PD AAJ 442
ISN 943
497 0249
PN-TIV-32
ISN = 45890
62

REPUBLIC OF INDONESIA
MINISTRY OF PUBLIC WORKS
DIRECTORATE GENERAL OF HOUSING BUILDING
PLANNING AND URBAN DEVELOPMENT (CIPTA KARYA)

MEDAN URBAN DEVELOPMENT, HOUSING, WATER SUPPLY AND SANITATION PROJECT

TECHNICAL MEMORANDUM NO. 42

MEDAN GROUNDWATER DRILLING PROGRAM

OCTOBER 1980

ENGINEERING – SCIENCE, INC. • SINOTECH ENGINEERING CONSULTANTS, INC
A JOINT VENTURE
in association with
PADCO and P.T. DACREA

MEDAN URBAN DEVELOPMENT, HOUSING, WATER SUPPLY AND SANITATION PROJECT

Jln. Singamangaraja 1-3, P. O. Box 26, Phone 20716, Medan-Sumatra, Indonesia

Our ref.: 80/1058/GWDP

6th October 1980

Director Cipta Karya
Ministry of Public Works
Jalan Pattimura 20
Kebayoran Baru
JAKARTA SELATAN

Subject: Technical Memorandum No.42
Medan Groundwater Drilling Program

Dear Sir:

Attached are 20 copies of the subject Technical Memorandum for your information and review. This memorandum represents Appendix A of the revised Final Master Plan and First Stage Program (Volume V, Part 1) and all references are to the revised Final Report.

Yours faithfully,

Dr. C.T. Williams
Project Representative

cc: Ir. Ruslan Diwiryo, Director of City & Regional Planning
Ir. Susanto Mertodiningrat, Director of Sanitary Engineering
Ir. Sunaryo, Head Sub-Directorate Town Planning
Ir. K. Pohan, Project Manager, MUDS
AID - Jakarta, attn.: Mr. P. Thorn, Project Officer
ES - Arcadia
SINOTECH - Taipei
DACREA - Jakarta

TW/s

LIST OF TECHNICAL MEMORANDA PREVIOUSLY SUBMITTED

Report No.	Title	Date Submitted
1.	Preliminary Site Selection Criteria for Perumnas Medan III, SSCH/LCH Project	March, 1979
2.	Work Plan for Water Supply and Sanitation Master Plans and Feasibility Studies	April, 1979
3.	Policy Issues for Project Guidance	March, 1979
4.	Drainage - Principal Rivers and Rainfall Analysis	May, 197
5.	Preliminary Evaluation of Sunggal Water Treatment Plant	May, 1979
6.	Public Health Considerations	July, 1979
7.	The Present Drainage System	August, 1979
8.	Recommended Drilling Program	August, 1979
9.	Medan Household Income/Expenditures	August, 1979
10.	Existing Land Use in Medan	August, 1979
11.	The Regional Functions of Medan	August, 1979
12.	Existing Solid Wastes Systems and Projected Solid Wastes Characteristics	August, 1979
13.	Evaluation of Medan Master Plan	August, 1979
14.	Physical Constraints to Urbanization	August, 1979
15.	Development in Health Care in Medan	September, 1979
16.	Existing Water Supply Systems	September, 1979
17.	Developments in Education	October, 1979
18.	Existing Water Supply and Sanitation Systems	October, 1979
19.	Public Health and Environmental Aspects	October, 1979
20.	Alternative Solid Wastes Management Systems	October, 1979

LIST OF TECHNICAL MEMORANDA PREVIOUSLY SUBMITTED (CONTINUED)

Report No.	Title	Date Submitted
21	The Distributed Investment Strategy Plan (DISP)	October, 1979
22	Recommended Solid Wastes Management System	October, 1979
23	Recommended Drainage Management System	October, 1979
24	Alternative Water Supply Management Systems	November, 1979
25	Water, Wastewater, Stormwater and Solid Wastes Systems	November, 1979
26	Alternative Wastewater Management Systems	November, 1979
27	Design Criteria and Bases for Cost Estimates	November, 1979
28	Recommended Water Supply Management System	November, 1979
29	Recommended Wastewater Management System	November, 1979
30	Environmental Assessment	November, 1979
31	Finance	November, 1979
32	Groundwater Resources	November, 1979
33	The Existing Urban Situation	November, 1979
34	Sibolangit Springs	November, 1979
35	Distribution System Analysis	November, 1979
36	Surface Water Hydrology	November, 1979
37	Detailed Projections of Water and Waste Quantities	November, 1979
38	Organization for Water Supply and Sanitation	November, 1979
39	Background Notes on Medan's Housing Strategy	November, 1979
40	Housing and Planning Norms and Standards	November, 1979
41	The Existing Situation in the Areas Selected for Kampung Improvement (KIP)	December, 1979

TABLE OF CONTENTS

	LIST OF FIGURES	vi
	LIST OF TABLES	viii
SECTION A.1	INTRODUCTION	A-1
	A.1.1 Summary of Results	A-1
	A.1.2 Medan Urban Development Study	A-3
	A.1.3 The Groundwater Program	A-3
SECTION A.2	THE WELLS	A-5
	A.2.1 General Settings	A-5
	A.2.1.1 Mabar Well (Mabar Industrial Estate)	A-5
	A.2.1.2 Medan Denai Well (Medan Tenggara II Street)	A-8
	A.2.1.3 Kotamatsum Wells	A-15
	A.2.1.4 P.T. Brasseries Well	A-15
SECTION A.3	GEOLOGICAL FINDINGS	A-19
	A.3.1 General Stratigraphy	A-19
	A.3.2 Aquifer Stratigraphy	A-19
	A.3.2.1 Mabar	A-20
	A.3.2.2 Medan Denai	A-20
	A.3.2.3 Kotamatsum	A-20
	A.3.2.4 P.T. Brasseries	A-27
	A.3.2.5 Jati Street	A-27
	A.3.3 Hydrogeological Implications	A-27
	A.3.3.1 Lateral Extent	A-27
	A.3.3.2 Vertical Interconnections	A-28
SECTION A.4	GEOHYDROLOGICAL ANALYSES	A-29
	A.4.1 General	A-29
	A.4.1.1 Aquifers and Thickness	A-29
	A.4.1.2 Porosity and Permeability	A-29
	A.4.1.3 Transmissivity	A-30
	A.4.1.4 Storage Coefficient	A-31
	A.4.2 Well Analyses	A-31
	A.4.2.1 Mabar Analyses	A-31
	A.4.2.2 Medan Denai Analyses	A-41
	A.4.2.3 Kotamatsum Wells Analyses	A-49
	A.4.2.4 P.T. Brasseries Well Analyses	A-53
	A.4.2.5 Other Wells Analyses	A-53

A.4.3 General Hydrologic Implications A-56
A.4.3.1 Production, Drawdown and Distance A-56
A.4.3.2 Groundwater Flow and Water Levels A-62
A.4.3.3 Long-Term Safe Yields A-63

SECTION A.5 GROUNDWATER RESOURCES AND THEIR DEVELOPMENT A-63

A.5.1 Well Designs, Production Facilities and Distribution A-64
A.5.1.1 Well Procedures and Designs A-64
A.5.1.2 Production Facilities A-69
A.5.1.3 Well Distribution A-69
A.5.1.4 Water Quality and Treatment Facilities A-70
A.5.2 Recommended Well Development Program A-71
A.5.2.1 Schedule A-71
A.5.2.2 Locations A-72
A.5.2.3 First Stage Well Locations A-72
A.5.2.4 Second Stage - Phase 3 Analyses A-76
A.5.2.5 Third Stage Wells A-76

LIST OF FIGURES

		Page
A.1	General Project Area for Medan Groundwater Drilling Program	A-4
A.2	Location Map for Mabar Industrial Estate Well Site	A-6
A.3	Plan of Mabar Industrial Estate Water Well Site	A-7
A.4	Well Design for Observation Well at Mabar Industrial Estate	A-9
A.5	Well - Design - Test Production Well at Mabar Industrial Estate	A-10
A.6	Location Map for Medan Denai Well Site	A-11
A.7	Site Plan for Medan Denai Wells and PAM Tirtanadi Facilities	A-12
A.8	Well Design for Observation Well at Medan Denai, Jln. Tenggara Site	A-13
A.9	Well Design for Test Well at Medan Denai Site	A-14
A.10	Well Design for Proudction Well at Laksana - Kotamatsum Site	A-16
A.11	Well Design for Production Well at Ismailiyah - Kotamatsum Site	A-17
A.12	Well Design for P.T. Brasseries	A-18
A.13	Electric Log and Lithologic Log for Mabar Observation Well	A-21
A.14	Electric Log and Lithologic Log for Mabar Test Well	A-21
A.15	Electric Log and Lithologic for Medan Denai Observation Well	A-23
A.16	Electric Log for Ismailiyah - Kotamatsum Production Well	A-23
A.17	Electric Log for Laksana - Kotamatsum Production Well	A-25
A.18	Drawdown Test Results from Mabar Site	A-32
A.19	Recovery Test Results from Mabar Site	A-33
A.20	Drawdown Test Results from Medan Denai Site	A-45
A.21	Recovery Test Results from Medan Denai Site	A-46
A.22	Drawdown and Recovery Curves for Ismailiyah - Kotamatsum Well Test	A-50
A.23	Drawdown and Recovery Curves for Laksana - Kotamatsum Well Test	A-51
A.24	Drawdown: Capacity for Step-Drawdown Test at Ismailiyah - Kotamatsum Well	A-52

A.25	Recovery Results from Preliminary Test at the P.T. Brasseries Well	A-54
A.26	Probable Production: Drawdown: Distance at Mabar	A-58
A.27	Probable Production: Drawdown: Distance at Medan Denai	A-60
A.28	Modified Well Design for Medan's First Stage Well	A-67
A.29	Proposed First Stage Well Locations in Medan	A-73

LIST OF TABLES

A.1	Representative Porosity and Permeability	A-30
A.2	Well Test Results at Mabar	A-35
A.3	Well Test Results at Medan Denai	A-42
A.4	Probable Proudction: Drawdown: Distance at Kotamatsum	A-61
A.5	First Stage Wells in Medan	A-75

APPENDIX A

MEDAN GROUNDWATER DRILLING PROGRAM

A.1 INTRODUCTION

A.1.1 Summary of Results

The Medan Groundwater Drilling Program has confirmed the presence of widespread deep aquifers capable of providing 1000 cu m/d from wells separated by 1000 - 2000 m. The program well requirements severely taxed the capability of local well drilling equipment and personnel. The recommended First Stage Program for water supply from wells appears to be attainable as recommended.

Well data were collected from six new production wells and two observation wells in Medan City and near the Deli River and Belawan Road. All wells were 100 to 200 m deep and the production wells were planned to have capacities of 40 to 72 cu m/hr (more than 960 cu m/d). The wells were located on six sites: two in Titipapan-Mabar, Medan Timur, Medan Denai and Kotamatsum.

The general geological stratigraphy at each well was similar to each other and to previous records:

0 - 10 m	Sandy clay (ground water table)
10-40 m	Sand and gravels (shallow aquifer)
40-90 m	Clay with some sand layers
90-190 m	Interbedded clays, sands, and gravels-sands and gravels of 20-40 m thickness (deep aquifers)
190 + m	Clay and sandy clay with some sands.

The deep aquifers are thickest in Belawan (70 m), of moderate thickness at Titipapan (40 m), and thinnest under southern Medan (15-25 m). Although the aquifers vary in thickness and depth, the two major aquifers appear to extend throughout the entire basin. The three clay formations appear to separate the aquifers, although some sands may interconnect the aquifers.

All monitored production wells could produce more than 40 cu m/hr but with different drawdowns. Greatest specific capacity (production/metre drawdown) occurred in the P.T. Brasseries well and the Mabar well in Titipapan, while the lowest occurred in the three wells in southern Medan

city. The trend in aquifer thickness and specific capacities follows the trend in transmissivity and storage coefficient, decreasing from North to South. Transmissivity and permeability values are as follows:

P.T. Brasseries:	200 to 750 cu m/m.d;	5-17 cu m/sq m.d
Mabar :	430 to 800 cu m/m.d;	17-26 cu m/sq m.d
Medan Denai :	320 to 540 cu m/m.d;	17-23 cu m/sq m.d
Kotamatsum :	230 to 350 cu m/m.d;	9-13 cu m/sq m.d

The transmissivity and permeability values are consistent with the geologic record of fine to medium sand aquifers under Medan and medium to coarse sands under the Belawan corridor.

Calculated storage values from Mabar and Medan Denai well tests suggest that the shallow or very deep aquifers may contribute to the deep aquifers during pumping. The interconnection appears to be greater at Mabar than at Medan Denai, which is consistent with thicker aquifers and thinner clay layers at Mabar than at Medan Denai.

Calculated drawdown: distance values indicate interference may occur within 500 m separation between pumping wells at Mabar and within 1000 m separation at Medan Denai. This supports initial spacing criteria of 1000 m and up to 2000 m. With drawdown of 10 m and a gradient of 10 m/1000 m, standard production wells of 1000 cu m/d should be adequately provided by the available aquifers during the First Stage Period.

The First Stage Groundwater Program should:

1. Import newer, larger drilling rigs to Sumatra or reduce bore diameters

2. Use long conductor casings and telescoping casing/screen assemblies

3. Eliminate accessory building, offices, and reservoir from well sites

4. Avoid well field arrangements during the First Stage Period

5. Disregard iron and clay content and resulting discoloration until water supply is fully pressurized and protected from public health deficiencies.

The Recommended Well Development Program depends on a four-part sequence:

First Stage
- Phase 1 - Initial well program of 13 wells
- Phase 2 - Expanded well program of 40 wells

Second Stage - Assessment of well data and production monitoring

Third Stage - Long-term well program.

The First Stage Well Program - Phase 1 concentrates wells in the eastern area of Medan, while Phase 2 expands wells into the northern area of Medan. Ten exploratory production wells would be dispersed in western Medan.

After the First Stage wells have been installed and monitored for one to five years, analyses of data from more than 50 wells would provide the basis for long range projection of the basin's safe yield and for optimal distribution of wells.

The long-term well program may include more than 50 wells but these would be drilled over a 15-year period.

A.1.2 Medan Urban Development Study

The Medan Urban Development Study was initiated in January 1979 and produce more than 40 technical memoranda, master plan and first stage feasibility reports for services, urban planning and housing. The Medan Groundwater Program (MGP) formed a portion of the MUDS effort and was directed towards initial confirmation of the potential groundwater resources which were estimated in the Master Plan and First Stage Program (Vol.V, Part 1). Results of this groundwater program have confirmed the potential groundwater resources in the eastern area of Medan and along the Belawan corridor. A third element of this program involved the testing of new well designs which will reduce the entrance of sand into the wells and prolong their life. The last element of the program involves the future use of the test wells to provide water to poorly supplied areas of Medan.

A.1.3 The Groundwater Program

The Groundwater Program was organized so as to provide the following:

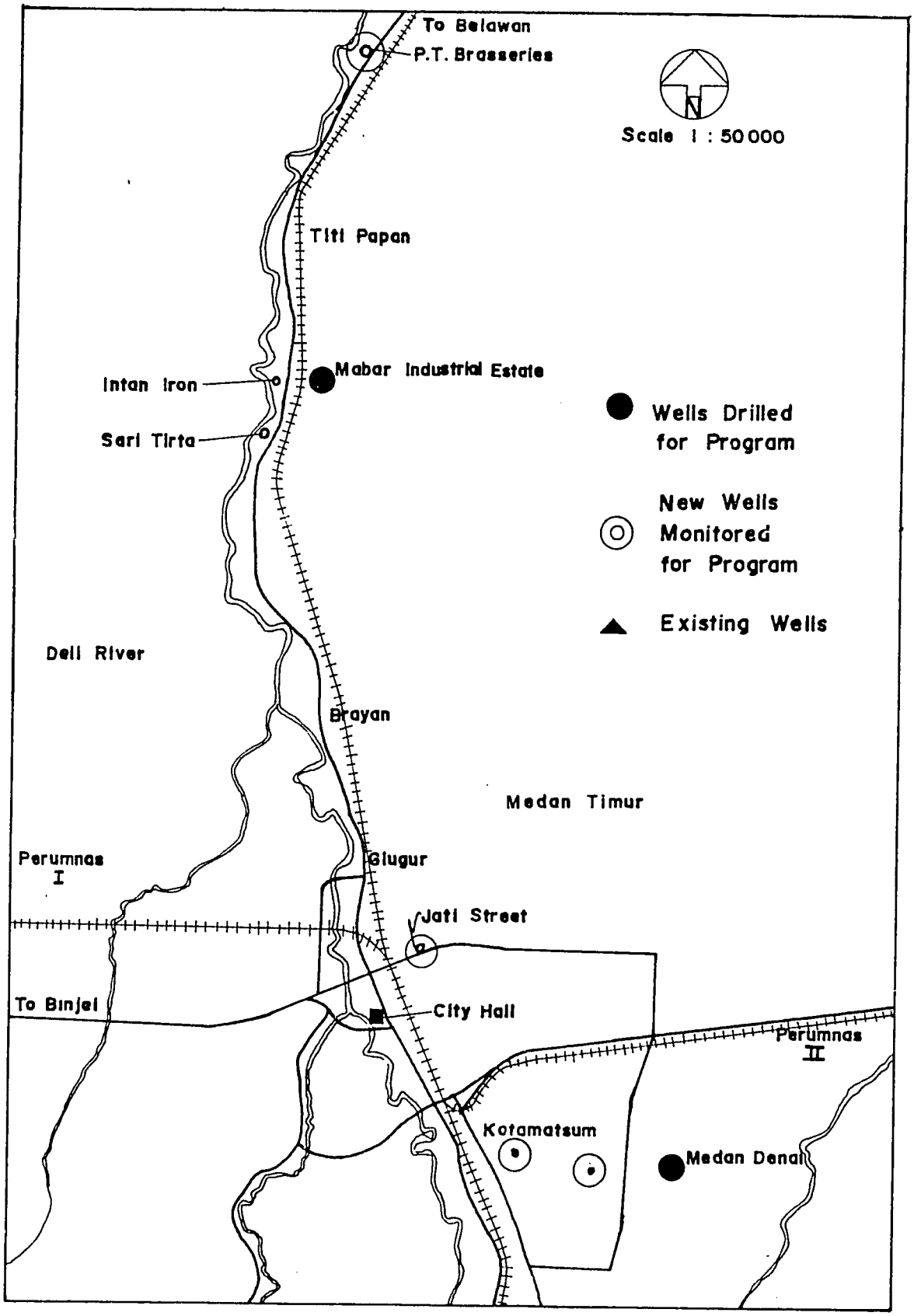
1. Program Plan
2. Preparationsof Specifications of Drilling Contract
3. Well Drilling Supervision and Inspection and Supervision of Well Testing and Monitoring
4. Preparations of a Program Report and Integration with the MUDS Master Plan and Feasibility Report.

The program began in April 1980 and drilling began in June 1980. Two test wells and two observation wells were completed by September 22, 1980. Monitoring and test results were analyzed in August and this report was presented in September, 1980. Delays occurred in finalization of the contracts and in the drilling of the wells (total time on site: two and half months).

Two sites were selected (Figure A.1) based upon land availability within the general areas for exploration. The Mabar wells were located in the Mabar Industrial Estate on the Belawan Road. The Medan Denai wells were located in the southeast area of the city, 3.0 km east of Sisingamangaraja Street (the P. Siantar Road).

FIGURE A.1

GENERAL PROJECT AREA FOR MEDAN GROUND WATER DRILLING PROGRAM



The groundwater program has several objectives and thereby the interpretations of the drilling and testing results involve different analyses. Analyses of the drilling, development, and well designs will indicate where improvements can be made to current practices and equipment. Lithologic and electric logs at the two well sites, from two Kotamatsum wells and reinterpretation of previous well logs will be used to develop better estimates of the available thicknesses of aquifers and groundwater reservoirs. The pumping tests from the two MGP wells and from the two Kotamatsum wells will be analyzed for both well characteristics and aquifer characteristics. The two MGP wells will provide additional information regarding the permeability and transmissivity of the aquifers between 100 and 200 m depths. The MGP and Kotamatsum wells will provide additional drawdown and specific yield values and these will be compared to those previously presented.

A.2 THE WELLS

Following completion of the Medan Urban Development Study Master Plan, six new production wells have been drilled for P.A.M. Tirtanadi or others. Two production and two observation wells have been drilled for this study, two production wells for the Kampung Improvement Program in Kotamatsum, and two small production well for P.T. Brasseries (brewery) in Titipapan. and for a private hotel in Medan Timur. These six production wells and two observation wells are described in the following sections.

A.2.1 General Settings

The general site location map (see Figure A.1) indicates the general geographic location of the six new production wells and their topographic setting. The Medan Denai well lies about 3.0 km from the Deli River and about 2.0 km from the Percut River. The remaining four production wells lie less than 2,000 m east the Deli River. The new brewery well is furthest north, while the brewery well and the Mabar well site are about midway between the Belawan and Kotamatsum wells. Three of the new production wells form a line of groundwater monitoring points within 1,200 m east of the Deli River at about 5,000 - 7,000 m intervals. The Medan Denai and Ismailiyah Street wells represent new explorations of the eastern groundwater basin.

A.2.1.1 Mabar Well (Mabar Industrial Estate)

The site for the northern well in the Medan Groundwater Drilling Program was chosen because of the need for new water supply in the Belawan - Deli River corridor and specifically for the new industrial estate. Furthermore, the site represents a monitoring point along the anticipated south-north flow of the groundwater between Medan and Belawan. The entrance of the Mabar Industrial Estate lies 10.0 km north of Medan City Hall (see Figure A.1), 2.5 km south of the main road junction in the village of Deli, and 15 km south of the water tower in Belawan. The well site is located 450 m east of the Medan-Belawan Highway and 350 m east of the railway crossing and the main entrance to the Mabar Industrial Estate (see Figure A.2). The site plan is given in Figure A.3, and the test well lies 150 m south of the main west-east road across the industrial estate.

FIGURE A.2

LOCATION MAP

FOR MABAR INDUSTRIAL ESTATE WELL

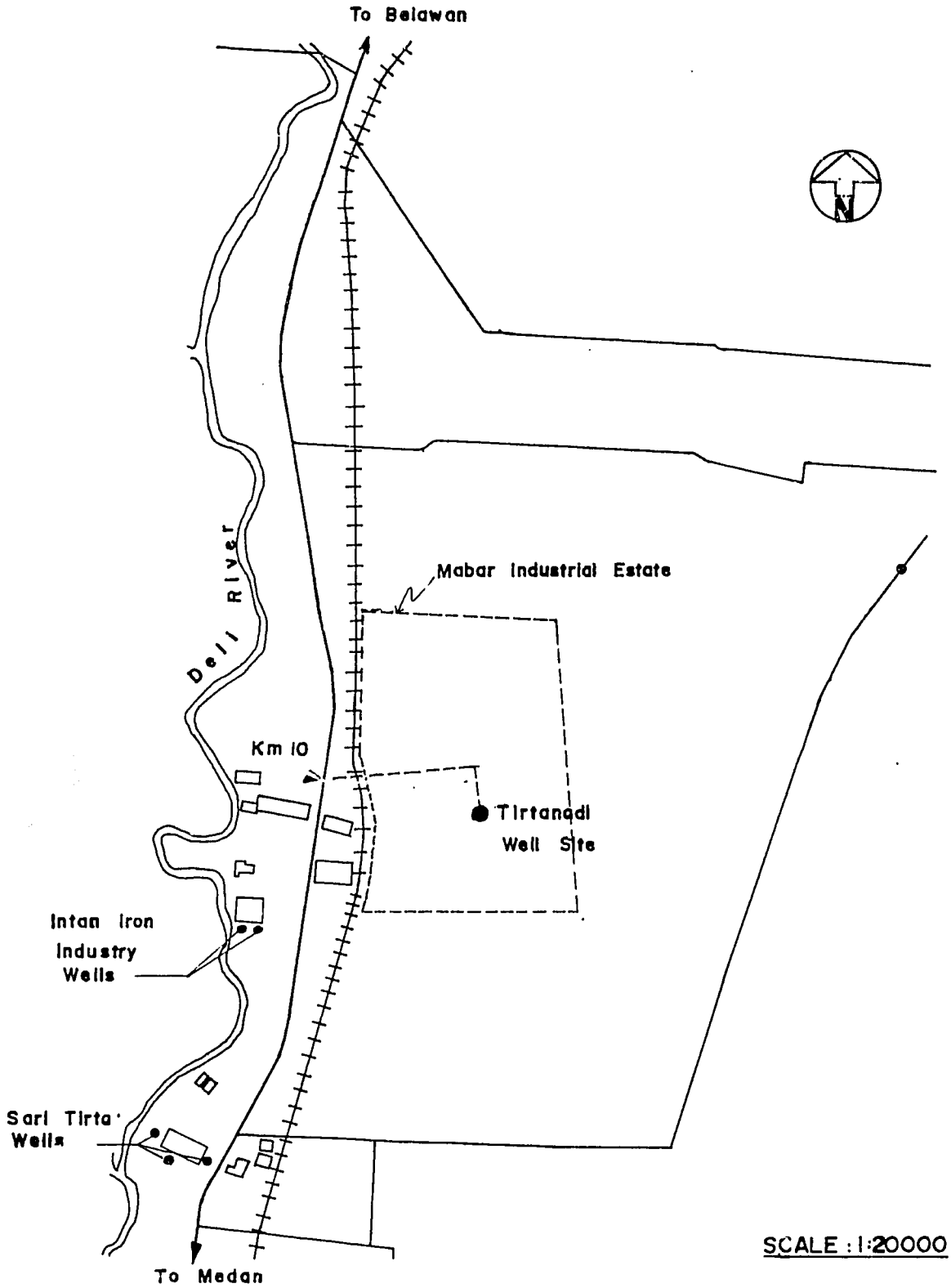
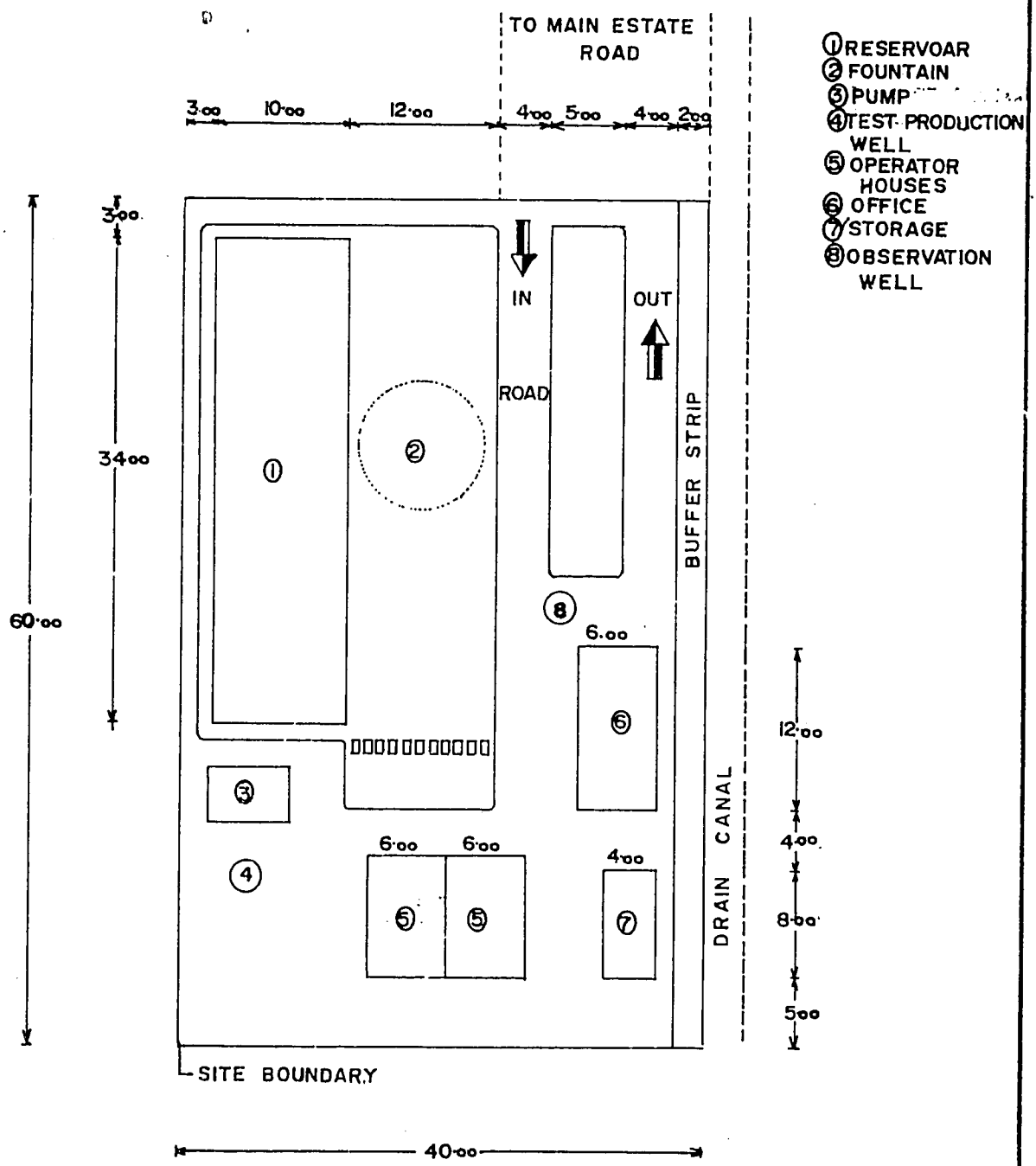


FIGURE A.3

PLAN OF MABAR INDUSTRIAL ESTATE
WATER WELL SITE



SCALE 1:500

PADCO-DACREA ENGINEERING SCIENCE-SINOTECH

No industry had occupied the estate as of August 1980, although first occupants should begin construction in 1981. The site is generally level as the entire estate has been filled and graded. South-North storm water drains pass across the centre of the estate and along the eastern and western perimeters.

The site was occupied on June 12. Drilling of the observation well was begun on June 17 and completed on June 25. The well was completed on July 3. The test well drilling began on July 4, and the pilot bore was completed on July 12, 1980. The reaming of the pilot bore was begun on July 14, was stopped on July 21, and then repeated from July 26 to July 29, and from August 2 to August 18, 1980. The well was completed on August 30, 1980.

The designs of the observation and test wells are given in Figures A.4 and A.5 respectively. The observation well was drilled at 200 mm to 200 m and had a continuous 50 mm casing and screen down to 160 m. A third drilling water supply well was drilled to 6 m, and no water was drawn from the observation well.

The test well at Mabar was first drilled to 190 m depth at 150 mm diameter and then an electric log was made of this pilot bore. The pilot bore was then enlarged to 300 mm diameter but only to 185 m depth. The additional pilot bore depth was required to locate the base of the aquifer and allow proper enlargement of the well above 185 m depth.

A.2.1.2 Medan Denai Well (Medan Tenggara II Street)

The site for the Medan Denai Well was chosen because of the great need for new water supplies in eastern Medan, the earlier indications of potential groundwater sources by a preliminary ground resistivity survey, and the availability of pipelines and sites. The Medan Denai Well site lies just off Bromo Lane 450 m east of Bakti Street and 50 m south of Bromo Land (see Figure A.6). The site plan is given in Figure A.7. The site generally slopes from west to east and has been covered with fill and debris at various times. The site lies along the southern property boundary of a small neighborhood mosque. The land parcel to the south is vacant at present, although small residences lie further south; other residences lie immediately to the east and across Tenggara Street to the west.

The site was occupied on June 4, 1980, and drilling of the observation well began on June 13, 1980 and finished on June 26, 1980. Drilling of the first pilot bore of the test well was started on July 19 and was completed on July 30, 1980. Reaming of the pilot hole began on August 1, but was abandoned on August 26, 1980. Numerous failures of the well hole occurred between 20 and 50 m below ground, and the well head also collapsed. Drilling of a new test well began on August 26, and was completed by September 15, 1980.

The designs of the observation and test wells are given in Figures A.8 and A.9 respectively. The observation well was first designed to have a continuous 50 mm observation casing and screen, but the Contractor required on-site water for the test well drilling and provided a 100 mm

4

WELL-DESIGN-OBSERVATION WELL

MABAR INDUSTRIAL ESTATE

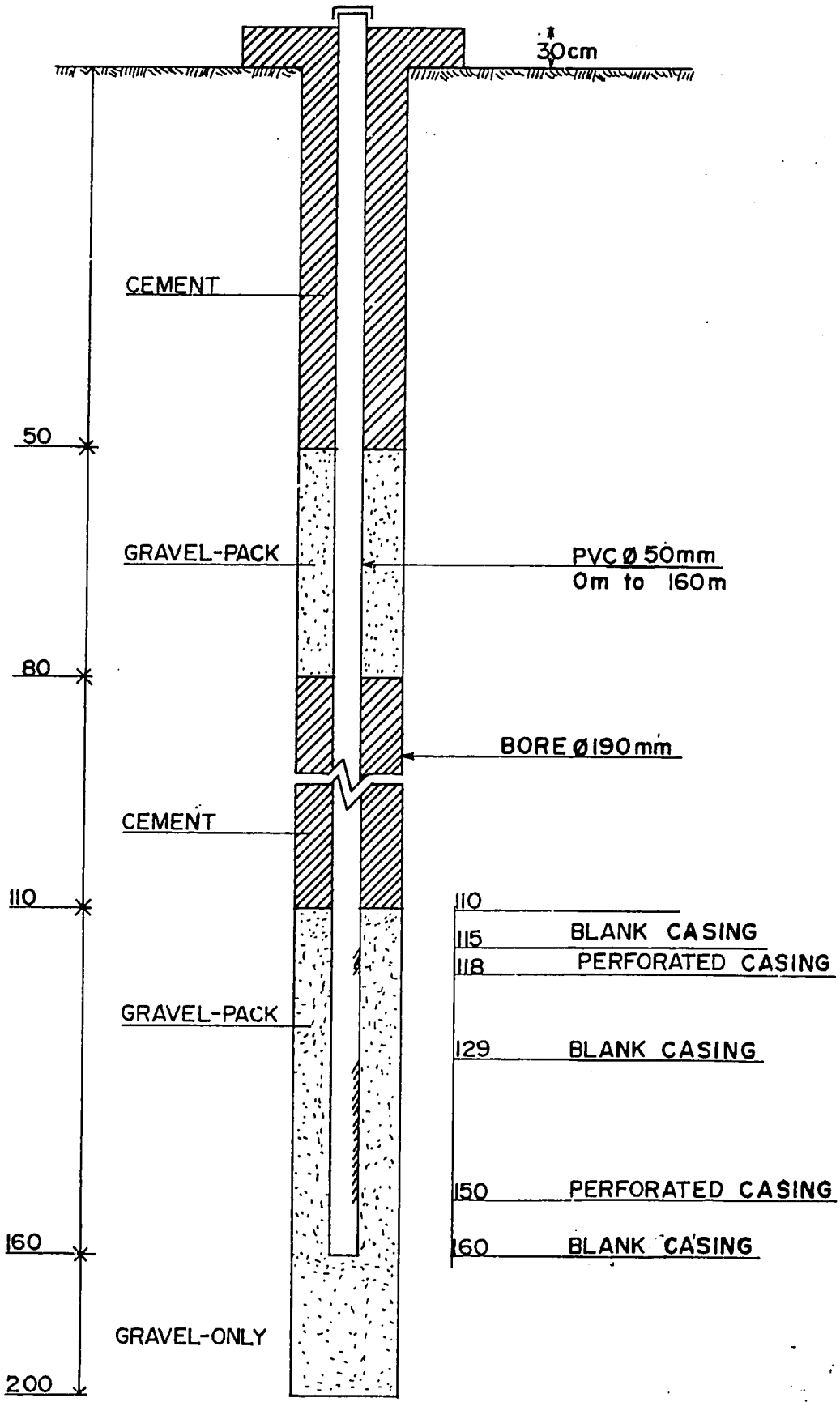
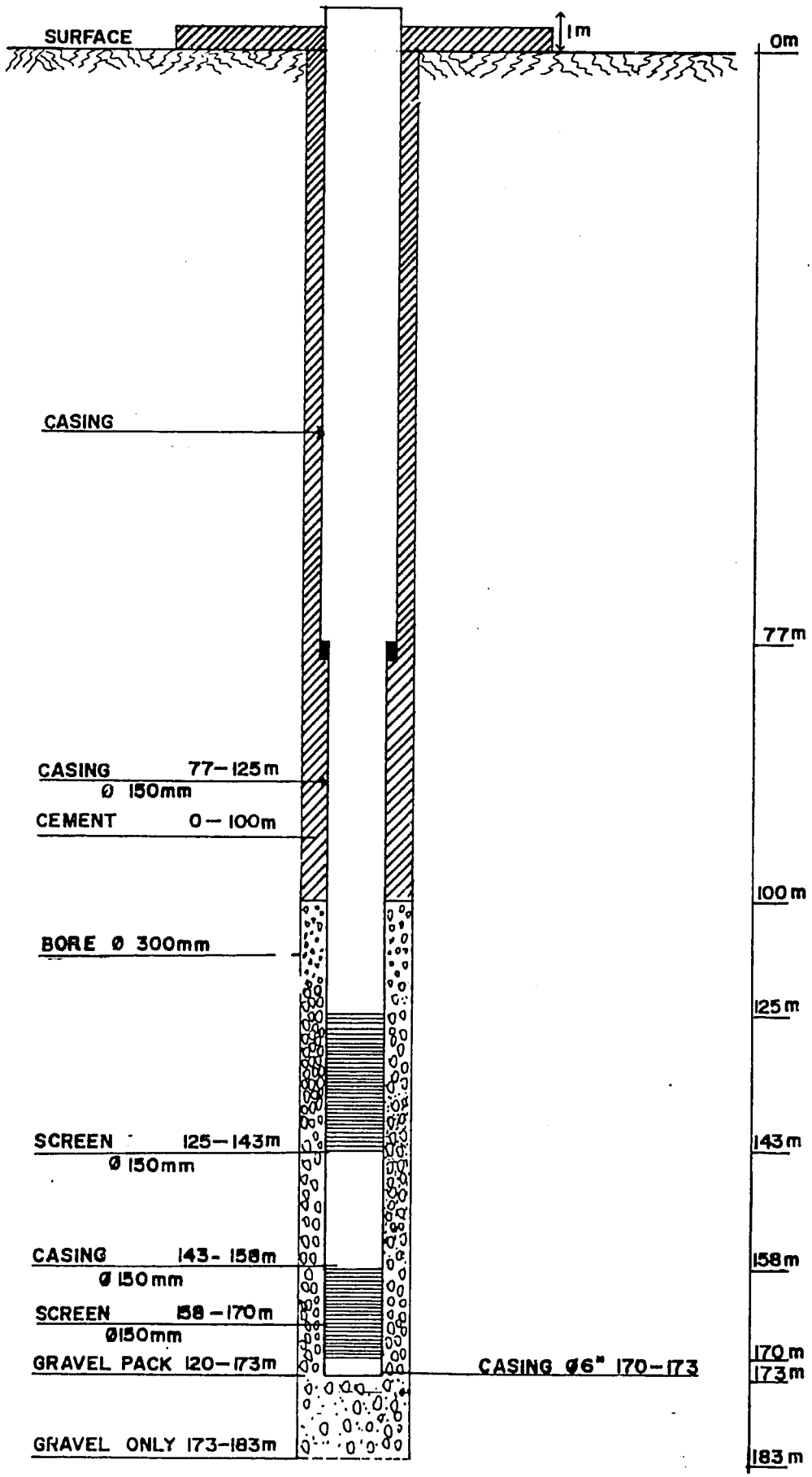


FIGURE A.5

WELL DESIGN - TEST PRODUCTION WELL

MABAR INDUSTRIAL ESTATE



PADCO-DACREA

ENGINEERING SCIENCE-SINOTECH

10

LOCATION MAP FOR MEDAN DENAI WELL

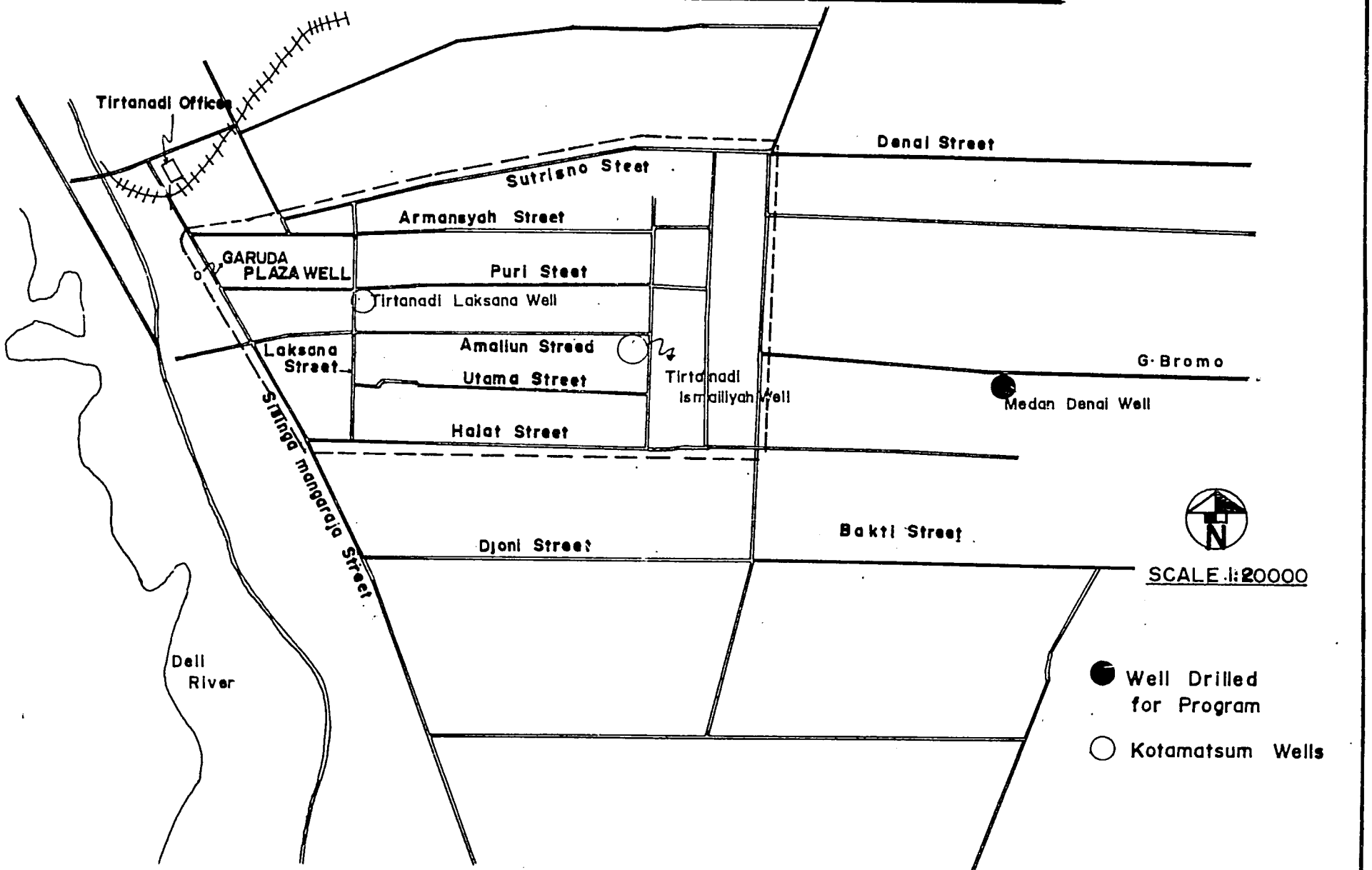
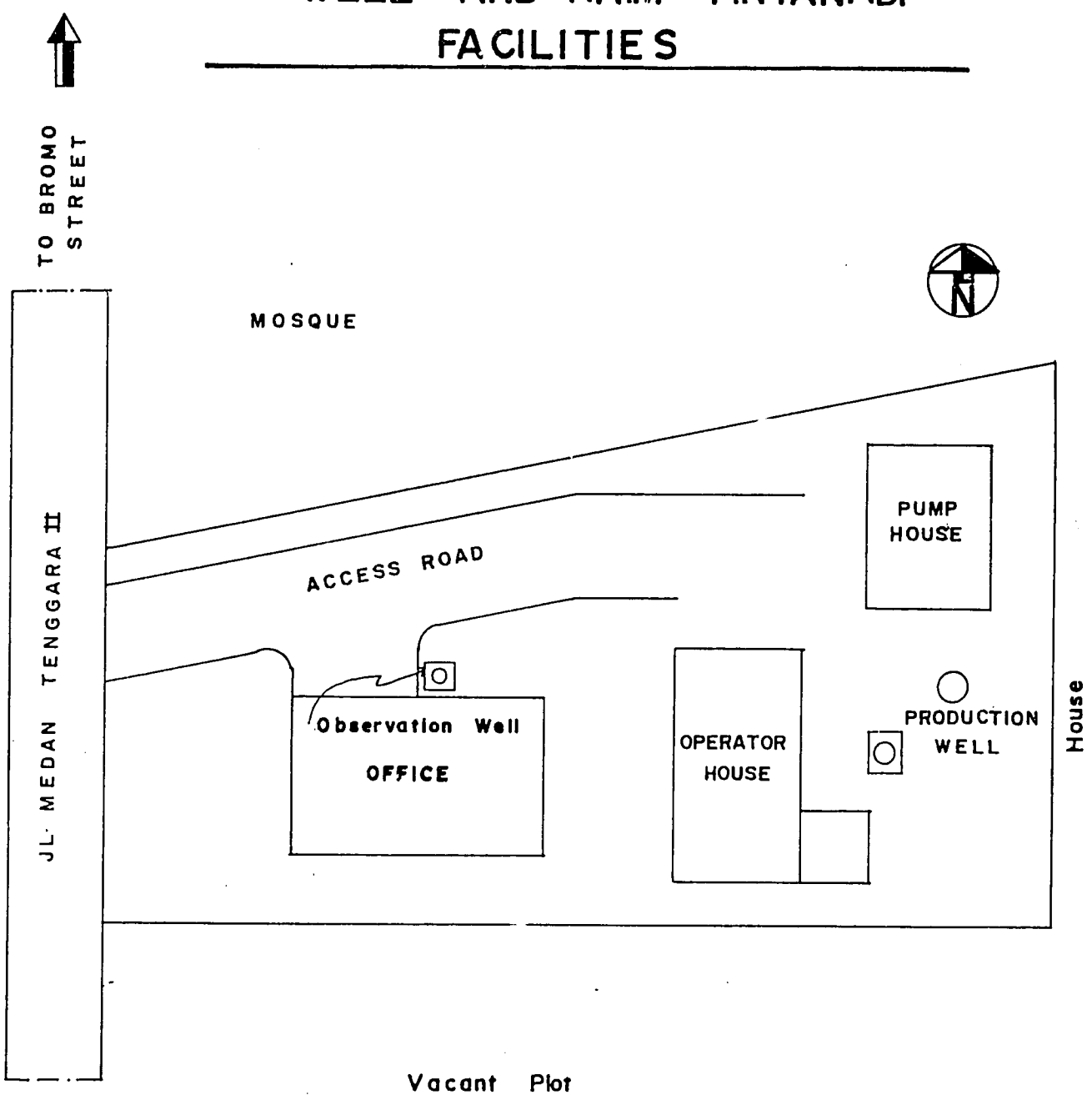


FIGURE A.7

SITE PLAN FOR MEDAN DENAI WELL AND P.A.M TIRTANADI FACILITIES



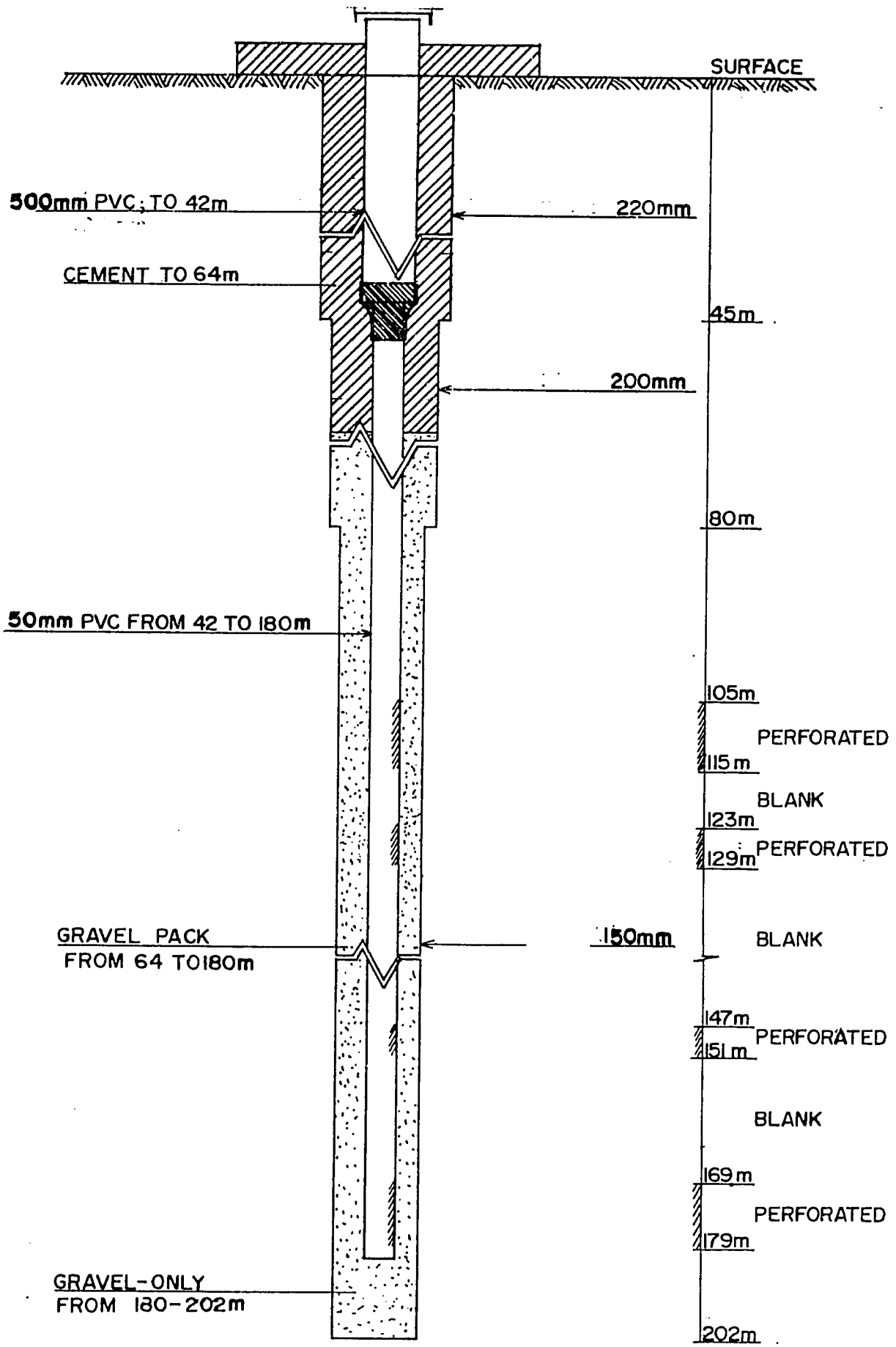
SCALE : 1 :200

PADCO–DACREA ENGINEERING SCIENCE–SINOTECH

FIGURE A.8

WELL DESIGN—OBSERVATION WELL

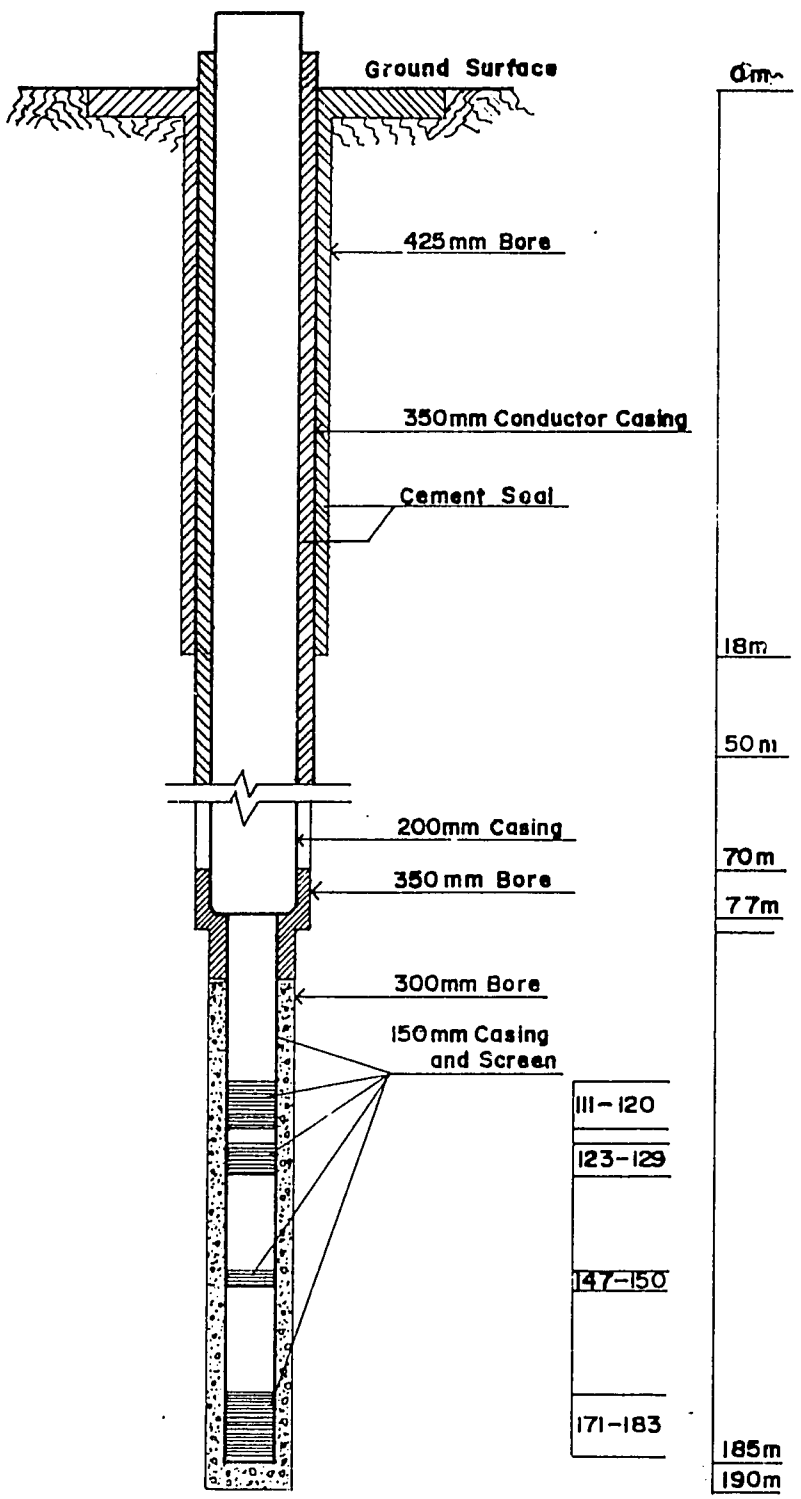
MEDAN DENAI-JL TENGGARA SITE



PADCO-DACREA

ENGINEERING SCIENCE-SINOTECH

WELL DESIGN
FOR MEDAN DENAI TEST WELL



casing of 20 m from which water was drawn. The observation well drilling was continued to 200 m, but the casing and screen extended to 185 m depth with the lower portion of the well filled with gravel. This design was considered adequate for an observation well and provided preliminary data used for final design of the test well. This well should not be used for a continuous production well.

As indicated in Figure A.9, the Medan Denai well was drilled to a total depth of 190 m with a bore diameter of 300 mm (12 inches) and with 30 m of 150 mm diameter screen and 155 m of 150 mm and 200 mm casing.

A.2.1.3 Kotamatsum Wells

As part of the Kampung Improvement Program in Medan, two production wells were drilled south of the P.A.M. Tirtanadi offices and east of Sisingamangaraja Street (see Figure A.6). These wells will add to the local water supply and standpipes planned as part of the KIP. The two wells were finished before drilling started on the MGP: these wells were drilled by the same contractors used for the MGP wells.

The Laksana Street well was drilled by Supra Indodrill between May 1 and June 1, 1980. The well is located 400 m east of Sisingamangaraja Street and 20 m south of Puri Street. The well lies 2,200 m west of the Medan Denai well and 500 m east of the production well at the Garuda Plaza Hotel. Only one well was drilled on the Laksana Street well site, and the production well was bored and then reamed. The designs for the Kotamatsum wells are given in Figures A.10 and A.11 for the Laksana Street well and that on Ismailiyah Street.

The Ismailiyah well lies 50 m south of Amaliun Street, west of Bakti Street and 1,700 m east of Sisingamangaraja Street. The well lies 1,300 m east of the Laksana well and 800 m west of the Medan Denai well.

The Laksana Street well is completely obscured by building construction on three sides and will be closed on the open side. The well will not be accessible for cleaning by any truck mounted systems. Similarly, planned construction of a small elevated water tank on the Ismailiyah site will make the Ismailiyah well inaccessible for most cleaning and renovation.

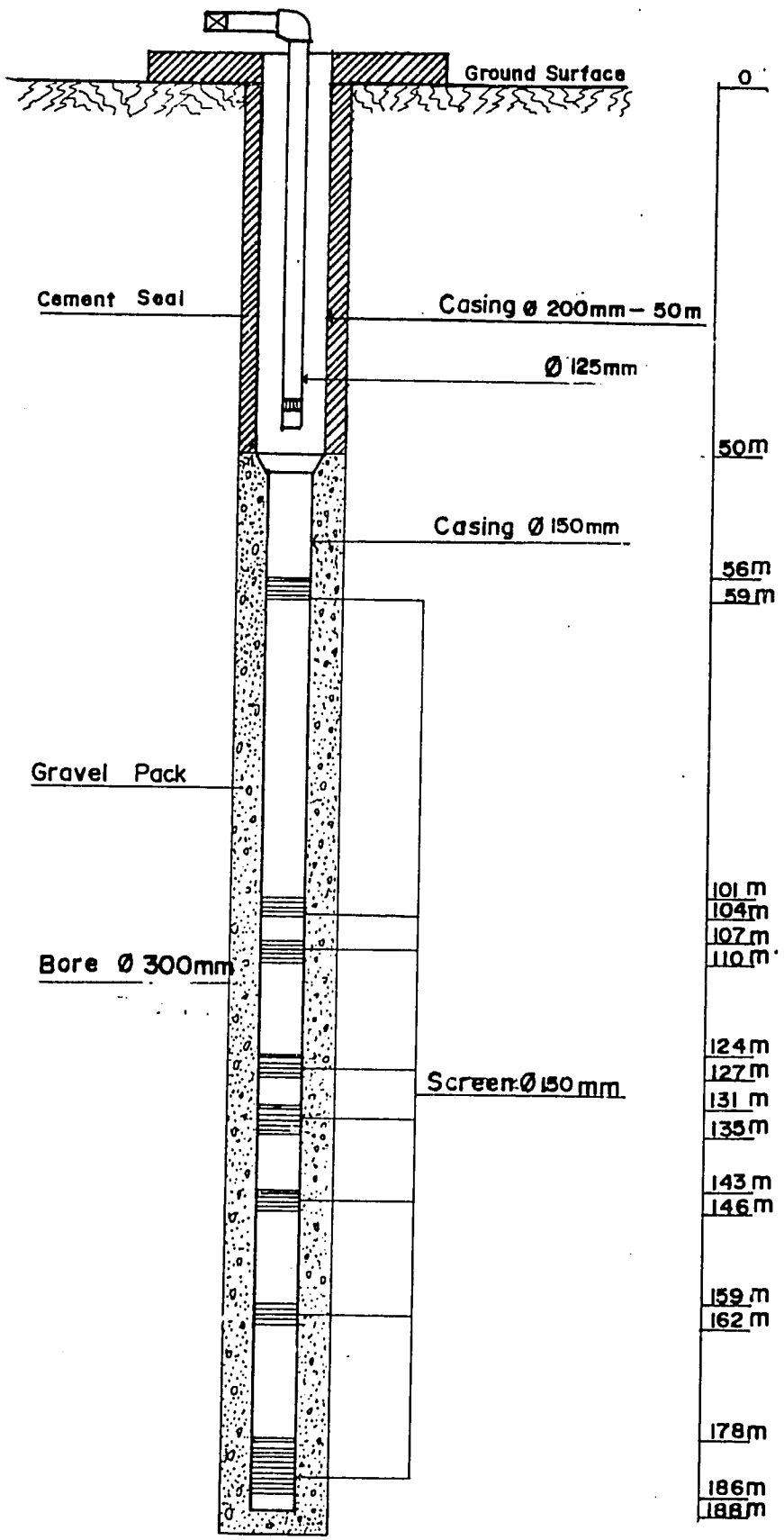
A.2.1.4 P.T. Brasseries Well

During June to August, a new deep well was drilled at the P.T. Brasseries Brewery on the Belawan Road, about 4 km north of the Mabar Industrial Estate and 9 km south of the Belawan City Centre. The well is located in the southwesterly corner of the brewery site and about 50 m from an existing deep well, 500 m from the Belawan Road and 15 m from the Deli River. The surveyed ground elevation is 2.5 m above sea level.

Will Greene Co. drilled the well under the supervision of DHV Consultants (Netherlands). The well was drilled to a depth of 117 m by a percussion rig, had diameters of 300 and 150 mm with 49 m of 200 mm casing, 30 m of 100 mm casing, and 36 m of machine slotted 100 mm casing (see Figure A.12). This represents a different design, although the geological occurrences are quite similar to those at the Mabar site.

WELL DESIGN - PRODUCTION WELL

LAKSANA - KOTAMATSUM



WELL DESIGN - PRODUCTION WELL

ISMAILIYAH – KOTAMATSUM

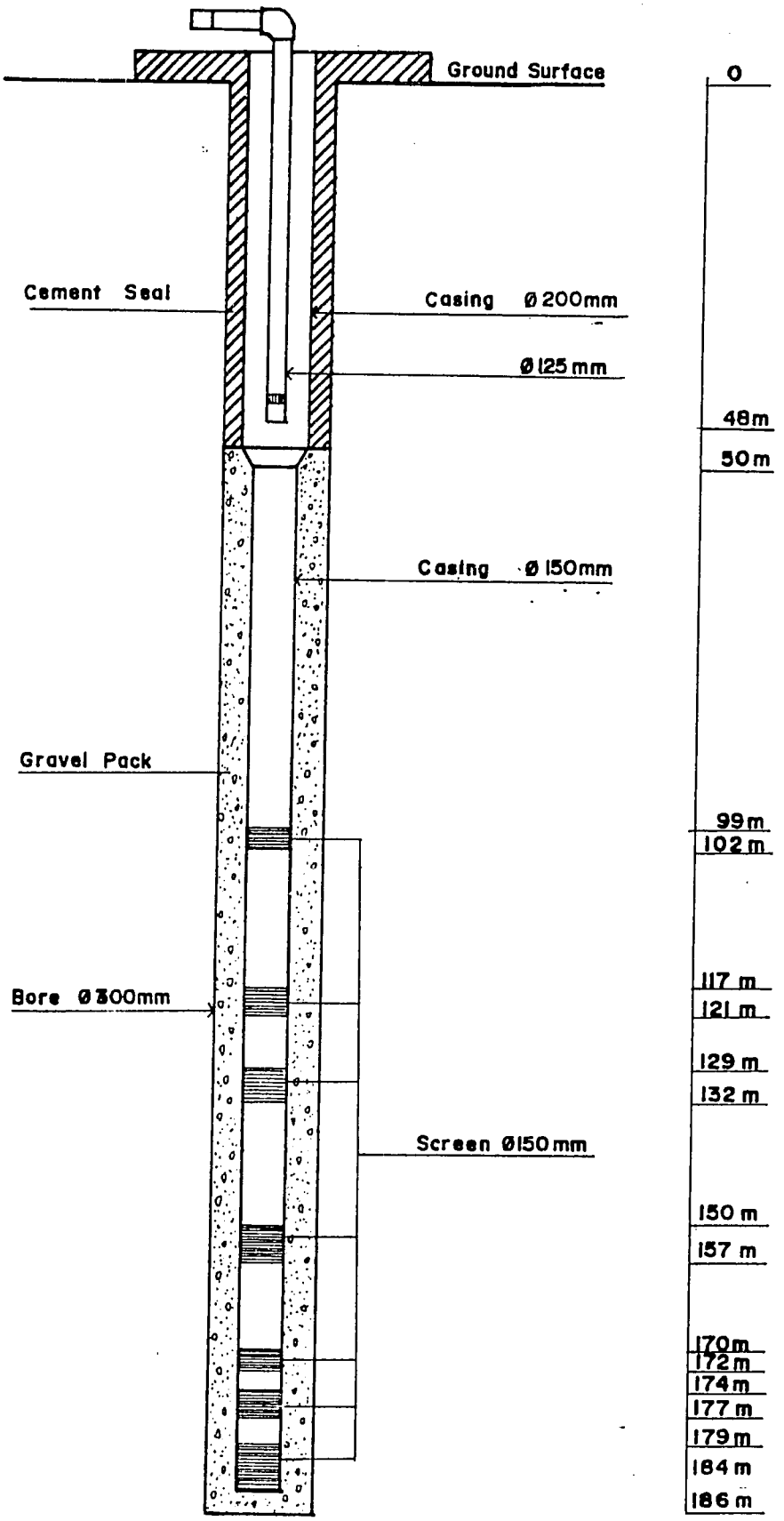
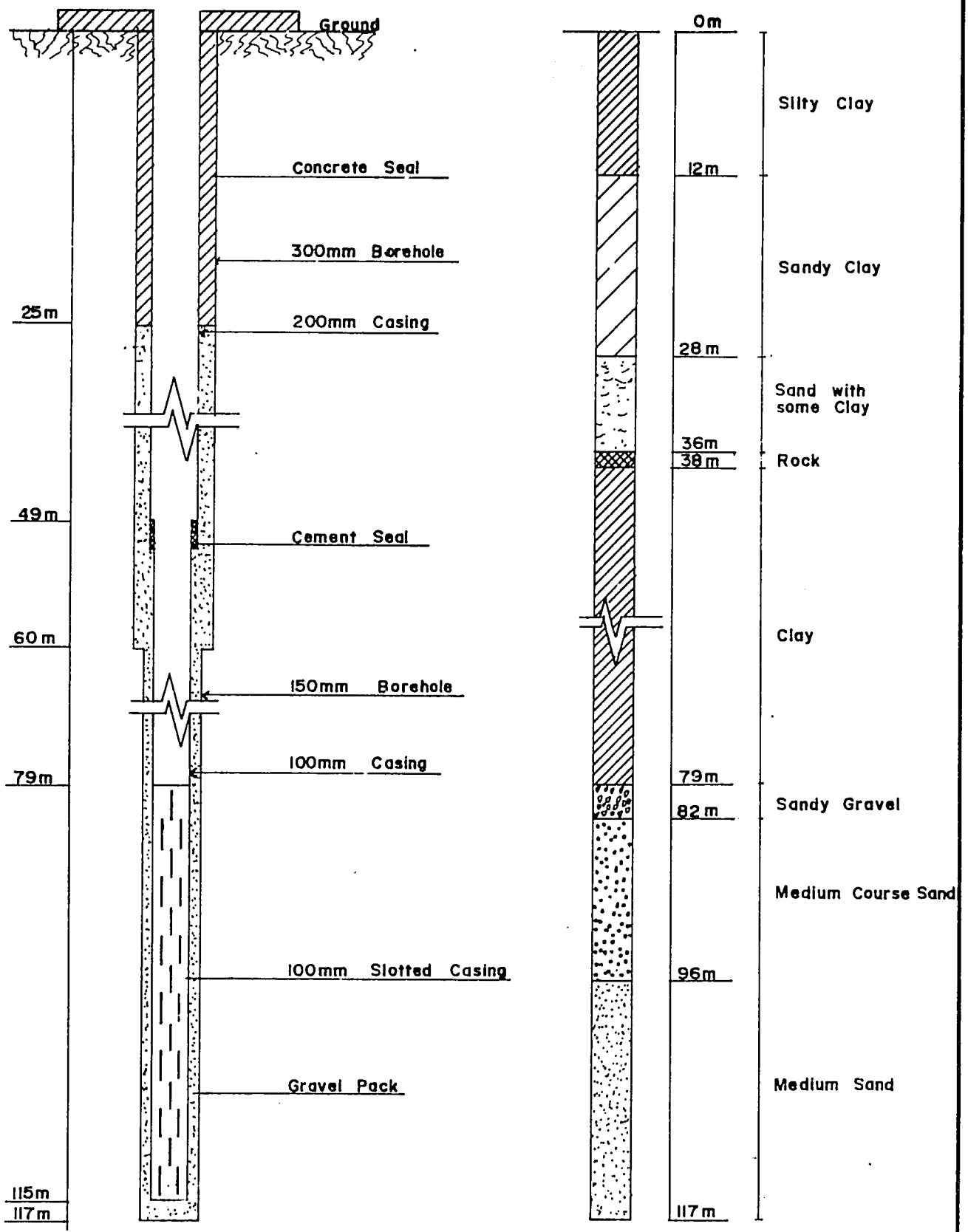


FIGURE A.12

WELL DESIGN FOR P.T BRASSERIES



PADCO-DACREA

ENGINEERING SCIENCE-SINOTECH

A.3 GEOLOGICAL FINDINGS

A.3.1 General Stratigraphy

The general stratigraphy of the eastern coastal area of Sumatra was presented in Appendix E-1 and is summarized below as it relates to the records from the test and observation wells of the MGP, the two production wells of the Kotamatsum Kampung Improvement Program and the P.T. Brasseries well. The general stratigraphic section in the coastal region from the Wampu to the Ular Rivers consists of the following:

Formation	
No Name	Recent floodplain and terrace alluvium
Julu Rayeu	Pleistocene alluvium, volcanic ash, and marine deposits
Serula	Late Tertirary and Quarternary alluvium and marine deposits
Keutapang-Baong-Parapat	Tertiary marine deposits
Pre-Tertiary Basement	Igneous and Metamorphic rocks.

The Julu Rayeu and Serula formations have been penetrated by many water wells, although the precise separation of the two formations is very difficult to determine. In the Pertamina exploratory well at Morawa, the base of the Serula formation was placed at about 400 m depth, but no delineation of the top of the formation was given. A significant increase in spontaneous potential and electrical resistivity at about 200 m depth and a thick clay layer at that depth may be assumed as a major lithological division between the Julu Rayeu and Serula formations. Similar thick clay units between 190 and 220 m depth were found in the other exploratory wells to the north of Medan (i.e. Diski, Pental Pakam and Wampu). Therefore, most if not all groundwater used in the Medan Region comes from the Julu Rayeu and more shallow formations.

Earlier studies of the Julu Rayeu formation and equivalent formations indicate a very comples stratigraphic sequence could be expected in the coastal area, and indeed the known sequences, include: clays, lignites, very fine sands, coarse sands and "grits", gravels, some shells, and volcanic deposits. In Belawan, an earlier study delineated three sedimentary members of the Julu Rayeu formation (Appendix E-1, Figure E-1.2), while to the south, the alluvial and marine deposits are overlain by thick volcanic formations.

A.3.2 Aquifer Stratigraphy

The general geological stratigraphy of the aquifers in Belawan has been described in several well reports and a general geological study of the Belawan area (see Figure E-1.2). The three part division found in Belawan was also found 10 to 15 km to the south in the stratigraphy of the Mabar wells and to some extent in the shallower Brasseries well. As indicated in Figure A.12, the Brasseries well appears to pass through the shallow groundwater table between 20 and 40 m depth and may penetrate only part of the second shallow artesian aquifer.

A.3.2.1 Mabar

The stratigraphy of the Mabar wells is presented in Figures A.13 and A.14 and clearly relates to that of the Brasseries well and the wells of Belawan. A major shallow groundwater table lies between 5 and 50 m below ground. The intermediate aquifers contain several lenses of sands and gravels, each separated by clay layers. Comparisons of stratigraphies in the observation and test wells show some variations in water-bearing units and the lithologies. The numerous peaks of short normal electric resistivity of one-two metres thick indicates numerous small layers of sands and gravels between clays and silts. The water-bearing layers with electrical resistivity of more than 100 ohms are limited to three units with a total thickness of 31 m.

A.3.2.2 Medan Denai

The general stratigraphy at the Medan Denai site (Figure A.15) resembles that at the Mabar site (Figure A.13), but deep sand and gravel layers in the Medan Denai well are much thinner (total of all 16 m). The lithologic log indicated a thick, shallow sand and gravel layer from -22 down to -48 m, and then prominent clay layers from -48 to -56 m and from -62 to -78 m separate the upper sand layers from those below. From -78 m to -170 m, sand layers are very thin, 1.0 - 2.0 m, and interbedded with clay beds. In the Medan Denai well, clays are mixed with coarse sands at -106 to -172 m, -122 to -132 m, and -134 to -140 m, and these sands appear to correlate to formations with increased electrical resistivity on well logs from the Laksana and Ismailiyah wells in Kotamatsum. The thickest aquifer lies between -172 and -182 m; the total aquifer thickness is less than 20 m.

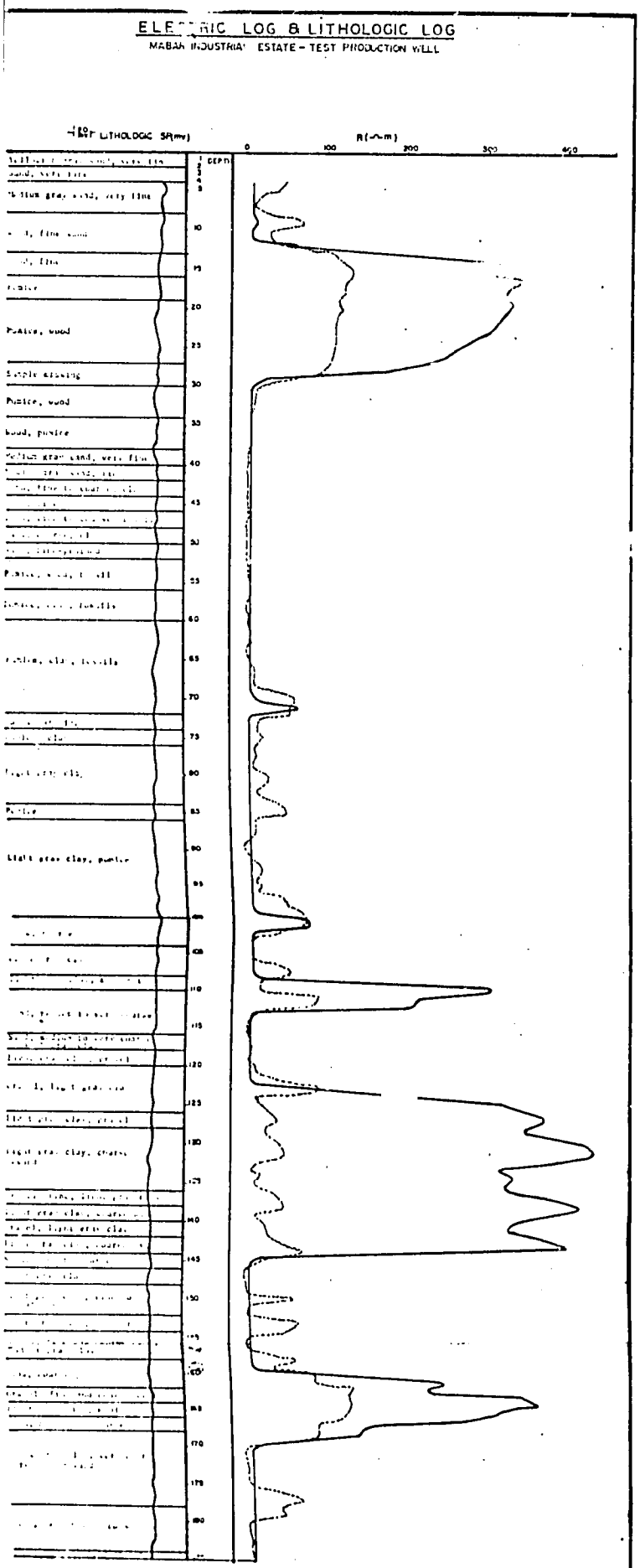
A.3.2.3 Kotamatsum

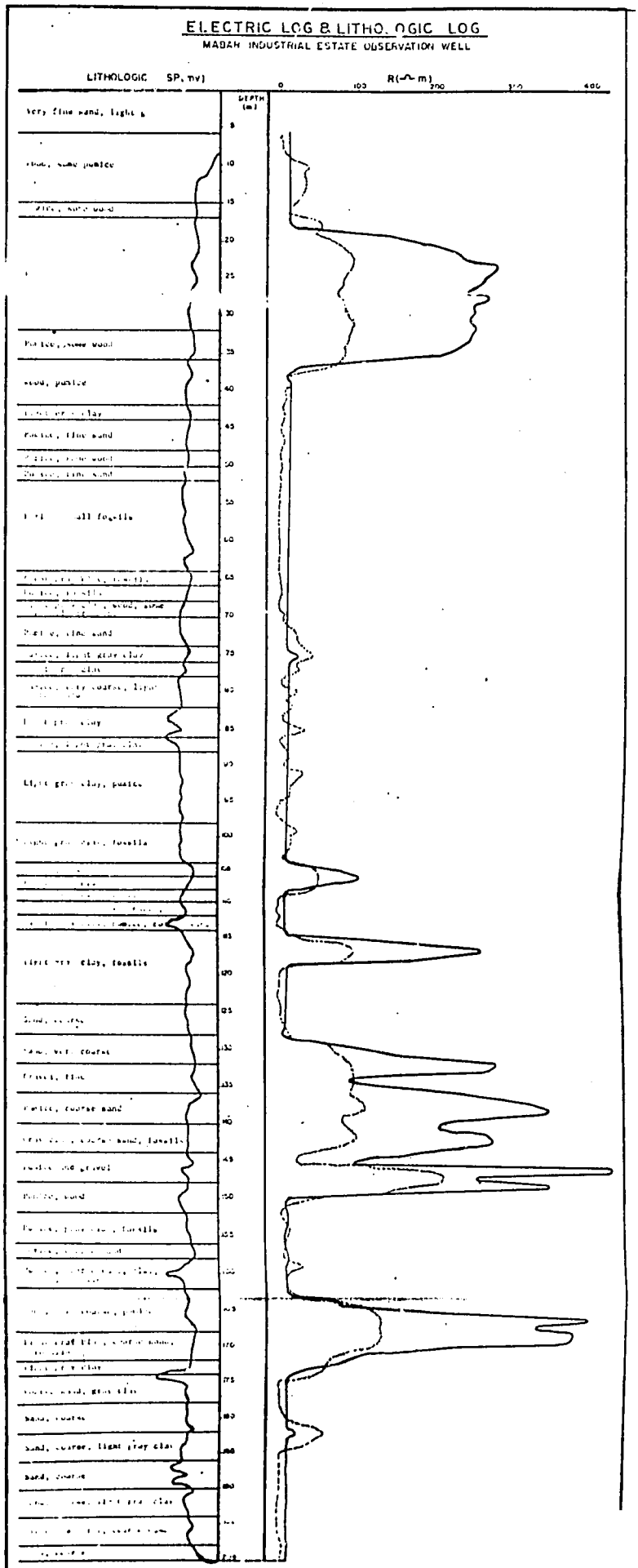
Lithological records were not available for the two wells in the Kotamatsum area, although electric logs of both wells were available.

The electric log for the Ismailiyah well (Figure A.16) shows a thick aquifer, sands and gravels, from -5 to -40 m and up to seven water-bearing layers from -85 to -195 m. The low response of the short normal resistivity plots suggests that the layers are slowly intergrading and have few distinct boundaries. Interpretations of the resistivity plots suggest that not more than about 34 m of significant water-bearing layers were penetrated in the Ismailiyah well.

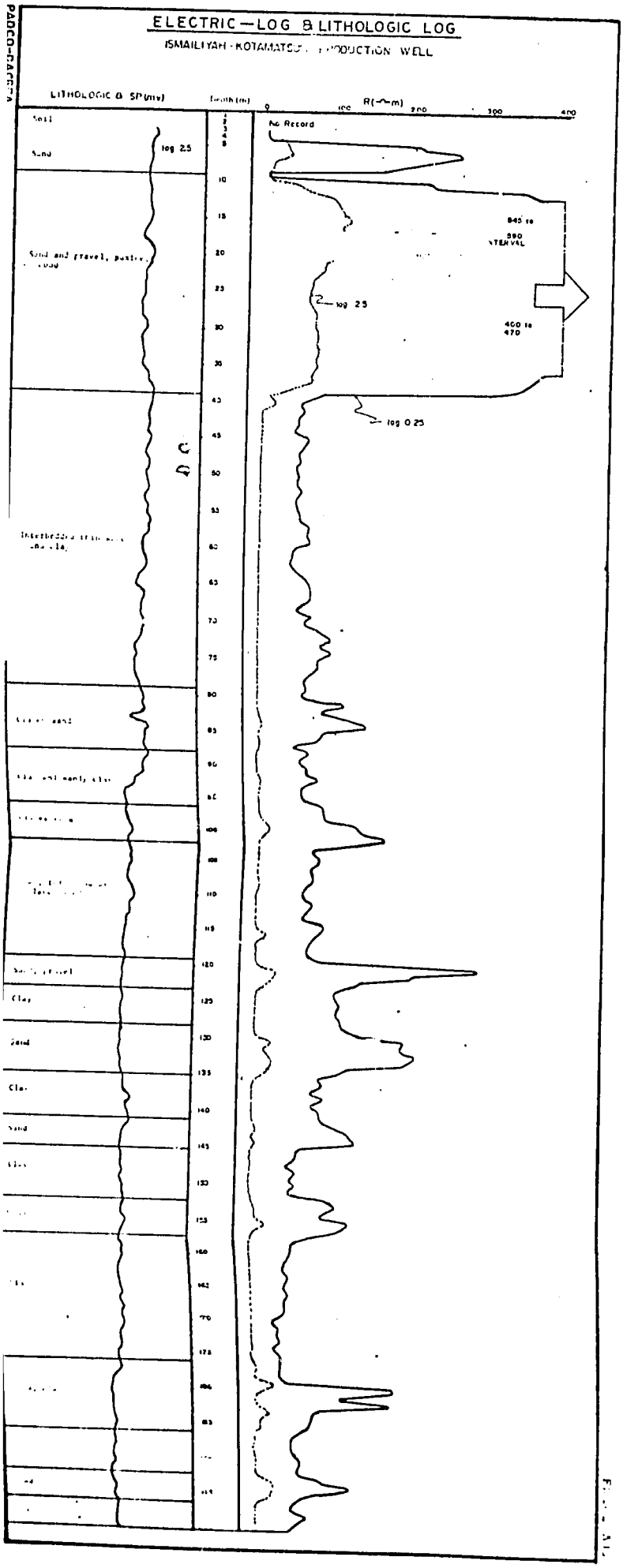
The electric log of the Laksana well (Figure A.17) shows the same shallow water-bearing layer between -5 and -40 m, plus an additional layer from -50 to -65 m. The deeper aquifers begin at -100 m and extend to -185 m, but the most prominent are at -100 to -111 m, -124 to -128 m, and -132 to -136 m. These are similar to those in the Ismailiyah well and the Medan Denai well. Other thinner and probably less productive layers occur at -142 to -146 m, -160 to -164 m, and -178 to -185 m and again are similar to those in the Ismailiyah and Medan Denai wells. The responses of the short normal resistivity are more distinct that those from the other two wells and may indicate sharper boundaries between the layers at Laksana. Assuming a threshold of 100 ohm, or more, may indicate an aquifer, the

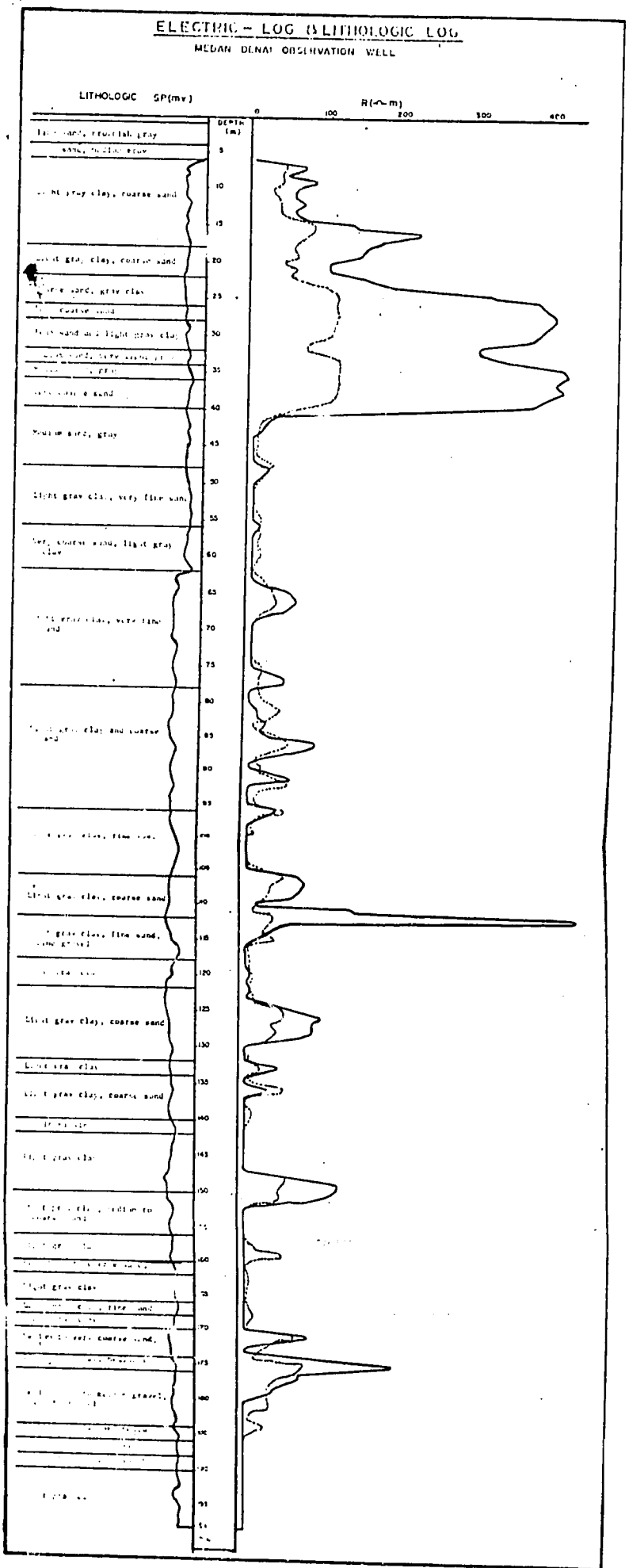
20



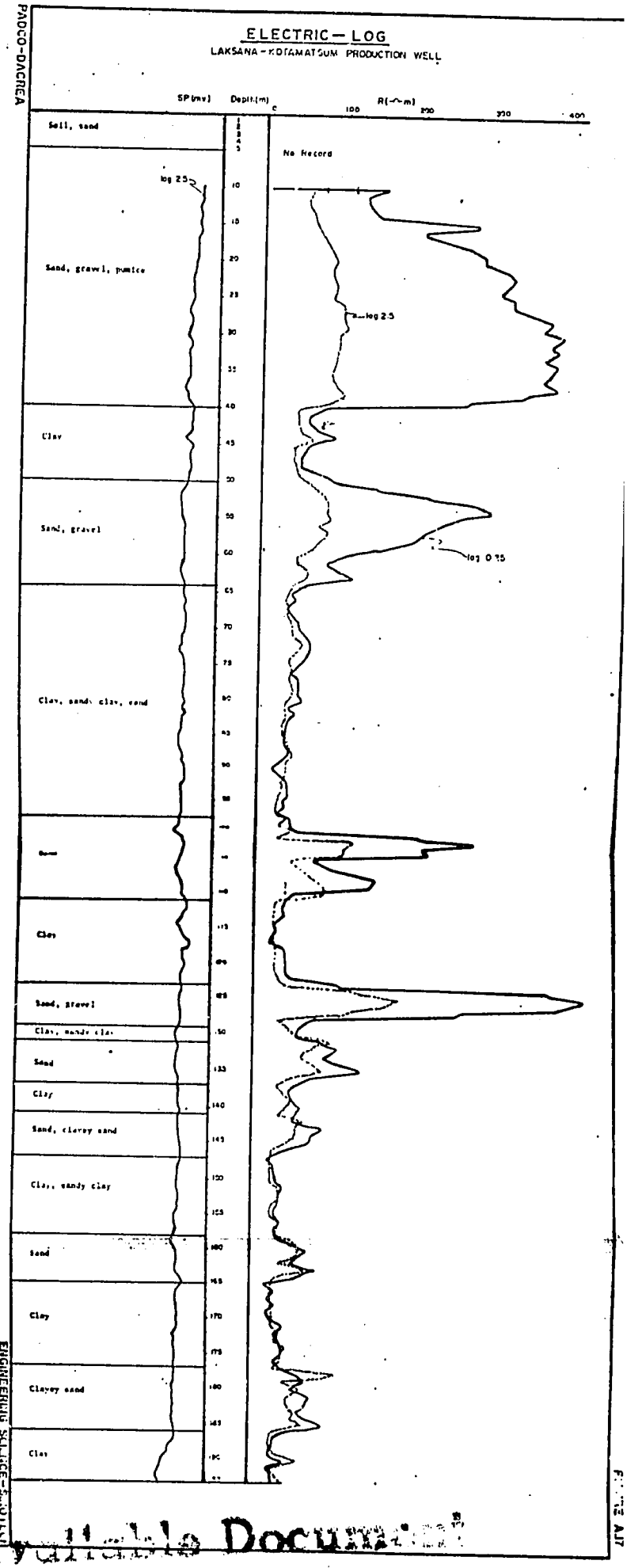


Best Available





Best Available Document



Best Available Document

Laksana electric log suggests a total aquifer thickness of 15 to 20 m, compared to about 34 m in the Ismailiyah well and to about 20 m in the Medan Denai well.

A.3.2.4 P.T. Brasseries

The well at the P.T. Brasseries Brewery on the Belawan Road lies about half way between the well at Belawan and the Mabar well and its lithology was as expected (see Figure A.12). A sand and sandy clay layer occurs from -12 to -38 m and then is separated by 38 m of clay from a deeper sand and gravel layer from -79 to -117 m. No electric log was made for the well, as it was drilled by percussion, but the lithological record should be more exact than from a rotary-drilled well.

A lithological comparison of the Brasseries well and the Mabar well indicates a somewhat thinner upper sand layer than in the Mabar well. The deeper sand and gravel layer was thicker and did not contain as much clay as encountered in the Mabar section. The sand and gravel at the brewery appear to be equivalent to those found between -80 and -125 m, although clay layers separated several sand layers.

A.3.2.5 Jati Street

During the last stage of the Drilling Program, one well was drilled by the local contractor near the intersection of Jati Street and Timor Street on the northern side of Medan and East of the Railway (see Figure A.1). The geological record from the well was available for use in this report, although the well had not been tested or designed.

The lithological record of the Jati well is quite similar to that of Mabar and appears to have thicker sands and gravels beneath -50 m than in the Medan Denai and Kotamatsum wells. The shallow groundwater table sands and gravels extended from -5 to -45 m; a thick clay from -45 to -94 m separated the upper sands and gravels from a lower sand layers. About 45 m of predominately sands and gravels were penetrated between -94 m and - 168 m, the bottom of the boring, and were separated by clays. Electric logs indicated water in the major deep aquifers with the greatest production from the deepest, -146 to -168 m.

A.3.3 Hydrogeological Implications

A.3.3.1 Lateral Extent

As discussed in Appendix E of the Master Plan for Water Supply (Vol.V, Part 1), the geology of the Medan groundwater basin indicates that several widespread aquifer extend northward from the Medan urban core. Similarities of the stratigraphy in the Medan Denai, Ismailiyah, and Laksana wells support the occurrence of laterally connected aquifers to the East, although single layers may not extend over the entire area with the exception of the -10 to -50 m aquifer. Comparisons with other well records show that similar stratigraphy continues westward.

Records from the Jati, Mabar, and Brasseries wells are quite similar to those from Belawan wells. In general, the sand and gravel aquifers appear to thicken in a northerly direction. No record is available to the South of Medan, and aquifers cannot be assumed to extend more than 10 to 15 km South.

The lateral stratigraphic continuity of aquifers and the hydraulic inter-connection between various aquifers at the same level indicate that the groundwater basin under Medan may extend more than 5 to 15 km to the West and perhaps to the East. Such breadth greatly increases the potential infiltration area and the recharge capacity of the Medan aquifers. In Appendix E, estimated yield and long-term drawdowns, used a conservative estimate of aquifer size, whereas data from the new wells and re-interpretations of older records support much larger areal extent of the aquifers, at least 15 to 20 km, East-West.

The relative thinness of the aquifers beneath the Medan urban core compared to those below the Belawan corridor would require more limited or cautious development of the Medan aquifer compared to those at Glugur, Brayan, Titipapan and Belawan. This precaution has been assumed in the Master Plan for groundwater development and the scheduling of wells in the First Stage Feasibility period.

A.3.3.2 Vertical Interconnections

The Drilling Program has not directly determined the source of recharge for the Medan basin. The occurrence of the upper, shallow aquifer, however, may be of importance to this question. The shallow aquifer between -10 and -50 m is composed of very soft white to yellow pumice. The widespread occurrence of this unit beneath Medan and its thickness of 20 to 40 m would suggest a common origin. Based upon the regional volcanic setting, the pumice layer could have been deposited either directly or indirectly by rivers eroding an ash fall or by avalanche from the Sinabung, Sibayak or Toba volcanoes. Wind-blown volcanic debris from the Toba volcano explosion has been reported in Malaysia and across other parts of Sumatra. The thick deposit appears to have been deposited on land and therefore would be at least 20,000 to 70,000 years old and could represent such an explosion.

If this pumice layer is a widespread volcanic deposit and is as permeable and saturated as indicated in Medan, a very large infiltration area could recharge this shallow layer. Although most well logs indicate some 20 to 40 separation between the shallow pumice layer and the highest of the deep aquifers at -75 to -85 m, logs from Binjei (15 km West) indicate that the sands and gravels may be lenticular units which could be connected in some areas but separated in others. The shallow pumice layer may act as an intermediate recharge source to the deeper aquifers, collecting and storing shallow groundwater then eventually recharging the deeper aquifers through interconnecting sand layers.

A.4 GEOHYDROLOGICAL ANALYSES

A.4.1 General

Analyses of groundwater resources in Medan involves the interpretation of known physical and hydraulic characteristics of the Medan aquifers and those portions penetrated by the five wells drilled during the program period. General groundwater features provide a framework for understanding the applicability of local features and test results to the entire basin. The physical features have been described in the geological discussions (Section A.3, Appendix E-1 and below). Hydraulic analyses for the basin, aquifers and wells follow the physical framework.

A.4.1.1 Aquifers and Thickness

The geological description indicated the presence of deep aquifers and shallow water table. This report considers production from the three confined aquifers. The shallow groundwater table will remain for individual residential and industrial users. The two upper aquifers generally lie below 85 and above 205 m, and the third aquifer may lie below 200 m.

The two aquifers of the Medan basin between 85 and 200 m have an aggregate thickness of 20 to 70 m. The total thickness appears to increase from South to North. Aquifers under Medan may be interconnected with those in the Binjei - Wampu River basin and in the Tanjung Morawa - Ular River basin. This interconnection would increase the potential recharge area for the Medan basin. Such a large basin allows analyses with fewer restrictions and with greater applicability.

For the purposes of this report, the very deep aquifer and the groundwater table have been assumed to be completely or near-completely sealed from the two intermediate producing zones. Based on the program wells and others, the thickness of producing aquifers over the entire basin averages at least 20 m but less than 70 m.

A.4.1.2 Porosity and Permeability

Porosity and permeability are related and have been recorded for many types of aquifers. In Belawan, porosities were estimated from electric log records. Table A.1 contains estimated porosity and permeability for various types of lithology encountered in wells of Medan.

As indicate in Table A.1, the porosity and permeability are generally related when dealing with well sorted sediments. Mixtures, however, can significantly lower permeability.

TABLE A.1

REPRESENTATIVE POROSITY AND PERMEABILITY

	Porosity % Open	Permeability cu m d/sq m	Specific Yield %
Gravel	30 - 45	10^4	15 - 30
Sand and Gravel	20 - 30	10^2	15 - 25
Coarse Sand	15 - 25	50	10 - 20
Medium Sand	15 - 20	10^1	10 - 30
Fine Sand	10 - 15	1	5 - 25
Mixed Sand, Silt and Clay	5 - 10	10^{-3}	5 - 15
Clay	30 - 45	10^{-5}	1 - 10

A.4.1.3 Transmissivity

The permeability of the Medan aquifers should be within the ranges given in Table A.1 for sands and gravels. The aquifer's coefficient for permeability normally known as transmissivity, equals to: T = K M (permeability x thickness of aquifer). The following transmissivity values show the influence of thickness and permeability.

Lithology	Permeability	Transmissivity (cu m/m.d)			
		Aquifer Thickness			
		40 m	50 m	60 m	70 m
Fine Sand	1 cu m/sq m.d	40	50	60	70
Coarse Sand and Gravel	10^2 cu m/sq m.d	4,000	5,000	6,000	7,000
Gravel	10^4 cu m/sq m.d	$4x10^5$	$5x10^5$	$6x10^5$	$7x10^5$

These values easily demonstrate the greater influence of permeability compared to aquifer thickness and a probably range of 200 to 7,000 cu m d/m for transmissivity for aquifers in Medan.

Since no available borings indicate very thick gravel formations, the transmissivity for Medan should be less than 5,000 cu m d/m width of aquifer and will probably be less than 2,000 and more than 50 cu m/m.d Analyses of individual wells have produced transmissivity values of 300 to 600 cu m/m.d equal to a medium size sand aquifer. These individual measurements are assumed to be similar to those for the remainder of the basin.

A.4.1.4 Storage Coefficient

The storage coefficient is an estimate of the water released from storage per sq m of surface per m change in water level and is inversely related to transmissivity. Values range from 0.01 to 0.35 for ground water table wells and from 0.00001 to 0.001 (5×10^{-5} is common) for confined aquifers. A storage estimate for confined aquifers has also been used as thickness in metres x 3.28×10^{-6} (e.g. $20 \times 3.28 \times 10^{-6} = 6.56 \times 10^{-5}$).

Separation of influences from storage compared to leakage is difficult to determine in several days of pumping. Large leakage will reduce long-term drawdown much in the same way as surface water may recharge an aquifer or as an aquifer with a very high storage may release large volumes when pumped.

A.4.2 WELL ANALYSES

The uses of well data for geohydrologic analyses primarily focus on the comparison of production to drawdown either at the test well or at the observation well during the pumping and recovery tests. Most analyses involve calculation of transmissivity which relates permeability and total aquifer thickness. Several simplified formulae are commonly used to estimate transmissivity but few have been applied to storage coefficients. With the combined monitoring of the test and observation wells, additional analyses were made to compare to values derived from the simplified, steady state formula. Data was analyzed for use in graphical solutions of the Theis equation for non-steady conditions.

The Theis equation was also used to estimate the radius of influence while the long-term drawdown was estimated by projection of short-term drawdown.

A.4.2.1 Mabar Analyses

The testing of the Mabar well involved pumping of the test well and then recovery, while measuring drawdown at the test well and one observation well 30 m away. Water levels in the observation well had been measured for six weeks and in the test wells for two days before the test pumping. Flow was constant throughout the pumping test at 72 cu m/hr (20 litres/second). Table A.2 gives the time and water levels for the pumping and recovery tests. Figures A.18 and A.19 show the drawdown and recovery elapsed time values on semilog graph.

MEASURED AND PROJECTED DRAWDOWNS FOR TEST RESULTS AT MABAR SITE

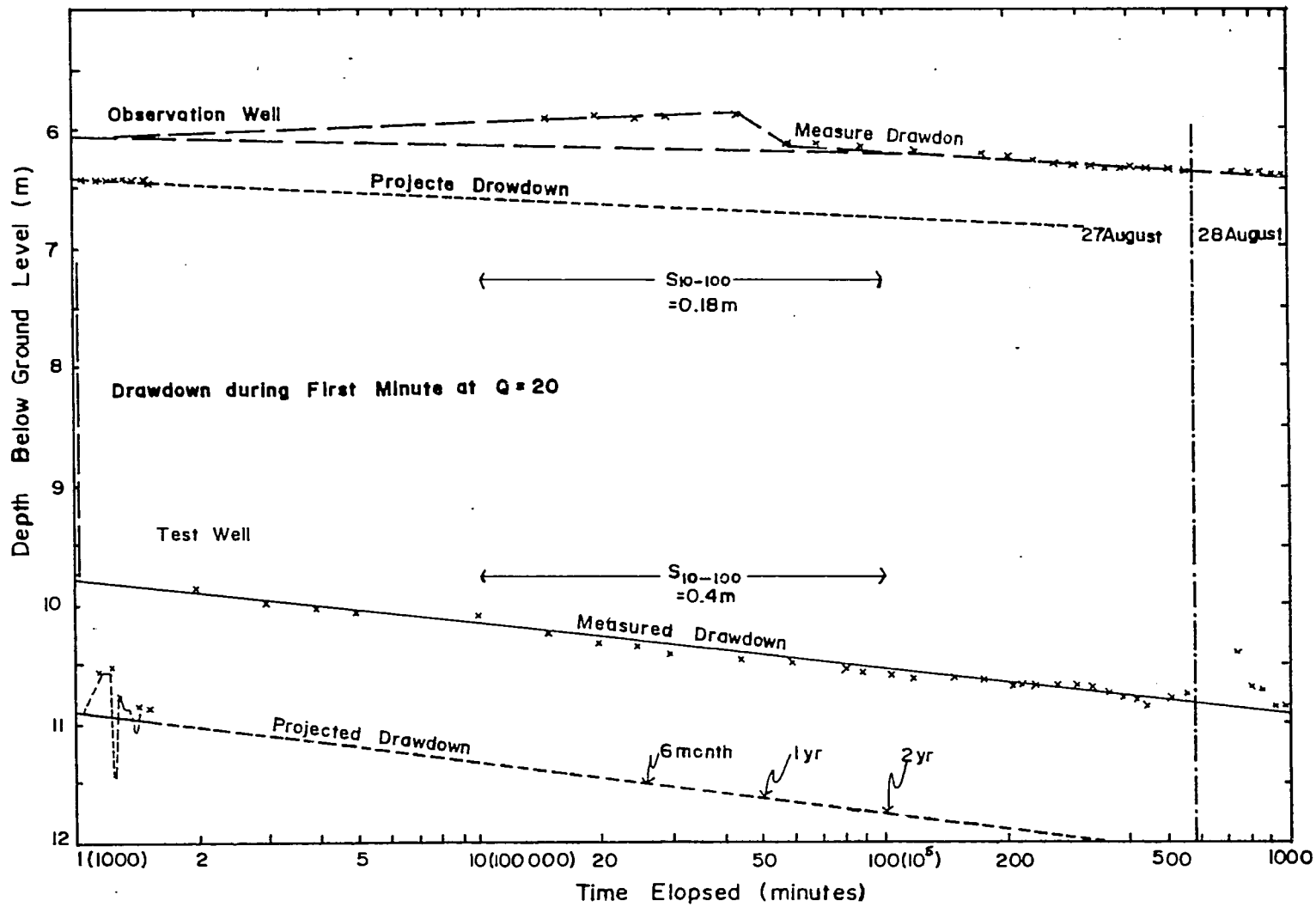


FIGURE A.18

RECOVERY TEST RESULTS FROM MABAR SITE

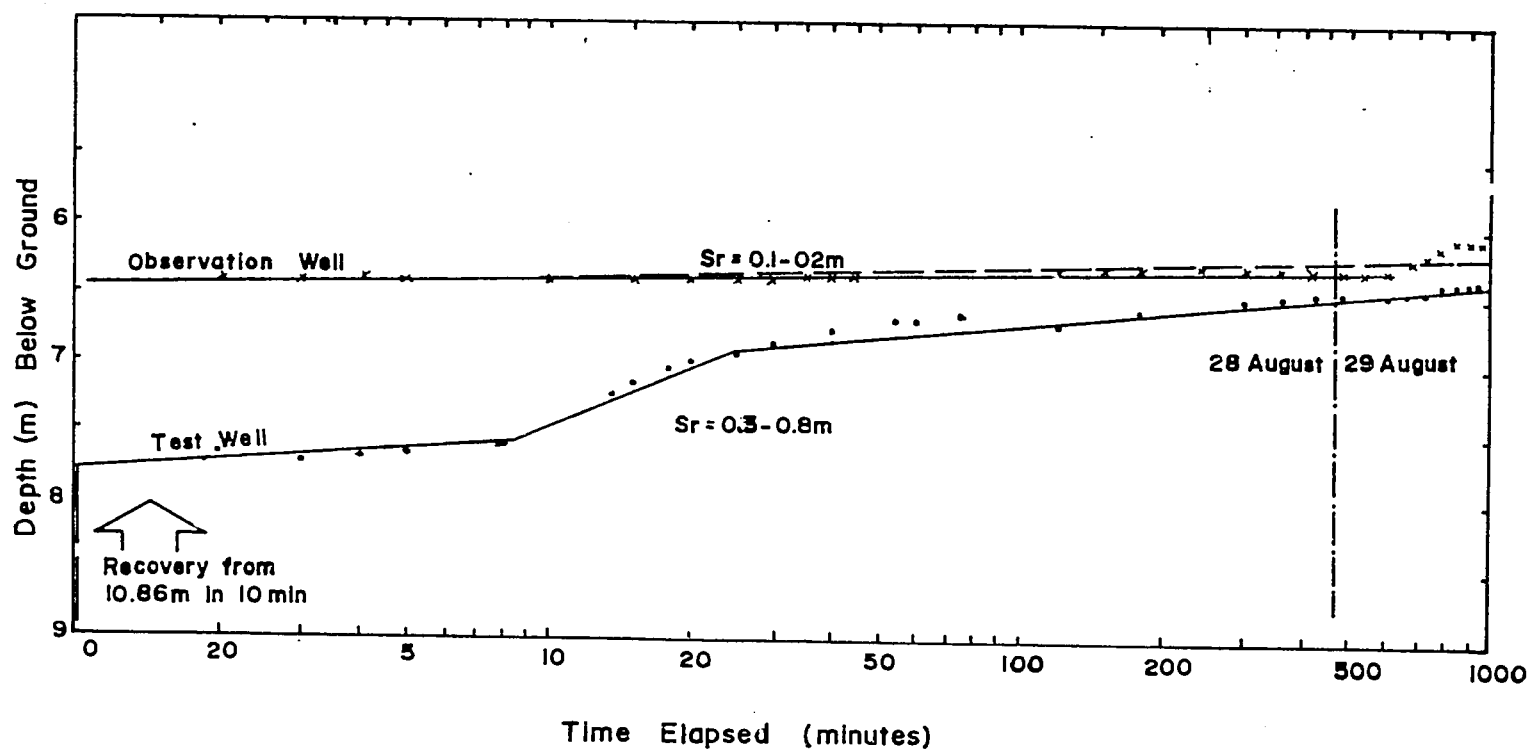


FIGURE A.19

ENGINEERING SCIENCE-SINOTECH

From the latter formulation, the value of T, 620, are identical to that derived in the previous calculation 643 cu m/m.d, but the storage coefficients, 0.19 and 0.18 are more as would be expected in a confined aquifer.

Comparison of the transmissivity estimates of 792 cu m/m.d and the Theis values of 630 cu m/m.d suggests that data analyses of production well only will result in higher values than actually exist. The calculated storage coefficient of S = 0.19 (u = 0.20) appears higher than that expected from confined aquifers (e.g. 40 x 3.28 x 10^{-6} = 0.00013 or less).

The very high storage values of 0.18 may reflect use of non-leaky confined aquifer type curves for the Theis equation. More typical S values of 0.0001 would require either greater distance (thereby greater radius of influence) or much smaller transmissivity value, and therefore would result in increased drawdown or decreased production. A second alternative would involve the assumption that the aquifer system is leaky and pumps other sources (e.g. the shallow ground water table or the deeper aquifer below -200 m).

Recalculation and transposition of type curves for confined aquifers with leaky confining layers and with or without release from storage resulted in transmissivity values of 500 to 650 cu m/m.d or about 610 cu m/m.d. The storage values decreased somewhat from the high value of 0.19 down to 0.013 - 0.039. These values are quite high compared to 1.3 x 10^{-4}.

The only other recharge source is the Deli River, about 1.0 km west of the well site. Some recharge may occur between the river and the shallow ground water table and indirectly to the deeper aquifer, but the magnitude and responsiveness of such an interconnection cannot be estimated.

Transmissivity values of 510 to 790 appear to be reasonable estimates when compared to expected permeability (See Table A.1). Assuming an aquifer thickness of 30 m, the calculated permeability (P = T/M) equal 17 to 26 cu m/sq m.d. This lies within the expected range for medium sand.

As indicated in Table A.2 and Figure A.18, the drawdown in the observation well was quite small (0.39 m) and relatively small in the pumped well (3.8 m, compared to more than 10 m in other wells). In other basis, long-term drawdown has been estimated by projecting semilog plots of short-term drawdown. In Figure A.18, projections are provided for the Mabar test and observation wells. Total drawdown in the test well would be about 4.5 m (-11.5 m) after 6 months and 4.75 m (-12.0 m) after 2.5 years of continuous pumping at 72 cu m/hr.

At 30 m distance, water level should decline by 0.75 m after 2.0 years of pumping at the test well. At distances of more than 250 m, little if any drawdown should be observed. Very deep drawdowns (more than 20 m drawdown) at the Intan Iron Factory along the Belawan Road do not appear to influence the Mabar water levels.

TABLE A.2

WELL TEST RESULTS AT MABAR

a. Mabar Test Well
Pumping Test : 27-28 August 1980
Begun : 14:22
Casing Level : + 0.81 a g l*

Time	Minutes Elapsed	Depth* (m)	Time	Minutes Elapsed	Depth* (m)
August 27, 1980			August 28, 1980		
14:21	0	7.01		630	-
14:22	1	9.75		690	-
	2	9.81	02:52	750	10.36
	3	9.94		810	10.65
	4	9.97		870	10.68
	5	10.00		930	10.82
	10	10.03		990	10.82
	15	10.19	07:22	1020	10.88
	20	10.26		1155	10.53
	25	10.30		1220	10.50
	30	10.34	11:22	1260	11.39
	45	10.40		1290	10.73
	60	10.42		1320	10.82
	81	10.48		1350	10.82
	90	10.52		1380	10.87
	105	10.54		1410	11.03
16:22	120	10.57		1440	10.77
	150	10.57		1470	10.82
17:22	180	10.57	16:00	1538	10.81
	210	10.62			
18:22	240	10.62			
	270	10.63			
19:22	300	10.63			
	330	10.65			
20:22	360	10.70	(Total Drawdown 3.80m)		
	390	10.72			
21:22	420	10.76			
	450	10.81			
	510				
23:52	570				

* Depths measured above or below ground level (a/b g l) at well head.

37

TABLE A.2--Continued

b. Mabar Observation Well
Pumping Test : 27-28 August 1980
Begun : 14:22
Casing Level : + 0.565 m* - observation well
+ 0.635 m* - test well

Time	Minutes Elapsed	Depth* (m)	Time	Minutes Elapsed	Depth* (m)
August 27, 1980			August 28, 1980		
14:21	0	6.10		630	
	1			690	
	3		02:52	750	6.40
	4			810	6.40
	5			870	6.41
	10			930	6.41
	15	5.90		990	6.42
	20	5.93	02:22	1020	6.42
	25	5.93		1155	6.42
	30			1220	6.43
	45		11:22	1260	6.43
	60	6.16		1290	6.43
	70	6.17		1320	6.44
	90	6.18		1350	6.45
	105	6.23		1380	6.45
	120	6.22		1410	6.45
	150	6.26	14:22	1440	6.46
	180	6.26	14:52	1470	6.46
	210	6.27	16:07	1545	6.46
	240	6.29			
	270	6.32			
	300	6.33			
	330	6.34			
	360	6.35	(Total Drawdown 0.39 m)		
	390	6.35			
	420	6.36			
	450	6.37			
	510	6.38			
23:52	570	6.39			

* Depth measured above or below ground level at test well head, 30.5 m to South-West.

37

Table A.2--Continued

c. Mabar Test Well
Recovery Test : 28-29 August 1980

Time	Minutes Elapsed	Depth* (m)	Time	Minutes Elapsed	Depth* (m)
August 28, 1980			August 29, 1980		
	0	10.86		480	6.48
16:12	1	7.87		540	6.48
	2	7.68	02:12	600	6.47
	3	7.74		660	6.46
	4	7.71		720	6.44
	5	7.68		780	6.43
	8	7.62		840	6.42
	9	7.53	07:12	900	6.40
	10	7.48	07:45	933	6.39
	13.5	7.24	11:20	1088	6.34
	15	7.15			
	18	7.04**			
	20	7.01			
	22	6.97			
	25	6.93	Original Level		
16:42	30	6.84	14:21	0	-7.06
	40	6.76	(Total Recovery : + 3.8 m)		
	55	6.70	(Residual Drawdown: +0.72**)		
17:12	60	6.68			
	75	6.65			
	120	6.70			
19:12	180	6.62			
	240	6.60			
	300	6.52			
	360	6.49			
23:12	420	6.48			

* Depths measured above or below ground level (a/b g l) at well head.

**Original static water level 7.06 m b g l, 27 August 1980. Recovery level at 14:21, 1st September 1980 (5600 minutes) was -6.89 m.

34

TABLE A.2--Continued

d. Mabar Observation Well
Recovery Test : 28-29 August 1980
Begun : 16:12
Casing Level : + 0.565 a g l - observation well
+ 0.635 a g l - test well

Time	Minutes Elapsed	Depth* (m)	Time	Minutes Elapsed	Depth* (m)
August 28, 1980			August 29, 1980		
	0	6.49		480	6.32
16:12	1	6.48		540	6.32
	2	6.43	02:12	600	6.30
	3	6.43		660	6.32
	4	6.42		720	6.19
	5	6.42		780	6.12
	10	6.41		840	6.07
	15	6.41	07:12	900	6.06
	20	6.40	07:45	933	6.07
	25	6.40	08:07	955	6.07
	30	6.39	11:20	1148	6.07**
	35	6.39			
	40	6.38			
	45	6.37			
17:12	60	6.35			
	120	6.32			
19:12	180	6.32			
	240	6.32			
21:12	300	6.32			
	360	6.32			
23:12	420	6.32			

* Depths measured above or below ground level at test well head
** Original static level was -6.10 m b g l at 14:21, 27 August 1980. Recovery level at 14:21, 1 September 1980 (5600 minutes) was -6.00.

35

The total drawdown at the test well was 3.8 m while at the observation well drawdown was only 0.39 m. The specific capacity of 19.0 cu m hr/m drawdown is more productive than most Medan and Belawan wells, except for the Port No.20 well with 33 cu m hr/m drawdown.

Transmissivity for Medan wells has been estimated previously by the formula:

$$T \text{ (cu m/m.d)} = \frac{264 \times Q \text{ (cu m/min)}}{\text{delta s (drawdown in m per log cycle)}} \quad \left(= \frac{2.303\ Q}{4 \times \pi \times \text{delta s}}\right)$$

Using this formula, T values for Belawan wells nos. 16, 17, 18, 19 and 20 were estimated at 647 (539 by ES), 565, 440, 880 and 5060 cu m/m.d. The same estimate for the Mabar test well equals:

$$T = \frac{264 \times 1.2}{0.4} = 792 \text{ cu m/m.d}$$

Other estimates of transmissivity yield similar results:

$$T = \frac{1.6 \times 1728 \text{ cu m/d}}{3.8 \text{ m}} = 728 \text{ cu m/m.d}$$

Calculations of Dupuit equation (steady state) for pumped and one observation wells result in the following:

$$K\,M = T = \frac{Q \log e\ (r_1/rw)}{2 \times \pi \times (s_w - s_1)}$$

$$T = \frac{1728 \times \log e\ (30.5/0.15)}{2 \times \pi \times (3.80 - 0.39)}$$

$$T = \frac{9184}{21.43} = 429 \text{ cu m/m.d}$$

and for one well:

$$K\,M = T = \frac{Q \times \log e\ (r_e/r_w)}{2 \times \pi \times s_w}$$

$$r_e = 250,\ 500,\ 1000 \text{ m}$$

$$\ln (r_e/r_w) = 7.42,\ 8.11,\ 8.8 = R$$

$$T = \frac{1728 \times R}{2 \times \pi \times 3.8} = 537,\ 587, \text{ and } 637 \text{ cu m/m.d}$$

Therefore, the trends of capacities and estimated transmissivity follow similar trends.

36

Past use of these estimates was required in the absence of any observation wells in the vicinity of the pumping well. The drilling and monitoring of the observation well at Mabar allows a different transient type of analyses (after Theis):

$$s = \frac{Q}{4 \times \pi \times T} W(u) \qquad u = \frac{r^2 S}{4Tt}$$

s = drawdown
Q = pumping rate
T = transmissivity
W (u) = well function of u

r = distance to observation well
S = storage coefficient
t = time in days

Based upon transpositions of the Theis type curve and drawdown : t/r^2 curve from the observation well, the curve transposition yeild the following factors:

W (u) = 1.24 when
1/u = 5, u = 0.2, and
s = 0.265 when
t/r^2 = 0.00035.

Substituting these values into the general Theis formulae yield:

$$0.265 = \frac{1738 \text{ cu m/d}}{4 \times \pi \times T} \times 1.24 \quad \text{or} \quad T = \frac{1738 \times 1.24}{4 \times \pi \times 0.205}$$

$$T = 643 \text{ cu m/m.d}$$

$$0.2 = \frac{S}{4 \times 643} \times (0.00035 = (\frac{r^2}{t}))$$

$$S = 0.2 \times 4 \times 643 \times 0.00035$$

$$S = 0.18$$

Using a modified form of the Theis equation and curves transpositions which substitutes 1/t and t, the following factors were found:

W (u) = 1.24 when
1/u = 5.0 and
u = 0.2; and

t/1 = 0.0115 and t = 0.35 when
s = 0.275

With these values, the Theis formulae yield the following results:

$$0.275 = \frac{1728 \text{ cu m/d}}{4 \times \pi \times T} \times 1.24 \quad \text{or} \quad T = \frac{1728}{4 \times \pi \times 0.275} \times 1.24 = 620 \text{ cu m/m.d}$$

$$S = \frac{(30.5)^2}{0.35} \times 0.2 \times 620 \times 4 = 0.18$$

A.4.2.2 Medan Denai Analyses

The testing of the Medan Denai well involved pumping of the test well and then allowing recovery during two 24-hour periods. Water levels were periodically measured for six weeks before the pumping test. Measurements were taken in the pumping well and at the observation well, 15.8 m away. Recovery measurements were measured periodically for four days following the pumping test because of slow rates of recovery. Table A.3 gives the time and water levels for the pumping and recovery tests. Figures A.20 and A.21 show the drawdown and recovery elapsed time values on semilog graph.

The total drawdown at the test well was 9.0 to 9.5 m, while at the observation well, the drawdown was 1.8 m. The specific capacity of the test well was about 5.0 cu m/hr per metre of drawdown. This capacity is slightly less than at the Kotamatsum Wells(see Section A.4.2.3) and is similar to many standard production wells in Medan and Belawan. The low capacity compared to the Mabar Well (5.0 cu m/hr compared to 19.0 cu m/hr) reflects the thinner aquifers and lower permeability of the finer sands encountered in the Medan Denai Well.

Transmissivity for Medan wells has been estimated previously by the formula:

$$T \text{ (cu m/m.d)} = \frac{264 \times Q \text{ (cu m/min)}}{\text{Delta s (drawdown in metres per log cycle)}}$$

Using this formula, the T values for the Medan Denai well can be estimated from the drawdown and recovery indicated on Figures A.20 and A.21:

	Delta s (m)	Transmissivity (cu m/m.d)
Drawdown	0.35	543
	0.45	422
	0.50	380
	0.80	238
	1.00	190
	1.80	106
Recovery	0.35	543
	0.40	475
	0.50	380
	0.60	317

Other estimates of transmissivity yield lower than average results:

$$T = \frac{1.6 \times 1037 \text{ cu m/d}}{9.0 \text{ m}} = 184 \text{ cu m/m.d}$$

TABLE A.3

WELL TEST RESULTS AT MEDAN DENAI

a. Medan Denai Test Well
Pumping Test : 20-21 September 1980
Begun : 09:04
Casing Level : 0.61 a g l*

Time	Minutes Elapsed	Depth* (m)	Time	Minutes Elapsed	Depth* (m)
September 20, 1980					
09:04	0	9.58	15:00	355	17.77
09:05	1	15.00		385	17.66
	2	15.60	16:00	415	17.65
	3	15.96		445	17.63
	4	16.17	17:00	475	17.74
	6	16.51		505	17.65
	7	16.62	18:00	535	17.72
	12	16.73		595	17.81
	13	16.82		655	17.90
	15	16.90		715	17.90
	16	16.91		775	18.11
	21	16.88		835	18.07
	27	16.95			
	47	17.07	September 21, 1980		
10:10	65	16.94	00:00	895	18.58
	79	17.18		955	18.39
	82	16.74		1015	18.22
	100	17.15		1075	18.17
	104	17.31	04:00	1135	18.62
	127	17.26		1195	18.65
	152	17.37		1255	19.07
	169	17.33		1315	19.53
12:04	179	17.33	08:00	1375	19.19
	205	17.36	09:10	1445	18.23
13:00	235	17.49			
13:30	265	17.76			
14:00	295	17.87			
14:30	325	17.73	(Total Drawdown: 9.00 - 9.55 m)		

* Depths measured above or below ground level (a/b g l) at well head.

29

TABLE A.3--Continued

b. Medan Denai Test Well
Pumping Test : 20-21 September 1980
Begun : 09:04
Casing Level : +0.55 m* - observation well
+0.62 m* - test well

Time	Minutes Elapsed	Depth* (m)	Time	Minutes Elapsed	Depth* (m)
September 20, 1980					
09:04	0	9.84	15:00	354	11.13
09:05	1	9.96		384	11.19
	2	10.04		414	11.20
	3	10.09		444	11.24
	4	10.12		474	11.26
	5	10.16		504	11.28
	6	10.18	18:00	534	11.23
	7	10.20		594	11.32
	8	10.23		654	11.42
	9	10.24		714	11.40
	10	10.26		774	11.40
	15	10.31	23:00	834	11.43
	20	10.34			
	25	10.40	September 21, 1980		
09:34	30	10.44			
	35	10.48	00:00	894	11.46
	40	10.51		954	11.48
	45	10.52		1014	11.51
10:04	60	10.61		1074	11.53
	75	10.64		1134	11.56
	90	10.69		1194	11.59
	105	10.73	06:00	1254	11.60
11:04	120	10.78		1314	11.65
	135	10.82	08:00	1374	11.63
	150	10.84	08:30	1404	11.61
12:04	180	10.87	09:10	1444	11.65
	204	10.90			
	234	10.98			
	264	10.99			
	294	11.06			
	324	11.10	(Total Drawdown: 1.83 m)		

* Depth measured above or below ground level at test well head, 15.8 m to East.

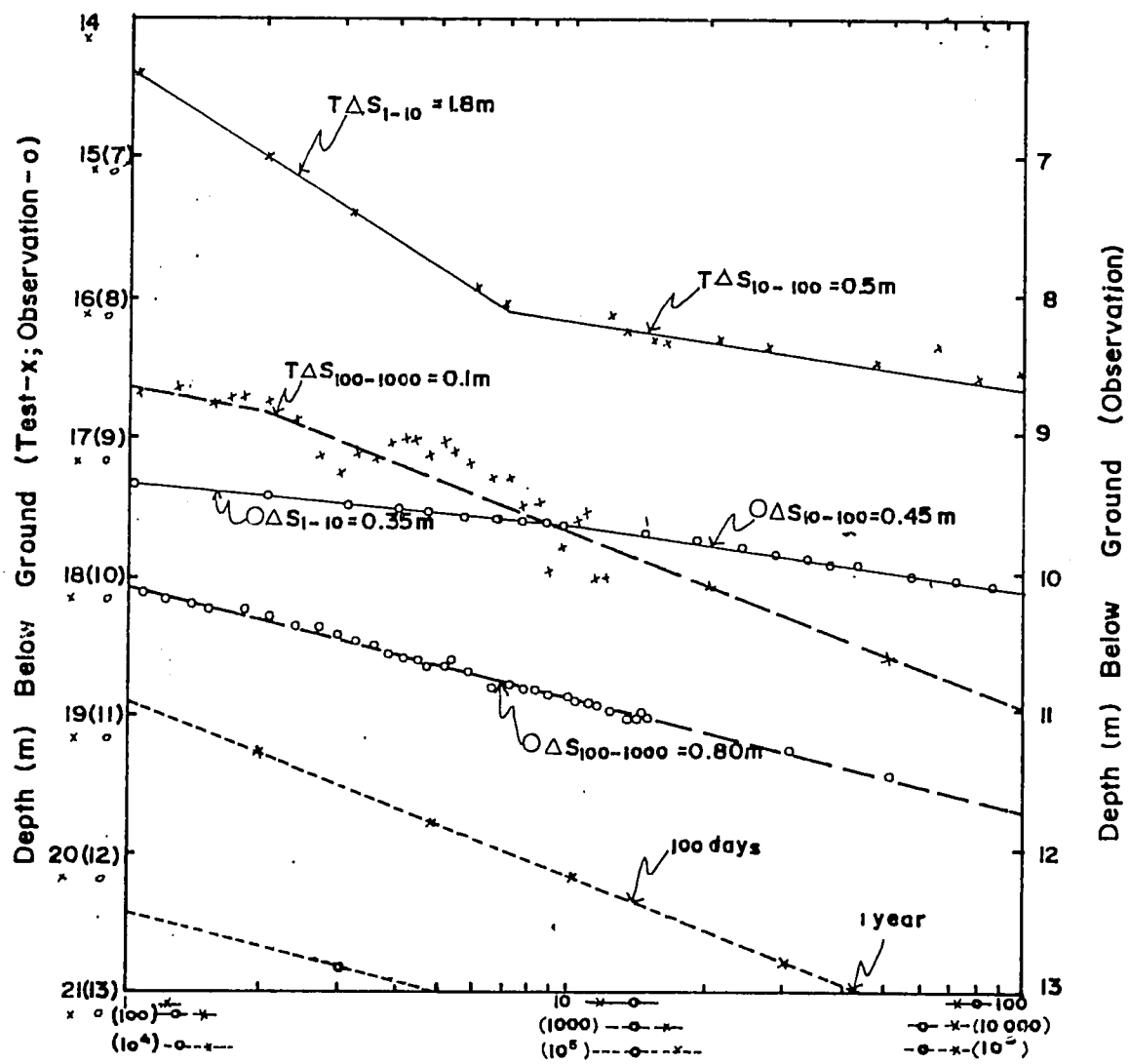
TABLE A.3--Continued

c. Medan Denai Test Well and Observation Well
Recovery Test : 21-24 September 1980
Begun : 09:10

Time	Minutes Elapsed	Test Well Depth* (m)	Observation Well Depth* (m)
September 21, 1980			
09:10	0	18.23	11.65
	1	11.75	11.61
	2	11.71	11.48
	3	11.64	11.45
	4	11.61	11.42
	5	11.56	11.40
	10	11.45	11.32
	15	11.39	11.29
	20	11.34	11.24
	25	11.29	11.21
09:40	30	11.26	11.18
	35	11.24	11.17
	40	11.22	11.14
	45	11.20	11.14
10:10	60	11.14	11.08
	90	11.02	10.97
11:10	120	10.94	10.90
	150	10.89	10.84
	180	10.88	10.83
	240	10.81	10.74
	270	10.74	10.71
	300	10.72	10.66
	330	10.70	10.64
15:10	360	10.67	10.63
	420	10.64	10.62
	540	10.58	10.56
	720	10.53	10.52
22:20	790	10.625	10.48
September 22, 1980			
07:45	1355	10.52	10.37
14:45	1775	10.43	10.32
September 23, 1980			
11:00	2990	10.38	10.25
September 24, 1980			
09:00	4310	10.33	10.20
Original Water Levels		-9.58 m	-9.84 m
Three-Day Recovery Level		-10.33 m	-10.20 m
Residual Drawdown		+0.75 m	+0.36 m

41

DRAWDOWN TEST RESULTS FROM MEDAN DENAI SITE



RECOVERY TEST RESULTS FOR MEDAN DENAI SITE

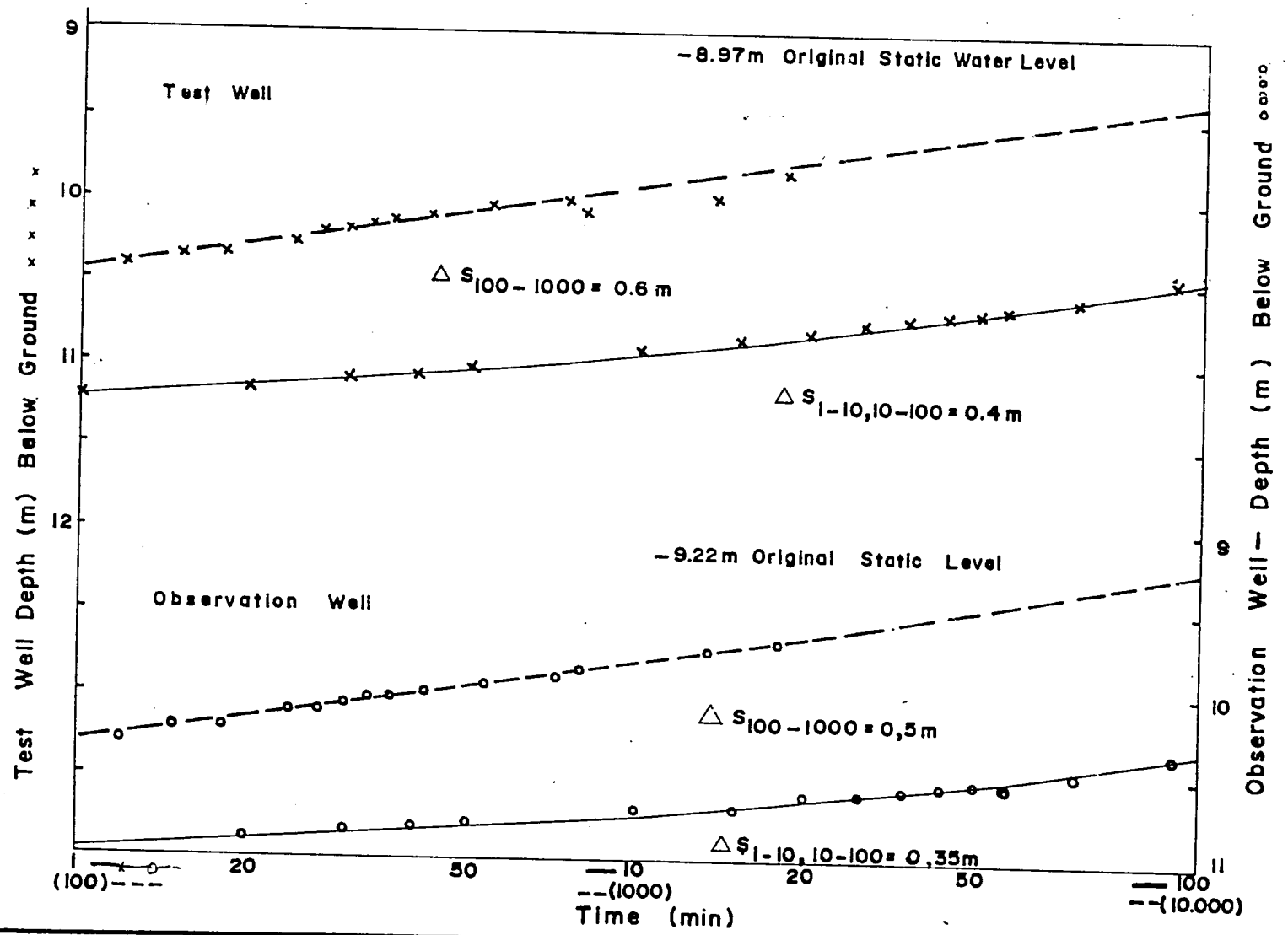


FIGURE A.21

PADCO-DACREA

ENGINEERING SCIENCE-SINOTECH

43

Calculations of Dupuit equation (steady state) for pumped and one observation wells result in the following:

$$K\,M = T = \frac{Q \log e\,(r_1/r_w)}{2 \times \pi \times (s_w - s_1)}$$

$$T = \frac{1037 \times \log e\,(15.9/0.15)}{2 \times \pi \times (9.0 - 1.8)}$$

$$T = \frac{4836}{45.2} = 107 \text{ cu m d/m}$$

and for one well with an estimated radius of influence:

$$K\,M = T = \frac{Q \times \log e\,(r_e/r_w)}{2 \times \pi \times s_w}$$

$$r_e = 250,\ 500,\ 1000 \text{ m}$$

$$\ln\,(r_e/r_w) = 7.42,\ 8.11,\ 8.8 = R$$

$$T = \frac{1728 \times R}{2 \times \pi \times 9.0} = 136,\ 149 \text{ and } 161 \text{ cu m d/m}$$

Therefore, the trends of capacities and some estimated transmissivities follow similar trends. Generally, the low specific capacity (5 - 10 cu m/m.hr) corresponds with low estimates of transmissivity (107 - 161 and 106 - 238 cu m/m.d). The higher rates of drawdown and recovery (0.8 - 1.8 m/log cycle) yield the low estimates, while the lower rates of drawdown (0.35 - 0.6 m/log cycle) support higher transmissivity values (x 2 - x 3 greater).

In general, recovery rates should be somewhat more reliable than drawdown rates since less influence is produced by well efficiency. Therefore, the recovery rates and the lower range of drawdown rates are assumed to be more typical of the aquifers at Medan Denai.

Past use of these estimates was required in the absence of any observation wells in the vicinity of the pumping well. The drilling and monitoring of the observation well at Mabar allows a different transient type of analyses (after Theis):

$$s = \frac{Q}{4 \times \pi \times T}\,W\,(u) \qquad u = \frac{r^2 S}{4Tt}$$

s = drawdown
Q = pumping rate (cu m/d)
T = transmissivity
W (u) = well function of u

r or 1 = distance to observation well
S = storage coefficient
t = time in days

41

Based upon transpositions of the Theis type curve and drawdown: t and t/1 curves from the observation well, the curve transposition yield the following factors:

First Trial	Second Trial
W (u) = 2.5 when	W (u) = 4.5 when
1/u = 20, u = 0.05, and	1/u = 150, u = 0.0067, and
s = 0.37 when	s = 1.1 when
t = 0.005	t = 0.15
t/1 = 3.1×10^{-4}, or	t/1 = 9.4×10^{-3}, or
$t/r^2 = 2.0 \times 10^{-5}$	$t/r^2 = 5.9 \times 10^{-4}$

Substituting these values into the general Theis formulae yield:

$$0.37 \text{ m} = \frac{1032 \text{ cu m/d}}{4 \times \pi \times T} \times 2.5 \qquad 1.1 \text{ m} = \frac{1032 \text{ cu m/d}}{4 \times \pi \times T} \times 2.5$$

$$T = 557 \text{ cu m/m.d} \qquad T = 338 \text{ cu m/m.d}$$

$$0.05 = \frac{(15.9)^2 \times S}{4 \times 557 \times 0.005} \qquad 0.0067 = \frac{(15.9)^2 \times S}{4 \times 338 \times 0.15}$$

$$S = 0.0022 \qquad S = 0.0054$$

Both trials produced transmissivity values (557-338) which are within the upper range of those derived from the simplified formulae. Storage values for the Medan Denai Well are lower than those calculated for the Mabar Well (0.002 - 0.005 compared to 0.18 - 0.19, respectively). The Medan Denai values are x 50 higher than that expected for a fully confined aquifer without leakage from other aquifers. However, a more typical fully confined aquifer with storage value of 0.000001 would produce greater drawdown. When the Medan Denai drawdown: time curve is compared to Theis type curves for leaky aquifers, transmissivity decreased to 300 to 400 cu m/m.d with storage values of 1×10^{-5} to 10^{-6} which are expected in the fine to medium sands below Medan City.

The aquifer thickness at Medan Denai is less than that at Mabar (i.e. 20 m compared to 40 m) and the derived permeability for the Medan Denai aquifers would be about 15 to 20 cu m/sq m.d (these values are expected in the medium sand at Medan Denai, see Table A.1) and are only slightly less than at Mabar.

The consistent results would support lower transmissivity and storage values than at Mabar. The range of 100 to 1000 cu m/m.d is generally considered as a fair or medium quality water supply well, whereas 5000 cu m/m.d would be considered as good production.

In Figure A.20 the measured drawdown was used to extrapolated the expected drawdowns at the pumping well and observation well. The projected drawdown in the pumping well would be 11.5 m (level at-20.5 m) after six months and 12.0 m after one(1) year. At a distance of 16 m, water level should fall to about -13.5 m after six months and -13.8 m after one year. Similar drawdown projections were found for the Kotamatsum Wells.

A.4.2.3 Kotamatsum Wells Analyses

The Kotamatsum wells were tested by constant production of 72 cum/hr for several days and then for recovery. The results are presented graphically in Figures A.22 and A.23. Both wells had static water levels of about -11.7 m and pumping water levels of -21.0 m at 72 cu m/hr production. A drawdown of 9.3 m at 72 cu m/hr results in a production capacity of only 7.7 cu m/m hr drawdown which is 40 percent of that in the Mabar well. From the plots and projections in Figures A.22 and A.23, transmissivity is as follows:

$$T_I = \frac{264 \times 1.2}{\text{delta } s = 1.0} \qquad T_L = \frac{264 \times 1.2}{\text{delta } x = 0.8}$$

$$T_I = 317 \text{ cu m d/m} \qquad T_L = 396 \text{ cu m d/m}$$

$$T = \frac{1.6 \times 1728}{8.95} \qquad T = \frac{1.6 \times 1728}{9.44}$$

$$T_I = 309 \text{ cu m d/m} \qquad T_L = 293 \text{ cu m d/m}$$

Other estimates are somewhat lower than those from the above formula:

$$T = \frac{Q \times \log e\ (r_e/r_w)}{2 \times \pi \times s_w} \qquad s_I = 8.95 \qquad s_L = 9.45$$

$$r_e = 250,\ 500,\ 1000 \text{ m} \qquad l_n\ (r_e/r_w) = 7.42,\ 8.11,\ 8.80$$

$$T_{I-250} = 228 \text{ cu m d/m} \qquad T_{L-250} = 216 \text{ cu m d/m}$$

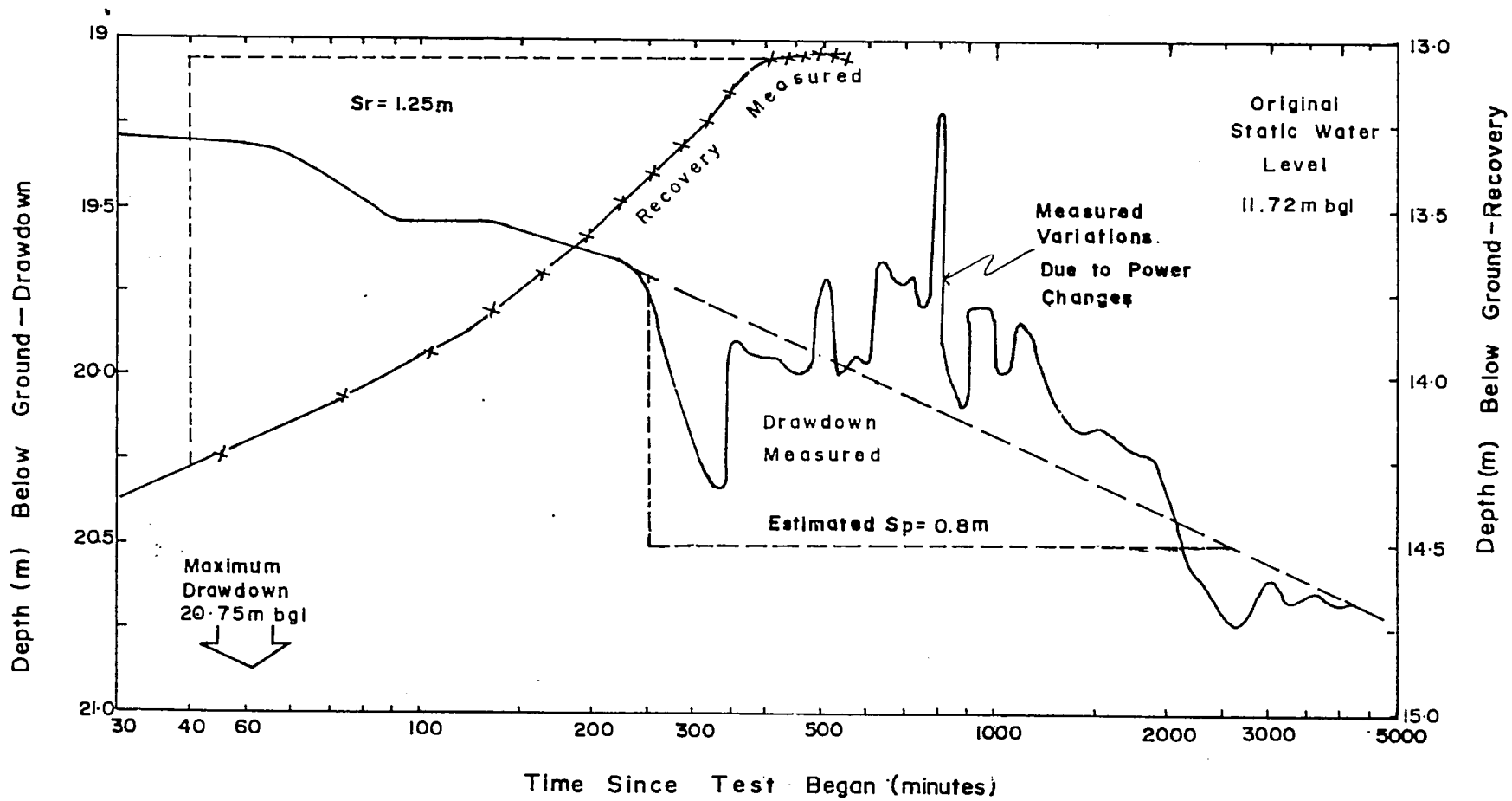
$$T_{I-500} = 249 \text{ cu m d/m} \qquad T_{L-500} = 236 \text{ cu m d/m}$$

$$T_{I-1000} = 270 \text{ cu m d/m} \qquad T_{L-1000} = 256 \text{ cu m d/m}$$

No observation well is available to determine distance: drawdown and transmissivity.

As indicated in Figure A.24, pumping tests at the Ismailiyah well include stepped-drawdown/production tests. The graph indicates a production/drawdown ratio of 0.07 cu m/m.min or 4.2 cu m/m.hr (or 1.2 m per 100 litres per minute). These production/drawdown ratios may decrease (increase) significantly if stepped tests were continued for more than the two-hour periods. A two-hour test period at 72 cu m/hr produce a 7.82 drawdown, while 24-hour period produce 8.98 m drawdown.

DRAWDOWN AND RECOVERY CURVES FOR KOTAMATSUM – ISMAILIYAH WELL TEST



PADCO–DACREA

ENGINEERING SCIENCE–SINOTECH

FIGURE A.22

DRAWDOWN AND RECOVERY CURVES FOR KOTAMATSUM-LAKSANA WELL TEST

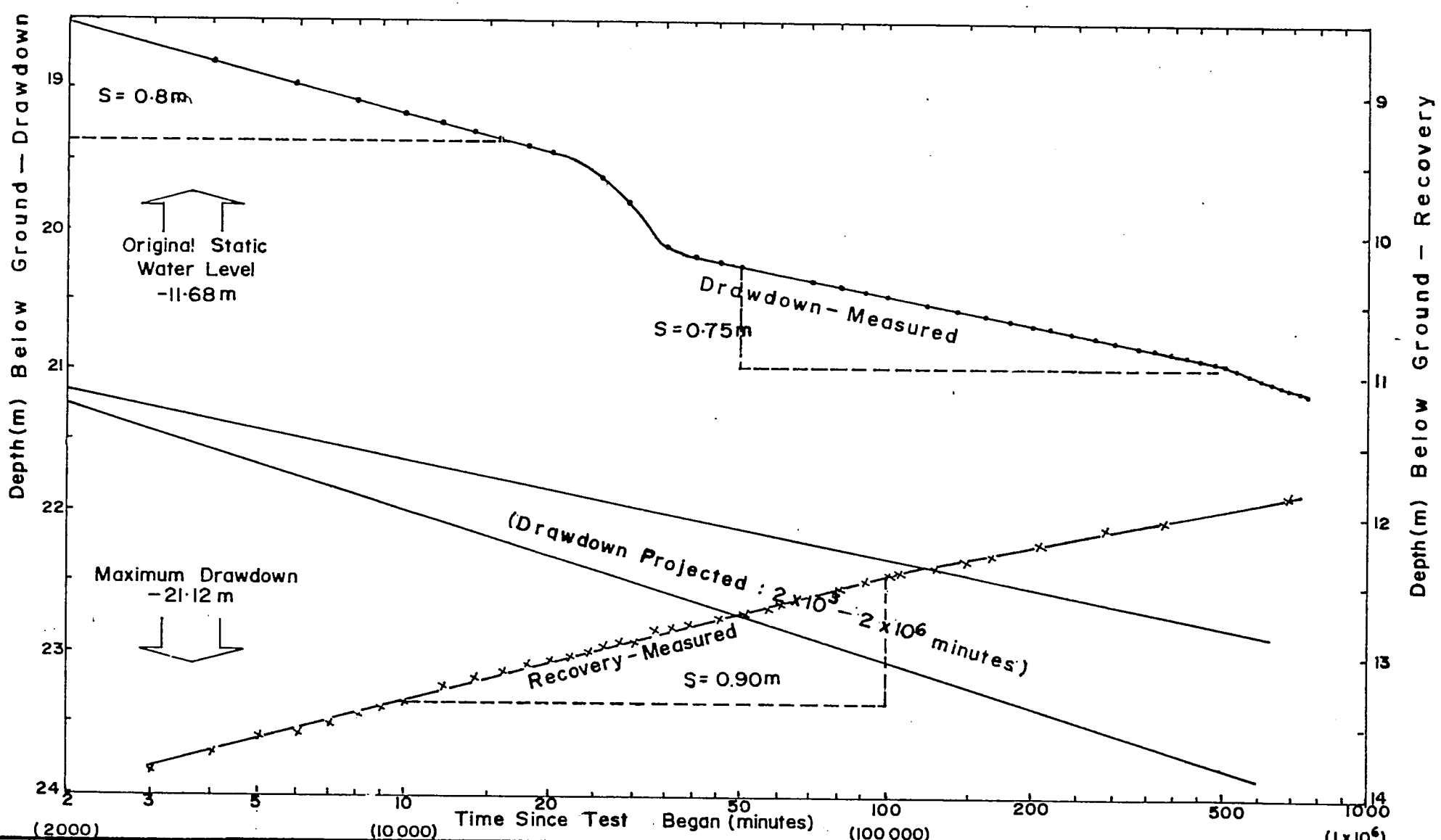
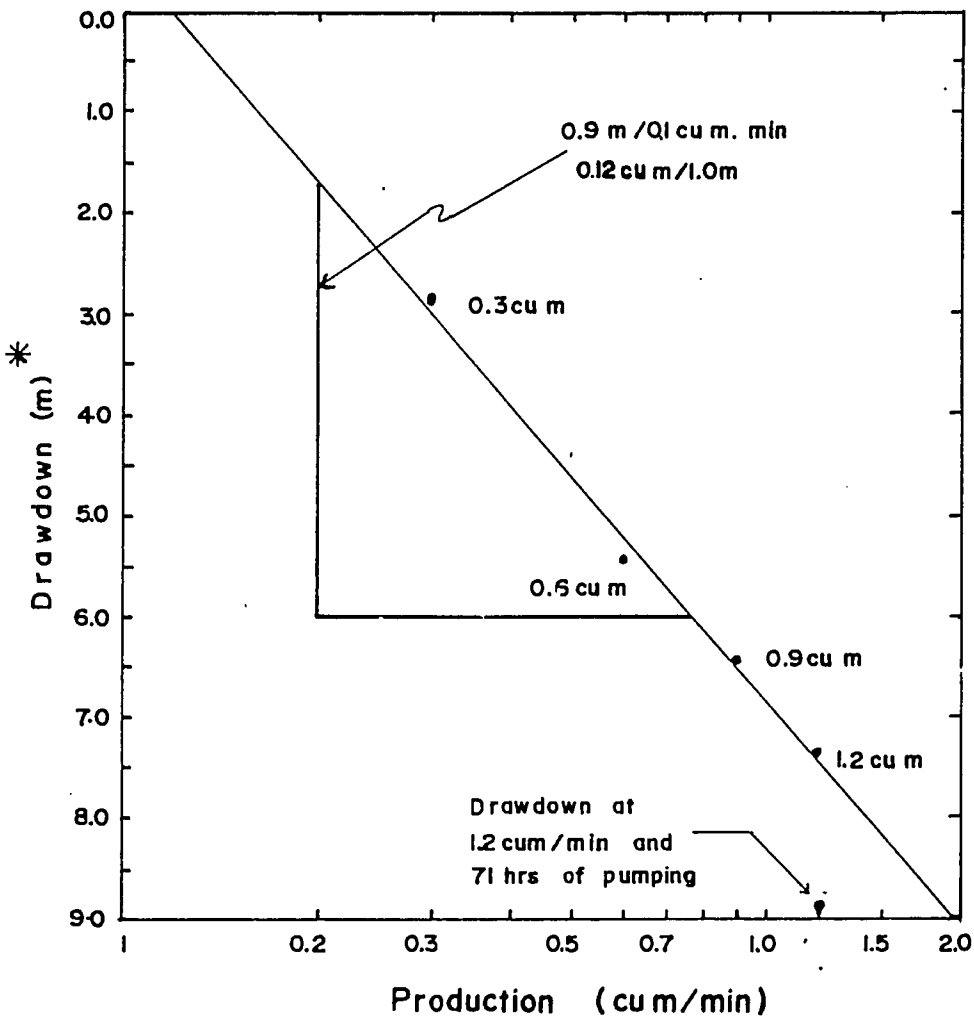


FIGURE A.23

PADCO-DACREA

ENGINEERING SCIENCE-SINOTECH

DRAWDOWN: CAPACITY FOR STEP DRAWDOWN TEST AT THE KOTAMATSUM-ISMAILIYAH WELL



*After 120 minutes of Pumping

49

A.4.2.4 P.T. Brasseries Well Analyses

The initial testing of the P.T. Brasseries well involved pumping directly from the open bore without screens and casings and will indicate maximum values for the aquifer. No losses due to gravel packs, screens, and casings are introduced. The drawdown and recovery levels are shown in Figure A.25. The static water level of 5.31 and maximum drawdown of 8.75 equals 3.44 m drawdown for production of 67.5 cu m/hr (1,620 cu m/d), these equal a capacity of 19.6 cu m/m.hr drawdown. This value is quite similar to those in Belawan and at Mabar (19.0 cu m/m.hr) and are greater than at Medan Denai and in the Kotamatsum.

From the plots and projections in Figure A.25, the following values are calculated:

$$T = \frac{2.303\ Q}{4 \times \pi \times \text{delta s}} = \frac{2.303 \times 1{,}620}{4 \times \pi \times (0.9 \text{ to } 1.5)} = 330 \text{ to } 200 \text{ cu m/m.d}$$

$$T = \frac{1.6 \times 1{,}620}{3.44} = 753 \text{ cu m/m.d}$$

$$T = \frac{1{,}620\ (=Q) \times \log e\ (r_e/r_w)}{2 \times \pi \times s_w}, \qquad r_e = 250,\ 500,\ 1000 \text{ m}$$

$$T_{250} = 556 \qquad T_{500} = 608 \qquad T_{1000} = 600 \text{ cu m/m.d}$$

Transmissivity values of 200, 330, 560 and 660 cu m/m.d appear to be reasonable. The range of T values and an aquifer thickness of more than 38 m produce a ranges of permeability values from 5.3 to 17.4 m/d compared with expected ranges of 1.0 to 50 cu m/sq m.d for fine sand, medium and coarse sands (see Table A.1).

No distance: drawdown can be estimated, but it should be similar to that at Mabar.

Projected long-term drawdown would be expected to reach 5.0 m or 10.3 m below ground level after continuous pumping.

A.4.2.5 Other Wells Analyses

Partial tests of operating production wells and reported tests of three wells in Belawan add some additional hydrologic data for the Medan and Belawan aquifers. Unfortunately, many production values cannot be accurately determined.

Belawan Wells. Three well reports for the Port of Belawan Wells No. 16, 17 and 18 provide some hydrologic data. The following values summarize the production test results:

Well	s	Delta s	T*	Specific Capacity
POB 16	4.7	0.49	647	15.4
POB 17	7.8	0.28	565	9.2
POB 18	8.2	0.24	440	8.8
	m	m	cu m/m.d	cu m/m.hr

50

RECOVERY RESULTS FROM PRELIMINARY TEST AT THE P.T. BRASSERIES WELL

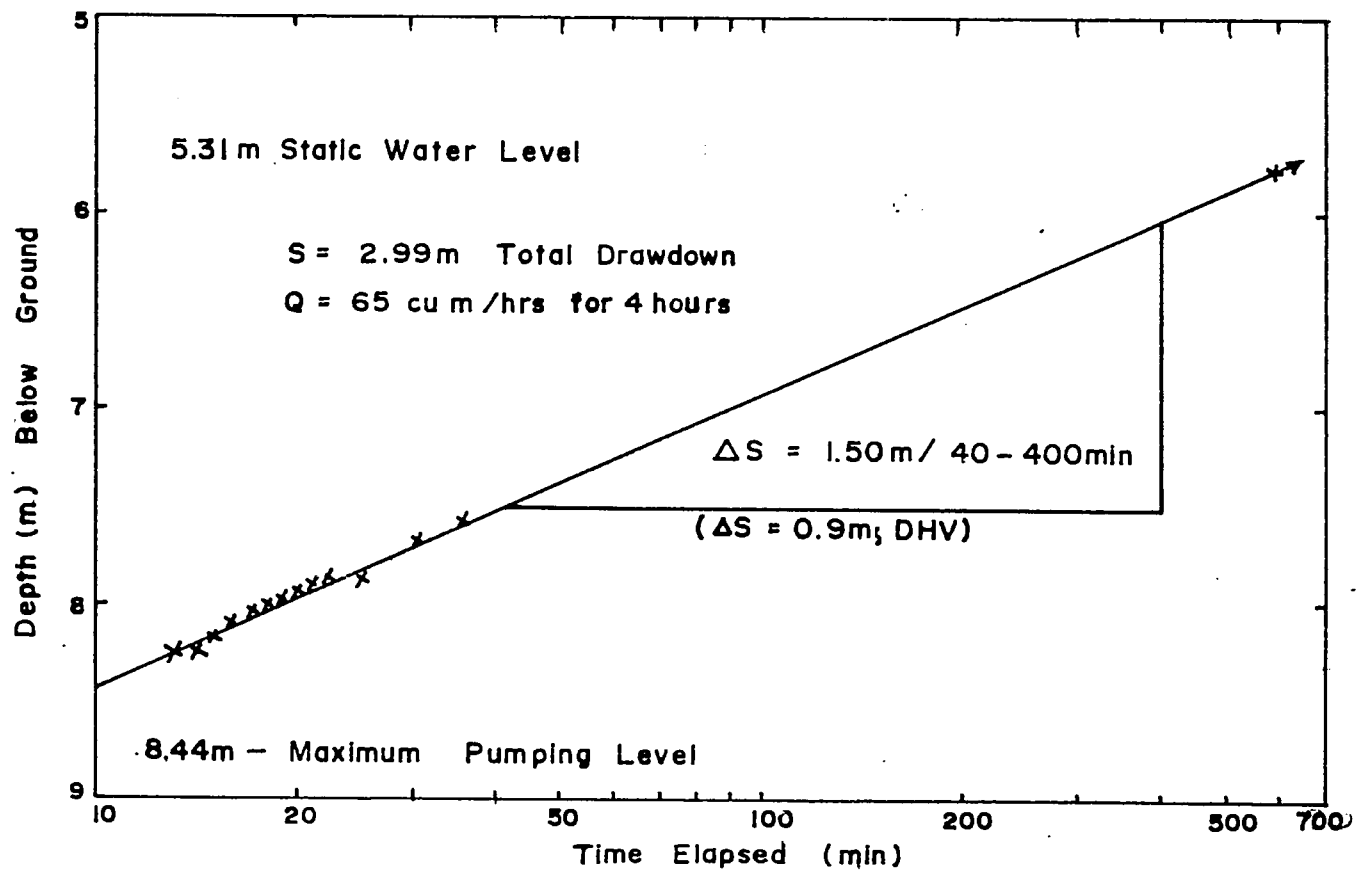


FIGURE A.25

Other Belawan production wells were monitored but pumping continued for about 18 hr and recovery was allowed for only 7 to 8 hr. The following values represent a summary of this monitoring:

Well	s (m)	Delta s (m)	T*	Capacity cu m/m.hr
PAM 6	3.0	0.3	220[1]	5.0
PAM 7	2.4	0.3	210[1]	5.9
PAM 9	3.6	0.4	330[1]	8.3
PAM 11	7.6	0.8	275[1]	6.6
PAM 12	6.0	0.7	220[1]	5.8
POB 14	(1.7)	0.2	330[1]	(8.8)
POB 16	13.0	0.5	528	4.2
POB 17	(7.5)	0.8	298[1]	7.2
POB 19	8.3	0.3	880	7.2
POB 20	3.1	0.1	5280	37.1

* T = 264 x Q/Delta s = cu m/m.d

1 Conservative estimate based on total drawdown rather than drawdown between 100 and 1000 minutes after pumping. Expect about twice T[1] values.

Well reports for the three Belawan wells indicate thicknesses of aquifers and transmissivity from which can be derived permeability as follows:

Well	T	Aquifer	Permeability
POB 16	647	48	13.5
POB 17	565	53	10.7
POB 18	440	39	11.3
	cu m/m.d (sq m/d)	m	cu m/sq m.d (m/d)

Medan Wells. No private well in Medan is provided with an accurate flow meter or measuring or recording device. Three wells were observed and recovery measurements were taken at the Danau Toba Hotel, the Indra Deli Food Processing Plant and the RISPA housing area wells. The following results may indicate general hydrologic conditions in central Medan:

Well	s	Delta s	T	Capacity
DTH	18+	7.8	11	1.1
ID	4.6	0.55	160	4.4
RISPA	4.5	0.80	40	1.6
	m	m	cu m/m.d	cu m/m.hr

These wells have unusually low transmissivities and capacities for wells used by commercial companies although other wells indicate similar low capacity of 1.0 to 10 cu m hr/m drawdown. Unfortunately, the low T and capacity may be more related to the conditions of the well and pump rather than the aquifer.

Private Mabar Wells. More than five deep wells at the Intan Iron Works and Sari Tirta lie within 1000+ m of the Mabar well site. At first these wells were thought to be influences upon water levels at the Mabar wells. During the program, several water levels were taken from the wells:

	Pump Water Levels (-m)				
Intan 1	24.37	26.28	27.43	25.65	25.10
2	-	16.84	21.58	22.69	21.10
Sari Tirta 1	18.46	19.05	19.28	18.42	19.04
2	12.32	12.40	12.50	12.49	12.24
3	13.54	13.58	13.60	13.60	13.41

All depths are during continuous pumping, and static water levels of -5.0 to -7.0 m would be expected. It was expected that such wells may interfere with testing and production at the Mabar site. However, no direct influence was discernible during the pumping: recovery test. Furthermore, one abandoned well served as an observation well and lies within 2.4 m of the pumping well at Sari Tirta. In less than 10 m distance, pumping water levels were about 2.0 to 2.5 m higher than in the pumping well. A conservative estimate of 2.0 to 2.5 m drop if 10 m distance equals a 28 percent slope on the pressure levels in wells. With drawdowns of 10 to 14 m at Sari Tirta, a 20 percent slope would reach zero drawdown by 80 m radius from the well. At a 1.0 percent slope, some interference may be expected at Mabar, while a 5.0 percent or lower slope from the Intan Iron Works may cause interference with the Mabar well.

The deep drawdowns may not reflect low permeability of the aquifers but may indicate that the wells have declined in efficiency or pumping exceeds the capacity of the screens and casing.

A.4.3 General Hydrologic Implications

A.4.3.1 Production, Drawdown and Distance

Mabar. Using the Theis equations,

$$s = \frac{Q}{4 \times \pi \times T} \times W(u) \quad \text{and} \quad u = \frac{r^2 S}{4 T t},$$

estimates can be made of drawdown (s): distance(r): production (Q) for a standard pumping period (t = 100 days). T at Mabar is assumed to be about 600 cu m/m.d and the storage coefficient, S, is 0.18 (much higher than probable). Such values indicate that the recommended wells (i.e. production = 1000 cu m/d) in the northern Belawan corridor could be placed at 100 m separation and would experience less than 1.0 metre interference (additional drawdown caused by other wells), as indicated by the following values:

59

Production (cu m/d)	Estimated Drawdown (s = m) r (m)						
	1	10	50	100	250	500	1000
1728 (20)*	3.1	2.0	1.3	1.0	0.6	0.3	0.08
1296 (15)	2.3	1.5	1.0	0.7	0.4	0.2	0.06
1000 (11.6)	1.8	1.2	0.7	0.6	0.3	0.17	0.05
864 (10)	1.6	1.0	0.6	0.5	0.3	0.15	0.04

* litres/second in ( )

To demonstrate possible variation in long-term drawdown at more than 250 m from production wells in Mabar, Figure A.26 shows the projected drawdowns calculated above with T = 600 cu m/d.m and S = 0.18. The estimated radius of influence (less than 0.1 m drawdown) is about 900 m after 100 days of continuous pumping. The high S produces a high value for "u", and therefore, a low value for "W (u)" and for s, drawdown. If a smaller S value (e.g. 0.00001 for typical confined aquifers) is used, "u" decreases and W (u) increases. This relationship and potential influence of smaller S on long-term regional drawdown can be seen in Figure A.26; an "S" = 0.00001 and production of 1000 cu m/d result in a well drawdown equal or greater than that at a production of 1728 cu m/d and a radius of influence of 1.0 m drawdown at 1000 m and 0.5 m drawdown at 10,000 m.

The apparent absence of significant drawdown effects from two industrial wells within 1000 m and three additional industrial wells within 1500 m suggest that: (1) the aquifers at Mabar are receiving recharge from other aquifers or the groundwater table (i.e. the confined aquifers have leaky confining clay layers) and that (2) the large S value (0.18) may be a reasonable estimate of the combined storage with the confined aquifers and the inflow from other sources. Such more complex relationships require long-term monitoring in order to clearly define groundwater conditions.

Medan Denai. Using the same methods for estimating long-term drawdown and for specific distances and production, the following values were derived for 100 days of pumping at a rate of 1037 cu m/d.

PROBABLE PRODUCTION : DRAWDOWN : DISTANCE AT MABAR

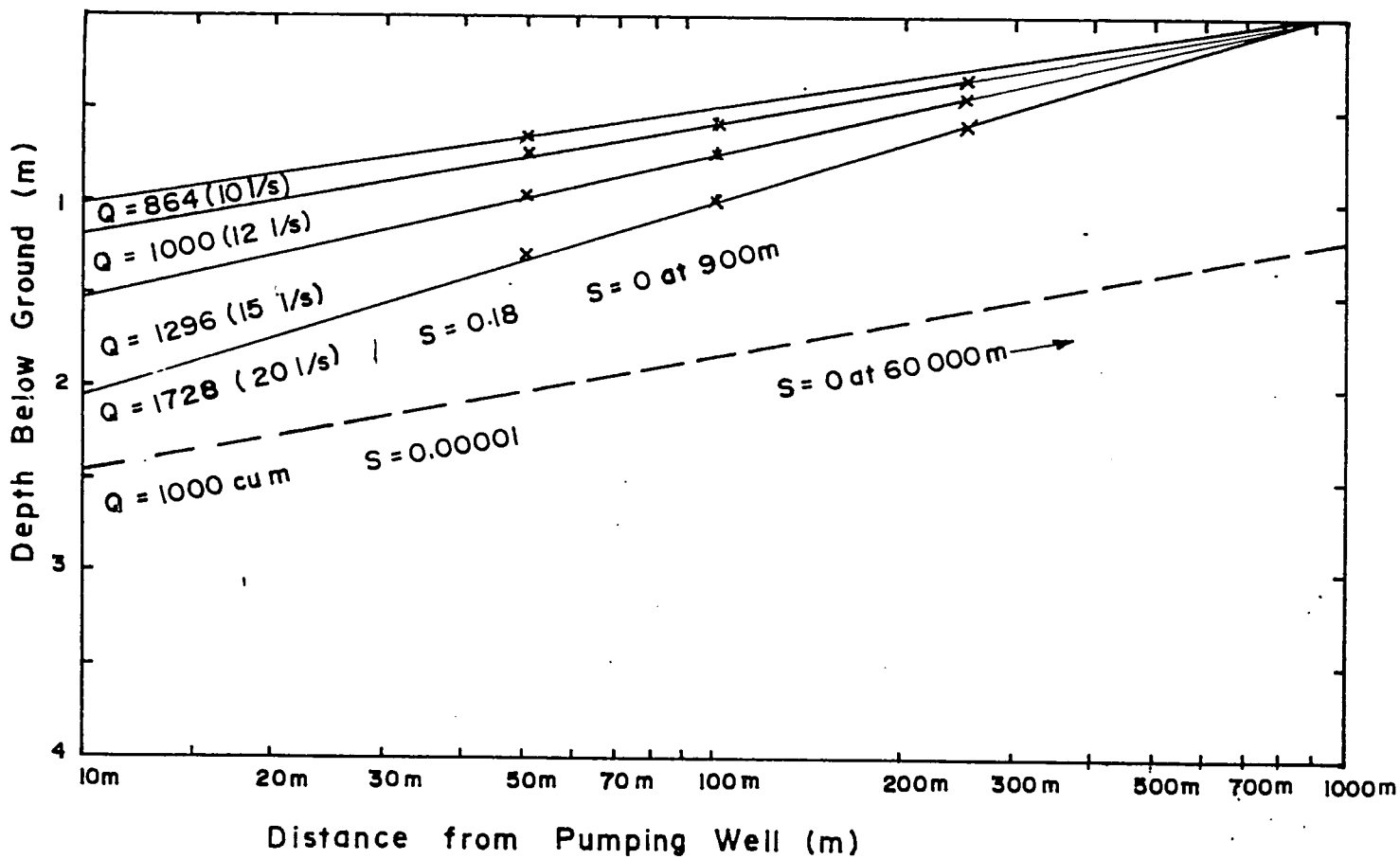


FIGURE A.26

Distance (r = m)	Drawdown (s, in m)			
	T = 340	450	450	557
	S = 0.00001	0.00001	0.0045	0.0025
0.1	6.64	5.24	3.96	3.31
15	4.21	3.36	2.12	1.82
30	3.89	3.08	1.87	1.62
50	3.62	2.89	1.68	1.47
100	3.29	2.62	1.42	1.26
250	2.84	2.28	1.09	0.99
500	2.50	2.01	1.25	0.79
1000	2.17	1.75	0.58	0.58

Drawdown is based upon: (1) T = cu m/m.d, (2) S = Storage Coefficient, (3) Production (Q) = 1037 cu m/d, (4) Time (t) = 100 d s and equation $u = \frac{r^2 S}{4Tt}$; $S = \frac{W(u)\,Q}{4x\pi xT}$.

Because of the greater variations in transmissivity and storage values at Medan Denai, several different values were substituted to indicate the range of drawdown which would be expected. Influence of storage values at Medan Denai is also shown in Figure A.27. As the transmissivity and storage values decrease, the radius of influence or drawdown increases at all distances from the pumping well. No apparent influence could be determined at the Mabar site from pumping of five industrial wells. However, the lower transmissivity and storage values found in southeastern Medan should result in larger drawdowns at greater distances. The three municipal production wells in the Kotamatsum and Medan Denai may produce some interference especially for the Ismailiyah well which lies between the Medan Denai well and the Laksana well (also the Garuda Plaza well). Assuming a depression of water levels of about 2.0 m at 1000 m from the pumping well, the drawdown water level at the Medan Denai would be expected to reach about 20 m below ground surface while at the Ismailiyah well combined drawdown influences may lower the pumping level to about 21 m below ground surface at a production of about 75 cu m/hr.

In order to minimize significant cumulative drawdown effects between wells, separation of at least 1000 m as recommended during the First Stage well program. Some cumulative may occur where three or four wells are at exactly 1000 m from each other and are in turn surrounded by other wells at 1000 m separation. Such arrangements should occur only after many wells have been drilled and further data from drilling and production monitoring is available.

Kotamatsum. From similar analyses, drawdowns at various distances in Kotamatsum were estimated from values calculated in Section A.4.2.3.

PROBABLE PRODUCTION : DRAWDOWN: DISTANCE AT MEDAN DENAI

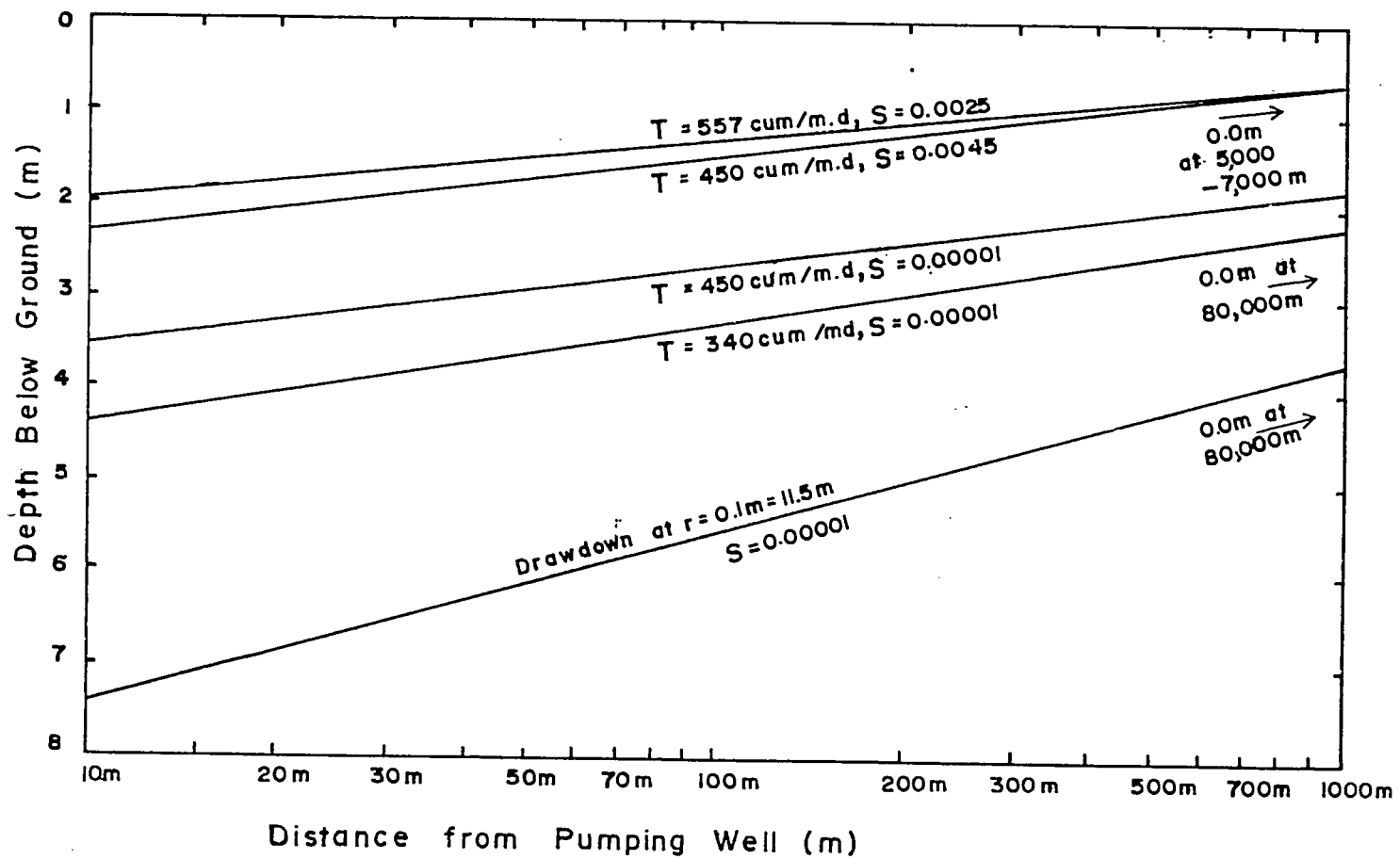


FIGURE A27

Projected long-term drawdown should not exceed 12 m, reaching 23 m below ground (see Figure A.23). Probable production: drawdown: distance has been estimated with a transmissivity value of 300 cu m d/m and storage coefficients of $S = 1 \times 10^{-4}$ and 1×10^{-6} (Table A.4). Based on $S = 1 \times 10^{-6}$ with pumping at 1728 cu m/d and only 1.0 day, the drawdown of 11.4 m at the well (r = 0.1) most closely agrees with the observed drawdown at both wells. Long-term drawdown in the Laksana well was projected (Figure A.23) to reach 13 - 14 m below below ground and the value corresponds to the projected 100 day drawdown of S = 13.5 m indicated in Table A.4. Such agreement would suggest that the aquifers under the Kotamatsum are fully confined with little direct recharge from the groundwater table or other aquifers. This represents a condition more similar to that at Medan Denai than at Mabar.

The values from Table A.4 suggest that the two Kotamatsum wells may produce a drawdown of 6.6 m at 1,000 m if pumped at 1,728 cu m/d (20 l/s). The proposed production capacity of 1,300 cu m/d (15 l/s) should produce the drawdown to about 4.8 m at 1,000 m. The two Kotamatsum wells are separated by about 1,000 m and an interference, increased drawdown, of 4.8 m may be expected at each well. This could produce a total drawdown at each well of about 15.3 m (or 26.5 m below ground level). Potential interference of about 1.0 m from the Medan Denai well may increase cumulative drawdown to about 17 m (-28 m) at the Ismailiyah well.

TABLE A.4

PROBABLE PRODUCTION : DRAWDOWN : DISTANCE AT KOTAMATSUM

	Drawdown (s = metres)			
Production	Q = 1,000 cu m/d		Q = 1,728 cu m/d	
Storage	$S = 1 \times 10^{-4}$	$S = 1 \times 10^{-6}$	$S = 1 \times 10^{-4}$	$S = 1 \times 10^{-6}$
Distance				
r = 0.1	6.61	7.83	11.43	13.54
r = 1.0	5.39	6.61	9.31	11.43
r = 10.0	4.17	5.39	7.21	9.31
r = 100	2.95	4.17	5.10	7.21
r = 500	2.13	3.81	3.61	5.10
r = 1000	1.73	2.95	2.99	6.58

Assumes Transmissivity = 300 cu m d/m and t = 100 days

A.4.3.2 Groundwater Flow and Water Levels

The geological logs for the wells have provided estimates of the aquifer thicknesses while the pump testings provided the transmissivity values and regional water levels. From these values more regional hydrological values may be estimated. Permeability can be estimated as below:

	Transmissivity cu m/m.d	Aquifer Thickness (m)	Permeability m/d
Belawan (low)	220-330	70	3-5
Belawan (high)	440-880 (5280)	70	6-32 (75)
Brasseries	200-750	40	5-17
Mabar	429-792	30+	17-26
Laksana	216-293	25	9-12
Ismailiyah	228-317	25	9-13
Medan Denai	340-540	20	17-23

Water level analyses in Appendix E-1 indicated an average regional slope of about 0.001 (1 m fall in 1000 m distance) from Medan to Belawan. The static water levels in the Brasseries, Mabar, Kotamatsum and Medan Denai show a similar drop from southern Medan to Titipapan (i.e. +12, +4, -1 m from sea level over a distance of 16 km; 13 m/16,000 = 0.00081). Using permeability and slope estimates and the Darcy equation for subsurface flow: Q = PIA, the following calculation can be made:

Q = 6-21 (75) cu m/sq m.d 0.001 x 30 m x 1000 m

Q = 180 - 630 (2250) cu m/d per 1000 m width

V = Q/a = 0.006, 0.021, and 0.075 m/d.

Therefore, under natural flow conditions, a kilometre wide aquifer would transport about 2.3 l/s from south to north.

If large scale production increased the drawdown to 10 m across a wide area, an induced gradient of 10 m per 1000 m could produce a total flow of about 3000 cu m/d at velocities of 0.01 m/d across a section of 1000 m x 30 m. At this rate, about three recommended production wells could be supplied per kilometre of aquifer section. A groundwater development area with more than three wells in hydraulic sequence would create greater than 10 m/1000 m drawdown in order to maintain production of 1000 cu m/d.

59

A.4.3.3 Long-Term Safe Yields

Results from testing of program wells and some other wells indicate that:

1. Aquifers are thinner (20 - 30 m) under Medan city and increase up to 40 - 70 m under Belawan, but are widespread (10 - 15 km).

2. Transmissivity ranges from about 300 to more than 600 cu m/m.d.

3. Permeability ranges from 10 to 50 cu m/sq m.d.

4. Storage coefficients are usually high and indicate recharge of the deep aquifers from very thick, widespread shallow aquifers.

5. Differences of 5 to 10 m between static water levels of the groundwater table and the deep aquifers indicate that although the deep aquifers receive recharge from the groundwater table, the rate of recharge is slow (i.e. 5 - 10 m of head is required to force water from -40 m to -100 m).

6. Long-term time and distance - drawdown values and the high storage/recharge rates indicate spacing of 1000 m radius in northern Medan and 2000 m radius in southern Medan could remove most if not all interference between wells.

These results generally confirm the presence of a moderately good groundwater basin beneath Medan, although wells should probably remain at modest production capacities of about 1000 cu m/d. Since demand commonly does not exceed 1700 cu m/sq km.d, wells can be spaced at about 1000 m interval with little adverse affect upon service and transmission.

A radius of 500 m would allow a recharge at a rate of 1.27 litres d/sq m ($V = 1.47 \times 10^{-8}$ m/s) to balance pumping from one standard production well (i.e. 1000 cu m/d). Additional recharge from laterally connected aquifer would also balance the withdrawals. Therefore, safe yields for individual wells appear to be maintained by spacing with 1000 to 2000 m separation.

Projection of long-term safe yield for the basin beneath the city requires long-term monitoring (100's days) of more than the four wells currently available. The proposed First Stage Well Program can accomplish this.

A.5 GROUNDWATER RESOURCES AND THEIR DEVELOPMENT

The future development of the groundwater resources in Medan requires the staged program as outlined in Sections 7.1.1.4 and 9 (the Feasibility Study). The MGP has clearly indicated that the estimated production of 1,000 cu m/d from each well is feasible; the long-term development and final production values cannot be reasonably predicted until the monitoring results of the next four to six years have been analyzed. The following

well and groundwater development program will further explore the limits of the Medan - Belawan groundwater system and provide the basis for final production goals after 1985. The program includes the following sections:

1. Well Designs, Production and Distribution

2. Recommended Well Development

3. Operations, Monitoring and Maintenance

4. Long-Term Yields.

A.5.1 Well Designs, Production Facilities and Distribution

The results of the MGP clearly indicate the need for changes in drilling procedures and designs of wells and well sites in order to implement an extensive groundwater program, meet drilling schedules, and attain the production goals with the least cost for construction and operation. The following recommendations have been derived from analyses of the drilling program.

A.5.1.1 Well Procedures and Designs

The design of the wells for the MGP severely taxed the capability of the drilling rigs available in North Sumatra during 1980. The large diameter borings (300 mm) required higher densities of drilling mud and more complicated operations which caused unnecessary breakdowns and delays. These delays and the interrupted drilling schedules commonly used by most local drillers allowed the unstable shallow formations to collapse more frequently which required greater cleaning and circulation time and in turn turn increased wear on equipment and caused yet more equipment failures. Use of reaming to achieve the large diameters extended the drilling schedule and weakened the wall of the borings; both of these factors increased the potential for wall failures.

These problems require corrective measures in order to meet the proposed schedule of drilling in 1981 - 1984. Two new measures can be taken: (1) contract for larger and better drilling rigs and for continuous drilling schedules and (2) change the well designs to meet the proven capability of local equipment. A third alternative involves acceptance of delays and use of more contractors. During the First Stage implementation period, importation of large drilling rigs from Java, Malaysia or Singapore would be required and would considerably increase the contractor costs and thereby the costs of drilling wells. The proposed well completion schedule of one per month could be met by two rigs drilling on a 24-hour basis; total time for mobilization, drilling, and completion would be two months per well. Continuous drilling schedules for four years would improve the economic return for each rig and may allow contractors with better rigs to meet bids from local contractors.

Some changes in well design could reduce the difficulties experienced by local drilling contractors during the MGP and during drilling

61

of the Kotamatsum and Brewery wells. In general, a return to more typical and smaller diameter wells would improve the drilling performance and reduce overall costs per well. The following guidelines would be used:

1. Entry velocities at the screens should be kept at less than 0.03 m/s

2. Velocities within the screen and casings should be less than 1.0 m/s

3. Screen slot sizes should be less than diameters of the lower 10 percent of the gravel pack (less than 3 mm in most cases)

4. The gravel pack should be at least 50 mm thick.

The following diameters and volumes and velocities demonstrate that the production objective of 1,000 cu m/d (0.01 cu m/s) can be met by smaller diameter wells and screens.

Diameter (mm)	Total Open Area[a] (sq m)	Volume[b] (cu m/s)	Casing Velocity[c] (m/s)
75	2.8	0.09	3.41
100	3.9	0.12	1.90
150	5.7	0.18	0.85
200	7.5	0.23	0.48

a Assumes 30 m of screen with an open area of 40 percent.
b Assumes an entry velocity of 0.031 m/s
c Assumes production volume of 0.015 cu m/s.

All screen diameters would allow a greater production than proposed without exceeding the entry velocity limits (0.03 m/s) or allow much lower velocities than the limit when pumped at the proposed production level of 1,000 cu m/d. Therefore, groundwater moving through the gravel pack and screen should have low carrying capacity and could hold little sediment after proper well development.

The typical slot size used in Medan is No.40 with an opening of 1.0 mm (0.040 in), although the particle size in the gravel pack ranges from 3.0 to 5.0 mm in diameter. Much larger slots should be used to increase the opening percentage, decrease entry velocities, and further reduce migration of sediment into the well. Larger slot openings would improve well development during construction.

The above relationships of screen diameters: production: velocities indicates that an optimal combination of 150 mm diameter casings and of 75 and 100 mm diameter screens could be used in Medan wells. These diameters would require well borings of 225 and 250 mm diameter, which is close to the maximum limit for boring, without reaming.

64

Although entry velocities at the screens appear to be adequate to prevent pumping fine sand into the well, velocities within the casings may be sufficient to suspend sand in the -105 to -140 m section unless large casing diameter or low production is used. Relationships of casing diameter, production, velocities, and headlosses are shown below.

VELOCITIES AND HEAD LOSSES IN VARIOUS CASINGS

	Screen and Casing Diameter (mm)			
Production	200	150	100	75
20 l/s	0.65/3*	1.20/11	2.50/70	-
12 l/s	0.38/1.2	0.70/4.5	1.55/30	2.8/120
6 l/s	-	0.35/1.6	0.70/7	1.4/35

* Head loss in m loss per 1,000 m, a Hazen-Williams Coefficient of 125.

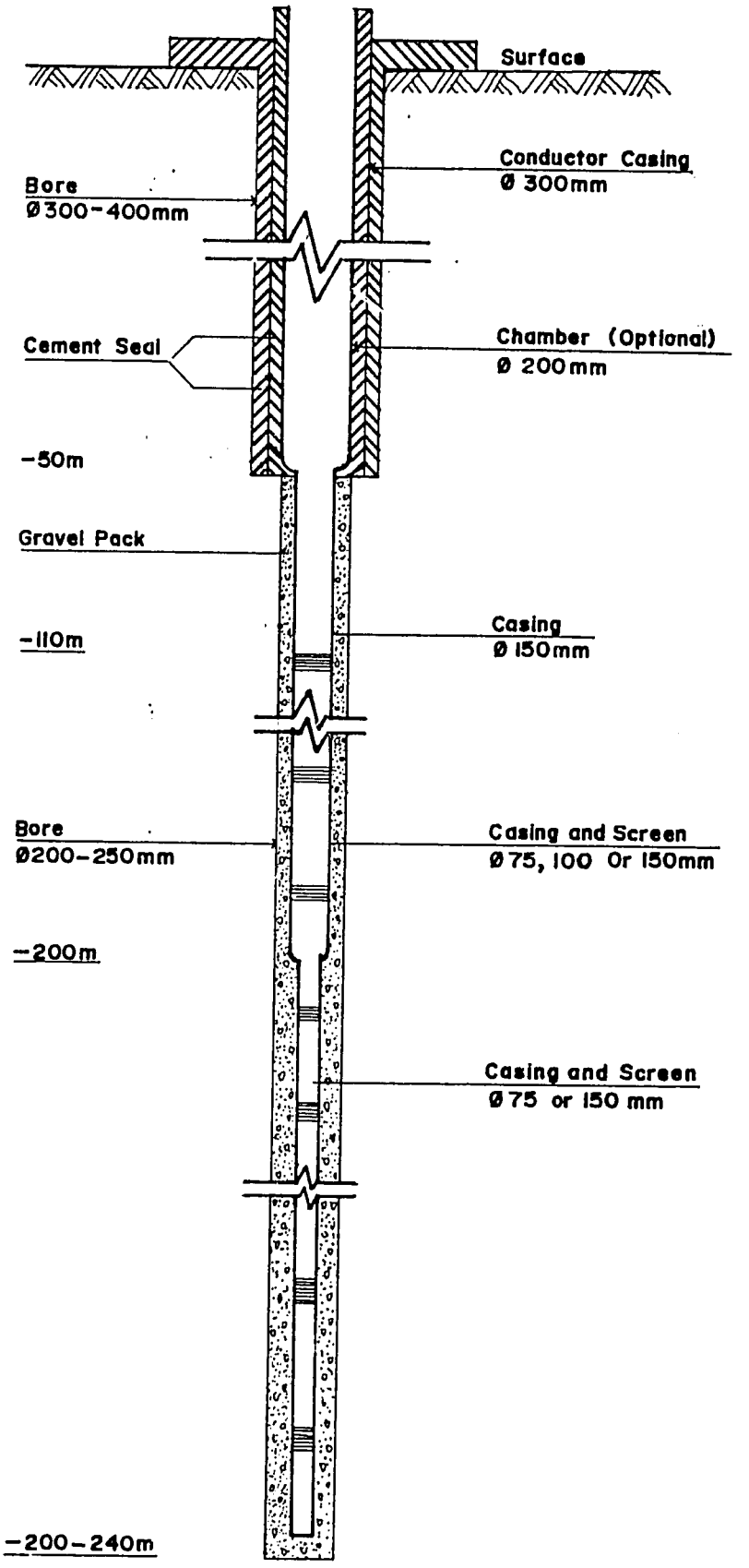
These values indicate that smaller diameter casings and screens (75 mm) could be used in the deeper sections and 100 mm in shallower sections, but this would cause up to 10 m head loss in small casings and screens of 100 to 150 m length.

The 75 mm screens would be limited to the lower 25 percent of the screened aquifers, while the larger 100 m screens would complete the upper 75 percent of the screened aquifers. In such a combination, upward velocities would be between 0.7 and 1.6 m/s and would not allow higher production than the project target of 0.012 cu m/s. Depending upon the precise distribution of screens and different diameters, the larger diameter (150 mm) upper casing could be extended to within 20 m of the uppermost screen, while a pumping chamber of 200 mm may extend to 60 m below ground.

The above discussion can be summarized in a typical well design which is compared to the design for the Kotamatsum and MGP wells (see Figure A.28). A typical cost for drilling to 240 m depth is given below:

62

MODIFIED WELL DESIGN FOR MEDAN'S FIRST STAGE WELL



Work	Length	Unit Costs (Rp)	Costs (Rp x 1000) MGP-1	MGP-2	Modified
Mobilize			100	100	100
Pilot Hole					
150 mm	240	21,000	5,040	-	-
200 mm	240/40	22,500	-	5,400	900
300 mm	200	25,000	-	-	5,000
Ream					
300 mm	190/60	22,500	5,400	1,350	-
425 mm	50	31,500	1,575	1,575	1,575
Casing					
300	48	36,500	1,752	1,752	1,752
200	60	30,000	1,800	1,800	1,800
150	72	21,000	1,512	-	-
100/75	72	15,000	-	1,080	1,080
Screen					
150	60	140,000	8,400	-	-
100	39	95,000	-	3,705	3,705
75	2	75,000	-	1,575	1,575
Gravel			150	150	150
Seal			705	705	705
Develop			1,000	1,000	1,000
Test			500	500	500
Total			27,934	20,692	19,842

Cost of shallower 200 m wells would be about Rp.21.8 M for MGP and about Rp.16 - 17 M for the modified design with telescopic screens and casings.

The MGP and the records from other wells in Medan and Belawan clearly indicate the presence of a significant shallow groundwater table and at least two major deeper productive aquifers. As part of the initial well development, several of the remaining ten wells should be drilled below the clays encountered between 190 and 210 m below ground and should be continued until the next lower significant clay unit or other major lithologic change is encountered (e.g. 240 m at 200 mm diameter). If the next ten wells prove the existence of a deper aquifer, then the following second phase of the First Stage well program (40 wells) should include at least eight major deeper wells.

A.5.1.2 Production Facilities

PAM Tirtanadi has commonly used large accessory facilities for production wells in Belawan and has incorporated similar facilities in the general plan for production at the Kotamatsum and MGP wells. The accessory facilities may include:

1. Housing for resident operator
2. Administrative offices
3. Sediment trap or filter
4. Storage tanks or reservoirs
5. Storage/pumping building.

Such facilities add costs equal to or exceeding those of the well itself. The higher costs of such facilities and land may often lead administrators to reduce the number of wells, or they may concentrate wells in an area, so that the accessory costs can be distributed over more than one well. Hydraulically, the placement of a producing well next to a storage reservoir creates poorer pressure patterns within the distribution systems compared to greater distances between storage and production. Similarly, concentrating several wells or wells and storage in one district requires greater costs for transmission of the excess production to other service areas. During the First Stage Implementation period, none of the above accessory facilities should be located on the well sites of fugure wells. The primary goal is to increase the production and storage in the most effective manner compared to the limited financial resources rather than creation of non-productive facilities.

A.5.1.3 Well Distribution

Two specific plans for well sytems have been considered during the discussions of the Medan Urban Development Study Master Plan: isolated wells and well fields. During 1980 - 1984, the well program has two goals: (1) producing sufficient water to meet supply demands and without significant cost increase per cubic metre and (2) providing sufficient monitoring data to project the final yield of the entire Medan aquifers and the most economical distribution of wells. Isolated wells can be placed at virtually any location in Medan where existing water pipelines and electric power are available, e.g. Kotamatsum wells. Therefore, low additional cost is required to pump the water into the distribution system.

Following discussions in Appendix A.4, the long-term drawdown would require a minimum distance of 250 m and probably 1,000 m separation between wells. Assuming the minimum separation of 250 m, a well field system of five wells would require 1,000 m of 200 mm pipeline to collect the water, and then an additional pipeline capacity to distribute the supply to the service area. If the five wells could serve about 500 ha of average residential areas, the transmission requirements from the distribution point would extend outward at least 1,250 m ($(5 \text{ sq km} \times 0.32)^{0.5}$). The additional costs would be equal to at least 2000/m of transmission pipeline. Head losses through the collector pipelines (about 10 m) and then through

66

through the distribution/transmission pipelines (about 10 m) would reduce supply pressures and rates of flow within the service area and reduce service quality. The combination of additional costs and degraded service should outweight any potential benefits from the well field pattern during the First State period.

The data requirements for long-term projection of groundwater yield and distribution can only be gained by an extensive distribution of monitoring points across the entire surface of the aquifer system. The groundwater basin under Medan has a surface area of about 150 sq km, excluding the Belawan urban area. During the First Stage period, about 50 wells will be drilled, about one well and monitoring point per three square kilometres (average well separation of 2,000 m). If two well fields of five wells each were formed, the coverage would be reduced by 15 to 25 percent. This reduction would reduce the accuracy of projection of final production from the groundwater basin or increase the period of monitoring before the projection. Following the projection of basin yield at the end of the First Stage period (1984 - 1985), a more accurate and cost effective distribution of well field combinations could be made if they are found to be required to meet water demands.

A.5.1.4 Water Quality and Treatment Facilities

Considerable concern has been expressed regarding the quality of groundwater and the facilities needed for treatment of degraded water. The two primary concerns have been iron content and turbidity. Both concerns have no direct public health limitation and pertain primarily to color, staining and odor, and possibly to the degree of disinfection by chlorination in the presence of suspended solids. During 1980/85, the primary goal has been to increase supply and distribution pressure. Although some wells may increase the iron content in the water supply, the very real benefits of increasing distribution pressure and prevention of bacterial contamination of pipelines by infiltration and backflow should more than balance the detriments of color and staining.

Sunggal water has an iron content of more than 0.3 mg/l, but the spring water source has less than 0.1 mg/l of iron. Water from these sources will mix with well water during daily peak periods and will reduce the average iron content of water delivered to users. This mixing and corresponding reduction will increase as more storage is constructed within the system and system pressures increase. Even assuming a concentration of a maximum 1.0 mg/l of iron from the wells and a maximum well production of about 50,000 cu m in 1985, the average concentration within the overall supply would be 0.4 mg/l (one part at 1.0 mg from wells, two parts at 0.3 mg from Sunggal, and one part at 0.0 mg/l from the springs). During 1985 - 1987, this average would decrease as the new Sunggal production was supplied to the service area. Since several existing well supplies contain less than 0.5 mg/l of iron, the iron should be less than the above estimate.

Treatment for iron generally involves precipitation of the iron and settlement or filteration of the precipitates. The treatment could be done at the well head, at pump stations within the distribution system, or at

61

storage facilities. Since the water quality standard is based on concentration, well water with iron content of 0.5 mg/l or more can be mixed with Sunggal, spring or other well waters with less than 0.5 mg/l iron and reach the water quality standard. Blending and general improvement of water quality for iron can be undertaken after 1985 with a fully pressurized distribution system.

New designs for production wells have emphasized measures to reduce the entry of sand and sediment into the well and passage into the pump and distribution sytem. These measures should reduce the need for any sand trap or filter systems at the well head. Since existing operations do not regularly backwash, the filters will reduce flow and increase headlosses, and the filters only act to impede service. At the end of the First Stage period, filters could be added to those wells which had declined in water quality and have demonstrated sand problems. Additions could be made following the first maintenance cleaning of the sand traps and redevelopment of the gravel packs some time between 1985 and 1990.

A.5.2 Recommended Well Development Program

The Medan well program is outlined in the Master Plan and First Stage Feasiblity Report (Vol.V, Part 1). The First Stage program provides for immediate production to meet supply deficits and for a data acquisition and monitoring program required for long-term projection of yields. Based upon the results of the drilling of the Kotmatsum wells, of the MGP wells and of the Brewery well and the incorporation of final design plans for the East Medan Distribution system, the Recommended Well Development Program can be more accurately defined for the First Stage Feasibility Study period and for the Master Plan.

The long-term program will incorporate the results of the First Stage drilling and production data and will determine an optimal well distribution plan. This program will also reflect the improved demand projections, the variation in well yields, groundwater costs, and transmission requirements, and eventually the future sources of new surface water supplies.

A.5.2.1 Schedule

The Groundwater Development Program is divided into four sequential phases: 1980-1982, 1982-1984, 1984-1989 and after 1989. These four phases have production goals of:

Stage I
- Phase 1. 1980-1982 - 13,000 cu m/d (0.15 cu m/s) or 13 wells
- Phase 2. 1982-1984 - 40,000 cu m/d (0.63 cu m/s) or 40 wells

Stage II 1984-1989 - Assessment of Initial Results or more wells

Stage III 1989-2000 - 47,000 cu m/d (1.16 cu m/s) or 47 wells or more.

Drilling in the first phase of the First Stage will concentrate on a preliminary exploration of the groundwater basin, while meeting water demands in poorly supplied areas. The second phase of the First Stage period concentrates on increasing groundwater production within the framework of the results derived from the first part. During the third part or the initiation of the long-term program element, geological and hydrogeological data from the First Stage wells will be assessed and long-term goals defined for groundwater development. The fourth and final phase will extend to at least 2,000 and will be devoted to gradual increase in groundwater supply while maintaining or improving the efficiency of the well system.

This schedule requires the drilling and completion of one well per month during the next four years (1980-1985) and then of one well per quarter (three months) from 1988 to 2000, although the latter drilling rate may vary depending on demands and long-term groundwater yields.

A.5.2.2 Locations.

The distribution of wells to be drilled during the next 20 years has been presented in Figure A.29. By the year 2000, the Medan urban area will cover about 150 sq km or more and will require 537,760 cu m/d of water supply. With an average population density of 13,000 p/sq km, the average water demand will be 3,600 cu m d/sq km. The present long-term groundwater production goal is about 100,000 cu m/d; therefore, groundwater could supply 28 sq km of Medan. Since the Sunggal Water Treatment Plant and the spring transmission system can supply 320,000 cu m/d or about 90 sq km, the long-term distribution of wells should reflect these supply allocations.

A.5.2.3 First Stage Well Locations

The detailed locations of wells to be drilled during the First Stage period, 1980 to 1985, will be based upon the general location of wells used in the computer analyses of the distribution system (see Figure 6.9 of Vol.V, Part 5, Section 6.4). In general, lines of wells pass along the eastern, northern, and western edges of the city. Table A.5 gives the distribution node number, the phasing of wells, and the number of wells and production for the First Stage period. The recommended allocation of wells to the nodes reflects integration of the need for geological and hydrological data base for making final projections of groundwater production with the daily demands near each node, the existing low pressure areas and first stage projects. The western wells are included primarily to provide data for future hydrogeological analyses, while production from the western wells will only add to the large First Stage production from the Sunggal Treatment Plant. Groundwater augmentation in western and northwestern district will require some greater cross-city transmission.

Most groundwater production in the First Stage period will be concentrated along the north-central and eastern edges of the city. Such concentration will reduce pipeline and pumping capacity requirements for cross-city transmission but will be integrated with planned projects so as to reduce interference.

PROPOSED FIRST STAGE WELL LOCATIONS IN MEDAN

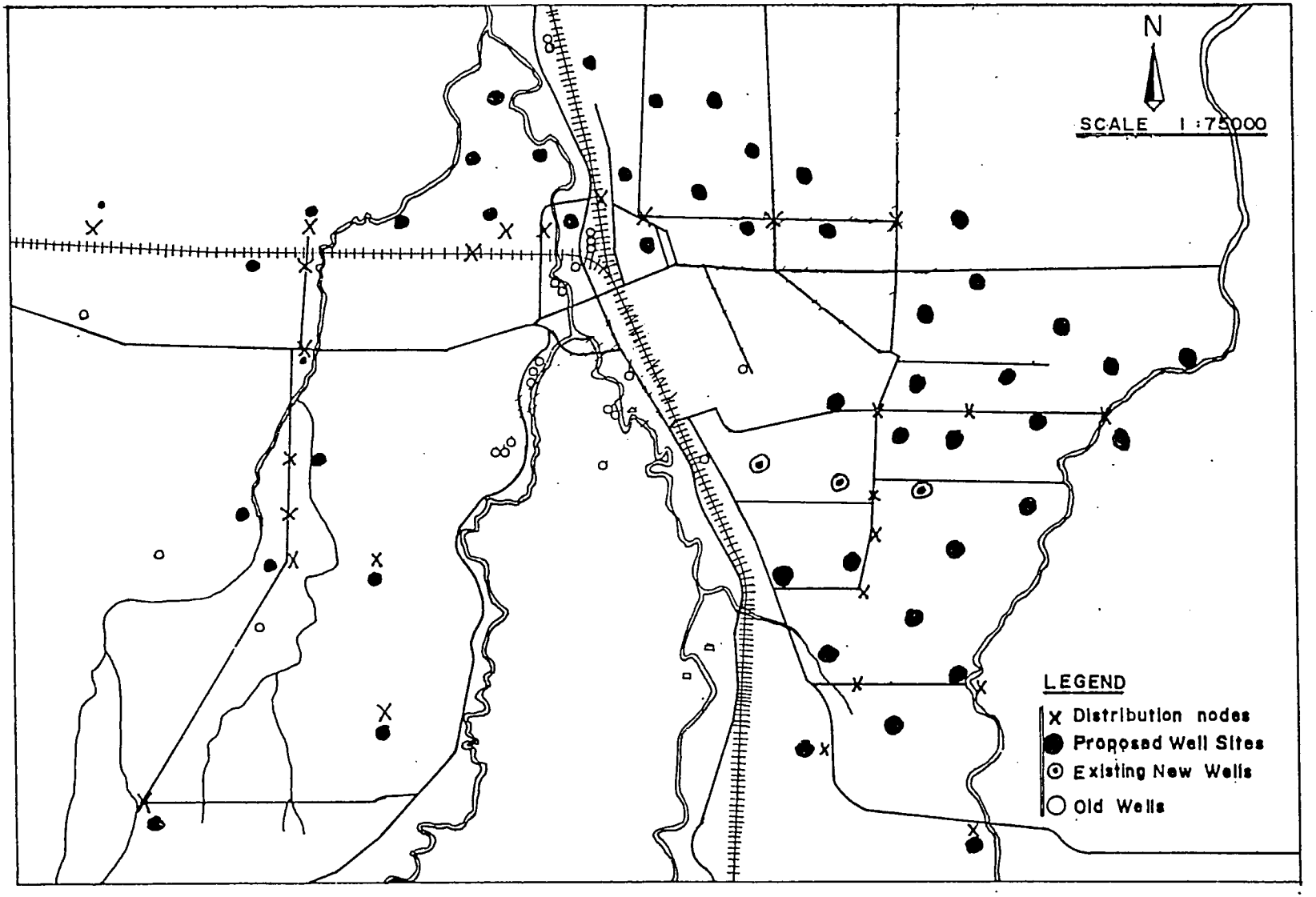


FIGURE A:29

PADCO-DACREA ENGINEERING SCIENCE-SINOTECH

The distribution system for the East Medan Project is dominated by the reservoir and pumping station at the northern end of the project area and by the 600 mm transmission pipeline on Jati Street. The recommended First Stage wells have been located within the context of this project, the two wells in the Kampung Improvement Program Area of the Kotamatsum, and the transmission pipelines for spring water in the southeastern district of Medan. Initial projections of distribution pressures indicated peak flow pressures of less than 10 m above ground level along the southern perimeter of the East Medan Project area. Therefore, more wells should be placed at the southeastern portion of East Medan (e.g. South of Sutrisno Street) than in the northern area (e.g. North of Asia Street).

The exact locations of well sites with general nodal area depends upon many different hydrogeological and practical factors. As indicated in Section A.4.3, an initial spacing of one well per square kilometre should be adequate to reduce or eliminate any interference between wells. Greater spacing along North-South axes of two kilometres should reduce any accumulative drawdowns, which may cause long-term interference along the main flow patterns and in the northern areas of Medan.

The locations of the wells within nodal service areas varies between the three major regions. Wells should be at the greatest distance from major production sources or their transmission corridors: Sunggal Treatment Plant, Sibolangit Spring water pipelines reservoirs, and major transmission pipelines. Wells in the northern district should be located in the northernmost portions of nodal service areas so as to avoid distribution interference and redundancy with the new 600 mm East Medan pipeline and those pipelines coming from the Sei Agul Booster Station. Wells in the eastern district should be located in the southern portion of the East Medan sector and along the eastern-most portions of those nodal areas centred on Bakti Street.

The eastern and northeastern distribution of wells during the First Stage (1980 to 1984) can be seen in Table A.5 where 26 wells would be constructed in the eastern districts, 17 in the northern districts and only 10 in the western districts. Within this general distribution, three or four wells would be located in the vicinity of eight distribution nodes (See Figure 6.9, Vol.V, Part 1). The eight nodes would receive water from a total of 29 wells and would be concentrated in the central portions of the northern and eastern districts. These two groups lie between the East Medan reservoir and pump station and the Sei Agul reservoir on the North and East Medan pump station and the end of the Sibolangit Springs transmission pipelines in the southern district.

In the eastern districts, major groundwater production from 15 wells would lie between the eastern railway track and Bromo and Halat Streets (Nodes 29, 64, 24, and 166). Eleven other wells (1 or 2 per distribution node) would be located further south, and these would provide more extensive geological control and long-term monitoring stations for the entire eastern ground water basin. Production from these wells would supply local demands and increase pressure in the southern portion of the East Medan Project area.

TABLE A.5

FIRST STAGE WELLS IN MEDAN

	1980/81	1981/82	1982/83	1983/84	Totals well	Totals cu m/d
Eastern						
26		1		1	2	2,000
29		1	1	1	3	3,000
64	1	1	1	1	4	9,000
106	1	1	1	1	4	4,000
74	1	1	1	1	4	4,000
30		1		1	2	2,000
31	1		1		2	2,000
75			1	1	2	2,000
76			1		1	1,000
107		1			1	1,000
77			1		1	1,000
Sub-Totals	(4)	7	8	7	26	26,000
Northern						
25		1	1	2	4	4,000
17	1		2	1	4	4,000
16			1	1	2	3,000
14			1	1	2	2,000
13			2	1	3	3,000
12				1	1	1,000
11			1		1	1,000
Sub-Totals	1	1	8	7	17	18,000
Western						
99				1	1	1,000
98			1		1	1,000
97				1	1	1,000
96				1	1	1,000
93				1	1	1,000
92				1	1	1,000
89			1		1	1,000
6			1		1	1,000
3				1	1	1,000
100			1		1	1,000
Sub-Totals	0	0	4	6	10	10,000
Annual Totals	5	8	20	20	53	53,000
Accumulative Total	5	13	33	53	106	

In the northern districts, 11 of 17 wells would be located at the southern end of the Belawan corridor. The large groundwater production would supply the area between the northerly perimeter of the East Medan Project area and the Deli River (e.g. Glugur and Brayan). The six other wells would extend westward towards Perumnas I and Helvetia. These wells would provide additional geohydrologic data and long-term groundwater monitoring stations. Their production would reinforce the Sei Agul distribution area and the Perumnas Housing area. Some water would increase supplies available to the Belawan corridor.

A.5.2.4 Second Stage - Phase 3 Analyses

At the end of the First Stage period, a total of more than 53 new wells would be under the control of PAM Tirtanadi and would provide data or monitoring points. The wells could provide more than 1,000 well-months of monitoring data in addition to the geological data and the hydraulic data from the intial pumping tests. The first 12 wells would provide about 42 months during the First Stage Program period. Completion of the next increment of the Sunggal Treatment Plant in 1985 would supply demands for about two years and add two years of monitoring data to the First Stage records. Therefore, during 1986, Tirtanadi would have at least a 54-month record and a total of 1580 well months of data from throughout the groundwater basin. A few new wells may be drilled from 1984/85 to 1988/89.

A.5.2.5 Third Stage Wells

A balance between water supply and demand for 60 percent of the Medan population would be achieved in 1984/85. This balance and the slower growth in population, percentage connected to the water supply, and the per capita demand will allow a slower rate of drilling and well completion. Depending upon the long-term projection of groundwater yield and distribution of this yield, the groundwater development may add about four wells and 4,000 cu m/d production each year. If a lesser yield exists, initial greater dependance upon the ground water development between 1986 and 1991 would allow planning to proceed with expansions of the Sunggal Treatment Plant and the development of preliminary designs for new treatment facilities on the Deli River.

The physical location of an additional 46 new wells would largely involve the augmentation of the existing well supply system on the eastern and northern district of the Medan urban area, along the Belawan corridor and in the Belawan urban area. All First Stage wells will be separated by at least 1,000 m, and the wells of the long-term would be located between wells with high proven production and with low power costs per cubic metre of water and in areas remote from other wells.