water supply Department	Mr. Nguyen Van Sang

(2) Saigon Metropolitan Water Office

Director	Mr. Nguyen Huu Tuan
Assistant Director	Mr. Nguyen Kim Chi
Assistant Director for Engineering	Mr. Tran Van Thach
Head of Saigon District	Mr. To Dang Que
Head of Gia Dinh District	Mr. Tran Huu Lai
Head of Thu Duc Plant	Mr. Dong Si Khiem

(3) Embassy of Japan

Ambassador	Mr. Fumihiko Togo
Counselor	Mr. Shinichi Yanai
First Secretary	Mr. Yasutaka Nishimura
Second Secretary	Mr. Toru Iwanami
Chief of Saigon Office, OTCA	Mr. Akira Kasai
Resident Officer, OTCA	Mr. Akihiko Hashimoto

CONTENTS

Introduction

An official survey team organized by the Overseas Technical Cooperation Agency (OTCA), namely by the government of Japan, visited the Republic of Vietnam for the purpose of undertaking preliminary study for water supply in January 1971. Saigon was one of cities in which the team learned situation of water supply. Due to the time limitation, however, the study was confined to the brief understanding of water supply problems in those cities.

Under the above circumstances, another survey team was sent by OTCA in response to a request by the government of the Republic of Vietnam. The team conducted electrical prospection on ground water in Hoc Mon area in the north of Saigon. It aimed at obtaining data and findings on one of potential water sources with which a water supply system expansion project shall be planned. At the same time, the team also studied some of the present situation of water supply in the city.

The team was furnished with kind cooperation and assistance by officials of the Vietnamese authorities concerned, so that a fruitful result had been yielded. Nevertheless, to our great regret, the time allotted to the field survey was so short as 45 days (March 23 through May 6, 1972), the first half of necessary work has only been completed, and it is believed essential that the rest of the study such as test well drilling be quickly performed in succession with this survey.

Chapter 1 Outline of Saigon Metropolitan Area

Saigon, the capital of the Republic of Vietnam, is located at lat. 11°N. where the temperature rises up to 30°C even in the so-called "cool season". Saigon has a decided variety of climatic conditions in the dry and rainy seasons. In the rainy season it rains almost every day while there are few rainfalls in the dry season. Late in the dry season (for one month prior to the beginning of the rainy season - generally in April)- the temperature shows nearly 40°C quite often. The climate in Saigon, however, is not so severe as that seen in desert areas in the Middle and Near East even in the afore-mentioned hottest season. In fact, this country is blessed with thick vegitation and plentiful fruits. Although this country is presently in the state of war, she produced a great deal of raw rubber and was one of the leading rice export countries thanks to bountiful rice crops there.

Saigon is a special city located in the Province of Gia Dinh. There are most of the governmental ministries and related organizations in this city. It is reported that her population which was approximately 450 thousand at the termination of World War II has increased to around 3 million. At the outset, city planning of Saigon was provably made, setting a target of her population at around 500 thousand, and various difficulties have been raised recently. For example, there are many citizens living in shacks due to the shortage of houses. Educational facilities are not exceptional. Double or triple class shifting system is forced to be adopted. Streets and roads are congested with people and vehicles particularly in the morning and evening because public transportation facilities are not available. Telecommunication circuits are in so much shortage that business activities might be suppresed to some extent. Needless to say, water supply facilities are far from satisfaction, and the assured supply of water can hardly be anticipated at present. Though there have been some city plans, it seems that expansion of the city and its population is too fast for the city plans to successively be implimented.

Nevertheless, Saigon is a city full of vitality and animation where every kind of consumable merchandise is on sale. This eloquently expounds the considerably high level of consumption of the citizen. After the long war and still under wartime circumstances, citizens look unexpectedly self-possessed. It is likely that executives of this country have very excellent administrative capacity. In reality, people with whom the team worked together showed high talents.

Notwithstanding the above, Saigon is one of areas which are devastated by the war. It is strongly desired that effective economic cooperation be furnished by the Government of Japan in order that people on every walk of this city may have a bright and hopeful future. Especially water supply is one of essential infrastructures for urban life, and thus it is our sincere hope that this undertaking shall be implemented in the shortest time.

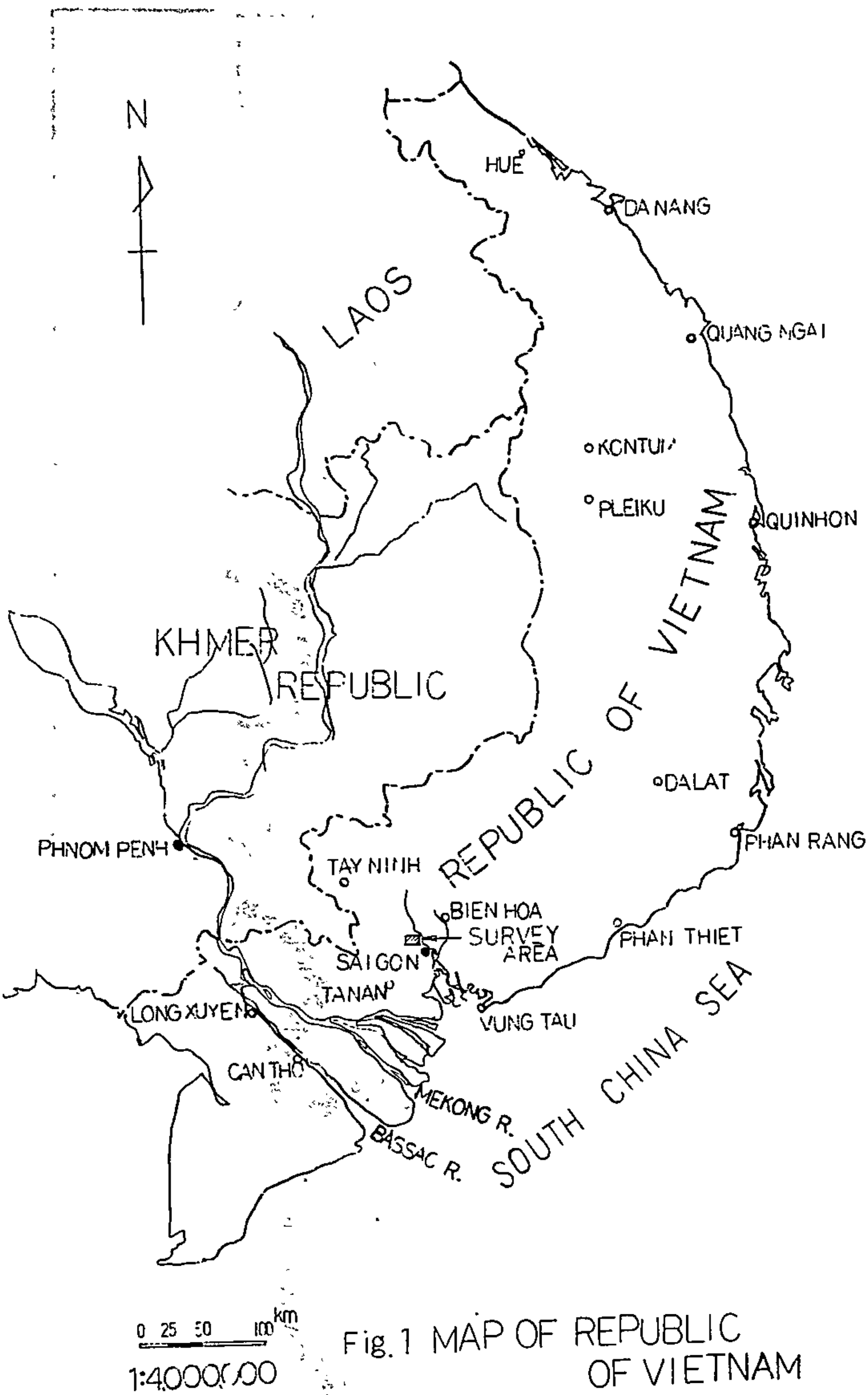


Fig. 1 MAP OF REPUBLIC OF VIETNAM

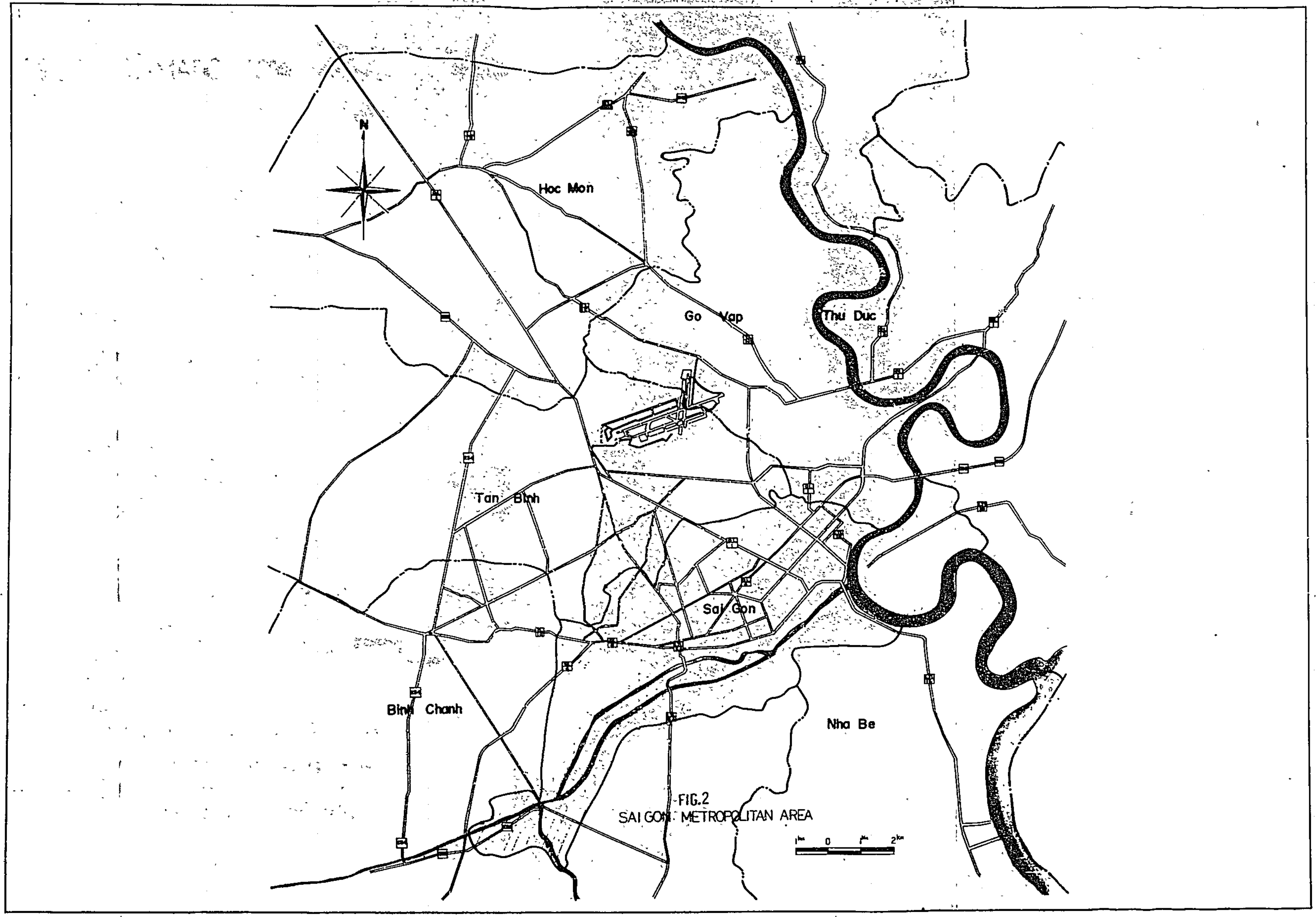
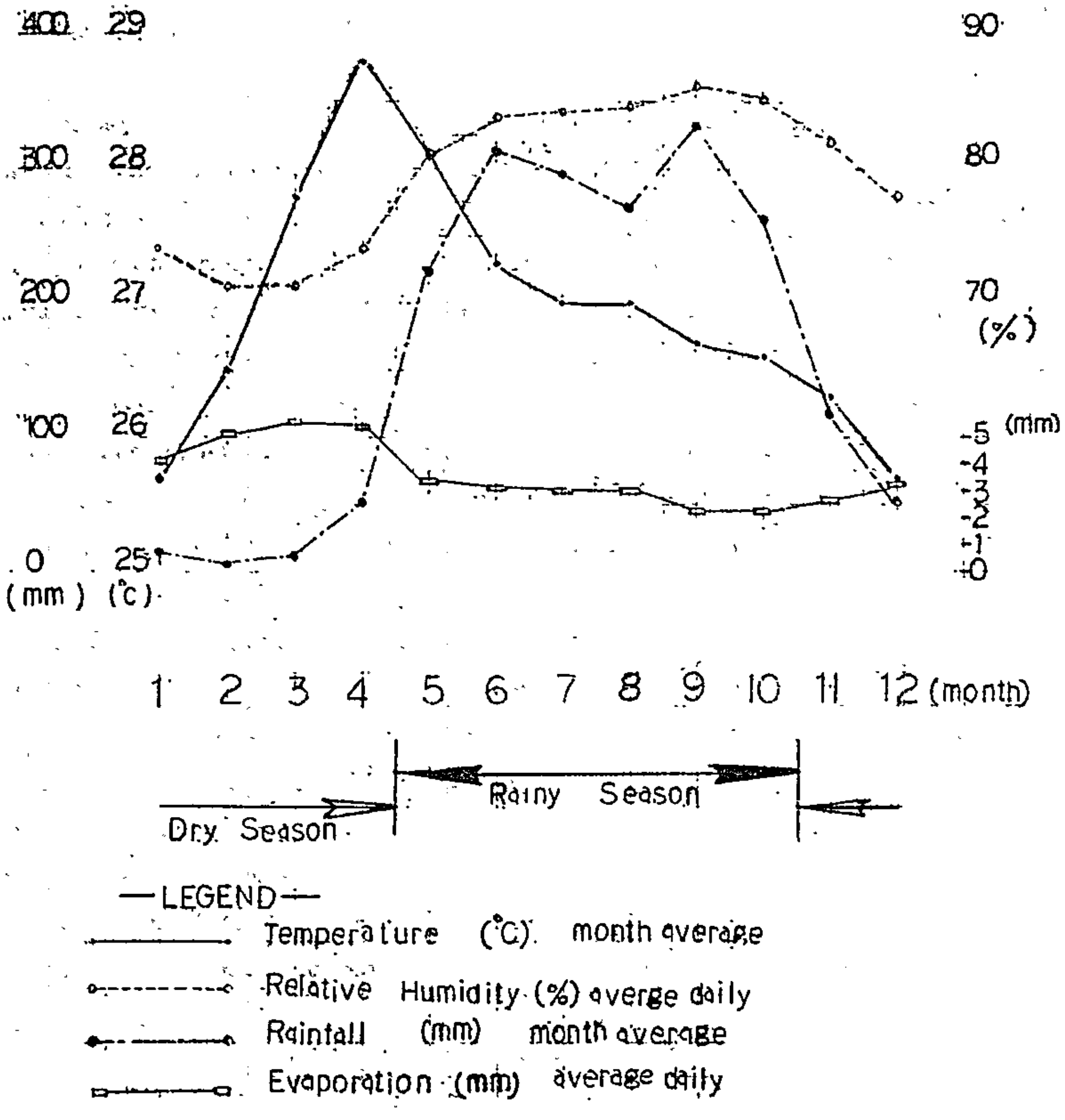


FIG.2
SAIGON METROPOLITAN AREA

Fig.3 CLIMATIC CONDITIONS IN SAIGON

From GVN



Chapter 2 History of Water Supply in Saigon Metropolitan Area

Long history of water supply here dates back to the end of the 19th century. It is in the 1920's, however, that the first shallow well collectors were made for a large scale water supply. In the 1930's when the population of Saigon increased to more than 300,000, the said equipment with a supply capacity of 30,000 CMD* came short for the subsequently increased demand. Thus a series of deep wells were newly drilled in order to increase supply capacity. However, it was impossible that this effort overtook the rapid increase in the population after World War II and resulted that a chronical shortage of water supply continued.

Another drawback to water supply was due to insufficient distribution pipes because they were laid only in the central parts of the Saigon and Cholon districts. A majority of such pipes were obsolete and rusty in inside causing a great deal of leakage. Accordingly, only a few people were favored with water supply, and the water supply was unavoidably ineffective. Despite this fact the quantity of water supply per day reached the level of 160,000 CMD in 1960. In years after 1960, it was not increased at all, but on the contrary it was on the decrease. Intake of ground water abnormally exceeding its proper yield caused lowering of a ground water level to a great extent and has resulted in decrease of pumping discharges in the whole area. At the same time, the quality of water was also extremely deteriorated. Thus, in many wells, pumpage of water was forced to be suspended one after another. In order to get out of these distressed circumstances, large scale extension work of water supply facilities intaking water from the Don Nai River was commenced with the loans furnished by the U.S.A. This project was to construct a large-scale water purification plant with facilities which were regarded as modernized at that time. Its design capacity of daily water supply was 450,000 CMD. Upon completion of the work in 1966, this new system replaced previous ground water intake systems. To be sure, water supply were greatly improved thanks to the completion of these facilities in respect of the quantity and quality of supplied water. But the system would not be considered as satisfactory for the following reasons.

(i) Water supply facilities constructed with the American loans as stated above were confined to those of intake works, raw water main, purification plant and transmission trunk mains. No improvement was added to defective and obsolete distribution networks during this period.

* cubic meter per day

(ii) There had been more intense growth of demand than expected.

(iii) The actual capacity of intake pumps was considerably below the design capacity.

As for (i) stated above, the Republic of Vietnam has been requesting the U.S.A. and Australia to grant pipes for distribution mains. The materials are still extremely insufficient as to their quantity to cope with increase in population and service area although the situation has gradually been improved by economic aids granted by these two countries. At present it seems doubtful that such assistance could further be anticipated also in years to come. (ii) and (iii) are correlated, and the water supply capacity of 450,000 CMD should have been equivalent to the water demand expected in 1980, but the recent intake has reached the order of 420,000 CMD. Even though intake pumps actually have the design capacity, the demand will surely catch up the capacity in only a couple of years. In fact the capacity of intake pums in approximately 400,000 CMD. Thus the situation will be further serious. (During our stay, the maximum daily intake was recorded at 420,000 CMD. It was obtained by means of operating stand-by units together with regular ones. Therefore, it is apparently believed that such a quantity of supply will hardly be maintained long.) It may be possible to recommence intake from the existing wells of which operation has been suspended up to the present. The problem is that such water contains a large quantity of iron and high acidity, which would not be intolerable for tap water. This water is very agressive against pipe material. Consequently, it would be doubtful that ground water in this area comes to be used again. However, sizable increase in supply should be ensured by any means and distribution pipes are to be arranged matching to increase in supply plus present supply. As to new water sources for expansion, such measures as extension of the Dong Nai River system, water resources development of the Saigon River and exploitation of ground water north of Saigon City could be implemented. Redevelopment of the Dong Nai River will take a great deal of time and money and will hardly be of help to fulfilment of the urgent requirements, even though this river must be inevitable for ultimate enpansion project.

In materializing water resources development on the Saigon River, it is essential that hydrological studies be performed first. Some of necessary study is being undertaken by the Vietnamese authorities concerned. But some more time and further assistance by engineering experts would be required in order to obtain reliable data and findings for planning. In view of the above facts, a study on ground water may be the shortest way to solve the urgent problem because investigation will be performed in relatively short time, construction cost is to be rather cheap and construction will not require too much time. A vast alluvial plain stretches north of Saigon, and considerable amount of ground water could be acquired there. In order to know allowable pumping discharge and water quality in such a vast area, it will be the best way to drill many test wells but such work will take a great deal of time and money. Then, a survey method named electrical prospection of ground water can be recommended. This method is useful for a field study of ground water in an extensive area in a short time. It has considerably good accuracy to infer the existance of ground water although it does not tell allowable intake quantity definitely. Accordignly, at a certain position in a area where ground water is prospected after the above survey, a well or wells will be drilled for pumping tests. Thus necessary data are collected and planning of a water supply system with ground water shall be initiated. There must be many important items to be learned such as geography, population, socio-economic background of city etc. together with water source when a water supply project is schemed. This time the survey team conducted some part of electrical ground water prospection and learned general aspects of water supply in Saigon. Hence, in succession to the study, test well borings and pumping tests are required in order to effectively make use of the former investigation and consequently to obtain data for feasibility study.

Stated above is about common ways of water supply expansion. However, it will take considerable time, say some two years, at shortest even for the ground water scheme to start supply since Saigon is a big city and requires great amount of supply in a new project. It is improvement of intake pumps mentioned above that the Saigon Metropolitan Water Office is planning first. Since this work is relatively simple, it can be completed before long bringing increase in discharge. By this measure, however, only 100,000 CMD of increase is estimated at most. In consideration of present annual demand increase rate of 30,000 to 50,000 CMD, it would be matter of time for the supply system to come short.

Therefore, although there will never be any objection to this project, we should not lose time to initiate a bigger expansion program with ground water source so long as it is feasible. Very big quantity, however, could not be expected from the ground water source since an excessive pumping may cause deterioration of water quality, unusual depression of ground water table and land subsidence.

Hence, development of reliable river water sources is urgently requested.

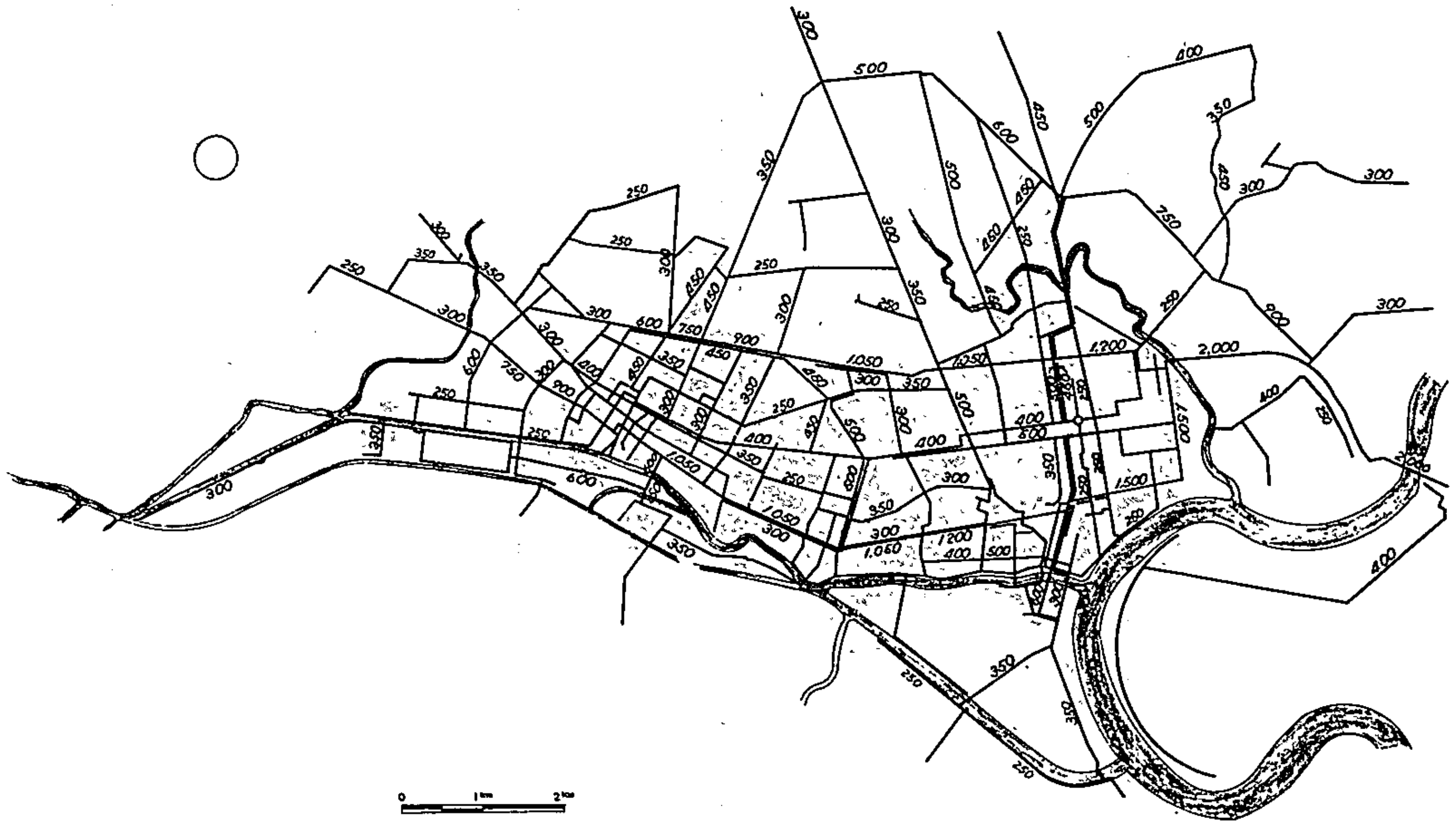
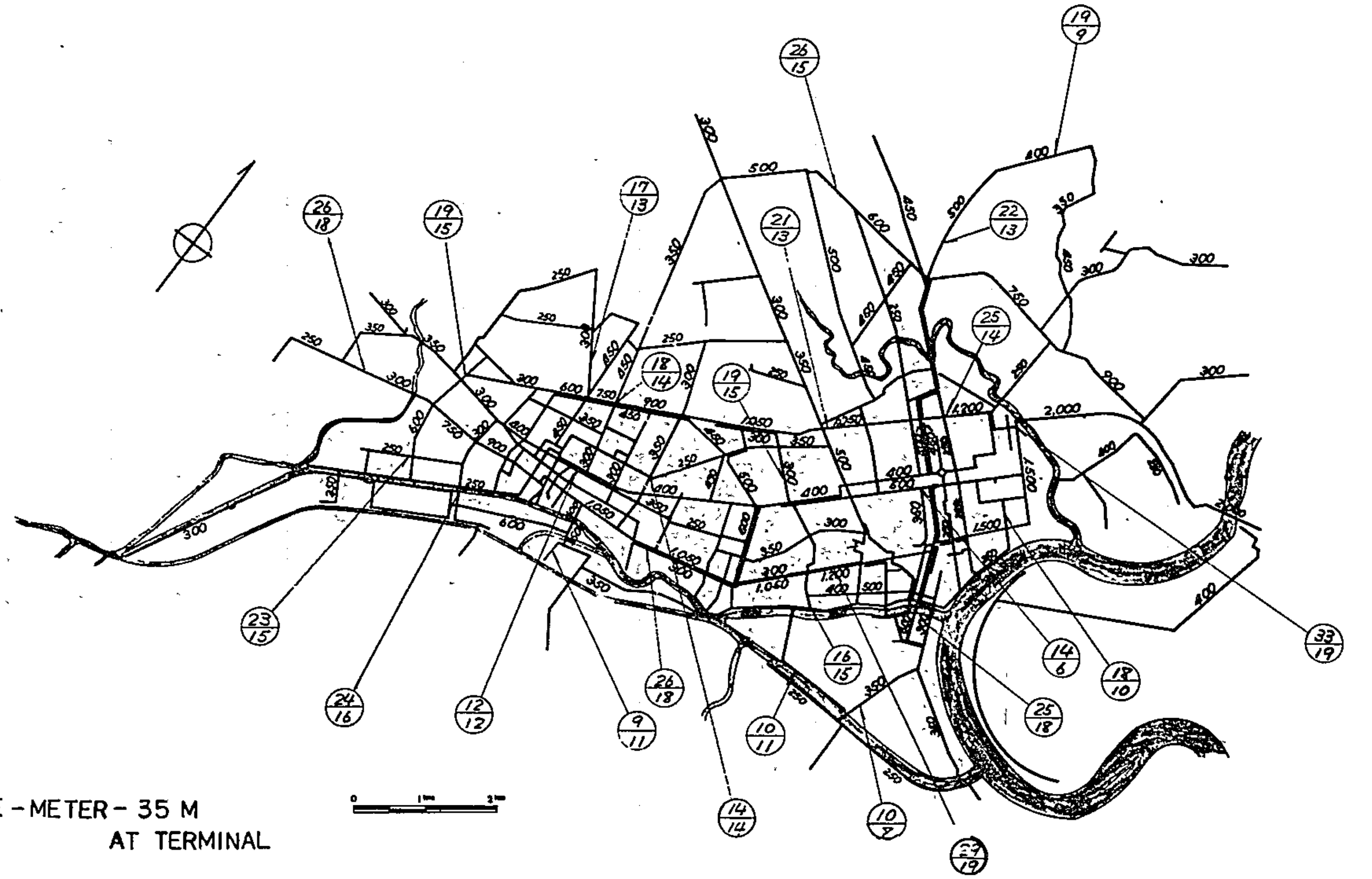


FIG. 4 EXISTING DISTRIBUTION SYSTEM



LEGEND

⊖ ← DAY TIME PRESSURE - METER - 35 M AT TERMINAL

↖ NIGHT TIME PRESSURE - METER - 21 M AT TERMINAL

FIG. 5 SYSTEM PRESSURE IN 1971

EXTRACT FROM " SAIGON WATER DISTRIBUTION PROJECT 1972 "

Chapter 3 Ground Water Investigation

1. General

The main part of the investigation was a geophysical prospecting operation. In parallel with this work, field surveys including study on existing shallow and deep wells were carried out in order to understand the hydrogeological aspect of the subject area.

2. General Background

The survey was executed mainly in the Hoc Mon district adjacent to the north-west part of the Saigon City. Saigon City situated to the north-east of the Mekon Delta which occupies the major part of the southern plain in the Republic of Vietnam is on the delta formed by the Saigon river and other streams as shown in Figure 6. The bed of rivers meandering on the delta are composed of very fine materials such as silt or clay. In the rainy season these materials are easily transported and the river-bed is deeply eroded out. In most places, therefore, rivers are blessed with a great amount of water and suitable for navigation. The Saigon River, one of the main tributaries of the Nha Be River, is typical one of navigatable rivers and ocean-going-ships of approximately 10,000 tons sail up and down the river. This river is also referred to as a "tidal river'. The tide influences to the considerable upper part of the river and it affects ground water too. It is reported that the ground water in and around the Hoc Mon district where the new ground water resource is expected is not yet suffered from salt water intrusion. However, in the development of the ground water in the said district adequate consideration should be given to the problem of salt water contamination in view of the fact that the remarkable drawdown of the ground water level took place after the excessive pumping and as the result salt water intruded into the water bearing formation in the downtown of Saigon.

The investigation area forms a delta and its typical features in underground geology are composed of top soil and alluvium.

In the southern part of Saigon City, this alluvium is continuously found to the depth of approximately 200 to 250 meters. There is sedimentary rock of the Mesozoic to

Paleozoic or metamorphic rock beneath the alluvium. These rocks are considered to be a bedrock and outcrops of such a bedrock still remain in a shape of monadnock in the district north-east of Saigon, as given in Figures 6 and 7. Diluvial and tertiary formations are not found there.

The alluvium can be divided into old and recent ones. The elevation of the latter is less than 2 meters in the recent flood plain. The former is higher at its elevation compared with the latter, and is 5 to 9 meters within the investigation area. As a rule, the old alluvium contains laterite and mainly consists of grave, while the recent one lacks of laterite and its main composition is clay and silt. The recent alluvium is not so clearly recognized as in the Mekong Delta, but its sedimentation seems to be still continued at present.

The investigation area is situated in lat. 11 N and belongs to the tropical monsoon climatic areas. It has two kinds of climatic differences, namely the dry season in winter and the rainly season in summer. The climatic condition is as given in Figure 3. The mean annual rainfall which is an important factor for recharge of ground water is recorded at 1952.5 mm. This value of rainfall is not always least as an amount of ground water recharge. The amount of 87% of the annual rainfall is concentrated in the rainy season (from May to October). This precipitation gives enormous effect upon the condition of ground water. The free-surface water aquifer in the survey area shows the difference of 2 meters in its water level between the rainy and dry season. Besides, it is probable that this rainfall causes variations in the degree of tidal effect.

3. Free-Surface Ground Water

Top soil in Hoc Mon district which is mostly pale grey is composed of very fine sand, silt and silty clay. Beneath the top soil there exists laterite layer which is produced by podsolization of soil. The nature of soil is acid. The level of the free-surface ground water is about 2 meters below the ground surface. Generally it is shallow to the west and deep to the south-east. However, it seems to be almost horizontal taking into consideration of the ground surface level. Many shallow wells are excavated in the Hoc Mon district, which serve for supplying drinking and irrigation water. They are open hole type in most cases. Only some domestic wells are equipped with concrete frames in their upper portion.

There are two types of irrigation wells. The first one is a well with a diameter of about 600 mm and a depth of 5 to 6 meters; not deeper than the laterite layer. The second one has the same construction as the first one in its appearance, but it has a small open hole at the bottom, which penetrates the laterite layer and collects the ground water in the lower portion. This hole is made by driving down a bamboo-pole of 5 cm dia. and 50 cm long in common way. If the hole is clogged with sand or clay, the bamboo-pole is again used for opening through the hole and the well yield is rehabilitated. The structure of a domestic well is almost the same as the first type. In general, the water in the free-surface water aquifer shows a few iron contents and is not so inferior in its quality in the survey area. However, this water is under such circumstances that it is easily polluted and contaminated. Accordingly, it is not preferable to completely rely upon the free-surface water aquifer as permanent ground water resources.

4. Confined Ground Water

The water supply work in Saigon city completely relied upon ground water at its initial stage. At the outset Saigon's population was small and the existing large collector wells met a demand. However, the capacity of the system came short as the population grew. And many deep wells were constructed to cope with the increasing demand. Year by year total pumping rate in the district increased and the lowering of ground water level took place giving rise to the salt-water intrusion into the aquifer; as a matter of course it became impossible to use groung water for the purpose of municipal water supply. Thus the surface water from the Dong Nai River was utilized as a new source of the water supply since 1966 and pumping from deep wells was suspended, as indicated in Figure 8. Followings are underground formations in the investigation area, which are roughly generalized on the basis of the formation log data of the existing deep wells (see Figure 10 and 11) in Saigon City and the Hoc Mon district.

Formation-I	Top-soil	0 - 2 meters
Formation-II	Laterite & clay	2 - 10
Formation-III	Clayey sand	10 - 30
Formation-IV	Sandy clay	30 - 60
Formation-V	Gravel	60 - 80
Formation-VI	Clay	80 - ?

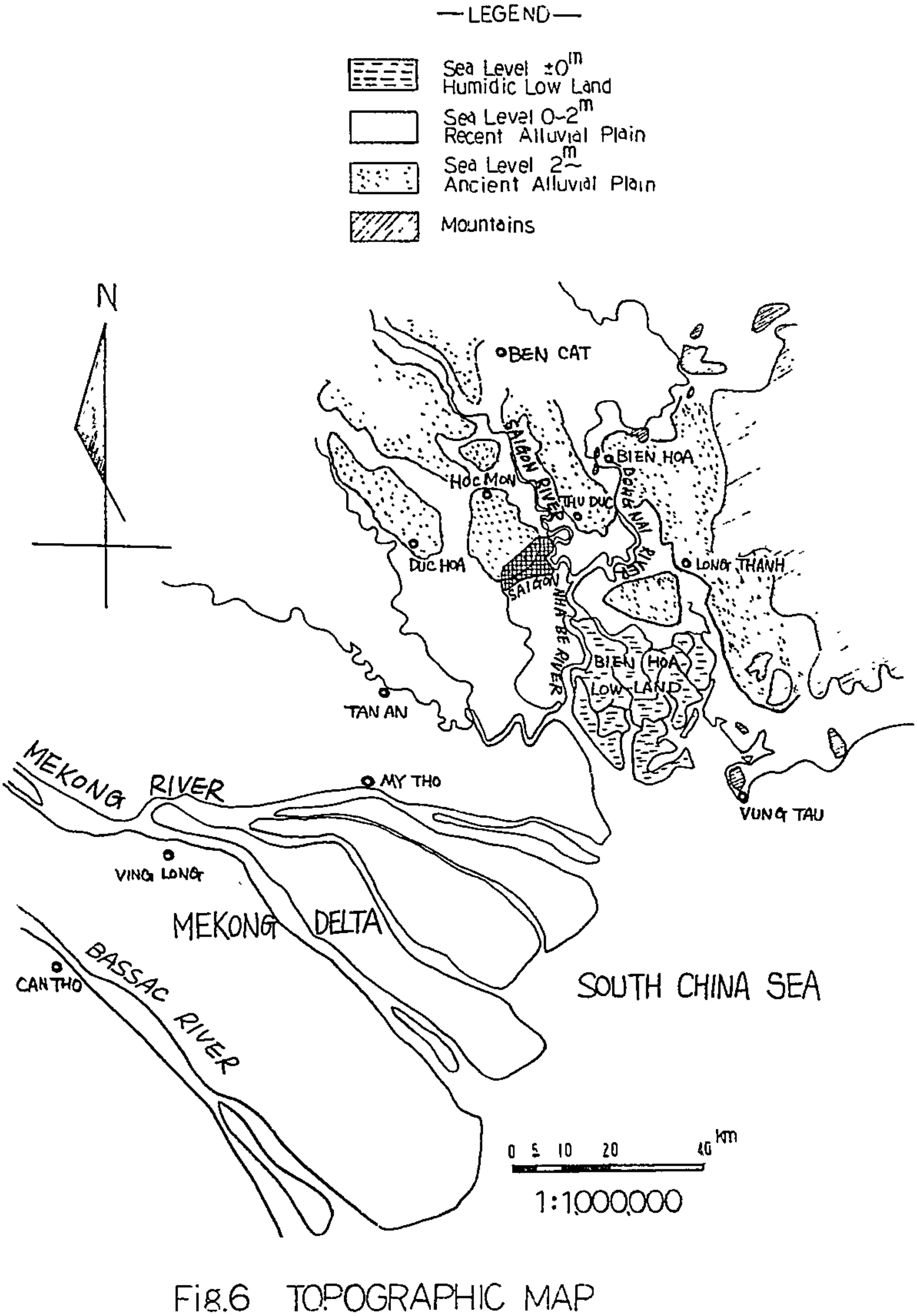


Fig.6 TOPOGRAPHIC MAP

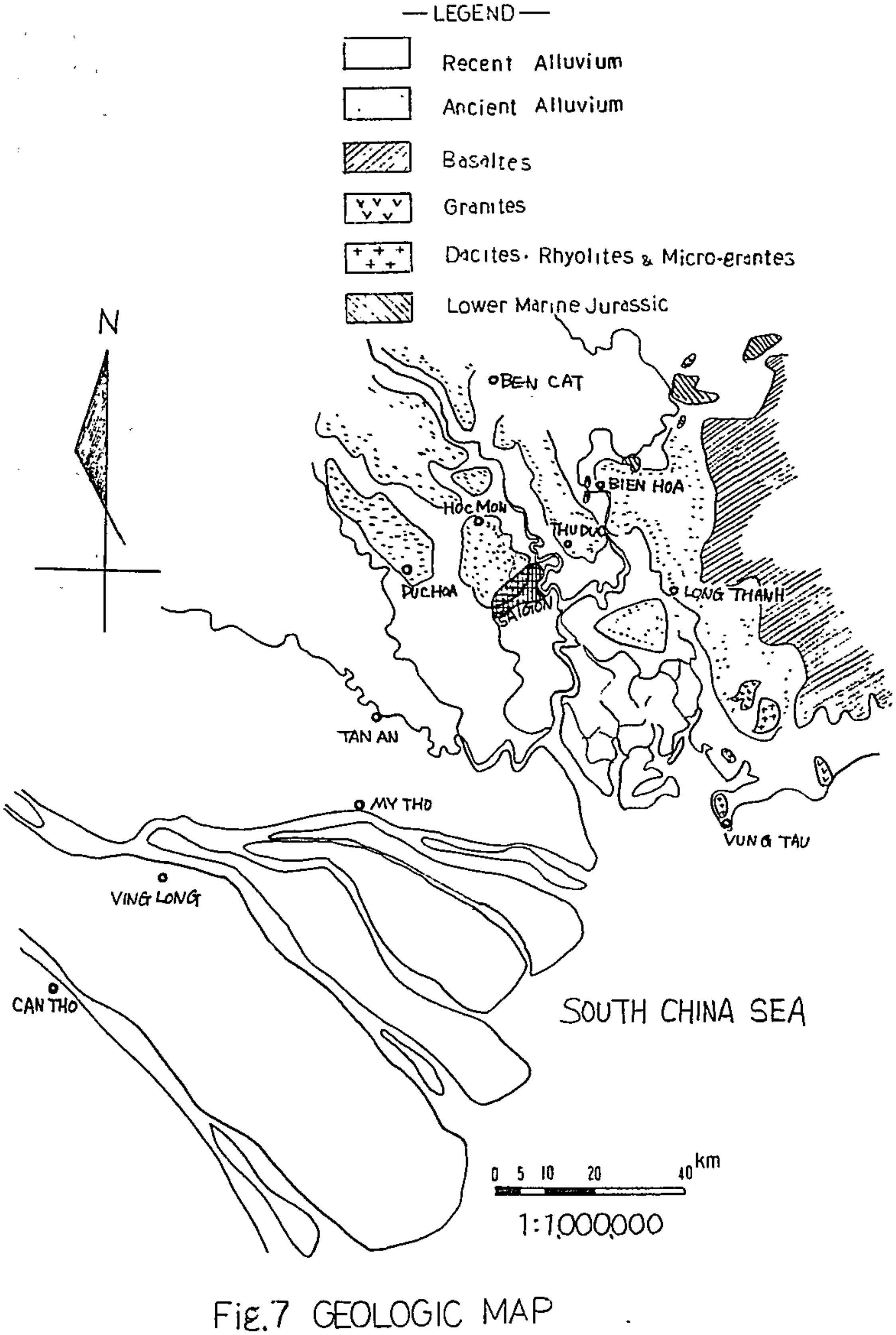


Fig.7 GEOLOGIC MAP

Figure 9 shows the strainer portion of existing wells. As a rule, a strainer is set in the lowest part of an aquifer and its depth is roughly the same with each other. The existing wells in Saigon City are less than 50 meters in depth with strainers of approximately 10 meters long. Strainers are placed 11 meters in the depth of 20 to 40 meters. The yielding capacity of wells ranges from 2,000 to 5,000 m^3/day. There is a well of 200 meters deep, but it is exceptional.

The ground water is taken from the formation-V (60 to 80 m) in the Hoc Mon district. This formation is expected to be a good aquifer. The ground water quality in the district is better than that in Saigon City as shown in Table 1 and 2.

According to the existing pumping records and well date, it is reasonable to believe that there is possibility of ground water development in the Hoc Mon district. On one hand, in view of the fact that existing wells in Saigon City became unfit for use owing to salt contamination, it is required that the ground water development should be carefully planned on the basis of sufficient and appropriate investigations concerning geologic and hydrologic characteristics of ground water reservoirs.

TABLE 1 SHALLOW WELLS IN HOC MON

No.		Date	Water table (pumping) (m)	Depth (m)	Diameter (mm)	Temperature (°C)	Resistivity (Ω-cm)	pH	Fe (ppm)	$C\ell^-$ (ppm)	Total hardness as $CaCO_3$ (ppm)
1	Irrigation & housing	1972. 3. 28	2. 5	-	700	27	0.75×10^4				
2	Farming	"	-	3. 0	50	28	5.00×10^4				
3	Irrigation	"	4. 2	-	-	26. 5	0.85×10^4				
4	Housing	"	3. 5	-	1500	28. 5	4.00×10^4	4. 7	0. 30	42. 9	5. 0
5	Irrigation	1972. 5. 1	4. 13	4. 8	-	28	2.20×10^4				
6	Housing	"	2. 46	3. 05	-	26. 5	1.40×10^4				
7	Irrigation	"	2. 92	3. 82	-	26. 5	0.85×10^4				
8	"	"	2. 165 (3. 285)	3. 9	-	28	2.30×10^4				
9	Housing	"	2. 1	2. 9	-	26	1.70×10^4	4. 8	0. 1	22. 3	7. 0
10	Irrigation	"	2. 55	-	-	26. 5	1.60×10^4				
11	Housing	1972. 5. 2	3. 53	6. 3	600	27. 5	0.38×10^4	5. 9	0. 1	85. 8	40. 0
12	"	"	3. 0	4	-	26	0.70×10^4				
13	Irrigation	1972. 3. 28	(2. 35)	4	650	27. 5	2.60×10^4				

TABLE 2 DEEP WELL DATA

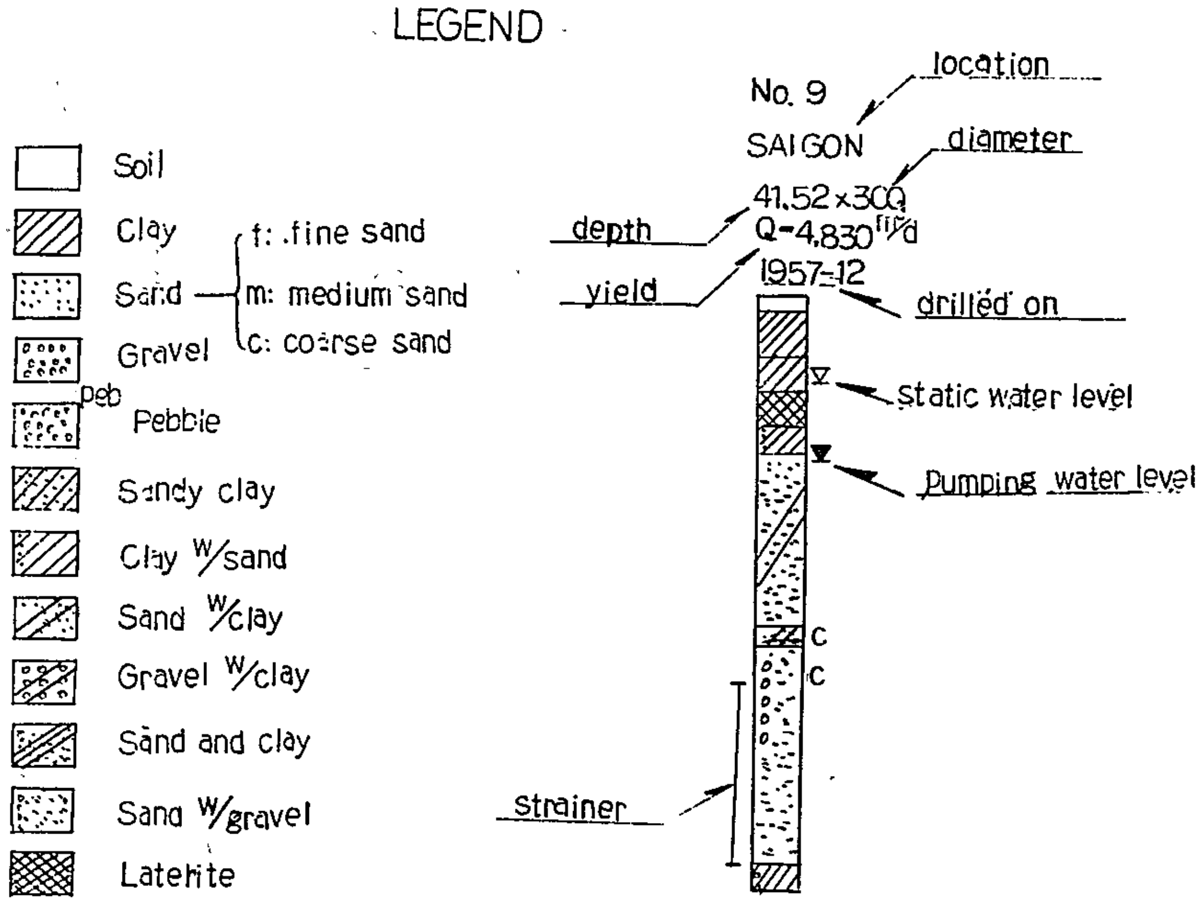
No.	Name	Year	Depth	Dia-meter	S.W.L.	P.W.L.	Discharge rate	Strainer Depth	Strainer Total	pH	Temper-ature	Fe	Cℓ	Resistivity
			m	mm	m	m	m^3/d	m~m	m		°C	ppm	ppm	Ω -cm
1	Hoc-Mon	1969-10	76	150	6.5	-	545	63 ~73	10	6.25	-	0.5	8	
2	"	1969-11	34	150	-	-	-	24 ~34	10	5.56	-	0.15	7	
3	"	1968-4	33	200	-	-	-	23 ~32	9	6.03	-	0.05	8	
4	"	-	31	150	4.5	13.5	695	21 ~31	10	6.45		0.05	6	
5	"	1970-2	74	150	-	-	-	64 ~74	10					
6	"	1964-9	39	150	2.5	8	458	28 ~37.5	9.5					
7	"	1965-7	35.5	200	3	12	1,150	24 ~34	10					
8	"	1960-3	90.68	200	6	20	5,180	78 ~91	13	5.50	30	0.35	trace	1.329×10^4
9	Saigon Vo-Di-Nguy	1957-12	41.52	300	6	11.5	4,830	26.5~39.5	13	4.3		0.11		
10	Phu-Nhuan	1933-3	32.94	300	4.5	22	3,040	20.5~33	12.5	4.1		0.10		
11	Nuynh-Tinh-Cua	1932-10	39.26	450	2	-	3,540	21 ~39	18	4.4		0.12		
12	Yen-Do II	1949	44.4	300	3.2	16	6,070	29.5~42	12.5	4.5		7.40		
13	Truong-Minh-Gian	1958-1	49.84	300	9	19	4,320	35.5~47.5	12	4.7		6.00		
14	Pham-Dang-Hung	1932	33.96	300	2.8	19.2	3,440	24.5~33.5	9	4.3		3.32		
15	Hong-Thap-Tu	1949	44.4	300	12.40	-	4,660	29.5~42.5	13	4.3		0.02		
16	Pham-Ding-Phung	1957-9	40.89	300	11	13	3,910	26 ~39.5	13.5	4.1		0.86		
17	Ba Huyen Tanh-Quan	1949	48.79	300	7	-	2,910	30.5~43	12.5	4.8		0.08		
18	Le-Van-Duyet II	1953-8	45.12	300	7	15	3,600	31.8~42.3	10.5	4.7		0.06		
19	Tran-Quoc-Toan 4	1959-1	45.09	300	8	23	4,400	29.5~43	13.5	5.0		1.70		

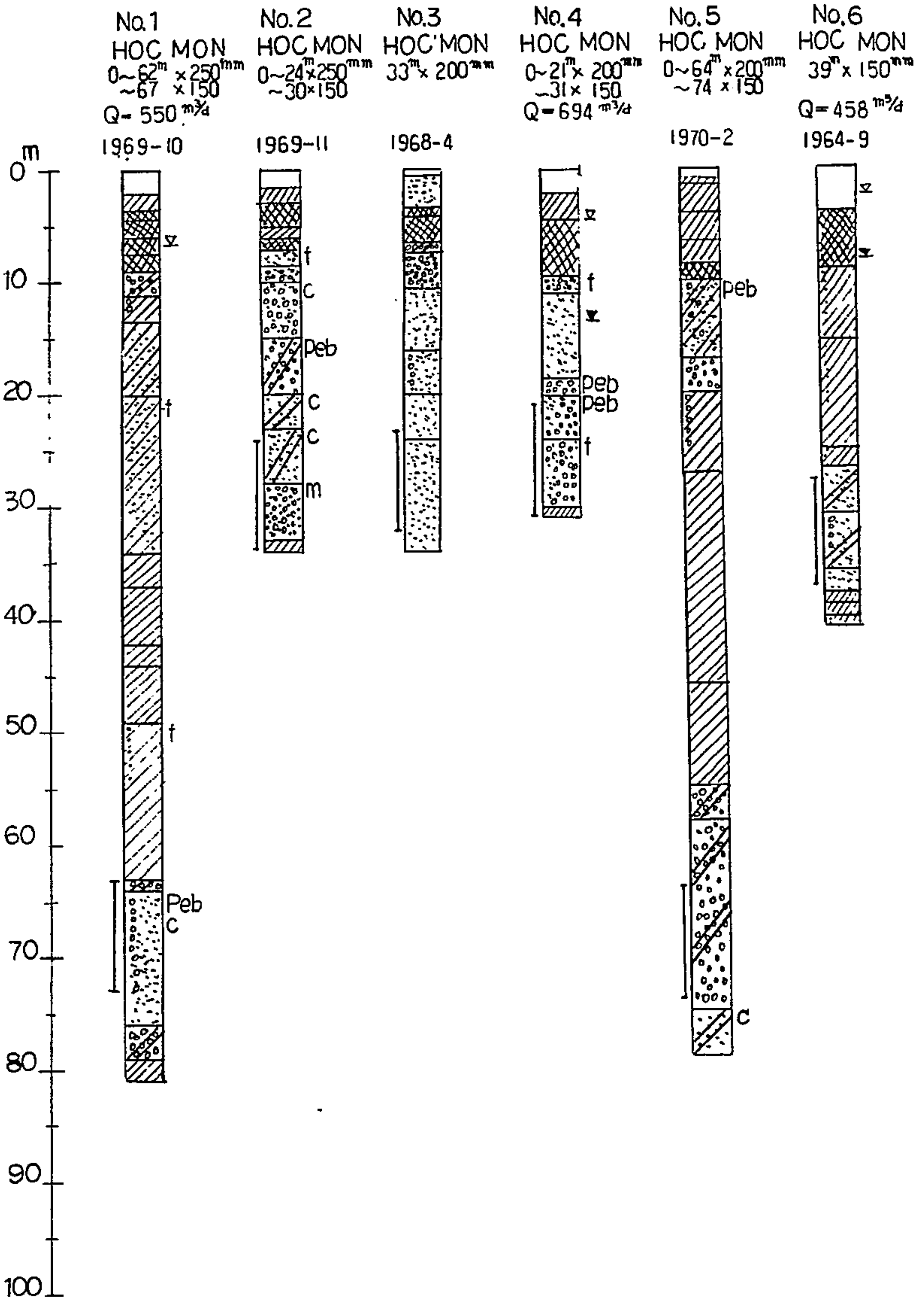
TABLE 3 DEEP WELL DATA

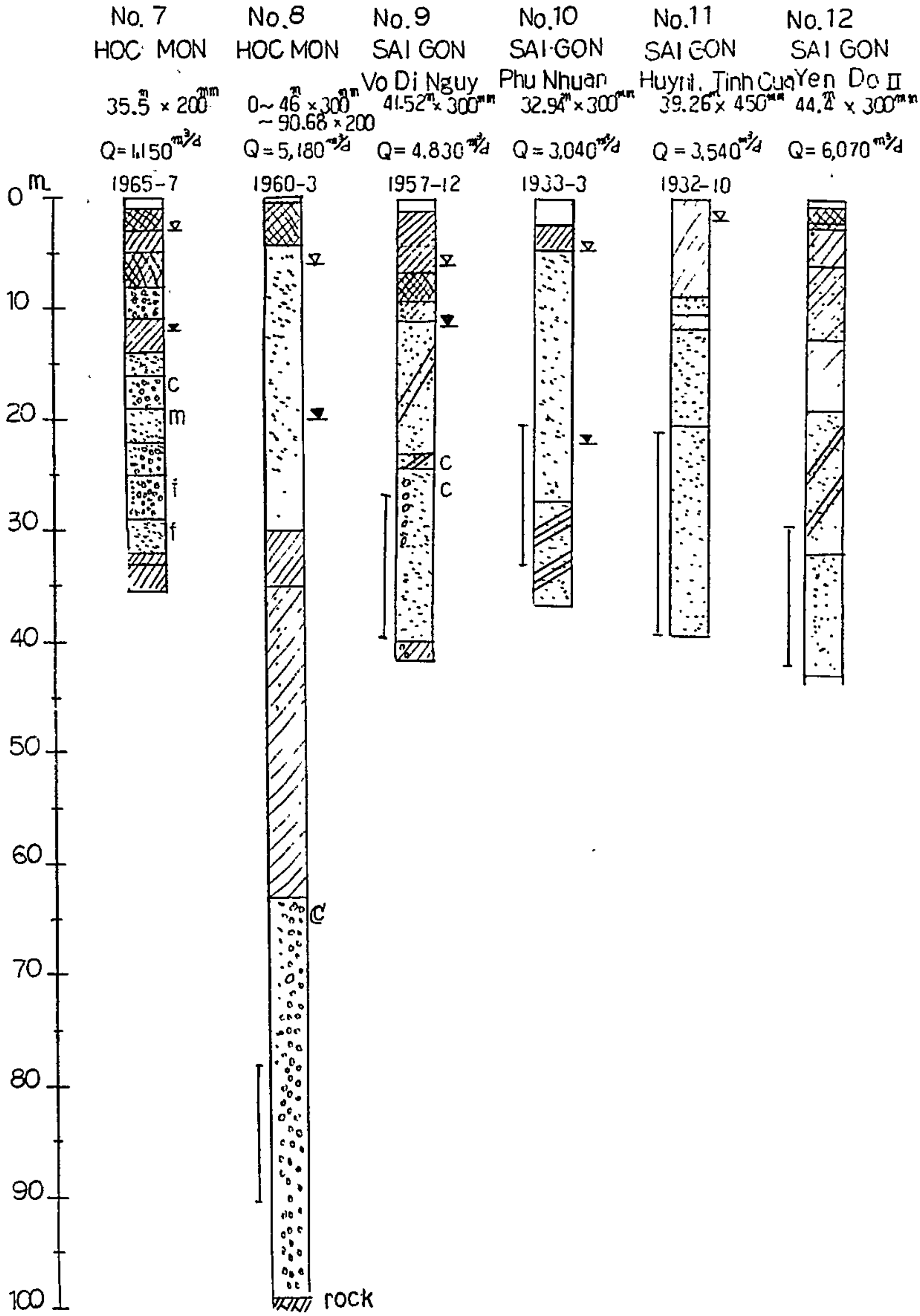
No.	Name	Year	Depth	Dia-meter	S.W.L.	P.W.L.	Discharge rate	Strainer		pH	Temper-ature	Fe	Cℓ	Resistivity
								Depth	Total					
			m	mm	m	m	m^3/d	m~m	m		°C	ppm	ppm	Ω -cm
20	Ban-Co II	1955-9	45.7	300	7	23	2,710	31 ~41.5	10.5	4.5		0.53		
21	Bui-Chu	1950	45.1	300	10.4	-	2,550	33 ~43	10	3.9		5.30		
22	Nguyen Du	1953	42.70	300	8	15	4,830	30.5~40.5	10	4.7		6.30		
23	Ban Co I	1952	43.95	300	4.5	22	2,430	28 ~41	13	4.4		15.40		
24	Cong Hoa	1958-3	44.16	300	8	21.5	2,700	29 ~42	13	4.6		63.00		
25	Tran Quoc Toan 3	1958-12	41.20	300	7	19	5,480	26 ~39	13	4.8		0.50		
26	Tran Quoc Toan 2	1958-9	39.96	300	8.5	21	4,580	25 ~38	13	4.6		0.54		
27	Tran Quoc Toan 1	1933-3	37.00	300	5.5	22	6,120	24.5~37	12.5	4.8		0.27		
28	Phu Tho II	1951-11	36.45	300	3.5	8.5	6,000	21 ~32.5	11.5	4.3		1.04		
29	Truong Dua I	1953-11	37.26	300	5	9	5,400	25 ~35	10	4.7		0.36		
30	Ly Thai To	1956-3	38.00	300	10.5	16	5,400	22 ~34.5	12.5	4.0		13.60		
31	Cay Go Nhi	1954-3	47.37	300	6	21.5	4,320	30.5~43	13.5	4.3		30.00		
32	Binh Tay	1950-9	204.57	300	7	20.5	6,960	178.5~201	22.5	6.2		18.40		

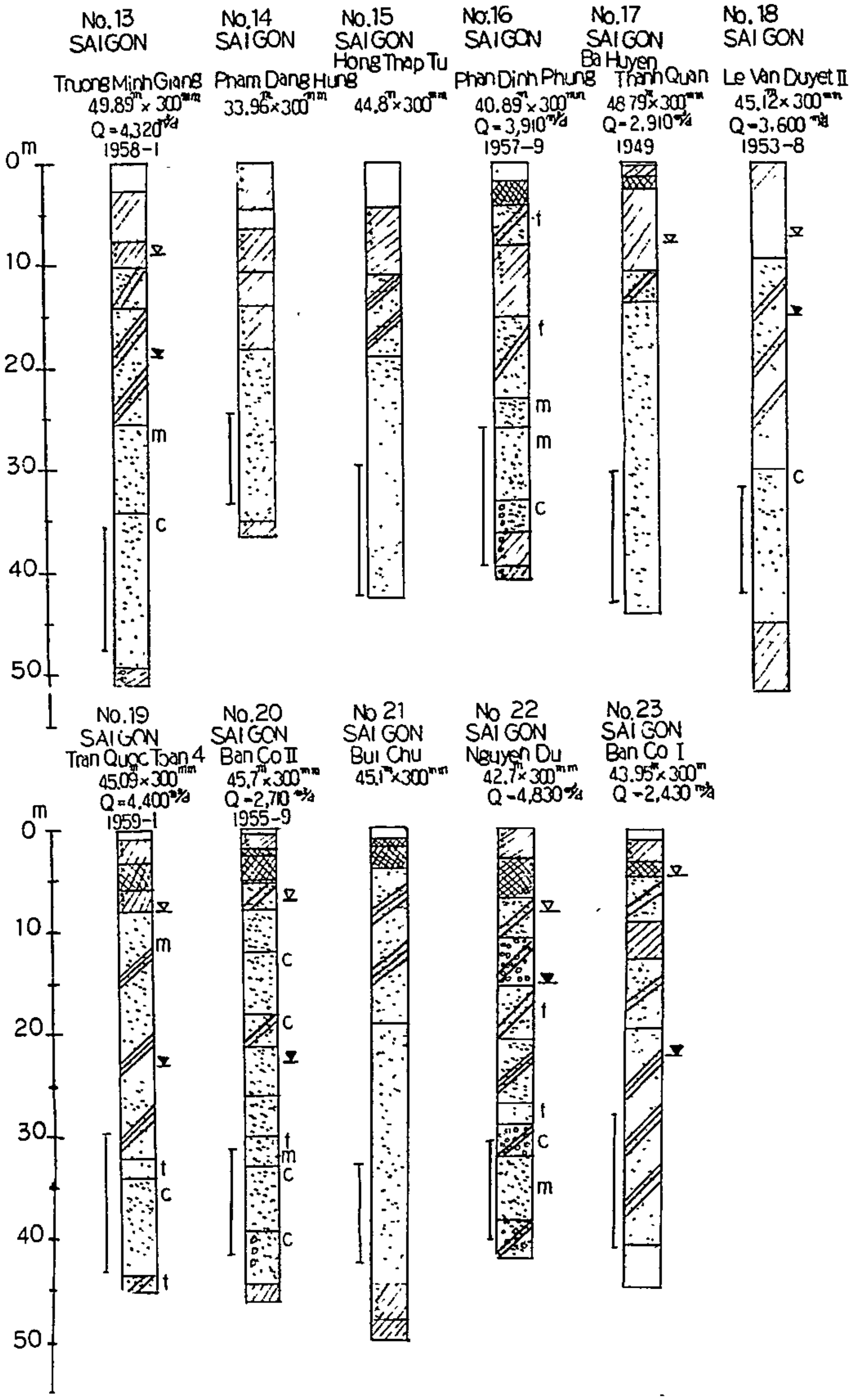
Fig. 8
LOCATION MAP OF THE DEEP WELLS AND SHALLOW WELLS IN SAI-GON AND HOC-MON ARER

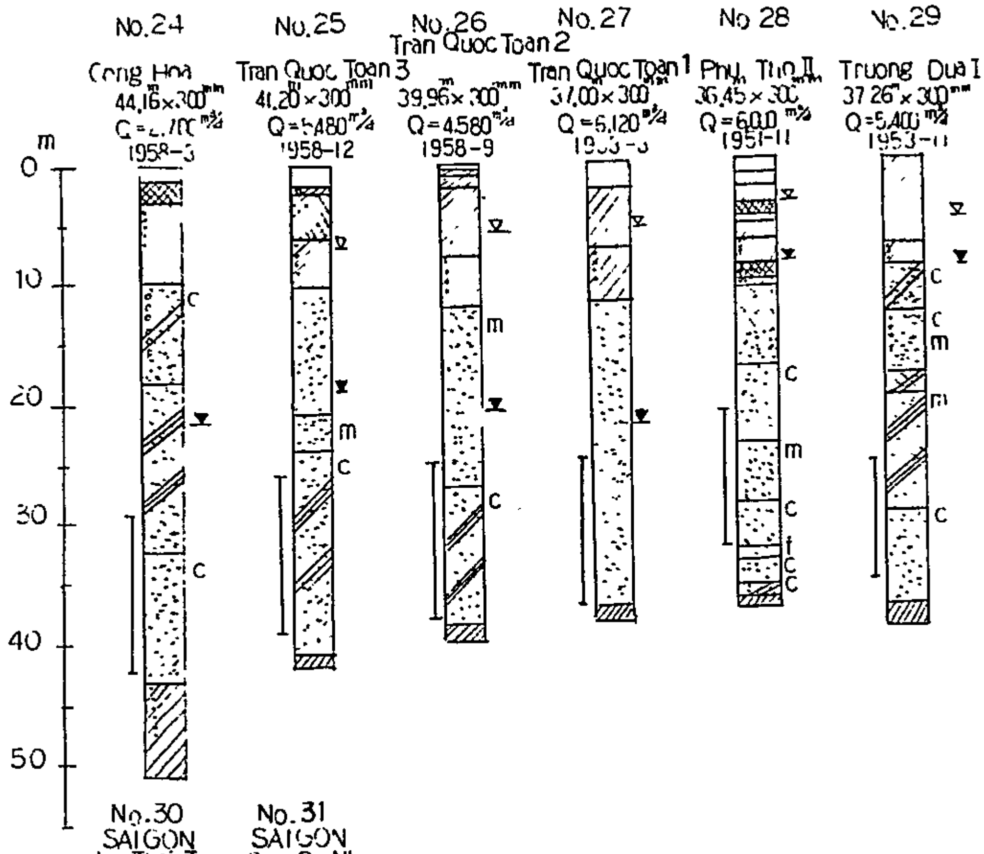
Fig.9 GRAPHIC LOGS OF WATER WELLS

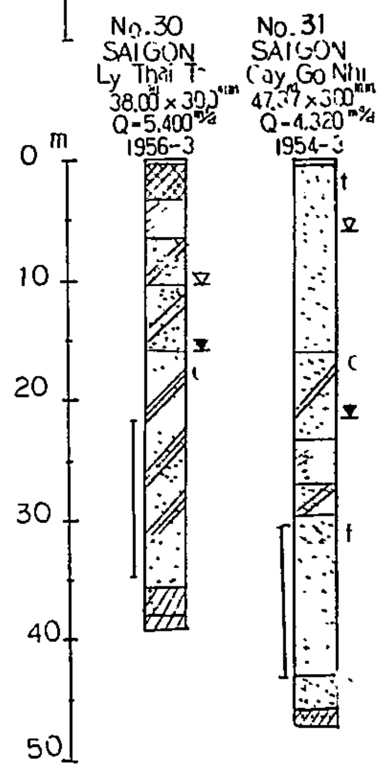



No.1
HOC MON
0~62m × 250mm
~67 × 150
Q= 550 m³/d
1969-10
No.2
HOC MON
0~24m × 250mm
~30 × 150
1969-11
No.3
HOC MON
33m × 200mm
1968-4
No.4
HOC MON
0~21m × 200mm
~31 × 150
Q= 694 m³/d
No.5
HOC MON
0~64m × 200mm
~74 × 150
1970-2
No.6
HOC MON
39m × 150mm
Q= 458 m³/d
1964-9
0m
10
20
30
40
50
60
70
80
90
100
f
c
Peb
m


No. 7
HOC MON
35.5 m × 200 mm
Q= 1,150 m³/d
1965-7
No. 8
HOC MON
0~46 m ×300 mm
~90.68 × 200
Q=5,180 m³/d
1960-3
No. 9
SAI GON
Vo Di Nguy
41.52 m × 300 mm
Q= 4,830 m³/d
1957-12
No. 10
SAI-GON
Phu Nhuan
32.94 m × 300 mm
Q= 3,040 m³/d
1933-3
No. 11
SAI GON
Huynh Tinh Cua
39.26 m × 450 mm
Q = 3,540 m³/d
1932-10
No. 12
SAI GON
Yen Do II
44.7 m × 300 mm
Q= 6,070 m³/d
0 m
10
20
30
40
50
60
70
80
90
100
c
m
f
f
c
c
c
rock


No.13
SAIGON
Truong Minh Giang
49.89m × 300mm
Q=4,320m³/d
1958-1
No.14
SAIGON
Pham Dang Hung
33.96m×300mm
No.15
SAIGON
Hong Thap Tu
44.8m×300mm
No.16
SAIGON
Phan Dinh Phung
40.89m×300mm
Q=3,910m³/d
1957-9
No.17
SAIGON
Ba Huyen Thanh Quan
48.79m×300mm
Q=2,910m³/d
1949
No.18
SAIGON
Le Van Duyet II
45.12m×300mm
Q=3,600m³/d
1953-8
No.19
SAIGON
Tran Quoc Toan 4
45.09m×300mm
Q=4,400m³/d
1959-1
No.20
SAIGON
Ban Co II
45.7m×300mm
Q=2,710m³/d
1955-9
No 21
SAIGON
Bui Chu
45.1m×300mm
No 22
SAIGON
Nguyen Du
42.7m×300mm
Q=4,830m³/d
No.23
SAIGON
Ban Co I
43.95m×300m
Q=2,430m³/d
0m
10
20
30
40
50
f
m
c
t


No.24
Cong Hoa
No.25
Tran Quoc Toan 3
No.26
Tran Quoc Toan 2
No.27
Tran Quoc Toan 1
No 28
No.29
Truong Dua I
1958-12
1958-9
m
0
10
20
30
40
50


No.30
SAIGON
No.31
SAIGON
1956-3
1954-3
m
0
10
20
30
40
50

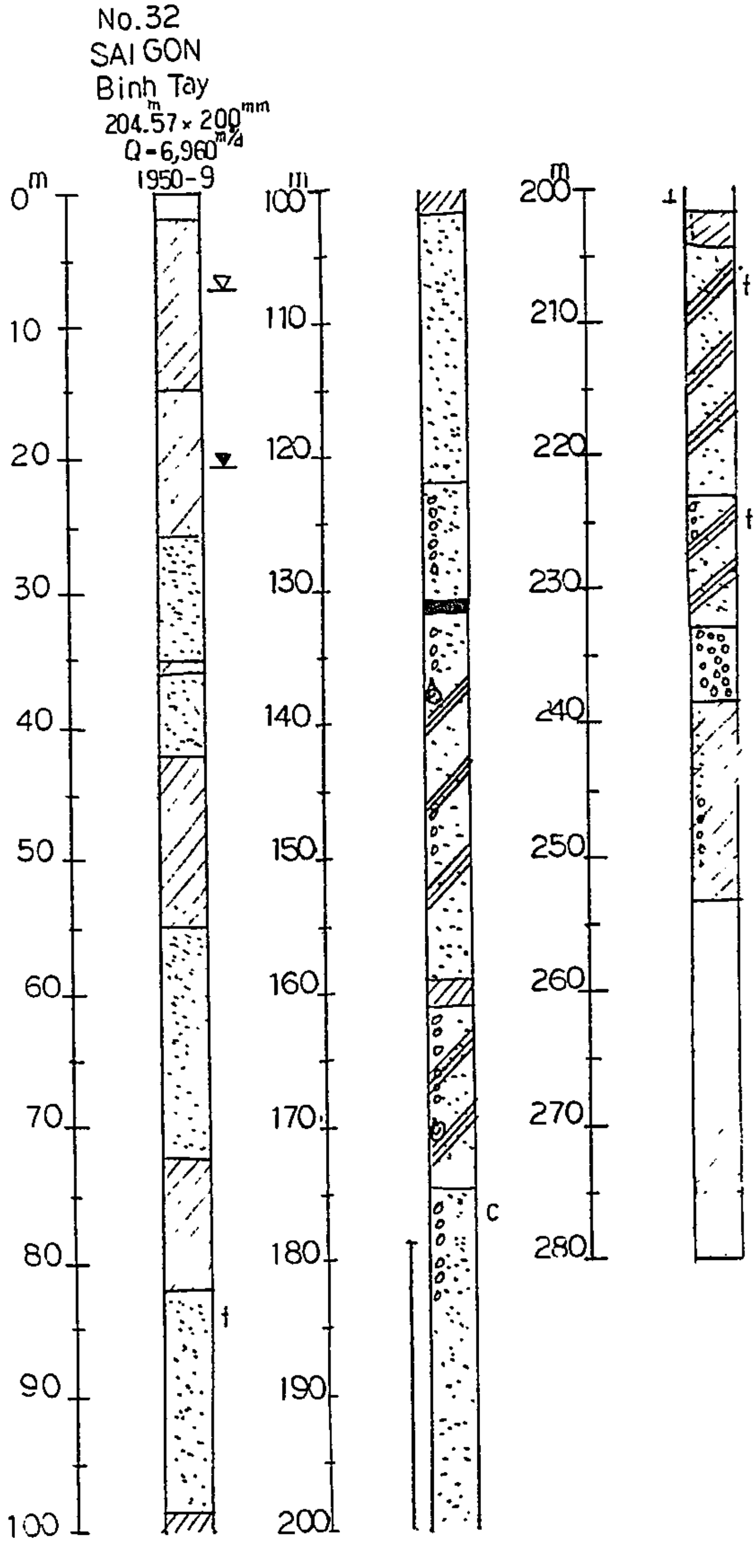
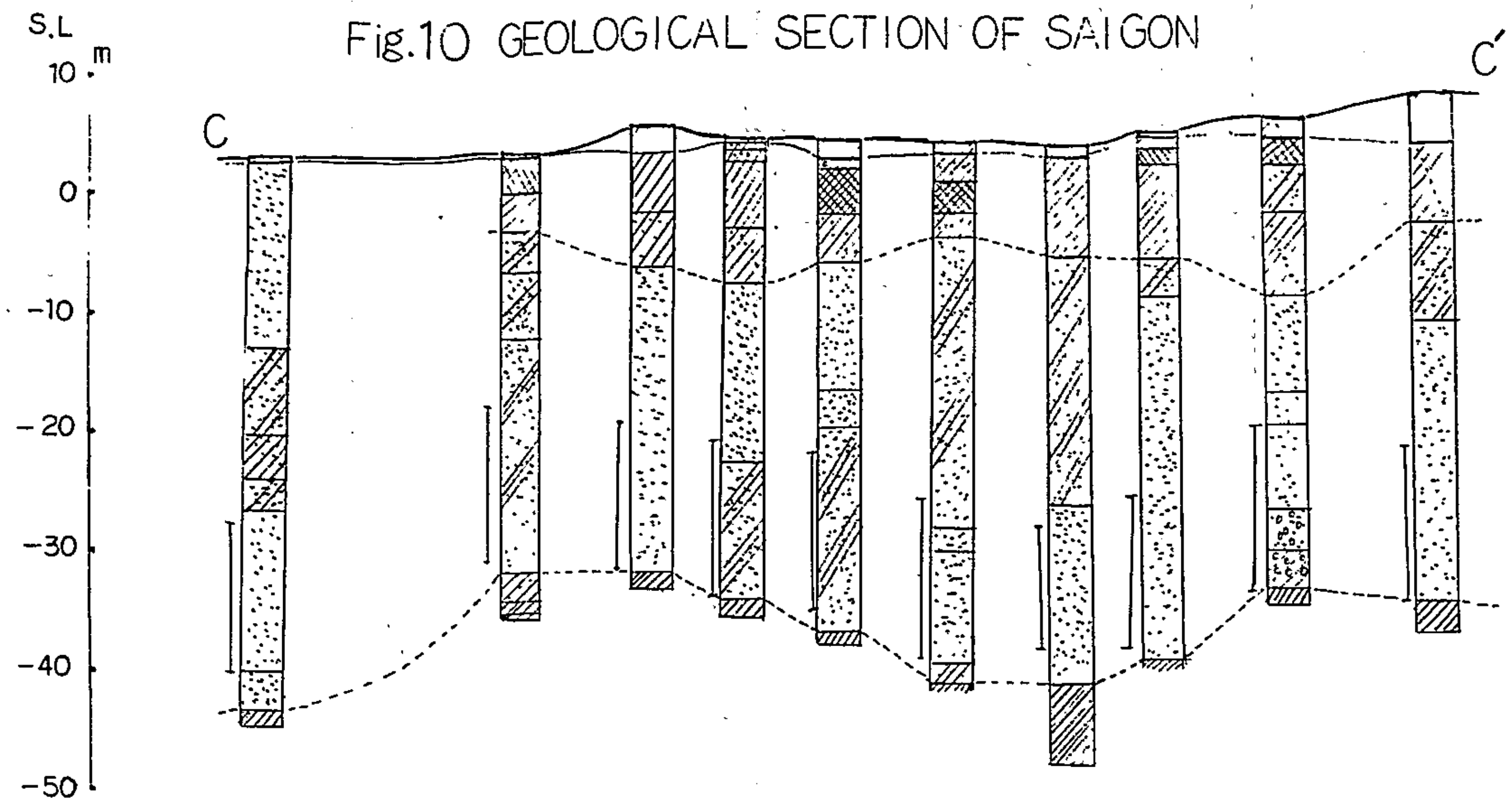

No.32
SAI GON
Binh Tay
204.57m × 200mm
Q-6,960m³/d
1950-9
0m
10
20
30
40
50
60
70
80
90
100
100m
110
120
130
140
150
160
170
180
190
200
200m
210
220
230
240
250
260
270
280
f
c

Fig.10 GEOLOGICAL SECTION OF SAIGON



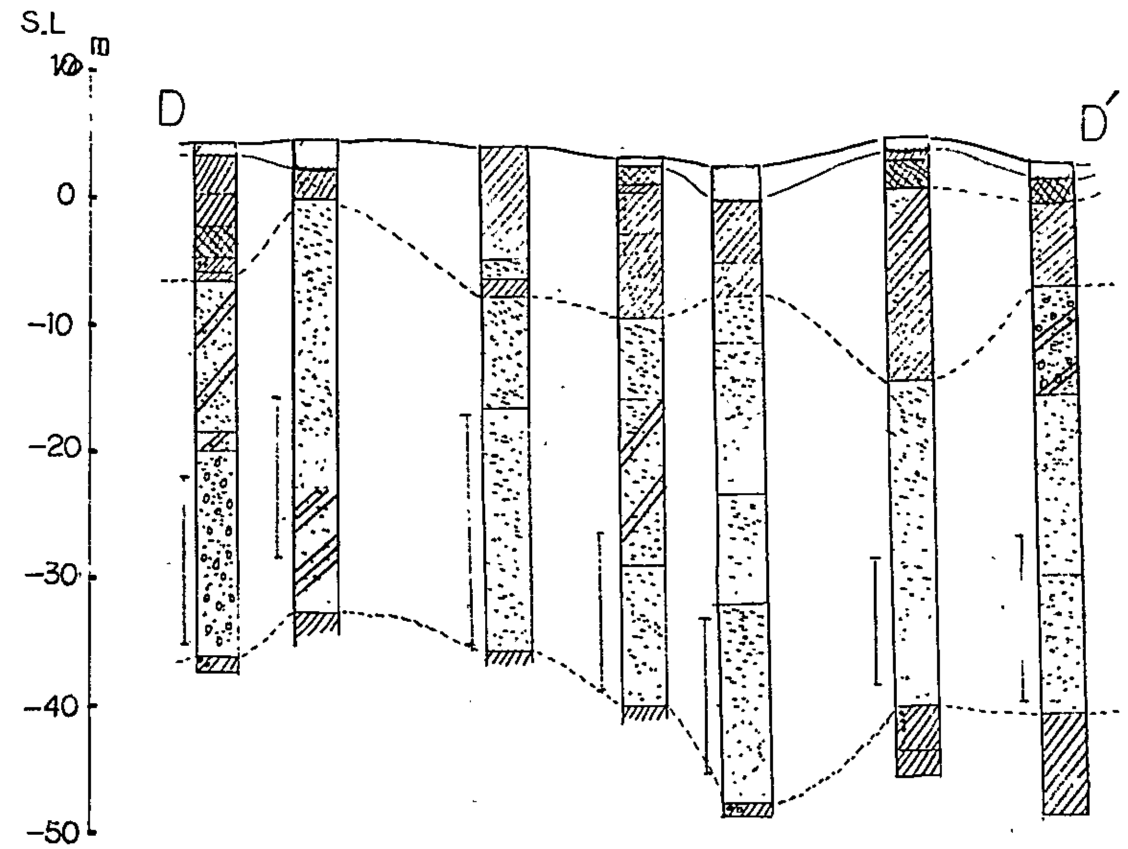
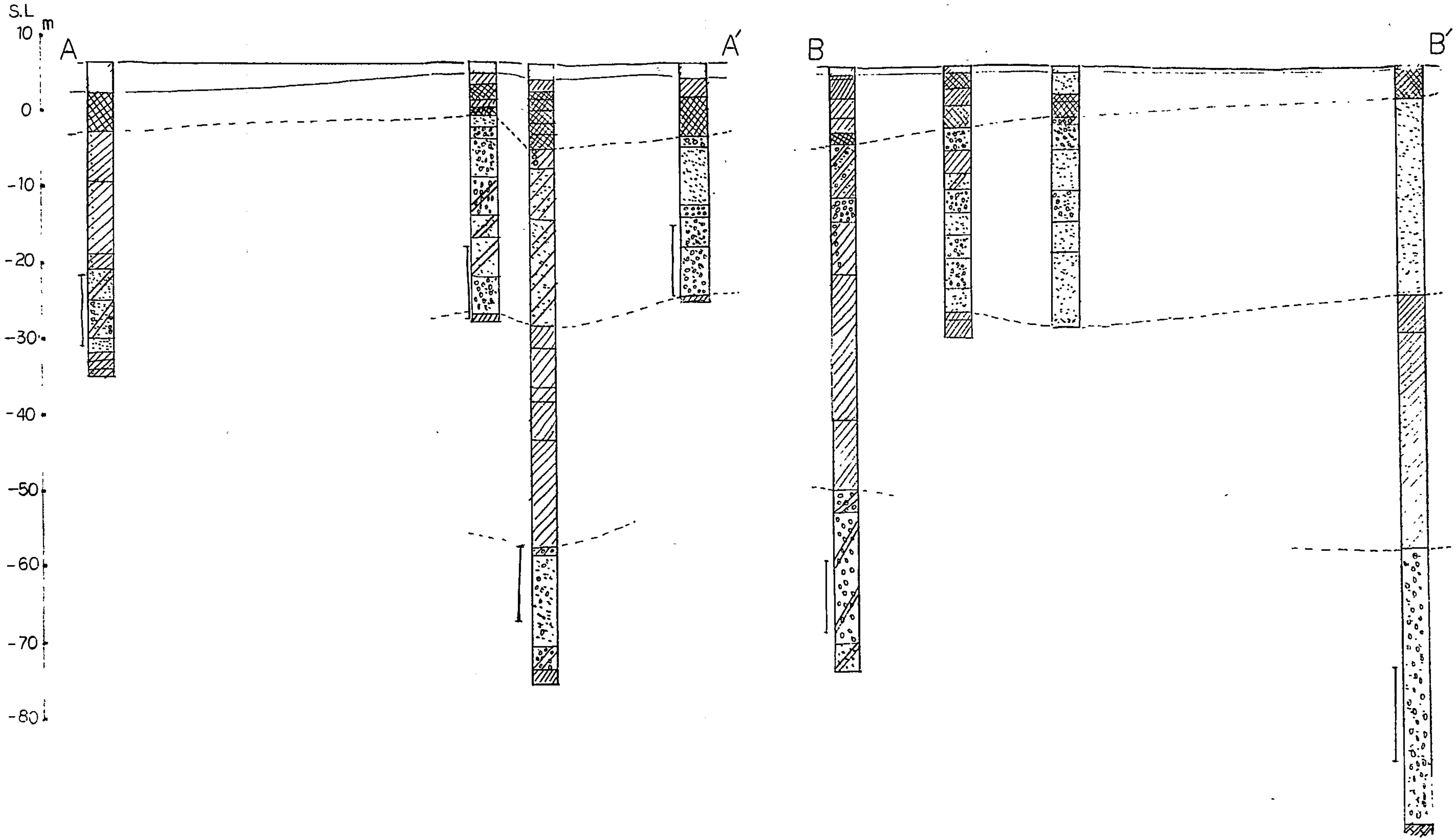


Fig.11 GEOLOGICAL SECTION OF HOCMON



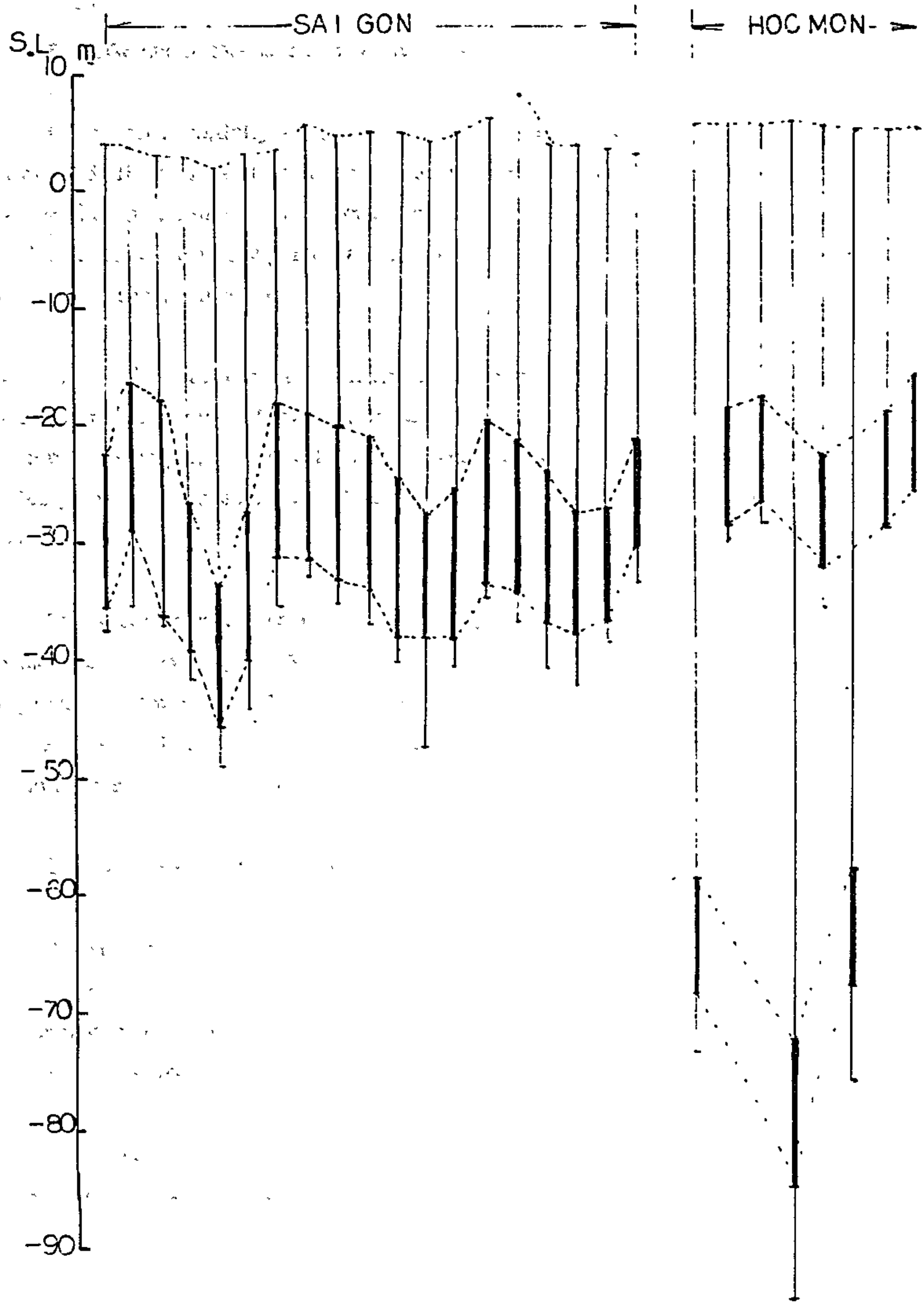


Fig.12 STRAINER SITUATION

5. Electrical Resistivity Surveying

5-1 Ground surface condition in survey area

Electrical resistivity surveying was carried out in the area covering about 2 km^2 out of paddy field zones stretched south-eastwards from the town of Hoc Mon. Since Vietnam was in the dry season at that time, most paddy fields were dried-up and consolidated. And except for partially cultivated farm land most places were undesirable for the resistivity surveying.

In view of measurement accuracy it is important to apply sufficient electrical current into the ground. However, it was impossible to obtain satisfactory results in some measuring points due to the specific condition of very high ground resistivity. In this point, every possible effort such as remeasurement was attempted to obtain accurate data.

The accuracy of the resistivity surveying greatly depends upon the topographic condition of a survey area. Since the ground surface in this area was very flat to a large extent, it was possible to space electrodes along a straight line almost in an ideal manner. Accordingly, it is assumed that any measuring errors contained in the results are almost due to the ground condition.

5-2 Arrangement of measuring point and surveying depth

There were 9 measuring lines in total at every distance of 200 meters. Measuring points number 3 to 6 in the respective lines, and the distance between measuring points was approximately 200 meters. The location of measuring points and their number are as shown in Figure 13.

The resistivity surveying was carried out at 46 points in total. And the maximum measuring depth was 130 meters each.

5-3 Measuring apparatus and method

Measuring apparatus: Model ES-G1 (Alternated direct current system, maximum load-----600V-3A)

Electric supply system: Dry battery EM-1 (45V) x 10 pieces

The arrangement of four electrodes (two current ones and two potential ones) adopted in the surveying is Wenner configuration. In this Wenner system, the electrodes are equally spaced along a straight line. Measurements of resistivity are made by using these four electrodes set in the ground. Current is applied to the ground through outer two current electrodes and the potential drop accross the inner two electrodes is noted.

The interval of four electrodes is enlarged so as to satisfy the above configuration and a series of resistance readings at different electrode spacings are taken at a single station or point. The electrodes were spaced to be every 1 meter from the depth of 1 to 20 meters, every 2 meters from that of 20 to 100 meters, and every 10 meters from that of 100 to 130 meters, respectively. The direction of the electrode arrangement was not made constant due to the surface conditions, but as a principle it was apointed to be east to west.

5-4 Classification of ρ-a curves

The depth-profile resistivity curves which are made by plotting apparent resistivity (ρ) against electrode spacing (a) are as shown in Figures 14 and 25. These curves, refered to as ρ-a curve, can be classified as follows according to their form.

Type-A: The curves of Points No. 3 and No. 11 are typical ones. The apparent resistivity rises up from a depth of approximately 5 meters, reaching the peak of about 500 ohm-meters and goes down to approximately 200 ohm-meters as electrode spacing increases. This type can be found mainly at the south-western side of the investigation area.

Type-B: This type could be represented mainly by Points No. 4 and No. 22. The apparent resistivity to a depth of 25 to 35 meters forms a gentle descending curve and rises up with the enlargement of electrode

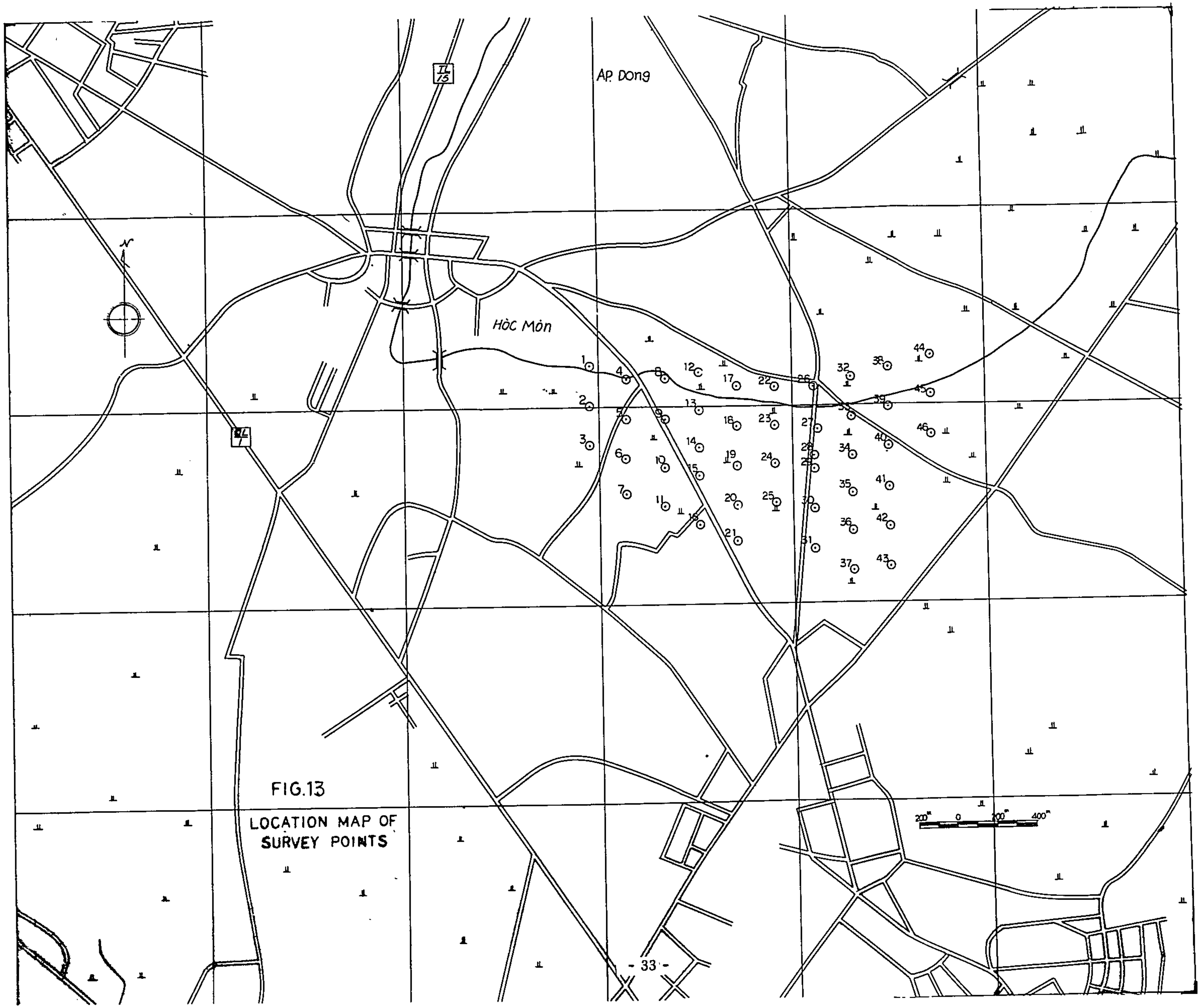


FIG.13

LOCATION MAP OF SURVEY POINTS

spacing, ascending the peak of 200 to 400 ohm-meters at a depth of approximately 80 meters. Then it goes down again at a further depth. This type of curves is distributed mainly at the north-eastern side of the area.

Type-C: Points No. 26, No. 36, etc. are typical of this kind. It has descending form within the upper 10 meters. Within a depth of 10 to 50 meters it becomes horizontal and goes down further as depth is increased. This seems to be an inter-appearance of Type-A and Type-B. The apparent resistivity in the horizontal part ranges from 200 to 400 ohm-meters. This type can be found mainly at the eastern side and partly at the western side of the area.

Type-D & E: Both types are quite similar to each other in the point that they have descending from to a depth of nearly 40 meters. Type-D follows further a descending curve while Type-E shows a value of about 200 ohm-meters at the depth 40 meters or so and then becomes horizontal. In the case of the latter, there is no remarkable change in value when and if the space of electrodes increases. The former is represented by Point No. 33 and the latter by No. 43, respectively. These types of a curve can be found at the south-eastern part of the area.

5-5 Analysis and interpretation of ρ-a curves

The results of ρ-a curve analysis are shown in Figure 26 and 28 in the form of a resistivity log.

Formations or rocks show different resistivity depending upon their physical and mineralogic characteristics due to component minerals, degree of crystalization, that of consolidation, etc. In paticular, when saturated with water, formations show resistivity in accordance with the quality of water contained. The apparent resistivity of pure water is extremely high while that of ground water is generally around less than 100 ohm-meters due to various dissolved ions. As a rule, apparent resistivity of water bearing formation is less than 1,000 ohm-meters while such high apparent resistivity as more than 1,000 ohm-meters is indicated by dried-up strata. The muddy formation which consists mainly of clay and/or silt is an aquiclude where movement of water by gravity force hardly takes place because the effective porosity is very small, and its apparent resistivity is relatively low; not higher than 100 ohm-meters in most cases. Accordingly, formations with apparent resistivity of 100 to 1,000 ohm-meters can be regarded as an aquifer composed mainly of sand and/or gravel.

On the basis of those principles and available data of the existing wells, as a result of the resistivity analysis, it is concluded that subsurface geology is presumably divided into five nearly horizontal formations to the depth of 130 meters. Figures 29 and 30 show the resistivity cross section of the survey area. For convenience of explanation these five formations are referred to as Formation A, B-1, B-2, C and D from the ground surface in succession.

Formation A: The lower boundary of this formation ranges from 5 to 13 meters deep. Its average thickness is 10 meters or so. The upper most portion, about 1 meter thick, shows the high apparent resistivity of 1,000 to maximum 7,500 ohm-meters. The apparent resistivity of a stratum following to this high resistivity zone is 200 to 500 ohm-meters.

Formation B-1: This is bounded at the depth of 35 to 50 meters. Its average thickness is 32 meters or so. The apparent resistivity ranges between 100 and 1,000 ohm-meters. It is from 150 to 600 ohm-meters for the most part. The apparent resistivity of this formation can be classified into two groups; the high resistivity of 300 to 1,000 ohm-meters and relatively low one of 100 to 200 ohm-meters. It is supposed by reference to formation logs of existing wells in and around the investigation area that the high resistivity parts consist of sand and/or gravel and the relatively low resistivity ones are mainly composed of sand and/or silt.

Formation B-2: As far as the apparent resistivity is concerned, materials of Formation B-2 seem to be nearly similar to those of Formation B-1. In spite of this similarity, both formations can be distinguished as a result of the analysis. Especially at the points of No. 1, No. 6, No. 10, No. 13, and No. 18, Formation B-2 is distinguishable from Formation B-1 by the boundary formation of 5 meters or so thick which has the relatively low apparent resistivity of 50 to 140 ohm-meters. However, it is not clear that this low apparent resistivity formation is a key bed to distinguish Formation B-2 from Formation B-1 as a whole, because it does not make its appearence in the analysis of other points data.

Formation B-2 shows the maximum apparent resistivity of 670 ohm-meters or so and the minimum of about 100 ohm-meters.

The analysis value of the apparent resistivity for the most part is 150 to 450 ohm-meters with its upper limit which is slightly lower than that of Formation B-1. The apparent resistivity of the order of 100 ohm-meters is distributed mainly at the southern half of the survey area.

The lower boundary of this formation ranges from 60 to 80 meters and its average thickness is equal to that of Formation B-1 which is 32 meters or so.

Formation C: The lower boundary of this formation is presumed to be 100 to 120 meters, but it is not made clarified in the analysis. The apparent resistivity is some 110 ohm-meters for the most part and partially 40 to 80 ohm-meters. According to such a low apparent resistivity, this formation seems to be aquiclude mainly composed of clay and/or silt. Its thickness is approximately 15 to over 20 meters.

Formation D: This is the high apparent resistivity formation lying beneath Formation C. As a result of the analysis, the apparent resistivity of 200 to 500 ohm-meters can be obtained at the point No. 1 and other 9 points. The thickness and continuity of the formation is not clear.

As mentioned beforehand, subsurface geology in the survey area can be presumably divided into five formations to the depth of 130 meters which are almost horizontal. Taking their formation and apparent resistivity into account, however, the upper section bounded by Formation C is regarded as a single water bearing formation. All of the existing deep wells constructed in and around the district are taking ground water from Formation B-1 and B-2. Since there is no available data concerning Formation D, it is unknown for the present whether Formation D is an aquifer or not.

It is required to make overall judgment on the hydrogeological properties of Formation B-1 and B-2 and Formation D such as thickness of a water bearing section, their yielding capacity, and so forth. To this end, a series of further investigations covering extensive area and including test borings, pumping tests, etc., should be carried out for the next program.

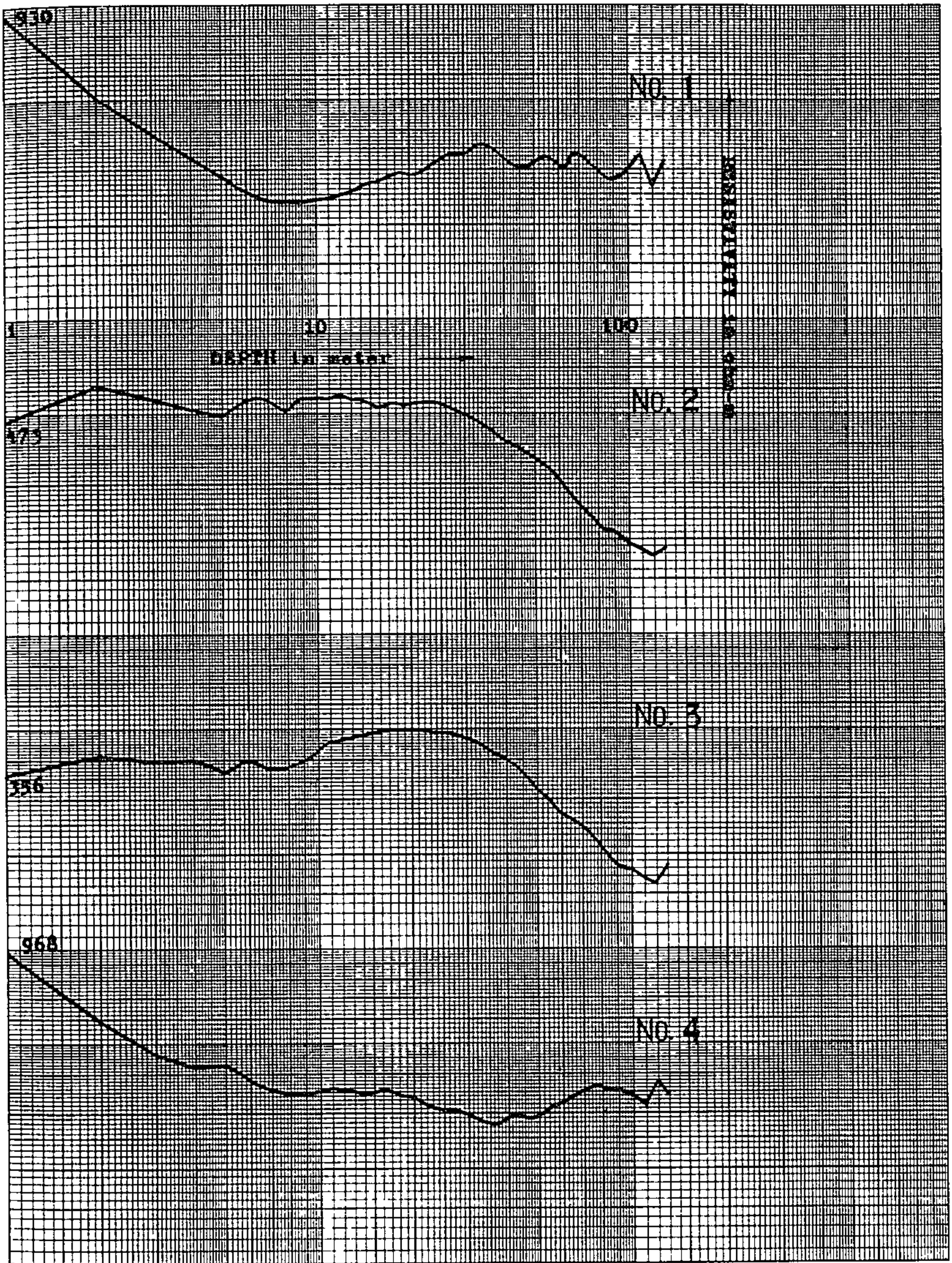


FIG. 14 ρ-a CURVE

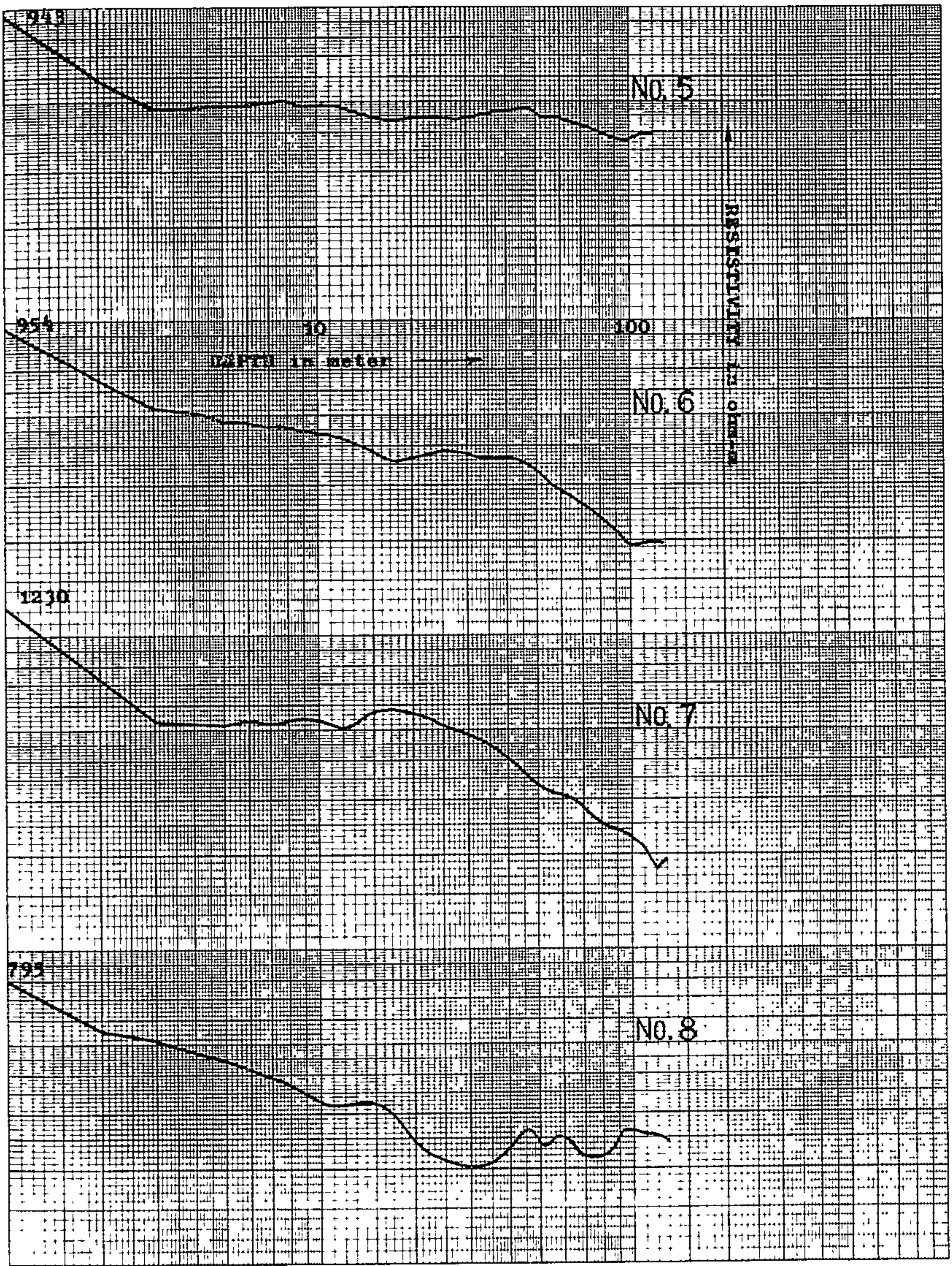


FIG. 15 ρ-a CURVE

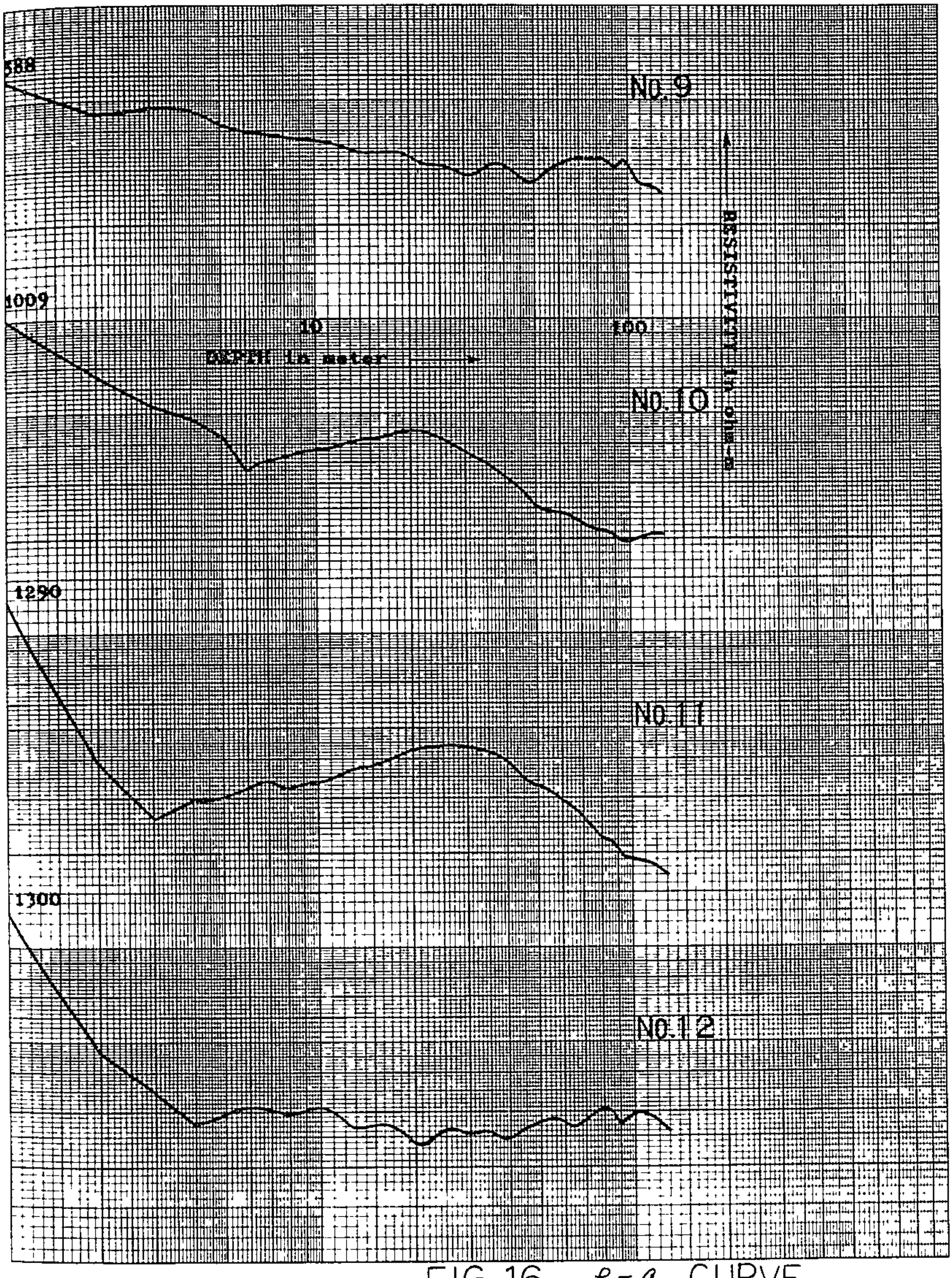


FIG. 16 $\rho - a$ CURVE

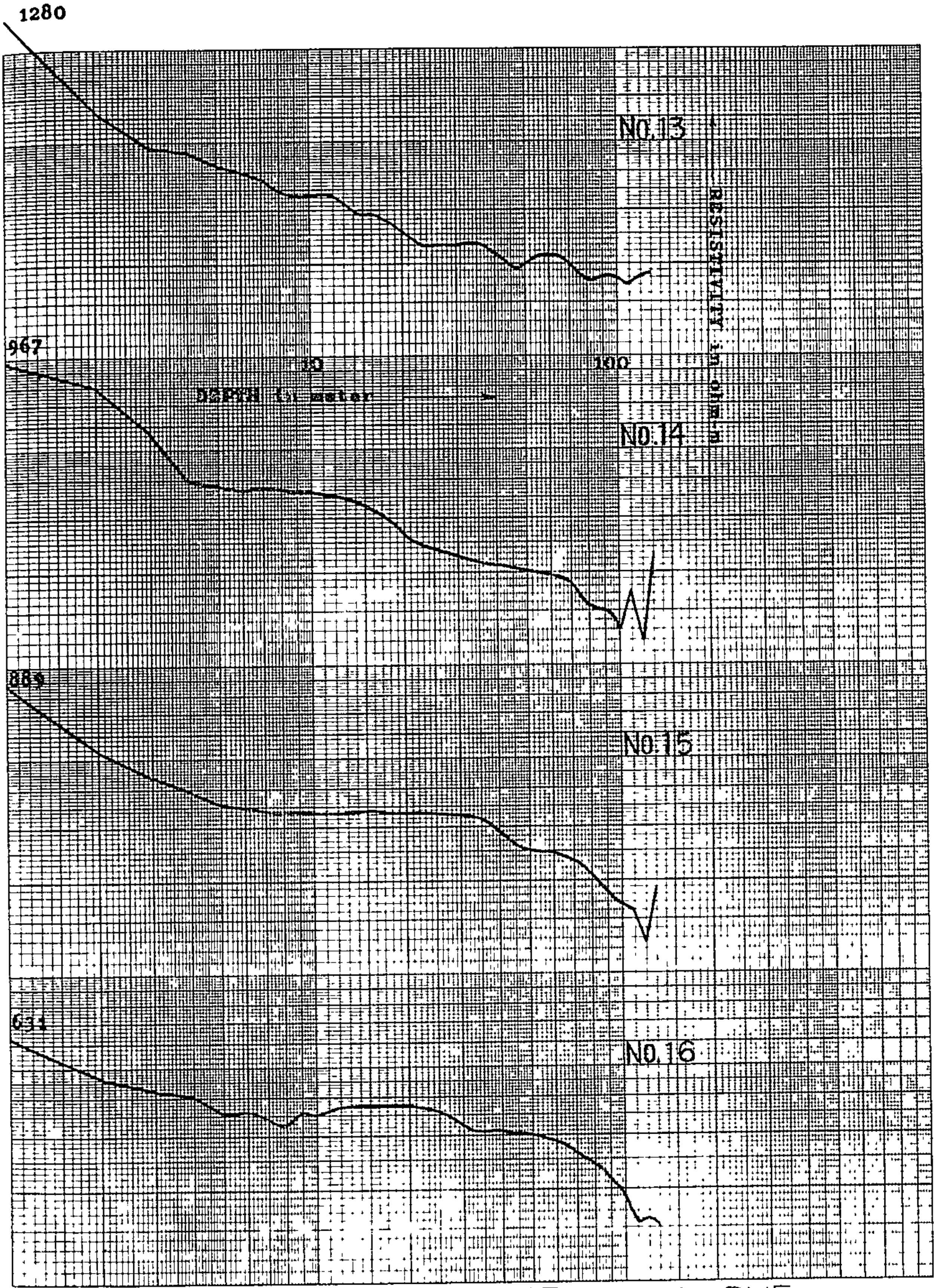


FIG. 17 ρ-a CURVE

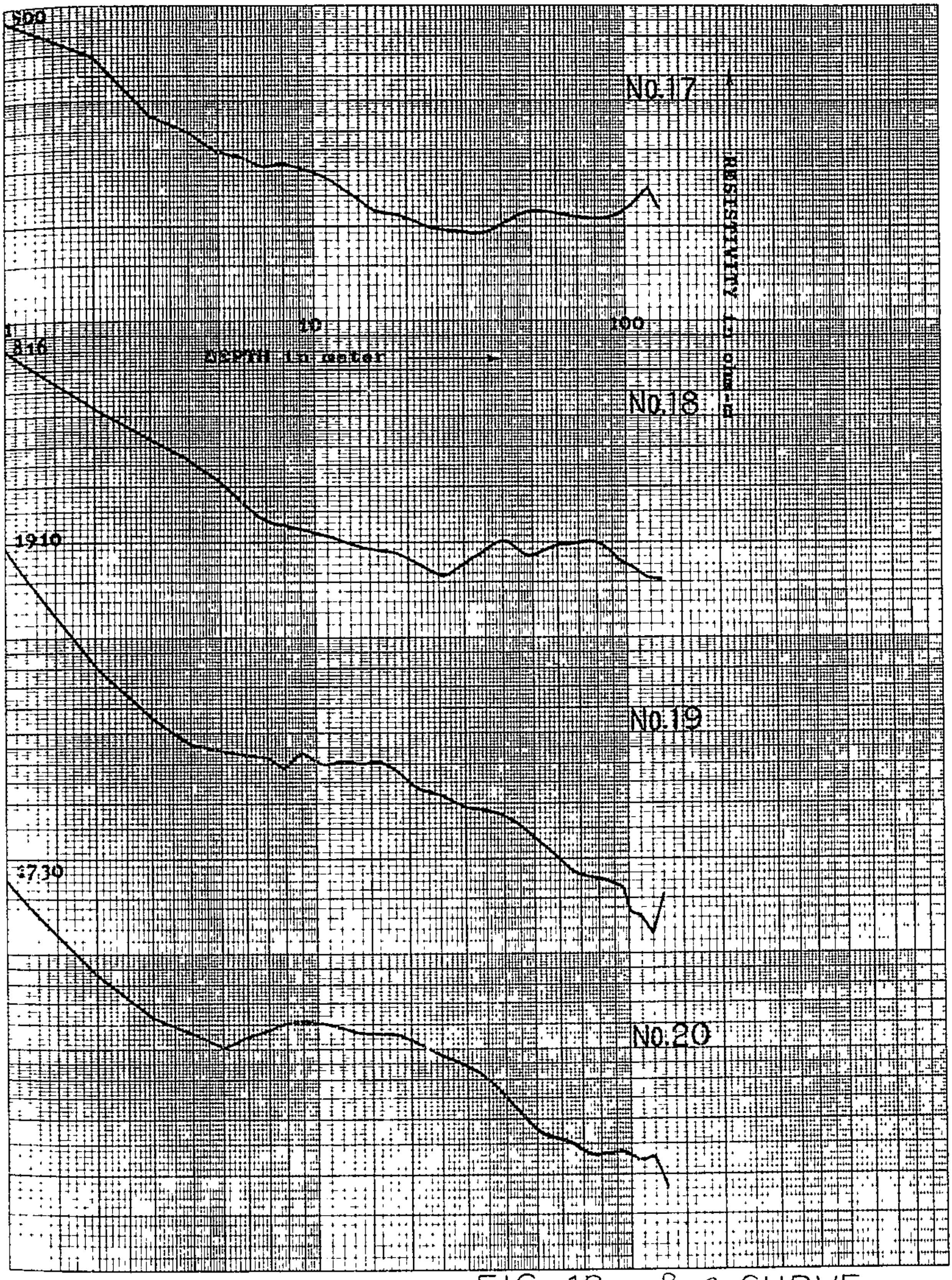


FIG. 18 ρ-a CURVE

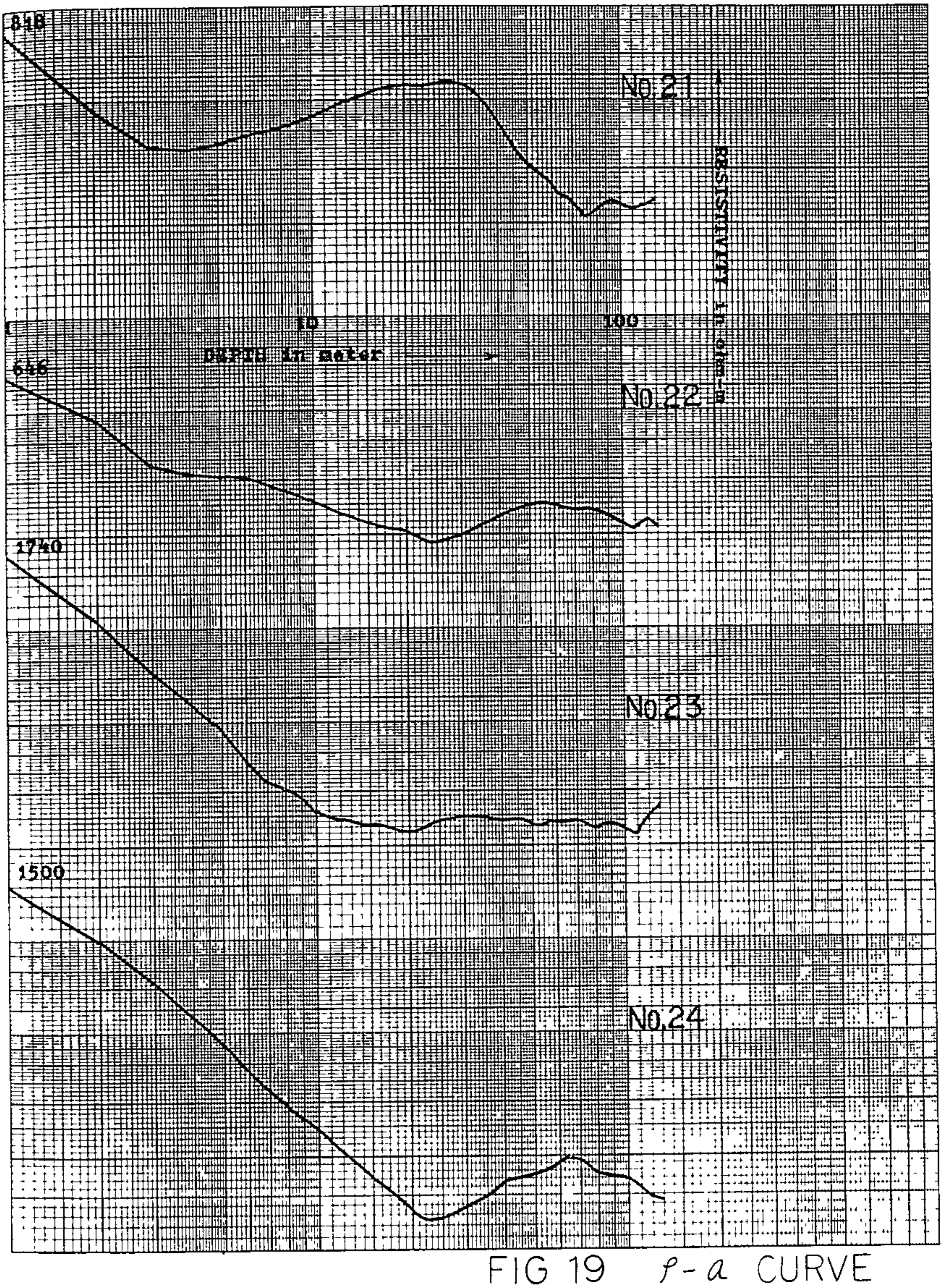


FIG 19 ρ-a CURVE

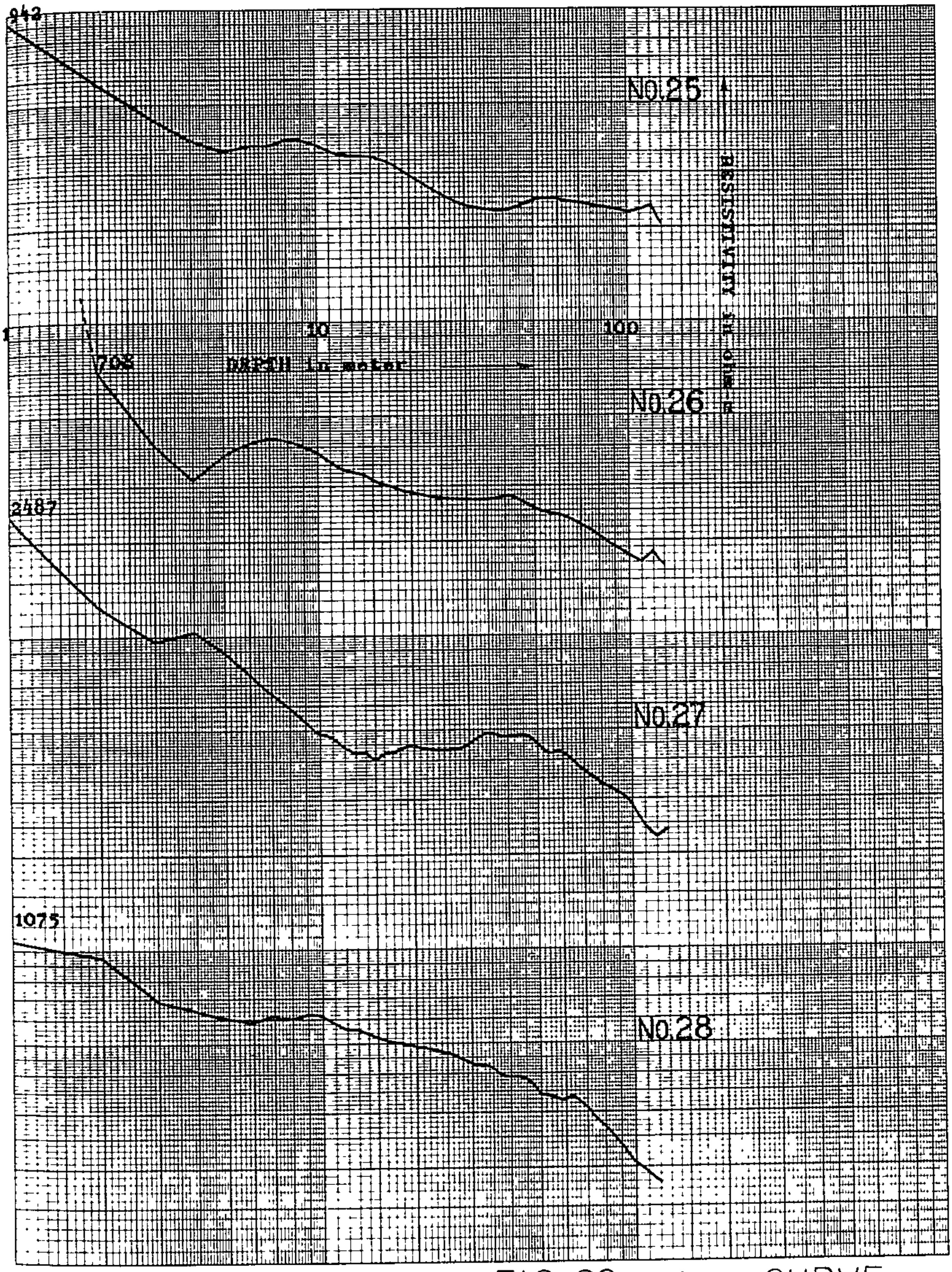


FIG. 20 ρ-a CURVE

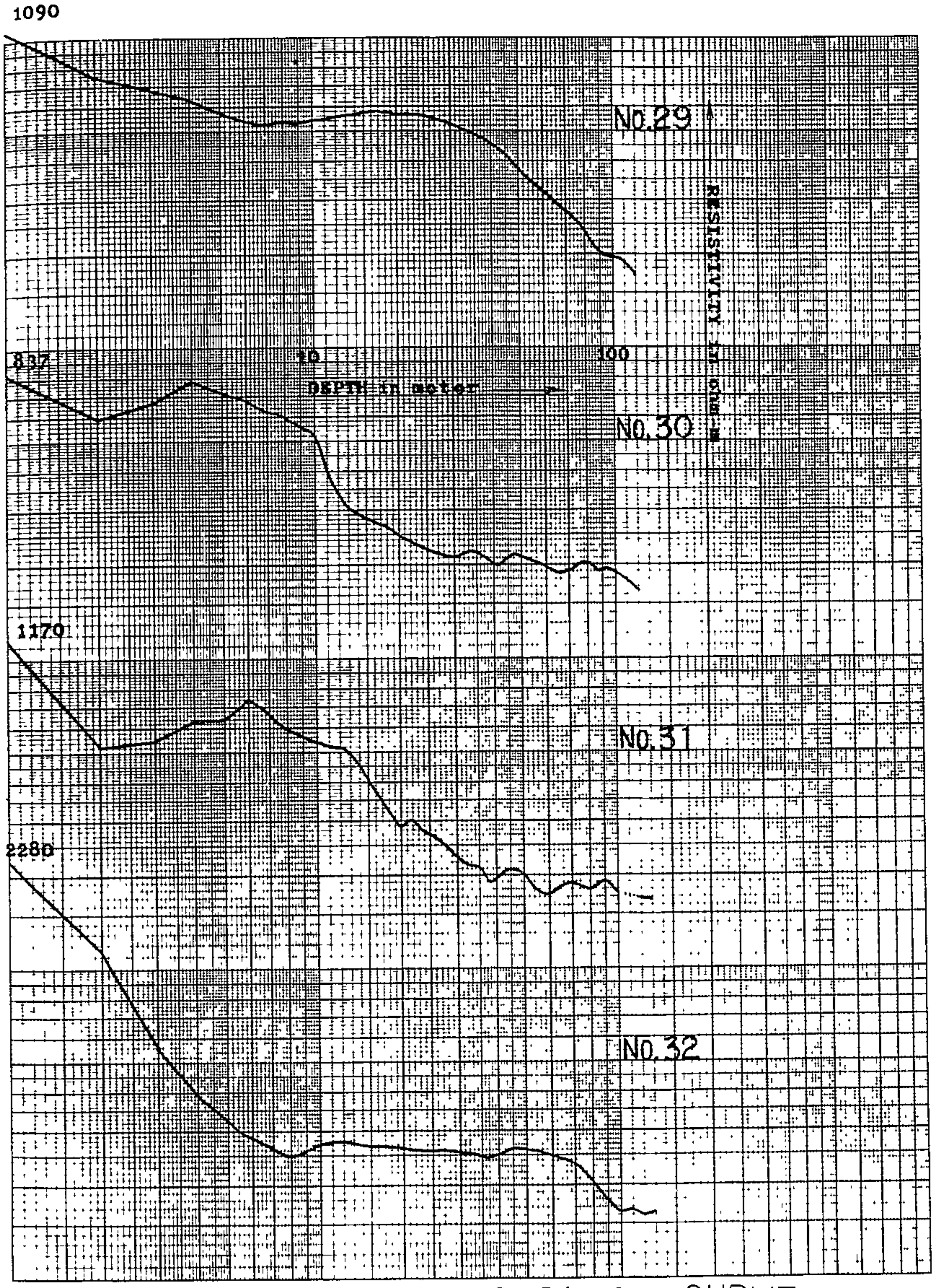


FIG. 21 ρ-a CURVE

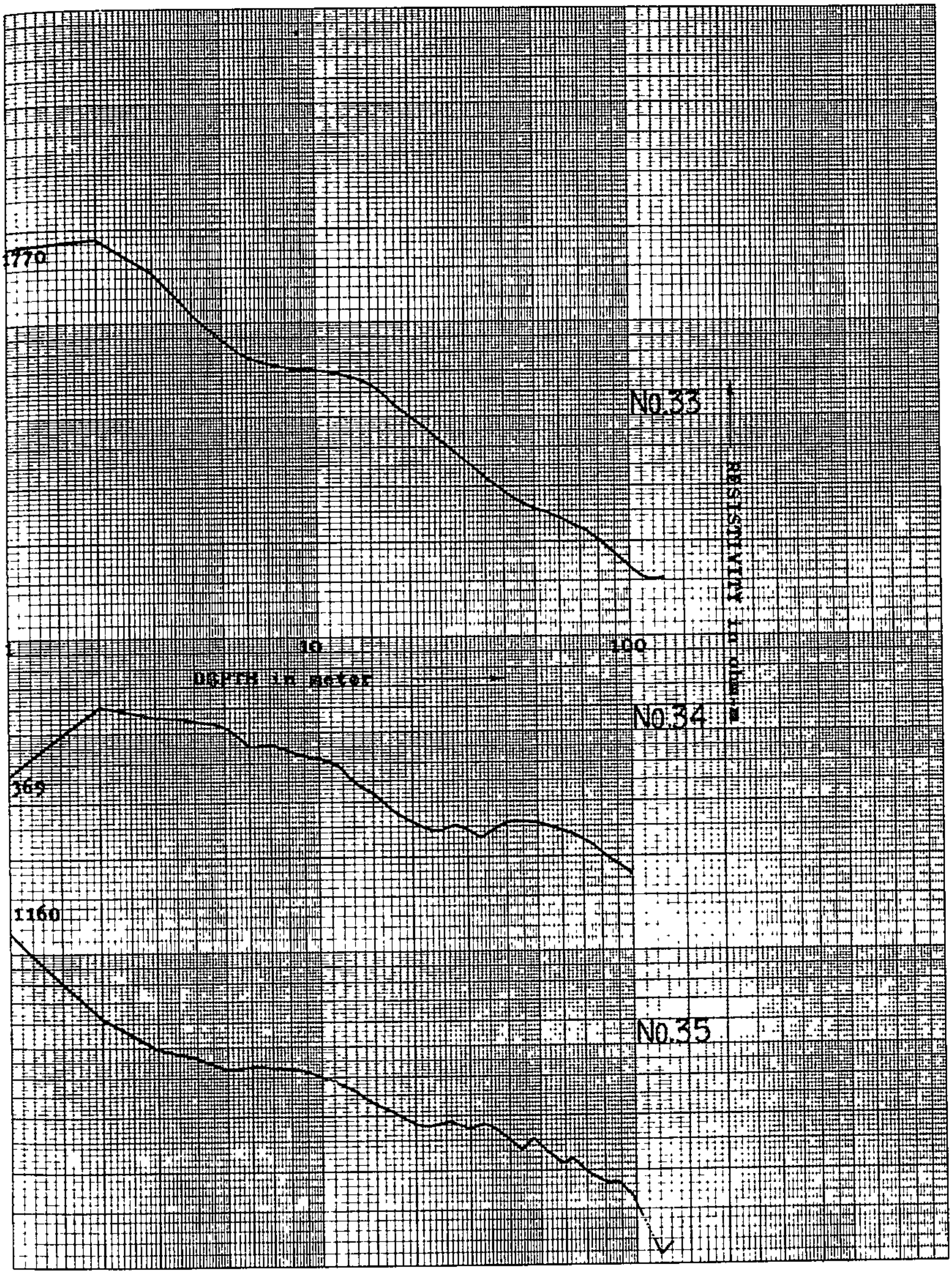


FIG. 22 ρ-a CURVE

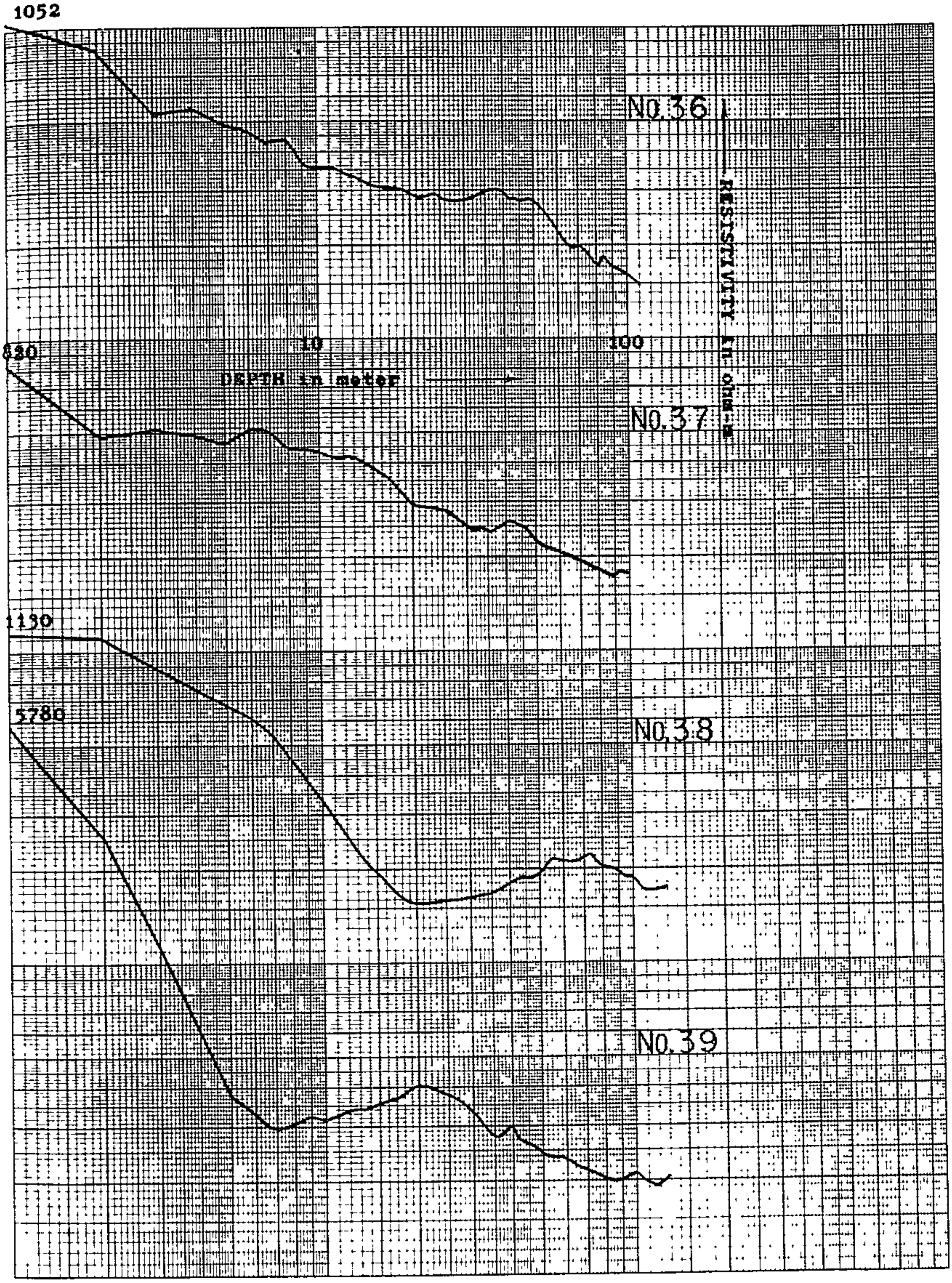


FIG. 23 ρ-a CURVE

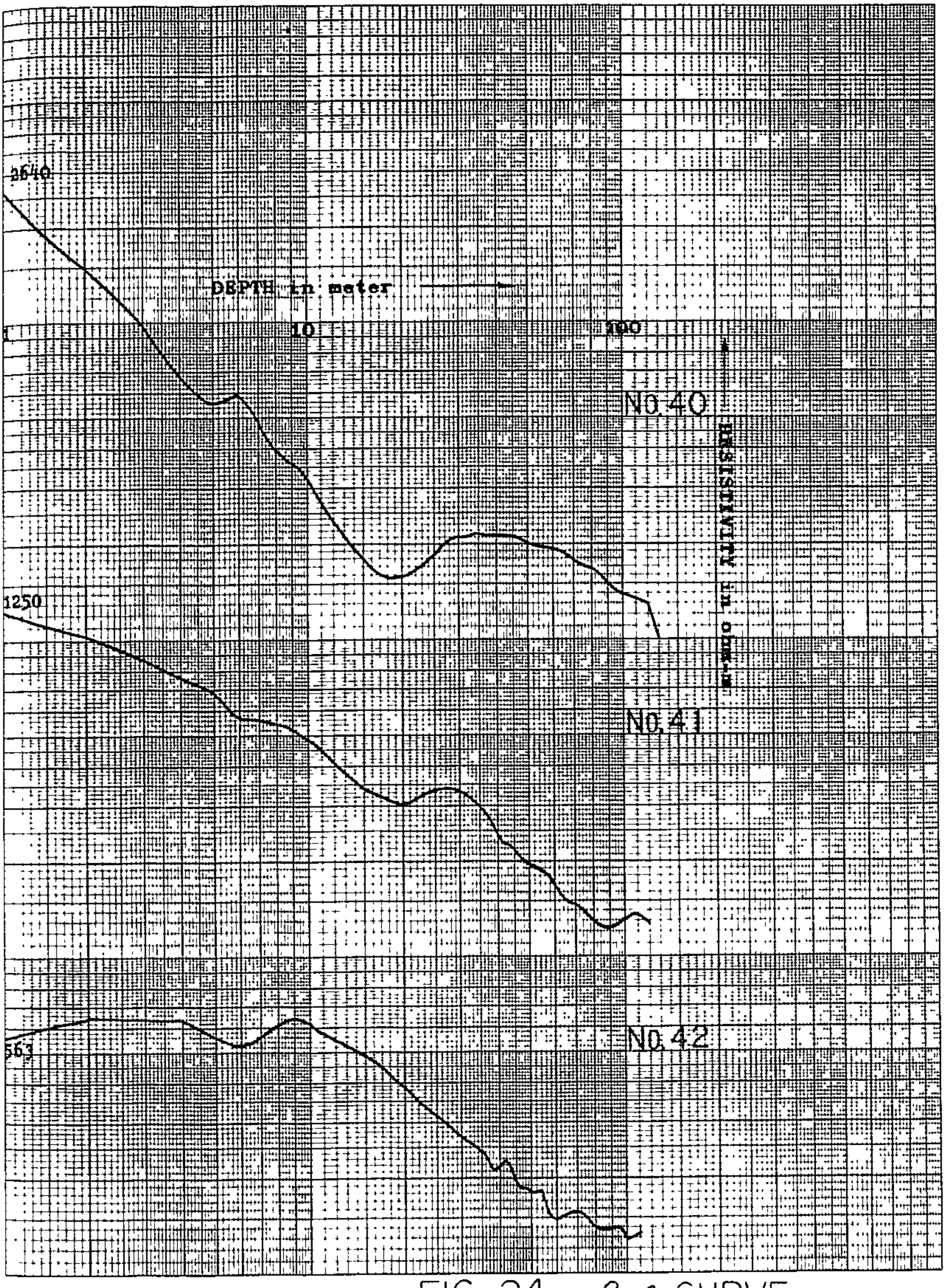


FIG 24 ρ-a CURVE

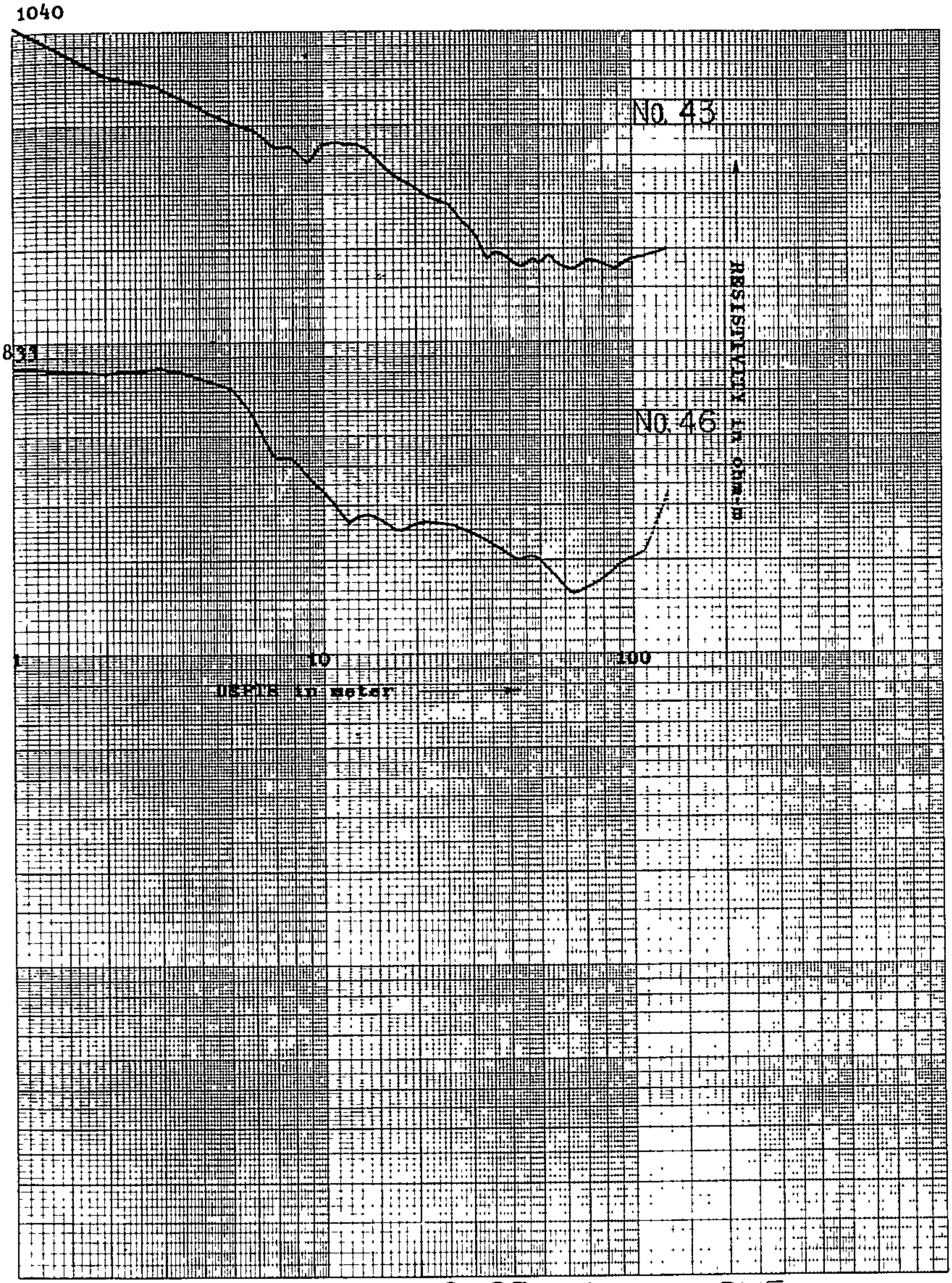


FIG 25 ρ-a CURVE

Fig.26 RESULT OF ρ-a CURVE ANALYSIS

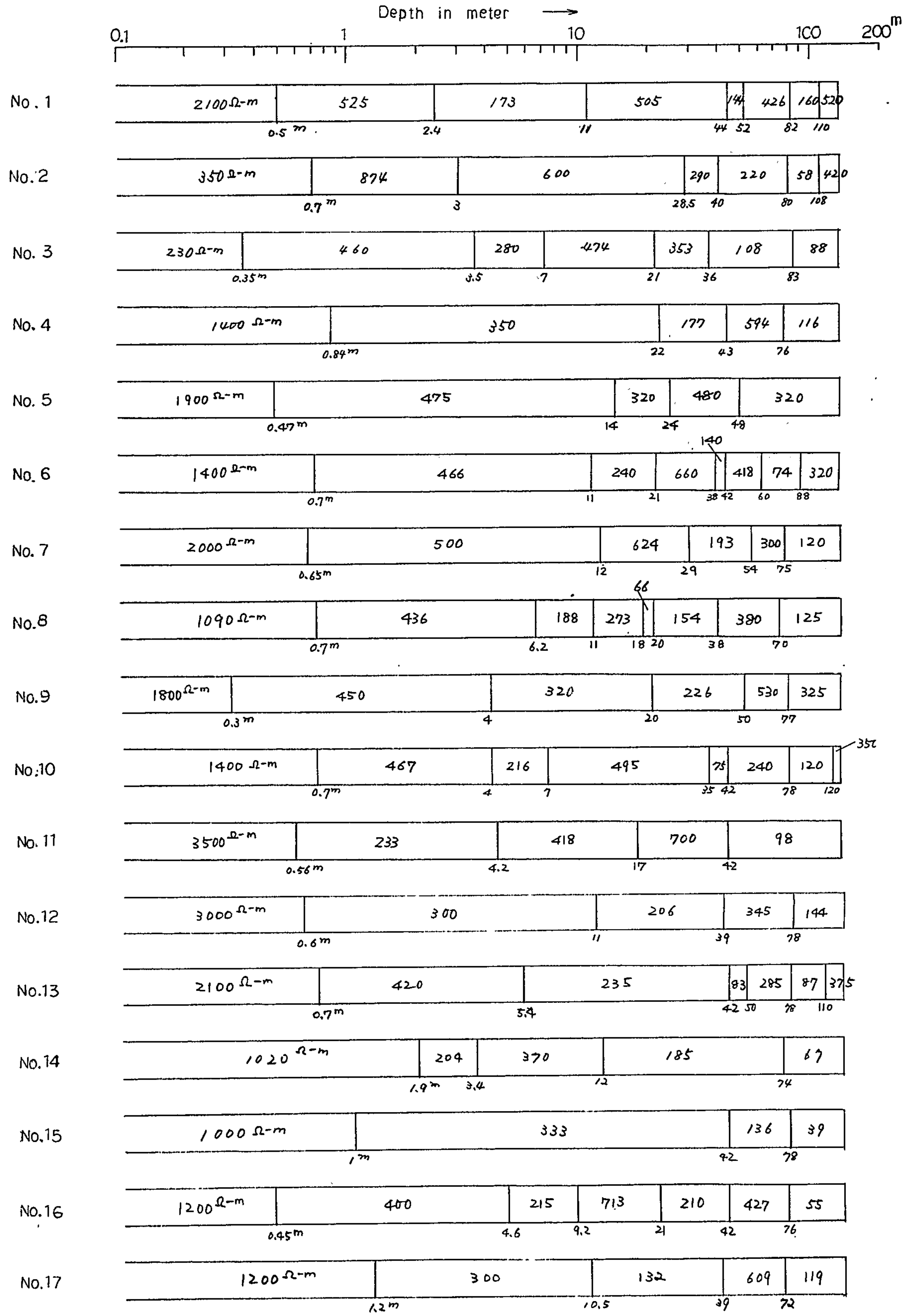


Fig.27 RESULT OF ρ-a CURVE ANALYSIS

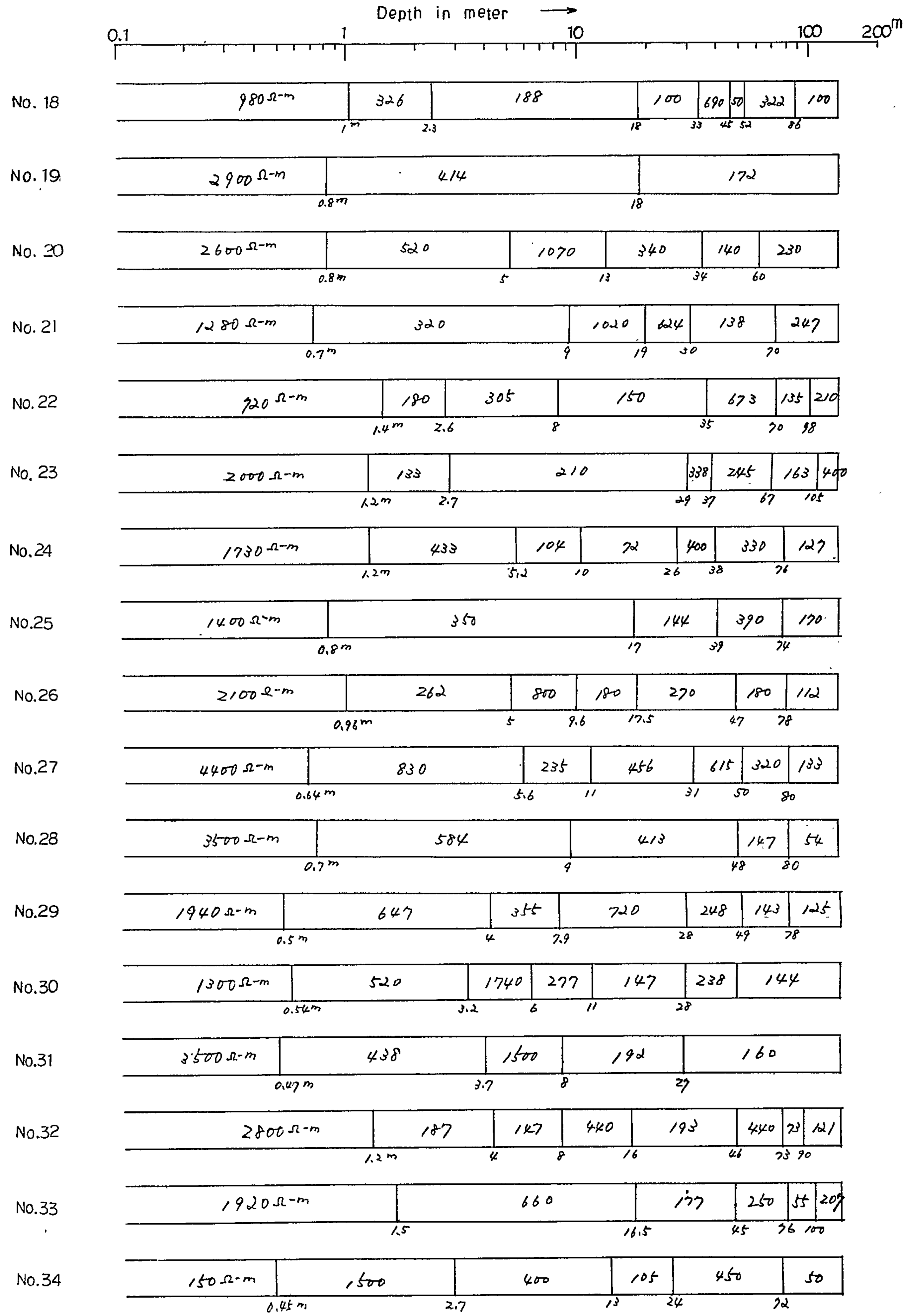


Fig28 RESULT OF ρ-a CURVE ANALYSIS

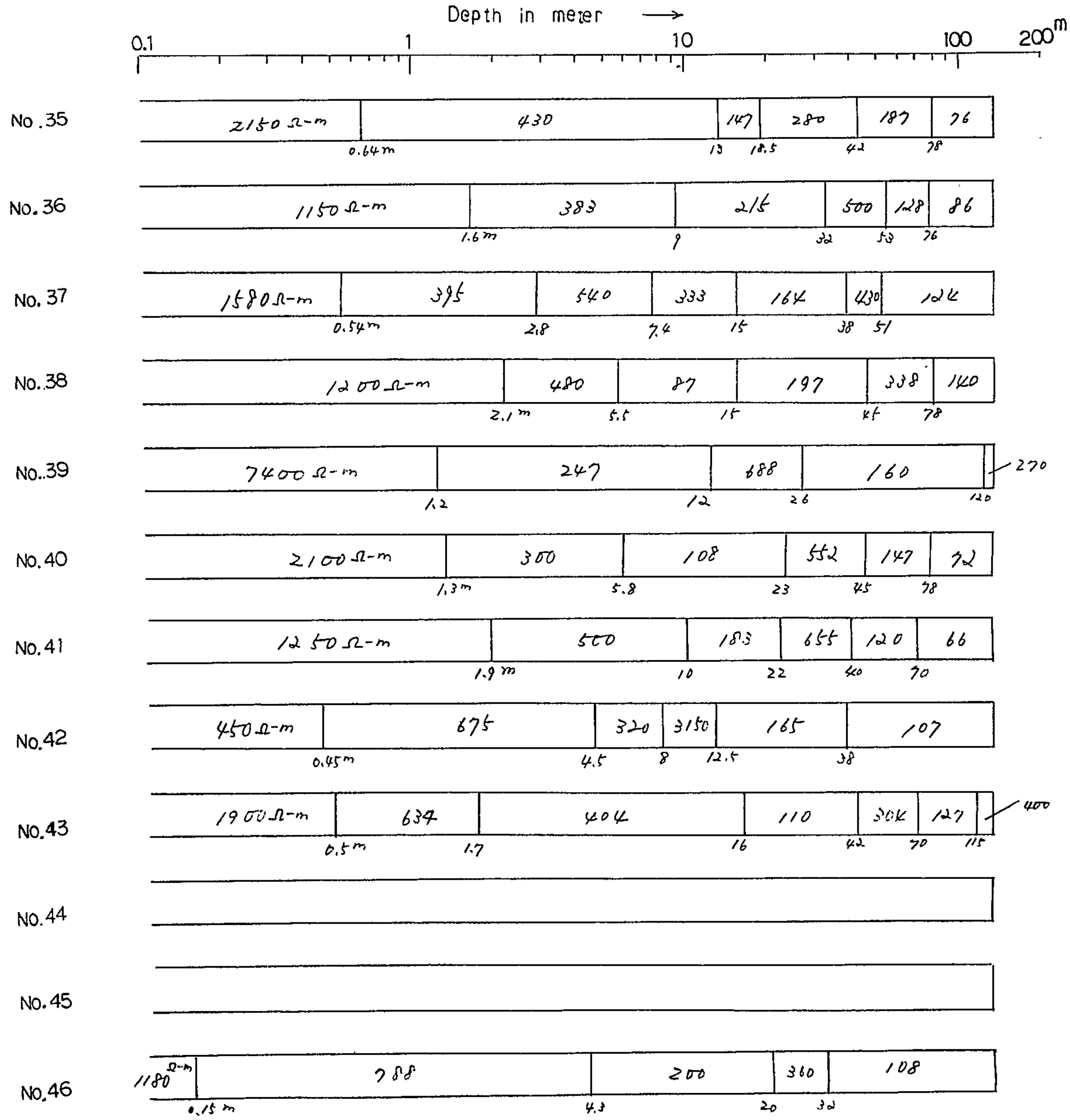


Fig29 RESISTIVITY CROSS SECTION

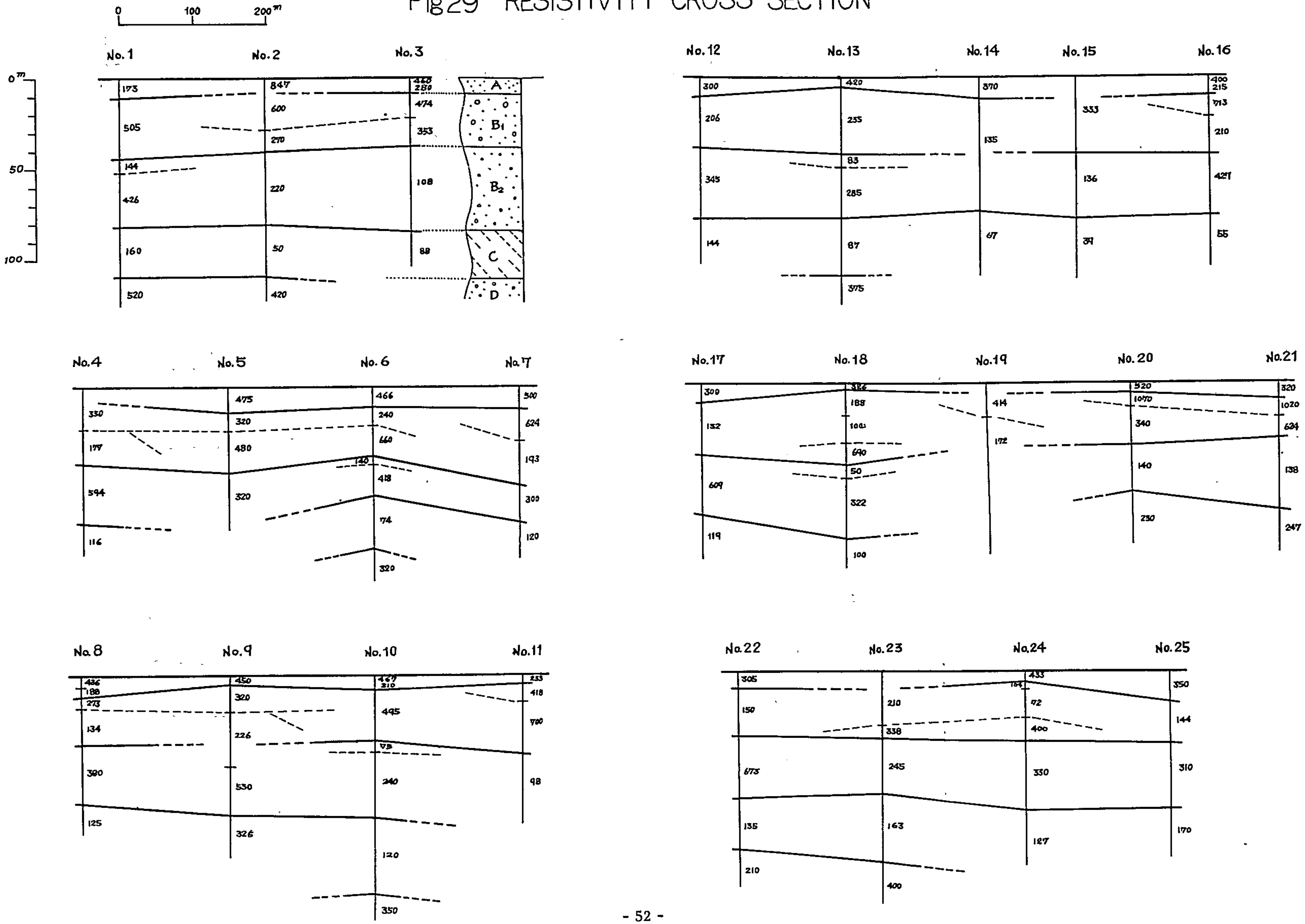
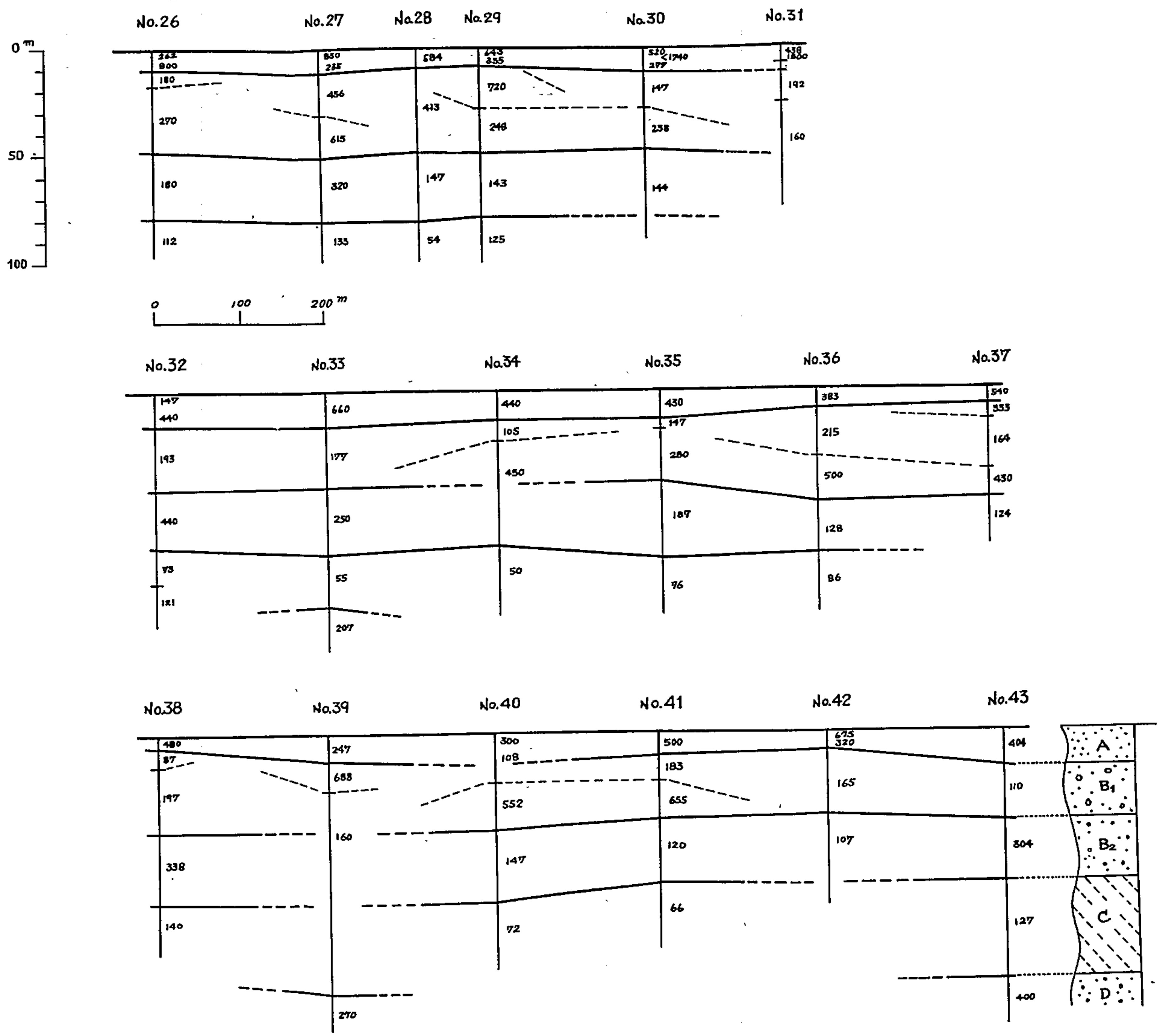


Fig.30 RESISTIVITY CROSS SECTION



Chapter 4 Future of Saigon Water Supply

As discussed earlier, the city of Saigon is growing very rapidly and its water demand is increasing accordingly. Imminency is aquisition of new water source or sources for a water supply expansion project since grave water shortage is easily predictable in near future unless effective measures are urgently produced. Development of largely three water sources will be envisaged for a water supply expansion project or projects as follows:

1) Ground water development in the Hoc Mon district and the district beyond the Saigon river
2) Saigon river
3) Redevelopment of Dong Nai river

Generally speaking, ground water will not be suitable for a very big water supply because great number of wells are required and big amount of discharge may tend to cause troubles such as unretrievable drawdown of ground water level and deterioration of water quality although any assertion could not be made before completion of the survey that is currently under way.

One can find advantages of intaking water from the Saigon river such that hydaulic inefficiency in the existing distribution system will beneficially be improved mainly by a topographic reason.

The Dong Nai river has been feeding raw water to the Thu Duc purification plant. There will be two alternatives for redevelopment of the river. One is to make a new intake station and to convey water to a new water purification plant and the other is to expand the existing facilities of the Thu Duc plant.

Both of the two rivers, however, would not be considered fully reliable for the new water source until hydrological data endorse capability of the rivers on quantity and quality of the streams. The Hydrotechnic Corporation, the consultants who designed the Thu Duc plant, once suggested in her report that the intake point of the Thu Duc water supply system might have been moved far upstream the current position because of tidal salinity contamination of the stream when intake quantity was largely increased. In the same manner, the Saigon river is cautioned for its salinity intrusion by tidal dffect in dry seasons. All such apprehensions are derived from small discharges of the river in dry seasons. "The Hydrologic Yearbook of South Vietnam" indicates that the smallest flows were less than 95 cum per second in the month of December 1969 at the point a little upstream Bienhoa. No data on flows of the Saigon river are contained in the book. However, in consideration of smaller watershed of the Saigon river than the Dong Nai river, the dry season flow of the former seems to be fairly small -- say, 13 cum per second or so. The sole available data on the Saigon river which were collected by the navigation office shows that a dry season flow was about 80 cum per second in average in 23rd March 1972. Considerable reduction must be made for this figure since it is learned in the above-mentioned hydrologic yearbook that the discharges of rivers in this area are largely fluctuating every day even in dry seasons.

More information should be required for planning of a water supply project for Saigon since economically feasible intake quantity would not be so small one--maybe 300,000 cum per day or so---and as a matter of cource a large river flow is necessary for a big quantity of intake. No information is currently available which will assure even a smallest practical intake from the Saigon river and the situation looks same about the Dong Nai river, for a big intake. However, more information can naturally be supplied by SMWO since a big modern water supply plant was relatively recently constructed by intaking water from the Dong Nai river.

No-one will denies bigger advantage of intaking water from rivers for their reliablity and perpetuity than that of ground water. But, now, people of Saigon may be too impatient to wait such long as five, six years for water source survey, planning, design and construction of new facilities. Hence, there will be considerable possibility for ground water to survive this discussion so long as its feasibility is established, because too long time will not be required for survey, design and construction of a ground supply project. Thus the current ground water survey by the Japanese survey team will be of great value.

As for river water sources, there will be other interesting ideas such as submerged dam for blocking of salinity intrusion downstream the proposed intake point at the Saigon river and diverting water from the Dong Nai river to the Saigon river somewhere upstream the proposed intake point in order to increase flow of the Saigon river. But these ideas seem not to be realized in near future. Anyhow, early implementation of river surveys are strongly desired.

After getting a certain water source, a master plan will be made in which long long range water resources development, the mode of intake, efficient application of water treatment processes, the most economical way of transmission and effective improvement and expansion of the distribution system will be described together with other important matters.

APPENDIX

CONTENTS

1. Climate

The climatic condition in Saigon Metropolitan Area is of tropical monsoon type and has characteristics of high temperature and humidity. In summer, the direction of winds is southwest and in winter southeast.

The climate of the so-called, "tropical monsoon type" can be found not only in Saigon Metropolitan Area but also in other districts. These places are affected by typhoons during the period from May through October when 85% of annual rainfall is recorded. Monsoon in winter is blown from January to March and in this period the temperature is high with considerably high humidity and becomes lower compared with that in summer. There are few rains and the rainfall is almost negligible in this season.

1.1 Temperature

Temperature (C) 1929 - 44, 1947 - 68

	Maximum (absolute)	Maximum (average)	Minimum (absolute)	Minimum (average)	Average
Jan.	36.4	31.6	13.8	21.0	257
Feb.	38.7	32.9	16.0	21.9	26.5
Mar.	39.4	34.0	17.4	235	278
Apr.	40.0	34.6	20.0	24.9	28.8
May.	39.0	33.4	31.1	24.7	281
Jun.	37.5	32.1	30.4	24.1	273
July.	34.6	31.4	19.4	23.9	270
Aug.	34.9	31.5	200	24.0	270
Sep.	35.3	31.1	208	238	26.7
Oct.	34.6	310	19.8	236	26.6
Nov.	35.0	30.9	17.0	22.8	26.3
Dec.	36.3	30.7	139	21.6	25.7
	40.0		13.8		27.0

1.2 Precipitation (Saigon Area)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1906	40mm	0	0	190	280	300	230	340	410	260	80	30	2160
1907	0	10	5	5	250	240	220	270	250	255	130	150	1775
1908	40	10	15	70	300	420	390	500	340	345	170	120	2720
1909	30	10	20	25	190	260	590	170	290	70	50	170	1975
1910	10	0	30	110	250	420	280	310	280	500	50	50	2290
1911	15	5	0	180	210	280	220	180	300	230	40	30	1690
1912	40	0	0	0	60	210	380	320	350	200	50	70	1680
1913	20	10	0	5	260	210	300	280	250	200	40	110	1685
1914	25	10	5	5	150	320	360	200	240	80	170	40	1605
1915	5	5	10	20	230	460	110	130	250	370	20	120	1730
1916	5	5	35	5	170	280	300	310	460	410	60	50	2090
1917	110	5	5	5	250	220	280	310	440	600	280	25	2530
1918	10	5	5	30	160	330	250	200	450	160	30	30	1660
1919	5	5	10	20	170	470	100	190	410	320	140	60	1900
1920	10	10	5	10	210	360	320	340	240	220	55	120	1900
1921	10	0	45	20	220	220	310	135	465	450	245	15	2135
1922	15	0	130	140	80	290	380	290	470	260	85	25	2165
1923	15	0	5	30	360	205	290	315	365	225	170	15	1995
1924	0	0	15	40	90	520	275	170	250	330	110	70	1870

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1925	10	0	60	105	170	415	565	300	295	300	150	15	2385
1926	0	0	0	0	115	325	385	390	290	340	270	65	2180
1927	0	0	5	25	220	350	320	230	340	175	145	5	1815
1928	0	0	5	65	215	390	260	340	505	285	5	20	2090
1929	25	5	0	50	230	325	350	465	325	200	150	45	2170
1930	5	5	0	80	375	250	320	210	205	190	180	70	1890
1931	30	0	0	5	270	180	340	160	335	415	80	25	1840
1932	0	5	10	20	335	420	310	225	280	280	180	30	2095
1933	30	0	0	20	50	405	245	300	295	290	110	60	1805
1934	0	5	15	140	385	275	215	220	375	115	80	25	1850
1935	5	0	0	50	205	280	340	120	370	185	105	30	1690
1936	15	0	10	25	70	255	330	230	255	255	60	50	1555
1937	30	10	0	30	165	335	420	370	275	150	150	20	1955
1938	5	10	0	15	310	405	430	240	395	360	125	25	2320
1939	5	0	15	105	460	325	235	330	350	120	205	5	2155
1940	0	0	0	15	220	415	230	255	295	175	40	40	1685
1941	0	5	5	15	120	150	220	325	330	300	170	60	1700
1942	90	5	10	145	205	260	280	263.3	682.5	364.8	130.0	15.1	2453.5

Unknown from 1943 to 1949

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1950	38.5	42.7	4.3	65.0	248.8	304.0	284.1	224.7	487.4	212.0	89.2	33.2	2033.9
1951	2.4	18.5	3.5	77.6	311.7	454.5	288.4	293.0	409.9	351.4	255.2	13.8	2479.9
1952	0.3	0.2	4.4	31.8	344.5	506.2	229.8	276.6	204.4	374.5	105.5	58.6	2136.8
1953	4.5	11.7	11.7	104.6	420.0	269.7	216.8	217.6	384.7	214.8	245.2	132.9	2234.2
1954	26.7	0	38.9	121.4	277.6	297.0	387.7	504.7	451.7	262.1	54.4	6.1	2428.3
1955	0.5	0.2	0	35.0	207.9	345.2	188.3	225.6	232.3	364.6	237.9	25.6	1863.1
1956	nil	nil	nil	94.8	198.0	101.2	296.0	241.1	451.7	204.8	90.2	83.0	1760.8
1957	1.0	nil	37.7	18.9	47.6	293.3	230.5	172.5	566.2	256.9	36.8	54.1	1715.3
1958	nil	5.6	7.6	16.2	159.2	246.9	286.4	283.6	276.1	362.1	13.3	17.4	1674.4
1959	-do-	nil	0.4	119.5	145.0	209.2	338.6	501.3	200.0	318.4	138.8	18.0	1989.2
1960	11.5	14.4	nil	70.7	290.4	478.4	182.3	236.9	241.7	189.5	74.2	32.3	1822.3
1961	2.6	0.4	6.6	58.1	172.8	241.4	289.7	292.6	439.3	184.5	82.4	40.2	1815.6
1962	27.7	nil	28.8	36.8	260.3	257.5	372.2	246.5	256.0	204.6	42.4	28.5	1761.3
1963	25.5	-do-	1.6	nil	320.1	449.1	534.4	315.7	470.0	232.6	44.4	26.7	2420.1
1964	nil	-do-	nil	-do-	137.1	271.0	298.5	309.9	156.1	194.3	197.4	26.8	1591.1
1965	-do-	-do-	-do-	27.9	167.4	214.1	221.9	330.3	335.3	137.0	154.7	52.0	1640.6
1966	19.4	Traces	32.7	47.6	510.2	269.4	251.3	209.9	331.2	308.7	204.2	96.7	2281.3
1967	27.7	nil	nil	4.7	244.3	140.8	351.7	150.4					

106,696.7mm/55 Years

Average 1939.8mm/Year

1.3 Humidity

Humidity in Saigon Metropolitan Area is considerably high throughout the year and is 77% on an average. The lowest humidity in the past has been recorded at 20% (March 1969).

Relative humidity (average daily)

	(%)
Jan.	74.0
Feb.	71.2
Mar.	71.2
Apr.	74.0
May.	81.1
Jun.	83.9
Jul.	84.4
Aug.	84.7
Sep.	86.3
Oct.	85.4
Nov.	82.0
Dec.	78.0
ANNUAL AVERAGE	79.9

NOTE (From recods in '23 through '25, '27, '29 and '44 as well as '47 to '68)

2. WATER DEMAND

2.1 Population and Density of Saigon Metropolitan Area

	1961 Population Density	1964 Population Density	1968 Population Density	1970 Population Density
Saigon	1,238,207 p 178 p/ha	1,332,854 p 191 p/ha	1,752,283 p 252 p/ha	2,075,000 p 300 p/ha
district 1		80,904 190	97,365 229	115,500 275
2		137,264 394	156,614 449	185,700 531
3		191,400 393	273,620 562	322,200 658
4		136,837 329	172,701 416	204,600 499
5		196,867 456	235,316 545	278,700 648
6		128,395 173	183,977 248	218,200 303
7		32,236 28	43,246 38	51,200 43
8		108,378 137	177,564 225	210,600 263
9		9,020 8	19,297 18	22,800 21
10		183,814 298	211,934 344	251,400 426
11		136,659 280	180,649 370	214,100 446
Gia Dinh	500,000 30		791,002 48	1,000,000 60

THESE DATA WERE OBTAINED FROM THE BOOKS BELOW.

- "SAIGON SEWERAGE FFASIBILITY STUDY"
- "DIALECTICS OF URBAN PROPOSALS FOR THE SAIGON METROPOLITAN AREA"

2.2 Population of Saigon Metropolitan Area

FROM MINISTRY OF INTERIOR AND NATIONAL INSTITUTE OF STATISTICS

	1968 Population Density persons/hectare	Saturated Density persons/hectare
(Saigon)		
District 1	229	199
" 2	449	430
" 3	562	693
" 4	416	435
" 5	545	660
" 6	248	281
" 7	38	42
" 8	225	307
" 9	18	60
" 10	344	1,158
" 11	370	529
Saigon Prefecture	252	370
(Gia Dinh)		
Quan Go Vap	82	392
Quan Tan Binh	69	458
Quan Binh Chanh	5	91
Quan Nha Be	11	161
Quan Hoc Mon	14	300
Gia Dinh	48	314
(Total)	108	330

2.3 Housing Units Families and Population in Saigon by Type of House

Type of Housing	Descrip-tion	Total Number	No. of Housing Unit (%)	No. of Families (%)	No. of People	No. of People Per Housing Unit	Average No. of People Per Family	No. of Families Per Housing Unit
Multi-Story Villa	Houses	840	0.36					
	Family	840		0.33		8.36	8.36	1.0
	People	7,020			0.40			
One-Story Villa		1,080	0.46					
		1,080		0.43		8.50	8.50	1.0
		9,180			0.53			
Apartment Building		480	0.12					
		480		0.19		4.75	4.75	1.0
		2,280			0.13			
Multi-Story House adjoining		38,700	16.63					
		43.500		17.12		8.06	7.17	1.12
		312,060			17.97			
One Story House adjoining		117,780	50.62					
		129,180		51.00		7.62	6.95	1.1
		897,780			51.69			
Single Family Housing separate		45,120	19.39					
		48,300		19.07		7.17	6.70	1.07
		323,520			18.63			
Thatch House		21,120	9.08					
		22,140		8.74		6.57	6.27	1.05
		138,720			7.99			
Boat House		3,060	1.32					
		3,060		1.21		5.35	5.35	1.00
		16,380			0.34			
Other Category		4,500	1.93					
		4,740		1.87		6.65	6.32	1.06
		29,940			1.72			
Total	Houses	232,680	100	100	100	7.47	6.86	1.09
	Family	253,320						
	People	1,736,880						

Extract from Table LXIV, 1967 Demographic Study
by National Institute of Statistics

2.4 QUANTITY OF WATER SUPPLIED

BY S. M. W. O.

YEAR	SUPPLIED WATER			CONSUMPTION
	WELL WATER	SURFACE WATER	TOTAL	
	m^3/year	m^3/year	m^3/year	m^3/year
1950	35,964,000	0	35,964,000	
51	38,374,000	0	38,374,000	
52	43,705,217	0	43,705,217	
53	52,585,060	0	52,585,060	
54	58,005,456	0	58,005,456	
55	55,633,660	0	55,633,660	
56	56,997,075	0	56,997,075	
57	55,823,504	0	55,823,504	
58	56,861,873	0	56,861,873	
59	58,434,837	0	58,434,837	
1960	60,984,449	0	60,984,449	
61	58,695,685	0	58,695,685	
62	58,083,161	0	58,083,161	
63	58,135,955	0	58,135,955	
64	54,576,315	0	54,576,315	
65	55,491,064	0	55,491,064	
66	52,304,755	?	?	
67	9,865,613	63,130,442	72,996,055	59,251,236
68	1,075,692	80,807,581	81,883,273	63,769,595
69	6,329,095	99,160,162	105,489,257	73,316,767
70 *	150,376	105,111,710	105,262,085	70,835,030

* FOR 10 MONTHS

2.5 CONSUMPTION ESTIMATE

	ITEM	QUANTITY (m^3/d) JANUARY 11-31, 1970
a.	TOTAL WATER PRODUCTION TO SAIGON-GIA DINH	345,000
b.	UNCOUNTABLE (15% of a)	51,750
c.	PUBLIC WATER (12% of a)	41,400
d.	TOTAL UNCOUNTABLE AND PUBLIC WATER (b + c)	93,150
e.	WATER CONSUMED BY CONNECTED POPULATION (a - d)	251,850
f.	WATER CONSUMPTION (e ÷ 1,730,000)	0.145
		= 145 l/capita/day

2.6 STUDY AREA POPULATION SERVED BY CITY WATER

AREA	POPULATION *				
	IN SERVICE AREA *	TRANSIENT	TOTAL	USE FACTOR	TOTAL SERVED
SAIGON	1,720,000	60,500	1,780,000	80 %	1,420,000
GIA-DINH	560,000	60,000	620,000	50 %	310,000
TOTAL					1,730,000

* JUNE 30, 1968 POPULATION USED. NEAREST 10,000 ONLY

EXTRACTS FROM "SAIGON SEWERAGE FEASIBILITY STUDY"

2.7 WATER CONSUMPTION IN EACH DISTRICT

DISTRICT \ YEAR	1969	1970
SAIGON	62,446,000 m^3	69,193,000 m^3
GIA-DINH	7,596,000	11,921,000
OUTSIDE	2,808,000	4,659,000
TOTAL	72,850,000	85,143,000

NOTE: OUTSIDE MEANS A PART OF BIEN-HOA.

2.8 UNACCOUNTED-FOR WATER RATIO

YEAR	THU DUC WATER PRODUCTION TO DISTRIBUTION SYSTEM MILLION CU m (*)	METERED WATER USE MILLION CU m	UNACCOUNTED-FOR WATER PRODUCTION PERCENT
1966	61.4	37.1	40
1967	72.8	51.0	30
1968	85.0	58.0	32
1969	105.9	72.9	31
1970	126.7	85.1 *	33

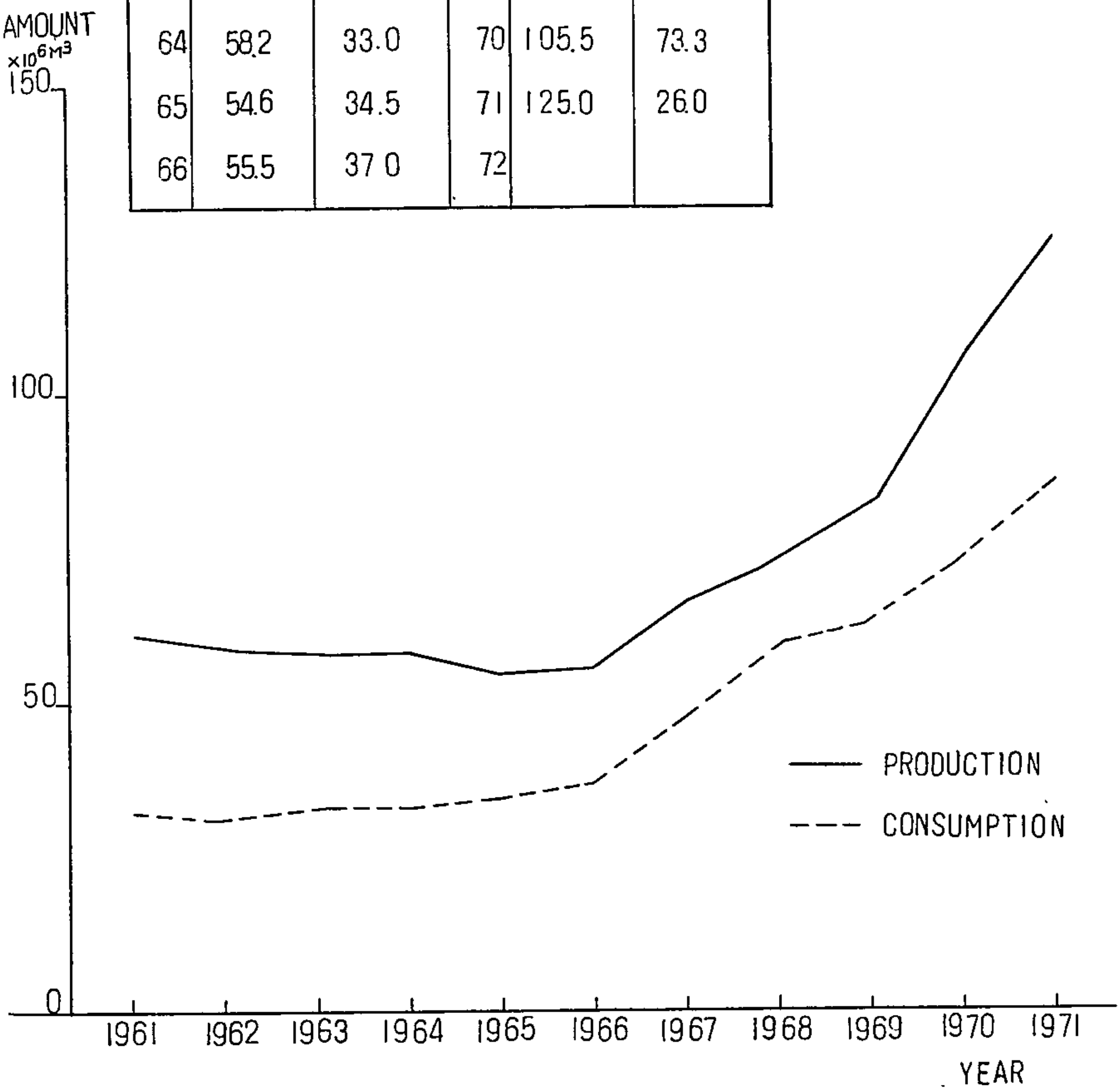
(*) INCLUDES SERVICE TO BIEN HOA INDUSTRIAL COMPLEX

* INCLUDES BILLED ALLOWANCE FOR USE OF GROUNDWATER BY A LARGE INDUSTRIAL CUSTOMER

EXTRACT FROM "SAIGON WATER DISTRIBUTION PROJECT" 1972

PRODUCTION AND CONSUMPTION (METERED)

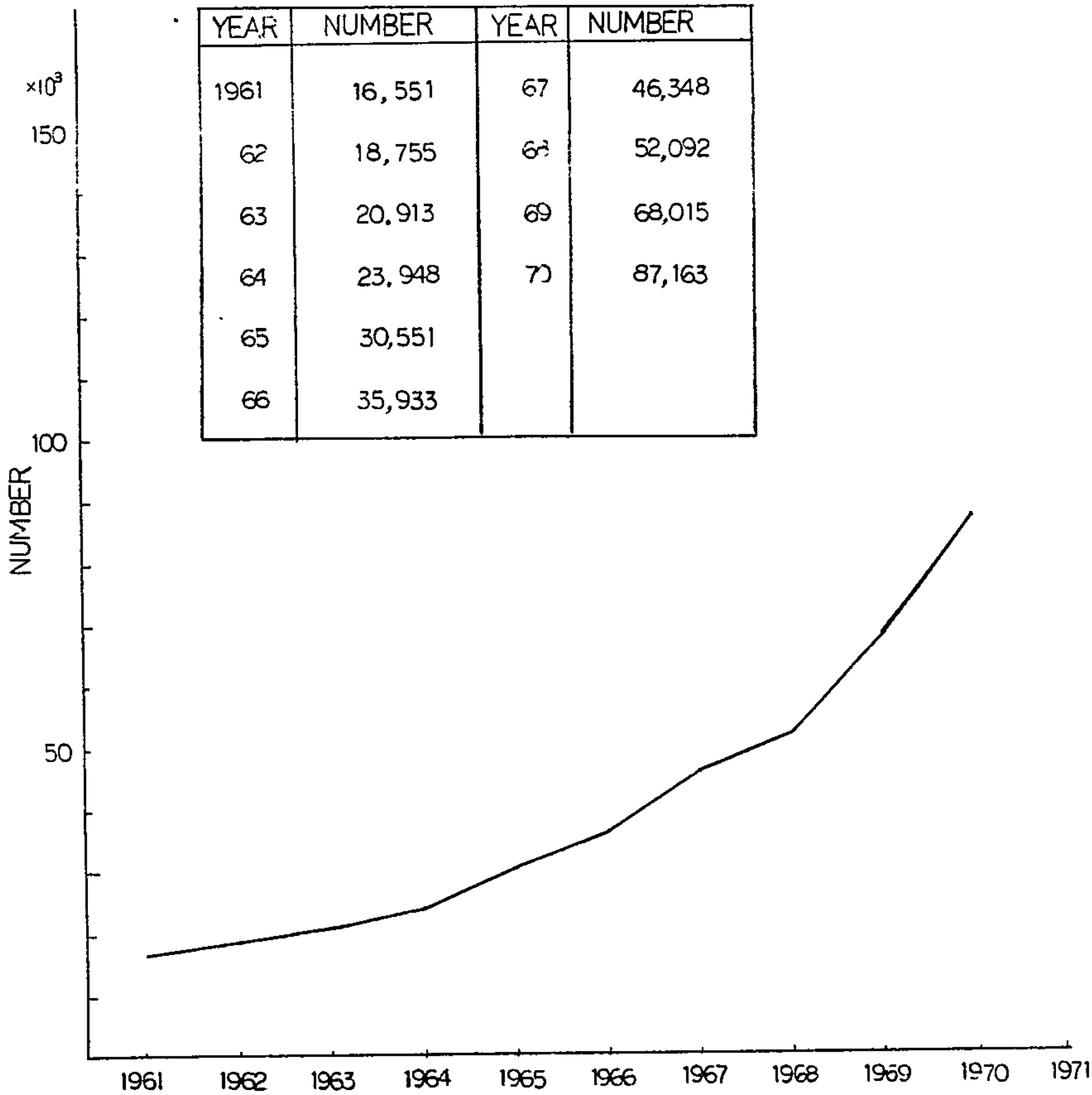
YEAR	PRODUCTION $\times 10^6 M^3$	CONSUMPTION $\times 10^6 M^3$	YEAR	PRODUCTION $\times 10^6 M^3$	CONSUMPTION $\times 10^6 M^3$
1961	61.0	32.0	67	66 1	47.8
63	58.7	31.0	68	73.0	59.3
63	58.1	33.0	69	81.9	63.3
64	58.2	33.0	70	105.5	73.3
65	54.6	34.5	71	125.0	26.0
66	55.5	37 0	72		



FROM SMWO

FIG. NUMBER OF WATER METERS

YEAR	NUMBER	YEAR	NUMBER
1961	16, 551	67	46,348
62	18, 755	68	52,092
63	20. 913	69	68,015
64	23. 948	70	87, 163
65	30,551		
66	35,933		



EXTRACT FROM "NGUON LOI THIEN-NHIEN & CO-SO HIEN-HUU" BY SMWO

3. Existing Facilities

3.1 Outline of Thu Duc Water Purification Plant

Intake Pumping Station

Location	Located approximately 25 km north-east from the downtown of Saigon Intake from the Dong Nai River
Intake pump	6 units
Capacity	450,000 m^3/day

Raw Water Transmission Main

ø 72"	PS-Concrete Pipes 11 km
Capacity	505,000 m^3/day

Water Purification Plant

Capacity	480,000 m^3/day
Rectangular Sedimentation basins	5
Rapid Sand Filters	
(Filtration Rate of 150 m/day)	20
Water Purification Plant	2 × 40,000 m^3 = 80,000 m^3 2 × 95,000 m^3 = 190,000 m^3 Total .... 270,000 m^3
Transmission and Distribution Pumps	Of 5 units, 2 units are of speed control type
Capacity	680,000 m^3/day

Distribution System

Trunk Main	ø 76" PS Concrete Pipe 12 km

Distribution Tower	Major distribution towers with a total capacity of 49, 000 m^3 are located at 8 points
Distribution Main	cf. FIG. 4 and FIG. 5

3.2 Outline of Waterworks in Saigon

Metropolitan Area

YEAR	MAIN LINE	SERVICE CONNECTIONS	TOTAL DISTRIBUTION SYSTEM
1961	285,466 m	130,000 m	415,466 m
1962	292,285	145,546	437,831
1963	306,764	162,063	468,827
1964	348,043	176,056	524,099
1965	376,911	193,578	570,489
1966	403,308	213,073	616,381
1967	480,643	239,200	719,843
1968	574,815	275,588	850,403
1969	632,702	296,829	929,531
1970	727,241	352,533	1,079,774
1971	838,322	431,226	1,269,548
1972	898,879	514,315	1,413,194

TABLE LENGTH OF OLD PIPLE LINES

PERIOD / DISTRICT / DIAMETER	PERIOD OF CONSTRUCTION			
	BEFORE 1920	1920 ~ 1940	1920 ~ 1929	1930 ~ 1939
	SAIGON	CHOLON	SAIGON	SAIGON
mm	m			
ϕ 80	12,806	6,565	8,820	570
ϕ 100	11,360	19,781	4,760	1,230
ϕ 150	1,350	8,850	3,410	4,850
ϕ 200		5,510	2,120	710
ϕ 250	8,800	3,260	8,770	4,140
ϕ 300	750	3,600	4,170	4,450
ϕ 350	450	1,920		3,310
ϕ 400	100	1,030		
ϕ 450				
ϕ 500				
ϕ 600	170	290		
TOTAL	35,786 m	50,841 m	32,050 m	19,260 m

TABLE EXISTING PIPES IN CITY OF SAIGON

SUMMARY OF PIPE CONDITION TESTS

Size (mm)	Age	Sector	Location (NAMES OF STREET)	"C" value
450	1907	Saigon	Pasteur, Hien Vuong + Chien Si	64 ~ 68
250	1938	Saigon	L. V. Duet, P. H. Thai, Bui THi Xuan + Trau Hung Dao	73
300	1931	Saigon	Vo Di Nguy at Ben Nghe river crossing	73
450	1957	Cholon	Nguyen Van Thoai, Tran Quoc Toan + Cu Xa so 3	68
400	1925	Saigon	Tran Quy Cap, Chien Sie + Le Vau Duet	52 ~ 56
500	1925	Saigon	Pasteur, Hien Vuong + Chien Si	71
250	1957	Cholon	Nguyen Bieu, Nguen Trai, Cong Hoa, Trau Hung Dao + Hong thap Ju	36
500	1959	Cholon	Cong Hoa, Ly Thai To, Phan Thanh Gian + Tran Hung Dao	101
450	1910	Cholon	Phu Tho Race Track	70 ~ 71
300	1965	Cholon	Le Dai Hanh north of Binh Thoi	78
400	1925	Cholon	Hung Vuong, Trieu Da + Nguyen Tri Phuong	
400	1965	Gia Dinh	Hung Vuong south of Bien Hoa Highway	81
300	1928	Saigon	Ben Van Don at Cau Chong River crossing	56
300	1960	Cholon	Nguyen Bieu, Tran Hung Dao + Ham Tu	?
350	1935	Saigon	Vo Tanh, Nguyen Cu Trinh + Cong Hoa	53
350	1935	Saigon	L. V. Duet, Hoa Hung + Yen Do	74
150	1924	Cholon	Le Quang Liem at Ben Nghe River crossing	65
250	1958	Cholon	Thanh Thai, Tran Binh Trong + Cong Hoa	?
200	1962	Cholon	Nguyen Hoang, Petrus Ky + Cong Hoa	68
150	1928	Saigon	Truong Minh Gian at Thi Nghe River crossing	68

Size (mm)	Age	Sector	Location	"C" value
250	1956	Gia Dinh	Phan Thanh Gian east of Vo Di Nguy	89
300	1969	Gia Dinh	Nguyen Van Hoc at Bang Ky Bridge	125
200	1956	Cholon	Binh Thoi Foot Bridge near Nguyen Chi Nghia	86
350	1924	Cholon	Luc Tinh at Phu Lam Bridge	65
350	1935	Saigon	Vo Tanh, Nguyen Cu Trinh + Cong Hoa	53
350	1935	Saigon	Le Van Duyet, Hoa Hung + Yen Do	74
150	1924	Cholon	Le Quang Liem at Ben Nghe River crossing	65
1050	1965	Saigon	Tran Quoc Toan	128
200	1962	Cholon	Nguyen Hoang, Petrus Ky + Cong Hoa	68
150	1928	Saigon	Truong Minh Giang at Thi Nghe River crossing	68
250	1956	Cholon	Minh Plung at Cay Go Bridge	45
400	1965	Gia Dinh	Phan Thanh Gian east of Vo Di Nguy	89
300	1969	Gia Dinh	Nguyen Van Hoc at Bang Ky Bridge	125
200	1956	Cholon	Binh Thoi Foot Bridge near Nguyen Chi Nghia	86
350	1924	Cholon	Luc Tinh at Phu Lam Bridge	65
750	1965	Cholon	Tran Quoc Toan at Phu Tho	130

4. Discharge and Water Level of Saigon River

As regards discharge, it has been impossible to obtain precise and reliable data which will satisfy the requirements of the project. Discharge may be estimated by means of discharge diagrams and data collected during the period from March 21 through 23, 1972.

Severe tidal effect must influence the accuracy of flow measurement since the end of March is still in the dry season in this area and Binh Duong is situated within the tidal area.

No discharge measurement methods are made clarified in these data. In other words, mean discharge in the section is not made known.

Even the Saigon River is regarded as one of the tidal areas. As it is feared that density currents composed of fresh water and salty water is produced, some difficulties are encountered in making the measurement of current velocity.

Mean discharge from PM 1, March 22 to PM 2, March 23 is 80.9 m^3/sec. Total discharge from 12:45 hours of March 22 to 13:45 hours of March 23 is 7281,000 m^3.

Water Level at Binh Duong for 7 years from '66 to '72 is as follows;

high-water level	1.23 m
low-water level	- 2.15 m

Under the condition that mean sea level at Mui Nai is to be 0.0 m

Refer to the data for details

8-10 m^3/sec is listed as max. discharge in the dry season in a report entitled "Report on Water Supply for the Saigon-Cholon Area" which was issued in 1960. As far as concrete examples of upward flow are concerned, a series of surveys which were conducted for 51 hours from eight o'clock in the morning of April 14, 1970 indicated that upward flow was 25 m^3/sec. according to SMWO.

TABLE SAIGON RIVER WATER LEVEL AT BINH DUONG

NOTES
UNIT: METER
0.0 m IS MEAN SEA LEVEL AT NUI NAI

Year / Month	1966		1967		1968		1969		1970		1971		1972	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	-	-	1.22	-1.54	1.17	-1.35	1.17	-1.71	1.22	-0.94	1.18	-1.13	1.11	-1.93
2	-	-	1.17	-1.66	1.07	-1.29	1.13	-1.68	1.21	-1.01	1.10	-1.36	1.02	-1.72
3	-	-	1.15	-1.82	1.01	-1.79	1.10	-1.70	-	-	1.14	-1.68		
4	1.13	-1.93	1.08	-1.82	1.08	-1.60	1.15	-1.69	-	-	1.04	-1.77		
5	1.06	-1.84	0.96	-1.82	1.02	-1.89	1.05	-1.71	-	-	1.04	-1.77		
6	1.03	-2.03	0.94	-1.78	0.96	-1.86	1.02	-1.84	-	-	0.90	-2.02		
7	1.04	-2.10	1.12	-1.88	0.90	-2.03	1.02	-1.82	1.05	-1.93	0.92	-2.09		
8	1.12	-1.97	1.07	-2.15	1.01	-2.06	0.95	-1.94	0.88	-1.80	1.01	-2.03		
9	1.23	-1.92	1.10	-1.95	1.15	-0.70	-	-	1.07	-1.68	1.12	-1.77		
10	1.23	-1.40	1.17	-1.35	1.20	-1.06	1.14	-1.51	1.16	-1.00	1.19	-1.40		
11	1.21	-1.19	1.13	-1.19	1.06	-1.69	1.18	-1.10	1.15	-1.13	1.16	-1.39		
12	1.19	-1.50	1.17	-1.40	1.15	-1.45	1.18	-1.02	1.21	-1.26	1.19	-1.18		
Max.	1.23		1.22		1.20		1.18		1.22		1.19			
Min.		-2.10		-2.15		-2.06		-1.94		-1.93		-2.09		

TABLE WATER LEVEL AND FLOW RATE

FROM 1300 MARCH 22 TO 1400 MARCH 23, 1972

DATE	TIME	WATER LEVEL cm	FLOW RATE m^3/sec	DATE	TIME	WATER LEVEL cm	FLOW RATE m^3/sec
MARCH 22	1300	123	-175	MARCH 23	200	204	+ 940
	30	246	-160		30	187	+1020
	1400	244	- 30		300	170	+1060
	30	242	0		30	154	+1070
	1500	238	0		400	139	+1070
	30	234	0		30	126	+1060
	1600	231	0		500	108	+1050
	30	229	0		30	80	+1020
	1700	229	0		600	60	+ 980
	30	229	0		30	45	+ 910
	1800	231	0		700	34	+ 800
	30	234	0		30	32	+ 580
	1900	238	0		800	47	+ 200
	30	243	0		30	77	+ 220
	2000	248	0		900	105	- 530
	30	253	- 30		30	129	- 660
	2100	256	-210		1000	151	- 710
	30	259	-310		30	169	- 750
	2200	261	-350		1100	185	- 770
	30	263	-320		30	200	- 770
	2300	263	-250		1200	212	- 750
MARCH 23	30	259	-130		30	223	- 710
	0000	252	+ 30		1300	230	- 660
	30	243	+280		30	238	- 590
	100	231	+540		1400	242	- 520
	30	218	+780				

\+ MEANS DOWNSTREAM

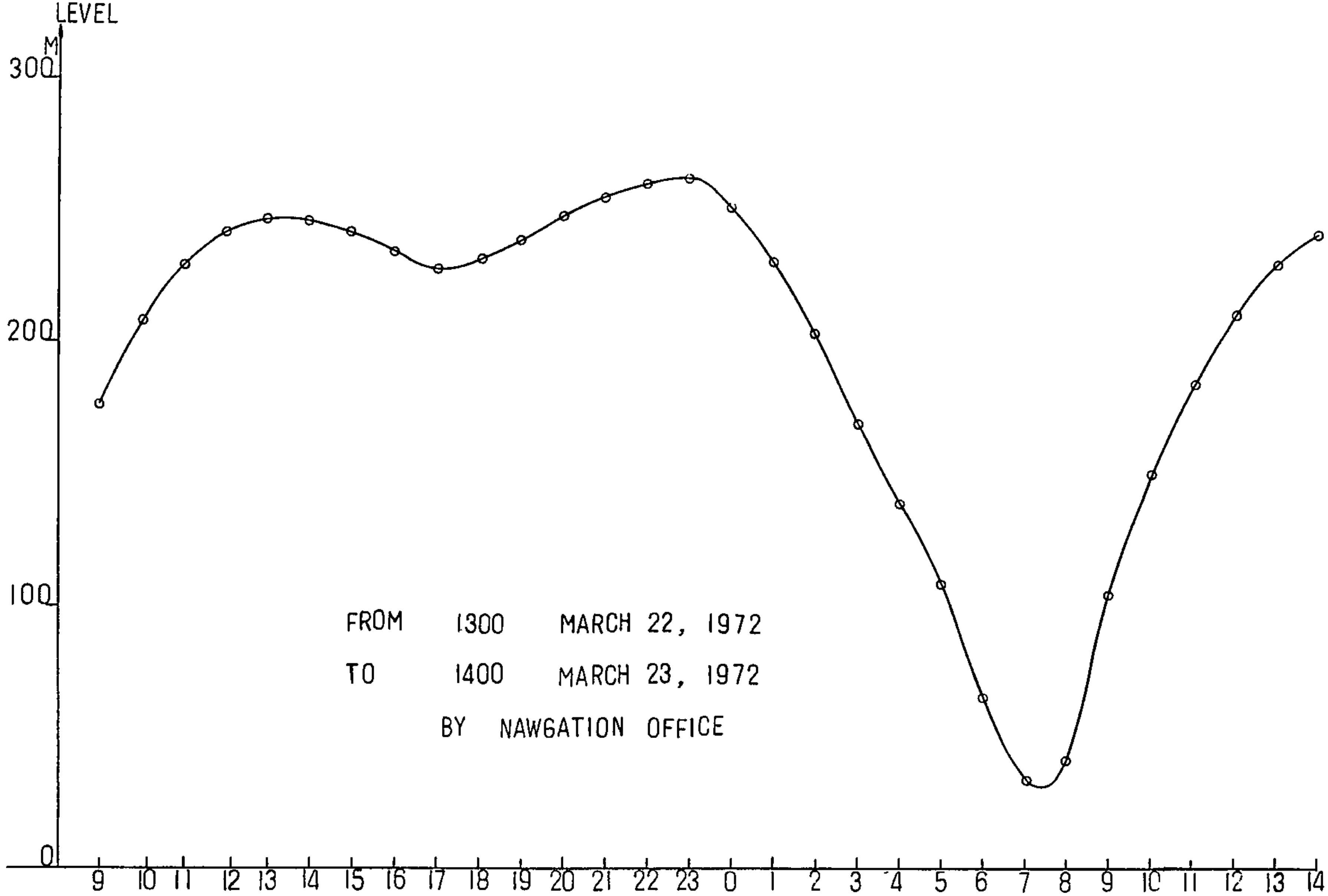
\- MEANS UPSTREAM

MEAN WATER LEVEL 1.9246 m

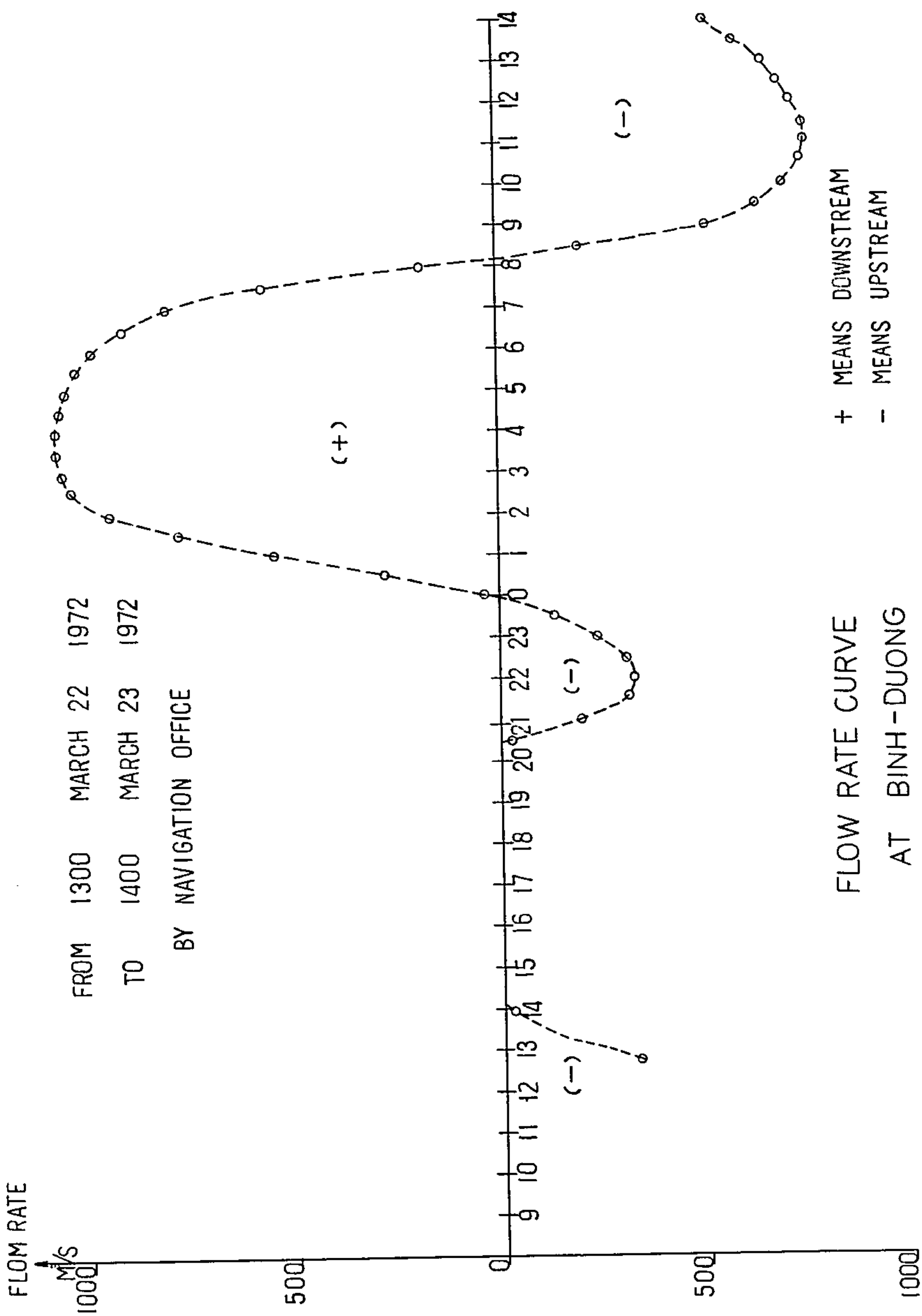
MEAN FLOW + 80.90 m^3/sec

MEASURED AT BINH-DU'O'NG

REPORTED BY NAVIGATION OFFICE



WATER LEVEL CURVE AT BINH-DUONG


FLOW RATE CURVE
AT BINH-DUONG
FROM 1300 MARCH 22 1972
TO 1400 MARCH 23 1972
BY NAVIGATION OFFICE
+ MEANS DOWNSTREAM
− MEANS UPSTREAM
FLOW RATE
M³/S
1000
500
0
500
1000
(+)
(−)
(−)
(−)
9
10
11
12
13
14
15
16
17
18
19
20
21
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1
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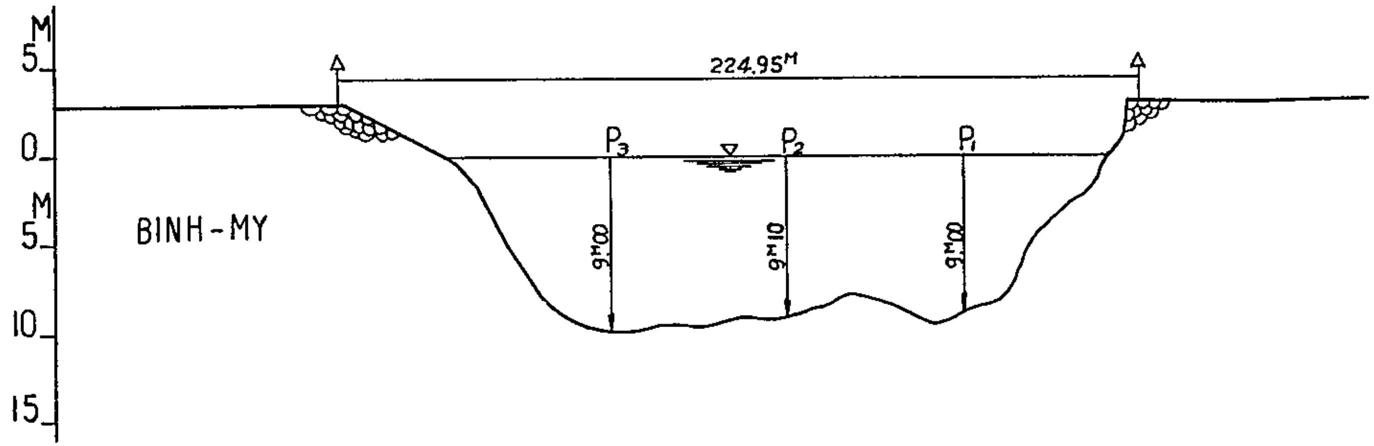
14



CROSS SECTION AT BINH-DUONG

BY NAVIGATION OFFICE

SCALE
VERTICAL : 1/400
HORIZONTAL : 1/1000

Intake from the Saigon River involves the risk of an admixture of salinity. It is essential that further detailed data be obtained for the purpose of taking in good-qualitied raw water from the said river.

Under the present circumstances, there are scarcely reliable data and findings which will satisfy the requirements of investigations in order to judge whether or not it will be possible to sufficiently take such water in from the river.

5. Water Quality of Saigon River

August 8, '71 to January 22, 1972

Color (Min.) 20 - (Max.) 120 unit

The value is high in some part of rainy season (August and September) and low in the dry season.

Turbidity: (Min.) 6 - (Max.) 35 ppm

Cloride: Salinity concentration is always bigger at the time of high tide due to upstream salinity enchroachment than that at the time of low tide.

(Min.) 1.7 - 6.6 ppm

Max. = 24.0 ppm

* It is assumed that there will be many variations in the salinity concentration mentioned above depending upon measurement places and measurement water level. Consequently, it is very doubtful to employ such values as reference data.

August 8 through August 26, 1971

Alkalinity	(Min.) 8 - (Max.) 15 ppm
Solidity	(Min.) 8 - (Max.) 12 ppm
Iron Content	0.1 ppm
PH	6.2 - 7.1

Refer to Table for details

Data are also reticent in connection with "salinity".

According to SMWO, salinity was detected at Thu Dau Mot, 23 km north of Saigon.

October 1959 to June 1960	500 mg/	Nacl
April to May 1960	750 mg/	Nacl

These values were obtained as a result of measurements conducted by the Ministry of Public Works.

(The figures listed below are also made available by the aforementioned organization.)

Following is water quality in the Saigon River on July 27, 1971. (Sampling was performed in the place close to Phu Cuong Bridge.)

PH	6.6
Alkalinity (total)	12.0 ppm as $CaCO_3$
Hardness (total)	8.0 ppm as $CaCO_3$
Chloride	3.5 ppm
Turbidity	22.0 PPM SiO_2
Iron	0.1 ppm
Dissolved oxygen	6.8 ppm
Color	100 ppm
Oxygen consumed	2.24 ppm
PH Stable	9.1
Alkalinity *	30.0 ppm

* AFTER DOSAGE OF LIME

TABLE WATER ANALYSIS OF SAIGON RIVER I

YEAR	MONTH	DAY	TIDE	CONDUCTIVITY	ALKALINITY P	ALKALINITY TOTAL	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-	HARDNESS TOTAL	HARDNESS Ca^{2+}	HARDNESS Mg^{2+}	Fe	TURBIDITY	pH	NOTES
				$\times 10^{-6}$ Ʊ/cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	SiO_2 ppm		
71	FEB	22	L	20	0	8	6	8	0	8	6	4	2		50	6.2	
			H S	20	0	6	6	8	0	6	6	4	2		54	6.25	
			H B	20	0	8	6	8			6	4	2		70	6.05	
		23	L	20	0	6	7	7	0	6	6	4	2		58	6.42	
			H S	20	0	4	6	9	0	4	8	4	4		72	6.15	
			H B	20	0	4	5	8	0	4	8	4	4		77	6.2	
		24	L	20	0	6	6	8	0	6	6	4	2		72	6.13	
			H S	20	0	4	6	9	0	4	6	4	2		65	6.3	
			H B	20	0	4	6	9	0	4	6	4	2		70	6.35	
		25	L	20	0	6	7	8	0	6	6	4	2		60	6.25	
			H S	19	0	8	6	8	0	8	4	2	2		44	6.35	
			H B	19	0	6	7	10	0	6	4	2	2		66	6.2	
		27	L	21	0	4	8	7.5	0	4	6	2	4		50	6.12	
			H S	21	0	6	8	12	0	6	5	2	3		60	6.18	
			H B	20	0	4	8	8	0	4	6	2	4		50	6.22	
		28	L	20	0	6	4	11	0	6	6	2	4		70	5.98	
			H S	21	0	6	9	11	0	6	7	2	5		50	6	
			H B	20	0	4	8	8	0	4	6	4	2		70		
	MAR.	1	L	21	0	5	8	9	0	5	6	4	2		60	6.08	
			H S	20	0	4	6	9	0	4	8	4	4		55	6.05	
			H B	20	0	6	6	11	0	6	6	2	4		65	6.18	
		2	H S	19	0	6	5	8	0	6	8	4	4		50	6.08	
			H B	19	0	8	7	8	0	8	6	3	3		55	6.1	
		4	L	18	0	6	5	6	0	6	5	3	2		43	6.3	
			H S	18	0	6	5	4	0	6	5	3	2		42	6.24	
			H B	18	0	5	5	7	0	5	5	2	3		45	6.21	
		5	L	17	0	5	5	7	0	5	5	3	2		47	6.22	
			H S	22	0	5	6	8	0	5	6	3	3		89	6.2	
			H B	22	0	5	5	9	0	5	6	3	3		93	6.22	
		6	L	18	0	5	5	4	0	5	5	3	2	0.65	61	6.25	
			H S	21	0	4	5	7.5	0	4	5	2	3	0.77	72	6.18	
			H B	21	0	4	6	9	0	4	5	3	2	0.96	77	6.1	
		7	L	20	0	5	5	7	0	5	7	3	4	0.76	87	6.00	
			H S	20	0	5	5	8	0	5	5	2	3	0.71	75	6.18	
			H B	20	0	4	5	4	0	4	7	3	4	0.72	78	6.16	

TABLE WATER ANALYSIS OF SAIGON RIVER II

YEAR	MONTH	DAY	TIDE	CONDUCTIVITY	ALKALINTY P	ALKALINTY TOTAL	Cℓ	SO_4^{2-}	CO_3^{2-}	HCO_3^-	HARDNESS TOTAL	HARDNESS Ca^{2+}	HARDNESS Mg^{2+}	Fe	TURBIDITY	pH	NOTES
				$\times 10^{-6}$ ℧/cm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	SiO_2 ppm		
71	MAR.	9	L	22	0	5	7	4	0	5	6	4	2		61	6.27	
			H S	22	0	4	6	7	0	4	6	4	2		70	6.13	
			H B	22	0	5	6	6	0	5	6	3	3		72	6.13	
		10	L	20	0	5	6	3	0	5	6	3	3		43	6.25	
			H S	22	0	5	7	4	0	5	6	4	2		48	6.03	
			H B	20	0	4	10	8	0	4	6	3	3	0.78	48	6.2	
		11	L	20	0	4	7	7	0	4	6	4	2	0.82	70	6.23	
			H S	22	0	4	8	5	0	4	6	3	3	0.78	50	6.2	
			H B	24	0	4	8	6	0	4	6	3	3	0.77	70	6.18	
		12	H S	22	0	4	6	6	0	4	6	4	2	0.97	78	6.21	
			H B	22	0	3	6	7	0	3	6	3	3	0.89	78	6.28	
		14	L	20	0	6	7	8	0	6	8	2	6		37	6 1	
			H S	40	0	4	11	6	0	4	8	4	4		29	5 93	
			H B	40	0	4	4	8	0	4	6	2	4		31	5.85	
		15	L	30	0	4	8	9	0	4	6	2	4		78	5 95	
			H S	30	0	4	8	7	0	4	6	2	4		30	6.00	
			H B	30	0	4	8	4	0	4	6	3	3	0.75	52	6.4	
		16	L	22	0	6	7	5	0	6	6	2	4	0.68	46	6.38	
			H S	22	0	4	7	6	0	4	6	2	4	0.65	45	6.22	
			H B	22	0	4	8	5	0	4	6	3	3	0.66	48	6.33	
		17	L	30	0	6	8	4	0	6	6	4	2	0.63	57	6.33	
			H S	20	0	4	6	5	0	4	7	2	5	0.65	58	6.52	
			H B	23	0	4	7	5	0	4	7	3	4	0.61	58	6 3	
MAXIMUM				40	0	8	11	12	0	8	8	4	5		93	6.5	
MINIMUM				17	0	3	4	3	0	3	4	2	2		29	5.85	
AVERAGE				21.8	0	5.0	0.5	7.2	0	4.9	6.1	3.1	3.0		59.6	6.1	

EXPLANATIONS

FROM FEBRUARY 22, 1972 TO MARCH 17, 1972
BY S.M.W.O

L . LOW TIDE
H : HIGH TIDE
S : SAMPLE TAKEN AT SURFACE
B . SAMPLE TAKEN AT BOTTOM
P · PHENOLPHTHALEIN ALKALINITY

6. HYDROGEOLOGY OF SAIGON AREA