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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

VOLUME V

MASTER PLAN AND FIRST STAGE PROGRAM FOR WATER SUPPLY AND SANITATION

PART 1- MASTER PLAN AND FIRST STAGE PROGRAM FOR WATER SUPPLY APPENDICES A TO H

OCTOBER 1980

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

PREFACE

The feasibility reports emanating from the Medan Urban Development, Housing, Water Supply and Sanitation Project were submitted in draft form to the Government of Indonesia (GOI) in February 1980. These reports, together with the earlier master plan reports, were reviewed by GOI in July 1980 and discussed with the Consultant at a series of meetings at that time. The outcome of this review process was that certain changes in content and format were agreed. These changes have been incorporated into the final printed reports.

A result of adopting the new guidelines provided by GOI is that differences occur between the Repelita III investments proposed in the master plan studies and those contained in the first stage program recommendations. The latter incorporate the final adjustments and represent the recommended program for Repelita III.

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ORGANIZATION OF PROJECT REPORTS

The results of investigations carried out in connection with the Medan Urban Development, Housing, Water Supply and Sanitation Project are contained in the following series of reports:

Inception Report for Long Term Urban Development Plan and Feasbility Study on First Stage Housing Development Project

Volume I	Summary
Volume II	Interim Strategic Plan and Feasibility Study
Volume III	Long Range Urban Development Plan
Volume IV	Housing Development Program
	Part 1 - Housing Development Situation and Strategy
	Part 2 - Kampung Improvement Program
	Part 3 - Sites and Services / Low Cost Housing Program
Volume V	Master Plan and First Stage Program for Water Supply and Sanitation
	Part 1 - Master Plan and First Stage Program for Water Supply
	Part 2 - Master Plan and First Stage Program for Wastewater
	Part 3 - Master Plan and First Stage Program for Drainage
	Part 4 - Master Plan and First Stage Program for Solid Wastes

Note: Parts 1-3 of Volume IV and Parts 1-4 of Volume V are bound as separate report volumes. Appendices to Part 1, Volume V are also bound separately.

1A

LIST OF ABBREVIATIONS

ORGANIZATIONS

ADB	Asian Development Bank
DKKP	Medan Solid Waste Management Department
KIP	Kampung Improvement Program
LCH	Low Cost Housing
MUDS	Mudan Urban Development Study
SSCH	Sites and Services and Core Housing
UNDP	United States Development Program
USAID	United States Agency for International Development

TECHNICAL

mm	millimetre
m	metre
km	kilometre
sq m	square metre
ha	hectare
sq km	square kilometre
l	litre
cu m	cubic metre
s	second
min	minute
d	day
y	year
m/s	metres per second
l/min	litres per minute
cu m/s	cubic metres per second
cu m/d	cubic metres per day
mg/l	milligrams per litre
l/c.d	litres per capita per day
mg	milligram
g	gram
kg	kilogram
t	tonne (metric)
BOD	5-day, biochemical oxygen demand
TDS	Total dissolved solids
ES	Electrical conductivity
TU	Turbidity units
DO	Dissolved oxygen
TDH	Total dynamic head
LS	Lump sum
ea	each
na	not available or not known
Rp	Indonesian Rupiah

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APPENDIX A

MEDAN GROUNDWATER DRILLING PROGRAM

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. Preparations of 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).

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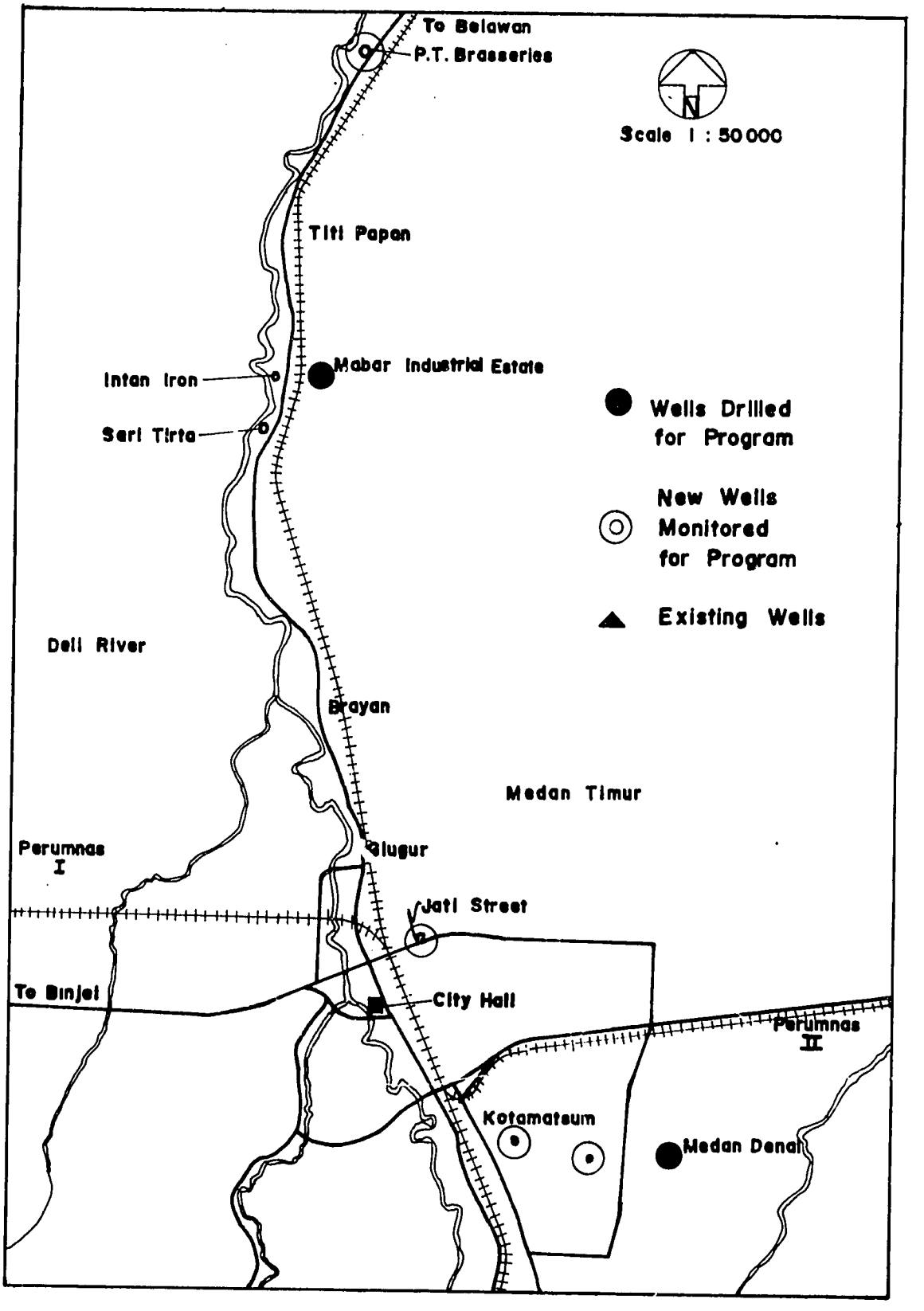
FIGURE A.1

GENERAL PROJECT AREA FOR MEDAN GROUNDWATER 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

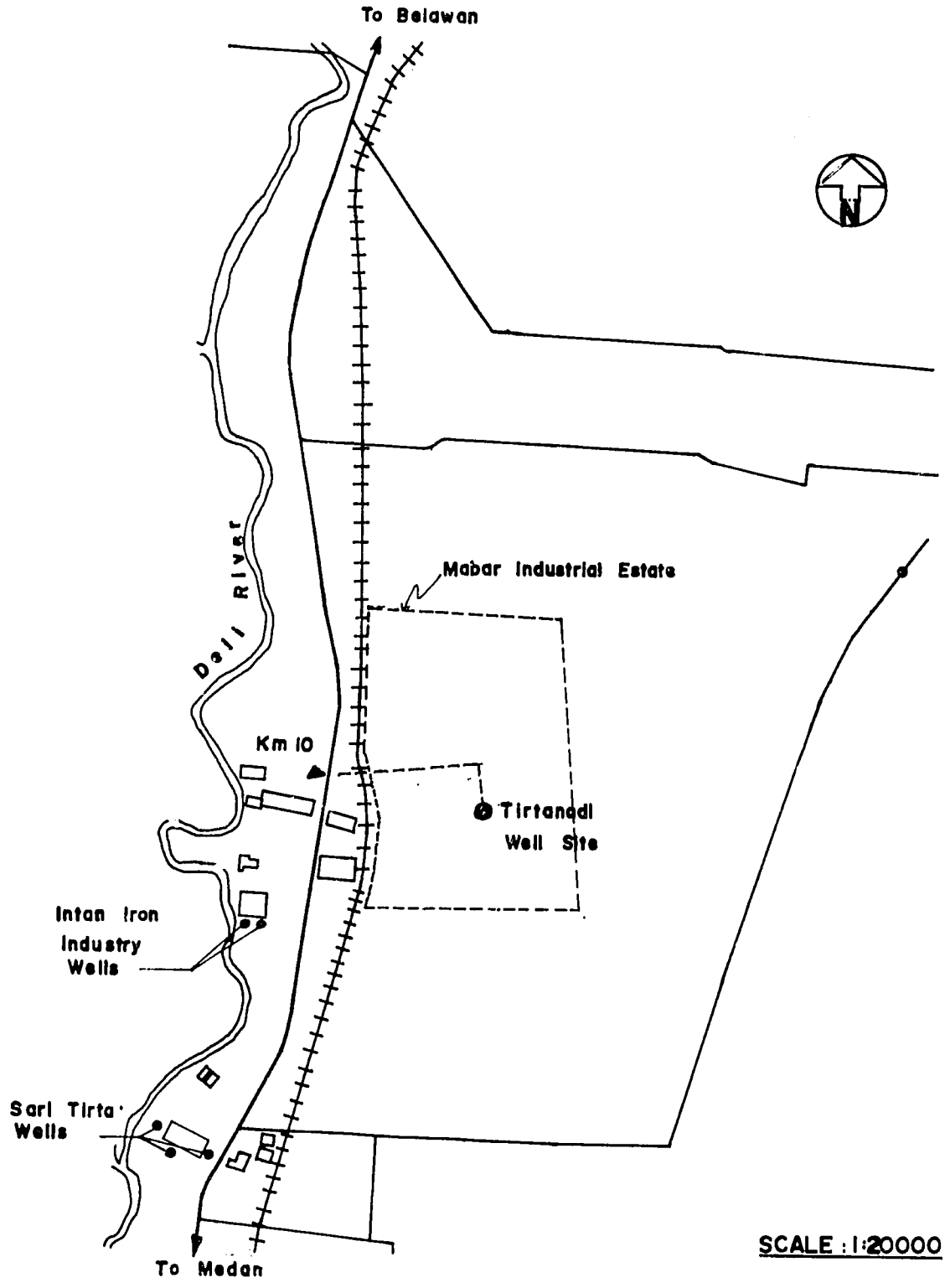
The general site location map (see Figure A.1) indicates the general geographic location of the six new production wells and their topographic setting. The Medan Denai well lies about 3.0 km from the Deli River and about 2.0 km from the Percut River. The remaining four production wells lie less than 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.

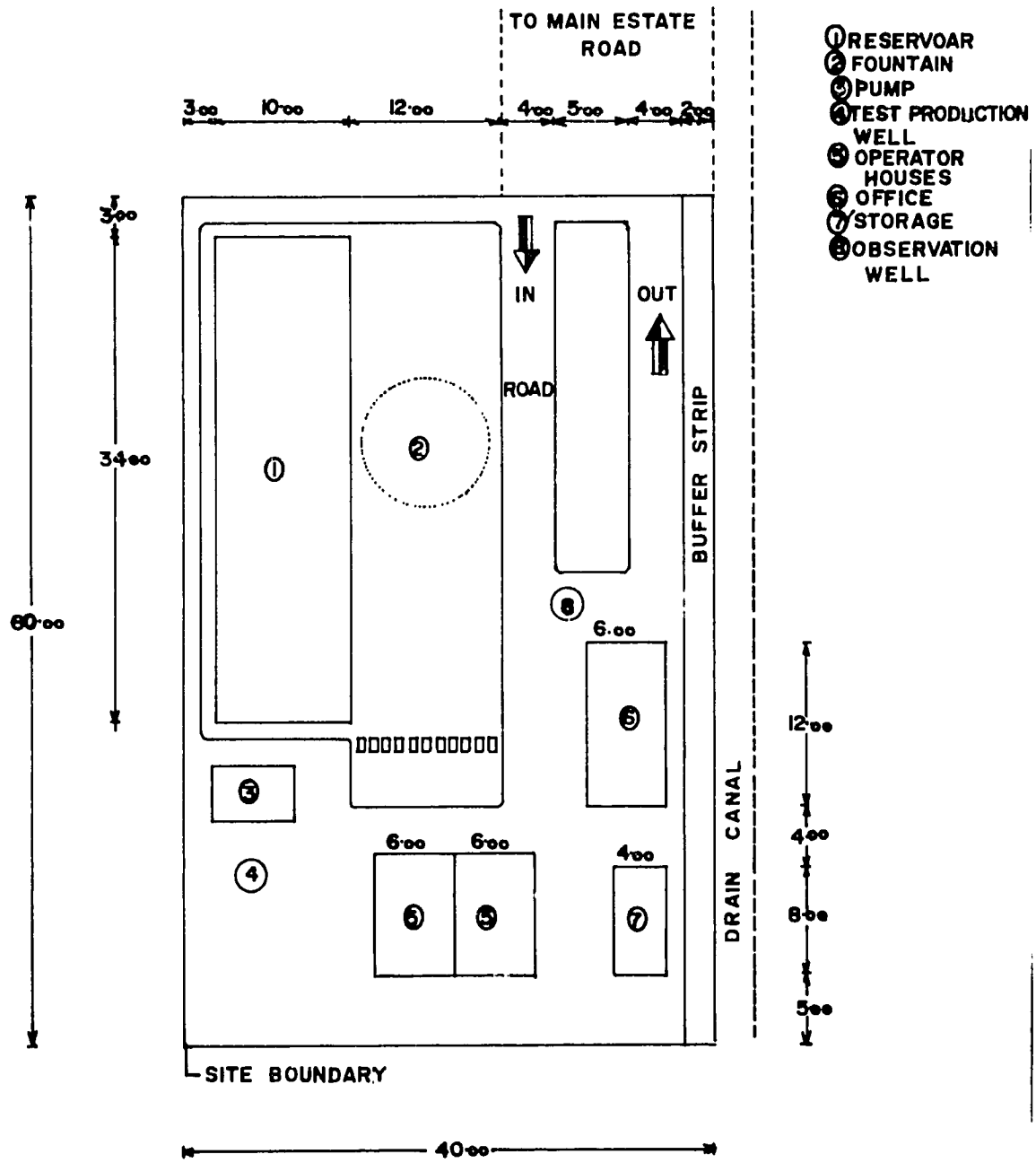
FIGURE A.2

LOCATION MAP FOR MABAR INDUSTRIAL ESTATE WELL SITE



PLAN OF MABAR INDUSTRIAL ESTATE

WATER WELL SITE



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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

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WELL DESIGN FOR OBSERVATION WELL AT MABAR INDUSTRIAL ESTATE

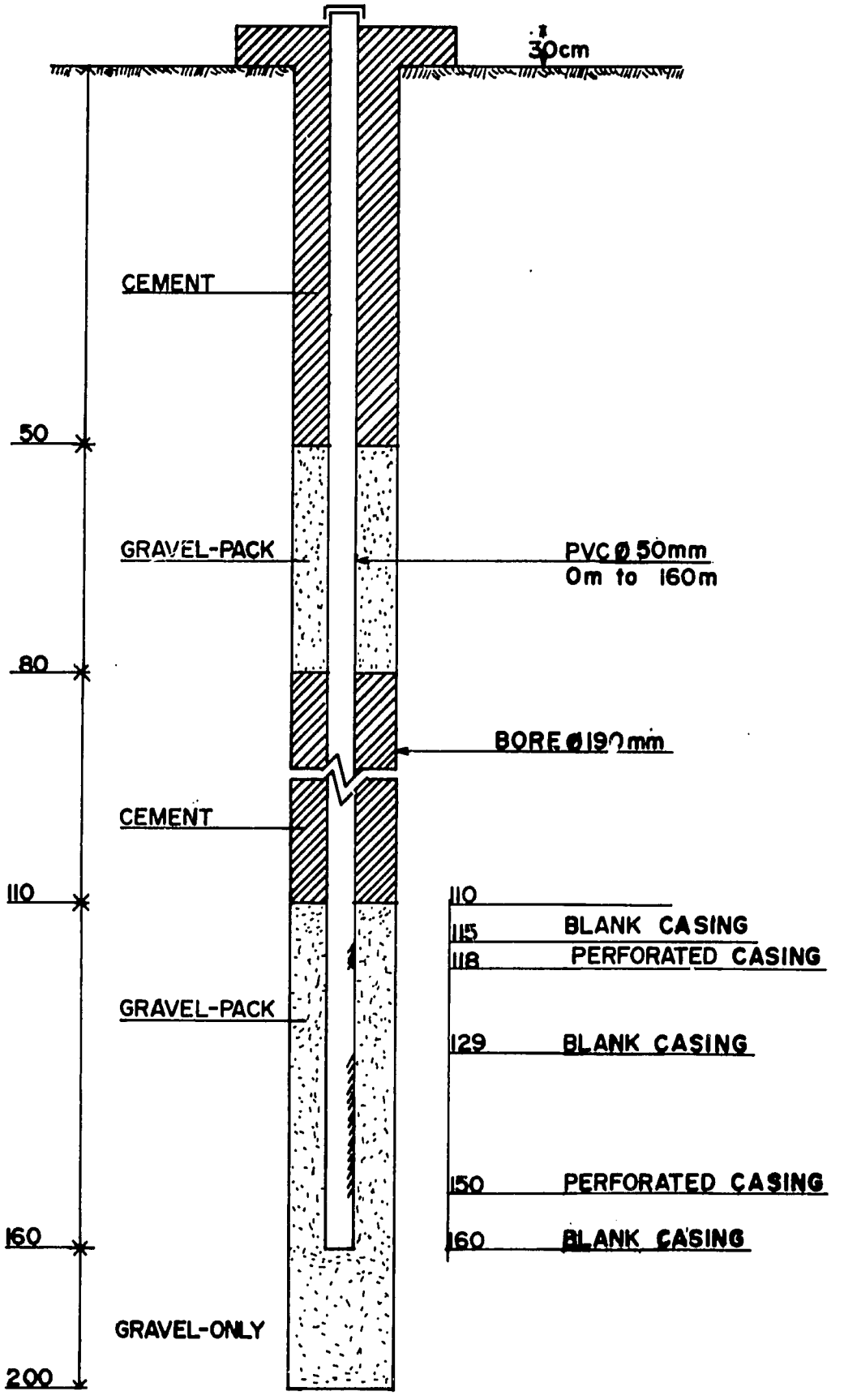
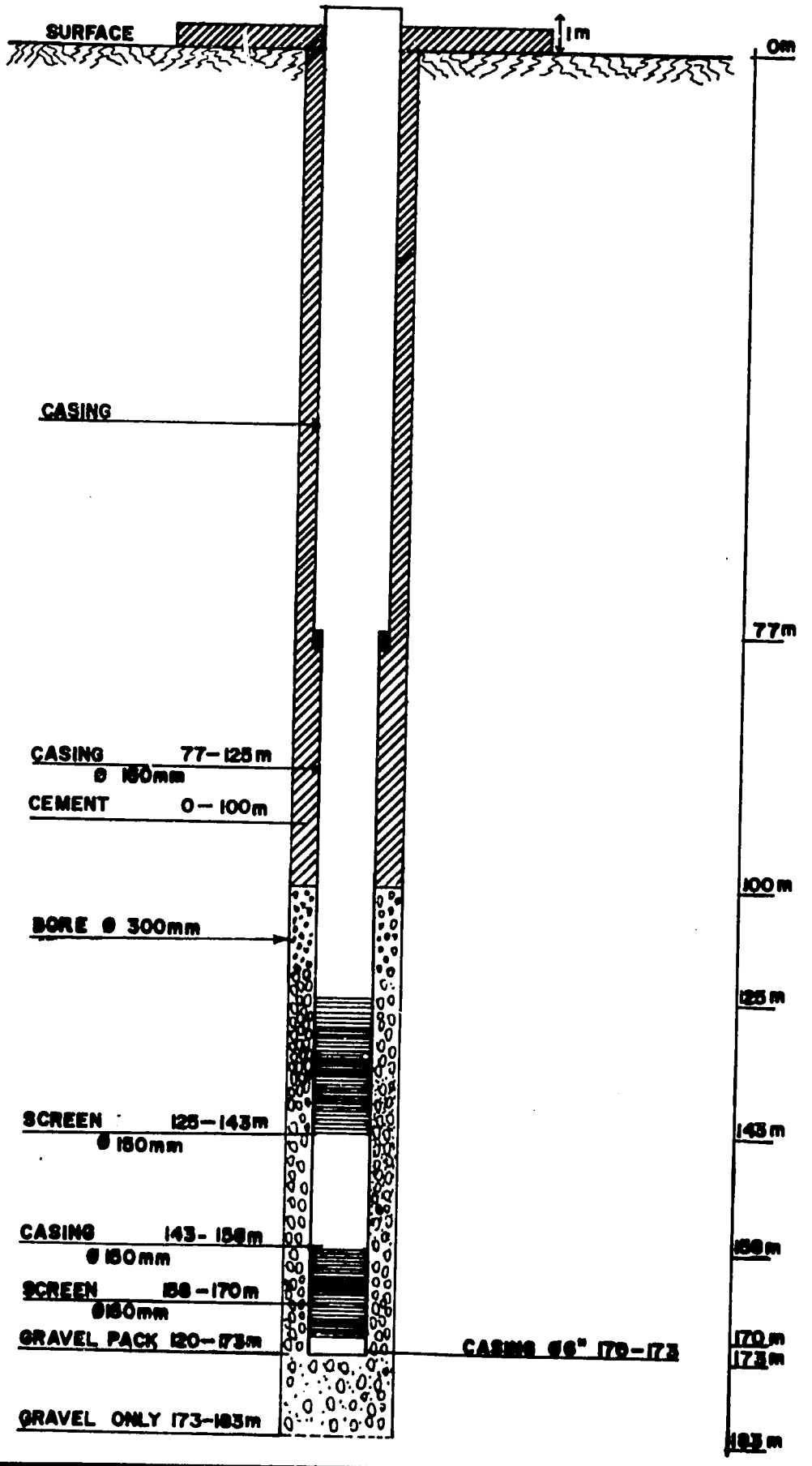


FIGURE A.5

WELL DESIGN-TEST PRODUCTION WELL AT MABAR INDUSTRIAL ESTATE



LOCATION MAP FOR MEDAN DENAI WELL SITE

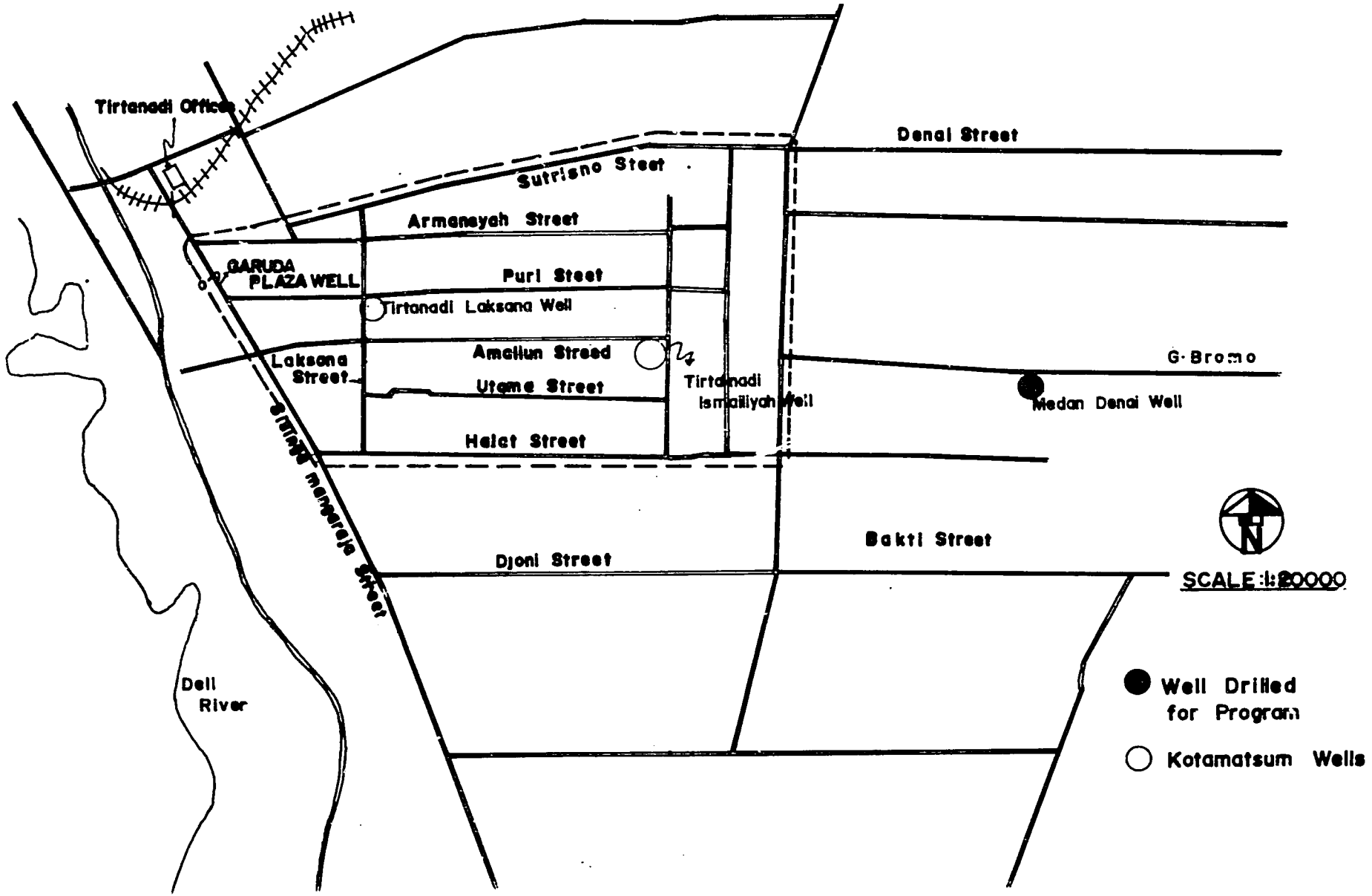


FIGURE A.6

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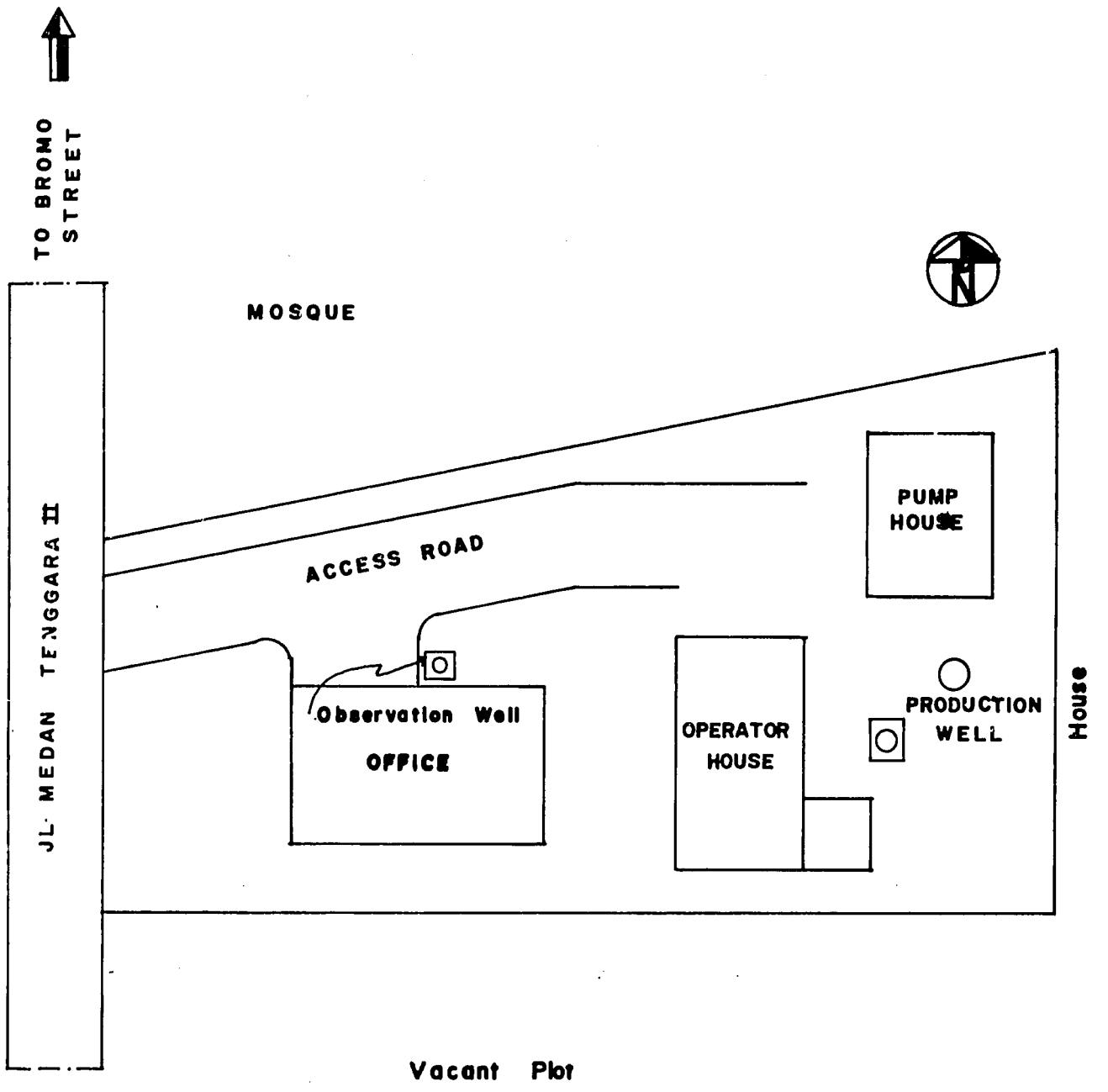
FIGURE A.7

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



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WELL DESIGN FOR OBSERVATION WELL AT MEDAN DENAI, TENGGARA STREET SITE

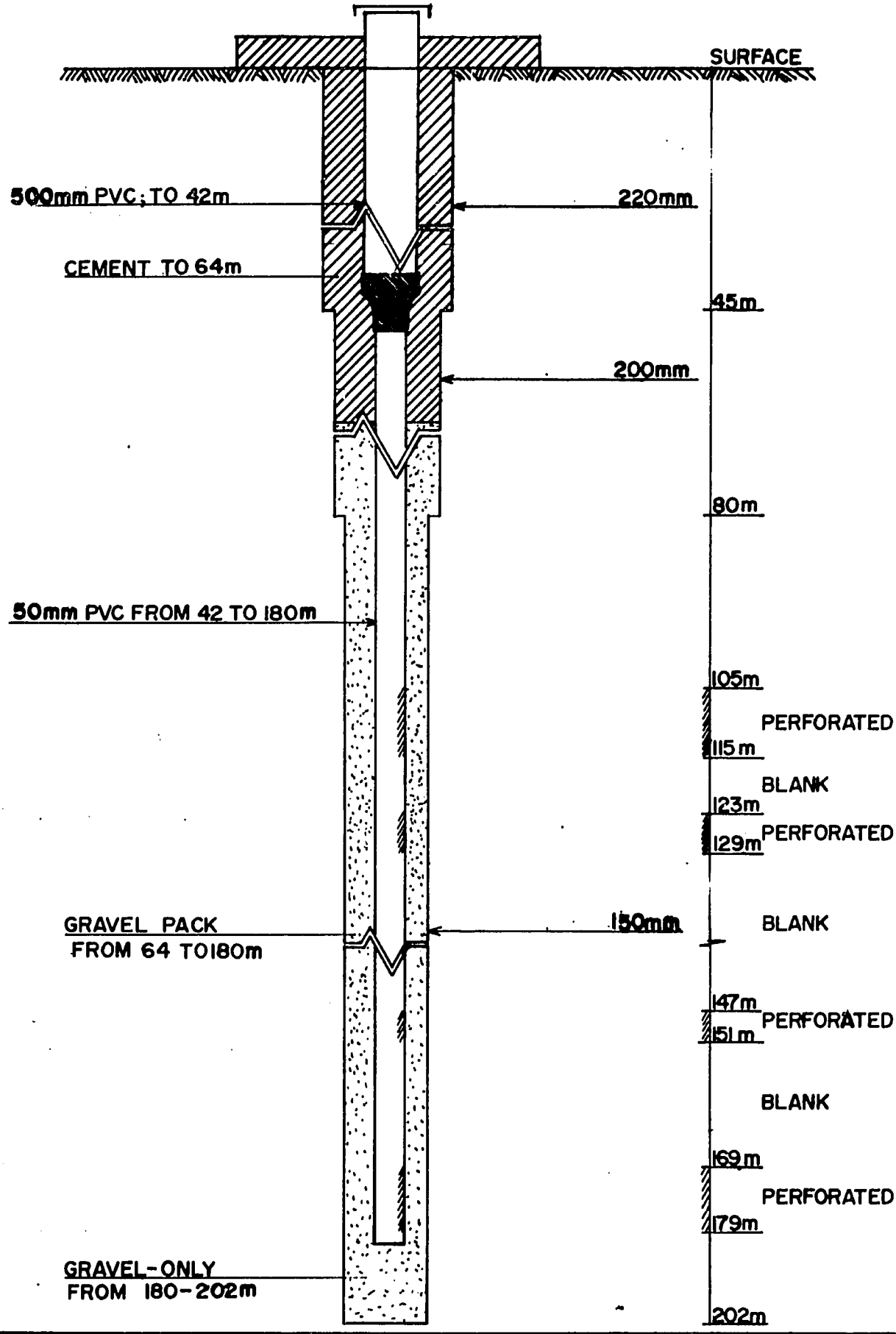
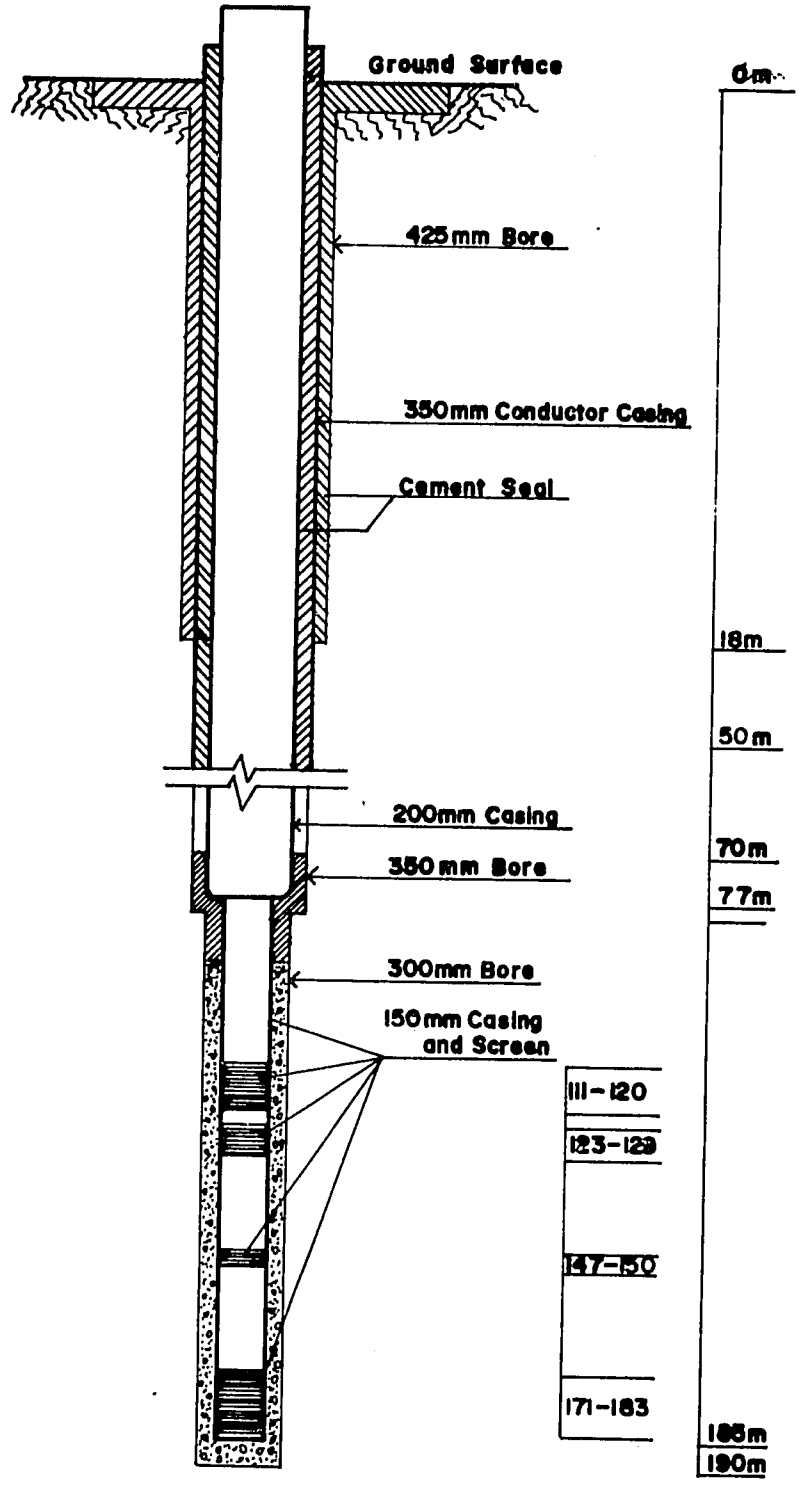


FIGURE A.9

WELL DESIGN FOR TEST WELL

AT MEDAN DENAI SITE



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.

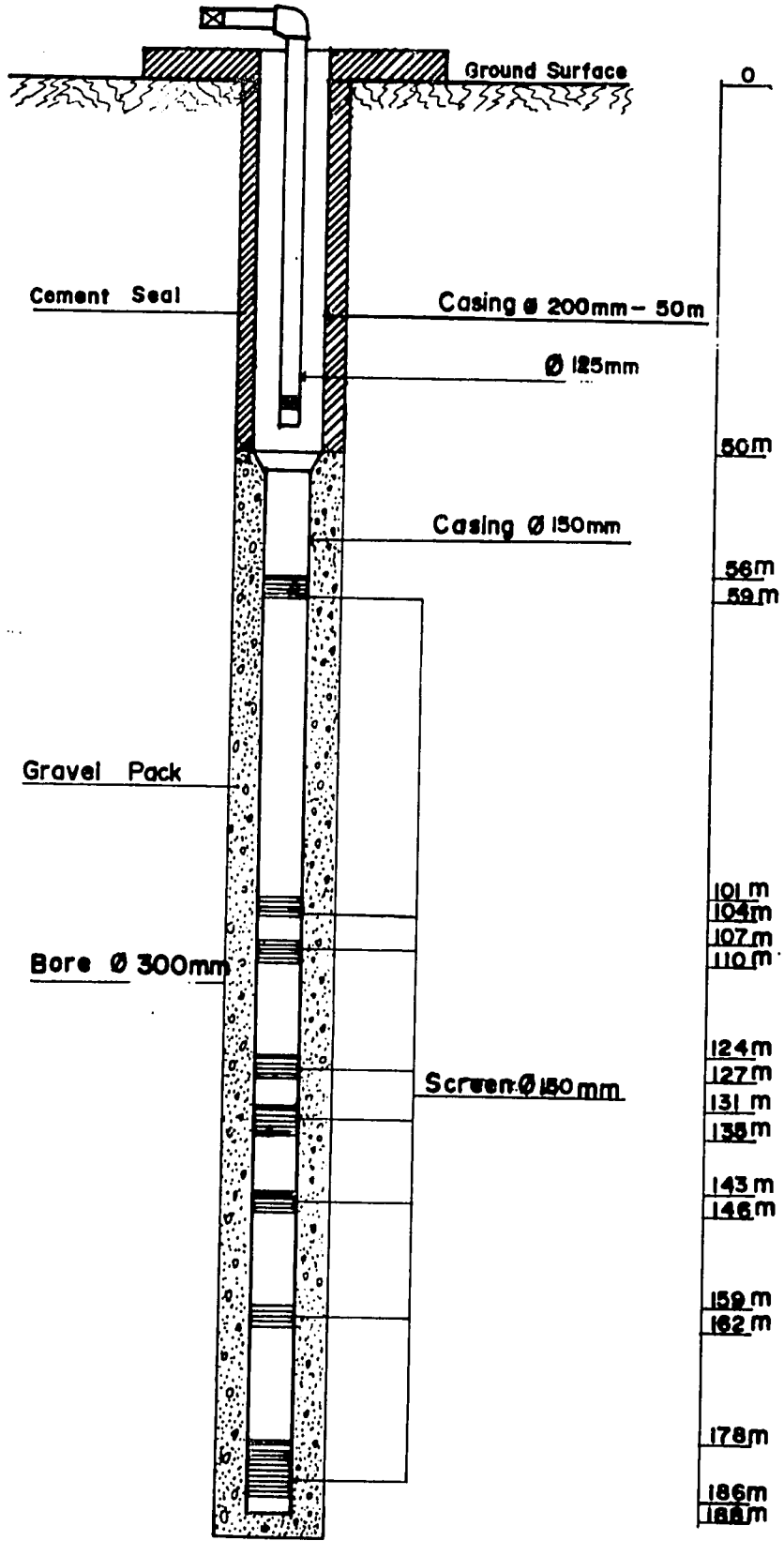
A.2.1.4 P.T. Brasseries Well

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.

FIGURE A.10

WELL DESIGN FOR PRODUCTION WELL AT LAKSANA-KOTAMATSUM SITE



WELL DESIGN FOR PRODUCTION WELL AT ISMAILIAH - KOTAMATSUM SITE

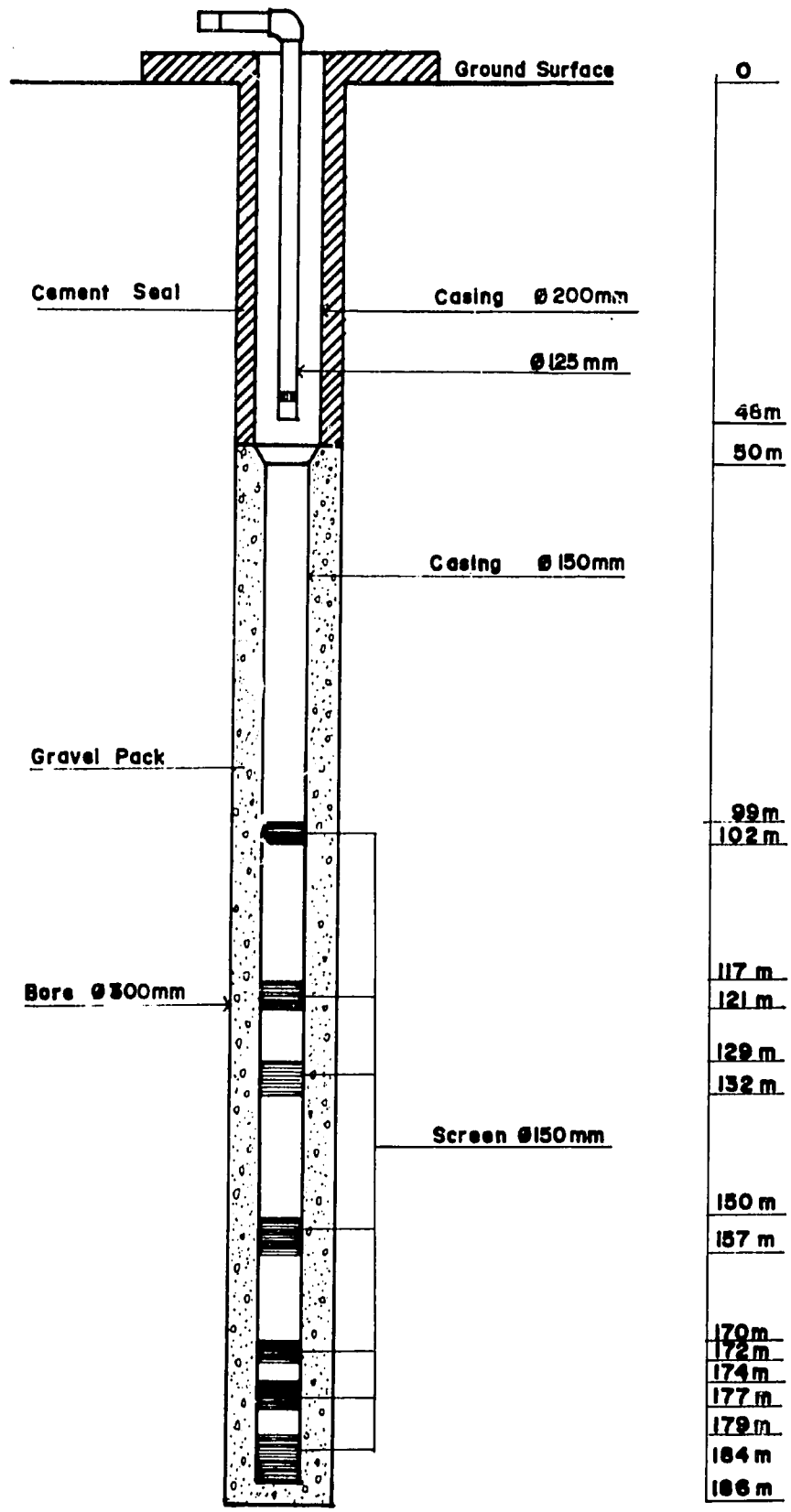
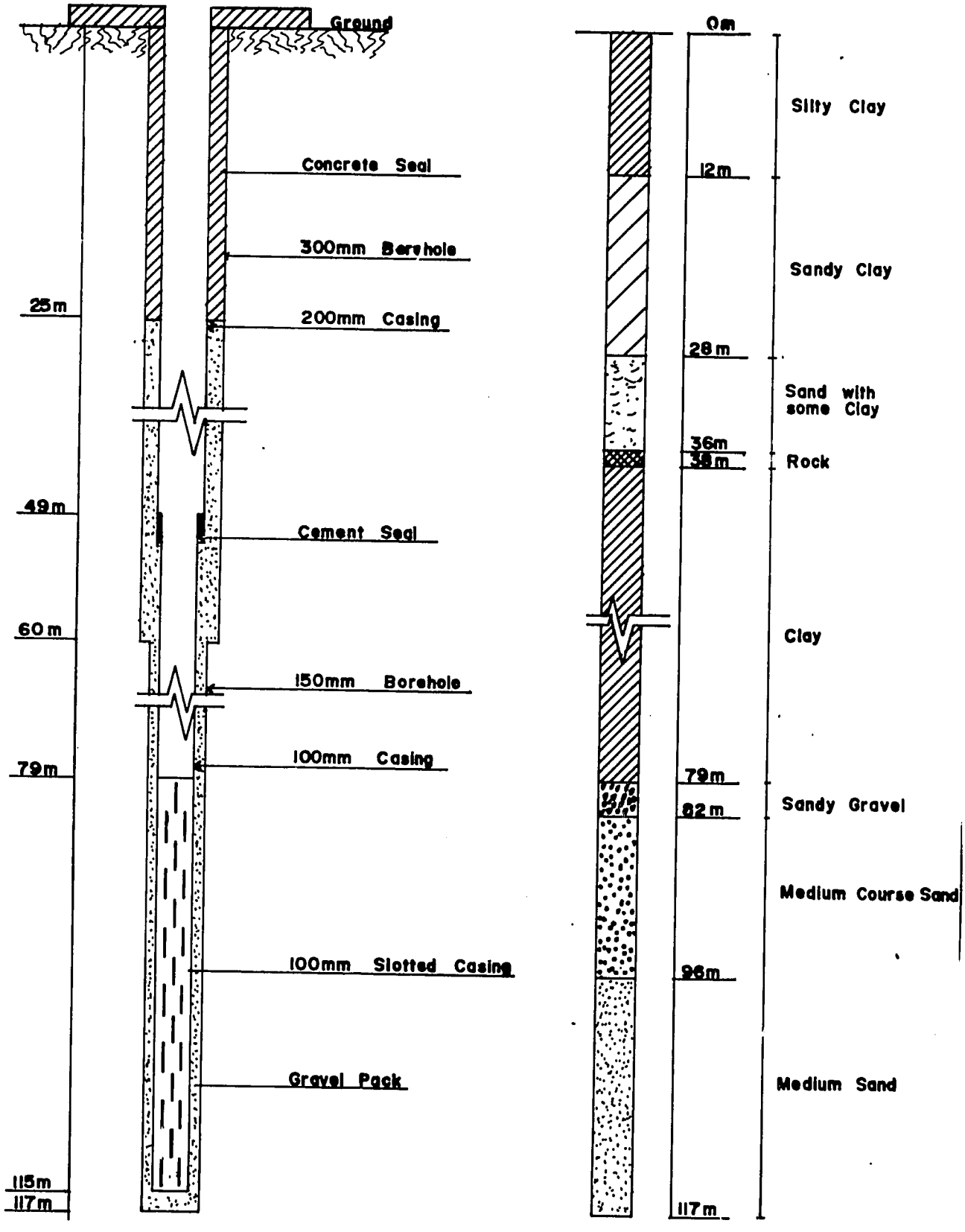


FIGURE A.12

WELL DESIGN FOR P.T BRASSERIES



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

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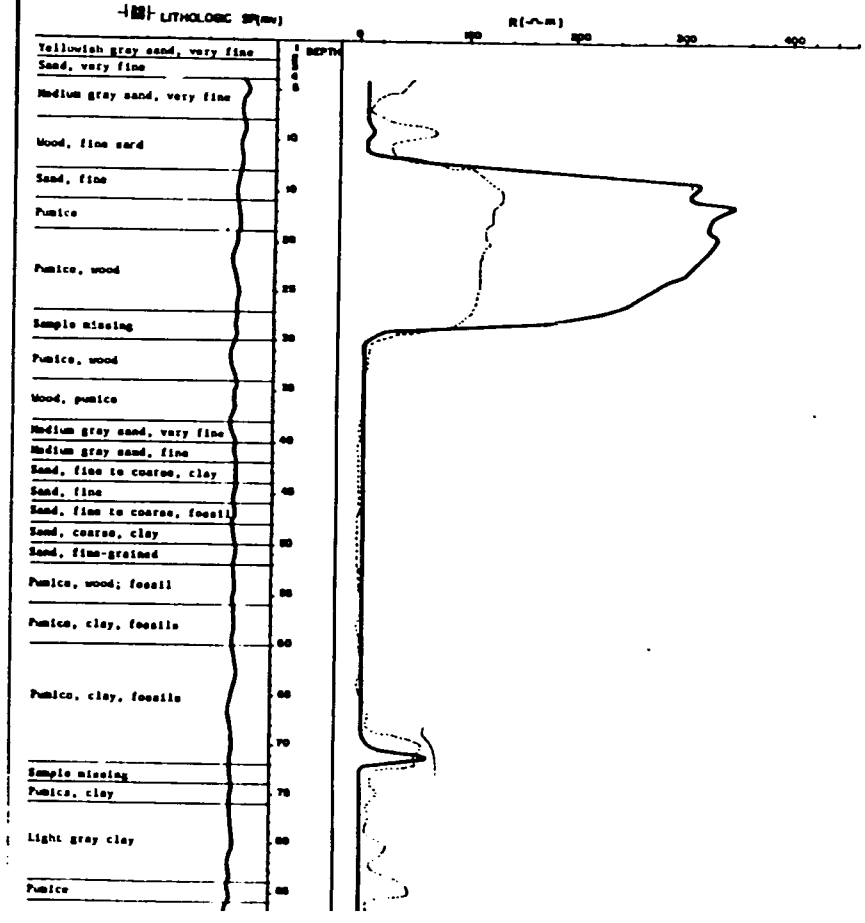
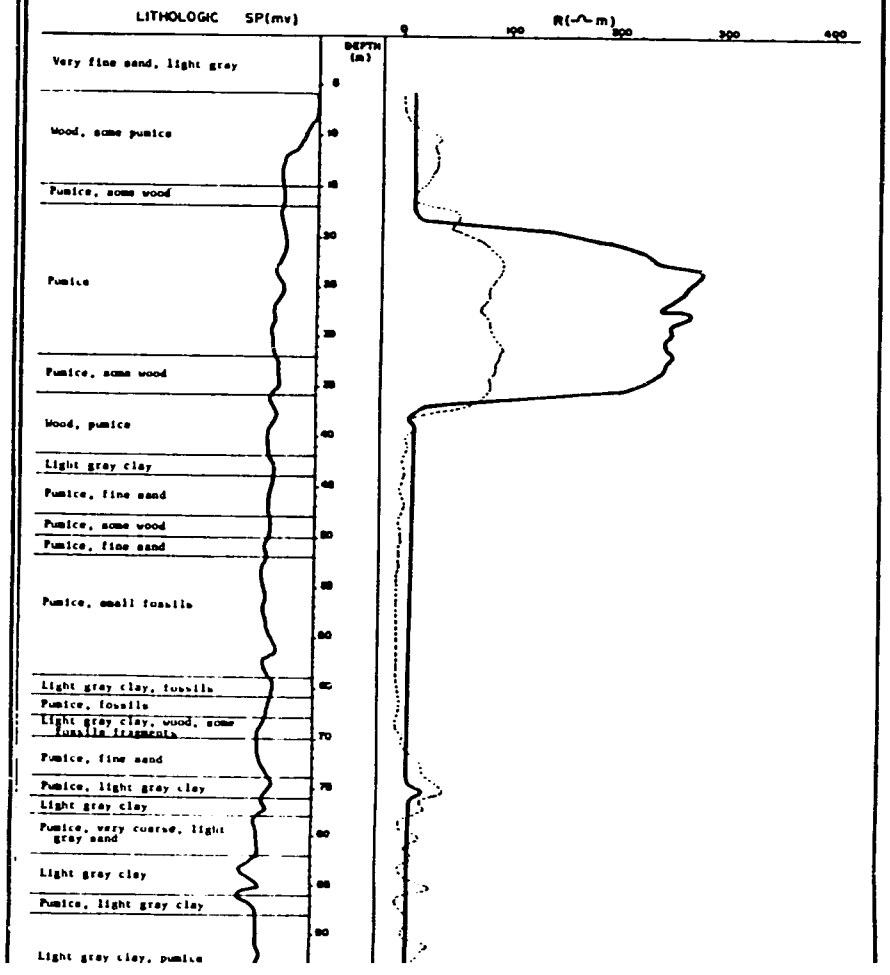
ELECTRIC LOG & LITHOLOGIC LOG

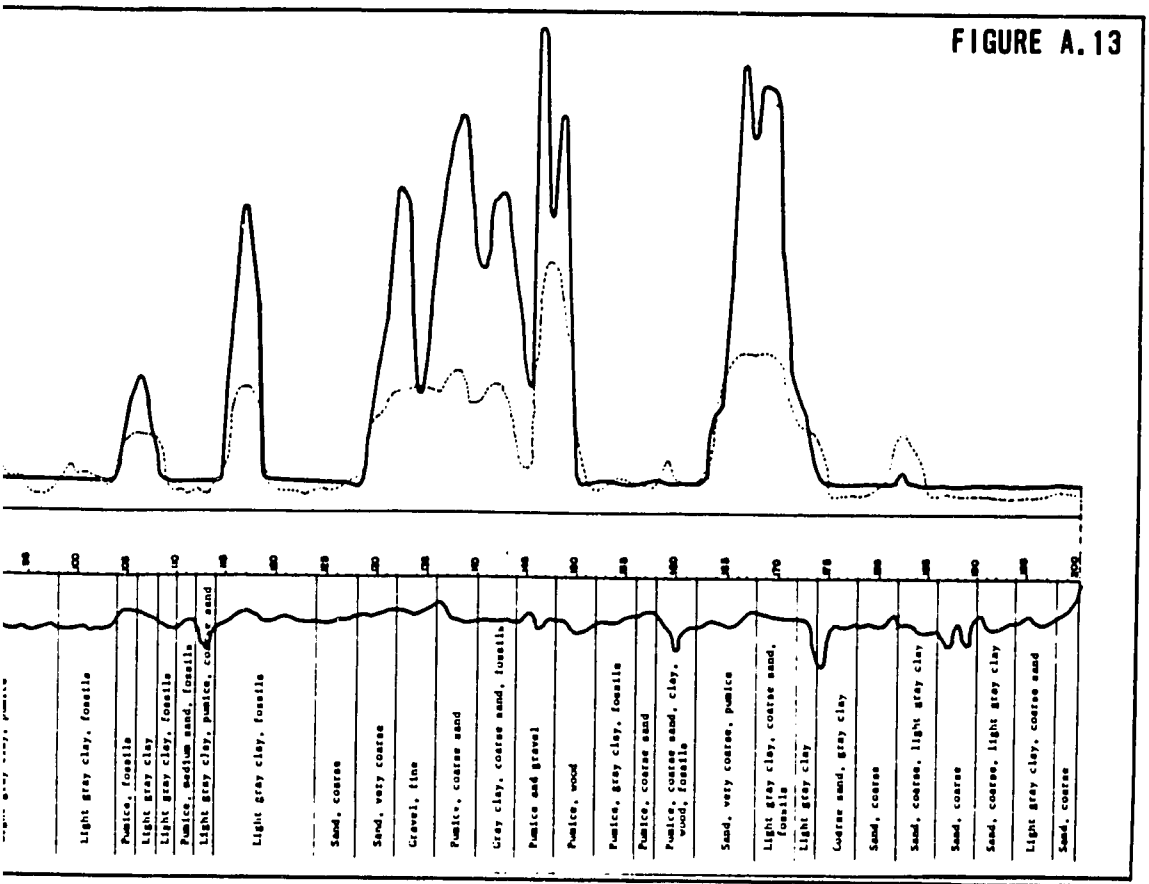
MABAR INDUSTRIAL ESTATE – TEST PRODUCTION WELL

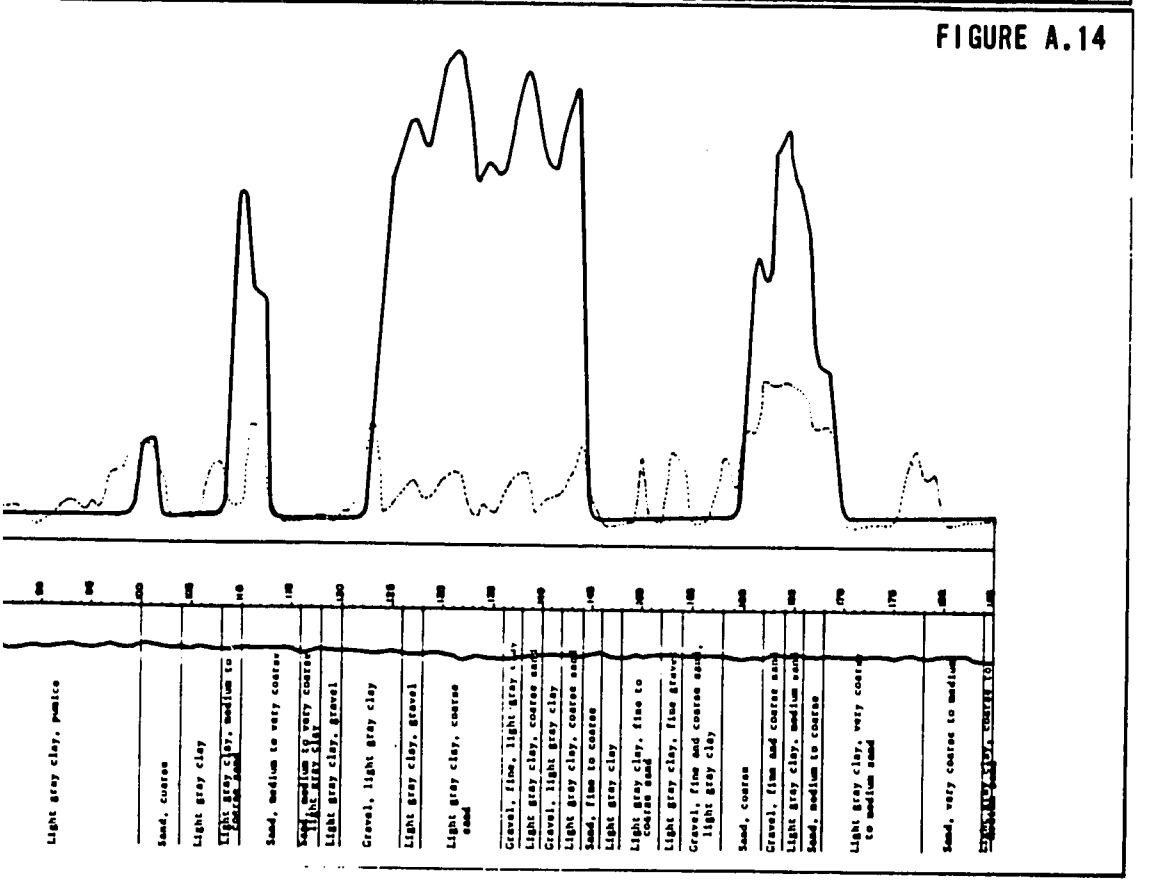


ELECTRIC LOG & LITHOLOGIC LOG

MABAR INDUSTRIAL ESTATE OBSERVATION WELL







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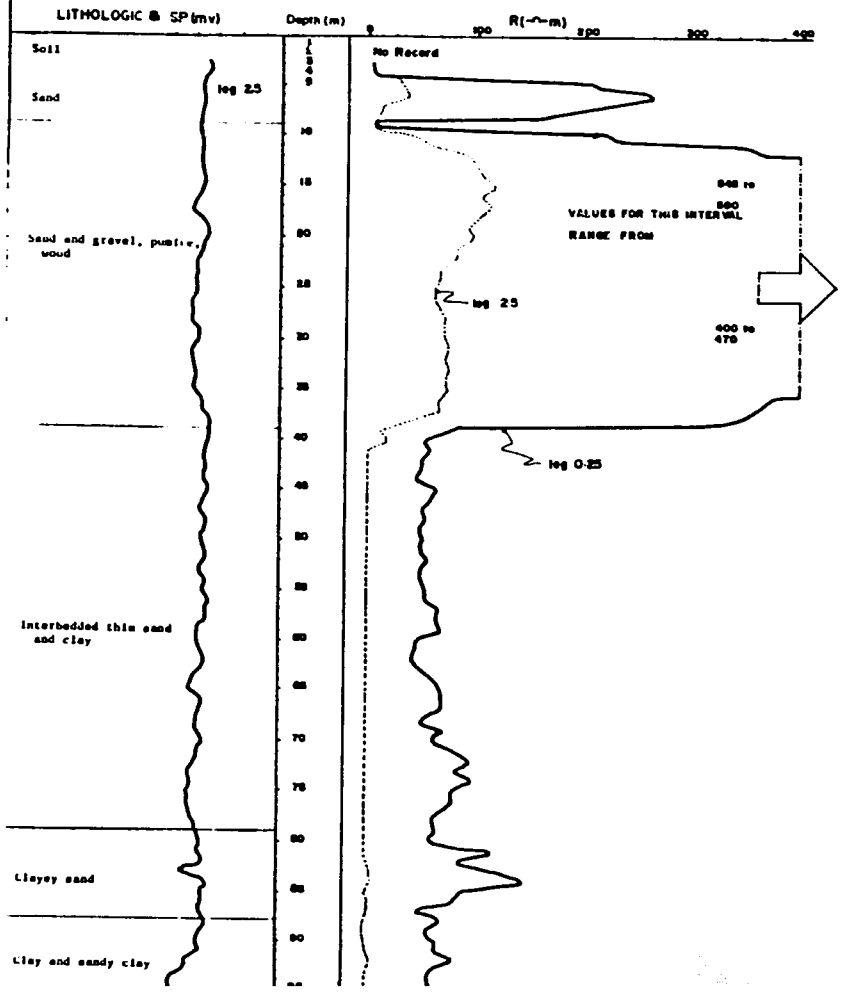
ELECTRIC—LOG & LITHOLOGIC LOG

ISMAILIYAH-KOTAMATSUM PRODUCTION WELL



ELECTRIC-LOG & LITHOLOGIC LOG

MEDAN DENAI OBSERVATION WELL

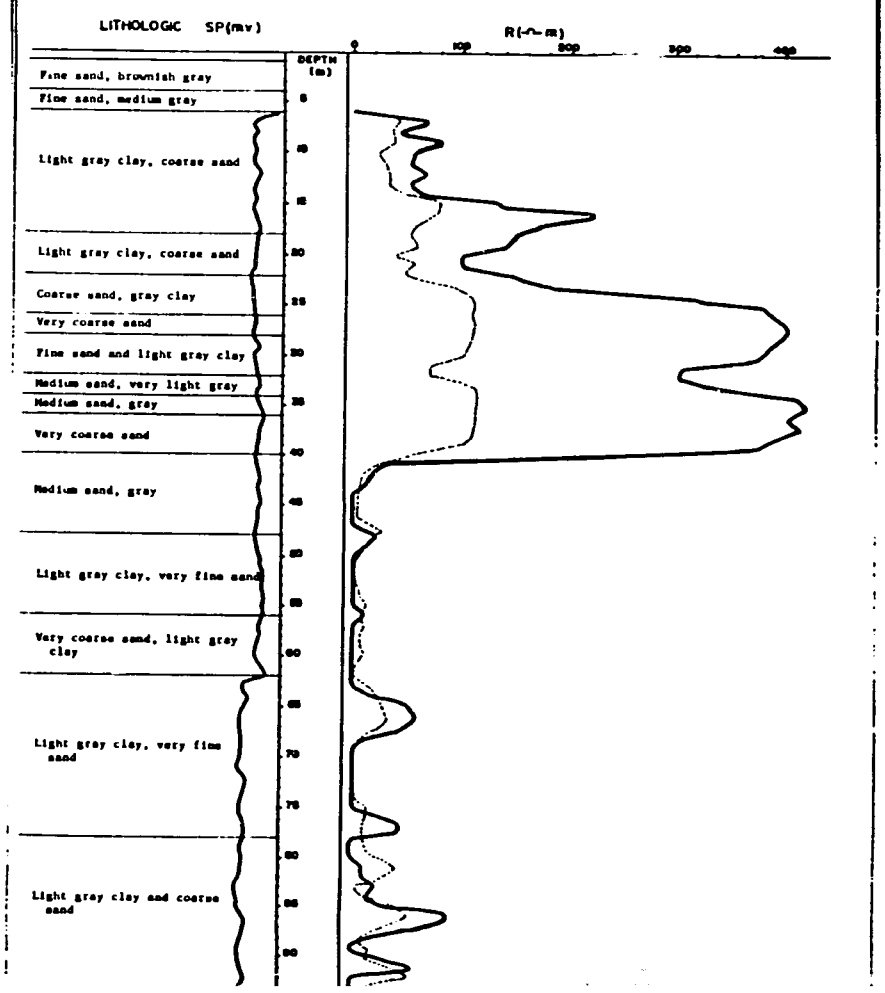


FIGURE A.15

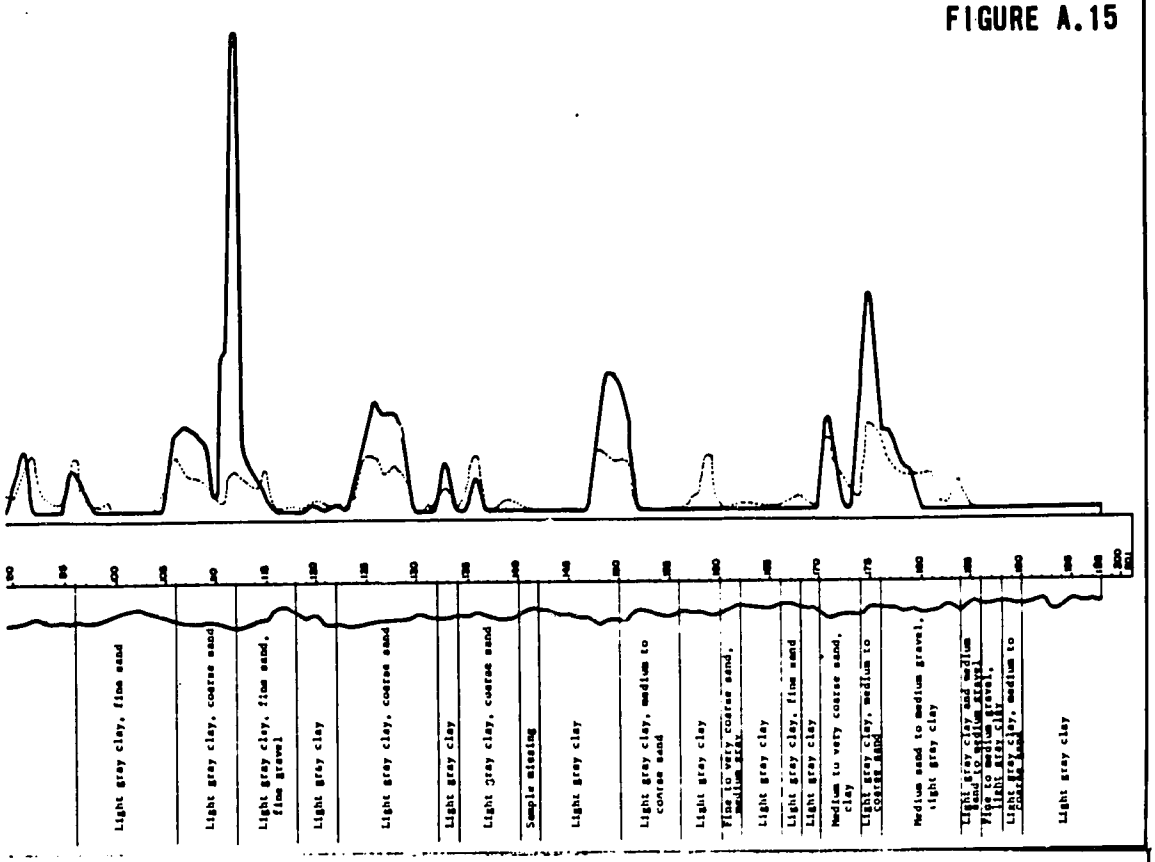
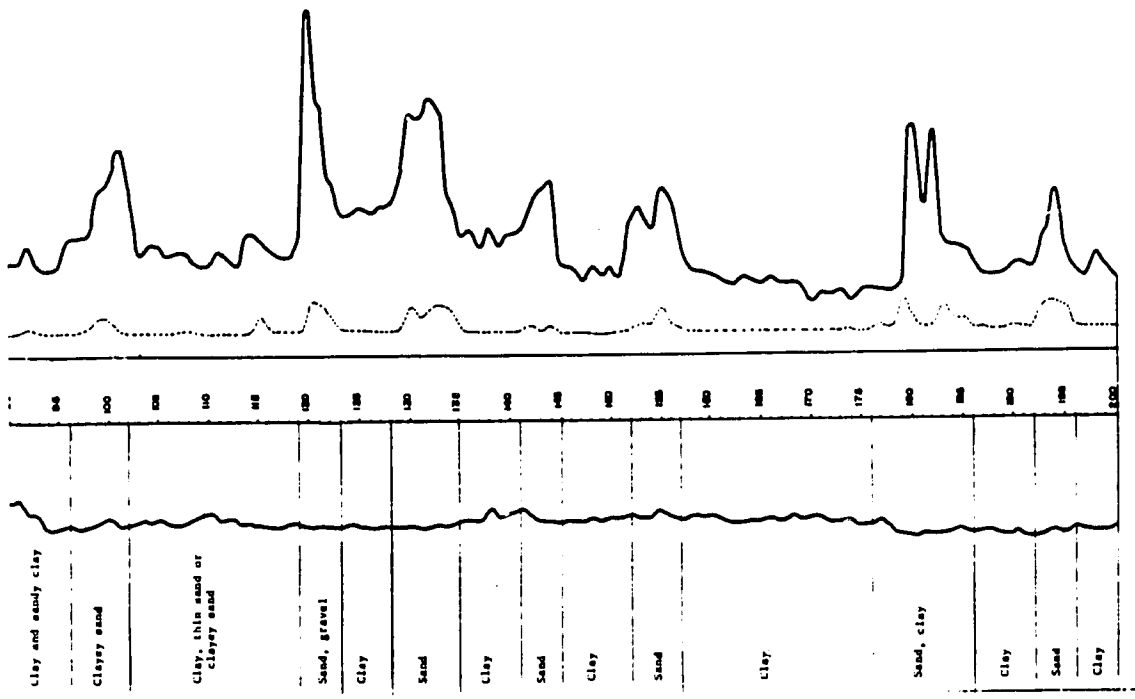


FIGURE A.16



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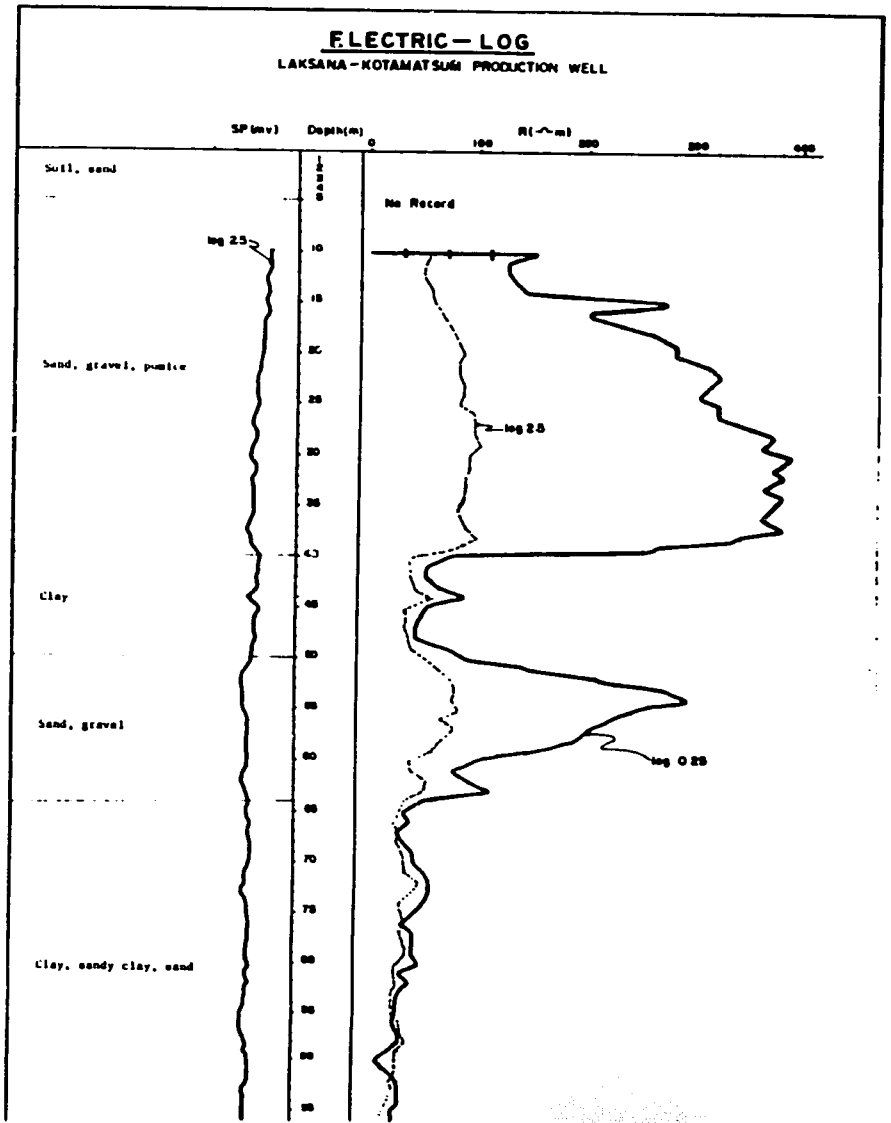

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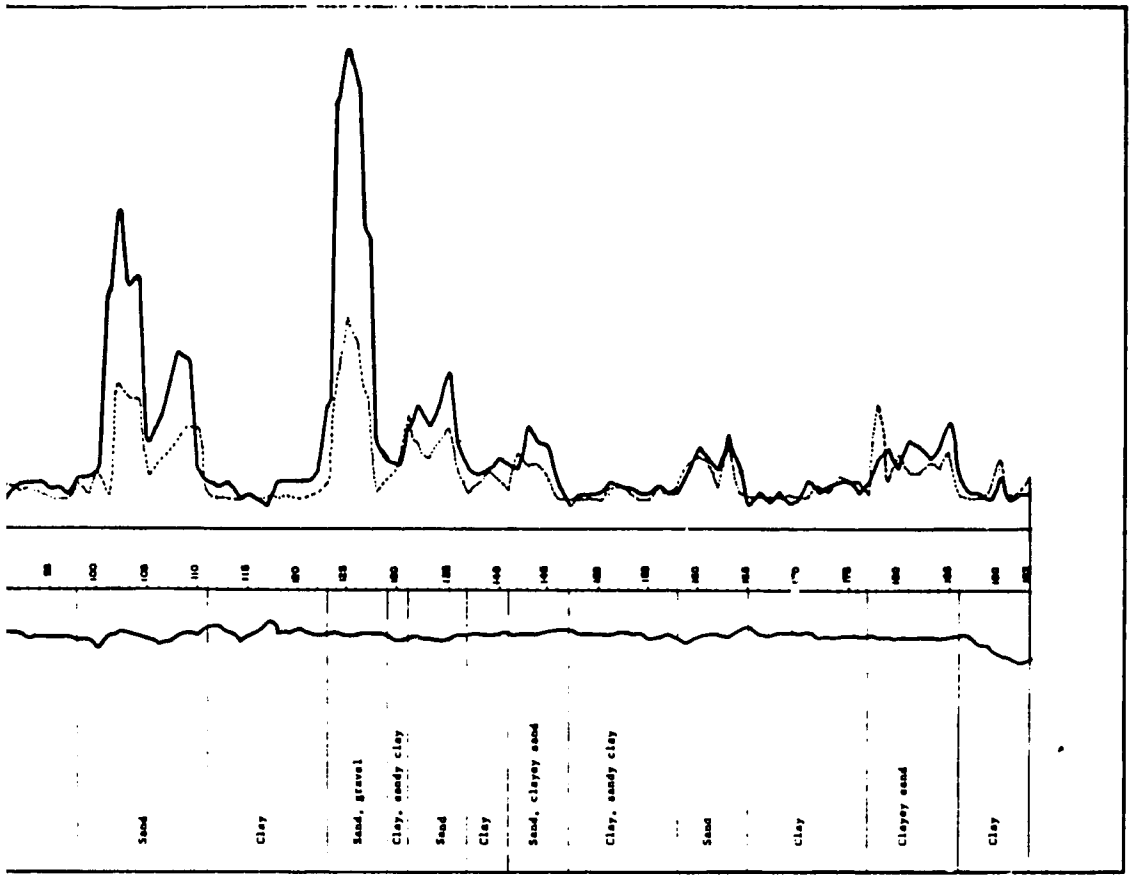

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Laksana electric log suggests a total aquifer thickness of 15 to 20 m, compared to about 34 m in the Ismailiyah well and to about 20 m in the Medan Denai well.

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.

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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

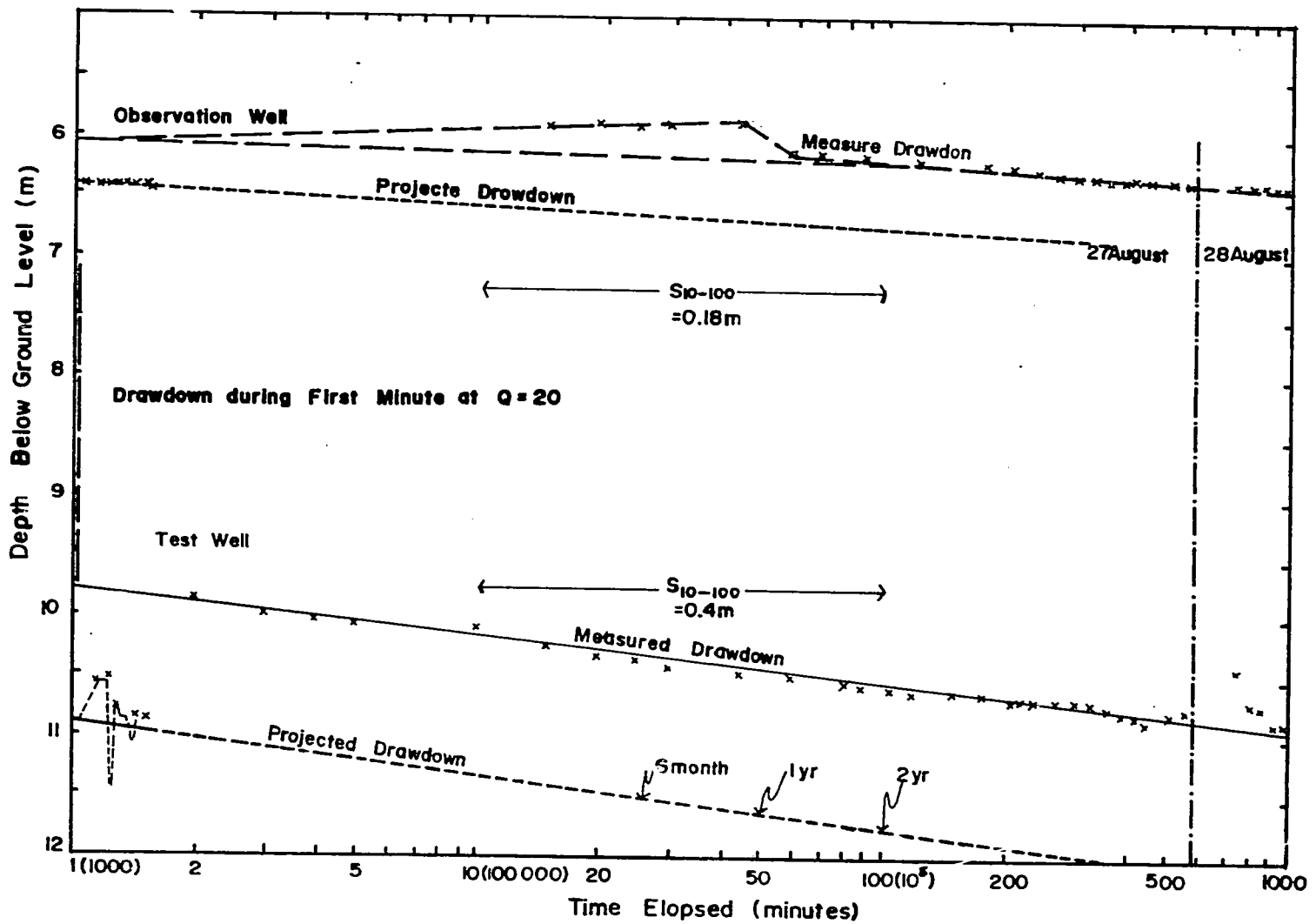
The uses of well data for geohydrologic analyses primarily focus on the comparison of production to drawdown either at the test well or at the observation well during the pumping and recovery tests. Most analyses involve calculation of transmissivity which relates permeability and total aquifer thickness. 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

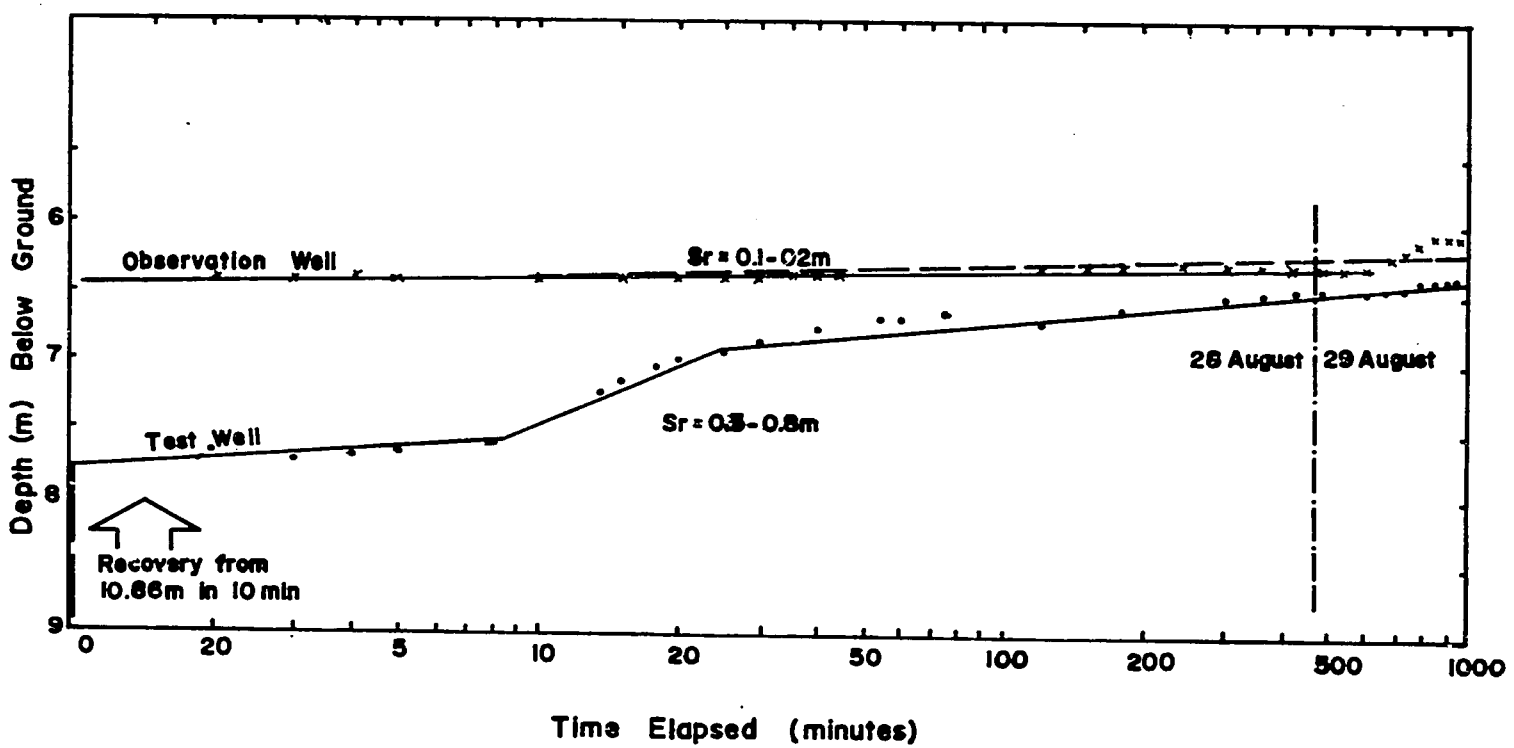
The testing of the Mabar well involved pumping of the test well and then recovery, while measuring drawdown at the test well and one observation well 30 m away. Water levels in the observation well had been measured for six weeks and in the test wells for two days before the test pumping. Flow was constant 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.

DRAWDOWN TEST RESULTS FROM MABAR SITE



RECOVERY TEST RESULTS

FROM MABAR SITE



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.

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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.

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**)		
117:12	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.

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.

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.

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:

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

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

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

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

$$S = 0.18$$

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:

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

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

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

(Total Drawdown: 9.00 - 9.55 m)

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

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.

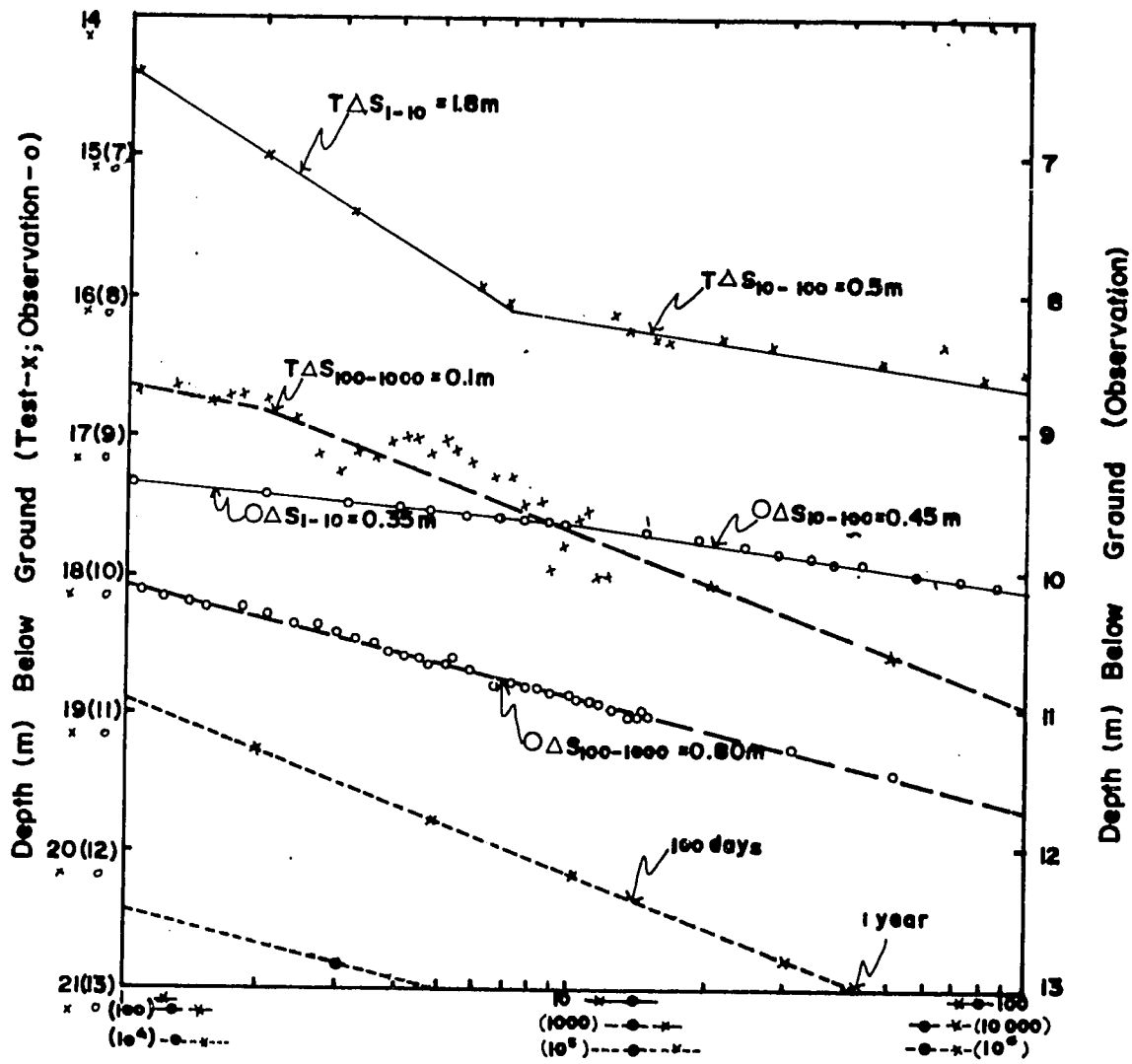
TABLE A.3--Continued

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

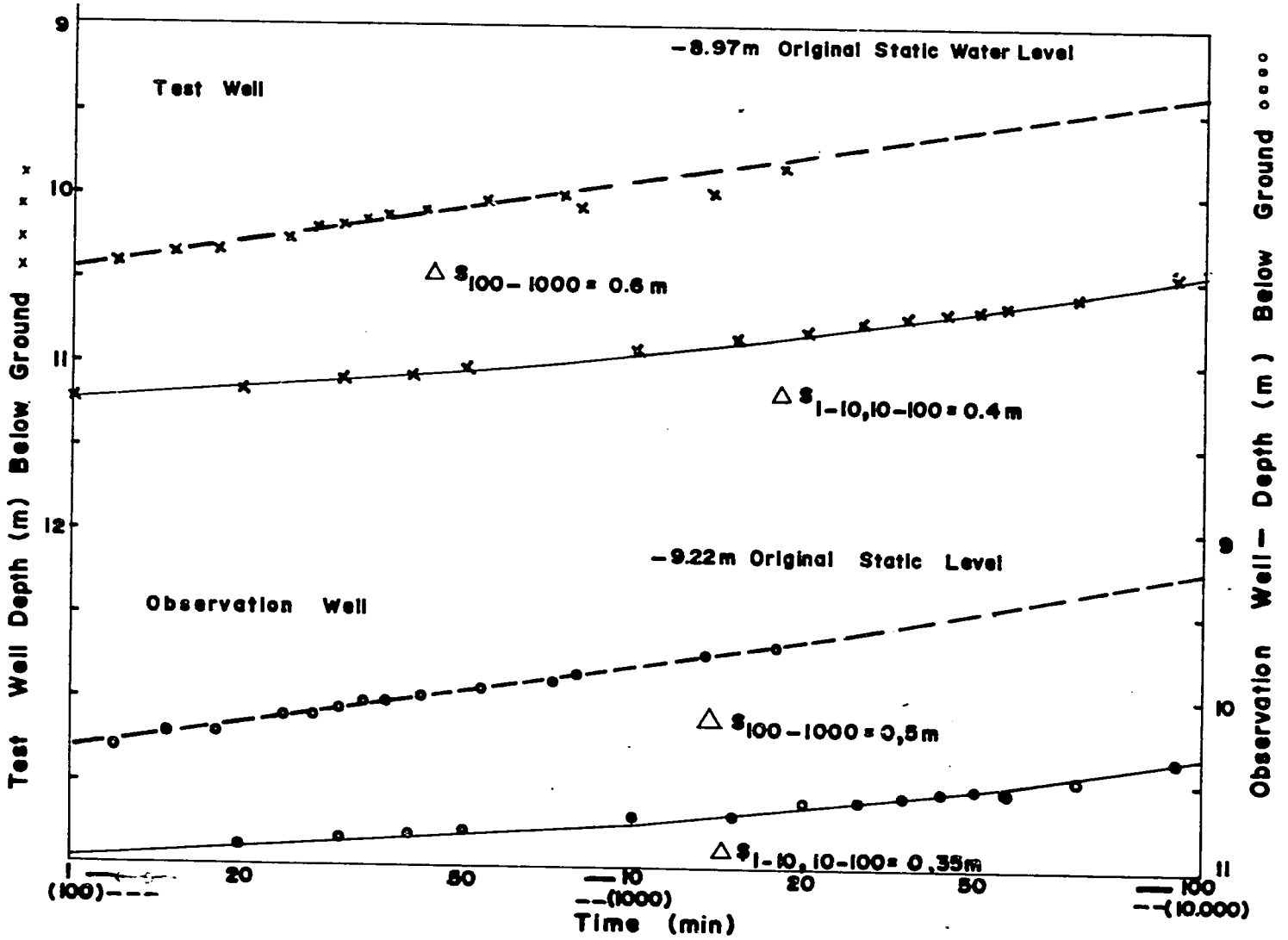
Time	Minutes Elapsed	Test Well Depth* (m)	Observation Well Depth* (m)
September 21, 1980			
09:10	0	18.23	11.65
	1	11.75	11.61
	2	11.71	11.48
	3	11.64	11.45
	4	11.61	11.42
	5	11.56	11.40
	10	11.45	11.32
	15	11.39	11.29
	20	11.34	11.24
	25	11.29	11.21
09:40	30	11.26	11.18
	35	11.24	11.17
	40	11.22	11.14
	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

DRAWDOWN TEST RESULTS

FROM MEDAN DENAI SITE



RECOVERY TEST RESULTS FROM MEDAN DENAI SITE



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

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:

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

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

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

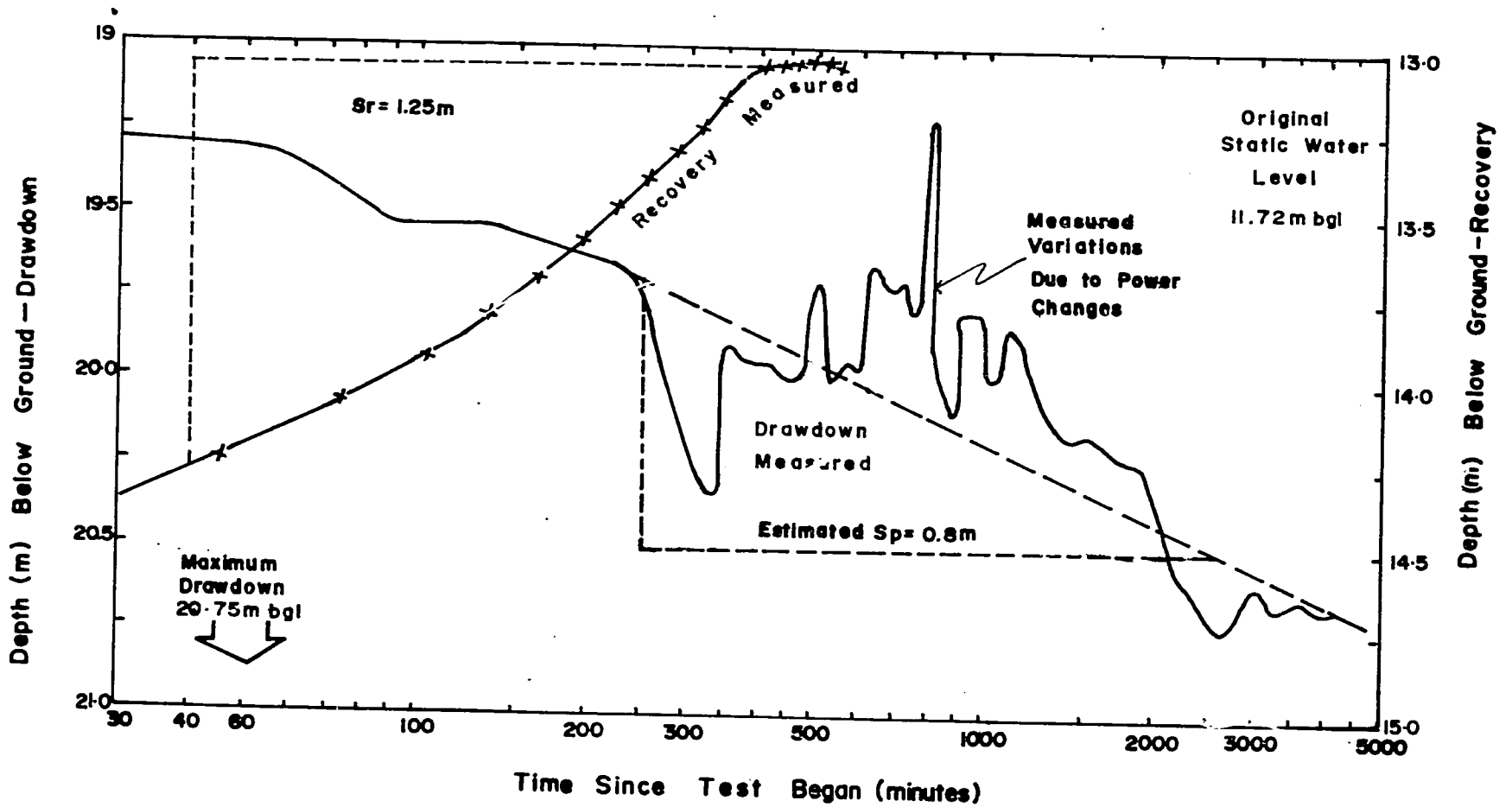
$$T_{I-500} = 249 \text{ cu m d/m} \qquad T_{L-500} = 236 \text{ cu m d/m}$$

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

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 ISMAILIYAH - KOTAMATSUM WELL TEST



DRAWDOWN AND RECOVERY CURVES FOR LAKSANA - KOTAMATSUM WELL TEST

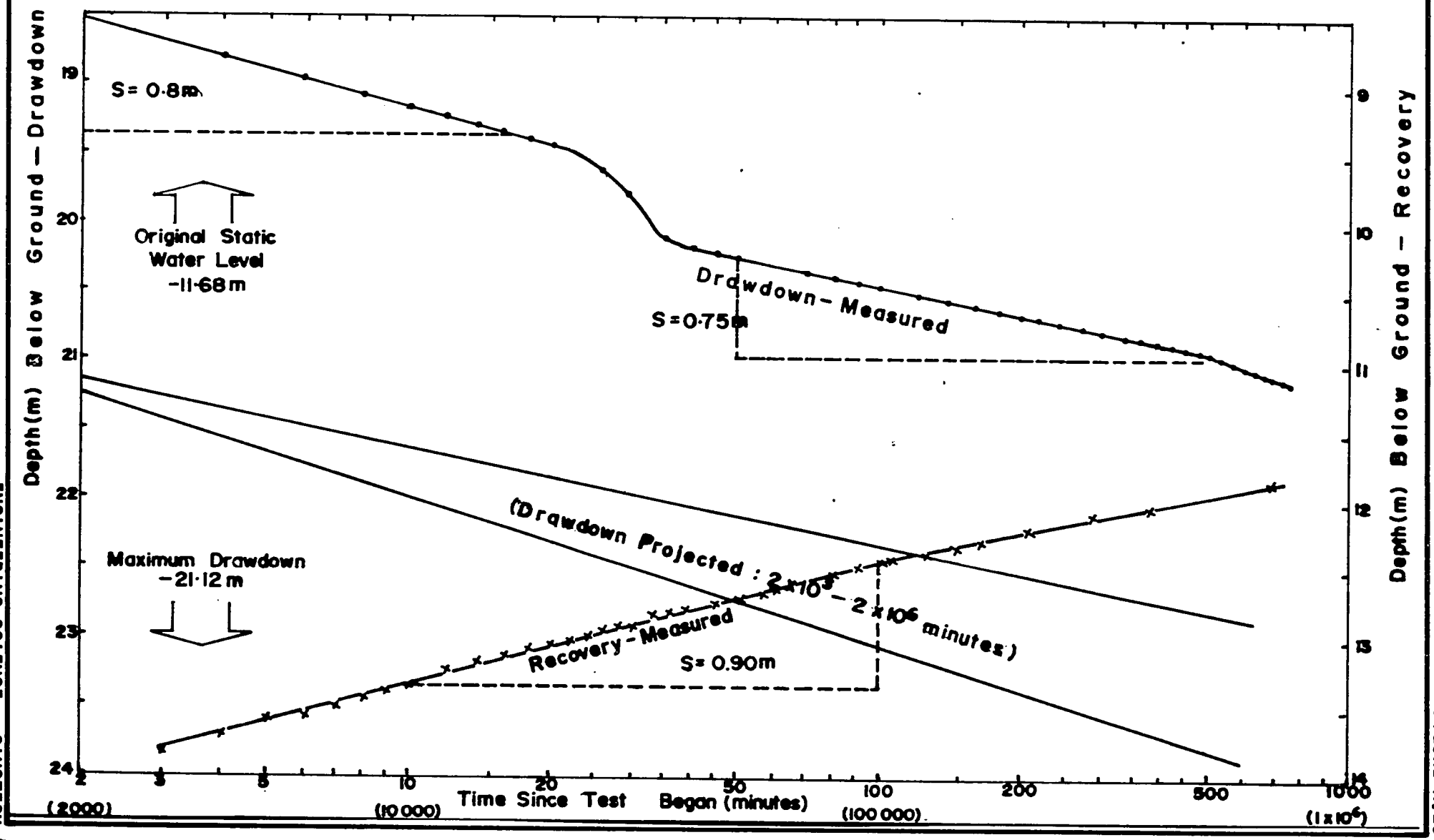
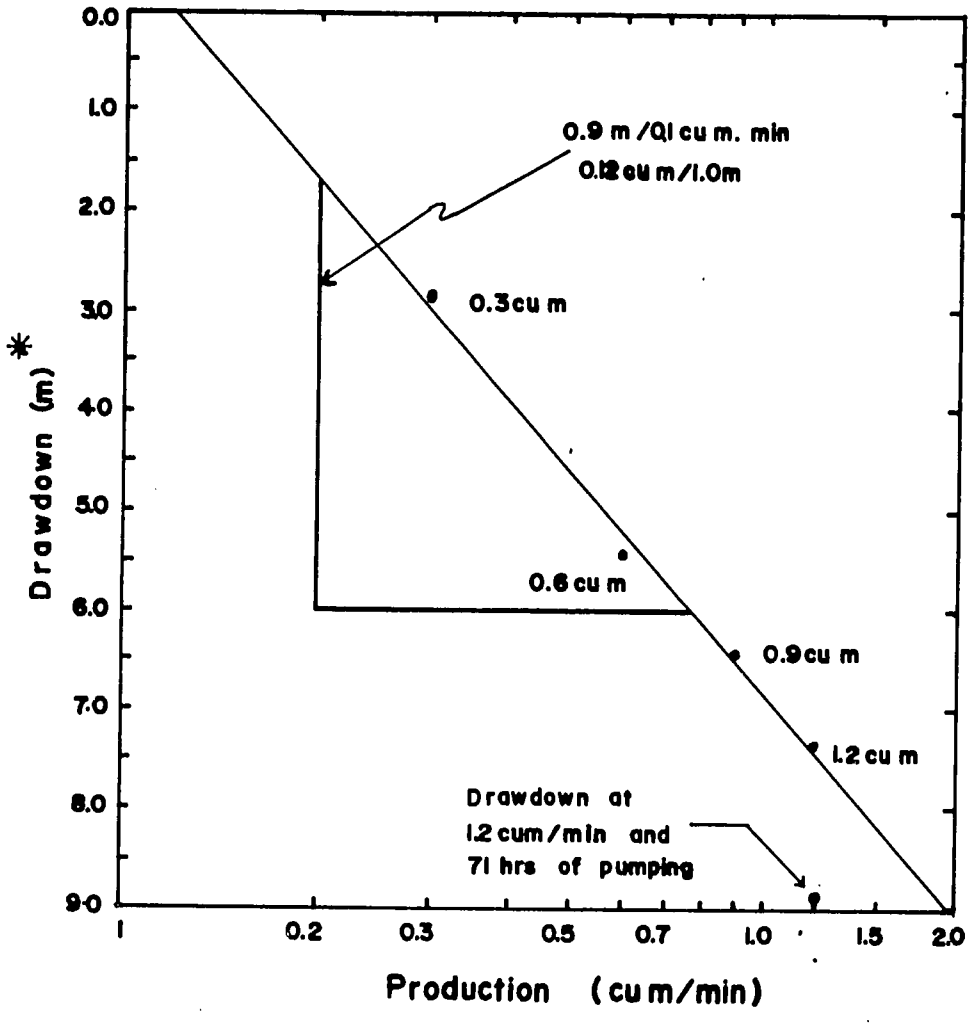


FIGURE A.23

FIGURE A.24

DRAWDOWN : CAPASITY FOR STEP-DRAWDOWN TEST AT ISMAILIYAH - KOTAMATSUM WELL



*After 120 minutes of Pumping

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.

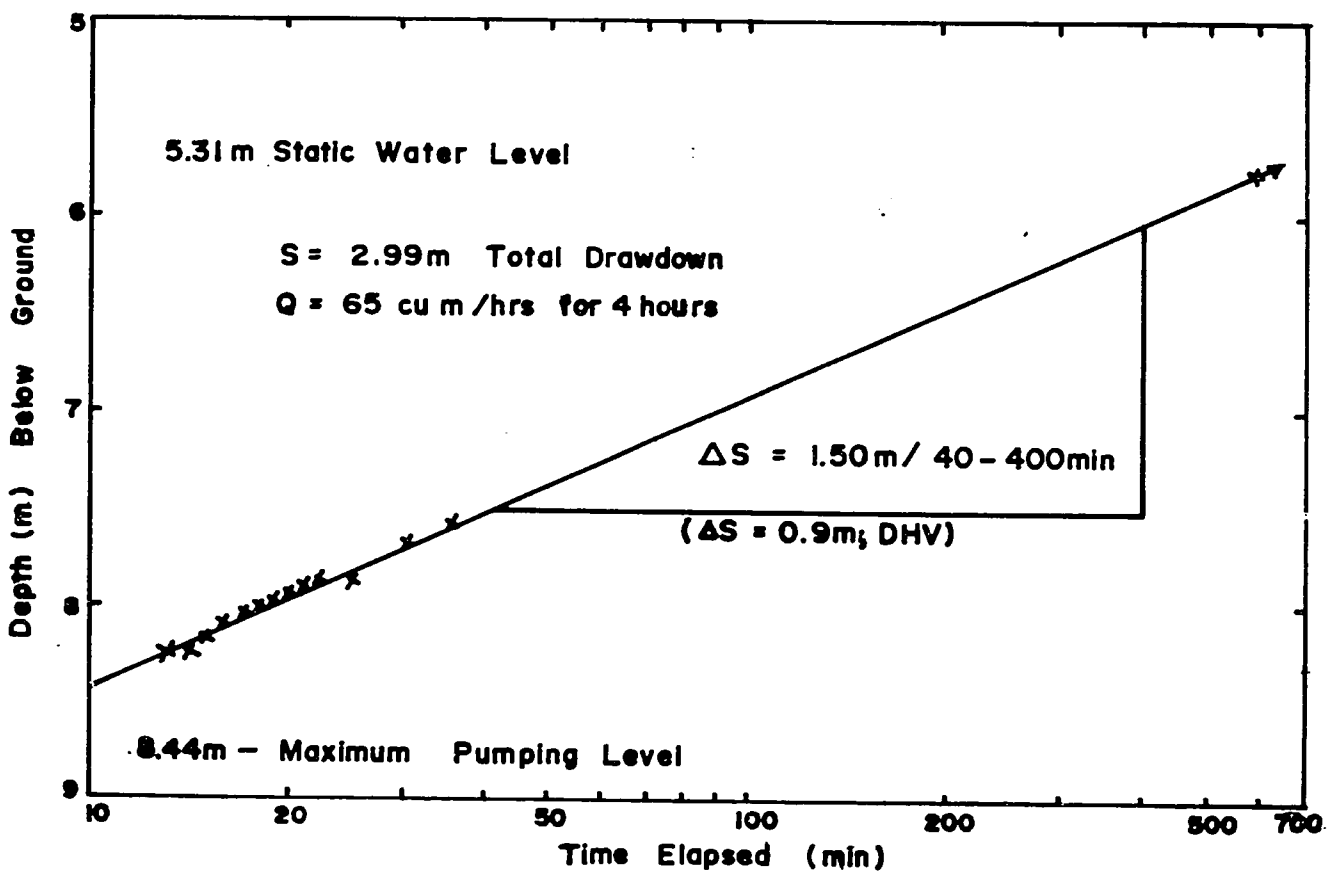
A.4.2.5 Other Wells Analyses

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

RECOVERY RESULTS FROM PRELIMINARY TEST AT THEP P.T. BRASSERIES



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,

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

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:

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

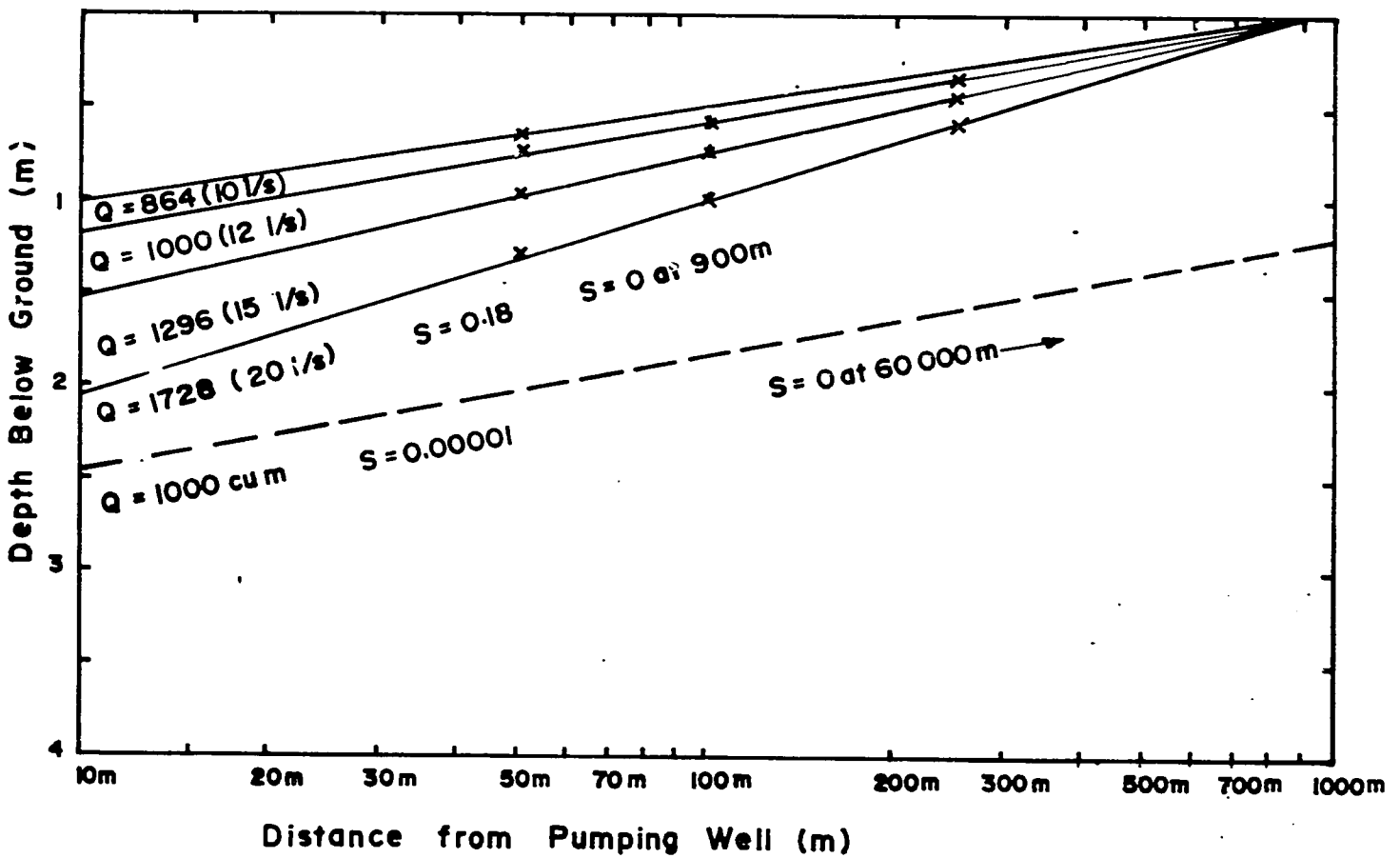
* litres/second in ( )

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



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 days and equation $u = \frac{r^2 S}{4Tt}$; $S = \frac{W(u)\,Q}{4 x \pi x T}$.

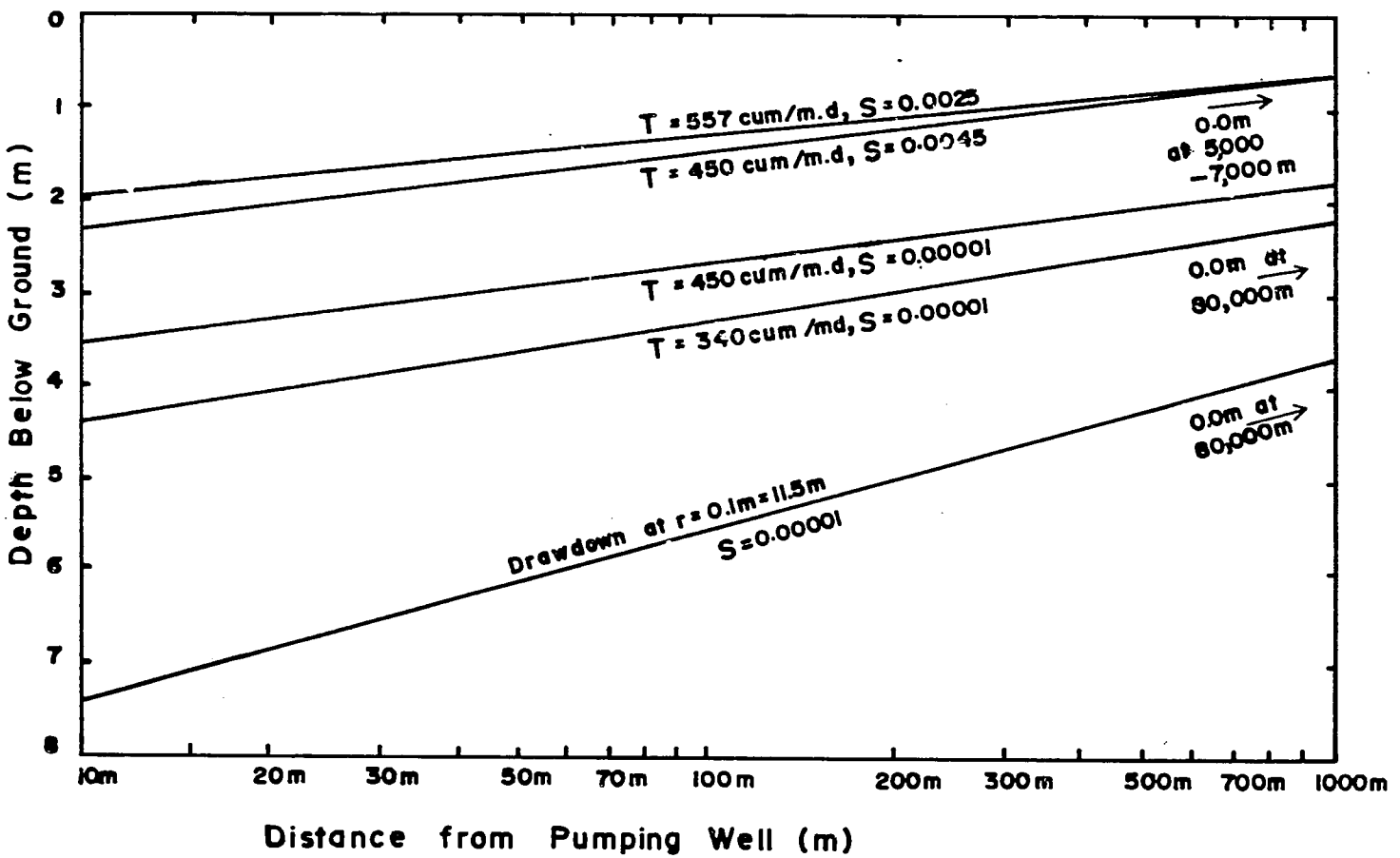
Because of the greater variations in transmissivity and storage values at Medan Denai, several different values were substituted to indicate the range of drawdown which would be expected. Influence of storage values at Medan Denai is also shown in Figure A.27. As the transmissivity and storage values 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



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.

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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

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.

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

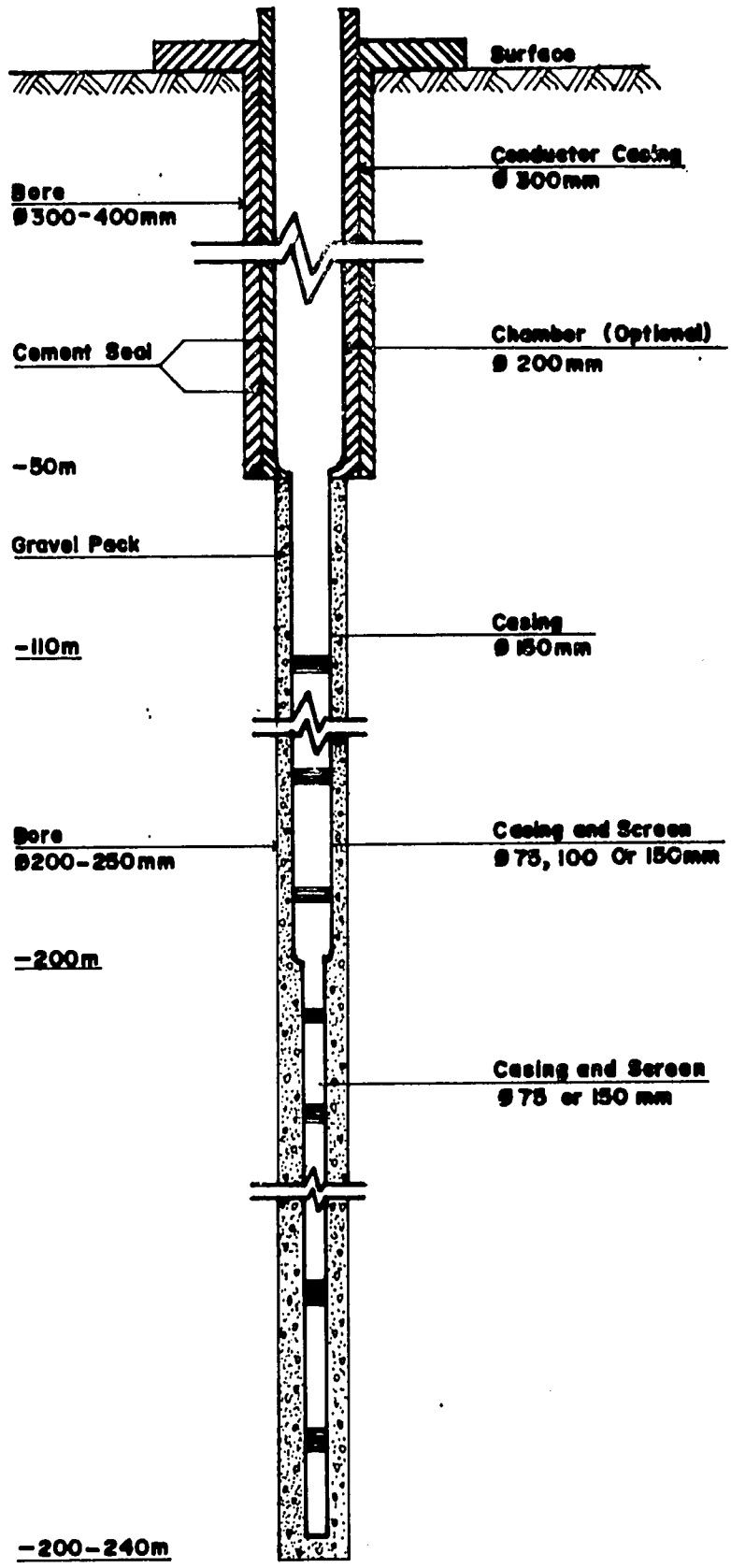
* Head loss in m loss per 1,000 m, a Hazen-Williams Coefficient of 125.

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:

MODIFED 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

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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

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

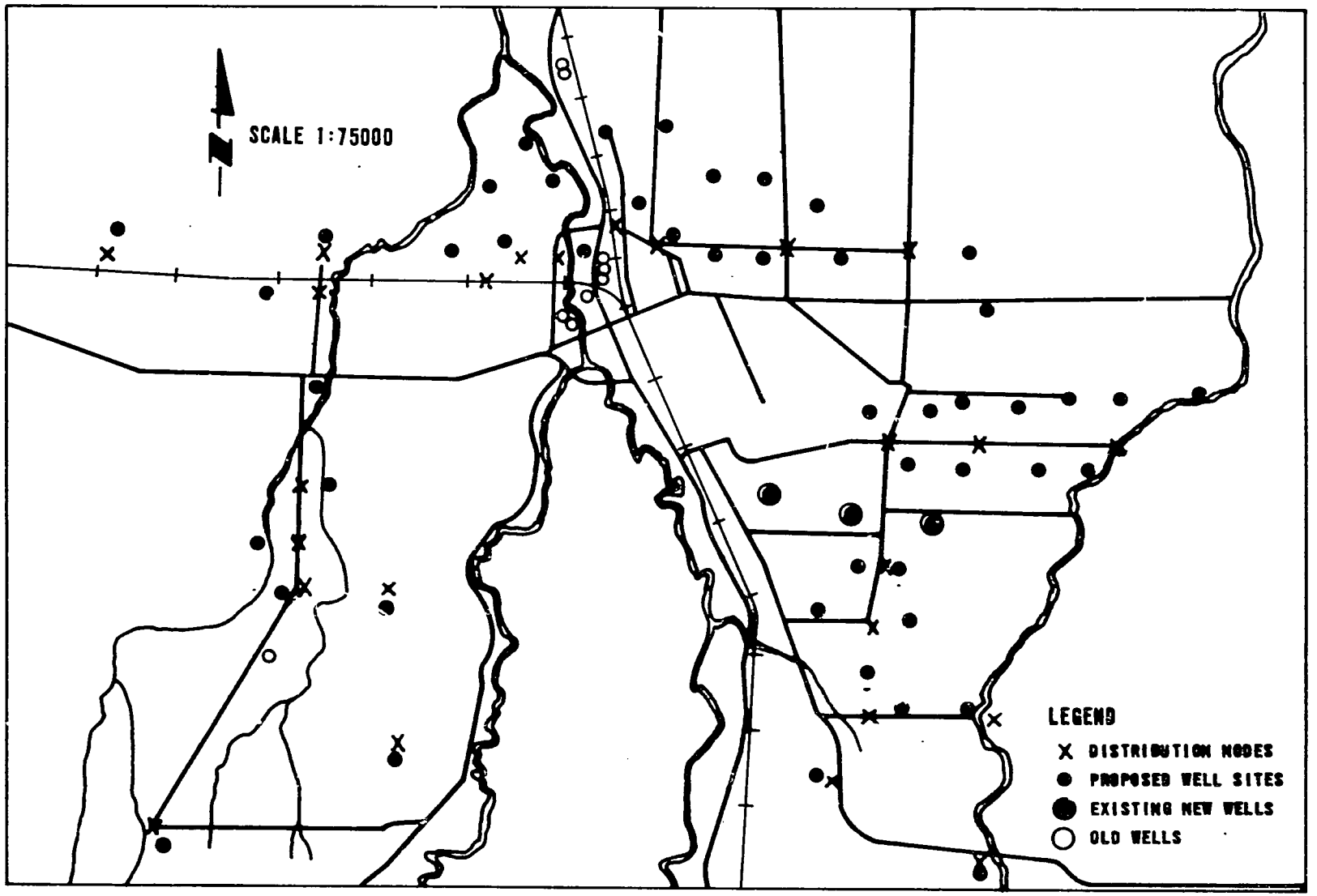

FIGURE A-28

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.

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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	

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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.

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APPENDIX B

DETAILED PROJECTIONS OF WATER AND WASTE QUANTITIES

Table	Title
B.1	Demographic Projections
B.2	Projected Total Water Demand
B.3	Projected Municipal Water Demand
B.4	Projected Solid Waste Quantities

KP No.	Name of Kampung	Population	Predominant Residential Type		Projected Populat		
		1978		%	1978	1980	1985
	KECAMATAN MEDAN KOTA				1.0000	1.0201	1.0511
1	Pasar Baru	7667	MI/MD		76.67	78.21	82.21
2	Pandau Hulu I	6466	MI/MD MI/LD	82% 18%	53.02 11.64	54.09 11.87	56.85 12.48
3	Sukaramai I	9089	LI/MD		90.89	92.72	99.56
4	Sudirejo I	9254	LI/MD		92.54	94.40	99.22
5	Tegal Sari I	20554	LI/HD		205.54	209.67	220.38
6	Tegal Sari II	9295	LI/MD		92.95	94.82	99.67
7	Kotamatsum I	14170	LI/MD		141.70	144.55	151.94
8	Sukaramai II	12957	LI/HD MI/MD	95% 5%	123.09 6.48	125.56 6.61	131.98 6.95
9	Mesjid	5368	MI/MD LI/MD LI/HD MI/LD	44% 26% 24% 6%	23.62 13.96 12.88 3.22	24.09 14.24 13.14 3.28	25.32 14.97 13.81 3.45
10	Kotamatsum II	23144	LI/MD		231.44	236.09	248.15
11	Pusat Pasar	6220	MI/HD MI/LD	75% 25%	46.65 15.55	47.59 15.85	50.02 16.67
12	Sei. Rengas I	9621	MI/MD MI/LD LI/HD	60% 30% 10%	57.73 28.86 9.62	58.89 29.44 9.81	6[illegible].90 30.94 10.31
13	Sei. Rengas II	13162	MI/HD		131.62	134.27	141.13
14	Kotamatsum III	9393	LI/HD		93.93	95.82	1[illegible].72
15	Pandau Hulu II	9423	MI/MD		94.23	96.1[illegible]	101.03
16	Teladan Timur	10568	LI/LD		105.68	107.80	113.34
17	Teladan Barat	10994	LI/MD MI/MD LI/HD	60% 38% 2%	65.96 41.78 2.20	67.29 42.62 2.24	70.73 44.80 2.35
18	Pasar Merah Timur	10810	LI/MD		108.10	110.27	115.91
19	Pasar Merah Barat	5358	LI/MD MI/LD LI/HD	70% 20% 10%	37.51 10.72 5.35	38.26 10.94 5.46	40.22 11.50 5.74
20	Siti Rejo I	8645	LI/MD		86.45	88.19	92.70
21	Siti Rejo II	13422	LI/MD		134.22	136.92	143.92
22	Sudi Rejo II	6734	LI/MD		67.34	68.69	72.20

TABLE B.1

)GRAPHIC PROJECTIONS

ılation, in 100's			Commercial/Industrial/Government/Institutional Land Use-Existing		Projected Commercial/Industrial/Government/Institutional Land-Use, in ha.			
85	1990	2000	HA	% of City	1980	1985	1990	2000
511	1.0486	1.1069			1.0000	1.1614	1.1486	1.2881
.21	86.20	91.43	3.5	0.326	3.50	4.065	4.669	6.014
.85 .48	59.61 13.09	65.98 14.49	6.2	0.578	6.20	7.201	8.270	10.653
.56	104.40	115.56	0.8	0.075	0.80	0.929	1.067	1.375
.22	104.04	115.16	2.1	0.196	2.10	2.439	2.801	3.608
.38	231.09	255.79	0.0	0	0	0	0	0
.67	104.51	115.68	0.6	0.056	0.60	0.697	0.800	1.031
.94	159.32	176.35	2.0	0.186	2.00	2.323	2.668	3.436
.98 .95	138.39 7.29	153.18 8.07	1.4	0.130	1.40	1.626	1.868	2.405
.32 .97 .81 .45	26.55 15.70 14.48 3.62	29.39 17.38 16.03 4.01	8.3	0.773	8.30	9.639	11.072	14.261
.15	260.21	288.03	0.3	0.281	0.30	0.348	0.400	0.515
.02 .67	52.45 17.48	58.06 19.35	8.4	0.783	8.40	9.756	11.205	14.433
..90 .94 .31	64.91 32.44 10.81	71.85 35.91 11.97	8.7	0.811	8.70	10.104	11.605	14.948
..13	147.99	163.81	2.1	0.196	2.10	2.439	2.801	3.608
.72	105.62	116.91	1.2	0.112	1.20	1.394	1.601	2.062
..03	105.94	117.27	6.1	0.568	6.10	7.084	8.137	10.481
.34	118.85	131.56	6.0	0.559	6.00	6.968	8.004	10.309
.73 .80 .35	74.17 46.98 2.46	82.10 52.00 2.72	7.1	0.662	7.10	8.246	9.471	12.199
.91	121.54	134.53	0.8	0.075	0.80	0.929	1.067	1.375
.22 ..50 .74	42.17 12.06 6.02	46.68 13.35 6.66	30.0	2.795	30.00	34.841	40.017	51.545
.70	97.21	107.60	15.1	1.407	15.10	17.537	20.142	25.944
.92	150.91	167.04	1.8	0.168	1.80	2.091	2.401	3.093
.20	75.71	83.80	2.6	0.242	2.60	3.020	3.468	4.467

TABLE B.

KP No	Name of Kampung	Population	Predominant Residential Type		Projected Populati		
		1978		%	1978	1980	1985
	KECAMATAN MEDAN TIMUR				1.0000	1.0289	1.0510
23	Sei.Kera Hulu		LI/HD		199.69	205.46	215.94
24	Sei.Kera Hilir		LI/MD		191.13	196.65	206.68
25	Sidorame Barat	21259	LI/MD LI/HD	72% 28%	153.06 59.53	157.48 61.25	161.51 64.38
26	Durian	20123	LI/MD LI/MD HI/LD	81% 17% 2%	163.00 34.21 4.02	167.71 35.20 4.14	176.26 37.00 4.35
27	Gelugur Darat	17369	LI/MD LI/LD LI/MD HI/LD	71% 25% 3% 1%	123.32 43.42 5.21 1.74	126.88 44.67 5.36 1.79	133.35 46.95 5.63 1.88
28	Gang Buntu	9739	MI/HD LI/MD HI/LD	88% 9% 3%	85.70 8.77 2.92	88.18 9.02 3.00	92.68 9.48 3.15
29	Pandau Hilir	10729	LI/MD MI/HD LI/HD	43% 35% 22%	46.13 37.55 23.61	47.46 38.64 24.29	49.88 40.61 25.53
30	Sidodadi	12560	LI/MD LI/HD HI/LD LI/MD	44% 39% 13% 4%	55.26 48.98 16.33 5.03	56.86 50.40 16.80 5.18	59.76 52.97 17.66 5.44
31	Pulau Brayan Darat	13874	LI/MD LI/LD	51% 49%	70.76 67.98	72.81 69.94	76.52 73.51
32	Pulau Brayan Bengkel	11176	LI/MD LI/LD LI/MD HI/LD	54% 32% 12% 2%	60.35 35.76 13.41 2.24	62.09 36.79 13.80 2.30	65.26 38.67 14.50 2.42
33	Sidorame Timur	10105	LI/MD		101.05	103.97	109.27
34	Tegal Rejo	12730	LI/LD		127.34	131.02	137.70
	KECAMATAN MEDAN DENAI				1.0000	1.0404	1.113
35	Bantan		LI/MD		237.48	247.07	271.0
36	Bandar Selamat		LI/MD		103.86	108.06	120.2
37	Indra Kasih		LI/LD		74.85	77.871	86.6
38	Sidorejo		LI/MD		269.74	280.64	312.3

B.1— Continued

lation, in 100's			Commercial/Industrial/Government/Institutional Land Use-Existing		Projected Commercial/Industrial/Government/Institutional Land-Use in ha			
85	1990	2000	Ha	% of City	1980	1985	1990	2000
510	1.1069	1.1051			1.0000	1.1614	1.1486	1.2881
.94	239.02	264.14	1.9	0.177	1.90	2.21	2.54	3.27
.68	228.77	252.81	1.0	0.093	1.00	1.16	1.33	1.71
51 .38	178.78 71.26	197.57 78.75	2.4	0.224	2.00	2.32	2.67	3.44
.26 .00 .35	195.10 40.96 4.82	215.61 45.26 5.33	9.2	0.857	9.20	10.68	12.27	15.80
.35 .95 .63 .88	147.61 51.97 6.23 2.08	163.12 57.43 6.88 2.30	4.8	0.447	4.80	5.57	6.40	8.24
.68 .48 .15	102.59 10.49 3.49	113.37 11.59 3.86	7.7	0.717	7.70	8.94	10.27	13.23
.88 .61 .53	55.21 44.95 28.26	61.01 49.67 31.23	8.8	0.820	8.80	10.22	11.74	15.12
.76 .97 .66 .44	66.15 58.63 19.55 6.02	73.10 64.79 21.60 6.65	36.5	3.401	36.50	42.39	48.69	62.72
.52 .51	84.70 81.37	93.60 89.92	2.4	0.224	2.40	2.79	3.20	4.12
.26 .67 .50 .42	72.24 42.80 16.05 2.68	79.83 47.30 17.74 2.96	33.8	3.149	33.80	39.25	45.08	58.07
.27	120.95	133.66	0	0	0	0	0	0
.70	152.42	168.44	0	0	0	0	0	0
.130	1.2873	1.3989			1.000	1.1614	1.1486	1.2881
.01	347.01	488.23	0	0	0	0	0	0
.28	154.90	216.69	0	0	0	0	0	0
.68	111.63	156.16	8.0	0.745	8.00	9.29	10.67	13.74
.38	402.28	562.75	0.8	0.075	0.80	0.93	1.07	1.38

TABLE D.

KP No	Name of Kampung	Population	Predominant Residential Type		Projected Populati		
		1978		%	1978	1980	1985
39	Tegal Sari		LI/MD		314.78	327.49	364.53
	KECAMATAN MEDAN JOHOR				1.0000	1.0404	1.1043
40	Harjosari	20945	LI/MD LI/HD	77% 23%	161.28 48.17	167.80 50.12	185.30 55.35
	KECAMATAN MEDAN BARU				1.0000	1.0403	1.1161
41	Petisah Hulu	8770	HI/LD LI/HD MI/HD	54% 40% 6%	47.36 35.08 5.26	49.27 36.49 5.47	54.99 40.73 6.11
42	Madras Hulu	5320	HI/LD HI/MD	63% 37%	33.52 19.68	34.87 20.47	38.92 22.85
43	Jati	3213	HI/LD		32.13	33.42	37.30
44	Aur	10681	MI/HD LI/HD LI/HD MI/LD	55% 35% 9% 1%	58.75 37.38 9.61 1.07	61.12 38.89 10.00 1.11	68.22 43.41 11.16 1.24
45	Sei. Mati	7941	LI/HD		79.41	82.61	92.20
46	Hamdan	7557	LI/HD HI/LD MI/HD	63% 27% 10%	47.64 20.40 7.56	49.53 21.22 7.86	55.28 23.68 8.77
47	Babura	10675	LI/MD HI/LD MI/MD	48% 40% 12%	51.24 42.70 12.81	53.31 44.42 13.33	59.50 49.58 14.88
48	Anggrung	3613	LI/MD HI/LD	77% 23%	27.82 8.31	28.94 8.65	32.30 9.65
49	Baru	8801	LI/MD HI/LD	98% 2%	86.25 1.76	89.73 1.83	100.15 2.04
50	Merdeka	9123	LI/MD MI/MD LI/MD HI/LD	63% 31% 4% 2%	57.48 28.28 3.65 1.82	59.80 29.42 3.80 1.89	66.74 32.84 4.24 2.11
51	Sukaraja	5190	LI/HD MI/HD	94% 6%	48.79 3.11	50.76 3.24	56.65 3.62
52	Titi Rantai	9837	LI/MD LI/HD	82% 18%	80.66 17.71	83.91 18.42	93.65 20.56

BLE B.1-Continued

ulation, in 100's			Commercial/Industrial/Government/Institutional Land Use-Existing		Projected Commercial/Industrial/Government/Institutional Land-Use, in ha			
35	1990	2000	Ha	% of City	1980	1985	1990	2000
.53	469.44	656.70	6.4	0.596	6.40	7.43	8.53	10.99
043	1.2627	1.5158			1.0000	1.1614	1.1486	1.2881
.30 .35	233.98 69.89	354.67 105.94	6.4	0.596	6.40	7.43	8.53	10.99
161	1.1271	1.2996			1.0000	1.1614	1.1486	1.2881
.99 .73 .11	61.98 45.91 6.89	80.55 59.66 8.95	7.4	0.69	7.40	8.594	9.872	12.716
92 85	43.87 25.75	57.01 33.46	16.0	1.491	16.00	18.582	21.344	27.493
30	42.04	54.64	4.5	0.419	4.50	5.226	6.003	7.732
22 41 16 24	76.89 48.93 12.58 1.40	99.93 63.59 16.35 1.82	38.8	3.615	38.80	45.06	51.76	66.67
20	103.92	135.05	1.3	0.121	1.30	1.510	1.734	2.234
28 68 77	62.31 26.69 9.88	80.78 34.69 12.84	8.0	0.745	8.00	9.291	10.672	13.746
50 58 89	67.06 55.88 16.77	87.15 72.62 21.79	2.3	0.214	2.30	2.671	3.068	3.952
30 65	36.41 10.88	47.32 14.14	0	0	0	0	0	0
15 04	112.88 2.30	146.70 2.99	3.9	0.363	3.90	4.530	5.203	6.701
74 84 24 11	75.22 37.01 4.78 2.38	97.76 48.10 6.21 3.09	6.0	0.559	6.00	6.968	8.004	10.310
65 62	63.85 4.08	82.98 5.30	1.5	0.140	1.50	1.742	2.001	2.578
65 56	105.55 23.14	137.17 30.11	1.7	0.158	1.70	1.974	2.268	2.921

TABLE B.1

KP No	Name of Kampung	Population	Predominant Residential Type		Projected Populatio		
		1978		%	1978	1980	1985
53	Darat	3638	MI/MD LI/MD HI/LD	60% 34% 6%	21.83 12.37 2.18	22.71 12.87 2.27	25.35 14.36 2.53
54	Polonia	20905	LI/MD LI/HD HI/LD	69% 29% 2%	144.24 60.63 4.18	150.05 63.07 4.35	167.47 70.39 4.86
55	Padang Bulan	6244	LI/MD MI/MD HI/LD	92% 6% 2%	57.44 3.75 1.25	59.75 3.90 1.30	66.69 4.35 1.45
	KECAMATAN MEDAN BARAT				1.0000	1.0402	1.1039
56	Kesawan	9729	MI/HD MI/LD LI/MD	86% 8% 6%	83.67 7.78 5.84	87.03 8.09 6.08	96.07 8.93 6.71
57	Petisah Tengah	13744	MI/MD MI/HD HI/LD LI/MD	55% 28% 11% 6%	75.59 38.48 15.12 8.25	78.63 40.03 15.73 8.58	86.80 44.19 17.36 9.47
58	Silalas	9990	LI/MD MI/MD	83% 17%	82.92 16.98	86.25 17.66	95.21 19.50
59	Sekip	9099	LI/MD LI/HD	90% 10%	81.89 9.1	85.18 9.47	94.03 10.45
60	Sei. Putih Timur	16077	LI/MD		160.77	167.23	184.61
61	Sei. Putih Barat	18847	LI/MD		188.47	196.05	216.42
62	Sei. Sikambing	11329	MI/MD LI/MD	41% 59%	46.45 66.84	48.32 69.53	53.34 76.75
63	Sei. Agul	23945	LI/MD		239.45	249.08	274.96
64	Gelugur Kota	7122	LI/MD MI/MD HI/LD	86% 12% 2%	61.25 8.55 1.42	63.71 8.89 1.48	70.33 9.81 1.63
65	Pulau Brayan Kota	12124	LI/HD MI/MD MI/HD	91% 5% 4%	110.33 6.06 4.85	114.77 6.30 5.05	126.70 6.96 5.58

B.1.— Continued

ation, in 100's			Commercial/Industrial/Government/Institutional Land Use-Existing		Projected Commercial/Industrial/Government/Institutional Land-Use, in ha			
35	1990	2000	Ha	% of City	1980	1985	1990	2000
35 36 53	28.57 16.19 2.85	37.13 21.04 3.70	0	0	0	0	0	0
47 39 86	188.76 79.34 5.48	245.31 103.11 7.12	277.2	25.827	277.20	321.94	369.780	476.314
69 35 45	75.17 4.90 1.63	97.69 6.37 2.12	106.3	9.904	106.30	123.457	141.803	182.656
39	1.1567	1.2242			1.0000	1.1614	1.1486	1.2881
07 93 71	111.12 10.33 7.76	136.03 12.65 9.50	58.1	5.413	58.10	67.477	77.505	99.834
80 19 36 47	100.40 51.12 20.08 10.95	122.91 62.58 24.58 13.41	6.0	0.559	6.00	6.968	8.004	10.310
21 50	110.13 22.56	134.82 27.62	26.3	2.450	26.30	30.545	35.084	45.191
03 45	108.77 12.09	133.16 14.80	16.6	1.547	16.60	19.279	22.144	28.524
.61	213.54	261.42	2.5	0.233	2.50	2.904	3.335	4.296
.42	250.33	306.45	5.0	0.466	5.00	5.807	6.670	8.592
.34 .75	61.70 88.78	75.53 108.69	0.6	0.056	0.60	0.697	0.800	1.031
.96	318.05	389.36	4.1	0.382	4.10	4.762	5.469	7.045
.33 .81 .63	81.35 11.35 1.89	99.59 13.90 2.31	31.5	2.935	31.50	36.584	42.021	54.127
.70 .96 .58	146.55 8.05 6.45	179.41 9.86 7.90	28.6	2.665	28.60	33.216	38.152	49.144

91

KP No.	Name of Kampung	Population	Predominant Residential Type		Projected Population		
		1978		%	1978	1980	1985
	KECAMATAN MEDAN BELAWAN				1.0000	1.0200	1.0507
66	Belawan I	11500	LI/HD MI/HD LI/MD MI/MD	34% 33% 24% 9%	39.1 37.95 27.6 10.35	39.88 38.71 28.15 10.56	41.90 40.67 29.58 11.10
67	Belawan II	27533	LI/MD LI/HD MI/MD	62% 36% 2%	170.7 99.12 5.51	174.11 101.10 5.62	182.94 106.23 5.91
68	Belawan III	10500	LI/MD LI/HD	56% 44%	58.8 46.2	59.98 47.12	63.02 49.51
	KECAMATAN MEDAN SUNGGAL				1.0000	1.0510	1.1038
69	Padang Bulan Selayang	5865	LI/MD		58.65	61.64	68.04
70	Sei. Sikambing-C	7700	LI/MD		77.0	80.93	89.33
71	Sei. Sikambing-B	10100	LI/MD		101.0	106.15	117.17
72	Dwikora	4625	LI/LD		46.25	48.61	53.65
73	Tanjung Rejo	11238	MI/MD LI/MD	83% 17%	90.28 19.10	98.04 20.07	108.21 22.16
74	Babura Sunggal	9398	LI/MD		93.98	98.77	109.03
75	Perladangan Helvetia	18338	LI/LD MI/MD	50% 50%	91.69 91.69	96.37 96.37	106.37 106.37
A_1	1978 Built Up Area (75 Kampungs)	902387			902387	931736	1006104
A_2	2000 Built Up Area + Industrial Estate	110065	MI/HI /LD	30% 70%	330.20 770.45	348.49 .813.14	427.21 996.82
A_3	Out side Built Up Area	103748	LI/LD	30% 70%	311.25 726.23	328.49 766.47	402.70 939.62
A	Medan Study Area - Medan City	1116200			1116200	1157395	1282739

1 — Continued

.ation (100's)			Commercial/Industrial/Government/Institutional Land Use-Existing		Projected Commercial/Industrial/Government/Institutional Land-Use, in ha			
985	1990	2000	Ha	% of City	1980	1985	1990	2000
)507	1.0513	1.1095			1.0000	1.1614	1.1486	1.2881
.90).67).58 1.10	44.05 42.76 31.10 11.67	48.87 47.44 34.51 12.95	20.7	1.929	20.70	24.041	27.614	35.569
2.94 5.23 5.91	192.33 111.68 6.21	213.39 123.91 6.89	2.5	0.233	2.50	2.904	3.335	4.296
3.02).51	66.25 52.05	73.50 57.75	184.3	17.171	184.30	214.046	245.853	316.684
1038	1.3142	1.4670			1.0000	1.1614	1.1486	1.2881
3.04	89.42	131.18	0	0	0	0	0	0
).33	117.39	172.22	2.3	0.214	2.30	2.671	3.068	3.952
7.17	153.98	225.90	4.1	0.382	4.10	4.762	5.469	7.045
3.65	70.51	103.44	6.3	0.587	6.30	7.317	8.404	10.825
3.21 2.16	142.21 29.12	208.63 42.72	2.0	0.186	2.00	2.323	2.668	3.437
).03	143.28	210.19	1.0	0.093	1.00	1.161	1.334	1.718
5.37 5.37	139.79 139.79	205.07 205.07	1.0	0.093	1.00	1.161	1.334	1.718
5104	1147412	1413928						
7.21 6.82	517.10 1,206.55	732.37 1,708.84	180	16.771	180.0	253.549	327.097	474.195
2.70 9.62	487.42 1,137.32	690.33 1,610.78	0	0	0	0	0	0
2739	1482251	1888160						

TABLE E.2

PROJECTED TOTAL WATER DE

KP No.	Name of Kampung	Domestic Water Use Projection, Litres/Second				Commercial/Industrial/Gov Institutional Water U Litres/Second		
		1980	1985	1990	2000	1980	1985	1990
	KECAMATAN MEDAN KOTA							
1	Pasar Baru	19.46	21.41	23.94	27.51	1.66	1.92	2.21
2	Pandau Hulu I	16.41	18.06	20.19	24.22	2.94	3.41	3.92
3	Sukaramai I	10.73	13.25	15.10	20.06	0.38	0.44	0.50
4	Sudirejo I	10.93	13.21	15.05	19.99	0.99	1.15	1.32
5	Tegal Sari I	8.67	8.93	9.36	10.36	0	0	0
6	Tegal Sari II	10.98	13.27	15.12	20.08	0.28	0.33	0.38
7	Kotamatsum I	16.73	20.22	23.05	30.62	0.94	1.10	1.26
8	Sukaramai II	6.73	7.16	7.63	8.63	0.66	0.77	0.88
9	Mesjid	8.99	10.04	11.69	13.72	3.93	4.57	5.25
10	Kotamatsum II	27.33	33.03	37.65	50.01	0.14	0.16	0.19
11	Pusat Pasar	11.93	13.60	15.48	19.26	3.98	4.63	5.31
12	Sei. Rengas I	17.61	19.94	22.60	27.92	4.12	4.79	5.50
13	Sei. Rengas II	22.53	26.14	29.98	37.92	0.99	1.15	1.32
14	Kotamatsum III	3.88	4.08	4.28	4.74	0.56	0.66	0.76
15	Pandau Hulu II	23.92	26.31	29.43	35.29	2.89	3.36	3.86
16	Teladan Timur	18.09	20.99	24.07	30.45	2.84	3.30	3.79
17	Teladan Barat	19.03	21.18	23.88	30.01	3.36	3.91	4.49
18	Pasar Merah Timur	12.76	15.43	17.58	23.36	0.38	0.44	0.50
19	Pasar Merah Barat	7.37	8.58	9.70	12.39	14.23	16.53	18.98
20	Siti Rejo I	10.21	12.34	14.06	18.68	7.16	8.32	9.55
21	Siti Rejo II	15.85	19.16	21.83	29.00	0.85	0.99	1.13
22	Sudi Rejo II	7.95	9.61	10.95	14.55	1.23	1.43	1.64

E.2

WATER DEMAND

ıtrial/Government ıl Water Use, Second		Total Water Use Projections Litres/Second				Total Water Use Projections with Allowance for Unaccounted for Water (25%), Litres/Second			
1990	2000	1980	1985	1990	2000	1980	1985	1990	2000
2.21	2.85	21.12	23.34	26.16	30.36	28.15	31.11	34.87	40.48
3.92	5.05	19.35	21.48	24.11	29.28	25.80	28.63	32.14	39.02
0.50	0.65	11.11	13.69	15.61	20.71	17.73	18.25	20.80	27.61
1.32	1.71	11.93	14.37	16.38	21.70	15.90	19.15	21.83	28.93
0	0	8.67	8.93	9.36	10.36	11.56	11.90	12.48	13.81
0.38	0.48	11.27	13.60	15.50	20.57	16.02	18.13	20.66	27.42
1.26	1.63	17.68	21.32	24.32	32.25	23.57	28.42	32.41	42.99
0.88	1.14	7.39	7.93	8.52	9.77	9.86	10.57	11.35	13.03
5.25	6.76	12.93	14.61	16.94	20.49	17.23	19.48	22.59	27.31
0.19	0.24	27.47	33.20	37.84	50.25	36.62	44.25	50.44	66.99
5.31	6.84	15.92	18.23	20.80	26.11	30.62	31.0	31.0	34.80
5.50	7.09	21.74	24.73	28.11	35.01	28.98	32.97	37.47	46.67
1.32	1.71	23.53	27.30	31.31	39.63	31.36	36.39	41.74	52.83
0.76	0.97	4.45	4.74	5.04	5.72	12.38	13.0	13.0	13.0
3.86	4.97	26.82	29.67	33.29	40.26	35.74	39.55	44.38	53.67
3.79	4.89	20.94	24.30	27.87	35.34	27.91	32.39	37.15	47.11
4.49	5.78	22.40	25.09	28.37	35.80	29.86	33.45	37.82	47.72
0.50	0.65	13.14	15.87	18.09	24.01	17.52	21.16	24.11	32.01
18.98	24.45	21.61	25.11	28.69	36.85	28.80	33.47	38.24	49.12
9.55	12.31	17.38	20.66	23.62	30.99	23.16	27.54	31.48	41.31
1.13	1.44	16.70	20.15	22.97	30.44	22.27	26.86	30.62	40.58
1.64	2.12	9.18	11.04	12.60	16.67	12.24	14.72	16.79	22.22

KP No.	Name of Kampung	Domestic Water Use Projection, Litres/Second				Commercial/Industrial, Institutional Wat Litres/Second		
		1980	1985	1990	2000	1980	1985	199
	KECAMATAN MEDAN TIMUR							
23	Sei. Kera Hulu	8.32	8.75	9.68	10.70	0.90	1.04	1.2
24	Sei. Kera Hilir	22.76	27.51	33.10	43.89	0.47	0.55	0.6
25	Sidorame Barat	20.71	24.11	28.75	37.49	0.94	1.10	1.2
26	Durian	24.76	29.78	35.74	47.14	4.36	5.06	5.8
27	Gelugur Darat	23.35	27.79	33.47	43.61	2.27	2.64	3.0
28	Gang Buntu	16.76	19.55	23.45	29.60	3.65	4.24	4.8
29	Pandau Hilir	12.96	15.19	17.08	23.36	4.17	4.85	5.5
30	Sidodadi	14.38	16.56	20.41	23.97	17.31	20.11	23.1
31	Pulau Brayan Darat	20.17	23.80	28.75	37.07	1.13	1.32	1.5
32	Pulau Brayan Bengkel	15.66	18.42	22.33	28.91	16.03	18.62	21.3
33	Sidorame Timur	12.03	14.54	17.50	23.21	0	0	
34	Tegal Rejo	21.99	25.50	30.87	38.99	0	0	
	KECAMATAN MEDAN DENAI							
35	Bantan	28.60	36.07	50.49	84.76	0	0	
36	Bandar Selamat	12.51	16.01	22.41	37.62	0	0	
37	Indra Kasih	13.07	16.05	22.61	36.15	3.79	4.40	5.0
38	Sidorejo	32.48	41.58	58.20	97.70	0.38	0.44	0.5

- Continued

trial/Government ıl Water Use, econd		Total Water Use Projections Litres/Second				Total Water Use Projections with Allowance for Unaccounted for Water (25%), Litres/Second			
1990	2000	1980	1985	1990	2000	1980	1985	1990	2000
1.20	1.55	9.22	9.80	10.89	12.25	22.64	23.0	23.0	23.0
0.63	0.81	23.24	28.06	33.73	44.70	30.97	37.40	44.96	59.59
1.26	1.63	21.66	25.21	30.02	39.12	28.87	33.61	40.01	52.15
5.82	7.49	29.13	34.85	41.56	54.64	38.82	46.45	55.40	72.83
3.03	3.91	25.63	30.43	36.51	47.52	34.16	40.57	48.66	63.34
4.87	6.27	20.41	23.79	28.32	35.88	27.21	31.72	37.76	47.83
5.57	7.17	17.14	20.04	22.65	30.53	22.84	26.71	30.20	40.72
23.10	29.76	31.70	36.67	43.51	53.73	42.26	48.89	58.00	71.62
1.51	1.95	21.31	25.12	30.33	39.02	28.41	33.49	40.43	52.01
21.39	27.55	31.70	37.04	43.72	56.46	42.25	49.38	58.28	75.27
0	0	12.03	14.54	17.50	23.21	16.04	19.38	23.33	30.94
0	0	21.99	25.50	30.87	38.99	29.31	33.99	41.15	51.97
0	0	28.60	36.07	50.49	84.76	38.12	48.02	67.30	112.99
0	0	12.51	16.01	22.41	37.62	16.68	21.34	29.87	50.15
5.06	6.52	16.87	20.46	27.67	42.67	22.48	27.27	36.89	56.88
0.50	0.65	32.86	42.02	58.71	98.66	43.80	56.01	78.26	131.51

TABLE B.2— Co

KP No.	Name of Kampung	Domestic Water Use Projection, Litres/Second				Commercial/Industr Institutional Litres/Sec		
		1980	1985	1990	2000	1980	1985	
39	Tegal Sari	37.90	48.52	67.92	114.01	3.03	3.52	4
	KECAMATAN MEDAN JOHOR							
40	Harjosari	21.45	26.91	36.68	65.87	3.03	3.52	4
	KECAMATAN MEDAN BARU							
41	Petisah Hulu	17.51	20.28	23.70	32.46	3.51	4.07	4
42	Madras Hulu	16.98	19.66	22.96	31.42	7.59	8.81	10
43	Jati	10.25	11.87	13.87	18.97	2.13	2.48	2
44	Aur	12.53	15.16	18.45	26.92	18.41	21.38	24
45	Sei. Mati	3.35	3.73	4.21	5.47	0.61	0.71	0.
46	Hamdan	9.84	11.40	13.32	18.28	3.79	4.40	5.
47	Babura	23.11	27.58	32.79	46.90	1.09	1.26	1.
48	Anggrung	6.00	7.37	8.86	13.13	0	0	
49	Baru	10.95	13.98	17.09	26.51	1.85	2.14	2.
50	Merdeka	15.26	18.79	22.82	33.90	2.84	3.30	3.
51	Suka Raja	2.60	2.96	3.42	4.58	0.71	0.82	0.
52	Titi Rantai	11.84	15.21	18.62	29.07	0.80	0.93	1.

Continued

trial/Government l Water Use, econd		Total Water Use Projections Litres/Second				Total Water Use Projections with Allowance for Unaccounted for Water (25%), Litres/Second			
1990	2000	1980	1985	1990	2000	1980	1985	1990	2000
4.04	5.21	40.94	52.05	71.97	119.23	54.57	69.38	95.93	158.93
4.04	5.21	24.49	30.43	40.73	71.08	32.64	40.57	54.29	94.75
4.64	6.03	21.02	24.36	28.38	38.49	28.02	32.47	37.84	51.31
10.12	13.04	24.57	28.48	33.09	44.47	32.76	37.96	44.11	59.27
2.84	3.66	12.39	14.35	16.72	22.64	16.51	19.13	22.29	30.18
24.56	31.64	30.94	36.54	43.01	58.56	41.24	48.71	57.33	78.06
0.82	1.06	3.97	4.45	5.03	6.53	5.29	5.93	6.71	8.71
5.06	6.52	13.64	15.81	18.38	24.80	18.18	21.07	24.51	33.06
1.45	1.87	24.20	28.85	34.25	48.78	32.26	38.45	45.65	65.02
0	0	6.00	7.37	8.86	13.13	8.00	9.82	11.81	17.50
2.46	3.18	12.80	16.13	19.56	29.69	17.06	21.50	26.07	39.58
3.79	4.89	18.11	22.10	26.62	38.79	24.14	29.46	35.48	51.71
0.95	1.22	3.31	3.88	4.37	5.80	4.42	5.05	5.83	7.74
1.07	1.38	12.65	16.15	19.70	30.46	16.86	21.52	26.26	40.60

TABLE B.2— Co

KP No.	Name of Kampung	Domestic Water Use Projection, Litres/Second				Commercial/Industri Institutional Litres/Sec		
		1980	1985	1990	2000	1980	1985	1
53	Darat	7.84	9.32	11.30	16.10	0	0	
54	Polonia	21.25	26.69	32.33	49.24	131.53	152.76	175.
55	Padang Bulan	8.29	10.47	12.78	19.62	50.43	58.58	67
	KECAMATAN MEDAN BARAT							
56	Kesawan	17.32	21.01	26.50	36.94	27.56	32.01	36.
57	Petisah Tengah	32.10	37.54	46.45	62.34	2.84	3.30	3.
58	Silalas	14.38	17.75	22.20	31.72	12.47	14.49	16.
59	Sekip	10.24	12.94	16.23	23.72	7.87	9.14	10.
60	Sei. Putih Timur	19.36	24.57	30.89	45.39	1.18	1.37	1.
61	Sei. Putih Barat	22.69	28.81	36.22	53.20	2.37	2.75	3.
62	Sei. Sikambing	20.07	24.11	29.98	41.60	0.28	0.33	0.
63	Sei. Agul	28.82	36.60	46.01	67.60	1.94	2.26	2.
64	Gelugur Kota	10.04	12.44	15.55	22.28	14.94	17.35	19.
65	Pulau Brayan Kota	7.07	7.98	9.48	12.06	13.57	15.76	18.

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strial/Government al Water Use, /Second		Total Water Use Projections Litres/Second				Total Water Use Projections with Allowance for Unaccounted for Water (25%), Litres/Second			
1990	2000	1980	1985	1990	2000	1980	1985	1990	2000
0	0	7.84	9.32	11.30	16.10	10.45	12.42	15.06	21.46
175.46	226.01	152.78	179.45	207.79	275.25	203.66	239.21	276.99	366.91
67.28	86.67	58.73	69.05	80.07	106.29	78.29	92.04	106.73	141.69
36.77	47.37	44.89	53.03	63.28	84.32	59.84	70.69	84.35	112.40
3.79	4.89	34.95	40.19	50.25	67.23	46.58	54.45	66.92	89.62
16.64	21.44	26.86	32.24	38.85	53.16	35.80	42.98	51.78	70.87
10.50	13.53	17.73	22.09	26.74	37.26	23.63	29.44	25.64	49.66
1.53	2.03	20.55	25.95	32.47	47.43	27.39	34.59	43.29	63.223
3.16	4.07	25.06	31.57	39.39	57.28	33.41	42.08	52.50	76.35
0.38	0.48	20.36	24.44	30.36	42.09	27.13	32.58	40.47	56.105
2.59	3.34	30.77	38.86	48.61	70.94	41.01	51.80	64.79	94.567
19.93	25.68	24.99	29.80	35.49	47.96	33.31	39.72	47.31	63.94
18.10	23.31	20.64	23.74	27.58	35.38	27.52	31.65	36.77	47.16

TABLE B.2 – Con

KP No.	Name of Kampung	Domestic Water Use Projection, Litres/Second				Commercial/Industri Institutional W Litres/Seco		
		1980	1985	1990	2000	1980	1985	19
	KECAMATAN MEDAN BELAWAN							
66	Belawan I	14.00	16.06	18.19	22.85	9.82	11.40	13.
67	Belawan II	25.65	30.19	34.08	40.14	1.18	1.37	1.
68	Belawan III	8.85	10.39	11.69	17.10	87.45	101.56	116.
	KECAMATAN MEDAN SUNGGAL							
69	Padang Bulan Selayang	7.13	9.06	12.94	22.77	0	0	
70	Sei. Sikambing-C	9.37	11.89	16.98	29.90	1.09	1.26	1.
71	Sei. Sikambing-B	12.29	15.60	22.28	39.22	1.94	2.26	2.
72	Dwikora	8.16	9.94	14.28	23.94	2.98	3.47	3.
73	Tanjung Rejo	26.72	31.13	43.72	70.20	0.94	1.10	1.
74	Babura Sunggal	11.43	14.51	20.73	36.49	0.47	0.55	0.
75	Perladangan Helvetia	40.15	47.40	67.15	109.18	0.47	0.55	0.
A_2	2000 Built Up Area + Industrial Estate	96.803	123.614	158.601	237.342			
		136.465	184.596	244.382	395.565	85.41	120.30	155.
A_3	Out side Built Up Area	91.247	116.522	149.498	223.718			
		128.632	174.004	230.360	372.866	–	–	–

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ıstrial/Government ıal Water Use, 'Second		Total Water Use Projections Litres/Second				Total Water Use Projections with Allowance for Unaccounted for Water (25%), Litres/Second			
1990	2000	1980	1985	1990	2000	1980	1985	1990	2000
13.10	16.87	23.82	27.47	31.29	39.73	31.76	36.62	41.71	52.96
1.58	2.03	26.84	31.57	35.66	42.18	35.77	42.08	47.54	56.23
116.65	150.26	96.30	111.96	128.35	167.37	128.37	149.24	171.09	223.10
0	0	7.13	9.06	12.94	22.77	24.57	25.0	25.0	30.35
1.45	1.87	10.46	13.16	18.44	31.78	13.95	17.54	24.58	42.36
2.59	3.34	14.24	17.86	24.88	42.56	19.78	23.81	33.16	56.74
3.98	5.13	11.15	13.41	18.77	29.08	14.86	17.88	24.35	38.76
1.26	1.63	27.67	32.23	45.00	71.83	36.88	42.97	59.97	95.75
0.63	0.81	11.91	15.06	21.36	37.31	19.0	20.08	28.48	49.73
0.63	0.81	40.63	47.95	67.78	110.00	54.15	63.92	90.36	146.62
		233.27	303.21	402.98	632.91	311.02	410.94	537.29	843.86
155.20	225.00	85.410	120.309	155.208	225.006	113.88	160.41	206.94	300.00
		219.88	290.53	379.86	596.58	293.17	387.36	506.47	795.42
-	-	-	-	-	-	-	-	-	-

TABLE

PROJECTED MUNICI

KP No.	Name of Kampung	Present Municipal Water Use Litres/Second	Municipal Domestic Water Use Projections Litres/Second (% served)			
		Tirtanadi 1978	1980 (25%)	1985 (60%)	1990 (75%)	2000 (80%)
	KECAMATAN MEDAN KOTA					
1	Pasar Baru	21.21	4.87	12.85	17.96	22.01
2	Pandau Hulu I	8.38	4.10	10.83	15.15	19.37
3	Sukaramai I	13.65	2.68	7.95	11.33	16.05
4	Sudirejo I	5.99	2.73	7.92	11.29	15.99
5	Tegal Sari I	2.26	2.23	5.36	7.02	8.29
6	Tegal Sari II	2.04	2.74	7.96	11.34	16.07
7	Kotamatsum I	8.64	4.18	12.13	17.29	24.49
8	Sukaramai II	2.90	1.68	4.29	5.72	6.91
9	Mesjid	9.85	2.25	6.03	8.77	10.97
10	Kotamatsum II	8.63	6.83	19.82	28.24	40.00
11	Pusat Pasar	23.58	2.98	8.16	11.61	15.41
12	Sei. Rengas I	20.42	4.38	11.96	16.95	22.34
13	Sei. Rengas II	22.52	5.63	15.68	22.48	30.34
14	Kotamatsum III	9.53	0.97	2.45	3.21	3.79
15	Pandau Hulu II	12.08	5.98	15.79	22.07	28.23
16	Teladan Timur	3.83	4.52	12.59	18.06	24.36
17	Teladan Barat	3.19	4.76	12.71	17.91	24.01
18	Pasar Merah Timur	4.79	3.19	9.26	13.18	18.69
19	Pasar Merah Barat	4.70	1.84	5.15	7.27	9.91
20	Siti Rejo I	3.72	2.55	7.40	10.55	14.94
21	Siti Rejo II	6.52	3.96	11.49	16.38	23.20
22	Sudi Rejo II	4.32	1.99	5.77	8.22	11.64

Note: Tirtanadi Figures include 23% unaccounted for water

BLE B.3

ICIPAL WATER DEMAND

ns	Municipal Commercial/Industrial/Government/Institutional Water Use Projection Litres/Second (% served)				Total Municipal Water Use Projections With Allowance for Unaccounted for Water (25%), Litres/Second			
80%)	1980 (71%)	1985 (73%)	1990 (76%)	2000 (84%)	1980	1985	1990	2000
1	1.17	1.40	1.68	2.39	27.55	28.00	26.00	32.54
7	2.08	2.49	2.98	4.24	10.88	17.77	24.17	31.48
5	0.27	0.32	0.38	0.54	17.73	18.00	18.00	22.13
9	0.70	0.84	1.00	1.43	7.78	11.69	16.39	23.24
9	0	0	0	0	2.97	7.14	9.36	11.05
7	0.20	0.24	0.28	0.41	3.92	10.93	15.50	21.97
9	0.67	0.80	0.96	1.36	11.22	17.25	24.33	34.47
1	0.47	0.56	0.67	0.95	3.77	6.48	8.53	10.48
7	2.79	3.33	3.99	5.64	6.73	12.49	17.01	22.21
0	0.10	0.12	0.14	0.20	9.24	26.58	37.83	53.60
1	2.83	3.38	4.04	5.75	30.62	31.00	31.00	31.00
4	2.93	3.50	4.18	5.95	26.52	27.00	28.17	37.72
4	0.70	0.84	1.01	1.43	29.25	30.00	31.31	42.35
9	0.40	0.48	0.57	0.82	12.38	13.00	13.00	13.00
3	2.05	2.45	2.93	4.17	15.69	24.31	33.33	43.20
6	2.02	2.41	2.88	4.10	8.72	20.00	27.92	37.95
1	2.39	2.85	3.41	4.86	9.53	20.75	28.43	38.49
9	0.27	0.32	0.38	0.54	6.22	12.77	18.09	25.64
1	10.10	12.06	14.43	20.54	15.93	22.95	28.93	40.60
4	5.08	6.07	7.26	10.34	10.18	17.97	23.74	33.70
0	0.60	0.72	0.86	1.21	8.47	16.29	22.98	32.54
4	0.87	1.04	1.25	1.78	5.61	9.08	12.62	17.89

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KP No.	Name of Kampung	Present Municipal Water Use Litres/Second	Municipal Domestic Water Use Projections Litres/Second (% served)			
		Tirtanadi 1978	1980(25%)	1985 (60%)	1990 (75%)	2000 (80%)
	KECAMATAN MEDAN TIMUR					
23	Sei. Kera Hulu	17.43	2.08	5.25	7.26	8.56
24	Sei. Kera Hilir	8.50	5.69	16.51	24.82	35.11
25	Sidorame Barat	5.35	5.18	14.46	21.56	29.99
26	Durian	6.73	6.19	17.83	26.81	37.71
27	Gelugur Darat	7.77	5.84	16.68	25.10	34.89
28	Gang Buntu	15.38	4.19	11.73	17.59	23.68
29	Pandau Hilir	15.66	3.24	9.12	12.81	18.68
30	Sidodadi	15.66	3.59	9.94	15.31	19.18
31	Pulau Brayan Darat	2.55	5.04	14.28	21.56	29.65
32	Pulau Brayan Bengkel	0.48	3.92	11.05	16.75	23.13
33	Sidorame Timur	3.29	3.01	8.28	13.12	18.56
34	Tegal Rejo	Outside W.D.	5.50	15.30	23.15	31.19
	KECAMATAN MEDAN DENAI					
35	Bantan	6.19	7.15	21.64	37.87	67.81
36	Bandar Selamat	0.22	3.12	9.61	16.81	30.10
37	Indra Kasih	Outside W.D	3.27	9.63	16.96	28.92
38	Sidorejo	3.71	8.12	24.95	43.65	78.16

Note: Tirtanadi Figures (column 49) include 23% unaccounted for water

B:3 - Continued

ns	Municipal Commercial/Industrial/Government/Institutional Water Use Projection Litres/Second (% served)				Total Municipal Water Use Projections With Allowance for Unaccounted for Water (25%), Litres/Second			
0%)	1980 (71%)	1985 (73%)	1990 (76%)	2000 (84%)	1980	1985	1990	2000
5	0.64	0.76	0.91	1.30	22.64	23.00	23.00	23.00
1	0.33	0.40	0.48	0.68	11.04	22.54	33.73	47.71
9	0.67	0.80	0.96	1.37	7.80	20.35	30.03	41.81
1	3.09	3.70	4.42	6.29	12.38	28.72	41.63	58.67
9	1.61	1.92	2.308	3.28	10.09	24.80	36.54	50.88
8	2.59	3.09	3.70	5.27	19.97	20.00	28.38	38.59
8	2.96	3.54	4.23	6.02	20.34	21.00	22.72	32.94
18	12.29	14.68	17.55	24.99	21.18	32.82	43.81	58.89
55	0.80	0.96	1.15	1.64	7.80	20.32	30.28	41.72
13	11.38	13.59	16.25	23.14	20.40	32.86	43.99	61.68
56	0	0	0	0	4.27	11.03	17.49	24.75
19	0	0	0	0	7.33	20.40	30.86	41.58
81	0	0	0	0	9.53	28.85	50.45	90.39
10	0	0	0	0	4.16	12.81	22.41	40.12
92	2.69	3.21	3.84	5.47	7.95	17.13	27.73	45.85
16	0.27	0.32	0.38	0.55	11.18	33.68	58.70	104.92

TABLE B13

KP No.	Name of Kampung	Present Municipal Water Use Litres/Second	Municipal Domestic Water Use Projections Litres/Second (% served)			
		Tirtanadi 1978	1980 (25%)	1985 (60%)	1990 (75%)	2000 (80%)
39	Tegal Sari	0.48	9.47	29.11	50.94	91.21
	KECAMATAN MEDAN JOHOR					
40	Harjosari	3.49	5.54	16.14	27.51	52.69
	KECAMATAN MEDAN BARU					
41	Petisah Hulu	7.18	4.38	12.17	17.78	25.97
42	Madras Hulu	6.18	4.25	11.80	17.22	25.13
43	Jati	7.38	2.56	7.12	10.40	15.18
44	Aur	12.00	3.13	9.10	13.84	21.54
45	Sei. Mati	1.90	0,84	2.24	3.16	4.38
46	Hamdan	6.73	2.46	6.84	10.09	14.63
47	Babura	9.73	5.78	16.37	24.60	37.45
48	Anggrung	6.11	1.50	4.42	6.64	10.50
49	Baru	7.73	2.74	8.39	12.82	21.21
50	Merdeka	8.31	3.80	11.20	16.98	26.88
51	Suka Raja	2.42	0.65	1.78	2.56	3.67
52	Titi Rantai	8.21	2.96	9.12	13.97	23.23

B13 — Continued

ions l)	Municipal Commercial/Industrial/Government/Institutional Water Use Projection Litres/Second (% served)				Total Municipal Water Use Projections With Allowance for Unaccounted for Water (25%), Litres/Second			
(80%)	1980 (71%)	1985 (73%)	1990 (76%)	2000 (84%)	1980	1985	1990	2000
.21	2.15	2.57	3.07	4.38	15.51	42.24	72.00	127.42
.69	2.15	2.57	3.07	4.38	10.26	25.95	40.78	76.08
.97	2.49	2.97	3.56	5.06	9.33	20.19	28.44	41.37
.13	5.39	6.43	7.69	10.95	12.85	24.31	23.22	48.11
.18	1.51	1.81	2.16	3.08	9.58	11.91	16.75	24.34
.54	13.07	15.61	18.67	26.58	21.60	32.94	43.34	64.14
.38	0.43	0.52	0.62	0.89	2.47	3.68	5.04	7.02
.63	2.69	3.21	3.84	5.47	8.74	13.41	18.58	26.81
.45	0.75	0.92	1.10	1.57	12.64	23.05	34.26	52.02
.50	0	0	0	0	7.94	7.94	8.86	14.00
.21	1.31	1.56	1.87	2.67	10.04	13.27	19.59	31.83
.88	2.02	2.41	2.88	4.10	10.79	18.15	26.48	41.31
.67	0.50	0.60	0.72	1.02	3.14	3.18	4.38	6.26
.23	0.57	0.68	0.81	1.16	10.66	13.07	19.71	32.52

KP No.	Name of Kampung	Present Municipal Water Use Litres/Second	Municipal Domestic Water Use Projections Litres/Second (% served)			
		Tirtanadi 1978	1980 (25%)	1985 (60%	1990 (75%)	2000 (80%)
53	Darat	3.20	1.96	5.59	8.41	12.89
54	Polonia	26.58	5.31	16.01	24.25	39.39
55	Padang Bulan	15.81	2.07	6.29	9.58	15.69
	KECAMATAN MEDAN BARAT					
56	Kesawan	29.99	4.72	12.61	19.87	29.56
57	Petisah Tengah	33.90	8.02	22.54	34.84	49.87
58	Silalas	11.63	3.59	10.65	16.29	22.37
59	Sekip	8.01	2.56	7.76	12.17	18.97
60	Sei. Putih Timur	8.62	4.84	14.74	23.17	36.31
61	Sei. Putih Barat	22.08	5.67	17.28	27.16	42.56
62	Sei. Sikambing	9.77	5.02	14.46	21.89	33.28
63	Sei. Agul	23.50	7.21	21.96	34.51	51.08
64	Gelugur Kota	3.03	2.51	7.46	11.66	17.82
65	Pulau Brayan Kota	3.99	1.77	4.79	7.11	9.65

B.3 -Continued

ns	Municipal Commercial/Industrial/Government/Institutional Water Use Projections Litres/Second (% served)				Total Municipal Water Use Projections With Allowance for Unaccounted for Water (25%), Litres/Second			
30%)	1980 (71%)	1985 (73%)	1990 (76%)	2000 (84%)	1980	1985	1990	2000
39	0	0	0	0	4.16	7.45	11.12	17.18
39	93.38	111.51	133.35	189.84	131.56	170.00	210.08	305.58
59	35.81	42.76	51.13	72.80	50.50	65.39	80.94	117.96
56	19.57	23.37	27.95	39.79	38.95	47.96	63.75	92.46
37	2.02	2.41	2.88	4.10	44.03	45.00	50.29	71.97
37	8.86	10.58	12.65	18.44	16.60	28.30	38.58	58.42
97	5.59	6.67	7.98	11.36	10.87	19.25	26.87	40.46
31	0.84	1.00	1.20	1.71	11.20	20.99	32.49	50.69
56	1.68	2.01	2.40	3.42	28.68	29.00	39.41	61.32
28	0.20	0.24	0.28	0.41	12.69	19.60	29.56	44.92
08	1.38	1.65	1.97	2.80	30.52	31.47	48.63	75.85
32	10.61	12.67	15.15	21.57	17.49	26.84	35.74	52.52
55	9.63	11.50	13.75	19.58	15.20	21.72	27.82	38.98

TABLE B.3

KP No.	Name of Kampung	Present Municipal Water Use Litres/Second	Municipal Domestic Water Use Projections Litres/Second (% served)			
		Tirtanadi 1978	1980 (25%)	1985 (60%)	1990 (75%)	2000 (80
	KECAMATAN MEDAN BELAWAN					
66	Belawan I	Not in W.D.	3.50	9.63	13.64	18.28
67	Belawan II	Not in W.D.	6.41	18.12	25.56	35.31
68	Belawan III	Not in W.D.	2.21	6.24	8.77	12.08
	KECAMATAN MEDAN SUNGGAL					
69	Padang Bulan Selayang	18.92	1.78	5.43	9.70	18.22
70	Sei. Sikambing-C	6.05	2.34	7.13	12.74	23.92
71	Sei. Sikambing-B	15.23	3.08	9.36	16.71	31.38
72	Dwikora	3.54	2.04	5.96	10.71	19.16
73	Tanjung Rejo	5.10	6.68	18.68	32.79	56.16
74	Babura Sunggal	14.63	2.86	8.71	15.55	29.19
75	Perladangan Helvetia	3.42	10.04	28.44	50.36	87.35
A_2	2000 Built Up Area + Industrial Estate	Not in W.D.	48.63	58.32	184.93	302.24
A_3	Out side Built Up Area	Not in W.D.	-	-	-	-

B.3 – Continued

ions	Municipal Commercial/Industrial/Government/Institutional Water Use Projection Litres/Second (% served)				Total Municipal Water Use Projections With Allowance for Unaccounted for Water (25%), Litres/Second			
(80%)	1980 (71%)	1985 (73%)	1990 (76%)	2000 (84%)	1980	1985	1990	2000
.28	6.79	8.32	9.95	14.17	13.96	23.94	31.46	43.28
.31	0.84	1.00	1.20	1.71	9.67	25.49	35.67	49.37
.08	62.09	74.14	88.65	126.22	85.71	107.15	129.87	184.40
.22	0	0	0	0	24.57	25.00	25.00	25.00
.92	0.77	0.92	1.10	1.57	7.86	10.74	18.46	33.99
.38	1.38	1.65	1.97	2.80	19.78	20.00	24.60	45.58
.16	2.12	2.53	3.90	4.31	5.55	11.33	19.08	31.29
.16	0.67	0.80	0.96	1.37	9.80	25.97	44.99	76.70
.19	0.33	0.40	0.48	0.68	19.00	20.00	21.37	39.88
.35	0.33	0.40	0.48	0.68	13.83	38.45	67.77	117.34
.24	92.65	110.63	132.29	188.35	77.76 123.53	246.57 147.50	402.98 176.38	675.10 251.13
	–	–	–	–	– –	– –	– –	– –

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PROJECTED SOL

Kp. No.	Name of Kampung	Projected Population				
1	2	3	4	5	6	
		1978	1980	1985	1990	
	KECAMATAN MEDAN KOTA	1.0000	1.0201	1.0511	1.0486	1.
1.	Pasar Baru	7667	7,821	8,221	8,620	9,
2.	Pandau Hulu I	6466	6,596	6,933	7,270	8,
3.	Sukaramai I	9089	9,272	9,956	10,440	11,
4.	Sudirejo I	9254	9,440	9,922	10,404	11,
5.	Tegal Sari I	20554	20,967	22,038	23,109	25,
6.	Tegal Sari II	9295	9,482	9,967	10,451	11,
7.	Kota Matsum I	14170	14,455	15,194	15,932	17,
8.	Sukaramai II	12957	13,217	13,893	14,568	16,
9.	Mesjid	5368	5,475	5,755	6,035	6,
10.	Kota Matsum II	23144	23,609	24,815	26,021	28,
11.	Pusat Pasar	6220	6,345	6,669	6,993	7,
12.	Sei Rengas I	9621	9,814	10,315	10,816	11,
13.	Sei Rengas II	13162	13,427	14,113	14,799	16,
14.	Kota Matsum III	9393	9,582	10,072	10,562	11,
15.	Pandau Hulu II	9423	9,612	10,103	10,594	11,
16.	Teladan Timur	10568	10,780	11,334	11,885	13,
17.	Teladan Barat	10994	11,215	11,788	12,361	13,
18.	Pasar Merah Timur	10810	11,027	11,591	12,154	13,
19.	Pasar Merah Barat	5358	5,466	5,746	6,025	6,
20.	Sitirejo I	8645	8,819	9,270	9,721	10,
21.	Sitirejo II	13422	13,692	14,392	15,091	16,
22.	Sudirejo II	6734	6,869	7,220	7,571	8,
	KECAMATAN MEDAN TIMUR	1.0000	1.0289	1.0510	1.1069	1.1
23.	Sei Kera Hulu	19969	20,546	21,594	23,902	26,
24.	Sei Kera Hilir	19113	19,665	20,668	22,877	25,
25.	Sidorame Barat	21259	21,873	22,589	25,004	27,
26.	Durian	20123	20,705	21,761	24,088	26,
27.	Gelugur Darat	17369	17,870	18,781	20,789	22,
28.	Gang Buntu	9739	10,020	10,531	11,657	12,
29.	Pandau Hilir	10729	11,039	11,602	12,842	14,
30.	Sidodadi	12560	12,924	13,583	15,035	16,
31.	Pulo Brayan Darat	13874	14,275	15,003	16,607	18,
32.	Pulo Brayan Bengkei	11176	11,498	12,085	13,377	14,
33.	Sidorame Timur	10105	10,397	10,927	12,005	13,

.BLE B.4

ID WASTE QUANTITIES

	Domestic Solid Waste Projections					
	Generation (Kilograms/Day)				Collections (Kilograms/Day)	
7	8	9	10	11	12	13
2000	1980	1985	1990	2000	1980	1985
.1069	0.51	0.56	0.62	0.75		
9,143	3,989	4,604	5,344	6,857	3,989	4,604
8,047	3,364	3,883	4,507	6,035	3,364	3,883
1,556	4,729	5,575	6,473	8,667	4,729	5,575
1,516	4,814	5,556	6,451	8,637	-	5,556
5,579	10,587	12,090	13,920	18,523	-	12,090
1,568	4,942	5,833	6,887	9,338	-	5,833
7,635	7,372	8,509	9,878	13,226	7,372	8,509
6,125	6,741	7,780	9,032	12,094	6,741	7,780
6,681	2,792	3,223	3,742	5,011	2,792	3,223
28,803	12,041	13,896	16,133	21,602	12,041	13,896
7,741	3,236	3,735	4,336	5,806	3,236	3,735
11,973	5,005	5,776	6,706	8,980	5,005	5,776
16,381	6,898	7,903	9,175	12,286	6,898	7,903
11,691	4,886	5,617	6,467	8,449	4,886	5,617
11,727	4,902	5,658	6,568	8,795	4,902	5,658
13,156	5,499	6,371	7,450	10,187	-	6,371
13,682	5,720	6,601	7,664	10,262	5,720	6,601
13,453	5,624	6,491	7,536	10,090	5,624	6,491
6,669	2,788	3,218	3,736	5,002	2,788	3,218
10,760	4,498	5,191	6,027	8,070	-	5,191
16,704	6,983	8,060	9,356	12,528	-	8,060
8,380	3,503	4,043	4,694	6,285	-	4,043
1.1051						
26,414	10,388	11,942	14,279	20,905	-	11,942
25,281	10,029	11,574	14,184	18,861	-	11,574
27,632	11,155	12,650	15,503	20,724	-	12,650
26,620	10,560	12,186	14,935	19,965	10,560	12,186
22,973	9,114	10,517	12,889	17,230	-	10,517
12,882	5,110	5,897	7,227	9,662	5,110	5,897
14,191	5,630	6,497	7,962	10,643	5,630	6,497
16,614	6,591	7,607	9,322	12,461	6,591	7,607
18,352	7,371	8,552	10,837	14,920	-	8,552
14,783	5,864	6,768	8,294	11,087	-	6,768
13,366	5,303	6,119	7,499	10,025	-	6,119

Kp. No.	Name of Kampung	Projected Population				
1	2	3	4	5	6	7
		1978	1980	1985	1990	200
34.	Tegal Rejo	12730	13,102	13,770	15,242	16,84
	KECAMATAN MEDAN DENAI	1.0000	1.0404	1.1130	1.2873	1.39
35.	Bantan	23748	24,707	27,101	34,901	48,82
36.	Bandar Selamat	10386	10,806	12,028	15,490	21,66
37.	Indra Kasih	7485	7,787	8,668	11,163	15,61
38.	Sidorejo	26974	28,064	31,238	40,228	56,27
39.	Tegal Sari	47606	32,749	36,453	46,944	65,67
	KECAMATAN MEDAN JOHOR	1.000	1.0404	1.1043	1.2627	1.51
40.	Harjosari	20945	21,792	24,065	30,387	46,06
	KECAMATAN MEDAN BARU	1.0000	1.0403	1.1161	1.1271	1.29
41.	Petisah Hulu	8770	9,123	10,183	11,478	14,91
42.	Madras Hulu	5320	5,534	6,177	6,962	9,04
43.	Jati	3213	3,342	3,730	4,204	5,46
44.	Aur	10681	11,112	12,403	13,980	18,16
45.	Sei Mati	7941	8,261	9,220	10,392	13,50
46.	Hamdan	7557	7,861	8,773	9,888	12,83
47.	Babura	10675	11,106	12,396	13,971	18,15
48.	Anggrung	3613	3,759	4,195	4,729	6,14
49.	Baru	8801	9,156	10,219	11,518	14,96
50.	Merdeka	9123	9,491	10,593	11,939	15,51
51.	Sukaraja	5190	5,400	6,027	6,793	8,82
52.	Titi Rantai	9837	10,233	11,421	12,872	16,72
53.	Darat	3638	3,785	4,224	4,761	6,18
54.	Polonia	20905	21,747	24,272	27,358	35,55
55.	Padang Bulan	6244	6,495	7,249	8,170	10,61
	KECAMATAN MEDAN BARAT	1.0000	1.0402	1.1039	1.1567	1.22
56.	Kesawan	9729	10,120	11,171	12,921	15,81
57.	Petisah Tengah	13744	14,297	15,782	18,255	22,34
58.	Silalas	9990	10,391	11,471	13,269	16,244

B.4 – Continued

	Domestic Solid Waste Projections					
	Generation (Kilograms/Day)				Collections (Kilograms/Day)	
7	8	9	10	11	12	13
2000	1980	1985	1990	2000	1980	1985
,844	6,682	7,711	9,450	12,633	-	7,711
..3989						
,823	12,601	15,177	21,639	36,617	-	-
,669	5,511	6,736	9,634	16,252	-	-
,616	3,971	4,854	6,921	11,712	-	-
,275	14,313	17,493	24,941	42,206	-	-
,670	16,702	20,414	29,105	49,253	-	-
..5158						
,061	11,114	13,476	18,840	34,546	-	-
L.2996						
,916	4,653	5,703	7,116	11,187	4,653	5,703
,047	2,822	3,459	4,316	6,785	2,822	3,459
,464	1,704	2,089	2,607	4,098	1,704	2,089
,169	5,557	6,711	8,173	11,073	5,557	6,711
,505	4,213	5,163	6,443	10,129	4,213	5,163
,831	4,009	4,913	6,131	9,623	4,009	4,913
,156	5,664	6,942	8,662	13,617	5,664	6,942
,146	1,917	2,349	2,932	4,610	1,917	2,349
,969	4,670	5,723	7,141	11,227	-	5,723
,516	4,840	5,932	7,402	11,637	4,840	5,932
,828	2,754	3,375	4,212	6,621	2,754	3,375
,728	5,228	6,518	8,170	12,546	-	6,518
,187	1,930	2,365	2,952	4,640	1,930	2,365
,554	11,193	13,704	17,266	29,219	11,193	13,704
,618	3,313	4,059	5,065	7,964	-	4,059
1.2242						
,818	5,161	6,256	8,011	11,864	5,161	6,256
,348	7,292	8,838	11,318	16,761	7,292	8,838
,244	5,299	6,424	8,227	12,183	5,299	6,424

Kp. No.	Name of Kampung	Projected Population				
1	2	3	4	5	6	
		1978	1980	1985	1990	20
59.	Sekip	9099	9,465	10,448	12,086	14,7
60.	Sei Putih Timur	16077	16,723	18,461	21,354	26,1
61.	Sei Putih Barat	18847	19,605	21,642	25,033	30,6
62.	Sei Sikambing	11329	11,785	13,009	15,048	18,4
63.	Sei Agul	23945	24,908	27,496	31,805	38,9
64.	Gelugur Kota	7122	7,408	8,177	9,459	11,5
65.	Pulau Brayan Kota	12124	12,612	13,924	16,105	19,7
	KECAMATAN MEDAN BELAWAN	1.0000	1.0200	1.0507	1.0513	1.10
66.	Belawan I	11500	11,730	12,325	12,958	14,7
67.	Belawan II	27533	28,083	29,508	31,022	34,4
68.	Belawan III	10500	10,710	11,253	11,830	13,7
	KECAMATAN MEDAN SUNGGAL	1.0000	1.0510	1.1038	1.3142	1.46
69.	Padang Bulan Selayang	5865	6,164	6,804	8,942	13,7
70.	Sei Sikambing C	7700	8,093	8,933	11,739	17,2
71.	Sei Sikambing B	10100	10,615	11,717	15,398	22,5
72.	Dwikora	4625	4,861	5,365	7,051	10,2
73.	Tanjung Rejo	11238	11,811	13,037	17,133	25,7
74.	Babura Sunggal	9398	9,877	10,903	14,328	21,6
75.	Perladangan Helvetia	18338	19,274	21,274	27,958	41,6
A2	2000 Built Up Area	110065	116,163	142,403	172,365	244,
A3	Outside Built Up Area	103748	109,496	134,232	162,474	230,

E B.4 — Continued

	Domestic Solid Waste Projections					
	Generation (Kilograms/Day)				Collection (Kilograms/Day)	
7	8	9	10	11	12	13
2000	1980	1985	1990	2000	1980	1985
14,796	4,827	5,851	7,493	11,097	4,827	5,851
26,142	8,529	10,338	13,240	19,607	-	10,338
30,645	9,999	12,120	15,521	22,984	-	12,120
18,422	6,010	7,285	9,330	13,817	6,010	7,285
38,936	12,703	15,398	19,719	29,202	-	15,398
11,580	3,778	4,579	5,865	8,685	3,778	4,579
19,717	6,432	7,797	9,985	14,788	6,432	7,797
1.1095						
14,377	5,982	6,902	8,034	10,783	5,982	6,902
34,419	14,322	16,525	19,234	25,814	14,322	16,525
13,125	5.462	6,302	7,335	9,844	-	6,302
1.4670						
13,118	3,144	3,810	5,544	9,839	-	-
17,222	4,127	5,003	7,278	12,917	-	-
22,590	5,414	6,562	9,547	16,943	-	-
10,344	2,479	3,004	4,372	7,758	-	-
25,135	6,024	7,301	10,623	18,851	-	-
21,019	5,037	6,106	8,883	15,764	-	-
41,014	9,830	11,913	17,334	30,761	-	-
					218,337	441,253
244,121	59,243	79,746	106,866	183,091	15,663	26,747
230,111	55,843	75,170	100,734	172,583	-	-

APPENDIX C

SIBOLANGIT SPRINGS

C.1 SPRINGS LOCATIONS AND FLOWS

The springs near Sibolangit and Sembahe have supplied Medan with water for more than 70 years. These springs are located about 40 km south of the city center of Medan and about 26 km from the near connection with the distribution system. Analyses of the spring transmission system has been presented in Section 2 and Section 6. As indicated in report Figure 2.1, the springs lie along the tributaries of the Petani and Betimus branches of the Deli River. Several springs also lie to the west in the Tenbengan and Bentar branches of the Belawan River.

Flows from the Sibolangit springs have been reported by the Geological Survey of Indonesia (Bandung, 1973) and by old Dutch maps of the water company. These reports indicate eight major groups of springs:

<u>Eastern</u>		
No. 31	Puang Aja* Sembahe	13,000 cu.m/d
No. 32	Lau Kaban*	18,000 cu.m/d
No. 33	Lau Bengklewang*	14,000 cu.m/d
No. 34	Rumah Sumbul*	13,000 cu.m/d
<u>Western</u>		
No. 27	Lau Seram	
No. 28	Lau Gurisa	19,000 cu.m/d
No. 29	Lau Tambunan	
No. 30	Lau Timah	
Total		77,000 cu.m/d

(* Springs collected by Tirtanadi).

P.A.M. Tirtanadi collects about 46,500 cu.m/d from the eastern group of the Sibolangit springs or about 75 percent of their estimated flow. Old map records of Tirtanadi indicated flows which are quite similar to

those reported by the GSI (above) for the eastern group. The old maps also indicated several other nearby springs with a combined flow of about 4,000 cu.m/d. The western group of springs were recorded on the old maps with a combined flow of 18,100 cu.m/d which is again similar to that reported by the GSI for the same group. The exact locations of these springs are not known.

Reports have been made that the springs have very stable flows without significant daily or seasonal changes. A review of the available production measurements taken during the last year indicates some seasonal changes and flow variations of more than 10 percent. Furthermore, total production has been about 43,000 cu.m/d, about 10 percent less than the reported production of 47,000 cu.m/d. Production from the Lau Bengklewang and Rumah Sumbul springs have varied by about 20 percent. Rumah Sumbul production showed increases from July to December, 1978, from the dry to wet seasons. Variations at Lau Bengklewang showed no clear trend. Combined production from the Puang Aja and Lau Kaban springs varied by 25 percent and showed increased production from the dry season to the wet season and then a slight decline in the dryer months of January and February, 1979.

Less than 60 percent of the total available spring flow is collected by Tirtanadi, and the remainder passes into the Belawan and Deli rivers. Tirtanadi collects 47,000 cu.m/d from the eastern spring group which has a combined flow of 57,000 cu.m/d. Therefore, about 10,000 cu.m/d flows into the Deli river from these springs. If the other reported smaller springs were separate from the GSI estimates, another 4,000 cu.m/d flows into the Petani branch of the Deli. Of the western group, 6,400 cu.m/d flows into the Betimus branch of the Deli River, and perhaps as much as 15,000 cu.m/d passes into the Tembengan and Bentar branches of the Belawan River.

C.2 FACILITIES

In 1908, the springs of Rumah Sumbul were developed to produce about 13,000 cu.m/d. An additional 11,200 cu.m/d were collected from the springs of the Lau Bengklewang in 1929. These springs were served by a common transmission system. Springs on the east side of the Medan-Brastagi Road were collected between 1958 and 1968. The Lau Kaban and Puang Aja springs (or the Sembahe springs) were collected to the Sembahe treatment facilities, and 22,500 cu.m/d conveyed via the Rumah Sumbul and Lau Bengklewang transmission pipelines. The total production level in 1968 was about 46,500 cu.m/d and has continued to 1979.

Spring water is collected from seepage areas by a series of excavated tunnels which are usually lined with brick to allow seepage into the tunnel. The collected flow passes along the bottom of the tunnel and enters a sump where the water flows into the collection pipeline. From the individual collectors, pipelines carry the spring waters to the central treatment facilities. Sufficient gravity head is available to allow aeration, chlorination and gravity flow through the entire treatment facility and then collection in a sump before the treated spring water enters the transmission pipelines to reach Medan. The Rumah Sumbul and Lau Bengklewang springs water are combined in a central chamber and then

eventually combined with the spring waters from Puang Aja and Lau Kaban at Sembahe. The transmission pipelines follow the west or left bank of the Petani Branch of the Deli River and split near Deli Tua before entering the Medan distribution system.

C.3 WATER QUALITY

The water quality of the Sibolangit Springs is better than any other source. Additional analyses were conducted and confirm its good quality. The raw spring water has low pH and high CO_2 levels which are buffered and lowered by aeration before the water enters the transmission pipelines. Similarities between the four major spring sources suggest that the spring waters may arise from the same aquifer.

C.4 GEOLOGICAL OCCURENCE

The springs are located along a northwest-southwest line which parallels the contact to the south between the upper lahar and breccia and the lower andesitic tuffs of the Post - "Toba" volcanics. Available geological surveys of the areahave not indicated the underlying geological structure or sources of the springs. Surface exposures of bedrock are isolated and do not provide clear evidence of the geological relationships of the springs to the volcanic deposits.

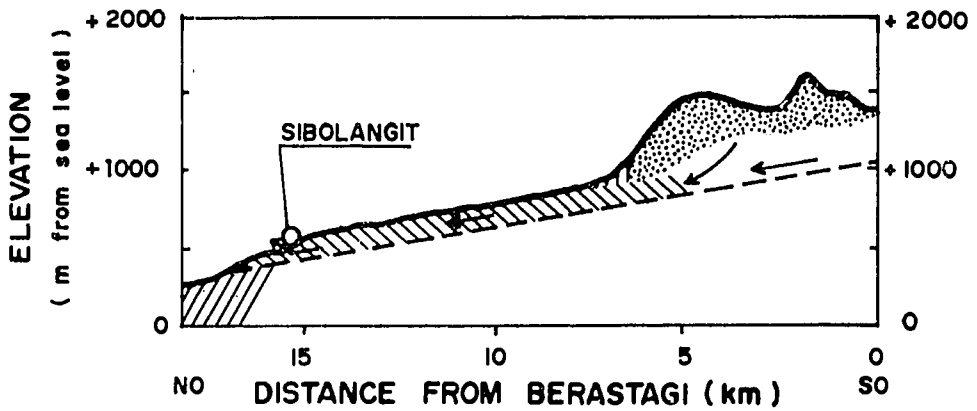
General interpretations of the available geological data suggest two possible sources for the springs, and perhaps both for different groups of springs (Figure C.1). The springs may arise from faults or formation contacts between different volcanic layers (Figure C.1). The map for the Belawan-Medan-Brastagi area indicates that the upper formation of the post-Toba volcanics is composed of lavas and breccias, and breccias cover the higher drainage basins of the Deli and Belawan rivers and from Sibolangit to Brastagi valley (about 15 kilometres). The upper breccia overlies the lower andestic tuff which forms the floor of the Brastagi valley and the hills between Sibolangit and Medan.

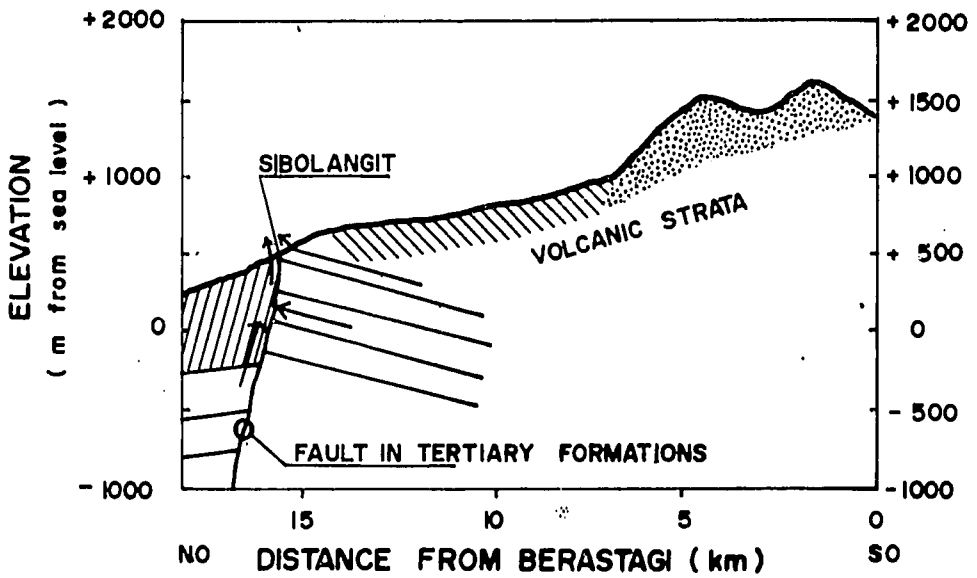
The contact between these formations winds back and forth across a zone of about one kilometre, and some of the upper breccia occur as long narrow remnants along several streams. Such occurrences suggest that the breccia may have flowed out into an irregular surface over the lower tuff. In some places, the breccias may have filled the old valleys eroded in the underlying tuff. The irregular contact surface between the two volcanic layers would tend to collect the rainfall which infiltrates into the breccia from the drainage divide of Gundaling-Sibayak down to Sibolangit. If an ancient valley had followed the same course as the Petani river, the contact between the breccia and tuff would concentrate the breccia groundwater and direct the groundwater flow along the old buried river course which passes through Sibolangit. Wherever modern erosion has cut through the filled river valley, groundwater moving along the contact would be discharged as springs.

A second potential source of groundwater in the area may be associated with the structure of the deeper Tertiary and overlying volcanic deposits in the Serengitrengit-Sembahe area (Figure C.1). The geological map indicates the presence of a northwest-southeast aligned fault in the

SCHEMATIC GEOLOGICAL CROSS - SECTIONS OF POTENTIAL SOURCES OF SIBOLANGIT SPRINGS

a. VOLCANIC OR SHALLOW SOURCES





Seruwai river, about five kilometres east of Sibolangit. Exposures of Seurula, Keutapang, and Barong formations of Tertiary age have been uplifted more than 1,000 m along the fault. This fault and others under the volcanic breccia may intercept groundwater moving in the Tertiary bedrock. Groundwater may also be forced to the surface by a large uplifted block of consolidated Tertiary bedrock which would form a subsurface dam.

The most probable source could be defined more thoroughly by data from a single borehole placed along the Brastagi road at about 600 m elevation. Such a boring would indicate the geological character of the volcanic deposits and whether the contact between the volcanic strata is geologically the source of the spring water. Analyses of the chemical composition of the well water would indicate whether it is similar to or different from that in the spring. Changes in the water level in the well should also be related to changes of spring flows.

APPENDIX D

SURFACE WATER HYDROLOGY

D.1 RAINFALL CHARACTERISTICS

The equatorial location and low elevation of Medan (3° 35' N, sea level to 50 m) largely determines the tropical climate of the region. Although rainfall, temperatures and sunshine show some seasonal variation, these seasons are not as distinctly marked as in Java and many other parts of Asia. Two rainy periods occur during the fall and spring rather than during the more typical "monsoon" seasons which occurs over much of Asia. These rainy periods more closely resemble those in southern India, Sri Lanka, and Equatorial Africa.

Medan rainfall has been recorded since 1879 at three stations (different recording periods) and is summarized in several reports (US 6, 7, 8, 9, 13 and 14). These reports and monthly records for 935 months in an 83 year period have been summarized (Table D.1) to focus on the major storms which will affect drainage planning and on the major drought periods which govern water supply planning. During the period of record, annual rainfall has varied from 1,352 to 2,873 mm. The 10 and 90 percentile values are 1,633 and 2,388 mm, respectively. Fifty percent (25 to 75 percentile) of the annual rainfall records ranged from about 1,810 to 2,250 mm, and the average annual rainfall for 1901 to 1941 was about 2,050 mm.

D.1.1 Rainy Seasons

Distribution of rainfall throughout the year shows two high rain months: October and May, although the longer rainy season extends from September to January. Of the 935 months of complete annual rainfall records, 80 percent of the months have rainfall between 60 and 300 mm, while about seven percent of the months have rainfalls from 300 to 400 mm with two percent (six months) greater than 400 mm per month (Table D.2). About 20 percent of the years of record had rainfalls during two consecutive months of more than 300 mm/month or less than 600 mm/month. Two percent of the years had rains of greater than 300 mm for three consecutive months while seven percent had less than 60 mm/month for three or four months.

TABLE D.1

SUMMARY OF ANNUAL AND MONTHLY
RAINFALL RECORDS FOR MEDAN PUTRI,
1879 TO 1941 AND 1955 TO 1974

Annual Rainfall (mm)	Number of Years	Percent
2,800-2,899	1	11
2,700-2,799	0	
2,600-2,699*	2	
2,500-2,599	2	
2,400	4	
2,300-2,399*	7	33
2,200	11	
2,100	10	
2,000-2,099	13	15
1,900	6	31
1,800	8	
1,700	6	
1,600	6	
1,500	6	10
1,400	0	
1,300-1,399	2	
Total	84 years	100

Monthly Rainfall (mm)	Number of Months	Percent	
600-700	3	0.3	7
500	3	0.3	
400	0	0	
300	68	7.3	
200	760	81.3	81.3
100			
60			
20-60	87	9.3	10.8
0-20	14	1.5	
Total (Months of complete years)	935	100.0	100.0

* Includes storm of record.
Reference--DPU--Hydrological Design Unit.

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TABLE D.2

SEQUENTIAL MONTHS WITH HIGH OR LOW RAINFALL

	Wet (> 300 mm)		Dry (< 60 mm)		
	3 Months	2 Months	2 Months	3 Months	4 Months
Periods	IX-XI/1895 X-XII/1973	X-XI/1881 VIII-IX/1884 X-XI/1893 XI-XII/1903 XII/1916-I/1917 X-XI/1922 X-XI/1923 X-XI/1925 X-XI/1929 IX-X/1931 X-XI/1936 IX-X/1940 X-XI/1969 X-XI/1970	II-III/1884 III-IV/1901 II-III/1903 II-III/1906 II-III/1911 II-III/1919 I-II/1923 III-IV/1929 II-III/1931 VI-VII/1938 IV-V/1962 III-IV/1963 I-II/1965 II-III/1966 I-II/1968	I-III/1886 III-V/1891 II-IV/1926 I-III/1940 I-III/1976	I-IV/1885
Total Periods	2	14	15	5	1
Percent of Total Months	0.6	3.0	3.2	1.6	0.4
Percent Years	2.6	19.0	19.0	6.4	1.3
Total Months	943 (78 x 12 months + 7 months)				

D.1.2 Storms

The three stations in Medan had three different days with 250 to 290 mm of rain in 24 hours (Table D.3). Although these storms occurred in December or January, they occurred in widely different years, 1907, 1937, and 1956, and these storms coincide with high monthly rainfalls, but not with highest rainfall years. Such temporal distribution indicates that the storms were of limited areal extent and period and that rainfall quickly decreased beyond the intense centre of rain storm.

TABLE D.3

STORMS OF RECORD

Reference Station (US-8)	Date (mo/y)	24 Hours Rainfall (mm)		Long Term Rainfall (mm)	
		Highest	Second Highest	Monthly	Annual
Medan Putri	I/1931	205	104	686	2,695
Medan	I/1931	262	133		
Polonia	XI/1956	285	151		2,296
Medan Putri	XII/1907	253	-	684	2,358

Note: Storms of Record did not occur during unusually high rainfall periods.
Reference - DPU - Hydrological Design Unit.

Comparison of Medan with twelve other northern North Sumatran Stations (below 50 m elevation) show average annual rainfall varied from 1,800 to 3,177 mm. Monthly averages for daily maxima varied from 26 to 85 mm, while storms of record ranged from 112 to 309 mm/d during 10 to 20 year periods. Most records showed the storms of I/1931 and XI/1956 to have been the most widespread with limited local centres of very high rainfall.

The rainfall daily maxima for Sibolangit were 130 to 140 mm or similar to the secondary maxima in the more northern, lower stations. A 1931 daily maxima at Binjei and a 1956 maximum at Tanjung Pura indicate that some frontal storms could provide widespread heavy rains and locally very heavy rains.

D.1.3 Daily Rainfalls

Diurnal rainfall (US 14) shows a strong tendency towards afternoon and night rains and relatively dry morning periods. For a 15 year period, rainfalls of more than 5 mm/h during January to September generally occur between 12.00 to 01.00, while during the "long rainy season"

rains would continue from 12.00 or 15.00 to 06.00 the next morning (adding 50 percent to the total rain period). These records indicate that periods of 6 to 12 hours separate the rainy periods of each day and thereby allow runoff and drainage before the next day's rains.

The same diurnal rain records (US 14) indicated that the higher hourly rainfalls of 16 to 30 mm most commonly occurred between 18.00 and 22.00 during March to September and between 23.00 and 01.00 during the rainy period of October to December. Maximum hourly rainfalls during January to March were below 15 mm.

D.1.4 Rainfall and Elevation

Rainfall records for 1879 to 1941 have been summarized (US 6) for 15 stations within the regional drainage basin of Medan. These records clearly indicated the increase of rainfall with elevation:

Average Annual Rain (mm)		Elevation (m)
1,773-2,036	Mabar	6-12
2,065-2,269	Medan	28-38
2,298-3,098	Two rivers, Deli Tua	60-101
3,127-3,978	Petani	129-174
4,520	Sibolangit	565
5,279-6,676	Bandar Baru	864-928

A comparison of monthly rainfall at Sibolangit and Medan (Table D.4) showed the same highest rainfall during October and May, but in Sibolangit, the rainy period extended from August through May with more than 250 m of rain per month in a summer "day" season.

TABLE D.4

SUMMARY OF MONTHLY RAINFALLS OF MEDAN
AND OTHER STATIONS IN NORTHERN NORTH SUMATRA

Station		10 Year Average Annual Rainfall (mm)	Monthly Average Daily Maxima (mm)	Daily Maxima (mm)	Daily Date
126		2,053	28-64	205	I/1931
127 a	Medan and Vicinity	1,872	28-74	262	I/1931
d		1,944	26-77	173	XI/1956
e		2,237	40-74	264	IX/1960
f		1,974	31-64	135	IX/1959
g		1,960	36-76	208	XI/1956
h		1,800	30-76	309	XI/1956
i		2,174	38-85	285	XI/1956

TABLE D.4--Continued

Station	10 Year Average Annual Rainfall (mm)	Monthly Average Daily Maxima (mm)	Daily Maxima (mm)	Daily Date
Binjei	2,561	29-81	177	I/1931
Tanden	2,334	37-73	181	I/1931
Tanjung Pura	2,097	26-64	112	XI/1956
Pangkalan Berandan	3,177	38-72	184	VII/1955
Sibolangit (500 m)	4,078	52-87	141	III/1954

D.1.5 Dry Seasons

Two dry seasons occur in northern Sumatra between: (1) February and April and (2) July and August. During these seasons, monthly rainfall decreases to less than 100 mm per month and often to about 60 mm. These two seasons of five months may produce only 20 to 30 percent of the annual rainfall. When the dry season's monthly rains fall below 60 mm, drought conditions may be formed, and when more than one month of less than 60 mm/month rainfall occurs, the drought will intensify. Review of the monthly rainfall records for Medan (Table D.2) indicates the dates and relative frequency of droughts during the record of about 80 years. A total of 21 years (27%) had a period of two to four months with less than 60 mm/month of rainfall, and about five percent of all months had less than 60 mm/month. The most recent drought of 1976 was reported by residents in many places in Medan who depend upon shallow groundwater wells which went dry.

D.2 SURFACE HYDROLOGY

D.2.1 Basin Form

Surface hydrology of the Medan area largely involves three major basins, the Belawan, Deli and Percut rivers. As shown in Table D.5 and Figure D.1, the forms of these major basins are quite linear from south to north, while the smaller basins along the coast are much more triangular, as indicated by the length to area ratios. The three major rivers begin in the Barisan Range, 60-80 kilometres south of Medan. Gradients in the upper sub-basins vary from 8 to 18 percent in the hills, while gradients decrease to 2.0 to 2.2 percent between elevation of 50 to 600 metres, and then 0.1 to 1.0 in the lower reaches of the major streams.

The Belawan River has its major channel along the eastern margin of its basin and collects runoff from a series of distinct branches rather than a more typical dendritic river basin form. The Percut basin is the narrowest of the three with small lower and middle sub-basins. However, the upper sub-basin expands and collects runoff with a more typically

dendritic area in the highest rainfall zone (4,000 to 6,000 mm/y). The Deli River has an intermediate basinal form with the main channel along the eastern margin and with a major expansion in the middle and upper sub-basins. The altitudinal zonation of rainfall and the relative proportions of basins in the upper, middle, and lower segments should strongly influence both floods and low flows.

TABLE D.5

BASIN FORMS OF MAJOR MEDAN RIVERS

Basin	Total Area (sq m)	Length (km)	Area/ Length Ratio (sq km/km)	Gradients (percent)
Belawan	270	62	4,35	U 8.0
				M 2.1
				L 0.11-0.26
Deli (E and W)	395	68	5.81	U 16.0
				M 2.2
				L 0.13-0.23
Percut	213	65	3.23	U 8.0
Upper	143	35	4.10	M 2.0
				L 0.11-0.33

U : Upper segment between 600 and 1,900 m.
M : Middle segment between 50 and 600 m.
L : Lower segment between sea level and 50 m.

D.2.2 Basin Flows

Most major rivers in North Sumatra have been monitored for flows and river stages in order to plan for irrigation and flood protection. Most records, however, are for less than ten years, and many available records are for 1972-1979. River gages were located on only the Belawan and Deli rivers within the Medan study area as shown in Figure D.1. The Babura branch of the Deli River and the Percut River have not been monitored for flows.

D.2.2.1 Belawan River

The Belawan River has been monitored by the Institute for Hydrological Investigation (Bandung) and DPU Medan for seven years at Asam Kumbang. The gage was located about one kilometre above the Sunggal Water

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Plant and about six kilometres from the Medan city centre (Figure D.1). Available flow measurements include three years of average daily flows and 52 instantaneous discharges periodically taken over seven years. An additional gage has been located downstream near the mouth of the Belawan River, 25 km north of the old gage site and Sunggal Plant.

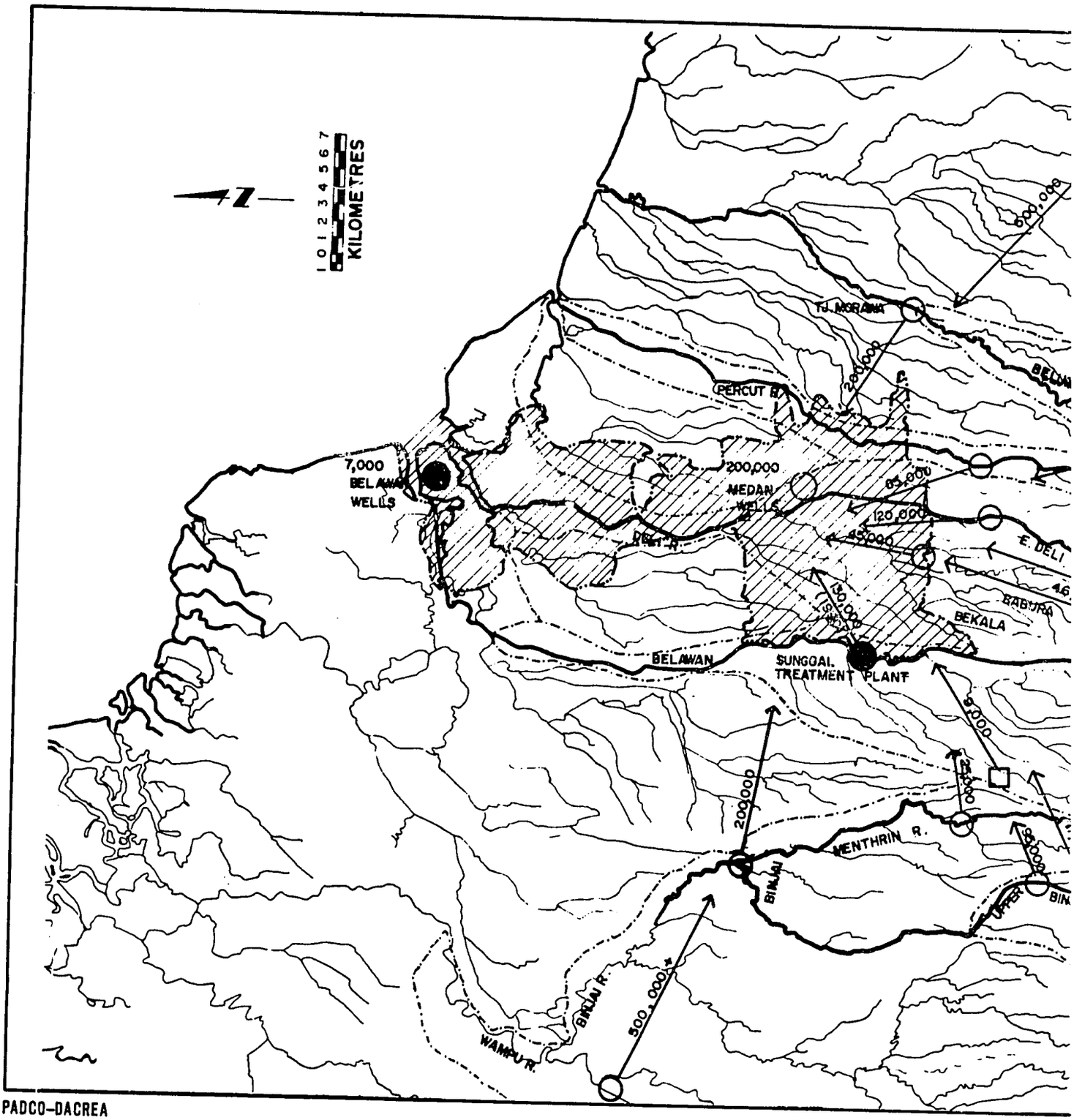
The Belawan River gage and that on the Deli River were relocated downstream because of unstable and highly variable cross-sections at the gage sites. Such variable sections and their influences upon the accuracy of the flow measurements are generally more important to high flood flows than to low flows. Unfortunately, no direct means are available to verify or modify the low flows recorded at the gage sites. Therefore, these previous data cannot be used for design purposes.

Similarities of yield rates (averaged low flows distributed over the total catchment area of the gage) can be seen from catchments above the Belawan, Deli, Binjei, Belumai, and Ular River gages (see individual river discussions). Yield rates for one percent recurrent flows vary from about 700 to 1,000 cu m/sq km. Such similarities support use of the low flows for this master planning study as a general guide for surface water development.

Short-term records have been reviewed and generalized projections were made for low flows in the Belawan and Deli rivers (see Table D.6). During the three years of averaged daily flows, lowest flows for each month varied from 2.5 to 14.3 cu m/s and for each year was from 2.5 to 4.7 cu m/s. Lowest periodic discharge measurements in each year (total measurements: 52, 1971-1979) varied from 1.7 to 6.5 cu m/s (147,000 to 562,000 cu m/d). About 10 percent of all averaged daily flows in three years and the periodic discharges in eight years were less than 5.0 cu m/s or 430,000 cu m/d, while 20 percent were less than 6.0 cu m/s or 520,000 cu m/d.

Low flows at long-term recurrence intervals were projected using log-probability paper for periodically recorded discharges. Low flows were plotted and projections extended to the one and five intervals. Projected low flows were about 215,000 cu m/d for the one percent recurrence and 250,000 cu m/d for the five percent recurrence. Such flows or less would be expected to occur one percent and five percent of the years over a very long period (or one year and five years out of 100 years would have such a flow).

The lowest recorded flow at the Asam Kumbang gage reached a low flow of 1.7 cu m/s or 147,000 cu m/d. This flow would have been expected to have occurred only once in 200 years and its occurrence in the short monitoring period would inidcate an even lower projection for low flows (i.e. about 90,000 and 140,000 cu m/d) than that projected from the other flow measurements. Differences between the projections for other values and this extreme value clearly supports the use of the existing flow measurements only as a guide to general planning and the need for immediate and long-term monitoring of the rivers which can supply Medan. Slopes of projected flow lines for all other rivers appear to be quite similar and resemble the line projected for all Belawan values.



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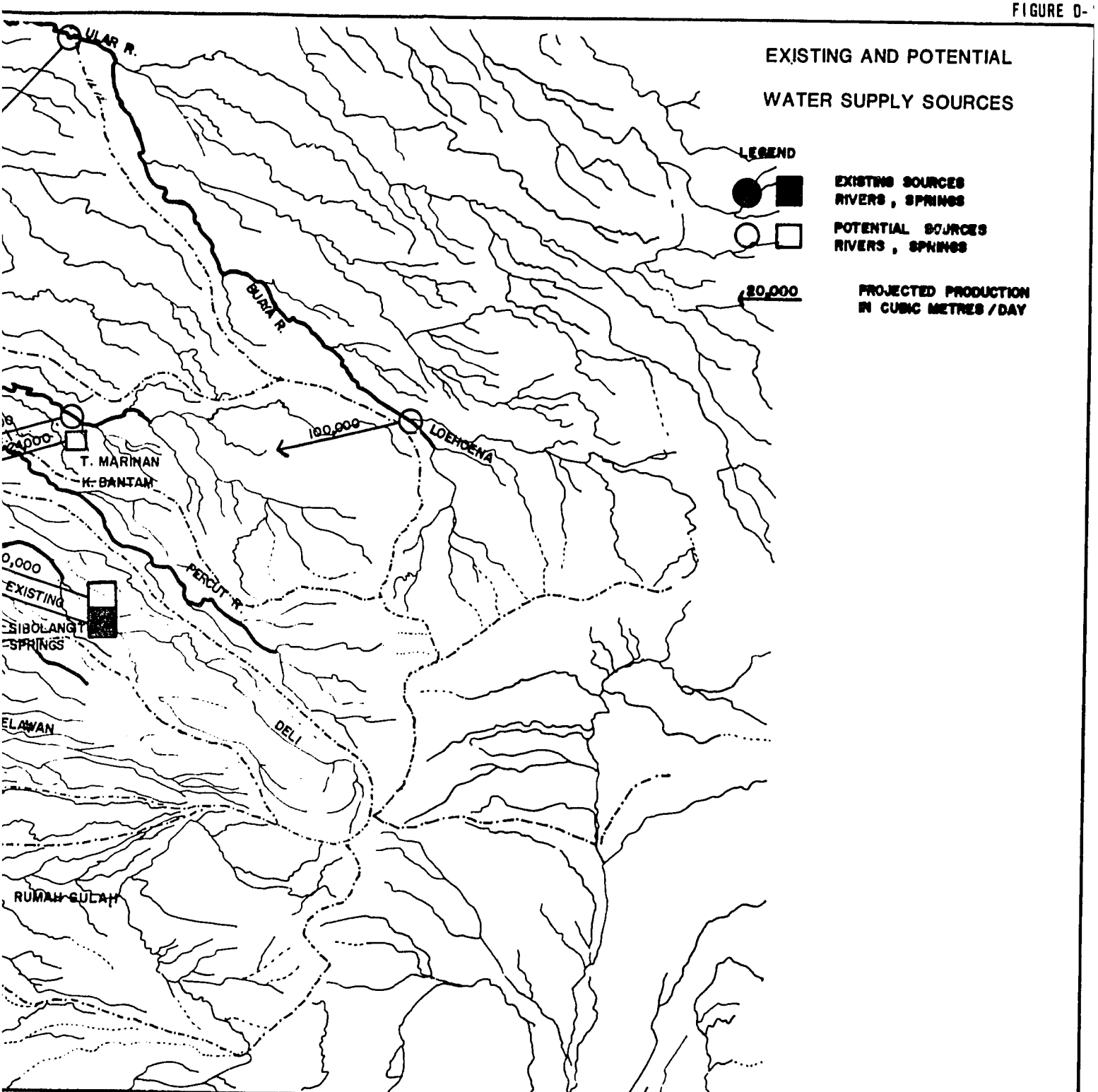

EXISTING AND POTENTIAL
WATER SUPPLY SOURCES
LEGEND
EXISTING SOURCES
RIVERS , SPRINGS
POTENTIAL SOURCES
RIVERS , SPRINGS
20,000
PROJECTED PRODUCTION
IN CUBIC METRES / DAY
ULAR R.
BURA R.
100,000
LOEHOENA
T. MARIHAN
K. BANTAM
PERCUT R.
EXISTING
SIBOLANGIT
SPRINGS
DELI
RUMAH GULAH

TABLE D.6

LOWEST DAILY FLOWS FROM MONTHLY RECORDS
AND LOWEST MEASURED DISCHARGES OF ANNUAL RECORDS NEAR MEDAN

Station		Year							
		1972	1973	1974	1975	1976	1977	1978	1979
	Monthly								
Belawan River	O.R.	3.9 - 9.4	2.5 - 14.2	4.7 - 10.7	-	-	-	-	-
	Mean	6.1	6.6	6.2	-	-	-	-	-
Periodic Discharge (Asam Kumbang)*		4.5	5.2	6.5	4.0	4.0	1.7	4.5	3.1
	Monthly								
Deli River	O.R.	2.4 - 6.8	4.8 - 9.0	-	-	-	-	-	-
	Mean	6.0	6.3	-	-	-	-	-	-
Periodic Discharge (Simeme)*		5.7	5.7	5.0	3.8	4.0	2.6	4.8	3.8
	Monthly								
Belumai River	O.R.	5.8 - 12.7	5.9 - 19.6	6.3 - 13.9	4.8 - 9.9	5.3 - 9.3	-	-	-
	Mean	7.5	8.4	8.9	7.1	7.0	-	-	-
Periodic Discharge (Tanjung Morawa)		5.9	7.1	8.3	5.2	5.5	4.0	6.4	4.3

TABLE D.6--Continued

Station	Year							
	1972	1973	1974	1975	1976	1977	1978	1979
Monthly								
Ular River O.R.	27 - 52	35 - 54	39 - 51	34 - 47	36 - 60	37 - 48	-	-
Periodic Discharge (Pulau Tagor)	26.8	35.0	38.6	33.5	36	36.5	33.6	32.7

* Records from 1971-1977 were taken at locations about 200 m away from site for 1978 and 1877 recording.

The catchment yields for the one percent low flow would be about 885 cu m/sq km.d for the sub-basins of 240 sq km above Asam Kumbang gage and the Sunggal Plant. This includes general seepage from the surficial groundwater table, a flow of 8,600 cu m/d from the Tuntungan Springs, and runoff from minor rainfall (less than 20 cu m/sq km.d and 60 mm/month). Excluding the spring flow, the net average yield would be about 850 cu m/sq km.d.

D.2.2.2 Deli River

The Deli River has been monitored by the Institute for Hydrological Investigation (Bandung) and DPU (Medan) for nine years at Simeme, about 3.0 km above Deli Tua and about 13 km south of Medan city centre. The stream gage was located on the main channel of the Deli River and did not receive flows from the Babura River tributary branch. The gage location has been given as near the bridge across Deli River and downstream from the confluence of the Petani and Saimaimai branches. The reported catchment area for the gage was given as 133 sq km. Such a total reported catchment area would be less than the total area of the two branches measured on 1:250,000 scale maps: 133 sq km rather than 164 sq km. The flow measurements will remain the same, but the areal yield from the catchment would be 30 percent smaller than that of the smaller reported catchment (800 cu m/sq km.d rather than 1,000 cu m/sq km.d).

Flow measurements included three years of average daily flows and 67 instantaneous measurements periodically taken over seven years. Discharge recordings of 1971-1979 have been considered as unreliable because of unstable and highly variable stream cross-sections, and the gage location was relocated to more stable sections and a second station has been placed near the mouth of the Deli River and the Port of Belawan. These recordings represent the only available data for potential surface water sources on the Deli River. However, as indicated in similar discussions of the Belawan River gage, the unstable cross-section may have influenced accurate recording of high flows more than low flows. Similarities between the basinal yield of several river basins in northern North Sumatra support the use of these recordings for general water resources planning, although design of final plant production and facilities should be based upon more accurate and long-term monitoring of the Deli River near Deli Tua.

Periodic flow discharge measurements were analysed for low flow projections. As indicated in Table D.6, lowest measured annual discharges varied from 2.6 to 5.7 cu m (225,000 to 490,000 cu m/d, while the lowest averaged daily flows of each month for 1972 and 1973 varied from 2.4 to 9.0 cu m/s (210,000 to 780,000 cu m/d). Projected low flow of 175,000 and 215,000 cu m/d for the catchment above the Simeme gage are presented in Report Figure 6.5. One and five percent recurrent flows are similar to but less than those at the Belawan River gage. Projected one and five percent low flows are less than those recorded during the seven year period, and thereby the projections are consistent with available recordings.

Gross areal yields for the Deli gage catchment would be about 1,070 cu m/sq km.d for a one percent recurrence. The Sibolangit Springs have a total flow of about 76,000 cu m/d of which about 45,000 cu m/d is collected by Tirtanadi. The remaining 31,000 cu m/d flows into the upper Deli River and is included in the downstream flow near Deli Tua. Excluding the spring flow, the net yield from the 164 sq km catchment would be about 880 cu m/sq km.d. The yield rate is similar to those of the Belawan and Belumai catchments, which also have similar forms and elevational distributions.

D.2.2.3 Babura Branch - Deli

The Babura branch forms a major sub-basin of the Deli River which joins the Deli River in Medan. This tributary sub-basin has not been gaged for stream flows and therefore no accurate projections of water supply potential can be made. Visual inspection of the stream indicates that it may prove to be a modest source of water supply, and estimates of possible flows are made by extrapolations from adjoining basins. Such estimates cannot be taken as adequate for design studies and must be verified or modified based upon accurate gaging of flows in similar locations.

Estimated low flows for the Deli and Belawan gages were 175,000 to 215,000 cu m/d with an estimated net yield from their catchments of between 800 and 900 cu m/sq km.d. As indicated in Table D.7, a conservative yield of 700 cu m/sq km.d would produce a flow of 75,000 cu m/d or less once in 100 years (one-percent recurrence) and about 130,000 cu m/d in five years out of every 100 years at the confluence of the Babura and main Deli River. Other sub-basins and reaches of the main Deli River are expected to have smaller yields and would add little to the overall low flow of the Deli River. The estimated flows of the Babura indicate that it is the only important water source downstream of Deli Tua, although it should be considered as a supplemental source rather than an independent source.

D.2.2.4 Percut River

Flows of the Percut River have not been measured and only general estimates can be made from the calculated flows and yields from the nearby Belawan, Deli, and Belumai basins. The basinal yields vary from a low of about 700 to a high of 1,000 cu m/sq km.d. As indicated in Table D.7, the long, north-south basin is divided into two groups with different yield rates: 700 cu m/sq km.d for the lower sub-basins and 1,000 cu m/sq km.d. The yields from the Ular, Binjei, and Wampu are higher than 1,000 cu m/sq km.d, while those of the Deli, Belawan, and Belumai are less than 1,000 cu m/sq km.d after excluding known springs. No significant spring has been recorded from the Percut River basin.

The Total basinal flow for the Percut River would be 181,000 cu m/d for a one-percent recurrent flow and about 265,000 cu m/d for a five-percent recurrent flow (assuming the same ratio as in the Deli flows: 1.47). Sub-basins of the Percut River above Deli Tua - have an area of about 173 sq km and would produce about 150,000 cu m/d and 220,000 cu m/d at one and five percent recurrent flows, respectively.

TABLE D.7

ESTIMATED LOW FLOWS AND YIELDS FOR THE DELI AND PERCUT BASINS

	Area (sq km)	Estimated 1% Areal Yield Rate (cu m/sq km.d)	Sub Basinal 1% Low Flow (x 1,000 cu m/d)	Accumulative Basinal Low Flow (x 1,000 cu m/d)
DELI				
Petani	113	1110	149	149
Saimaimai	31	805	26	175
Deli Tua-Medan	19	700	13	188
Batuan	24	700	17	205
Babura	106	700	75	280
Sikambing	36	500	18	298
Medan-Belawan	45	500	23	321
Total	394	905 (Averaged)	317	321
PERCUT				
F	37	1,000	37,000	37,000
E	24	1,000	24,000	61,000
D	17	1,000	17,000	78,000
C	25	1,000	25,000	103,000
B	21	700	15,000	118,000
A2	49	700	34,000	152,000
A1	41	700	29,000	181,000
Total	214	850 (Averaged)	181,000	181,000

Units of the Deli and Percut basins are sub-basins and major segments of the main channel of the Deli and Percut rivers from the basin divide down to the Straits of Malaca. No standard terms are available for the Percut sub-basins and they are given letter designations. These sub-basins are also discussed in Report Section 3.

D.2.2.5 Western Region - Binjei River

The Binjei River is the eastern most tributary or sub-basin of the Wampu River on the north side of the Barisan Range, and its upper sub-basins are adjacent to the Belawan and Deli sub-basins. The Diski basin separates the middle and lower sub-basins of the Binjei and Belawan rivers. Stream flows on two branches of the upper Binjei River were monitored in 1977, 1978, and 1979 at Namu Ukur and Namu Sira Sira, 30 km upstream of Binjei (Figure D.1). The recorded low discharges at Namu Ukur range from 10.2-14.3 cu m/s (880,000 to 1.2 million cu m/d), while the projected one percent low flow would be about 6.5 cu m/s (562,000 cu m/d) and the five percent low flow would be about 8.0 cu m/s (690,000 cu m/d) (See Figure D.2 and Table D.8). Low flow of Namu Ukur catchment would require yields of 2,130 to 2,610 cu m/sq km.d, respectively. Such high yields are more than twice those of the Wampu, Belawan, Deli, and Belumai rivers but are similar to those of the Ular River. Extra polation of the yield of 2,100 cu m/sq km.d over the entire Binjei basin above Binjei would indicate a one percent low flow of about 817,000 cu m/d at Binjei.

D.2.2.6 Western Region - Wampu River

The largest and longest river in northern North Sumatra is the Wampu River which lies about 30 km west of Medan. The river begins on the west side of the Barisan Range, passes through the range, and flows north between Binjei and Tanjung Pura, where it flows into the Straits of Malaca (See Figure D.1). The river has been gaged at Stabat about 25 km northwest of Binjei. As indicated in Table D.8 and Figure D.2, the Wampur River has had very large low flows of 70 to 100 cu m/s, or daily flows of six to nine million cubic metres. This is more than 10 times the projected low flows of the Deli and Belawan rivers. Projected low flows of Wampu River would be about 50 cu m/s or 4.3 million cu m/d for one percent recurrent flows and about 6.2 million cu m/d for five percent recurrent flows.

The reported area of the gage catchment is 1.620 sq km, although measured areas from maps of 1:250,000 scale indicates a total catchment of about 4,000 sq km. The basinal yield for one percent recurrent flow from the smaller basin would be about 2,700 cu m/sq km.d, twice that of the Deli and four times that of the Belawan. Using the larger basinal area, the yield falls to about 1,100 cu m/sq km.d. More than 20 springs lie within the upper Wampu basin but contribute less than 125,000 cu m/d to the river flow (less than five percent of the estimated low flows). A net yield with the larger basin would be about 1,030 cu m/sq km.d.

FREQUENCY - DISCHARGE FOR LOW FLOWS ON NORTH SUMATRA RIVERS

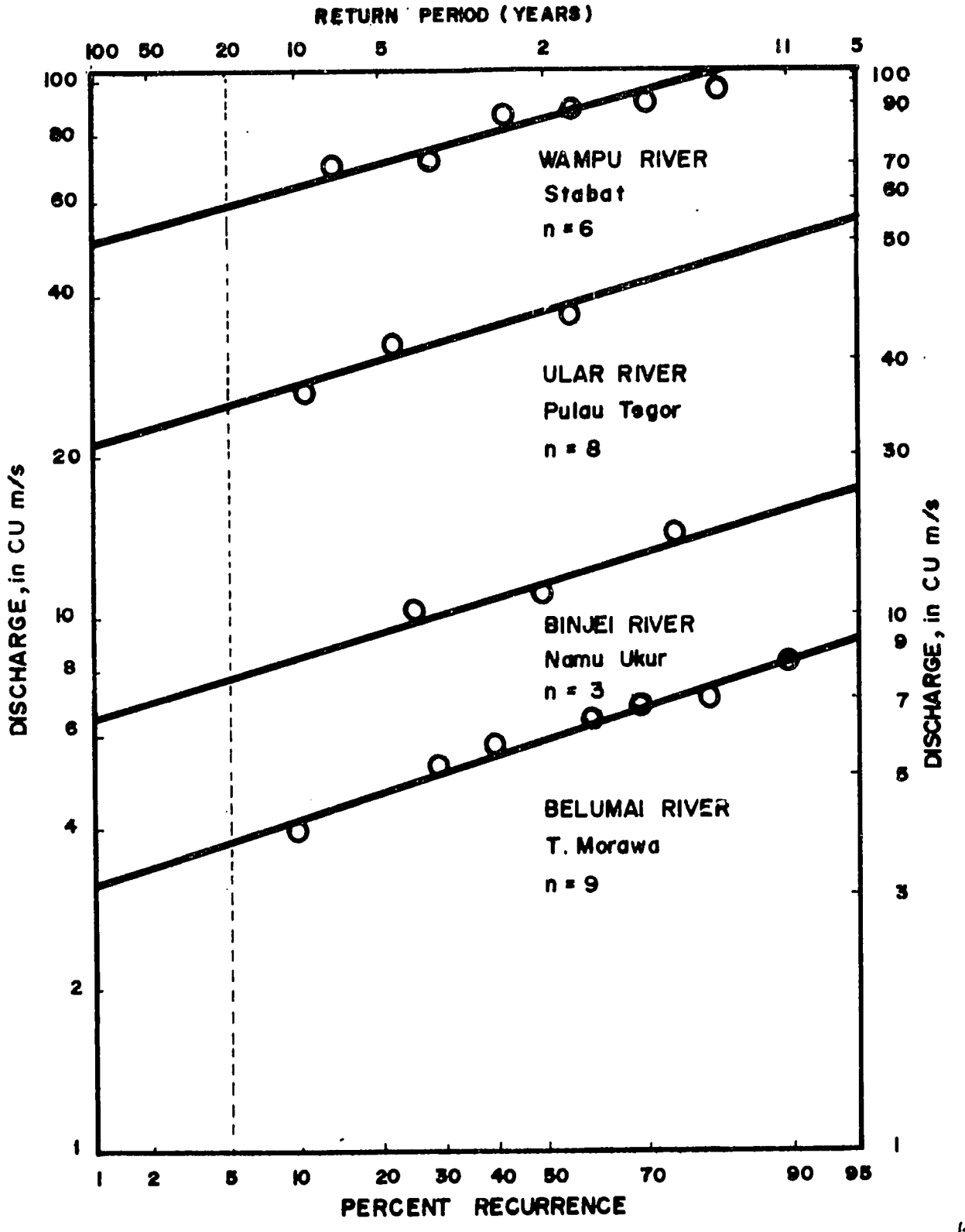


TABLE D.8

LOW FLOWS RECORDED IN NORTH SUMATRAN RIVERS

WESTERN REGION

Binjei River: Gage-Namu Ukur, Catchment Area - 264 sq km

Lowest Recorded Flows - 1977, 14.3 cu m/s
1978, 10.2 cu m/s
1979, 11.3 cu m/s

Projected One Percent Low Flow: 6.5 cu m/s; 562,000 cu m/d

Projected One Percent Yield Rate: 2,130 cu m/sq km.d

Wampu River: Gage-Stabat, Catchment Area - 1,621 sq km (actual 4005 sq km)

Lowest Recorded Flows - 1973, 95 cu m/s
1974, 100 cu m/s
1975, 90 cu m/s
1976, 87 cu m/s
1977, 72 cu m/s
1978, 70 cu m/s

Projected One Percent Low Flow : 50 cu m/s; 4.3 million cu m/d

Projected One Percent Yield Rate*: 2,665 cu m/sq km.d (1080 cu m/sq km.d)

EASTERN REGION

Belumai River: Gage-Tanjung Morawa, Catchment Area - 250 km

Lowest Recorded Flows - 1971, 5.8 cu m/s
1972, 6.9 cu m/s
1973, 7.1 cu m/s
1974, 8.3 cu m/s
1975, 5.2 cu m/s
1976, 5.5 cu m/s
1977, 4.0 cu m/s
1978, 6.4 cu m/s
1979, 4.3 cu m/s

Projected One Percent Low Flows: 3.2 cu m/s; 276,000 cu m/d

Projected One Percent Yield Rate: 1,100 cu m/sq km.d

* All projected yield rate are gross and include flows from springs

TABLE D.8--Continued

Ular River:	Gage-Pulau Tagor, Catchment Area - 1,031 sq km	
	Lowest Recorded Flows -	1972, 26.8 cu m/s
		1973, 35.0 cu m/s
		1974, 38.6 cu m/s
		1975, 33.5 cu m/s
		1976, 36.0 cu m/s
		1977, 36.5 cu m/s
		1978, 33.6 cu m/s
		1979, 32.7 cu m/s
	Projected One Percent Low Flow:	2.3 cu m/s; 2.0 million cu m/d
	Projected One Percent Yield Rate:	1,930 cu m/sq km.d

D.2.2.7 Eastern Region - Belumai River

Flows in the Belumai River have been measured during 1971 to 1979 near Tanjung Morawa at the Morawa-Medan Road Bridge. The lowest recorded flows of periodical discharges for 1971 to 1979 varied from 4.8-6.3 cu m/s (415-544,000 cu m/d; Table D.8, Figure D.2). The projected one percent recurrence would have a flow of about 3.2 cu m/s or 276,000 cu m/d (about 320,000 cu m/d for a five percent flow) or about 50 percent greater than those flows projected at the Deli and Belawan rivers gages.

The catchment area for the Belumai gage (250 sq km) is only slightly greater than that of the Belawan gage and about twice that of the Deli gage, the gross yield of the middle and upper sub-basins of the Belumai River is about 1,100 cu m/sq km.d and is similar to or higher than the net yields of the Petani-Deli sub-basin and the Belawan catchment above the Sunggal Water Plant. The springs at Tanjung Marihan and Kampung Bantan have combined flows of about 24,000 cu m/d or about 13 percent of the projected one percent flow at Morawa. Excluding this spring flow, the net yield rate would be about 660 cu m/sq km.d, 10 percent less than those for the catchment of the Deli and Belawan river gages.

D.2.2.8 Eastern Region-Ular River

Flows have been measured for more than five years in the Ular River at Pulau Tagor, about 25 km east of Medan and 18 km east of Morawa. This gage has a catchment of about 1,000 sq km about five times greater than those of the Belawan, Deli, Binjei, and Belumai gages and one-quarter of that of the Wampu gage (Table D.8 , Figure D.1). The lowest recorded discharge in six years was about 2.3 million cu m/d, about 5 to 10 times those of the Belumai gages but one-third of the low flows at the Wampu

gages. Projected flows at one and five percent recurrence intervals (Figure D.2) would be about 2.0 and 2.25 million cu m/d, respectively. The yield rates for the catchment are about 1,900 and 2,200 cu m/sq km/d for one and five percent recurrent events. The one percent yield rate is quite similar to the gross rate above the Binjei gage and two to three times greater than the net rate above Belawan, Deli, Wampu, and Belumai gages. Some springs may contribute to the higher yields for the Ular catchment above Pulau Tagor.

D.3 POTENTIAL SUPPLY SYSTEMS

Within 30 km of Medan, seven major rivers can supply Medan with water. Analyses of the available flow measurements indicate that these rivers in various combinations or even as separate sources can supply the projected average daily demand of 420,000 cu m/d in the year 2000 (maximum day demand: 480,000 cu m/d). Using the estimated flows of the various rivers, topographic data, and structure of the basins, potential treatment plant sites and development strategies have been formed. These strategies also reflect the poor data base for planning.

Surface water development strategies are divided into local and regional systems, although regional strategies could supplement or dominate the development of local sources. Both regional and local strategies depend upon single new treatment plants with some later diversions and inter-basinal transfers. Development of each plant would coordinate increases of plant capacity with a thorough and rigorous monitoring program. As local basin flows constrain further plant development, previous monitoring of adjacent, supplemental basins will have been conducted over the longest period of time. Since direct withdrawals will be used first, longer term monitoring will also allow rigorous evaluation of surface reservoirs.

All surface water development has assumed similar water quality in the raw water taken from the river above urban centres. No treatment plant has been considered below an urban centre, because of the assumed drainage of highly polluted water from Medan, Deli Tua, Binjei, and Tanjung Morawa. Such pollutants would cause even more severe degradation of raw water during the low flow conditions in the rivers.

D.3.1 Belawan River

The Sunggal Water Plant was assumed to be the only possible surface water source on the Belawan River. The only other potential site would be at Lalang on the Binjei Road, about 3.0 km downstream of the existing plant. The Lalang site receives flow from an additional 30 sq km and would add about 21,000 cu m/d to the projected low flow of 215,000 cu m/d at the Sunggal Plant. This more northerly site would receive more drainage from the urban corridor along the Binjei Road and intensive irrigation projects (e.g. Medan Kreo) between the Sunggal Plant and the Lalang site.

The planned Sunggal production of 130,000 will require about 60 percent of the projected one percent recurrent low flows. The other local rivers, Babura, Deli, and Percut cannot provide significant

interbasinal transfers to increase the low flows and reduce the percentage of raw water/low flow intake at the Sunggal Plant. In general, most of the Deli and Percut sub-basins lie below the closest points on the Belawan River. High ridges separate the uppermost Belawan basin from the Sibolangit reaches of the Deli River and could not be penetrated or spanned in any reasonable manner.

Available topographical maps are insufficient to locate potential surface reservoir sites. Some general considerations indicate that relatively small reservoirs could be a practical means to increase the production of the Sunggal Plant or reduce the percentage of low flows taken from the river by the plant. Potential sites (Figure D.3) may be located along the main channel of the Belawan River about 20 km above the Sunggal Plant but downstream of the Klumat or Tembengan branches.

As indicated in the discussions of regional strategies, the upper sub-basins of the Binjei River could be diverted from the Mencirim branch (Binjei) and the main Binjei River into the Tuntungan branch of the Belawan River. Estimates of yields of 1,800 cu m/sq km.d could allow 100,000 to 200,000 cu m/d production to be transferred from the Binjei sub-basins to the Belawan River. More detailed topographical maps and aerial photos must be made in order to accurately locate, evaluate, and compare reservoirs or gravity flow inter-basinal transfers. While the need for such supplements to the planned production capacity of the Sunggal Plant depend upon evaluation of long-term monitoring of river flows at the Sunggal Plant.

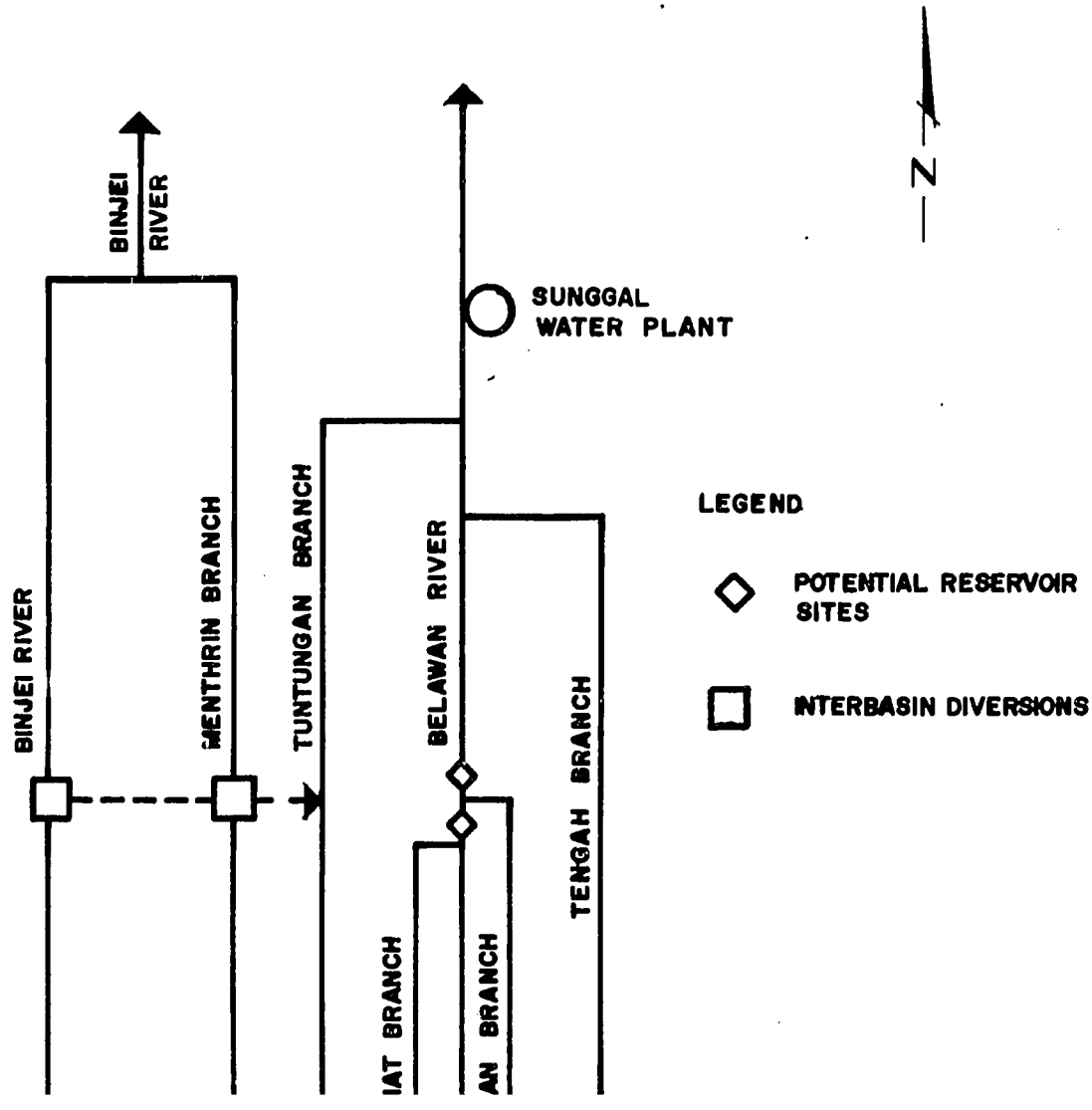
D.3.2 Deli and Percut Rivers

Cost of two separate water plants on the Deli and Percut rivers may be higher than a single plant with inter-basinal transfers. A single plant has been assumed to be located above the confluence on the Babura and Deli River and below the confluence of the Petani and Saimaimai branches. Raw water intakes would be located on the Babura and Percut rivers, and pump stations, pipelines, and canals could transfer water to the Deli sub-basins or directly to the treatment plant on the Deli River. An integrated system between the Deli and the Percut sub-basins allows the greatest flexibility in the use of these water sources in the light of the poor data on the Deli River and the absence of direct data on the Babura and the Percut rivers. As monitoring continues, the diversion of adjacent basins could be advanced or delayed depending upon monitoring results. Because of the physical capability of even more distance transfers, any planned plant production up to 400,000 cu m/d may be met but at higher costs. In addition to interbasinal transfers, storage reservoirs may be able to store and supplement low flows both in the Deli and Percut sub-basins and further expand the Deli Tua Plant production.

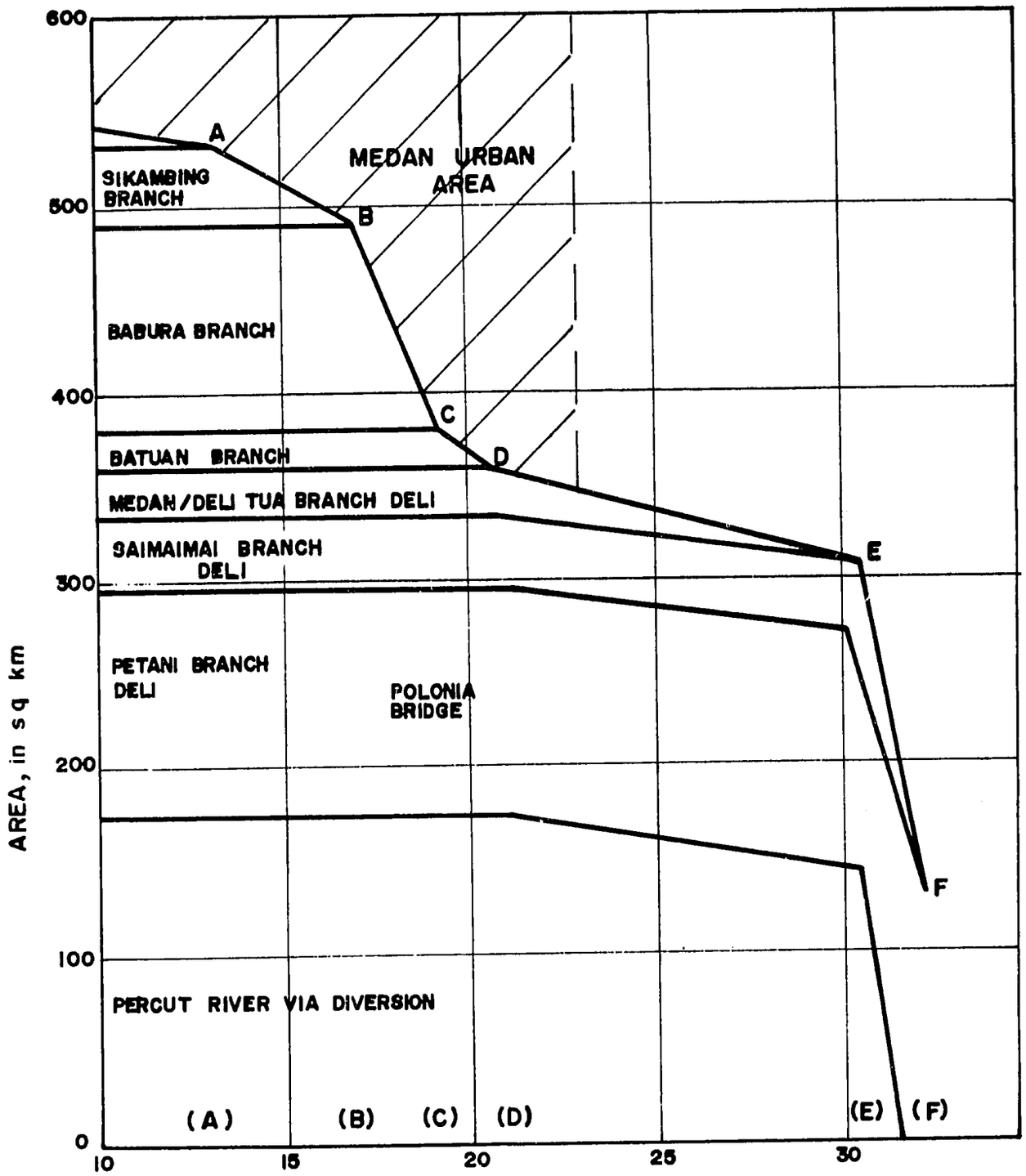
Figure D.4 and Table D.9 indicate the potential catchment areas and estimated flows for various plant sites along the Deli River; the graph clearly shows the importance of the Babura River branch to the total catchment and flows for a water plant on the Deli River. The urban area of southern Medan will expand in the lower portion of the Babura and Batuan sub-basins, and urban drainage will degrade the raw water quality for any treatment plant. In addition, the expanding and intensifying

FIGURE D.3

SCHEMATIC DIAGRAM OF THE BELAWAN BASIN FACILITIES AND POTENTIAL RESERVOIRS AND INTER BASINAL DIVERSIONS



COMPARISON OF POTENTIAL SOURCES ON THE DELI AND PERCUT RIVERS AND THEIR CATCHMENT



DISTANCE (Km) AND SITE LOCATIONS FROM BELAWAN DELI BRIDGE

A - F : PLANT SITE LOCATIONS IN FIGURE D.9 AND TABLE D.7

TABLE D.9

COMPARISONS OF POTENTIAL SOURCE
LOCATIONS ON THE DELI RIVER AND PERCUT RIVER

Location and Distance from Belawan (site)	(km)	Deli Basin Area (sq m)	Percut Basin Area (sq m)	Total Source Area (sq m)	Total Projected One Percent Low Flows (x 1,000 cu m/d)
0	0	397	173[e]	567	317 + 152 = 469
A	13.0	349	173[e]	522	294 + 152 = 446
B	17.0[a]	313	173[e]	486	276 + 152 = 428
C	19.3[b]	307	173[e]	380	202 + 152 = 354
D	20.7	183	173	356	185 + 152 = 337
E	30.5[c]	164	148	337	170 + 135 = 305
F	31.5[d]	133	0[e]	133	147 + 0 = 147

a. B is the confluence of the Babura and Deli River.
b. C is the Polonia-Suprapto St. Bridge on the Deli River.
c. E is the confluence of the Petani and Saimaimai branches.
d. F is the Petani branch above the confluence.
e. The Percut River could not be practically diverted to the Petani branch or to Deli below D (Deli Tua - Titi Kuning).

urban uses in the Babura and Titi Kuning - Deli Tua areas will also restrict or eliminate potential plant sites along the Babura or Deli rivers. Because of the relatively minor flows for sub-basins in and below the Medan urban area, the potential hazards of urban pollutants during low flows, and the restrictions on available plant sites, several sites near Deli Tua in river segment "D" and "E" were finally considered as feasible, and the flows and their productions at these sites are presented in Table D.10.

Several representative sites, D1-D4 and E (Figure D.5, D.6), were chosen to demonstrate differences in flows, production, and the diversion and transmission pipelines. Using a preliminary estimate of 50 percent of the one percent flows, tentative production targets varied from 169,000 up to 209,000 cu m/d for a plant on the Deli River (Table D.9). As indicated before, concerns over pollutants in urban runoff from Titi Kuning (south Medan) and Deli Tua restricted potential sites to D3, D4, and E (Figure D.5 and D.6). In order to improve the production from these sites, the Babura flows would be collected from near the confluence of the Babura branches and then pumped up tp the Deli Tua plant site. Production would also be increased to about 60 percent of the one percent low flows or to about 50 percent of a two to three percent low flow recurrence.

SCHEMATIC DIAGRAM OF POTENTIAL DIVERSIONS AND PLANT SITES WITH THE DELI AND PERCUT BASINS

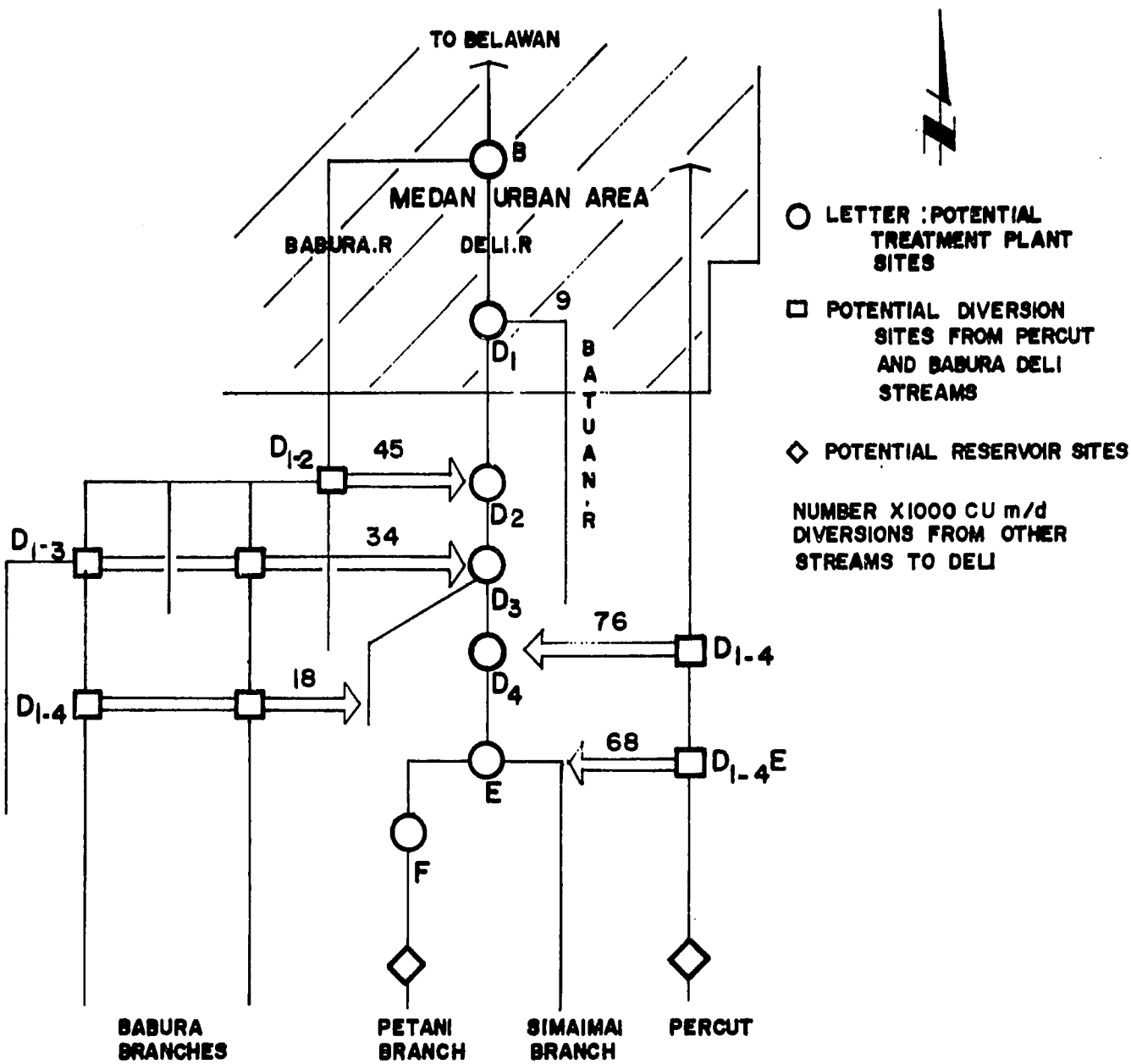


TABLE D.10

PROJECTED STREAM FLOWS AND PRODUCTION LEVELS

	Stream Flows and Production (x 1,000 cu m/d)				
Basin	Site D1	Site D2	Site D3	Site D4	Site E
Babura	64(32)*	64(32)	56(28)	36(18)	30(15)
Deli	202(101)	185(93)	182(91)	178(89)	172(86)
Percut	152(76)	152(76)	152(76)	152(76)	135(68)

* ( ) - Production given as 50 percent of the one percent recurrent flows, e.g. 64 x 0.50 = (32).

Figure D.6 provides a more detailed layout and organization of the D and E sites along the Deli River and the diversions to the Deli. All sites could receive water diverted from the Percut and Belumai rivers on the east. The more southerly sites, D3, D4, and E would normally receive decreasing quantities of water diverted from the Babura sub-basins. This general trend, however, would be reversed by pumping water collected at the main confluence of the Babura sub-basins, X, either directly to D2 or by a longer pipeline to D3, D4, and E (Table D.11). Conversely, Deli and Percut raw water could be collected at the sites of D3, D4, and E and then conveyed to sites D1 and D2 by pipelines in order to maintain higher raw water quality. The differences of these alternative routings of Babura and Deli-Percut raw waters can only be clarified by thorough analyses of slopes, elevations, and soil conditions which exceeds the resolution of the available data.

The phasing of plant construction of the Deli Tua Plant would generally reflect the three basic elements of this treatment system: Deli, Percut, and Babura elements. The first phase would concentrate on raw water from the Deli River. As the low flow capacity of the Deli River was approached, a decision would be made to construct either the Babura diversion or the Percut diversion and this would begin the second phase. The third phase would involve the construction and operation of the second remaining diversion. Each phase would extract about 60 percent of the one percent recurrent low flow or about 50 percent of the two percent recurrent low flows. The overall planned system capacity would be 250,000 cu m/d. The phasing within each of the three elements would be based on production increments of about 25,000 cu m/d (0.3 cu m/s). The Deli Plant would have six annual phases with three using raw water from the Deli River, four increments using water from the Percut River, and two increments using water from the Babura River. Each unit would be equivalent to about one years growth of water demand in Medan.

In summary, a relatively conservation estimate of low-flow safe yields in the Deli, Percut, and Babura rivers could support a treatment plant of 250,000 cu m/d at a site along the Deli River. Numerous potential

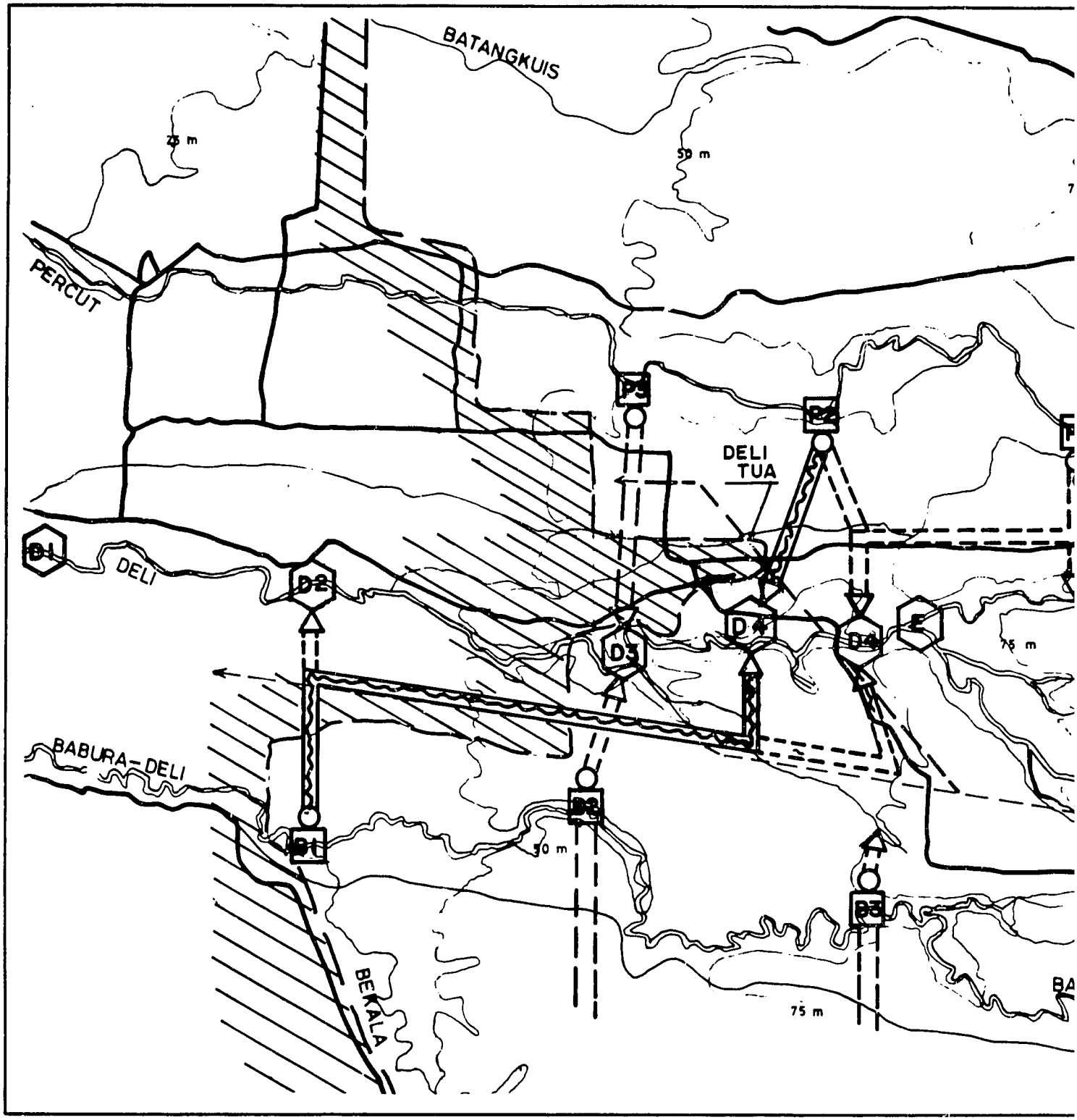


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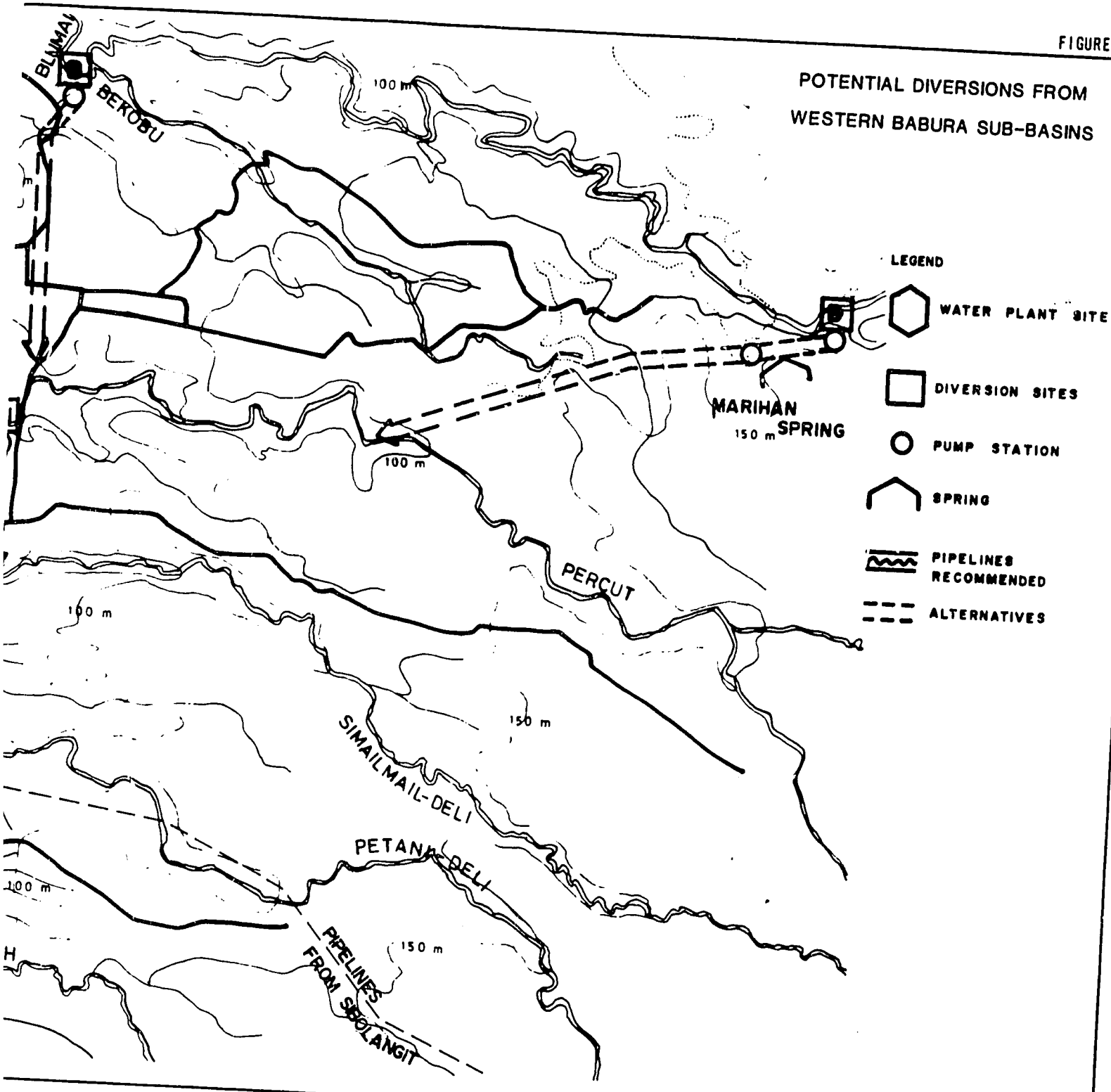
FIGURE

POTENTIAL DIVERSIONS FROM WESTERN BABURA SUB-BASINS



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sites exist between the Simeme Bridge above Deli Tua and the Johor Bridge in Titi Kuning. Site selection would involve a thorough comparison of the costs for site acquisition and development, of capital costs for pipelines and pump stations and of the costs and reliability of large volume pumping either of the raw water or the treated water. As an alternative to diversions and pumping through pipelines, a modest-sized water supply reservoir could be located in the upper Deli River sub-basins and could augment the low flows of the Deli River to the same extent as the diversions or could increase the potential plant capacity by about 50 percent (e.g. from 250,000 up to 370,000 cu m/d).

TABLE D.11

COMPARISON OF DELI TUA WATER PLANT SITES, FLOWS, PRODUCTION, AND PIPELINE OR CANAL TRANSMISSION SYSTEMS

Site	Elevation (m)	Distance above Polonia Bridge (km)	Production [a] (x 1,000 cu m/d)	Pipeline and Canal Length (km)			
				Babura [b]	Percut	Medan	Total
D1	25	2.0	289(250)	3.0	2.5	0	5.5
D2	35	5.5	201(250)	3.0	2.5	2.5	8.0
D3	50	7.5	195(250)	6.0(8.0)[b]	5.0	5.5	16.5(19)
D4	60	8.8	183(250)	4.0(9.0)[b]	4.0(9.0)	6.8	14.8(25)
E	80	11.3	169	4.0	2.5	8.0	14.5

a. Production target include both the 50 percent of one percent recurrent flows and a proposed plant production of 250,000 cu m/d.
b. Pipeline lengths in ( ) indicate longer distance transmission from same diversion site as in D2.

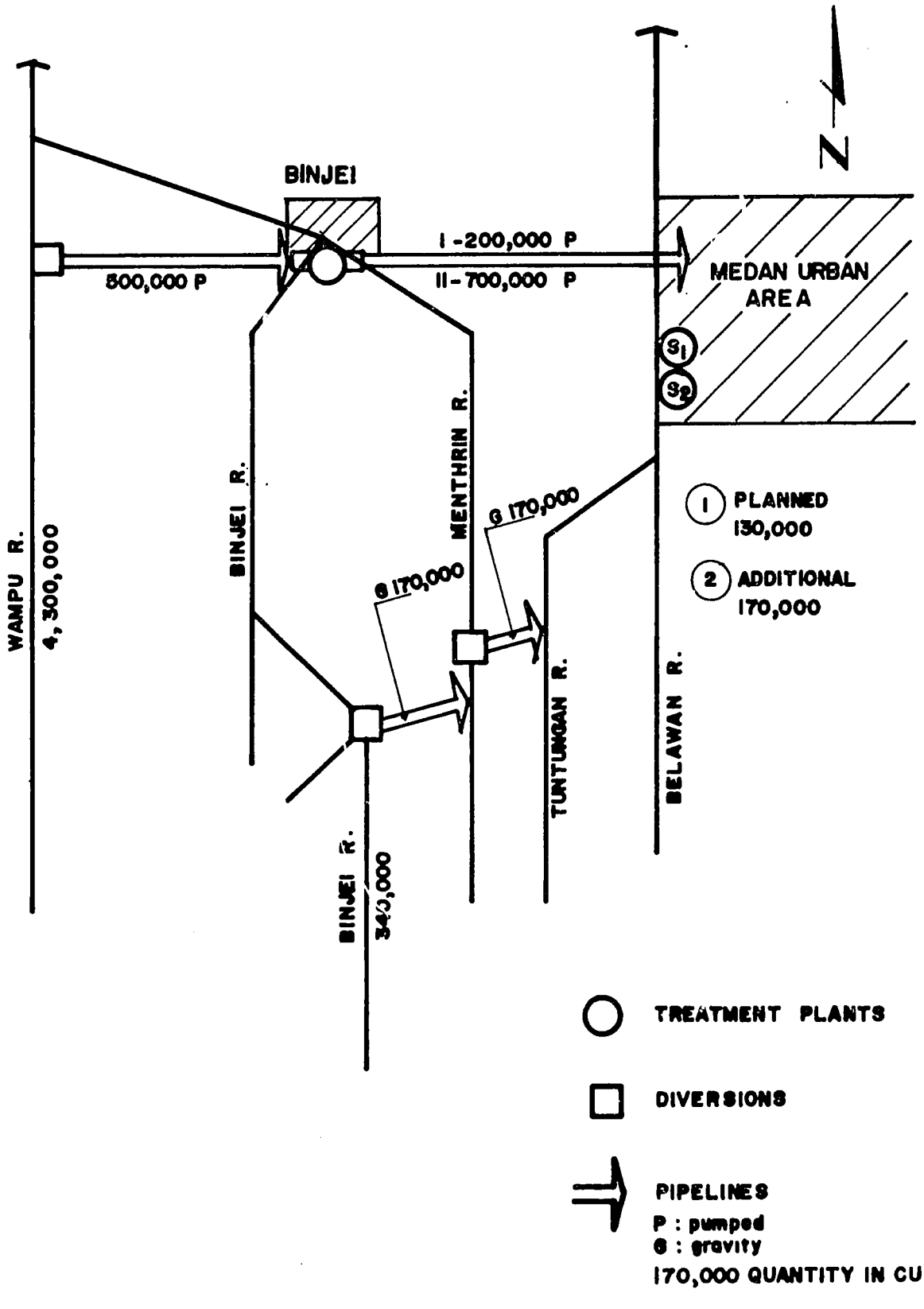
D.3.3 Western Basins - Binjei Water Plant

The western basins include the Binjei River and the main channel of the Wampu Rivver. The Binjei River is the major eastern tributary of the Wampu River and its upper sub-basins lie next to the Belawán Basin. The two main sub-basins of the Binjei River: the eastern Mencirim River and the western, main channel of the Binjei River. These sub-basins join in the town of Binjei. The estimated one percent recurrent flows for the two basins is 700,000 cu m/d. Such flows could provide about 350,000 cu m/d using only 50 percent of the combined flows if a plant was located only on the main channel of the Binjei River.

A single treatment plant could be located on the Binjei River (Figure D.7). This plant could collect raw water from Binjei River or from both rivers. Raw water intakes would be located above the urban area in order to reduce pollutants from urban runoff.

FIGURE D.7

SCHEMATIC DIAGRAM OF DIVERSION PIPELINES AND TREATMENT FACILITIES IN THE WESTERN RIVERS



The Binjei Plant would require a 13 km transmission pipeline and pump station (200,000 cu m/d, capacity) in order to reach the western edge of the Medan network system. The pipeline could connect with the Medan system in Lalang on the Binjei Road or in Sunggal at the water plant.

D.3.4 Western Basins - Binjei River Diversion

Diversions of flows from the upper basins of the Binjei River would involve using raw water transmission systems to the west branch to the Mencirim branch of the Binjei River and from the Mencirim branch of Binjei to the Tuntungan branch of the Belawan River (Figure D.1 and D.7). Such transfers would require about 8.0 km of gravity pipelines up to the Belawan Basin. Once in the Belawan Basin, the transfer would add 70,000 cu m/d to 200,000 cu m/d the low flow capacity of the Belawan River at the Sunggal Plant. This addition would be available for the plant and would increase plant production from about 130,000 cu m/d (1.5 cu m/s) up to about 300,000 cu m/d (3.5 cu m/s).

D.3.5 Western Basins - Wampu River

The Wampu River is the largest surface water in northern North Sumatra and even 15 percent of the one percent low flow (4.3 million cu m/d) could supply more than the total year 2000 demand for Medan. However, this source lies 26 km from the edge of the Medan network, and transmission of the large volume is very costly. In order to maintain a reasonable unit cost for this alternative system, the production must be very high. Production of less than 200,000 cu m/d from the regional basins can be more effectively provide by the Morawa plant alternative on the Belumai or the Binjei plant on the Binjei River.

A raw water intake could be located on the east (right) bank of the Wampu River near the town of Selesei. Because of the isolated location, raw water would be pumped by diesel-driven pumps. The raw water would be conveyed to the Binjei Water Plant along 13 km long pipelines and it would be treated in incremental expansion of the Binjei Plant. From the Binjei Plant the treated Wampu water would be pumped through additional 13 km long pipelines to the edge of the Medan network. Water user in Binjei and along the treated water pipeline corridor, the Medan-Binjei corridor, could also be supplied by this system.

Water quality of the Wampu Riveris expected to be similar to that of the Belawan and the treatment processes and effectiveness would be similar to those at the Sunggal Plant. The quality of the Wampu raw water reaching the Binjei Plant could be improved by pumping from settling basins along the Wampur or from horizontal collector wells located along the river bank. Such systems may reduce the expansion requirements for the Binjei Plant.

D.3.6 Eastern Basins - Belumai River

The Belumai and Ular basins have been assessed as possible sources for Medan. Yields and production from the Belumai basin would only supplement Medan's local sources and would require a new treatment plant near

Tanjung Morawa or a diversion from the Belumai into the Percut and then to the Deli-Percut treatment plant. The Ular River could provide the total of the Deli-Percut Plant.

Belumai River flows have been measured at Tanjung Morawa and have varied from 346,000 to 13.8 million cu m/d. An estimated on percent low flow would be about 276,000 cu m/d, while a five percent flow would be 320,000 cu m/d.

Figure D.1, D.2 and Figure D.8 show locations and the estimated low flow yields along the Belumai River at and above Tanjung Morawa. Diversions or separate treatment facilities at Tanjung Morawa would produce about 30,000 cu m/d (using 50 percent of one percent flow) more than a site above 100 m elevation would produce but the Morawa site would require extra pumping via a 7.5 km transmission system into Medan. More remote plant sites also may have smaller land costs, but they would have higher power, transportation, and housing costs, compared to a site very close to the urban area. The alternative Tanjung Morawa Plant has a planned capacity of 200,000 cu m/d, so as to be comparable to the other alternatives. Such production would require withdrawing 70 percent of the total one percent low flows or about 60 percent of the five percent flow.

Projections of urban growth and water demand has indicated some urban expansion in southeastern Medan and along the Siantar-Morawa Road. Production of treated water at Tanjung Morawa would have little service value, until it reaches the expanding Medan urban area. Therefore, a treatment plant at Tanjung Morawa would have no operational value over expansion of the Deli-Percut plant. Diversions of the Belumai River and collection of springs at Tanjung Marihan may allow gravity flow of about 100,000 cu m/d through pipelines/canals directly to the Deli-Percut plant or indirectly into the Percut River for withdrawal at the diversion.

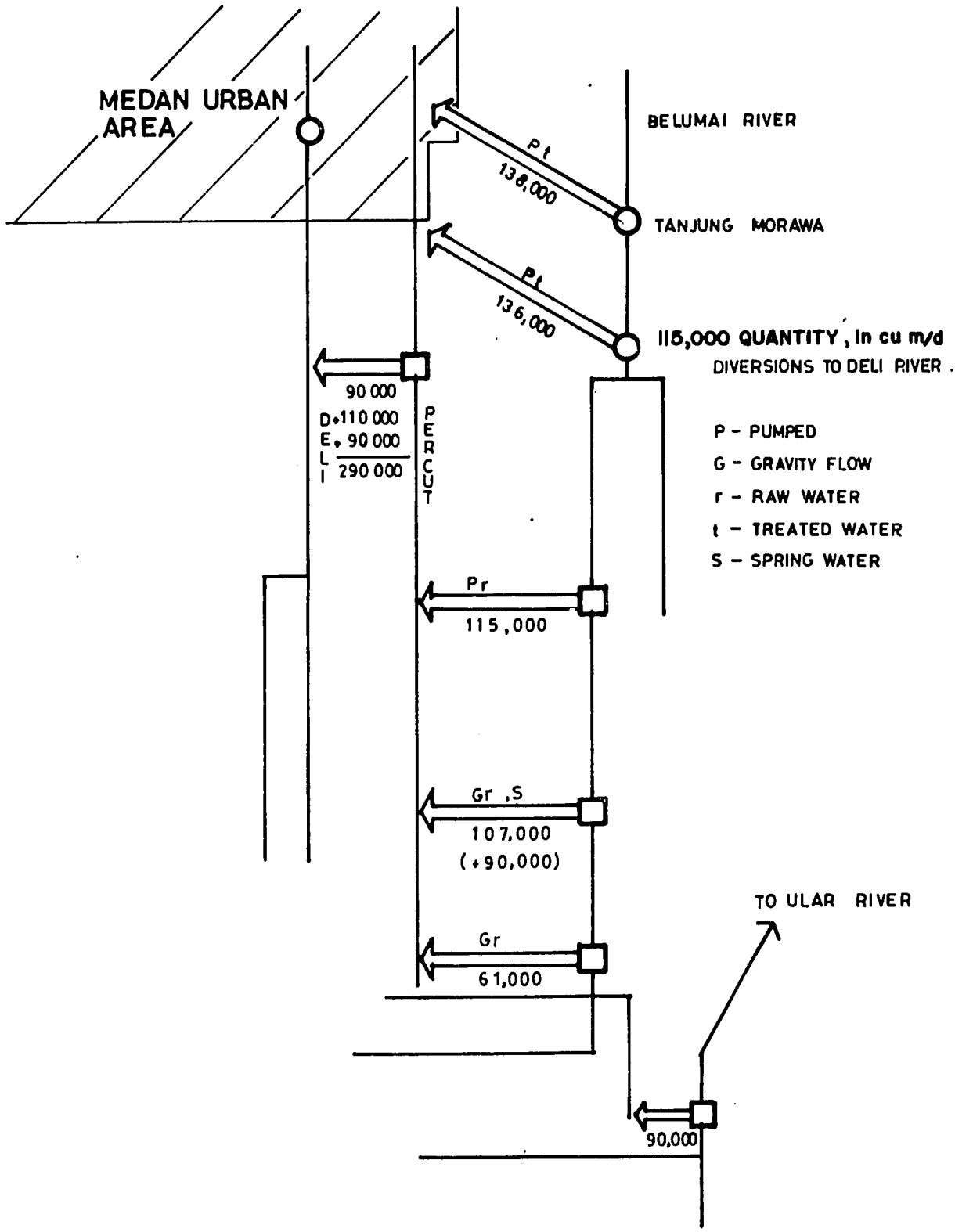
Water quality of the Belumai is expected to be similar to that of the Percut, Deli, or Belawan rivers and would require identical clarification and filtration treatment. Spring water from Tanjung Marihan/ Kampung Bantan is expected to be similar to that of Sibolangit and will require little or no treatment, other than disinfection and aeration.

Other beneficial uses of the Belumai River involve extraction at Tanjung Morawa and small historic allocations for irrigation and domestic use. The 40 to 50 percent production from the low flow capacity has been assumed to provide adequate supply for other users. Substantial use of the Marihan and Bantan springs would require negotiation with local users in order to ensure reasonable allocation.

D.3.7 Eastern Basins - Ular River

As in the Belumai River basin, a separate diversion to the Tanjung Morawa Plant or indirectly to the Deli-Percut system could be developed on the Ular River (Figure D.1). The one percent low flow is more than 2.0 million cu m/d at Pulau Tagor. The total demand to 2000 and beyond could be drawn from the Ular River between Sennan and Baungar. A raw water intake would be on the west bank (left) of Ular River and would

SCHEMATIC DIAGRAM OF POTENTIAL DIVERSION AND PLANT SITS BETWEEN THE DELI-PERCUT BASIN AND THE BELUMAI AND UPPER ULAR BASINS



have to have large diameter, pumped pipelines between the Ular and Medan. This pipeline system would be about 26 km long depending on the connection with the Medan distribution system (17.5 km to Morawa and 7.5 km to Medan). The high cost for such a pipeline and operation would require a very large production from the river (at least 500,000 cu m/d) for favorable costs and virtual dependence upon this source for all new supply between 1985 and 2000 and beyond. Surface water quality would be similar to those of local sources, and raw water would be treated with similar methods.

The Ular River source would provide an eastern supply for Medan and balance the eastern and western demands/supply. Since the Ular source would be implemented between 1985 and 1995, the eastern distribution system would have to be greatly expanded with both secondary transmission and local distribution pipelines in order to adequately use the Ular production. In order to spread the Ular water after 1990, cross-city transmission pipelines would add 10-15 km to the effective length of the Ular transmission system and add indirect distribution costs to the Ular sources. Withdrawal of the Ular raw water and pumping could be phased for best cost relationships, but little or no phasing could be made for the long, large pipelines. This eliminates much of the flexibility and adaptability of this alternative source.

Diversion of flow from the upper Ular River (Figure D.1) would depend on a gravity and low pressure pumped flow through pipelines/canals in the upper basin. The shortest diversion of 3.0 km would be located across the divide of the Loehoena and Belumai basins. Such diversion could supplement the Deli-Percut or Belumai sources with 85,000 to 100,000 cu m/d (1.0 to 1.2 cu m/s). The water quality in the upper Ular basin may be better than that below 100 m elevation, but the surface water treatment at the Deli Tua Plant would be identical with other surface water sources.

APPENDIX E

GROUNDWATER

Appendix E-1 Groundwater Resources

Appendix E-2 Recommended Drilling Program

APPENDIX E-1

GROUNDWATER RESOURCES

E-1.1 INTRODUCTION

E-1.1.1 Past Experience

Deep water wells were first drilled in the 1880s and 1890s and provided water supplies to the coastal areas of Labuhan and Belawan. Shallow wells provided much of the water supply in the central Medan area, while the poor water quality of the shallow groundwater table in the coastal area required deep wells in order to provide usable water supplies. Deep wells were concentrated in the coastal area until after 1945, when several wells were drilled in Medan in order to provide substantial production of good quality water. This trend of general dependence upon deep groundwater in the coastal area and individual deep wells for major institutional, commercial and industrial users has continued to the present; most deep groundwater production remains concentrated in Belawan, although deep groundwater use has expanded in Medan.

E-1.1.2 Potential and Objectives

The long historic use of the deep groundwater has clearly indicated the potential for greater, controlled use of groundwater for potable water supplies. The Geological Survey of Indonesia has recommended that non-artesian groundwater wells should be limited to production of about 40 cu m/h (960 cu m/d, 11 l/s) in order to reduce the potential for overdrafting of the deep aquifers and to maintain acceptable water quality. Some trends in Medan would support such a recommendation, while most existing wells have not maintained such production for a significant time. The groundwater potential and recommended objectives appear to be similar if not identical in the Medan area. The investigation of the Medan groundwater resources has focused on verification of the production objective and assessment of the effects of such well production when extended over very large areas (e.g. 160 sq km with an average of 1.3 wells per sq km).

E-1.1.3 Data Base

Data for the deep groundwater aquifers is limited to production and water quality information from the Port of Belawan and P.A.M. Tirtanadi wells in Belawan and to general information regarding private wells in Belawan and Medan. Detailed well reports were available for

only wells in Belawan, and no report was made available for the wells in Medan. Lithological logs of wells were provided for many Belawan wells and for many older wells within Labuhan and Medan from the Geological Survey and Port of Belawan. Monthly and daily production records were provided for the Port and Tirtanadi wells in Belawan. Most private deep wells are operated without flow meters, pressure gages, or electric metering. Most estimates of production have usually been made from the original reported production rather than from existing production levels. Production tests and monitoring of water levels in the wells have been done only in Belawan.

Some regional geological information was available from the well logs of Pertamina and a general geological review for the Belawan area. A ground resistivity survey was conducted for P.A.M. Tirtanadi along the east side of Medan and near the Deli River (near Titipapan), and the report estimated the thickness of the aquifer and potential production yields. Unfortunately, this resistivity survey was made without any well log control to the surface indications.

Water quality data were available for several wells in the Port of Belawan, and monthly records were available for the major Tirtanadi wells in Belawan. Single chemical analyses were reviewed for several private wells. Field analyses for iron were made on water from five wells. More complete analysis was conducted on a well water sample taken from the Garuda Plaza Hotel, Singamangaraja St., Medan. The relatively poor data base has been supplemented by study surveys of water levels, drawdowns and water temperatures.

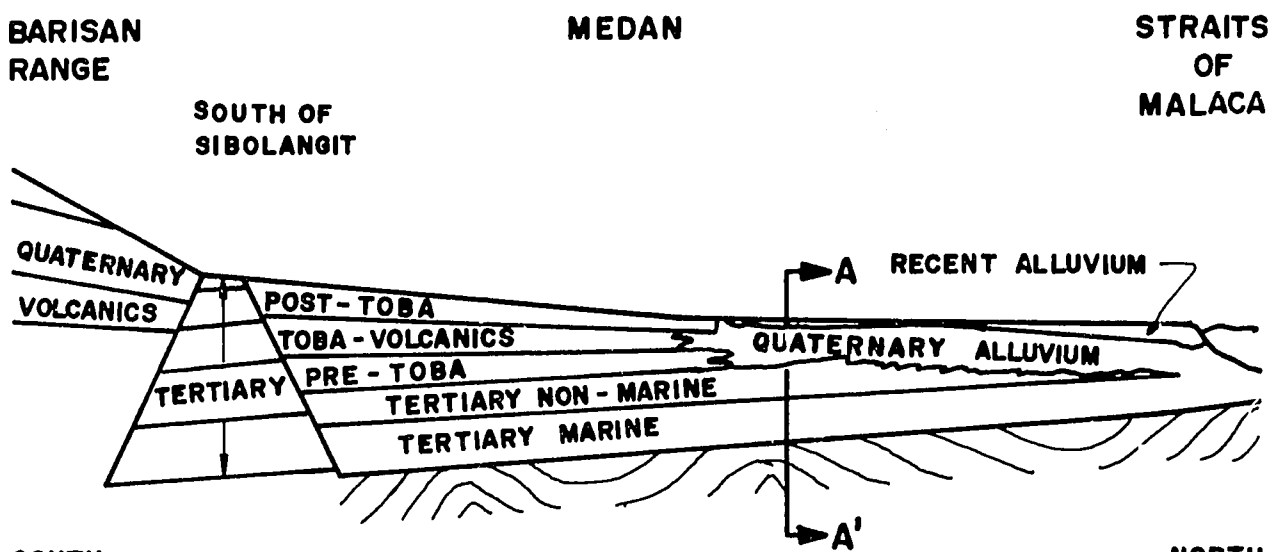
E-1.2 GEOLOGY

E-1.2.1 General Stratigraphy

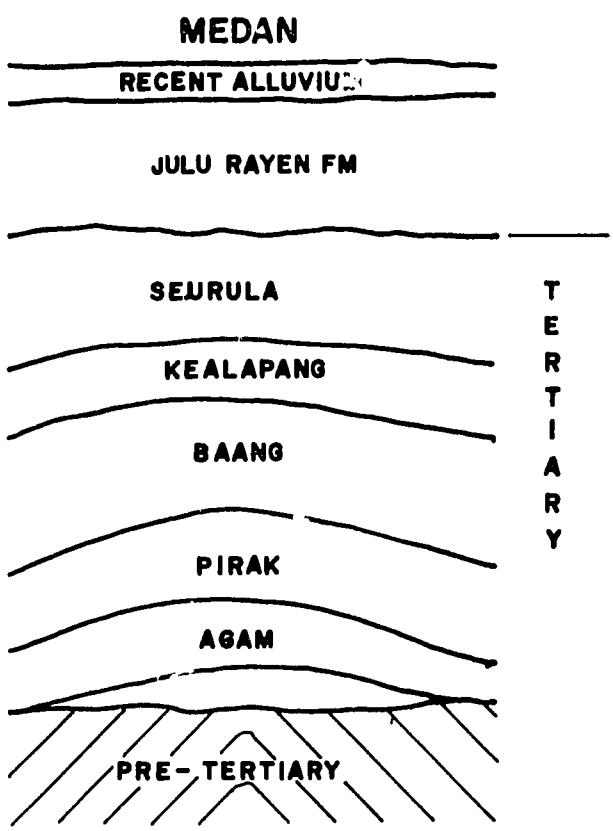
The geological stratigraphy within the Medan area consists of more than 2000 metres of Tertiary marine formation below complex quaternary and Tertiary volcanic and alluvial deposits. Detailed geological studies of this area have been restricted to exploration wells of Pertamina and to surveys of particular areas of the volcanic highlands. The general soil report for northern North Sumatra has also indicated the different underlying geological deposits. These studies in addition to the lithological logs of some water wells form the data base for the description of the geology of the region. The general geology and stratigraphic sequence within the study area and vicinity is shown in Figure E-1.1.

The "basement" formations of the study area consist of pre-Tertiary marine and coastal sediments. These formations are well-consolidated, metamorphosed, and folded. The eroded surface of the pre-Tertiary basement forms a depressed basin into which the later Tertiary sediments were deposited. This basin, or Medan Depression, is oriented from southeast to northwest and expands and slopes downward to the northwest.

GENERALIZED CROSS - SECTION OF STUDY AREA



REGIONAL SECTION



DETAILED SECTION A—A'

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During the Tertiary, thick marine shales and limestones formed over the basement formation. As the basin filled, coarse sands and some gravels were deposited in the basin. These formations thicken and are inclined toward the axis of the basin. During the late Tertiary, fresh water deposition expanded and then fluctuated across the basin. Volcanic debris first appears in the Seurula formation. Tertiary formations are exposed along the upper Percut River, 30 kilometres south of Medan and north of the Wampu River 40 kilometres north of Medan.

E-1.2.2 Groundwater Stratigraphy

Within the Medan region, Pertamina has drilled three wells through the Quaternary, and lithologic logs for 40 wells of at least 100 m depth have been used to construct more detailed stratigraphic correlations (Figure E-1.2). Two ground resistivity surveys of east and north Medan and the general gelogical study of the Belawan area have also been used in the following analyses.

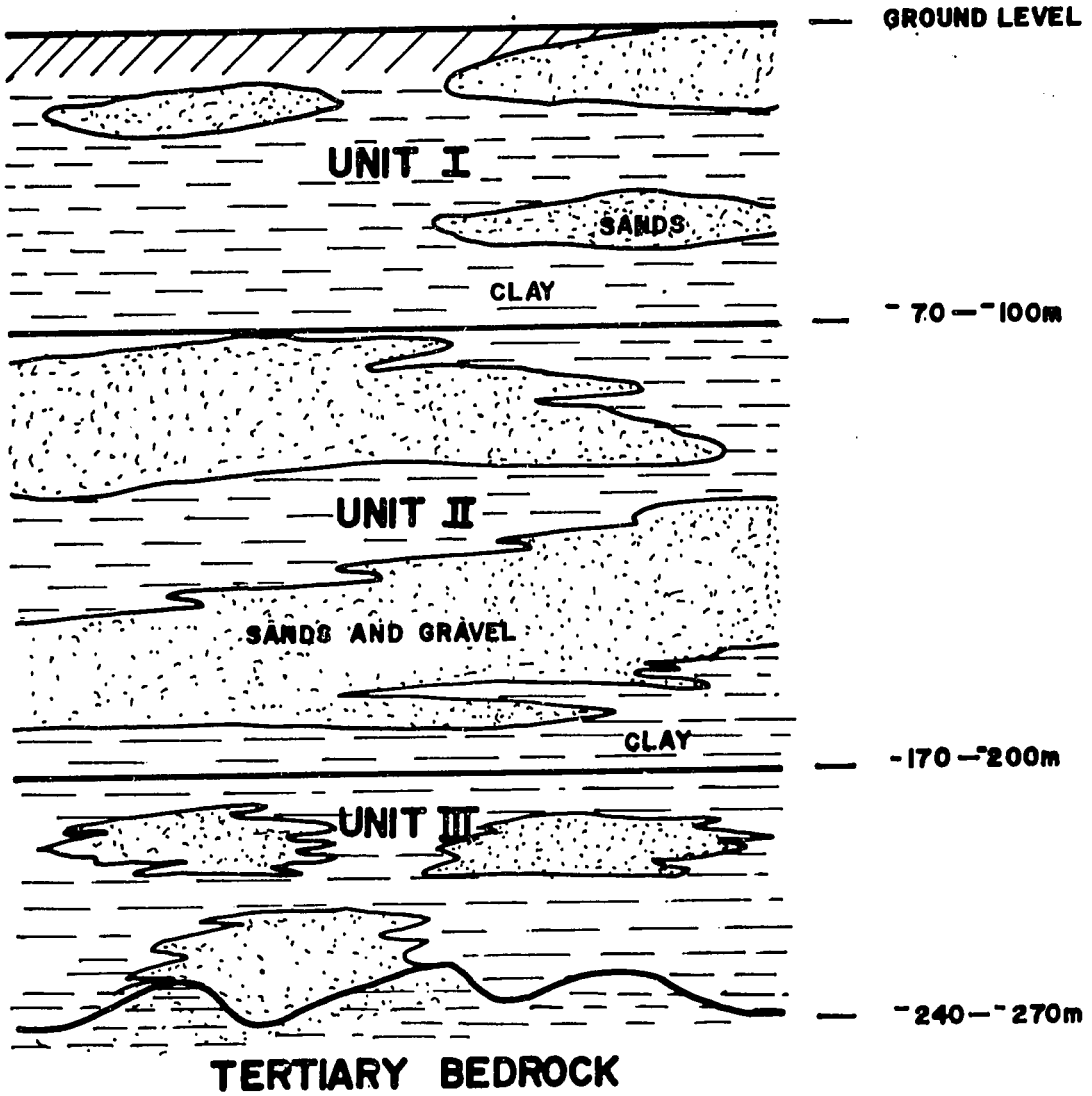
The division between the Tertiary and Quaternary in North Sumatra is poorly defined. Pertamina has defined the Seurula formation as belonging to the Tertiary (Figure E-1.1.), and it indicated the top of this formation at about 250 metres below surface at Tanjung Morawa, 235 m at Diski (west of Medan), and 100 m at Pantai Pakam (southwest of Belawan). In the Tanjung Morawa well, the division between the Julu Rayeu and the Seurula formations was characterized by an increase in the electrical resistivity and spontaneous potential between 200 and 220 m below the surface. This would reflect an increase in compaction of the formations below this zone. In all three wells, the Seurula formation is characterized by a thick sandstone, while the overlying sediments of the Julu Rayeu are dominated by interbedded sands and clays.

The contact between the more compacted Tertiary bedrock and the looser overlying Quaternary sediments should be indicated by marked differences in the movement and capacity of the groundwater aquifers in the Tertiary Seurula and Quaternary Julu Rayeu formations.

The general structural trends of the Tertiary formations indicate that a series of small anticlines and synclines are aligned from northwest to southeast but flatten towards Medan. These structures may significantly affect the relief of the contact surface between the Tertiary and Quaternary formations and the movement of deep groundwater across the surface. Since Tertiary formations are elevated well above sea level north of the Wampu River and lie 100 to 200+ m below ground levelunder Medan, the general inclination of the Tertiary/Quaternary contact is only 0.5 percent. This contact could direct regional groundwater movement from the Wampu River southward.

Similarly, the contact of the Tertiary strata with the thick volcanic sediments to the south of Medan is steeply inclined towards Medan. Surface exposures of Tertiary strata occur between 80 and 400 m elevation 25 to 35 km south of Medan, where the strata are 150 to 250 m below the surface; the inclination of the contact of Tertiary and volcanic strata is greater than 1.5 percent.

GENERALIZED GEOLOGIC CROSS - SECTION OF QUATERNARY UNITS IN MEDAN AND BELAWAN



As indicated above, the Quaternary deposits include part or all of the Julu Rayeu formation which overlies more compacted Tertiary sediments. This formation includes a series of alluvial deposits with gravels, sands, and clays, and these form the major groundwater aquifers of the coastal zone. Sands and gravels in the Julu Rayeu formation are derived from volcanic deposits, and the relationship of the thick Quaternary volcanic deposits in southern Medan and further south with the Julu Rayeu formation must be complex. In Tanjung Morawa, volcanic tuff overlies the Julu Rayeu formation while north of Medan and at Pantai Pakam and Diski, no tuff strata was found in shallow or deep wells. River bank exposures on the Percut, Deli, and Belawan, indicate that tuffs disappear from the surface within a few kilometres north of Medan's city center.

At Medan and to the south, the volcanic tuffs cannot be easily distinguished from many alluvial deposits. Compacted terrace sands and clays closely resemble volcanic tuffs which have been weathered deeply in the tropical climate and high rainfall. To the north of Medan, many well logs record volcanic sandy-clay and clay sands with pumice stone; such strata may be either weathered volcanic tuffs or eroded alluvium from volcanic tuffs. Therefore, the Julu Rayeu formation must be considered an alluvial equivalent to the three recognized volcanic units: Pre-Toba, Toba and Post-Toba volcanics. The continuity of the volcanic formation into the alluvial formations may also suggest that groundwater moving downslope in the volcanic deposits may discharge into the Julu Rayeu formation under Medan.

In Belawan, three general sedimentary units have been defined, and these may be distinguished in the Medan City area. Correlations of particular sedimentary strata however cannot be made between Belawan and Medan without more precise lithological analyses and closer spacing of wells. The Quaternary geology of any coastal area is often complicated by the repeated movements of river, delta, and coastal marine deposition which may have moved back and forth across the study area in response to the rise and fall of sea level during the last three million years. Similarly, the Medan coastal plain deposition should reflect a complex history, which is further complicated by volcanic eruptions and tectonic movement.

Presence of marine shells in sands beneath Belawan and somewhat more prominent sands and gravels in Belawan, compared to Medan, may indicate that some aquifers along the coast may be old beach deposits rather than filled stream channels. If the existing physiography bears any relationship to those during the Quaternary, aquifers to the north would be expected to be longer in an east-west alignment, while those to the south under Medan could be longer in north-south alignments. Some interconnections between these aquifers would be expected although probably further towards Medan than under Belawan.

Most Belawan wells penetrate three lithological units, and most groundwater may come from intermediate units (series sand and gravel aquifers). Silts and clays dominate the overlying unit (Unit I) and appear to seal off the intermediate aquifers from possible contamination by sea water. Historic well water levels indicate that the intermediate

aquifers of Unit II were confined under greater pressure than that expected by an aquifer with broad contact with the overlying, shallow aquifers. Some aquifers in Unit III occur below Unit II but are separated by a series of clay and silt strata. Such strata may completely separate the aquifers of the Unit III from those of Unit II.

The general groundwater geology of Belawan has been reported in a general survey (1977) which indicated that the sands and gravels may follow the same trends as the overlying Deli and Belawan Rivers. This trend indicated that thin aquifers should be found in the central area of Belawan. However, several wells have been drilled and produce significant groundwater within this central area. Widespread occurence of the sands and gravels within Unit II may suggest that its deposition may have occurred in a more widespread beach and sand bar environment rather than a more limited and variable river channel environment.

Particular sand and gravel strata cannot be confidently traced into the Labuhan area (5.0 km to the south), the general three-part sequence of Unit I: clay-silt, Unit II: sand and gravels, and Unit III: mixed clays and sands can also be found in Labuhan. Many wells penetrated only the upper portion of Unit II (down to 100 m) and do not provide a complete log of Units II and III.

Within Medan and Glugur, only 8 well records have been reviewed, but these generally indicate a similar three part division of the Quaternary sedimentary units. General comments from drilling contractors also suggest a three-part separation of the Quaternary.

Any separation of three lithological units in Belawan and Medan must recognize that the strata were probably deposited under water and that river and ground surface slopes may have been similar to or steeper than those today. If this is so, strata in Unit II should be at more than 20 m higher elevation in Medan than in Belawan.

Drilling records for the Medan study area are generally concentrated along the north-south line from Belawan to Medan and should not be entirely representative of the region (e.g. winding ancestral river valleys and alluvial fans would be expected beneath Medan). Furthermore, the effects of large volcanic eruptions can be seen south of Medan, (i.e. Medan lies on volcanic formations), and volcanic debris has been reported in many well logs. Geomorphic development in eruptive volcanic areas often involves complete filling of ancestral valleys by an eruption and initiation of entirely new drainage basins. Therefore, geological interpretations based upon the central alignment records should not indicate the total stratigraphic sequence.

E-1.2.3 Geology and Infiltration

The recharge of groundwater involves the infiltration of surface waters through the soil or bedrock or from river beds into the shallow aquifers and from the shallow aquifers into the deep aquifers. Geological data are insufficient to locate the areas of surface or river recharge for the deep aquifer in Medan. Several possible areas do exist, however:

1. Volcanic hills and mountains to the south,

2. River valleys above 40 m,

3. River floodplains and irrigated terraces, and

4. Deep river channels of the Wampu and Ular rivers.

The very high rainfall in the Barisan Ranges to the south of Medan offer many suitable areas for infiltration of rainfall. Rainfall of more than 5 m on well-vegetated slopes would allow deep infiltration. The springs of Sibolangit may represent a portion of the discharge of shallow to intermediate depth groundwater derived from infiltrated rainwater. As the groundwater follows the structural and stratigraphic trend of the volcanic deposits, the groundwater is eventually discharged into alluvial deposits which were formed along the northern edge of the old volcanic deposits. Once in the alluvial deposits, the groundwater would tend to follow the thicker and coarser lenses of sand and gravel.

Many river terraces and basins may be found at about 50 and 75 elevation with steeper grade between the basins. These terraces and basins often have thick deposits of sand and gravel. Rain water and river water many infiltrate through these coarse deposits and enter the coarse, older deposits which are on the bottom of basins and terraces. Such areas may be seen near Deli Tua on the Deli River and Tuntungan on the Belawan River.

Many smaller terraces and basins can be found below 50 m elevation. Upstream of the Sunggal Plant, thick sand and gravel deposits occur and hold groundwater. Between the Babura River and the Belawan River, terraces are cultivated for rice and may provide numerous sites for groundwater infiltration where sands reach the surface. Water levels in shallow groundwater table wells indicate that the finer terrace deposits are charged with groundwater. However, below 50 m elevation, the groundwater table overlies known producing deep aquifers, and the water pressure in wells within the deep aquifers is different from those of adjacent shallow wells. Therefore, infiltration into the deep aquifers may not occur below of south of the 50 m elevation. Similarly, water levels in Belawan are different from sea level and surficial groundwater tables.

Two major rivers, the Wampu to the west and Ular to the east, have wide, deep channels. Such channels can lose considerable water from their beds by exfiltration into surrounding sands and gravels. These rivers may contribute to the groundwater infiltration into the deep aquifers of the coastal zone. East-west movement of groundwater is not thought to be great but such movement could occur with increased withdrawal from the deep aquifers.

E-1.2.4 Geological Structure

The study area extends across the axis of the deeply buried Medan depression which has formed between the Asahan Ridge (beneath the Straits of Malaca) along the northeastern margin and the Barisan Range

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along the southwestern margin. A buried ridge separates the Medan Depression from the Siantar Deep to the south, while the Medan depression joins directly with the Tamiang depression on the north. Compression between the Asahan Ridge and Barisan Range has produced a series of smaller anticlinal-synclinal folds in upper Tertiary and Quaternary deposits with the Medan Depression oriented southeast-northwest. Earlier compression formed similar folds with more north south orientation. North of the Wampu River, a large syncline in late Tertiary (including Seurula and Julu Rayeu) bedrock is oriented so that an extension of its axis would lie along the southern margin of the study area. To the northeast, an anticline near Tanjung Pura may be extended southward to Medan city or to the north.

Geological survey of the Medan-Langkat area indicates the surface exposure of the Tertiary formation at about 500 m elevation. This formation is known from more than 1,000 m below Medan and the resulting differential movement of 1,500 m has occured between the edge of the Barisan Range and the Medan peidmont. Northwest-southeast oriented faults near Sibolangit indicate uplift on the southwest side, although the amounts of uplift from faulting and folding cannot be separated. The edge of the faulting cannot be accurately estimated but probably has occured several times over the last 2,000,000 years. The faults are also associated with volcanic intrusive rocks and may have formed weak spots in the earth's crust along which lava was forced to the surface and formed volcanoes. Prominent terraces at +5.0 m have been interpreted to indicate recent (last 10,000 years) uplift of the coastal areas.

E-1.2.5 Seismicity

Active volcanoes lie only 50 kilometres south of the study area and they indicate the seismically active setting of the study area. Geological uplifts of more than 1000 metres during the last three million years, major faults along the central axis of Sumatra, and occurrences of seismic epicentres within Sumatra and southeast Asia further testify to the moderate to high potential for significant, damaging earthquakes in the area. The general level of seismic hazard is only moderate with no structural damage, additional consideration should be made with regard to the high water table and to the poor structural support which the clay soils of the coastal plain and tidal zones can provide. Damage could be expected where high water table occurs in clay to sandy soils, and near relatively steep, unconfined slopes.

E-1.3 THE GROUNDWATER TABLE

E-1.3.1 Distribution

Groundwater near the surface in the soil and alluvium is called the groundwater table (the shallow, unconfined aquifer). The groundwater table is supplied by rainfall directly, by infiltration from surface waters (e.g. rivers, canals, ponds, etc.),and by deeper groundwater aquifers. In many places in Medan, artifical canals, ponds, lakes, and sewage infiltration fields also contribute to the shallow groundwater. The groundwater table provides the only local water supply to many thousands of people in Medan and is a valuable asset.

In many other places, the high level of the groundwater may provide convenient water supply, but greatly contrains the use of many areas for some agriculture and urban land use without substantial and continuing costs for drainage and fills or pilings. Urban and transportation developments have also modified the natural groundwater table and either caused the shallow groundwater to rise to the surface or has deprived the groundwater of natural recharge which has caused a decline in the groundwater table surface.

In the coastal tidal zone (below 5 m elevation above sea level), the groundwater is very close to the surface and is often continuous with ponds, marshes and other water-logged soils. The very low gradients reduce drainage and increases infiltration of the 2000 mm of rainfall each year and the surface water flowing into the area from higher elevations. Stagnation of the groundwater table and surface waters and the tidal intrusion of the sea water causes contamination of the water, and in many areas other potable water supplies must be found (e.g. the Port of Belawan drilled deep wells as early as 1888 in order to support the port development). Deep excavations must be artifically drained, and most construction requires about one metre of clean fill and pilings.

Along the major rivers and between +5 m and +25 m elevation, the groundwater table is quite high and usually lies within one metre of the surface. On the west side of the Deli River, agriculture development has drained the shallow groundwater, and the groundwater table may be more than one metre below the surface. Along the Belawan-Medan Road, the natural levee development of the Deli River provides slightly higher and dryer ground than further east, and this supported the early development of the railroad, road, and structural development of the corridor.

The small drainage area and the low gradient of the Kera River appears inadequate to carry the large runoff from the eastern area of Medan City, and the flooding and slow drainage increases rain infiltration into the groundwater table. Generally, the groundwater table is higher on the eastern side of the Deli than on the west, even at the same ground elevations.

Between +15 and +25 m elevation, human activities strongly influence the actual depth to the groundwater table which is generally within 0.5 to 1.5 of the surface. Natural movement of the shallow groundwater is towards the rivers, especially during droughts. When roads and widespread structural development occurs across the slope of the groundwater table, the groundwater accumulates on the higher side, and the level of the groundwater table rises, often to the surface as ponds and waterlogged lands. Congested drainage canals and septic tank infiltration fields contribute additional water to the groundwater tables and produce artifically high water table levels.

Above +25 m elevation, groundwater may often be deeper than 1.0 to 3.0 m from the surface. The level of the rivers and other surface water reflects the lower-most level of the groundwater table. Because of the relatively slow movement of the groundwater table towards the rivers and open channels, the level of the groundwater table above +25 m

depends upon the distance from an open channel and the amount of rainfall or irrigation. During dry periods of less than 60 mm rainfall per month, the groundwater table near the river will fall more rapidly than the level near the higher ground, or divides between the rivers. Wells within 100 m of the Deli, Belawan, or deeper channels of the Percut and Babura often decline faster during the dry periods than lands more than 1000 m from the channels. The water levels may change from 1.0 m to 6.0 below surface in a few months.

Between the Percut River and the Babura branch of the Deli River, and at a ground elevation of +35 to +50 m, the groundwater table may lie at least 2.0 m below the surface. The steep ground gradients and close proximity of the deep open channels in this elevational range allow rapid runoff of rainfall and small streams accelerate the flow of the shallow groundwater towards the open channels. Since the Babura branch lies across the north side of the hills, the open channel collects most of the shallow groundwater and decreases the level of groundwater immediately north of the stream. North and west of the Babura branch and up to the Belawan River, the low gradients of the ground and the small streams reduce the rate of runoff and increases the natural infiltration of rainfall to the groundwater table. Irrigation of many crops in this area further increases the amount of water reaching the groundwater table and tends to maintain higher water levels in the wells and excavations. Within 200 metres of the Belawan River, many streams drain into the Belawan channel and their steeper gradients reduce infiltration and increases the natural discharge from the groundwater table.

A prominent terrace or plain occurs along the rivers between 50 and 75 m elevation, and ground slopes and stream gradients are low, and the drainage is poor. Cultivation of irrigated crops further interferes with rapid drainage and tends to maintain a high groundwater table (within 2.0 m of the surface).

E-1.3.2 Water Table Development Constraints

As indicated above, the groundwater table has benefited the Medan residents by providing useable water supplies. Development and construction, however, will be constrained or restricted by the shallow groundwater in many areas. The Medan Urban Development Study has recognized the following groundwater table constraints and guidelines.

E-1.3.2.1 Belawan

The poor quality of the groundwater table and its shallow depth hinder the efficient development of the port and residential areas of Belawan and Labuhan. Roads and general urban development must be properly filled and diked to protect developments from water logging and flooding. Additional expenses for filling and other special measures increase the costs and may limit efficient land uses except for high value industry and commerce.

E-1.3.2.2 Medan-Belawan Corridor

The combination of flooding and high water tables constrains development to a narrow corridor along the Belawan Road and the railroad or to special projects which can afford the high costs of excavations, fills, deep doundations, and flood protection from both the Deli and Kera Rivers. Embankments for the railroad, the Medan-Belawan public road, and the proposed Belawan toll road may provide barriers to groundwater movement in east-west directions. If the toll road is properly aligned and filled, lands in the corridor between the railroad and toll road become more suitable for development with the partial flood protection offered by the embankments. The embankments will also reduce movement of shallow groundwater from the Deli and Kera River channels into this corridor. Properly aligned east-west dikes between the railroad and toll road embankments would close the flood protection and shallow groundwater barrier. Such enclosure would allow use of less fill and smaller drainage facilities compared to those required for a fully exposed site.

E-1.3.2.3 Upper Kera Basin

The Kera River drains much of eastern Medan, and the large volume of water, low channel gradients, and slow runoff increase the flooding and the infiltration of surface waters into the shallow groundwater table. Future flood protection facilities may deepen the channel and improve drainage for the groundwater table. These activities may also compact the shallow soils and line channels which will reduce the drainage and increase or maintain the existing high water table.

E-1.4 WELL FACILITIES

E-1.4.1 Groundwater resources and Facilities of PAM Tirtanadi, Belawan

The records and facilities for the groundwater wells at Belawan have been reviewed and are described in Section 2. Analyses of the available data indicate that existing production wells can supply the existing and short-term requirements of the Belawan area without significant imports of water from the Medan distribution system. Even if connection percentage and total demand increased over the next five years at the same rate as in Medan city, the existing supply facilities, with some changes in operations and equipment, could supply the intermediate phase through 1985. The major requirement appears to be storage for continuous production from existing and renovated wells.

E-1.4.2 General Well Design

Production wells in Medan-Belawan have used three types of designs which have reflected the types of pumps and water levels in the wells. Changes in well pumps and declines of groundwater levels have caused modifications of the older designs. Transferral of several wells from the authority of the Port of Belawan to P.A.M. Tirtanadi also involved renovation of the old well design and several modification which are not commonly found in other wells.

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E-1.4.2.1 Old Well Type

Early well designs in Belawan, Labuhan, and Medan depended upon artesian pressure which carried the water to within a few metres of ground surface or actually above the ground surface. Water from the well spilled over into a reservoir from which it was extracted by hand pump or bucket. These wells provided local domestic water supply. As the port expanded, these small capacity wells were replaced by larger facilities with larger capacity, but the basic design remained similar. All wells in Belawan, except Wells No. 19 and 20, were originally constructed with a tank system into which well water would flow under artesian pressure about 25 m below surface. Pumps would then draw water from the underground tanks and transmit the water into the distribution system. Thus most wells were not directly pumped (except Wells No. 3, 7, and 8).

E-1.4.2.2 Modified Old Well Type

The older artesian-tank type well provided most water demands before 1950. As groundwater levels fell between 1950 and 1979, production for the old type wells declined (e.g. POB No. 10). Water could not flow, passively, into the tanks at sufficient rates to equal required pumping from the tanks. In order to maintain production, the old type of well with tanks have been slowly modified, replaced, or abandoned (only Well No. 1 remains on the passive system). The major modification involved the mounting of a 7-15 HP submersible pump within the casing of the old well with discharge into the underground tank or into the distribution system. Even the newer POB Wells No. 16, 17 and 18 included the underground tank and surface pumping stations and now have been modified by installation of submersible pumps.

Tirtanadi has renovated several of the wells (wells No. 5, 9, 11, and 12) for which they assumed control. The underground tank was removed from the well operations. This exclusion reflects the high capacity submersible pumps being used and the use of pressurized sand filters before water passes directly to the distribution system.

With the modifications of the old type artesian-tank system, all operational wells but Wells No. 4, 6, 7, and 10 are now pumping directly from the well casing, and Wells No. 4 and 10 will be modified and operated with a submersible. These modifications largely reflect the drawdown of the deep aquifer to below the artesian inflow elevation to the old type tanks (about 2.5 m below ground surface) rather than increasing demands.

E-1.4.2.3 New Well Type

The "new-type" wells generally consist of the well and a submersible pump with an outflow pipe going either to a storage tank, pressure/gravity filter, or the distribution system. In Belawan, POB Wells No. 19 and 20 with submersible pumps produce more water than any other groups of wells in the entire Medan-Belawan area. The water is pumped directly to an industrial user's storage tank and then to processing units.

Other new wells in Belawan and Medan have submersible pumps which serve industrial or commercial users and treatment of the water depends on eventual use. For industrial use, including food processing, water is used from storage tanks with little treatment. For hotel and hospital use, well water passes through pressure/gravity filters and then is chlorinated before flowing into storage tanks. Many hotels provide separate water supplies for drinking and well water for general washing and swimming pools. No facility was found to reduce iron in the well or surface waters, and many use municipal water for drinking.

E-1.4.3 Operations

General operations of major wells within the Medan study area reflect the agencies and users of the wells, and control and centralized operating procedures extend over less than 10 wells at the Port of Belawan and P.A.M. Tirtanadi in Belawan.

Operations of the Port of Belawan provide 24 hour/day operators for each well, while large private users may have one or more technicians responsible for water and other utilities. Some smaller users may only have technicians inspect and repair wells, pumps, treatment facilities and electrical supply when some component has failed or shows signs of potential failure.

The port records flows and electrical consumption on a daily basis and has water quality analysed on a monthly basis for some wells or common storage tanks. Most other operators do not appear to make any meaningful records. As long as the wells produce water, little concern is directed towards maintaining their operating efficiency.

Back up power supply was available only for the wells in the Port of Belawan and at a few major hotels and industries which maintain on-site generators. Other well operators, including Tirtanadi, depend on common electrical distribution systems. Line voltage varies widely, especially for 3-phase equipment, and generally is well below the required 220/380 volts for optimal pump efficiency.

A common problem with many wells is loss of production or disruption of service due to the pump losing suction as the well water level falls to the level of the pump. Such losses or disruptions usually involve reduction of the effective screen opening. Sand sometimes passes through the gravel pack and screen; the sand then falls to the bottom where it eventually accumulates and begins to cover the screen openings. Although some operators may abandon wells due to loss of production, others, like Tirtanadi, periodically clean the screen of the deep well. This, most often, involves removing the accumulated fine sand from the bottom of the well.

Well cleaning most commonly uses a high pressure air compressor to inject air through a long pipe which reaches to the bottom of the well casing and screens. An injected air bubble under 200 m of water begins to rise and carries both water and sand up and out of the well. Air lifting may be conducted for several hours or days depending on the amount of sand to be cleaned from the well. Once the casing has been

cleared of sand and debris, swabbing may be done to clear material which has clogged the screen itself. Sometimes high pressure water jets may also be used. No air is injected through the screen and into the gravel pack.

Cleaning of the casing and clearing screens can immediately increase the production capacity of the well, improve efficiency, and reduce well draw down. If the production does not significantly increase, under water video viewers with lights can be lowered through the casing for visual inspection of the screening for obstructions. This has not been done in Medan nor have any reports of its use in Indonesia been received.

E-1.4.4 Well Drilling Practises and Designs

Poor production and frequent cleaning usually indicates poor designs or drilling/development of the well. All wells in the Medan area have been constructed in accordance with local well drilling practice and with locally made equipment. During this study an inspection was made of most of the existing public water wells. In addition to inspecting each well, the construction of a new well was observed drilled for the Polonia Hotel to augment their present supply. This well was drilled by the rotary method by a local contractor. The drilling equipment was very obviously a one-of-a kind, locally made rig and was capable of drilling to about 240 m and to a bore diameter of about 300 mm. Conversations held with the drilling foreman indicated that this or similar equipment was generally used for well construction in the greater Medan area. Because of these limitations, test well design will have to consider the contractors ability to perform the required work.

The current method of well construction depends to a large extent on the reduction of casing diameter as the well is deepened. A surface casing perhaps 300 mm in diameter is the largest diameter used. At depths of 150 to 175 metres, the casing is normally sequentially reduced to 100 mm. This scaling down of casing with depths is necessitated because the mud pump on the rig is not capable of moving the large volumes of cuttings against high heads (180 to 200 m) that would be the case in larger diameter boreholes.

Many private or older wells not only have small diameter casings but do not include any type of conductor casing normally provided to preclude the entrance of surface or shallow subsurface waters. Moreoever, the submersible pump, which is typically used, is hung in the well by a clamp affixed to and supported on the production casing. In most instances the casing extends no more than 0.3 m above ground surface. Electric wires connected to the motor cross the ground from the power source and are unprotected either against the elements or damage by vehicular or foot traffic.

Rotary drilled wells are purported to be gravel packed, but no evidence of the gravel pack was seen. No gravel feed pipe or water level monitoring pipe exists at the top of the casings. Often, the casing is not sealed or only partially sealed by concrete and steel caps.

No inspection is made during the well construction, and no independent verification of the gravel packing was made on any well. At some wells, settlement of ground around the surface casing suggests that compaction has taken place, but it is unknown whether compaction occured in the gravel pack or in loose fill placed around the casing. In one proposed design, a contractor provided a drawing with the gravel pack extended to the surface, while others indicated that the volume of gravel pack was neither calculated nor measured when placed.

Local drillers have concluded, based on information presently unavailable to us, that groundwater in the upper and intermediate aquifers, the zone lying between the surface and 170 meters, contains an unusually high iron content. For this reason, they have convinced well owners that the minimum well depth should be in the order of 200 m. It is interesting to note, however, that the upper water-bearing zone in these gravel packed wells is either only partially or not sealed-off thereby allowing hydraulic continuity to exist between and among all the water-bearing strata.

Designs of the wells often appear to reflect minimal initial costs and limitations of equipment. Some design elements would suggest that proper development of the standard well cannot be done even if proper techniques were used.

Well discharge and water level drawdown generally relate to the transmissivity of the aquifers. In any given area where aquifer constants are similar, all wells should exhibit the same rate of discharge with the same drawdown. If extreme differences exist (e.g. Belawan: 4 to 36 m drawdown), such differences usually reflect construction practices rather than variations in the aquifers ability to produce equivalent quantities of water.

The rotary method of drilling injects drilling mud into the wall of the well bore and the mud forms an inherent barrier to properly developing the well. In large diameter casings, tight-fitting swabs and prolonged reciprocating action of the drill stem causes the drilling muds and other fine-grained sediment in the wall to move through the gravel pack into the perforated casing where it is removed. Local well designs use progressively smaller diameter well casing with depth, and this precludes efficient well development. Some well designs install only one section of screen or several small sections. Without prolonged development, small screens do not allow clearing of drilling mud from the well bore. Only those sections near the screens or those along the gravel pack with the loosest compaction will release the drilling mud, while other less permeable but larger aquifers will remain clogged.

As a result of different degrees of effectiveness wells drilled in the same formation will exhibit different performance. Most probably, well efficiency in the greater Medan area is less than 50 percent, if that high.

E-1.5 WELL LOCATIONS AND PRODUCTION

More than 80 deep wells have been drilled in Medan and the Belawan corridor since 1889. Unfortunately, few records are available for the design, construction, operation, and production of these wells. The Geological Survey of Indonesia (Bandung, 1973) prepared a preliminary list of 68 wells within the Medan study area (Table E-1.1) and several hundred for all of North Sumatra. Most of the wells were summarized from old Dutch records still extant in the GSI files. A few well reports from private drillers and data supplied by P.A.M. Tirtanadi and the Port of Belawan or the only other sources.

Deep wells are concentrated between Central Medan and the Port of Belawan, in Labuhan to Titipapan, and in Central Medan (Figure E-1.3). Many wells listed by the GSI appear to be located at the sites of existing wells in Belawan, but the description of the wells suggest that two or more wells have been drilled at the same sites. No site had any indication of more than one well nor did Port of Belawan staff report any earlier wells. Where possible, notes have been added to the well list as to which numbered well corresponds to a well operated by P.A.M. Tirtanadi (PAM) and the Port of Belawan (POB). Several wells were known to have been drilled in the Medan-Belawan area but their locations were not known. Some wells had also been abandoned.

Total groundwater development may be generally reflected by the number or distribution of known wells, although interviews and review of existing data indicate several factors which strongly influence estimates of production. The only available records of well production are those of P.A.M. Tirtanadi and the Port of Belawan. The last seven years of production records were reviewed and may demonstrate general trends reported for other wells. Wells generally produce the most water during their first years of operation and then gradually decline in production. Such decline can result from poor construction which causes clogging, inflow of sand, and collapse of the gravel pack. Therefore, initial production estimates will be higher than production after a few years.

Production varies widely by day and hour. Tirtanadi and POB wells are shut off when demand is small (e.g. night-time or holidays), while power failure and low powerline voltage can interupt or reduce production. Among private operators, demand changes, storage tank capacity, poor power supplies, and other factors cause more frequent disruption or reductions in production. Therefore, both the initial estimated production and the pump capacities measures only the maximum well production, which may bear little resemblance to actual production.

Production of wells now operated by Tirtanadi has been presented in Section 2 of the Main Report on Water Supply and Sanitation and average monthly production is presented in Table E-1.2. Five operating wells out of six show declines in monthly production, except in 1977 when the wells had been renovated and transferred from the Port to Tirtanadi. After 1977, PAM wells No. 9 and No. 12 continued declining although starting from a higher capacity. Even with an average daily production of 3,000 cu m or more, the port has provided an additional

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TABLE E-1.1

LISTING OF KNOWN WELLS IN THE MEDAN AREA

No.	Name	Date	Depth/m
Wells Drilled by Department of Mining/Directorate of Geology			
8	Labuhan I	1887	75
9	Labuhan II	1887	87
10	Labuhan III	1887	87
11	Labuhan IV	1887	90
12	Labuhan V (not located)	1888	98
13	Labuhan VI	1888	218
14	Medan I	1889	195
17	Belawan Deli II (= PAM 8)	1894	76
18	Labuhan VII	1894	98
22	Belawan Deli III	1911	81
24	Labuhan VIII	1911	90
26	Hamparan Perak	1911	65
28	Pulau Sicanang	1914	119
29	Belawan Pelabuhan I (= PAM 3)	1915	233
30	Belawan Pelabuhan II (= PAM 4)	1916	235
34	Titipapan	1919	134
37	Bagan Deli	1921	116
38	Sisir Gunting	1922	144
39	Belawan Pelabuhan III (= PoB 2)	1926	153
43	Sunggal	1931	223
44	Percut	1932	168
Wells Registered with Department of Mining/Directorate of Geology			
1	Bulu Cina	1904	224
2	Bulu Cina	1904	112
40	P. Brayan I	-	-
43	P. Brayan II	1916	226
44	Bulu Cina	1918	224
45	Labuhan	-	-
49	Belawan Pelabuhan IV (= PoB 15)	-	-
76	Belawan Pelabuhan V (= PAM 5)	1950	120
77	Belawan Pelabuhan VI (= PAM 6)	1951	112
78	Medan A.V.R.O.S. (= RISPA)	1952	121
Private Wells, not registered			
25	Belawan: Jl. Kuburan VI (PAM 4)	1961	130
26	Belawan: Pardede (P.T. Surya Sakti)	-	-
27	Belawan: Dept. Fish (PAM 9)	1962	130
28	Belawan: Jl. Ujung Baru (PoB 10)	1970	160
29	Belawan: Jl. Cipanas (PAM 11)	1971	106
30	Belawan: Kp. Salam (PAM 12)	1971	110
31	Belawan: Gudang 201 (PoB 3)	1971	116

TABLE E-1.1--Continued

No.	Name	Date	Depth/m
32	Belawan: Bagan Deli (PoB 16)	1971	120
33	Bagan Deli	-	-
39	Hamparan Perak	1970	40
74	Pulau Sicanang	1954	85
78	Sisir Gunting	-	-
88	Tuntungan: Golf Course	-	235
89	Tuntungan: Horse Racing Track	-	-
106	Terjun	-	-
107	Titipapan	-	-
46	Medan: Tirta Sari (Ice Factory)	1969	140
47	Medan: Mabar (Ice Factory)	1977	126
48	Battalion	-	-
49	Pardede I	1956	-
50	Pardede II	1970	126
51	Pardede III	-	-
52	Pardede A: Food Factory	-	-
53	Pardede B: Shrimp Factory	1971	180
54	Pardede C	-	-
55	Petojo I (Ice Factory)	1920	170
56	Petojo II (Ice Factory)	1959	-
57	Petojo III(Ice Factory)	1968	110
58	University - Engineering School	1946	87
59	Pardede (Shrimp Factory I)	1971	120
60	Pardede (Shrimp Factory II)	1977	210
61	Coca Cola (Bottling Factory)	1971	118
62	Tj. Mulia - Mabar	1977	130
63	Danau Toba Hotel I	1972	120
64	Danau Toba Hotel II	1972	140
65	Bank B.D.	-	-
66	Hospital P.N.P. IX	1964	74
	Private wells, not registered. Recent additions		
	Intan Nasional Iron 1	1974	140
	2	1978	170
	United Rope Co.	1970	135
	Asrama Police Barrack	1963	83
	Indra-Deli Seafood Factory No. 3 (59B)	1977	193
	Dharma Deli Hotel	1978	200
	Garuda Plaza Hotel	1977	210
	Polonia Hotel 1 (Abandon)	1977	114
	2	1978	200
	3	1979	240
	Medan A.V.R.O.S. (RISPA) No. 2 (78 B)	1977	220
	Pemuda Tingkat I Sumut	1978	200

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TABLE E-1.1--Continued

No.	Name	Date	Depth/m
Private wells - sites unknown			
	Leligune Baru Belawan	1962	105
	Sebelum Perang	-	200
	Jl. Hanafiah (PAM 3)	1966	114
	Jl. Langkat (PAM 4)	1950	130
	Jl. Sumatra (PAM 6)	1951	130
	Leeoni	1952	120
	Belawan Km 14	-	1-12

TABLE E-1.2

AVERAGE MONTHLY PRODUCTION FROM THE
P.A.M. TIRTANADI WELLS IN WESTERN BELAWAN
WELLS AND MONTHLY PRODUCTION (IN 1,000 cu m/mo)

Year	5	6	7	9	11	12	Total
1972	9.2	7.1	3.8	36.0	36.0	30.5	92.10
1973	6.1	5.7	3.2	32.2	18.3	27.7	93.2
1974	6.1	5.5	4.1	31.5	14.6	24.7	86.5
1975	-	4.7	3.8	32.6	15.4	22.6	79.1
1976	5.5	2.1	3.5	33.8	8.9	19.5	73.3
1977*	5.1/16.5	0/0.4	3.9/3.6	30.1/27.9	26.9/27.6	18.3/28.8	189
1978	22.2	-	4.1	22.5	28.6	25.7	103
1979	22.8	-	4.8	19.6	29.4	20.0	96.6
Average Daily 1979	760	-	160	653	980	667	3,220 (2,890)**

* 1977 was the year for transfer to PAM Tirtanadi and renovations, only Wells No. 9 and 12 continued similar production.

** 2,890 is the average daily production for 1972-1976 and 1978.

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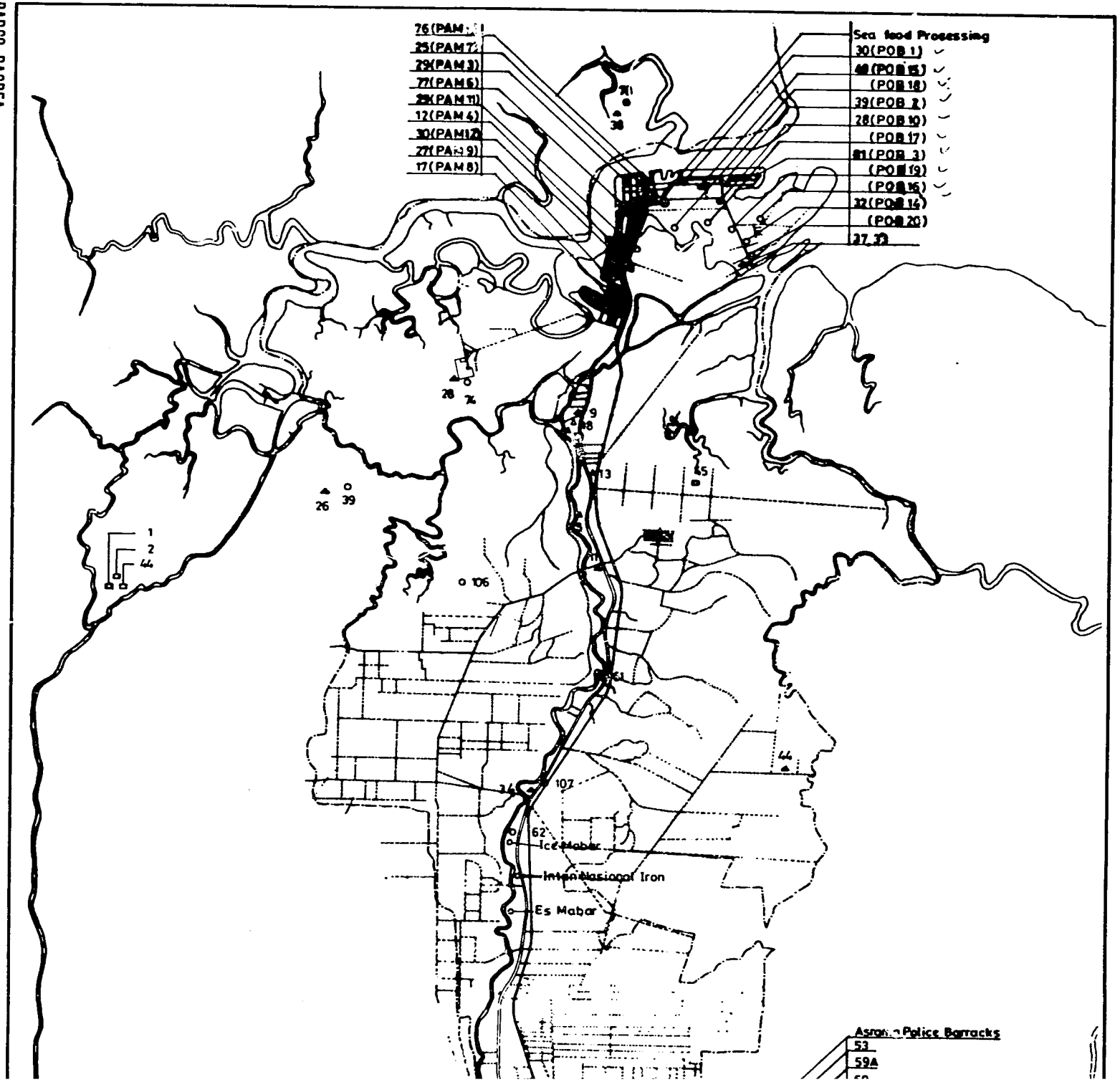

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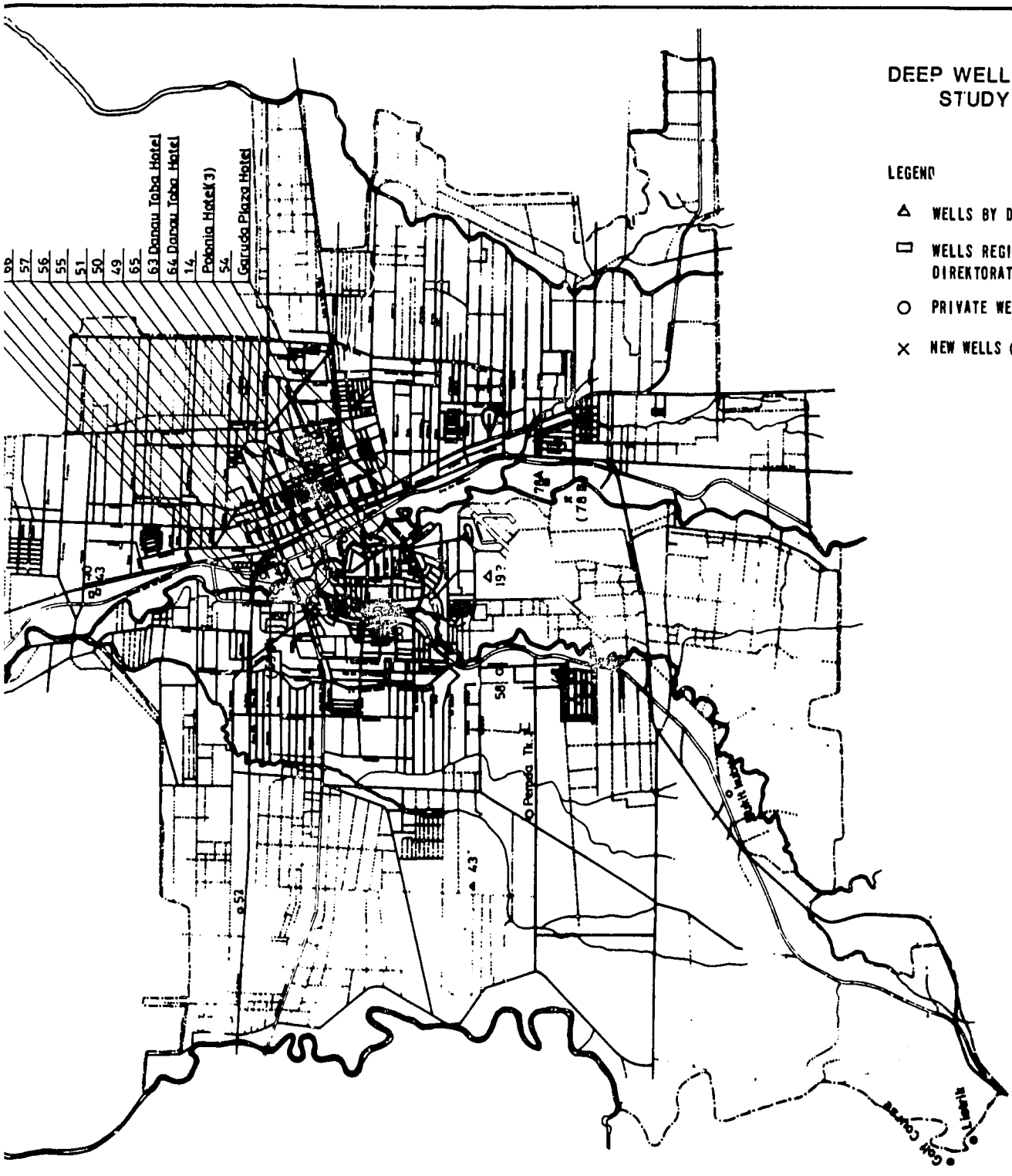

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daily supply of about 1,200 cu m in order to serve the non-port users in Belawan. This transfer equals about 25 percent of the total water supplied by Tirtanadi and 30 to 50 percent of the production of the port wells, excluding POB No. 19 and 20 which are solely for industrial use.

The Port of Belawan has operated nine wells since 1977 and 14 wells between 1972 and 1977. These wells have produced 70 to 90,000 cu m/mo up to 1977 (Table E-1.3), when production was increased to 180 to 195,000 cu m/mo, largely by addition of POB wells 19 and 20 producing about 100,000 cu m/mo. Although recent production has remained relatively constant, the level of production has been maintained by adding new wells rather than by increasing or maintaining production from existing wells. Seven of the Port wells have declined in production or have been abandoned. Even wells 16 and 17 have increased production by adding submersible pumps while water levels have declined.

Total Tirtanadi and Port production is now at about 290,000 cu m/mo or about 9,350 cu m/d. This is roughly distributed as 3,000 cu m/d by the Tirtanadi wells, 3,000 cu m/d smaller Port wells, and 3,350 by the Port's plant until 1977, when the transfer of wells to Tirtanadi occured.

Review of available data and interviews of technicians working for private well operators indicate that no well is operated at a production approaching that of the larger Port of Belawan well 20 (2,000 cu m/d). The largest reported initial pumping rate was 1,440 cu m/d, and most wells were reported to produce 240 to 600 cu m/d. Many wells were reported to produce only 36 to 120 cu m/d. Four major hotels, four seafood/food-beverage processing plants, three ice plants, and at least five institutions may have a combined pumping capacity of about 15,000 cu m/d. However, many of these wells are not operated on a 24 hour basis. Production may vary from 3,000 to 9,000 cu m/d (average of 4 to 14 hour operating schedule).

The combined production of Tirtanadi, Port of Belawan, and other private/institutional wells probably lies between 12,000 and 18,000 cu m/d. An intermediate value of 15,000 cu m/d would equal 5.48 cu m/y. This production, however, is restricted to a narrow development corridor of 3 km (E-W) and 25 km (N-S) between Medan and Belawan. This area would have an average annual production rate of about 73,000 cu m.y/sq km. No average or modal rates can be estimated for all the wells in Medan and Belawan, but most wells produce less than 50 cu m/d.

E-1.6 GEOHYDROLOGY

E-1.6.1 Water Levels and Specific Capacity of Wells

The water levels in the well casings indicate the pressure acting upon the groundwater in the deep aquifers. Differences between the static and pumping water levels is called drawdown and the amount of drawdown per volume withdrawn from the aquifer gives an indication

TABLE E-1.3

AVERAGE MONTHLY PRODUCTION FROM PORT OF BELAWAN WELLS
WELLS AND MONTHLY PRODUCTION (in 1000 cu m/mo)

Year	1*	2*	10*	13*	14*	16	17	18	19	20	Total
1972	12.3**	2.8	23.9	40.0	3.1	-	-	-	-	-	82
1973	7.0	5.7	14.6	26.8	18.7	-	-	-	-	-	71
1974	13.0	5.3	21.5	18.7	23.4	-	-	-	-	-	82
1975	12.6	3.1	18.1	30.0	20.0	6.1	-	-	-	-	90
1976	8.6	3.8	20.0	17.0	16.4	4.3	-	-	-	-	70
1977**	7.4	-	16.7	15.8	11.4	24.4	15.3	15.1	-	-	190
1978	9.6	-	6.2	5.3	6.8	26.8	23.1	10.1	37.3	62.3	193
1979	7.0	-		6.1	8.4	30.8	30.3	5.4	33.5	71.4	193
Average Daily Production 1979 (cu m/d)	236	-	-	-	200	280	1,027	1,010	180	1,117	6,430

* Wells 1 and 2 began pumping in 1952, 10 in 1971, and 13-14 in 1972. Other wells began production in years of first record.

** Total includes 84,000 cu m/mo from five wells during three months before wells were transferred to Tirtanadi

of the permeability and storage of the aquifer. A small volume per metre drawdown indicates that the aquifer is either small or has a low permeability, or both, while a very small drawdown indicates that the aquifer holds a large volume of water which can move rapidly through the aquifer.

Regional water levels indicate the direction of flow in the aquifer, much as pressure levels in a water pipe indicate the direction of flow (Figure E-1.4). Differences of water level elevations will also indicate the head loss or amount of energy lost in flowing water from one point to another in the aquifer. Long term regional records may indicate the effects of large scale production, droughts, and possible changes in the hydraulic conditions of the aquifers.

Water levels in Medan and Belawan have not been recorded systematically over the entire region nor at any well over a long period. Some initial and existing values, historic records, and physical structures suggest some trend in well production and the condition of the aquifer. No record of long-term production is available for the entire basin, although most long-term production has occured in Belawan.

During the early part of this century, well drilling logs indicated well water levels in Belawan rose to above ground level (+0.5 to +1.5 m). Drillers have reported that coastal aquifers to the north presently have artesian flows above ground level. Well No. 20 was reported to have had a +0.25 m water level above ground level in 1977. Early designs of Belawan and two Medan wells used artesian flows to fill underground tanks from which water was pumped, and the elevations of these structures suggest that artesian flow occured from +0.5 to -3.0 m from ground surface. No well in Belawan or Medan had well water levels above ground surface, although some were within a few metres of surface. Therefore over a span of 30 to 80 years, the water levels from the deep aquifers has fallen from ground level or above down to about 3 m below ground level.

This loss could occur from withdrawals of well water at a rate higher than the rate of recharge, from reduction of rainfall recharge ('droughts'), or from changes in land uses and recharge rates in the areas of deep aquifer infiltration. No readily apparent decrease in annual rainfall appear in available records. The infiltration areas are not defined, although increased growing of rice should increase the flooding of lands and the rates of infiltration in many areas. Groundwater production has been significant over at least the last ten years and this factor should be most related to declines in water levels.

Regional water levels can be seen in Table E-1.4 and vary from 3.0 - 5.0 m below ground surface in Belawan to 6.0 to 13.0 m below ground in Medan. Elevation of the ground level in Medan varies somewhat, although the wells generally lie between 20 and 35 m elevation. In Belawan, all wells lie within 1.0 to 2.0 m above sea level. Water levels vary from 20 to 25 m elevation in Medan to about 1.0 to 3.0 m below sea level in Belawan. The maximum distance between known wells is about 20 to 25 km. Therefore the slope of the hydraulic grade line on the intermediate and deep aquifers is about 1.0 m/1,000 m toward Belawan (south to north). Groundwater flows towards Belawan and appears to follow the general slope of the ground surface.

GROUND SLOPE STATIC WATER LEVELS AND REPRESENTATIVE PUMPING WATER LEVELS FROM MEDAN TO BELAWAN

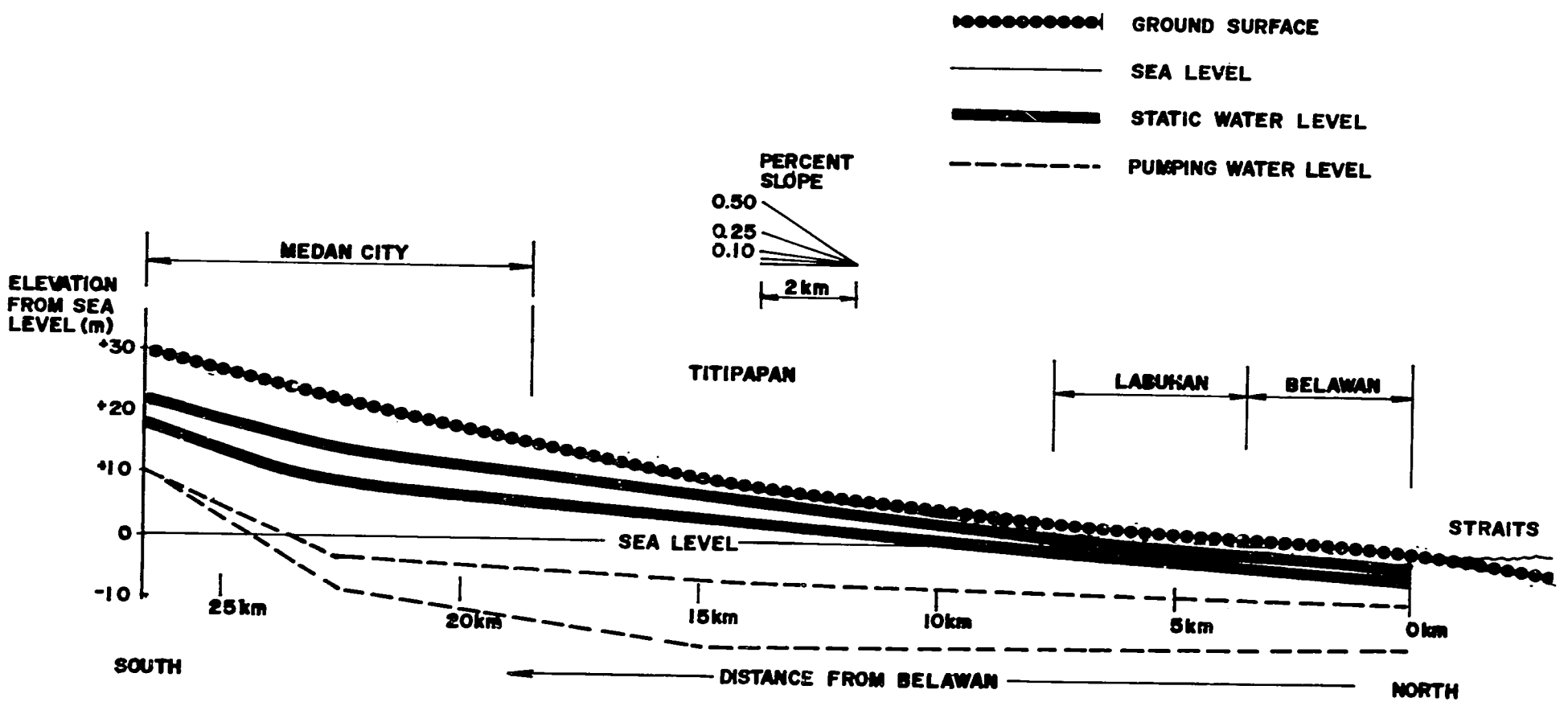

TABLE E-1.4

WATER LEVELS, DRAWDOWNS, AND SPECIFIC CAPACITIES FOR WELLS IN MEDAN AND BELAWAN WATER LEVELS

Well No. or Site	Static	Pumping	Drawdown (m)	Production (m 3/d)	Specific Capacity (m 3.d/m)
Belawan					
3(PAM)	-3.9 to	-	-	-	-
	-4.6	-	-	-	-
5(PAM)	-4.2 to	-	-	-	-
	-5.1	-	-	-	-
6(PAM)	-4.6	-7.5	3.0	360	120
7(PAM)	-4.5	-6.9	2.4	340	142
9(PAM)	-3.0	-6.5	3.6	720	200
11(PAM)	-3.4	-11.0	7.6	1,200	158
12(PAM-ES)	-2.9	-8.9	6.0	840	140
12(PAM-POB)	-2.8	-4.5	1.7	432	254
14(POB)	-2.8	-4.5	1.7	360	212
16(POB-ES)	-5.0	-18.0	13	1,300	100
16(POB)	-4.0	-7.0	3.0	1,300	433
17(POB)	-4.0	-11.5	7.5	1,300	173
19(POB-ES)	-3.5	-11.8	8.3	1,440	173
19(POB)	-0.8	-18	17.2	1,870	109
20(POB-ES)	-3.8	-7.2	3.4	2,690	791
20(POB)	+0.3	-5.0	5.3	1,870	353
Medan					
Rispa 1 (No. 78)	-12.8	-	-	-	-
Rispa 2-ES (No. 78A)	- 5.6	-10.1	4.5	240	53
Danau Toba (No. 63)	-10	-42	32	768	24
	- 8.3	-38.0	29.2	720	25
Indra Deli 3-ES (No. 60)	-11	-16	5	480	96
Polonia Hotel	-10	-50	40	1,440	36
Darma Deli Hotel	-12	-20	8	820	102
Intan Nat'l	-12	-22	10	600	60
Iron INI-ES	-12	-28	16	600	38
Ice Mabar	-10	-	-	-	-
Herna Hospital	- 8	-28	20	960	48
Asrama Police Barrack	- 6	-12	6	600	100

Specific capacity (cu m produced/m drawdown) of wells provides a measure of the well efficiency and the aquifer productive capacity. Available records and a series of water level measurements were made for more than 10 wells in Belawan and Medan (Table E-1.4). Some wells had earlier recorded water levels and comparisons could be made. Generally production has declined in most wells, and where water levels are known less water is now produced per metre of drawdown. Declines in capacity have occured at the same time as regional static water levels have declined, and discrimination of effects of poor well construction from aquifer production cannot be made with the available data.

Comparisons of the Belawan and Medan wells and drawdown (Table E-1.4) quickly show differences of specific capacity in the two areas. Wells in Belawan had specific capacities from 100 to 790 cu m.d/m drawdown with common values between 100 and 200 cu m.d/m. In Medan, specific capacities vary from 24 to 102 cu m.d/m. Such differences suggest that either the aquifers in Medan had smaller storage, porosity, or permeability or the wells in Medan are not built as well as those in Belawan. Visual inspection of the facilities and reports of the drilling machines used on the wells and well construction would support the latter reason for poor specific capacity in the Medan wells.

In both Medan and Belawan, proper construction and operation have produced up to 100 cu m.d/m drawdown. If this capacity can be applied to new prospective wells, a well which produced a 1000 cu m/d would have a drawdown of only 10 m. Static water levels in Medan were 5 to 12 m below ground surface, and new production pumps would need to be set at greater depths than 25 m below surface and require a pumping head of 60 to 80 m. Pumps of 15 to 20 HP could provide this volume with this head.

E-1.6.2 Storage Capacity

Storage capacity is the volume of water which can be held in the aquifers beneath Medan; it equals the porosity (percent of open space) times the volume of the aquifer. The water level of the aquifer does not directly reflect the storage capacity, although the pressure may have expanded the aquifers' capacities. The effective storage capacity relates to the amount of water which can be withdrawn from the aquifers over a very large area and which will cause the water levels to decline by a unit value. Specific yield relates to the total amount of water which can be drained from a unit volume of aquifer; specific retention equals the amount of water remaining in the aquifer after draining the specific yield (specific yield + specific retention equal total volume of water held in the aquifer). Reported porosities of aquifers in Belawan and east Medan vary from 20 to 30 percent, and a specific yield of 10 percent would be a conservative estimate for the aquifer.

Storage capacity for the Medan aquifers is equal to the groundwater development area of Medan, times the effective aquifer thickness, times the specific yield, which has been estimated as follows:

East Medan

6,000 m (E-W) x 15,000 m (N-S) x 70 m (thickness) x 0.10
= 630,000,000 cu m
= 7.0 cu m/sq m land area or 70,000 cu m/ha

West Medan

8,000 m (E-W) x 10,000 m (N-S) x 70 m (thickness) x 0.10
= 560,000,000 cu m

Belawan Corridor

3,000 m (E-W) x 15,000 m (N-S) x 70 m (thickness) x 0.10
= 315,000,000 cu m

Total of 1,505 M cu m

This volume is about 21.5 M cu m per metre of aquifer but is not directly related to drawdown of water levels in the well casing. This volume equals a conservative estimate of the specific yield.

Water levels in wells penetrating a pressurized aquifer reflect the total water column in the aquifer and its horizontal extensions. If water movement occurs in the aquifer, then pressure will diminish in the direction of flow; in the Medan study area, water levels fall towards Belawan and are below sea level in Belawan. In a static aquifer, water levels should be identical in all wells penetrating the same aquifer.

When withdrawals exceed the inflow to the total aquifer, the pressure levels will fall and eventually reach the depth at the top of the aquifer, in Medan it is assume to be at about 70 to 90 m below ground surface. If pumping continues, the water level will fall and water will drain from the aquifer - this represents the specific yield and water remaining in the aquifer is specific retention. Decline of the pressure level in well does equal a fall in the water level in peripheral extensions of the aquifer.

E-1.6.3 Subsurface Flow

Groundwater travels through the intermediate and deep aquifers from its recharge areas, probably to the south, to its discharge or outflow areas beneath the Straits of Malaca. Neither recharge nor outflow areas are known, although the flow from south to north can be estimated. The outflow represents that volume which is discharged without beneficial human uses. In order to compute the outflow, the values for the wetted cross-sectional area of the aquifer, the slope of the hydraulic gradient of the aquifer and the permeability of aquifer had to be determined.

The outflow section was considered to be 3 km in width, which is the width of the coastal zone formed by the Belawan and Deli rivers. The effective aquifer thickness was measured in several wells as at least 70 m (about 70 percent of a total 100 m). Slope of the hydraulic gradient between Medan and Belawan was estimated to be 0.001 which is based upon well water levels. The transmissivity of the aquifer was computed from pumping tests performed for the Port of Belawan during a previous study. Their value for T which is utilized herein is 565 cu m d/m.

Based on this value for T, the permeability of the aquifer was computed by the following formula:

$$P = \frac{T}{m}$$

where P = permeability
T = transmissivity
m = aquifer thickness

$$P = \frac{565 \text{ cu m.d/m}}{70 \text{ m}} = 8.07 \text{ sq m.d/m}$$

Using Darcy's equation for underflow:

$$Q = PIA$$

where Q = subsurface outfloor
P = coefficient of permeability
I = slope of the hydraulic gradient
A = wetted cross sectional area

Q = 8.07 m/d x .001 x 3000 m x 70 m
= 1695 cu m/d
= .02 cu m/s
= 20 l/s

E-1.6.4 Safe Yield

The storage capacity beneath Medan is estimated at about 1,500 M cu m or 22 M cu m/metre of aquifer thickness. Assuming no natural recharge enters the aquifer beneath Medan, one metre of aquifer thickness could supply about five years of production at 12,000 cu m/d (all existing wells). At somewhat lower averaged rates over the last 30 years (9,000 cu m/d), the decline in water levels should have been between 4.0 and 5.0 m, and more than that seen in Belawan about 3 m in 30 years. Such relationship suggest that either:

1. Recharge has an inflow of about 1.1 M cu m/y (3,000 cu m/d) and has balanced some withdrawals,

2. The aquifer is more widespread than presumed with an even larger volume per metre thickness of aquifer, but smaller recharge,

3. The aquifer is less widespread but with much higher recharge,

4. The lowered water levels in deep wells only reflects local concentrated pumping, and

5. Some combination of all the above (1) to (4).

These divergent alternatives clearly demonstrate the need for substantial increases in the amount of geohydrological data before any reasonable

estimate of groundwater resources can be made. Such data should describe:

1. Form and continuity of the aquifers

2. Location of recharge and outflow

3. Total withdrawals from groundwater

4. Pressure gradients on the deep aquifers

5. Local and regional drawdown, and

6. Porosity and transmissivity.

As an indication of the potential yield for the aquifer, the estimated available storage capacity of 1,500 M cu m and 22 M cu m/m aquifer thickness could be withdrawn over a period of 30 years at the rate of 50 M cu m/y. This equals a daily production of about 140,000 cu m/d. Such production withdrawal would lower the water level in the aquifer by about 2.3 m/y without only recharge.

All major aquifer under Medan are being recharged, but the rates of regional recharge and movement to replenish specific areas may be slower than the rate of withdrawals from the aquifers. As indicated above the rate of outflow in Belawan is equal to about 1,700 cu m/d with a withdrawal of about 9,000-12,000 cu m/d. This presumes a regional hydraulic gradient of about 0.1 percent (0.001). With increased withdrawals in Medan, the gradients towards central Medan should increase and inflow towards the production wells should increase the replenishment of the producing portion of the aquifer. The inflow will increase towards the permeability of the aquifer sediment. After the rate of inflow reaches the permeability value, no increase will occur and additional withdrawal will lower groundwater volume held in storage - i.e. mining the groundwater.

The hydraulic gradients on aquifers under Belawan is inclined towards the Straits of Malaca, and deep groundwater flows towards the Straits. If pumping in Medan depresses the regional groundwater pressure levels, the existing flow towards the Straits may be reversed and groundwater will begin to flow southward towards the Medan wells. Sea water may then infiltrate the aquifer under the Straits, and move towards and eventually pass the wells at Belawan. Sea water has not been observed in any Belawan wells which has been properly drilled, 10 of 20 wells.

E-1.7 GROUNDWATER QUALITY

The quality of groundwater in the Medan study area is best known from the Belawan wells operated by P.A.M. Tirtanadi. Other records are also available for some wells operated by the Port of Belawan. Single records of initial water quality for private wells have been gathered for only eight wells. Drilling contractors report a general improvement of water quality with greater depth down to about 200 or 240 m below

the surface. Wells deeper than this may enter the Tertiary bedrock and may encounter some natural gas and oil. Only one well (Port Well No.15) has been abandoned due to poor water quality; salt water contamination was attributed to improper sealing of the casing and leakage of contaminated shallow groundwater. Some preliminary analyses for iron have indicated valves of 0.5 to 2.5 mg/l.

Since most wells have long gravel packs (perhaps 100 m) which drain several aquifers, poor quality in the upper aquifers and better quality only in the deeper aquifers cannot be verified or refuted. The shallow groundwater table above 10-15 m below the surface can be assumed to be contaminated by bacteria, ammonia, hydrogen sulphide, and other chemicals. Presumed iron contamination of the aquifers between 80 and 150 m below surface may indicate leakage of contaminated shallow groundwaters into the deeper aquifers. River and the Sibolangit spring waters contain concentration ranges for iron of 0.3-2.8 mg/l and for chlorides of 0.7-17 mg/l. These are similar to those found in the groundwater.

Since the rivers and the groundwaters in the mountains to the south do contain significant levels of iron and chlorides, the groundwater below Medan and Belawan would be expected to contain similar levels of these elements, and the occurence of better quality water at greater depths could be explained by infiltration of the better quality water from some source other than that of the local rivers of the related aquifers supporting the Sibolangit springs.

Although the temperature of water is not of great significance for the overall quality of water supplies, a trend of higher temperatures in the groundwater was found from Medan to Belawan. Water temperatures in Medan were about 27°-29°C, 30°C in Titipapan and Labuhan, and from 31-33°C in Belawan. The temperature of groundwater from 100 m or more below the surface would be normally expected to reach at least 3-5°C warmer than the mean annual surface temperature; for Medan, temperatures of surface water samples ranged from 25° to 28° with a mean annual temperature of about 26°C. Thus the deep groundwater temperatures appear to be slightly cooler than would be expected based upon the surface temperatures and the geothermal temperature gradient of about 1°C per 30 m depth. Temperatures of the spring waters of Sibolangit vary from 23° to 25°C, and water from the same aquifer could contribute such cool water to the Medan and Belawan aquifers with some increase in water temperature as the water flows northwards. More detailed studies of the water temperature profiles within the water wells could provide indications of leakage of shallow waters into the deeper aquifers or the mixing of water in the deep aquifers.

In general the water quality of many wells appears to be equal to the water quality of some samples of the rivers or the springs. Although iron is reported at undesirable levels in the groundwater, no restriction is placed against the use of surface or spring waters with similar levels. Surface and well water in other cities and parts of Sumatra have similar water quality.

APPENDIX E-2

WELL DRILLING AND EXPLORATION PROGRAM

E-2.1 GENERAL

Because groundwater can be developed in small increments, is generally less expensive and more reliable than surface water sources, and can be located close to areas of immediate need, it is an extremely attractive source of supply for the chronically capital-short local water utility. Unfortunately, the existing data base for groundwater is limited to the extent that large-scale groundwater exploitation in the area should be approached with some caution. A staged program of production and test well drilling and geohydrological investigation aimed at expanding present knowledge of the local groundwater basins to the point where rational decisions regarding feasibility and staging can be made is developed in the following sections.

E-2.2 OBJECTIVES

The proposed drilling and testing program has four major objectives:

1. Determine the lithological, hydrological, and chemical character of the major aquifers underlying Medan.

2. Test well design modifications which will reduce costs of wells, improve operational reliability and life-time, and increase production capacity with less interference and power costs.

3. Explore the infiltration area and areal extent of the aquifer system below the existing and future area of Medan.

4. Confirm or modify preliminary geophysical surveys of aquifer character in Medan.

These objectives are directed towards the confirmation or modification of interpretations made under the present investigations from existing data and the establishment of guidelines for practical implementation of a drilling program in Medan during the next five years.

E-2.3 FINANCIAL CONSIDERATION

The contract under which the present investigations are being carried out provides Rp. 58,000,000 for a subcontract to construct test

wells, as well as an option to provide an unspecified amount of hydrogeologist time to coordinate the drilling program and analyze results. Although these items were originally intended to encompass a four well testing program, the rapid rise in construction costs experienced in Indonesia during the last year would result in a reduced program.

The magnitude of the groundwater exploration required to establish the feasibility (or non-feasibility) of further groundwater development is unfortunately considerably greater than can be accomplished with the available funds. In order to recognize this short-term financial constraint, and at the same time provide a complete program which can be implemented as future funding availability permits, the proposed exploratory program has been divided into two stages: (1) high priority elements which can be accomplished within the funds available under the present contract, and (2) other items which are necessary to establish a reasonable basis for future water resources management decisions.

The first stage well drilling program is aimed at obtaining geohydrologic data, while the second stage includes the development of production wells which would provide water to existing areas of undersupply within the Tirtanadi system. Wherever possible within the constraint of program data requirements, wells already scheduled for construction by Tirtanadi have been incorporated into the exploratory program.

E-2.4 LOCAL WELL DRILLING CAPABILITIES

Within Medan, North Sumatra, and Indonesia, numerous drilling contractors have drilled and tested water wells similar to the design proposed for this test program. Many have drilled wells within the Medan vicinity, but these wells have been drilled and developed with little regard to the regional productivity. Therefore, sufficient equipment, experience, and personnel are available within Sumatra and Indonesia to construct wells and operate the tests of the wells. At present, at least five drilling rigs are available within Sumatra for drilling the size and depth of well required for the proposed drilling program.

E-2.5 EXISTING DATA

During the course of the present investigation, all available information and data regarding surface and subsurface geologic features of the area were collected and evaluated. Analyses of subsurface geohydrologic characteristics were based upon approximately 40 water well drillers' logs and some historic and present water level data.

A previous electrical resistivity survey which covered part of the Belawan Road Corridor and a small area of the eastern Medan area provided some indication of the underlying hydrogeology. Priority should be given to drilling test wells in those areas in order to verify the electrical resistivity survey results.

When all data points were plotted on a map of the study area, irrespective of the type of data utilized, the points fell within a very narrow north-south trending data "corridor". Little if any data were available east or west of this corridor, which maintained an average width of approximately three kilometers.

E-2.6 GROUNDWATER SECTORS

The study area can be divided into seven sectors for groundwater study (see Figure E-2.1). Eventually, a series of test and observation wells should be located in each sector.

E-2.6.1 Belawan

In the Belawan Sector, test or observation wells should be installed near the existing Wells numbered 3, 5, 9, 12, and 20. The latter four are the important production wells, while 3 and 5 are close to potential saline water interfaces.

E-2.6.2 Labuhan and Titipapan

The Labuhan and Titipapan Sector largely depends on well water for numerous industries and housing projects along the Belawan Corridor. Many future industrial developments in the corridor may continue to depend upon the deep wells for water supply. Test and observation wells in this sector would guide groundwater development strategy and verify results of a small ground resistivity survey. Deep groundwater is expected to flow from south to north and the water drawn form the Belawan Sector has passed or will pass beneath the Labuhan-Titipapan Sector. Systematic monitoring of water levels and production in this sector would indicate when changes of water level and pressure gradients occur and if such changes will adversely affect the Belawan wells.

E-2.6.3 Medan Timur

The Medan Timur Sector includes the northeastern edge of Medan and the southern end of the Belawan corridor. Existing water supply comes largely from the Sunggal Treatment Plant, although the previous ground resistivity survey indicated considerable potential for groundwater development lies beneath this sector. Test and observation wells in this sector would determine the groundwater potential indicated by the ground resistivity survey and provide additional information regarding the aquifer continuity between Medan and Belawan. Development of the potential supply under the northeastern sector would reduce the long transmission distance for water from the Sunggal and provide an additional source for the southern end of the Belawan corridor and perhaps even Belawan.

E-2.6.4 Medan Denai

Groundwater potential in Medan Denai (East Medan) has been assessed by the ground resistivity survey for P.A.M. Tirtanadi. The survey has not been confirmed from well log data, and such confirmation will provide important guidance for groundwater development in the entire

eastern area of Medan. Confirmation will also provide calibration of the methods for application in other areas of Medan. Major residential development in east Medan has been inadequately provided by existing water supply, and production wells in this area would provide immediate and substantial supply for poorly served users.

E-2.6.5 Central Medan

The Central Medan Sector generally includes the commercial center of Medan along the Deli River to the Polonia Airport, and Tirtanadi provides most water supply. Several deep groundwater wells serve high consumption commercial and institutional users. Test and observation wells in this area would provide estimates of the local safe yield and potential interference of existing and future wells in the area. Such wells would continue the line of control points for monitoring of the regional groundwater slope and groundwater movement in the deep aquifer under Medan and the Belawan Corridor. New wells near the Tirtanadi ground and elevated reservoirs on Jln. Singamangaraja could augment public water supply to the poorly served eastern sectors.

E-2.6.6 Johor

The Johor Sector is presently supplied by pipeline from the Sibolangit Springs. Groundwater and surface resources have been used by a few institutions but the total demands are not great. The major groundwater importance of this sector involves its southernmost location in a regional groundwater flow from south to north. Inferred infiltration areas in the hills and along the rivers to the south may supply most water for recharge of the groundwater table from Medan to Belawan. Monitoring of groundwater levels and velocities in this area would provide an indication of long-term productivity in the central and eastern regions.

E-2.6.7 Medan Baru - Sunggal

The Sunggal Sector is largely supplied by water from the Sunggal Plant and only requires additional supplies for specific institutional users. However, Tuntungan and southern Sunggal districts may provide significant infiltration areas for the regional aquifer. Test and observation wells in this sector would complete the monitoring system for water levels, groundwater gradients, water quality, and productivity. The groundwater features in this southwestern sector will provide indications of long-term groundwater flow and productivity in the western region. As demands in the west side and throughout the city expand, the effective service area of the Sunggal Plant will diminish. Long-term groundwater monitoring would indicate the general availability of local groundwater in order to supplement the central and northern water supplies.

E-2.7 RECOMMENDED DRILLING PROGRAM

The recommended drilling program has been developed in two parts:

1. A basic well program of first priority to demonstrate local production capacity and groundwater yields.

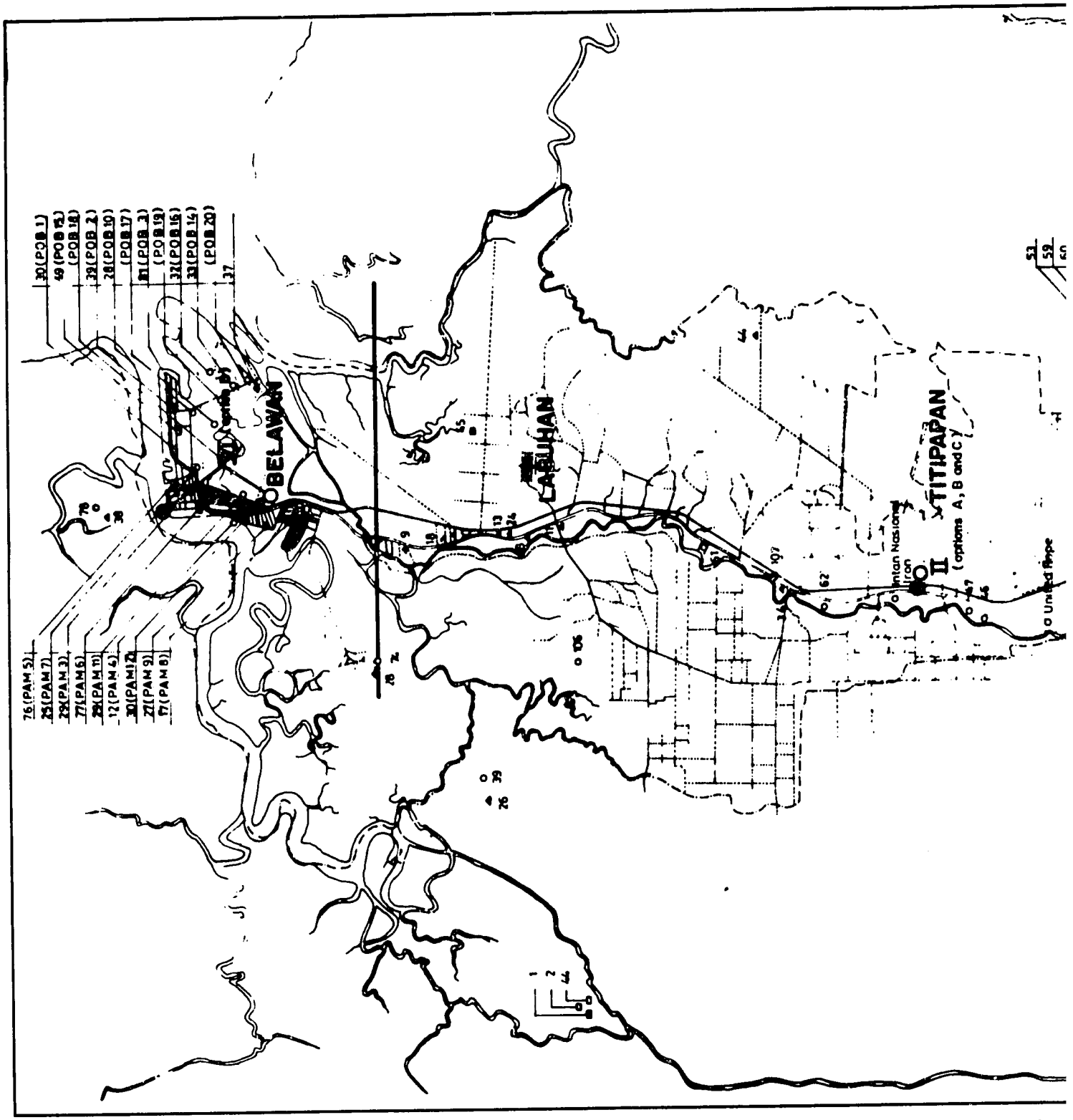

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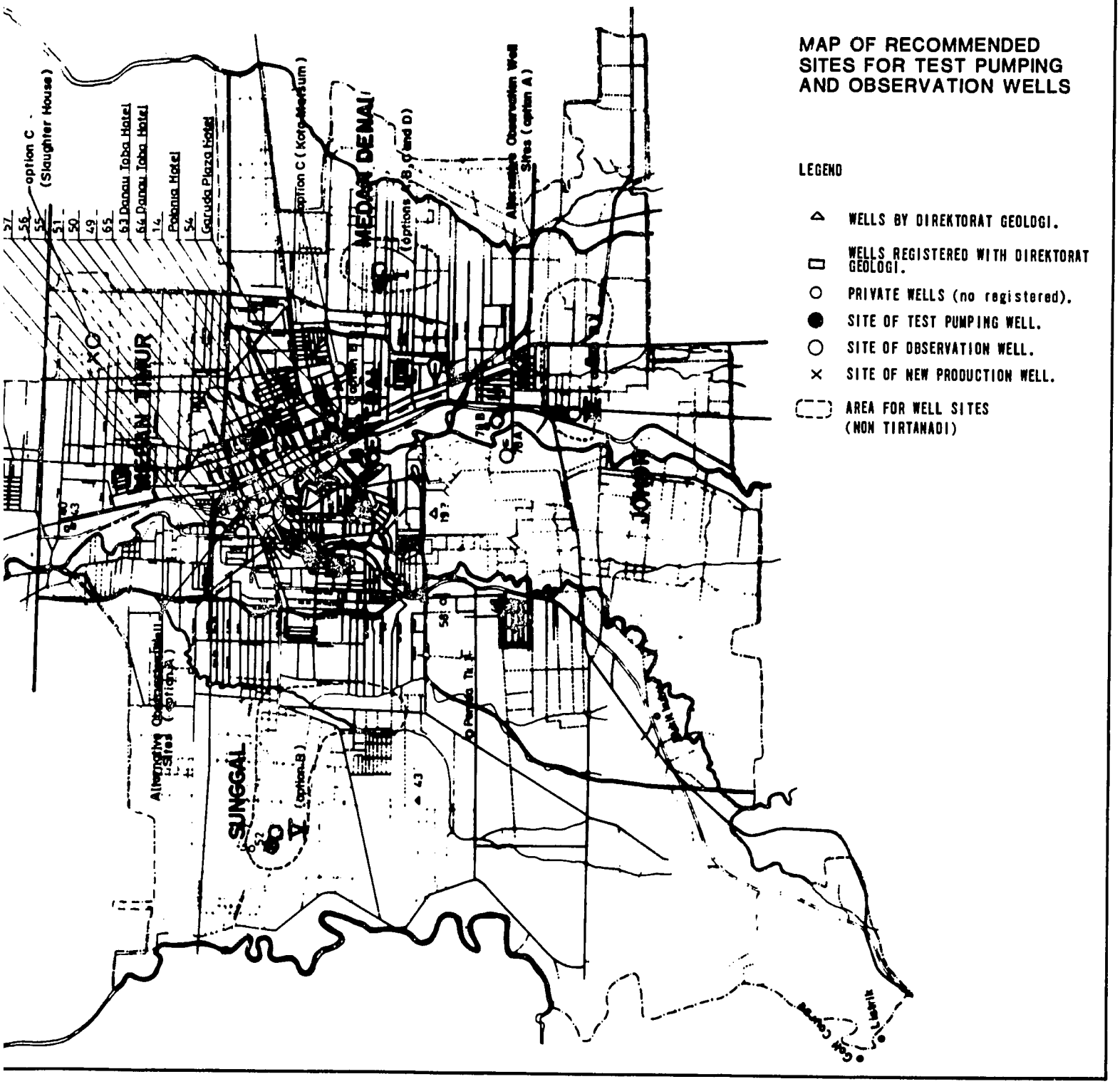
FIGURE E-2.1



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2. An expanded well program to demonstrate the regional groundwater yields and flows and to provide for long-term monitoring.

The first element (Option A) is limited by existing contractual funding, while the expanded program (Option B) would require additional funding from other sources. Detailed requirements for the program are presented in the attached Test Drilling Specifications.

E-2.7.1 Program Priorities

Highest priority has been given to collection of data which will allow reasonable estimates for the maximum well and aquifer production capacity. Within this general category, greater emphasis is given to increasing well capacity within high demand areas, while long-term, regional safe yield is given secondary emphasis. Beyond data collection, secondary priority is assigned to testing new well designs which will demonstrate maximum well production efficiency and reduce unit production costs. Final priority relates to provision of training and the immediate water supply from the test wells in areas of high need.

E-2.7.2 Program Description

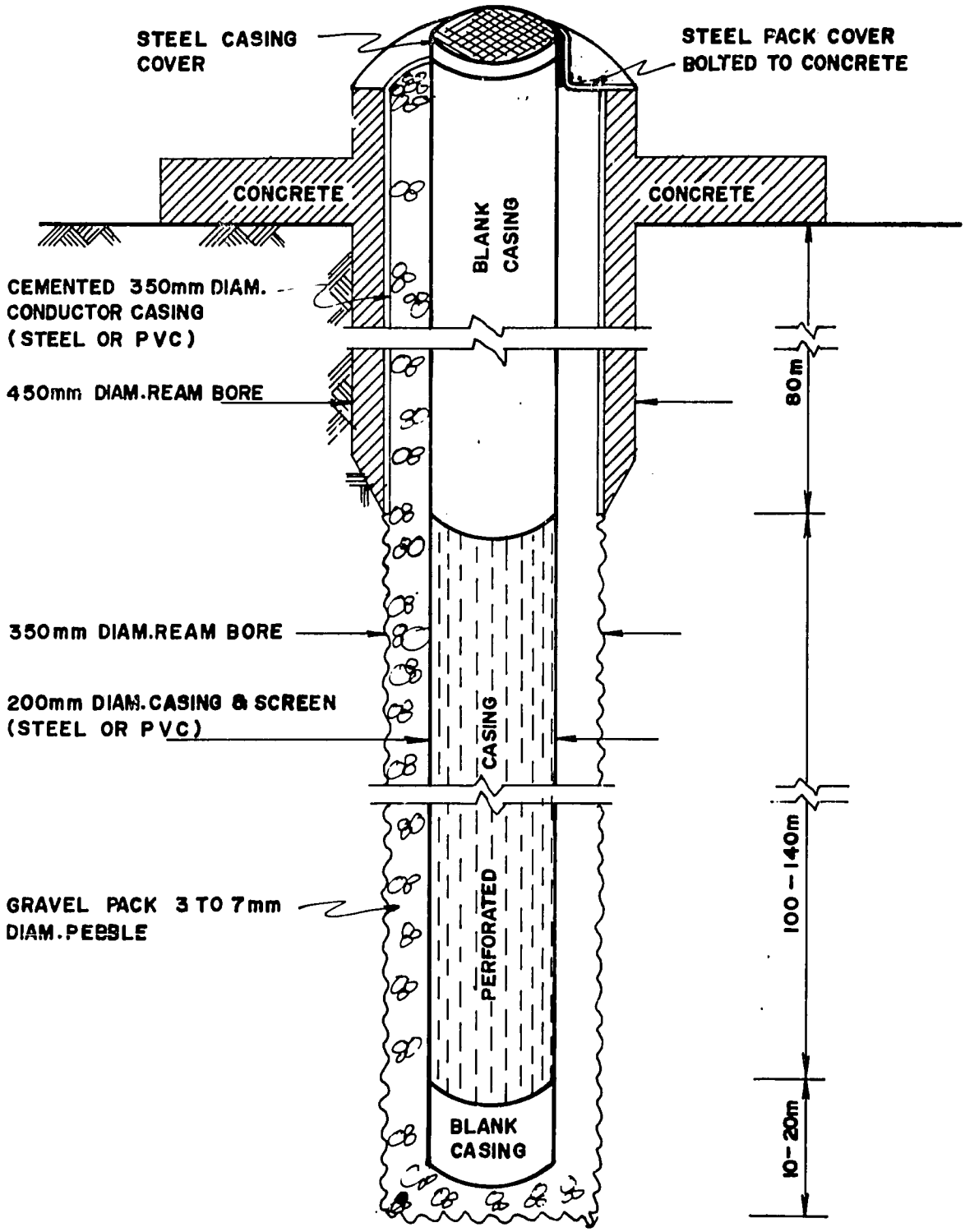
General designs for test and observation wells are presented in Figures E-2.2 and E-2.3. The test well design includes larger diameter boring and casing-screen than those of existing standard production wells. Provision is made for sealing the well head structure, sealing off shallow aquifers, and for adding gravel throughout the operating life of the test well. Unperforated casing is added at the bottom of the screen in order to provide a sand trap which could be cleaned periodically. Such a design should insure greater production and efficiency than local standard well designs.

The observation wells may be of somewhat shorter depths than the production wells but would be constructed to monitor water quality and pressure in the intermediate and deep aquifer system. Specific lengths would be determined following the drilling of the test well and analyses of boring and electrical logging data.

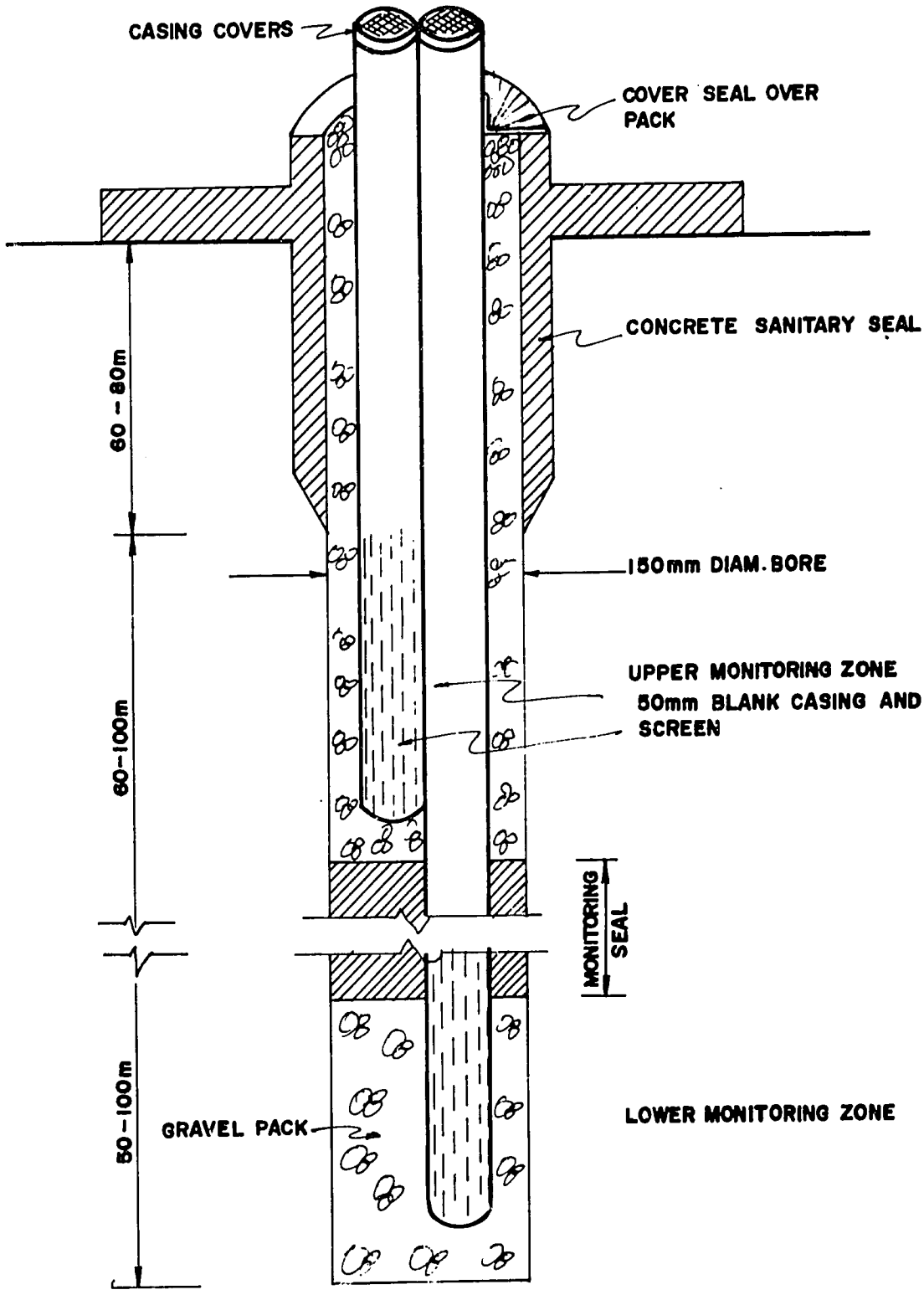
Testing of wells would be conducted following standard production testing methods with water level and water quality samples being taken from the test and observation wells during the testing. Following the final development of the test and observation wells, a pump would be mounted in the well casing. In stages, measured volumes of water would be pumped from the well for several hours while the water levels within the well casing would be measured. After the pumping water levels had stabilized for each pumping rate, the rate of pumping would be increased. Continuous plotting of water levels and pumping rates would indicate, eventually, a pumping rate at which further increases would cause significantly greater drawdowns of water levels in the casing. Water quality samples would be taken at the maximum rate of well production capacity. Water levels and water quality samples in the observation well would be taken at the same time as those in the test well.

FIGURE E-2.2

SCHEMATIC DRAWING OF TEST PUMPING WELL



SCHEMATIC DRAWING OF OBSERVATION WELL



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Option A - Basic Drilling Program

Option A would include drilling and logging of two test wells and four observation. Production and water level tests would be made on the two test wells. The two test well - observation well combination would be located in Medan Denai and Titipapan, while the two observation wells associated with existing production wells would be drilled in Central Medan and Johore. One or both of the test wells would be drilled to a larger diameter than typical production wells and may use plastic casings. Actual finished depths and diameter of wells would depend upon analysis of stratigraphic and resistivity information. Depending upon the quality of data obtained during initial phases of the program, a third set of test and observation wells could replace the recommended observation wells in Central Medan.

The first test well in Medan Denai would provide important stratigraphic, hydrologic, and chemical data for the unknown aquifers in eastern and northeastern Medan. Verification of the interpretations of the ground electrical resistivity surveys by this test well would greatly improve the reliability of the survey interpretation in Medan Denai, Medan Timur, and Titipapan.

No test well is included in the Medan Timur sector at this time, since the sector lies immediately north of the Medan Denai and was included within the original ground resistivity survey. Survey interpretations in Medan Timur should be consistent with those in Medan Denai, and the test well in Medan Denai will verify or modify interpretations in the Medan Timur area.

The second test well would be located in Titipapan and would provide data from the aquifers connecting Medan, Labuhan, and Belawan. Well data would also verify or modify the interpretations of a local ground electrical resistivity survey which indicated significant stratigraphic changes along the eastern edge of the principle aquifers. Existing and projected water demands in Titipapan and Medan Timur will require expansion of the existing transmission system from the Sunggal Plant or local groundwater production. Therefore, proven groundwater production capacity in Titipapan would greatly relieve supply and transmission problems in the next few years.

Location of the two separate observation wells would be selected based upon the information derived from the drilling of the test wells. If technically desireable and financially feasible, a third test well and one of the observation wells may be drilled in Central Medan at the offices of Tirtanadi. If funds are inadequate for this, then one observation well could be located near an existing production well in Central Medan (e.g. at a major hotel or a factory).

The second observation well would be located either in Johor or perhaps in Medan Timur. Final selection would depend upon consistency of well data and interpretations of the ground resistivity surveys in Medan Denai and Titipapan. If good correlation exists between the wells and surveys, then the second observation well would be drilled in Johor.

However, if correlations are poor, then the observation well should be drilled in the Medan Timur area at the site of one of two existing production wells in Medan Timur.

This locational alternative reflects the greater priority given to verifying data and interpretations from the ground resistivity surveys which cover a large high demand area in eastern and northeastern Medan. The next most important area for data would be in the Johor sector to help define the probable area of infiltration or of entrance for groundwater into the aquifers which can be used for effective municipal groundwater production. The Johor well would provide a valuable data point for hydrological characterization of the entire aquifer system east of the Deli River.

Option B - Expanded Program

Long-term regional water production depends upon the overall safe yield of the groundwater basin. A reliable estimate of long-term yield requires long-term monitoring and use of production and observation wells. Option B therefore recommends an expanded number of wells and a longer testing and evaluation period. The proposed test wells could be connected to the existing distribution system for immediate supply benefits.

Drilling and operation of six production wells and long-term monitoring of the wells require adequate staff which would become very important with a large groundwater development program. As a separate element within Option B, a basic training program of Tirtanadi staff, both in the US and locally, should be included.

The drilling program in Option B would include the recommended test and observation wells in Medan Denai and Titipapan and add test wells in Johor, Central Medan, Medan Baru-Sunggal, and Belawan. Ownership and daily production of wells may require different sites in Johore and Central Medan from those recommended in Option A. The Central Medan test well site would be located at Tirtanadi, while the test well site in Johor would be located along the southern margin of the sector, near major transmission pipelines.

Test and observation wells in Medan Baru-Sunggal would provide data regarding a largely unknown groundwater area which also may be a major infiltration area for the Medan aquifers. Inclusion of these wells in Option B reflects the lower priority of this area for groundwater supply, since the area is and will be supplied from increasing production at the Sunggal Plant.

A combination of one test well and one observation well in Belawan would provide stratigraphic data for existing production wells and hydrological data for wells near the potential sources of sea water intrusion and at the greatest distance from potential intrusion and therefore potential sites for future wells.

E-2.7.3 Drilling Site Selection

The recommended drilling program allows considerable flexibility in final selection for the drilling of both test and observation wells. Specific site selection should be based upon costs, accessibility, and other more practical and technical requirements. Long-term monitoring in both options and production in Option B suggests that some sites be owned or dedictated for use by Tirtanadi. In order to meet budgetary constraints within Option A, only one test well and observation well could be located on Tirtanadi property, while other sites could be leased for the period of the drilling and testing program and then returned to their owners. In Option B, property could be either in Tertanadi ownership, purchased or leased by Tirtanadi, or dedicated by other government agencies for exclusive use by Tirtanadi (e.g. on military or police compounds, city property, or school and other institutional grounds).

A series of candidate sites have been located and serve as an application of site selection criteria for this drilling program and future production well siting. Test wells should be located on sites which are adjacent to existing paved roads, have 220/380 electrical power supplies and transformers nearby, are within 200 m of a major drainage canal, and have at least 200 square metre clear land area. Site could be located in an area equivalent to two vacant house lots, in parking lots, equipment storage areas, school playgrounds or small parks, and unused railroad rights-of-way. This land use flexibility and the general physical requirements can allow numerous potential sites in any one area. Therefore final site selection commonly focuses more on the ease of acquisition and cost of the land per square metre.

The test well site in Option A and sites for three other test wells and three observation wells in Option B could be located on lands owned by Tirtanadi in Central Medan, Titipapan, and Belawan. Site selection of the test well and observation well in Medan Denai is more limited due to data requirements to verify the ground electrical resistivity survey. The test well must be sited at least 500 m east of Bakti Street and between Langgar Street on the north and the extension of H.M. Yoni Street on the south (Figure E-2.1). This area overlies the inferred greatest thickness of water-bearing aquifers in Medan Denai. Physical access on paved or all-weather roads limits site selection to Langgar Sukahati, Bromo or Seto Streets. Adequate power supplies, water distribution mains, and drainage canals are located only along Bromo Street. Therefore, the Medan Denai test well is restricted primilarly to sites on or near Bromo Street, between 500 m and 850 m east of Bakti Street. Several vacant parcels are located along this street, any one of which could be used.

Since Tirtanadi owns a large area in Titipapan, site selection reflects electrical supply, adequate drainage, and compatibility with adjacent land uses and planned development of the area. The site should lie within an area of about two hectares, 200 m northwest and 200 m northeast of the Kampung-Mabar Road, about 600 m southeast of the Medan Belawan Road. The report of the resistivity survey recommended a well site which would provide adequate data for this program. Review of the survey report indicates thicker aquifers underlie a well site along the

Belawan Road (also recommended for a test well by the survey report) about 400 m northwest of the site in the Tirtanadi property. If the Belawan Road site could be acquired then the additional information would be more useful.

One observation well in Option A could be located at either the housing compound for the Research Institute for Sumatra Plantation Association (RISPA) or the Police Barrack in Medan Timur. The second observation could be located at either the Garuda Plaza, Polonia, Danau Toba, or Dharma Deli Hotels, or the Indra Deli Seafood Processing Plant (Jambu Street).

Siting of the individual observation wells in Option A will reflect results and interpretations from the drilling of the test wells and their observation wells. Site selection within Central Medan would be affected by land owner acceptance of the drilling and monitoring activities. The most convenient sites would be at the Indra Deli Seafood Processing Plant or Medan Ice Factory; here, land use, clearance, and security are best, while the site at the Danau Toba Hotel would be least suitable. The observation well in Johor is restricted to one of two existing well sites. The existing well at the main office compound of RISPA and that at the RISPA housing compound across the Deli River have adequate secluded area for drilling of small bore observation wells. The RISPA well would require installation of a new pump and accessory equipment, while the housing compound well has a small-capacity pump powered by a gas-electric generator.

If Option B is funded, the observation well in Johor recommended in Option A would be replaced by test and observation wells further south in Titikuning. The exact site should lie along the power line and pipeline which parallel the old railroad right-of-way between Medan and Deli Tua. In order to provide useful water level monitoring results, the site should not be more than five kilometres south of the RISPA wells. For incorporation of well production into the distribution system, the site indicated in Figure E-2.1 could supply water to any of three existing major transmission pipelines.

The westernmost test and observation wells have been tentatively sited at government offices at km. 7 on the Binjei Road (extension of General Subroto Street). This site was selected for the large land areas available, the existing paved access, power, and drainage, and the available transmission pipeline along the Binjei Road. The site lies midway in the Sunggal development corridor. Sites further south in Tuntungan are extremely limited by available electrical power supplies but should be used in the near future.

Lowest information priority for the drilling program was assigned to Belawan, although sites may be selected at several locations. Two sites were selected within Belawan at existing wells owned by Tirtanadi. A test well would be sited at Tirtanadi Well No. 3, which would act as the observation well for the recommended test well. All site selection criteria are easily met at this site and at the site for the observation well at Tirtanadi Well No. 12 on the Belawan Road.

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E-2.8 DATA ACQUISITION PROGRAM

Gathering of hydrogeologic information is the major objective of the overall drilling program, although Option B would also allow water supply production after the testing program. Documentation of the Program would include four categories:

1. Well Construction and Design

2. Lithological and Electrical Logging

3. Water Chemistry

4. Geohydrology.

The documentation of the test program will provide the data and interpretations required for evaluation for the Medan regional groundwater potential. However, the confidence and reliability of the regional analyses and interpretation will be reflected by the detail and control upon the drilling and testing program. Regional analyses from Option A data will be less accurate and of more limited application than those based upon Option B data. Both Option A and Option B would provide data in all four categories. In Option A, only two pumping test wells would have fully controlled well design, logging, and development, whereas all six test wells would be fully documented and controlled in Option B. Observation wells would provide lithological/electrical logging of the aquifers in either program element.

Well construction and design data would include:

1. Diameter, lengths, and depths of sanitary seals, casings screens, and gravel packs

2. Diameter, percent open area and capacities of screens, and porosity of gravel packs.

Logging of test and observation wells would provide:

1. Depth and description of sedimentary strata penetrated by the wells

2. Depth and thickness of potential water-bearing strata and their porosities.

Water chemistry investigations will include analyses of standard groundwater chemical constituents and would provide:

1. Water quality of different water-bearing strata at different levels of pumping

2. Depth of possible excessive concentrations of iron, manganese, and fluorides.

The geohydrology would be tested during the pumping/drawdown tests. Such tests would include pumping at progressively higher levels in order to determine maximum and optimal operating capacities. The test results would include:

1. Static water levels and pumping water levels for at least three different pumping rates

2. Distances of potential drawdown interference at different pumping rates

3. Specific capacities, transmissivities, and storage capacities of representative sectors of the Medan study area.

E-2.9 CONSTRUCTION AND DESIGN

Following the review of existing wells, a series of modifications of existing well construction and design have been prepared in order to provide greater individual well pumping capacity, reduce infiltration of sands, and extend the wells' useful life. Details regarding well designs are presented in the attached Test Drilling Specifications. As indicated in Figure E-2.2, the new test well design uses a larger casing and screen diameter and has the screen extending the full length of the aquifer. This reduces the entrance velocity at the screens and reduces the infiltration of sand into the screen. In order to reduce clogging of the screens, allow acid washing, and prolong casing/screen life-time, Indonesian-produced PVC pipe is recommended for at least one well. PVC pipe has been used in many areas and its use here is only new for Sumatra. PVC also has the advantages of ease of slotting of different sizes and entrance angles.

The recommended drilling program includes the test of at least one well of this modified design. In Option B, the six test wells with modified design and construction would remain under public ownership and their performance could be monitored when they are developed as full production wells. In the central area, performance of the new ells could be directly compared and evaluated with standard design wells.

Observation wells would be constructed using much smaller diameter bores and casing/screens (Figure E-2.3). Since their locations are selected to determine the drawdown of the test or production well, they should not be developed as full production wells. In order to provide stratified observations, two piezometer tubes would extend to different depths (e.g. 100 and 150 m below ground surface) and the screens would be separated by seals in the gravel packs.

E-2.10 TRAINING

For the purpose of this recommended program, primary focus is on drilling and testing wells in Medan. However, to provide meaningful guidance in the development of the Medan aquifers, assistance is contemplated in two other efforts: 1) assistance with first wells drilled for Tirtanadi and 2) training of personnel to operate Tirtanadi wells in Medan and Belawan and to inspect all new wells. Although Tirtanadi

operates wells in Belawan, the staff of Tirtanadi is unfamilar with design and construction of deep wells, and training in proper inspection and supervision would insure long-term production. Training would also provide personnel with sufficient on-site experience in the US, at the test wells, and the first Tirtanadi wells to inspect and eventually supervise well construction by contractors for Tirtanadi. Therefore, two additional tasks may be provided by the program, although only the training would significantly add to the cost.

As part of the Medan groundwater development program and during the Recommended Drilling Program, P.A.M. Tirtanadi will begin drilling several production wells. These wells will represent the first wells ever drilled by Tirtanadi. Some technical assistance should be provided to Tirtanadi for the first well they drill. It is therefore recommended that an additional assistance task be provided as part of the groundwater exploration program. Funds would not be required for this task out would be included in costs of Option A or B. Tirtanadi would provide staff-time.

The selected trainee would be given general instruction on the proper drilling, development, and operations of large capacity, deep wells while in the USA. The trainee would then be assigned to assist in the drilling and development of a municipal production well for at least one month, at the Tirtanadi well in Titipapan or Central Medan.

E-2.11 RECOMMENDED IMPLEMENTATION SCHEDULE

Two options (A and B) have been analyses for implementation of the Recommended Drilling Program and their schedules are presented in Figure E-2.4.

Option A

Two test wells and four observation wells would be drilled. This program could be accomplished within the present budget of the Medan Urban Development, Housing, Water Supply and Sanitation Project.

Option B

Under this option, which would provide significantly more data over the entire region, a total of six test wells and six observations wells would be drilled in Option B, which adds four test and two observation wells to those in Option A. As described in Section E-2.12, this program would require additional funding.

For either program, the work has been divided into three tasks:

1. Preparation of Bid Documents and Contract Supervision

2. Drilling and Testing

3. Data Analysis, Interpretation and Reporting.

Task 1, Preparation of Bid Documents and Contract Supervision would include:

1. Preparation of Contractor Qualification Questionnaires (See attachment)

2. Preparation of final specifications and bid documents (See attachment)

3. Assistance in reviewing contractor qualifications

4. Assistance in reviewing bids

5. Review of contractor performance and certification of completed work.

Task 2, Drilling and Testing, will require the greatest effort and cost. The work would include:

1. Assistance in well site selection

2. Supervision of test and observation well drilling

3. Construction, lithological, and electrical well logging

4. Final design of well screens, casings, and gravel-pack

5. Well development and completion

6. Pump testing (output, drawdown, recovery)

7. Collecting of water quality samples

8. Review and approval of contractors' drilling report.

Task 3, Data Analysis, Interpretation, and Reporting, involves the following work items:

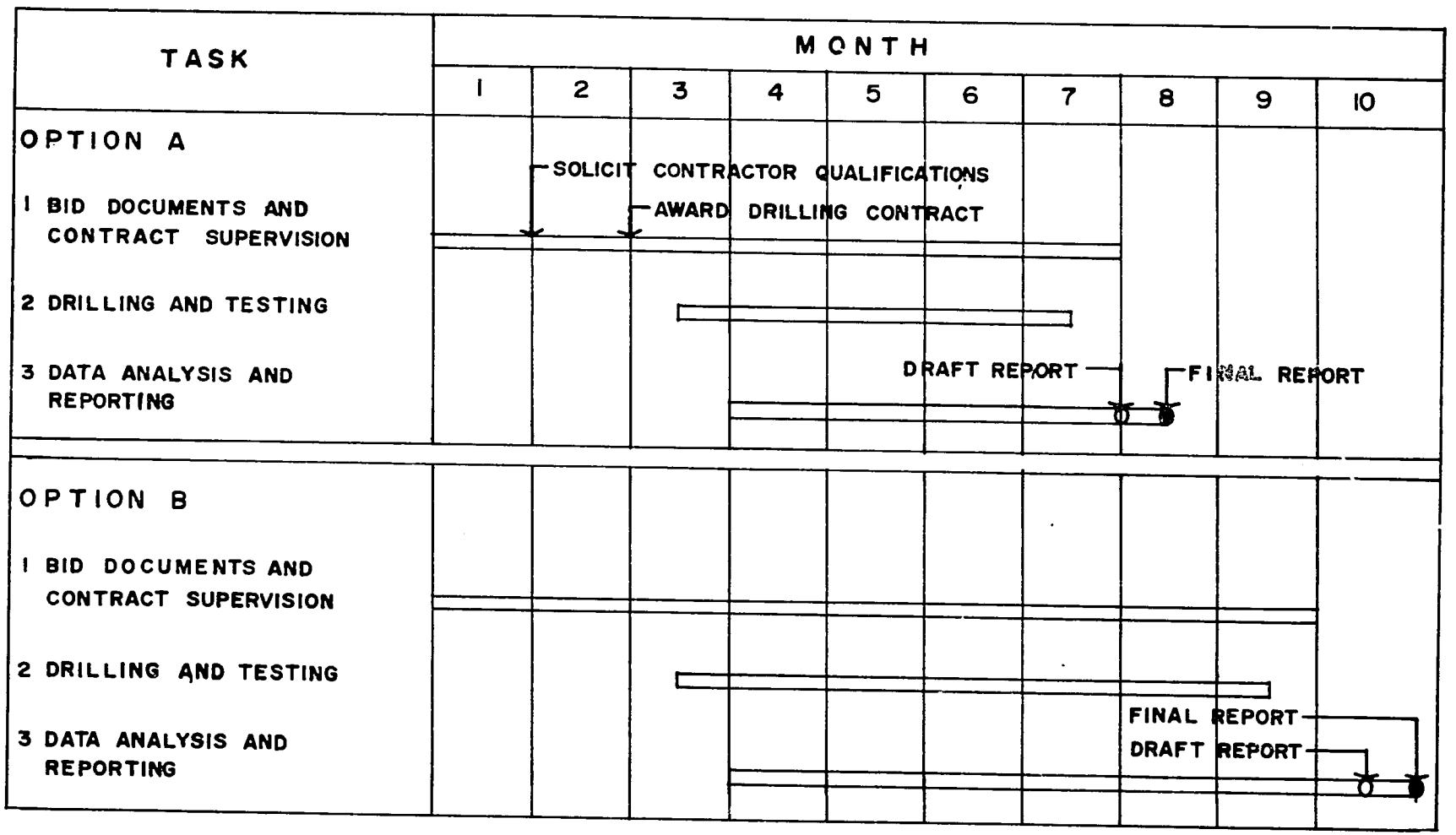
1. Compilation of data from well logs, pumping tests, and water quality analyses, and incorporation of these data with data from previous studies and reports

2. Interpretation and analysis of the data, both to obtain the maximum information for each well and to improve previous estimates of aquifer capacity and safe yield

3. Preparation of reports.

Proposed schedule for the work outlined above is shown on Figure E-2.4. The schedule is based on the assumptions that: (1) it will require one month from solicitation of qualifications from drilling contractors to award of a

PROPOSED IMPLEMEM IMPLEMENTATION SCHEDULE



drilling contract and (2) the well drilling and testing can be accomplished in either four months (Option A) or six months (Option B). In Option B, the time might be reduced, although the costs might be slightly higher if two drilling contractors were selected to work simultaneously.

E-2.12 ESTIMATED COSTS

The estimated costs of the proposed program are shown in Tables E-2.1 and E-2.2 for Option A and B, respectively. Total costs for Option A are Rp. 81,765,000 and US $82,989. Drilling and testing will require Rp. 53,400,000 and is less than the budgeted funds of Rp. 58,000,000. Total costs of Option B are Rp. 160,000,000 and US $111,721; these are higher than Option A by 196% and 135% respectively. Major cost differences lie in total salaries and allowances for ES and local personnel (30% higher in both), computer time (2.5 times), and drilling and testing program (2.3 times).

The costs of Option B do not include funds for purchase or long-term lease of lands for three well sites which should come directly from P.A.M. Tirtanadi. Also, costs of a training program are not included but would depend primarily on number of staff to be trained and sent to the US.

TABLE E-2.1

ESTIMATED COSTS FOR OPTION A

Item	Estimated Cost	
	1000's of Rupiah	US Dollars
A I - ES SALARIES AND O'SEAS DIFFERENTIAL		
1. On-site hydrogeologist - 7.5 m-m @ $ 2359 per m-m	-	17,693
2. Home office support - 2 m-m @ 2220/m-m	-	4,440
3. Overhead - @ 145% of 1 and 2	-	32,093
4. Profit - @ 25% of 1 and 2	-	5,533
Sub Total - I	-	59,759
A II - INTERNATIONAL TRAVEL AND ALLOWANCES		
1. Round trip air fares LAX-Medan, 2 x $ 1770 each	-	3,540
2. Intransit per diem - 2 trips x 2 days x $ 40 per day	-	160
3. Surface transport, and exam, etc.		
1 first trip @ $ 150	-	150
1 subsequent trip @ $50	-	50
4. Lodging for mob + demob - 2 trips x 5 days x $40 per day	-	400
5. Bagage allowance - 10 kg x 2 x $13 per kg	-	260
Sub Total - II	-	4,560
A III - INTERNATIONAL AIR FREIGHT		
1. Air freight - 1 single @ 30 kg x $13 per kg.	-	390
2. Air freight proj. supplies -		
- Equipment - 200 kg x $13/kg		2,600
- Samples - 250 kg x $13/kg		3,250
Sub Total - III	-	6,240

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TABLE E-2.1--Continued

Item	Estimated Costs	
	1000's of Rupiah	US Dollars
A IV - OTHER COSTS (US$) (assumes 1st November start date)		
1. Communications	-	1,600
2. Reproduction + printing of final reports	-	5,000
3. Computer services	-	4,000
4. Comsumable office shipped to project office	-	1,000
5. Workmans compensation - 0.0375 x $ 22,133	-	830
Sub Total - IV	-	12,430
A V - INDONESIAN PERSONNEL COSTS (assumes 1st November start date)		
1. On-site hydrogeologist - Rp. 750,000/m-m	5,625	-
2. Support staff		
a. Secretary - 8 m-m @ Rp. 220,000/m-m	1,760	-
b. Draftsman - 8 n-m @ Rp. 190,000/m-m	1,520	-
c. Drivers - 15 m-m @ Rp. 70,000/m-m	1,050	-
Sub Total - V	9,955	-
A VI - ALLOWANCE TO PROJECT PERSONNEL		
1. Per diem for expat. personnel - 1.5 m-m @ Rp. 25,000 per day	5,625	-
2. Per diem allowance for Indonesian hydrogeologist based in Jakarta but stationed in Medan - 1.5 m-m @ Rp. 15,000 per day	3,375	-
Sub Total - VI	9,000	-

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TABLE E-2.1--Continued

Item	Estimated Costs	
	1000's of Rupiah	US Dollars
A VII - PROJECT VEHICLES (assumes 1st November start date)		
1. Depreciation of consultant owned vehicles		
a. 1 sedan - 6 mo. x Rp.8,143,000 ÷ 60	814	-
b. 1 minibus - 6 mo. x Rp. 4,700,000 ÷ 60	476	-
2. Operation and maintenance of project vehicles		
a. 1 sedan - 6 mo. x Rp.60,000/mo	360	-
b. 1 minibus - 6 mo. x Rp.90,000/mo	540	-
Sub Total - VII	2,190	-
A VIII - OTHER COSTS (assumes 1st November start date)		
1. Office space - provided by Cipta Karya	-	-
2. Office maintenance - 6 mo. x Rp. 250,000/mo	1,500	-
3. Local communication - 4 mo @ Rp. 100,000/mo, 6 mo @ Rp.250,000/mo	1,900	-
4. Out of station support allowance -		
a. expatriate staff - 20 days x Rp.30,000/day	600	-
b. local staff - 20 days x Rp.20,000/day	400	-
5. Local air travel - Medan-Jakarta - 8 @ Rp.165,000	1,320	-
6. Office consumable supplies - 4 mo @ Rp.50,000/mo, 6 mo @ Rp.150,000/mo	1,100	-
7. Reporting printing locally	400	-
Sub Total - VIII	7,220	-

TABLE E-2.1--Continued

Item	Estimated Costs	
	1000's of Rupiah	US Dollars
A IX - SUBCONTRACT		
1. Well Drilling		
a. Test wells 2 x Rp.14,000,000/ well	28,000	-
b. Observation wells 4 x Rp.5,000,000/well	20,000	-
2. Logging and testing		
a. Electrical logging 6 x Rp.500,000/well	3,000	-
b. Pumping test 2 x Rp.700,000/ well	1,400	-
c. Water quality analysis 4 x Rp.250,000/well	1,000	-
Sub Total - IX	53,400	-
ESTIMATED TOTAL COST-OPTION A	Rp.81,765	$ 82,989

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TABLE E-2.2

ESTIMATED COSTS FOR OPTION B

Item	Estimated Costs	
	1,000's of Rupiah	US Dollars
B I - ES SALARIES AND OVERSEAS DIFFERENTIAL		
1. On-site Hydrogeologist 10 m-m x $ 2359/m-m	-	23,590
2. Home Office support 2.5 m-m x $2220/m-m	-	5,550
3. Overhead - @ 145%	-	42,253
4. Profit - @ 25%	-	7,285
Sub Total - I	-	78,678
B II - INTERNATIONAL TRAVEL AND ALLOWANCES		
1. Round trip air fares (LAX-Medan) 2 x $ 1770	-	3,540
2. Intransit per diem - 2 trip x 2 days x $ 40/d	-	160
3. Surface transport and travel preparations		
first trip	-	150
second trip		50
4. Lodging for mobilization 2 trips x 5 days x $ 40	-	400
5. Baggage allowance - 10 kg x $13/kg	-	260
Sub Total - II	-	4,560
B III - INTERNATIONAL AIR FREIGHT		
1. Air freight-Personnel 30 kg x $13/kg	-	390
2. Air freight-Project		
Equipment - 200 kg x $13/kg	-	2,600
Samples - 400 kg x $13/kg	-	5,200
Sub Total - III	-	8,190

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TABLE E-2.2--Continued

Item	Estimated Costs 1,000's of Rupiah	Estimated Costs US Dollars
B IV - OTHER COSTS (US$) (1st November start date)		
1. Communications 5 mo x $100/mo, 7.5 mo x $200/mo	-	2,000
2. Reproduction and Printing of final report	-	6,000
3. Computer Services	-	10,000
4. Consumable Office supplies shipped to project office	-	1,200
5. Workmans compensation - 0.0375 x $29,140	-	1,093
Sub Total - IV	-	20,293
B V - INDONESIAN PERSONNEL COSTS		
1. On-site hydrogeologist - 10 m-m x Rp. 750,000/m-m	7,500	-
2. Support Staff		
a. Secretary 10 m-m x Rp.220,000/m-m	2,200	-
b. Draftsman 10 m-m x Rp.190,000/m-m	1,900	-
c. Drivers 20 m-m x Rp. 70,000/m-m	1,400	-
Sub Total - V	13,000	-
B VI - ALLOWANCES TO PROJECT STAFF		
1. Per diem for ES personnel 1 m-m x Rp. 25,000/day	7,500	-
2. Per diem for Indonesian Personnel based in Jakarta but stationed in Medan 10 m-m x Rp. 15,000/day	4,500	-
Sub Total - VI	12,000	-

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TABLE E-2.2--Continued

Item	Estimated Costs	
	1,000's of Rupiah	US Dollars
B VII - PROJECT VEHICLES		
1. Depreciation of consultant owned vehicles		
a. 1 Sedan 9 mo x Rp.8,143,330 ÷ 60	1,222	-
b. 1 Minibus 9 mo x Rp.4,760,000 ÷ 60	714	-
2. Operation and maintenance of projec vehicles		
a. 1 Sedan 9 mo x Rp.60,000/mo	540	-
b. 1 Minibus 9 mo x Rp.90,000/mo	810	-
Sub Total - VII	3,286	-
B VIII - OTHER COSTS		
1. Office space - provided by Cipta Karya	-	-
2. Office maintenance 5 x Rp. 250,000/mo	1,250	-
3. Local communications 5 mo x Rp.100,000/mo, 8 mo x Rp.250,000/mo	2,500	-
4. Out-of-station support allowance		
a. Expatriate staff 25 days x Rp.30,000/day	750	-
b. Local staff 25 days x Rp.20,000/day	500	-
5. Local air travel (Medan-Jakarta) 10 trips x Rp.165,000/trip	1,650	-
6. Office consumable supplies 4 mo x Rp.50,000/mo, 9 mo x Rp.150,000/mo	1,550	-
7. Report printing local	800	-
Sub Total - VIII	9,000	-

TABLE E-2.2--Continued

Item	Estimated Costs	
	1,000's of Rupiah	US Dollars
B IX - SUBCONTRACTS		
1. Well Drilling		
a. Test wells 6 wells x Rp. 14,000,000/well	84,000	-
b. Observation wells 6 wells x Rp.5,000,000/well	30,000	-
2. Logging and Testing		
a. Electric logging 6 wells x Rp.500,000/well	3,000	-
b. Pumping tests 6 well x Rp.700,000	4,200	-
c. Water quality analyses 6 wells x Rp.250,000/well	1,500	-
Sub Total - IX	122,700	-
ESTIMATED TOTAL COST - OPTION B	159,986	111,721

SAMPLE
TEST DRILLING SPECIFICATIONS
MEDAN

01 GENERAL

01.1 Description of Project

The Drilling Project in the vicinity of Medan will be conducted to determine the feasibility of developing groundwater resources for a new city water supply source. Well drilling will be performed primarily for testing purposes; however, all test wells will be constructed as suitable for production sources to the existing or future water system. All drilling and testing for the subject Project will strictly follow the prepared Specifications and be directly supervised by Representatives of Engineering Science, Inc. (ES).

01.2 General Scope of Project

At least two (2) test pumping wells and at least two (2) test observation wells will be drilled in the area of Medan. Drilling and testing will be conducted to determine the following characteristics of the groundwater environment:

1. Depth and thickness of potential water bearing zones
2. Individual water well pumping capacity
3. Water bearing and lithologic characteristics of local and regional aquifers
4. Chemical quality of groundwater produced
5. Water levels under static and pumping conditions.

01.3 Location of Project

The city of Medan is located in Northern North Sumatra and is easily accessible over a number of paved roads, highways, and railroads. Specific test drilling sites, to be selected by Representatives of ES, will be located within Medan and perhaps Belawan. All drilling sites will be located in close prominity to roads accessible during both dry and wet seasons.

02 ACCESS TO WORK SITES

Test drilling sites will be provided by the Indonesian Government and egress for equipment and personnel performing Project Operations will be granted and enforced by the Government. Test sites provided will occupy an area measuring approximately 15 m long and 15 m wide.

The Drilling Contractor will be responsible for any damage to public or private property caused as a result of Contractor activities outside the defined boundaries of each drilling site.

02.1 Allowance for Purchase of Drilling Rights

The Contractor shall pay all costs resulting from acquisition of drilling rights or lost revenue of agriculture lands due to project drilling operations. The costs of these rights or assessment will be determined by ES prior to Contractor Mobilization and will be added to the Contract Price. No payment shall be made by the Contractor without prior approval by the ES representative.

03 LOCAL CONDITIONS

The Contractor is required to satisfy himself regarding all local conditions affecting his work by personal investigations, and neither information contained in this Section nor that derived from other maps, logs or other information furnished by ES shall act to relieve the Contractor of any responsibility of fulfilling any and all of the requirements of this Contract.

04 SITE REPRESENTATIVE

There shall continuously be a responsible representative of the Contractor on duty at the work site during working hours who will have full authority to supervise the proper execution of the contracted work. The Contractor Representative will provide all information required by the ES Representative.

05 RECORDS AND REPORTING

The Contractor shall at all times keep complete and accurate records of procedures conducted at the work site. All records relating to work shall be available to any ES Representative at all times. A copy of all Contract Documents will be kept at the work site.

The Contractor will prepare a written daily report of progress of work for the ES Representative. The report will include quantities of materials delivered to the site and/or used, labor and work performed, and cumulative totals of activities. Table E-2.3 shows a sample form of the daily drilling report. Two copies of the report will be made daily, one to be kept at the work site, and the other in English to be submitted weekly or upon request by the ES Representative.

TABLE E-2.3

SAMPLE DAILY DRILLING REPORT FORM
STUDIES
INDONESIA

LOCATION	MEDAN	DATE: JUNE 30, 1979
WELL DESIGNATION	: Production Well #1	
DRILLING OPERATION	: Time commenced	6 AM
	Time completed	10 AM
DAILY WORK CONDUCTED:	Actual Drilling Time	8 hr.
	Equipment Repair & Maintenance	3 hr.
	Casing Installation	1 hr.
	Standby Time	1 hr.

EQUIPMENT AND MATERIALS RECEIVED:

10 bags bentonite clay
5 - 20' lengths 8 inch. blank casing

EQUIPMENT AND MATERIALS USED:

4 bags bentonite clay
16 inch. drag bit
10 inch. tricone bit

DRILLING INFORMATION:	Static Water Level	2 m.	
	Previous depth of hole	10 m.	
	Meters drilled	5 m.	
	Total depth of hole	15 m.	
	Casing installed	15 m.	Conductor pipe
	Number of Welded Joints	3	Welded sections of 5 m lengths
	Drilling time for meters drilled	5 hr.	

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DESCRIPTION OF MATERIALS ENCOUNTERED:

Depth	Description of cutting samples
10 - 12.5 m	Red sandy clay-fine sand grains in tight sticky clay - easy drilling, one hour 2.5 m.
12.5 - 5 m	Sand - Coarse grained reddish sand, with no clay - caving formation, four hours 2.5 m.
REMARKS :	Drag bit was used to drill through soil materials. At 10 depth changed to tricone bit. Encountered caving sands at 12.5 m. Added 2 bags of bentonite to keep hole open. Drilling continued with no problems.
Weather :	Clear, light rains in afternoon.

06 EQUIPMENT

The following paragraphs shall provide a minimal basis for the Contractor's selection of equipment to be employed in the execution of the Contract.

06.a Drilling Machine

The Drilling Machine will be of the percussion type, rotary type or combination rotary wash/percussion, equipped with appurtances and auxiliary equipment necessary to perform the specified test water well construction. Such drilling equipment will have a minimum capacity to drill 450 m (18 inch) diameter borehole to a depth of 80 m and 356 mm (14 inch) diameter borehole to a depth of 230 m. The same equipment will have the capacity to emplace 240 m of well casing.

06.b Testing Pump

The Contractor will provide a testing pump capable of pumping at variable rates up to more than 35 l/s for at least 24 hours. The pump must be equipped with accurate flow measurement. The pump must be able to achieve this production at depths to 70 m below ground service.

06.c Electrical Well Logging Device

The electrical well logging device must be capable of accurate (± one metre) measurements of resistivity and spontaneous potential down to a depth of -240 m below ground surface.

07 TEST WELL CONSTRUCTION

07.1 General Procedure for Test Pumping Construction

The construction of test pumping wells will conform to the following general procedures:

1. Drill site preparation
2. Test boring
3. Borehole lithologic and electric logging
4. Ream boring for emplacement of conductor casing
5. Cementing conductor casing
6. Ream boring down to 240 m below surface
7. Placement of well casing and screen
8. Placement of gravel pack, if necessary
9. Well development

10. Well testing

11. Well completion and site clean up.

Figure E-2.2 depicts the general constructed configuration (without well head and pedestal detail) of each test pumping well.

07.2 General Procedure for Test Observation Well Construction

The construction of test observation wells will conform to the following general procedures:

1. Drill site preparation

2. Test boring

3. Borehole lithologic and electric logging

4. Placement of well casing and screen

5. Placement of gravel pack, if necessary

6. Well cleaning

7. Well completion and site clean up.

Figure E-2.3 depicts the general constructed configuration (without well head and pedestal detail) of each observation well.

07.3 Drill Site Preparation

Boundaries of each test drilling site will be defined by survey or other means prior to the movement of Contractor or personnel on the selected test location. Site boundaries will be submitted in writing to the Contractor by a Representative of ES. After a field inspection of the site by the selected Contractor in the company of a ES Representative, preparation of the well site for drilling and testing activities can commence. The drilling Contractor will be responsible for preparing and arranging each test site to provide for needs of Contractor equipment, personnel and operations. All clearing of vegetation, ground surface modification, grading, drainage provisions and digging of required mud pits will be the responsibility of the Drilling Contractor. The Drilling Contractor will prepare and maintain the test site in a manner which causes minimal public nuisance and no interference with public travel.

The Contractor will make provisions to keep unauthorized persons off the drilling site and maintain a safe working operation at all times. Payment for drilling site preparation will be based upon lump sum bid for this designated item.

07.4 Surface Pipe Placement (Optional)

A surface pipe may, at the option of the driller, be installed before test bore drilling is commenced. The surface pipe will be set and cemented in place to a depth considered by the Drilling Contractor to be adequate for Contractor well construction activities. The fabricating material, length and type of the surface pipe will be determined by the Drilling Contractor.

07.5 Test Boring

Test boring will be performed at the Medan drilling sites by percussion type, rotary type or combination rotary wash/percussion methods. The test bore at each site will be a minimum of 153 mm (6-in) in diameter and extend to a maximum depth of 240 m below ground surface elevation. Drilling will be conducted at a rate suitable for collecting lithologic samples, representative of strata penetrated. After each joint of drill stem is drilled down, the test bore will be circulated clean of all drill cuttings remaining in the borehole.

The completion depth of each test bore will be determined by a representative of ES. Payment for test boring will be made on the basis of unit bid price per meter of borehole completed.

07.6 Borehole Lithologic and Electric Logging

Continuous lithologic samples of formation materials penetrated will be collected and preserved at the test drilling site. The driller will collect a one kg representative sample of formation material at each 3 m of depth drilled and at each significant formation change. Collected samples will be placed unwashed in water proof containers of a type approved by a Representative of ES. The depth from which the sample was taken, name of collector, and the date of sampling will be clearly indicated on each sample container. Samples will be packaged and stored in a location safe from disturbance by weather and drilling operations. The Contractor will prepare a lithologic log of the test bore on the basis of formation sub-samples collected. Preserved samples will be retained for further analyses by ES Representatives. After completion of each test bore, a decision will be made as to need for running an electric log of the borehole. If an electric log is required, the driller will provide the logging equipment. At the time electric logging is completed and the logs are interpreted by the Drilling Contractor or his Sub-Contractor and the ES Representative, a decision will be made to:

1. Construct a test observation well

2. Construct a test pumping well.

Decision and/or well designs formulated will be provided to the driller by a Representative of ES.

07.7 Ream Boring

Ream bores, as required for testing wells, will be up to 450 mm in diameter to a depth of 80 m, and up to 300 mm in diameter from approximately 80 m to a maximum depth of 240 m in the vicinity of Medan. The completed depth of each ream bore will be determined by a Representative of ES. Payment to the Drilling Contractor for reaming operations will be based upon the total number of metres below ground surface reamed to a diameter of 450 mm, and the total number of metres below ground surface reamed to a diameter of 300 mm.

07.7a Placement of Conductor Casing

Immediately after reaming the borehole to a depth of 80 m, at a diameter of 450 mm, the reamed borehole will be cleaned of all drill cuttings throughout the total depth of the 450 mm diameter reamed bore. After the bore is suitably cleaned, 350 mm diameter conductor casing will be centered and emplaced in the 450 mm reamed borehole. When the conductor casing has been set, the annulus between the 450 mm reamed borehole and the 350 mm conductor casing will be filled with cement grout. The grout will be emplaced in the annular space between the borehole and the casing from the bottom, first by use of a tremie pipe and cement pipe. The quantity of cement grout to be used will first be calculated to ensure that the final quantity of cement grout used fills the annular space between the borehole and the conductor casing. When the cement seal has been emplaced, further drilling work will cease for a period of not less than 24 hours to allow the cement grout seal to set properly. The driller may use Calcium Chloride as an aid in decreasing the time for the cement to harden. After the 24 hour period, the borehole will be deepened to its full depth of approximately 240 m at a diameter of 350 mm.

07.8 Placement of Well Casing and Screen

Immediately upon completion of the final bore, the borehole will be cleaned of all drill cuttings throughout the total depth of the bore. After the bore is suitably cleaned, the casing and screen will be placed as indicated by the well design prepared by the ES Project Representative. Test Pumping Well casing and screen will be a minimum of 200 mm (8 inches nominal diameter) and have designed strengths sufficient to withstand normal stresses encountered in wells of 240 m depth. Test observation well casing and screen will be 40 mm (1.5 inches) nominal diameter. Casing and screen to be utilized in well construction will be subject to approval by the ES Project Representative.

The Contractor shall provide the ES Representative with unit cost comparison for slotted and wound wire screen of galvanized and stainless steel pipe and for slotted plastic pipe before placement of screen.

Centralizing devices of a design approved by the ES Project Representative will be placed on the well casing and screen at intervals of 10 m or less. Casing and screen will be held in tension from the top of the well during placement operations and secured in tension prior to gravel packing activities. Well construction will be continued through-

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out the operations of borehole cleaning, placement of casing and screen, and completion of gravel packing activities. In the event that casing and screen cannot be placed as required by design documents, the ES Project Representative will determine if the casing and screen must be removed from the borehole and/or remedial action is to be taken. If it is necessary to remove the casing and screen in order to correct borehole conditions, the corrective actions will be conducted at the cost of the Drilling Contractor.

07.9 Placement of Gravel Pack (If necessary)

The opening between the borehole and casing/screen within each test pumping well will be filled completely with selected gravel to the ground surface. The annulus between the borehole and casing/screen of each observation well will be filled completely with selected gravel to ground elevation. Gravel utilized will range in size from 3 mm to 7 mm in diameter and be comprised of rounded, hard, chemically inert particles. Gravel to be used will be subject to approval by the ES Project Representative. Gravel pack material will be measured and introduced into each well from the top of the annulus while simultaneously circulating clear water slowly through the screened zone(s). This operation will require placement of a circulation pipe inside the casing to the bottom of the screened interval, sealing off the casing at the top and pumping clear water down the circulation pipe.

Gravel packing operations will be conducted only while an ES Project Representative is present on the test site. In the event that the gravel pack material cannot be placed in the well annulus in the quantity and manner required, remedial action will be determined by the ES Project Representative. Payment for gravel packing operations will be based upon the unit price per meter gravel installed.

Payment for remedial work associated with gravel packing operations will be made on the basis of unit hour bid price for rig standby time.

07.10 Well Development

Within 12 hours after completion of gravel packing operations, well development operations will commence at each test observation and test pumping well.

Development procedures will require a sequence of bailing and swabbing in order to clean drilling and particulate material from the well and gravel packed annulus.

Development by air lift and bailing methods may be used at the option of the Contractor. Development operations will be continuous until the ES Representative determines the well to be adequately developed. Payment for well development will be based upon the unit bid price per hour of well development.

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07.11 Well Completion

Immediately upon completion of well development, two sounding tubes (optional) and a locking cap may be installed on each test pumping well casing. A locking cap will also be provided for each test observation well. Payment for well completion will be based upon a lump sum bid price.

07.12 Well Testing

All testing of the test wells will be conducted by the Drilling Contractor under the direction of the ES Representative. The test pump will be installed at a depth selected by ES. Testing will consist of step drawdown, time drawdown and recovery programs; the pumping rates and durations of which will be determined by ES. Only test pumping wells will be tested. Observation wells will not be tested. Acceptable test pumping equipment will be supplied by the Contractor.

The Contractor shall supply all fuel and discharge piping and will be responsible for the location of a suitable wasteway for the pumped water. In addition, the Contractor shall supply the necessary gages and devices to accurately measure well discharge and static and pumping levels of groundwater. The test pump shall be equipped in such a manner that the discharge rate of the pumped groundwater can vary. The test pump shall be capable of pumping up to 35 l/s from a depth of 70 m.

The Contractor shall provide qualified personnel to transport install, operate and remove the test pumping unit. Pump testing will be conducted on a continuous 24 hours per day basis for the duration of each test. Payment to the Contractor for test pumping operations will be made on the unit bid price per hour for pump testing to include the pump unit, transportation, installation, operation and removal.

07.13 Well Completion and Site Clean Up

After well testing is completed at each test pumping well, a concrete pedestal of dimensions one metre by one metre by 0.4 m is to be formed around the well head (see Figure E-2.2). The well cap and sounding pipe caps (if provided) will be reinstalled to secure the well. At the completion of the placement of the surface sanitary seal in each test observation well, a concrete pedestal 1 sq m by 0.25 m thick will be poured around the casing. A suitable locking cap will be installed on the top of the casing. The entire area of the drill site that has been disturbed by drilling operations will be cleaned of all waste materials and restored and leveled to a condition similar to that existing prior to commencement of drilling operations.

Payment for well completion and site clean up will be made on the basis of the lump sum bid for this item.

08 LIQUIDATION DAMAGES

The Contractor shall pay Liquidated Damages in an amount of Rp.200,000 for each day that the Contractor exceeds the agreed upon time schedule of this Contract as specified in the Contract Proposal. Liquidated Damages shall not exceed 10% of the Contract Price.

09 TERMINATION OF CONTRACT DUE TO EXCESS DELAY

In the event that work behind Schedule reaches a value of twenty percent (20%) of the Contract Price, the Contract may be terminated with any additional payment to be made to the Contractor subject to Section 03.9 (a).

10 MATERIALS, TEST PUMPING WELL(S)

10.1 Well Casing

Well casing to be used hereunder as a part of the test pumping well(s) shall be of high grade, butt-welded or threaded pipe and coupled steel pipe or other approved material of the required nominal diameter.

	Nominal dia.	O.D.	Min. Wall Thickness
Conductor Casing	350 mm (14")	-	-
Production Casing	204 m (8")	-	-

10.2 Well Screen

The Contractor shall submit Bids on the following type of screen as shown in the Bidding Schedule. Final selection of type of screen to be provided by the Contractor will be decided by ES after receipt of Bids. The requirements for the type of well screen is as follows and as shown on the attached Drawing (Figure E-2.3). Well screen shall be machine or torch perforated pipe or wire-wound. Perforated pipe shall be steel or PVC pipe having the same or compatible properties as the well casing and shall conform to the following requirements:

	Nominal Dia.	O.D.	Min. Wall Thicknes	Opening Area
Steel	204 mm (8")	215 mm	5.8 mm	10 percent
PVC	200 mm (8")	216 mm	9.2 mm	10 percent

Perforation on the steel pipe shall be cut by machine or torch methods. The openings or slots shall be so designed as to prevent clogging and shall be free of jagged edges, irregularities or anything that will accelerate corrosion. Perforations on the PVC pipe shall be cut by machine.

11 MATERIAL TEST OBSERVATIONS WELL(S)

11.1 Well Casing

Well casing to be used hereunder as a part of the test observation well(s) shall be of high grade, butt-welded or threaded and coupled steel pipe or other approved material of the required nominal diameter.

	Nominal Dia.	O.D.	Min. Wall Thickness
Steel	38 mm	48 mm	2 mm
PVC	40 mm	48 mm	3.6 mm

11.2 Well Screen (perforated Casing)

Well screen for the test observation well will be shop or field manufactured from pipe of the same type and size as the well casing. Screen perforations may be saw cut or torch cut. Any sizes and patterns to be used by the Contractor will be subject to approval by ES prior to installation in a well.

12 PACKING GRAVEL

Gravel pack material for all test wells shall be clean, with well-rounded grains that are smooth and uniform. The effective diameter of gravel shall range between 3 and 7 mm.

13 DRILLING WATER

Water supplies required to perform Contract Drilling will be provided and transported by the Contractor. Any arrangements for obtaining and/or buying such water are the sole responsibility of the Contractor.

14 DRILLING FLUID

Drilling fluid to be used in the construction of all test wells will be comprised of new, commercial grade bentonite clay and fresh water of a consistancy suitable to maintaining correct drilling operations. The cost of such material shall be included in the Contractor Drilling Bid.

15 APPROVAL OF MATERIAL

The Contractor is required to submit for ES approval, a list of materials he intends to incorporate into the construction of each test well.

16 BIDS AND COSTS

The Contractor will be provided with Bid Sheets for both the proposed drilling and the additive and deductive costs, if the drilling and testing proposed program exceeds or below the above specifications. Samples of these sheets are included in the following pages.

BID SHEET - PUMPING WELL - EACH WELL

Item No.	Description	Quantity	Unit	Unit Price	Total
1.	Mobilization of equipment, materials and persons to drilling site	1	l.s.		
2.	Move on, move-off and site clean up	1			
3.	Drilling of 150 mm (6-in) diameter borehole	240	m		
4.	Borehole electric logging	1	l.s.		
5.	Ream 150 mm (6-in) dia. borehole to 450 mm (18-in) dia.	80	m		
6.	Ream 150 mm (6-in) dia. borehole to 300 mm (12-in) dia.	160	m		
7.	Furnish 350 mm (4-in) dia. conductor casing				
	steel or	80	m		
	plastic (PVC)	80	m		
8.	Emplace and cement in place 350 mm (4-in) dia. conductor casing	1	l.s.		
9.	Furnish and install 200 mm (8-in) dia. blank production casing				
	steel or	80	m		
	plastic (PVC)	80	m		
10.	Furnish and install 100 mm (8-in) dia. perforated production casing				
	steel or	100	m		
	plastic (PVC)	100	m		

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ADDITIVE AND DEDUCTIVE COST ITEMS
COSTS FOR MORE AND LESS THAN:

Item No.	Description	Unit	Unit Price	
			More	Less
1.	240 m of 150 mm (6-in) dia. borehole	m		
2.	-80 m reaming of 150 mm (6-in) dia. borehole	m		
3.	-160 m reaming of 6-in dia. borehole	m		
4.	-Furnishing and installing 80 m, 12-inch dia. conductor casing			
	steel or	m		
	plastic (PVC)	m		
5.	-Furnishing and installing 60 m blank 8-in dia. production casing			
	steel or	m		
	plastic (PVC)	m		
6.	-Furnishing and installing 100 m perforated 8-in dia. production casing			
	steel or	m		
	plastic (PVC)	m		
7.	-24 hours well development by swabbing, air-lifting and bailing	hr		
8.	-24 hours development by pumping	hr		
9.	-24 hours test pumping	hr		
10.	-12 hours standby time	hr		
11.	-240 m gravel pack	m		

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SAMPLE REQUEST FOR QUALIFICATIONS

Numerous water well drilling contractors are invited to submit their qualifications for bidding on a contract to drill and test a series of exploration wells in Medan. Other production wells may be included at a later date in this program.

Exploratory wells of up to 300 mm diameter will be drilled to -200 to -240 m with nearby observation wells (-150 m with upto 100 mm casing). The program will include drilling, lithological and electrical logging, and pumping tests of the wells within two months of mobilization. This request for qualifications requires prospective bidders to submit the following:

1. Willingness to propose

2. Experience and client references (3) for large production wells in Medan, North Sumatra, and Aceh

3. Drilling equipment, electric well loggers, and pumps owned by contractor

4. Availability of equipment during next 6 months

5. Examples of well reports in North Sumatra (to be returned before bidding)

6. General coast rates for well drilling, development, and testing

7. Subcontractors which may be used by contractor, but less than 30% of total effort.

By ....., we hope to issue requests for proposal to acceptable contractors and will expect proposals within 15 days.

Qualifications are expected in Medan by ....., 1979.

APPENDIX F

DISTRIBUTION SYSTEM ANALYSIS

F-1 Program Users Guide

F-2 Distribution Network Analysis Program Listing

APPENDIX F-1

PROGRAM USERS GUIDE

F-1.1 INTRODUCTION

This program calculates the flow and pressure profile in a hydraulic network. The solution method is based on correcting the flow in each loop until a head loss balance is achieved. Flow corrections are determined from the solution of a set of algebraic equations. The equations are made up from the total differential of the head loss around each elementary loop in the network. The network does not require loop numbering or any special numbering sequence. The program is designed to operate efficiently on large networks: as it is presently configured it can accomodate 400 lines and 400 junctions. An option is available to allow adjustment of initial line sizes to fit specific head losses.

F-1.2 MODEL DESCRIPTION

The Hazen Williams flow formula is used as the mathematical model of the hydraulic network. This equation is expressed as described below and utilized in the program to relate pressure loss to flow in a circular conduit. Either USA, USA with imperial gallons, or metric units can be used provided they are consistent and not intermixed. The input data in Section F-1.4 delineates the appropriate units.

$$P = \frac{(Q)^{1.8518}}{(X)} \qquad \text{(equation 1)}$$

Where Q = flow in U.S. gpm, imperial gpm, or cubic metres per hour

P = pressure drop between the ends of the pipe in feet or metres

X = pipe characteristic computed from the following formula:

$$X = K\ C(D)^{2.63}\ (L)^{-0.54}$$

Where C = Hazen-Williams coefficient of roughness

D = Diameter of pipe in inches or millimetres

L = Length of the pipe in feet or metres

K = Constant

Since the sum of the pressure loss (gain) around each loop in a hydraulic network is zero, equation (1) can be applied to each pipe in each loop to yield a set of non-linear equations that, when solved, will define the pressure profile in the network. That is, each loop will have an equation of the form:

$$H_j = \sum_{k=1}^{\ell} \Delta P_{\ell_k} \qquad \text{(Equation 2)}$$

Where H_j = head loss in loop J

ℓ = number of pipes in loop J

The set of non-linear equations developed by utilizing equation (2) are solved using Newtons methods which is essentially a means of linearizing a non-linear equation set and thereby permitting the use of one of the many methods available to solve linear simultaneous equations. The procedure is to use the mathematical chain rule to develop the total differential of the loop head loss equation.

$$dH_j = \sum_k \frac{\partial H_j}{\partial q_k} \, dq_k$$

Where dH_j = total differential of head loss in loop j

dq_k = total differential of flow in pipe k

$\frac{\partial H_j}{\partial (q)_k}$ = partial differential of head loss in loop j with respect to flow in pipe k

Then, assuming $\Delta H_j = dH_j$ and $\Delta q_i = dq_k$ a set of linear equations result that can be solved simultaneously for Δq_i, where Δq_i is the loop flow correction. Using the corrected flow rate a new set of equations are found and another flow correction is determined. This procedure is continued until the loop flow adjustment in all loops is less than some preselected value.

The Choleski method of factorization is used in solving the linear equation set. For symmetric matrices, this method is extremely fast and very accurate.

The mathematical model described above will not, in general, satisfactorily represent an actual hydraulic network. Therefore, pipe fittings and pressure changing elements such as pressure reducing stations (PRV) and booster pumps can be included to obtain a model that is more representative of actual hydraulic systems.

The inclusion of pipe fittings is accomplished by assigning equivalent lengths to the lines. Equivalent lengths are input along with the line data as explained in Section F-1.4.

To include PRV's it is necessary to have both the set point and the pressure loss across the PRV. In this model the network is first solved without PRV's and then the hydraulic grade line (HGL) at the junctions downstream of each of the PRV's is compared to the set point. If the set point is below the calculated HGL then the pressure at the particular junction is maintained at the set point for any additional network solutions. Because controlling of the HGL at a junction may cause unwanted demand flows to occur, this condition is tested for and the model will make adjustments to the PRV set point in an effort to eliminate large demand flows.

The inclusion of booster pumps is accomplished merely by defining the line that contains the pump and the amount of the head increase across the pump. These requirements are described in Section F-1.4.

The model assures that reverse flow does not occur in either the PRV's or booster pumps. If reverse flow is found the pressure loss (gain) across the element is adjusted until the reverse flow ceases or the pressure loss (gain) becomes zero. If there is still reverse flow the resistance coefficient for the line that contains the pressure changing element is set to a large value to effectively eliminate flow in that line.

Also included in the model is a means of comparing the calculated head loss in each line to a specified tolerance. If the head loss is not within tolerance, the line diameter is adjusted. After each adjustment the system flows are rebalanced and again head losses are compared to the tolerance. This process is repeated until all head losses are satisfactory or some specified maximum or minimum line diamter is reached.

F-1.3 COMPUTER PROGRAM

The computer program is divided into a MAIN program and 12 subroutines; the subroutines are named INPUT, CHNG, TREE, LOOP, PARAM, NUMBER, MATRIX, ZERO, HYDGL, PROFILE, DIA, and COMP. A functional description of each subroutine is given in the following paragraphs. The algorithms used to define and number loops were devised by R. Epp and A.G. Fowler. The program listings are given in Appendix F.2.

Subroutine INPUT

This subroutine reads comments and parameter data and all data required to describe the lines, junctions, and demand flows of the network. Also, a table is established that relates line numbers to junction numbers. Output of line data is also accomplished if a data error is found or if this output option is selected on the parameter card (see Section F-1.4).

Subroutine CHNG

If there is reverse flow in a PRV with zero pressure loss this subroutine removes the set point control from the junction downstream of the PRV. Also, the effective resistance of the line that contains the PRV is set to a large value; this virtually eliminates the flow in this line.

Subroutine TREE

This subroutine initializes flow in all of the lines. The initialization is such that a mass flow balance at each junction is achieved; however, there may be zero flow in some lines.

Subroutine LOOP

This subroutine identifies all of the network loops.

Subroutine PARAM

This subroutine reads the water source and booster pump data. One card is needed for each water source (there must be at least one in the network) and the first such resource defined becomes the reference head for the network. The water source(s) can be either a pump or reservoir or both. Imaginary loops that connect the reference junction to all constant head junctions are established in this subroutine.

Subroutine NUMBER

This subroutine assigns numbers to the loops in the network. Adjacent loops are numbered sequentially; this tends to increase the number of zero filled diagonals in the coefficient matrix thereby reducing the number of elements that must be considered when solving the equation set.

Subroutine MATRIX

This subroutine calculates the partial differentials of the loop head loss and sets up the coefficient matrix. After calling subroutine COMP to solve the equation set, the flow rates in all lines are adjusted. The amount of flow rate adjustment is compared to the limit set on the parameter input card and if none of the adjustments exceed this limit the solution algorithm is stopped, if the adjustment in one of more lines does exceed the limit a new coefficient matrix is established and another solution is obtained. This iterative procedure is continued until the flow adjustment test is passed.

Subroutine ZERO

This subroutine is used to test the pressure downstream of all PRV's when they are wide open. If the pressure is above the PRV set point then the pressure at the affected junction is maintained at the set point. If the pressure is below the set point no action is taken.

Subroutine HYDGL

Starting with the given HGL at the reference juntion this subroutine calculates the HGL at all the remaining junctions. The procedure is to move from junction to junction in the network while subtracting the head loss in each connecting line.

Subroutine PROFILE

This subroutine generates all of the program output.

Subroutine DIA

This subroutine compares line head loss and makes any necessary adjustments to the line diameter.

Subroutine COMP

This subroutine solves the set of linear simultaneous equations. The results obtained from execution of this subroutine are used to adjust the flows in the network.

F-1.4 PROGRAM INPUT REQUIREMENTS

Preparation of Input Data

1. Prepare a sketch of the network. Show all lines, loops, variable head flow inputs and outputs, booster pumps, PRV's, and water sources.

   A line is a reach of pipe between two junctions.

   A loop is a closed circuit formed by two or more lines.

   A junction is a pipe tee, cross, point where water enters or leaves the system, or a point where pipe characteristics change.

   A constant head input or output is a point where water enters or leaves the system under a constant pressure while a variable head input or output is a point where flow remains constant.

2. Assign identifying numbers to each line. The sequence of the numbers is of no significance to the program, however, sequential grouping of line numbers in certain regions may be useful to the user when referencing lines.

3. Assign identifying numbers to each junction. The sequence of numbers is not significant to the program so the user can assign the numbers in any convenient manner.

4. Show the flow out (positive) or in (negative) at each junction that does not have a constant head.

5. Show the HGL in all junctions that are to have a constant head.

6. Using the sketch of the network as described above the data can be transcribed to the input forms described below.

Data Requirements

Program input requirements consists of a comment card, a system parameter card, junction data, line data, water source data, and booster pump data. The comment card is the first card in the data set and it can contain a maximum of 80 characters that are used to describe or identify the network being analyzed (See Table F-1.1). The second card in the data stream contains system parameters that are used to establish solution tolerance, adjust demands, limit the number of iterations, control output, indicate whether USA, USA with imperial gallons, or metric units are being used and to specify the head loss tolerance and related parameters.

The solution tolerance (Item 1 in Table F-1.2) is used to terminate program execution, i.e. when the flow adjustment in all loops is less than the solution tolerance it is assumed that the network is balanced. If necessary to change all of the demand flows by some amount a factor (Item 2 in Table F-1.2) can be entered to accomplish this. For example, if all flows were to be increased by 25 percent a factor of 1.25 would be entered. The maximum number of iterations (Item 3) is used as a means of terminating program execution if the solution procedure is diverging. Items 4 and 5 are self explanatory.

The minimum and maximum head loss allowable (Items 6 and 7) is used to determine if a line diameter is too large or too small. The increments (Items 8 and 9) are the step changes that will be made to a line diameter if the head loss in that line is not within the allowable. Small and large diameter lines can be varied at different increments if necessary. The diameter that separates small and large is determined by Item 10, i.e. all diameters equal to or greater than the value of Item 10 are considered large, all other diameters are considered small. There may be some cases in a network where the head loss in a line is fixed by conditions other than line size. For this reason a maximum and minimum diameter allowed can be included in terms 11 and 12 to stop the program from searching for a non-existent solution.

TABLE F-1.1

COMMENT CARD

Item	Column Position	Format	Unit
Comment	1-80	20A4	NA

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TABLE F-1,2

SYSTEM PARAMETER DATA

Item	Column Position		Unit
Solution Tolerance	01-06	F6.0	US, Imperial GPM, or cu.m/h
A factor to adjust the demand flow	07-12	F6.0	NA
Maximum number of iterations	13-16	14 (right justified)	NA
Enter a 0 if the line data is to be printed out, otherwise enter a 1	17-18	12 (right justified)	NA
Enter a 0 for US units, a 1 for metric units, or a 2 for US units with imperial gallons	19-20	12 (right justified)	NA
Minimum head loss allowable	21-26	F6.0	ft/1000 ft or m/1000 m
Maximum head loss allowable	27-32	F6.0	ft/1000 ft or m/1000 m
Increment for small diameter lines	33-38	F6.0	inches or millimetres
Increment for large diameter lines	39-44	F6.0	inches or millimetres
Diameter that separates large and small lines	45-50	F6.0	inches or millimetres
Maximum allowable diameter	51-56	F6.0	inches or millimetres
Minimum allowable diameter	57-62	F6.0	inches or millimetres
Enter a 0 if line diameter adjustments are not allowed; otherwise enter a 1	63-64	12	NA

Junction data follows system parameter data; one card is required for each junction in the network plus a blank card that is used to terminate the junction data input. Table F-1.3 lists the junction data requirements. Item 2 "ADDRESS" can be used to describe the location or any other pertinent information related to a junction.

TABLE F-1.3

JUNCTION INPUT DATA

Item	Column Position	Format	Unit
Junction Number	01-05	15 (right justified)	NA
Address	06-25	5A4	NA
Ground Elevation	26-32	F7.0	Feet or Metres
Demand Flow	33-39	F7.0	US GPM, Imperial GPM, cu.m/h
PRV Set Point	40-46	F7.0	Feet or Metres

The PRV requirement is used only for junctions downstream of a PRV. If the PRV is functioning the program will maintain the downstream HGL at this set point. If the PRV is not functioning no action is taken, that is the HGL at the downstream junction is allowed to vary.

Line data follows the junction data; one card is required for each line plus a blank card that is used to terminate the line data. Table F-1.4 describes line data input.

Following line data is the water source data. One card is needed for each water source (there must be at least one in the network) and the first such source defined becomes the reference head for the network. The water source(s) can be either a pump, a reservoir, or both. Table F-1.5 tabulates the water source data requirements.

Booster pump (or pressure reducing valve) data is next. One card is needed for each pump (or valve) plus a blank card that is used to terminate the booster pump data. See Table F-1.6.

TABLE F-1.4

LINE INPUT DATA

Item	Clumn Position	Format	Unit
Line Number	01-05	15	NA
Upstream Junction Number	05-10	15	NA
Downstream Junction Number	11-15		
Line Length	16-21	F6.0	Feet or Metres
Line Diameter	22-27	F6.0	Inches or Millitmetres
Hazen-Williams Coefficient	28-33	F6.0	$(\text{Feet})^{.037}/\text{sec}$
Equivalent	34-39	F6.0	Feet or Metres
Enter a 0 for existing line or a 1 for new lines	40-44	15	NA

TABLE F-1.5

WATER SOURCE INPUT DATA

Item	Column Position	Format	Unit	Comments
Junction No.	01-05	15 (right justified)	NA	Enter the identifying number of the junction that represents the water source
Hydraulic Grade Line	11-20	F10.0	Feet or Metres	Enter the hydraulic grade line of the water source, that is, the elevation of the water surface.
Storage	21-30	F10.0	MG	If a reservoir, then capacity in MG, otherwise 0 for pumpstation

TABLE F-1.6

BOOSTER PUMP OR PRESSURE REDUCING VALVE INPUT DATA

Item	Column Position	Format	Unit	Comments
Line Number	01-05	15 (right justified)	NA	Enter the identifying number of the line in which the booster pump is installed
Number of Pumps in Parallel	06-10	15 (right justified)	NA	Enter the number of pumps in parallel.
Pump Coefficients				Enter the coefficients of a third degree polynominal that expresses the pump head as a function of flow. If a constant head is desired, enter the required head as the first coefficient. Use a negative valve if a pressure reducing valve is used.
	11-20	F10.0	NA	First coefficient
	21-30	F10.0	NA	Second coefficient
	31-40	F10.0	NA	Third coefficient
	41-50	F10.0	NA	Fourth Coefficient

F-1.5 PROGRAM OUTPUT

Program output is shown in the attached Sample Data Sheets, Exhibits F-1.I to F-1.IV. The first Exhibit shows the number of junctions and lines in the network and the total system flow. Also some information is written out to indicate various stages of completion. Vector A in the program is limited to 6,400 elements, hence its length is printed out as an aid to the user.

It is necessary for the program to change the pressure loss (gain) in any of the PRV's or booster pumps, the number of the lines that contain the elements is printed out. The amount of pressure change can be determined by comparing the value printed under the columns heading, BOOSTER, or PRV, to the values that were input. Also, if it was necessary to adjust the PRV set point this information is printed out. If adjustments to line diameters were made, the affected line number, the new diameter, and the old unit head loss are printed out. The number of

the iterations required to balance the network flow is also shown. If this number is one greater than the input iteration limit, the model has not converged to a solution. See Section F-1.6 for a discussion concerning the occurrence of this problem.

The next set of data is junction related. Here the junction number, identification, if any, and the hydraulic grade line, hydraulic pressure, and demand flows are shown.

The next output is the line data. This consists of all information related to each line in the system. A minus sign on the flow and velocity means that the flow direction shown by the from-to node numbers is reversed. For example, in line 2 the flow is from node 157 to node 235 because the flow is positive, whereas in line 1, the flow is from node 160 to node 157 because the flow is negative.

F-1.6 GUIDANCE ON USING THE PROGRAM

The hydraulic network analysis program is easy to use and efficient in terms of computer run time and storage requirements. However, there are some techniques that can be used that will yield even better program performance. These are tabulated below.

1. If there are more than two (2) water sources, choose the reference source in a manner that minimizes the distance between the reference and the other sources.

2. Set the solution tolerance (Item 1 in Table F-1.3) as loose as possible. Experience with the program indicates a tolerance of 5 to 10 gpm will yield satisfactory answers for most networks. It is advisable, however, to make a test run at, say, 1 gpm and then 5 and then 10 gpm to determine the most appropriate magnitude.

3. The program will normally find a solution in less than 30 iterations; therefore, the iteration limit (Item 3 in Table F-1.3) should be set at approximately 30.

There are several data error detecting features in the program to aid the user in identifying data errors. These features are:

1. The junction numbers assigned to the line data are compared to the junction data. If a match is not found, the improperly defined line(s) number is printed out.

2. If a line is isolated from the network, this is noted and printed out.

3. If junctions have been defined and not used, this is printed out including a list of the unused numbers.

4. Incorrectly numbered pumps, PRV's, or reservoirs will be noted.

5. If the limit on iterations is reached the solution procedure is probably diverging.

Program Restrictions

1. The maximum number of lines is 400 and the maximum number of junctions is 400.

2. The maximum number of lines that can be connected to a junction is 7.

3. The maximum number of booster pumps is 40.

4. The maximum number of reservoirs plus PRV's is 40.

5. The maximum length of vector A is 6,400. The length of vector A is influenced significantly by the number of reservoirs and/or the number of parallel lines.

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APPENDIX F-2

DISTRIBUTION NETWORK ANALYSIS PROGRAM LISTING

```
C     PROGRAM COMPR COMPARES 2 HYD OUTPUT FILES TO SELECT LARGES DIAMETER
         DIMENSION COMP(20),ADR(5)
          REAL MAXQ
          NHYD=0
         TYPE 401
401      FORMAT(' ENTER OUTPUT DEVICE NAME'/)
         CALL ASSIGN(6,IOUT,-23)
           TYPE 400
400       FORMAT(' ENTER OUTPUT SAVE FILE NAME'./)
         CALL ASSIGN(2,OUT,-23,'NEW',NC,1)
          TYPE 410
410      FORMAT(' ENTER FIRST SAVE FILE NAME'/)
         CALL ASSIGN(3,SAVE,-23,'OLD',NC,1)
         TYPE 420
420      FORMAT(' ENTER SECOND SAVE FILE NAME'/)
         CALL ASSIGN(4,SAV1,-23,'OLD',NC,1)
         READ(3,22) (COM(I),I=1,10)
22       FORMAT(20A4)
         READ(4,22) COM(I),I=11,20)
          WRITE(2,22) COM
          WRITE(6,22) COM
          READ(3,23) MAXQ,PERCE,MAXIT,IRIT,IMETER,SMIN,SMAX,DINCS,DINCL,
        1DIAT,DMAX,NOPT
         WRITE(2,23) MAXQ,PERCE,MAXIT,IRIT,IMETER,SMIN,SMAX,DINCS,DINCL,
        1DIAT,DMAX,NOPT
         WRITE(6,23)  MAXQ,PERCE,MAXIT,IRIT,IMETER,SMIN,SMAX,DINCS,DINCL,
        1DIAT,DMAX,NOPT
         READ(4,23) MAXQ
23       FORMAT(F6.0,F6.4,I4,2I2,6F6.2,I2)
         DO 20 J=1,700
          READ(3,21) NOXY,(ADR(I1),I1=1,5),ELEV,D,TEMP
         WRITE(2,21) NOXY,(ADR(I1),I1=1,5),ELEV,D,TEMP
21        FORMAT(I5,5A4,F7.1,F7.0,F7.1)
         WRITE(6,21) NOXY,(ADR(I1),I1=1,5),ELEV,D,TEMP
          READ(4,21) NO
         IF(NOXY.EQ.0) GO TO 26
20       CONTINUE
26       CONTINUE
         DO 30 I=1,700
          READ(3,31) LI,NO1,NO2,C,D,HW,NEW,ICOST,D3
31       FORMAT(3I5,3F6.0,6X,2I5,F6.0,I5)
          D2=D3
         IF(NHYD.GT.0) D2=D
         D4=D
         D5=D3
         IF(NHYD.LT.1.AND.ICOST.EQ.0) D2=0.
         J=3
```


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```
      HW2-HW
      ICOST1=ICOST
       READ(4,31) LI,NO1,NO2,C,D,HW,NEW,ICOST,D3
      D6=D3
      IF(NHYD.GT.0) D6=D
       IF(NHYD.LT.1.AND.ICOST.EQ.0) GO TO 35
      IF(D6.LT.D2) GO TO 35
      D4=D
      D5=D3
      J=4
      HW2=HW
      ICOST1=ICOST
35    WRITE(2,31) LI,NO1,NO2,C,D4,HW2,NEW,ICOST1,D5
      WRITE(6,31) LI,NO1,NO2,C,D4,HW2,NEW,ICOST1,D5,J
      IF(LI.EQ.0) GO TO 40
   30  CONTINUE
40    CONTINUE
      DO 100 I=1,40
      READ(3,102) K,L,COR4
      WRITE(2,102) K,L,COR4
      WRITE(6,102) K,L,COR4
      IF(K.EQ.0) GO TO 101
100    CONTINUE
101   CONTINUE
102   FORMAT(2I5,5F10.0)
       END
```

```
      SUBROUTINE CHNG
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,ICI,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),(NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1 (A(801),ILI(1),IPL(1)),(A(1201),LLIN(1),NNST(1)),
     2 (A(1601),JUNCL(1)),(A(2001),IL(1)),(a(2401),HDGL(1),NX(1))
     3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),NDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,MET1
C IF  COBO IS ZERO AND THER IS REVERSE FLOW
C SET  COEF=1 AND REMOVE SET POINTS
      J1=0
      DO 22 J=1,NORS
      IJ=NOJUC(J)
      DO 23 I=IC1S,IC1
      LP=NRV1(I)
     READ(8'LP) LT,NO2,NO1,COMPR,D1,DO,C,T1,COEF,Q,NEW
      IF(NO1.EQ.IJ) GO TO 10
23    CONTINUE
      J1=J1+1
      NOJUC(J1)=IJ
      COR4(J1)=COR4(J)
      GO TO 22
10    COEF=1.
     WRITE(8'LP) LT,NO1,NO2,COMPR,D1,DO,C,T1,COEF,Q,NEW
22    CONTINUE
      J2=NORS-J1
      NRES=NRES-J2
      NORS=NRES-1
      RC=SUM/FLOAT(NRES)
     READ(4'NR) NOXYT,(A(I1),II=1,5),EL,DEMAND
     DEMAND=RC
     WRITE(4'NR) NOXYT,(A(I1),I1=1,5),EL,DEMAND
     DO 24 I=1,NORS
      L=NOJUC(I)
     READ(4'L) NOXYT,(A(I1),I1=1,5),EL,DEMAND
     DEMAND
     WRITE(4'L) NOXYT,(A(I1),I1=1,5),EL,DEMAND
24   CONTINUE
      DO 26 I=IC1S,IC1
```


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```
      LP=NRV1(I)
      READ(8'LP) LT,NO2,NO1
      READ(4'NO1) NOXYT,(A(I1),I1=1,5),EL,DEMAND
      DEMAND=0.
      WRITE(4'NO1) NOXYT,(A(I1),I1=1,5),EL,DEMAND
26    CONTINUE
      IC1S=IC1+1
      RETURN
      END
```


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```
      SUBROUTINE COMPAR
     COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
    2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
    3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
    4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
    5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
    6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
    7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
    BNR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
    9MAXIT,IC,ICI,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSDI(3)),(NOPIP(1),LPRP(1),NOLAL(1))
    1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(a(401),NLT(1),IDL(1)),
    1(A(801),ILI(1),IPL(1)),(A(1201),LLIN(1),NNST(1)),
    2(A(1601),JUNCL(1)),(A(2001),IL(1)),(A(2401),HDGL(1),NX(1))
    3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
    4,(A(5401),NOST(1)),(a(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
    1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
    2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
    3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,COM(20),MET1
      PERCE=1.
      WRITE(9,22) COM
22    FORMAT(20A4)
      WRITE(9,23) MAXQ,PERCE,MAXIT,IRIT,IMETER,SMIN,SMAX,DINCS,
    IDINCL,DIAT,DMAX,NOPT
23    FORMAT(2F6.1,I4,2I2,6F6.2,I2)
      DO 2o J=1,JUNCS
       READ(4'J) NOXYT,(A(I1),I1=1,5),RC,D
       DO 40 J1=1,NRES
       IF(NRN(J1).EQ.J) D=1.
40     CONTINUE
20     WRITE(9,21) NOXYT,(A(I1),I1=1,5),RC,D,TEMP
21     FORMAT(I5,5A4,F7.1,F7.0,F7.1)
       1=0
       WRITE(9,21) I
31     FORMAT(3I5,3F6.0,6X,2I5,F6.0)
       WRITE(IOUT,100)
 100   FORMAT(1H1,'LINE NO  EXISTING  NEW    EQUIVALENT')
       DO 10 I=1,LINES
       READ(8'I) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,Q,NEW
       D=D1
       ICOST=1
       IF(NEW.GT.0) GO TO 11
       ICOST=0
       IF(DO.EQ.D) GO TO 11
       PERCE=COEF*ABS(Q)**1.8518
       Q1=HW*DO**2.63*(PERCE/(10.41*MET1*COMPR)**.54
       Q2=ABS(Q)-Q1
       D=(Q2/ABS(Q)**.3802*D1
       ID=D/10.+.5
```


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```
      D=ID*10
      WRITE(IOUT,110) LT,DO,D1,D
110   FORMAT(1H ,I5,3F10.1)
      ICOST=1
11    CONTINUE
      READ(4'NO1) NOXYT
      READ(4'NO2) N2
      WRITE(9,31) LT,NOXYT,N2,COMPR,D1,HW,NEW,ICOST,D
10    CONTINUE
       I=0
       WRITE(9,21) I
       RETURN
       END
```


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```
      SUBROUTINE ZERO
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20)
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,IC1,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),(NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1),IPL(1)),(a(1201),LLIN(1),NNST(1)),
     2(A(1601),JUNCL(1)),(A(2001),IL(1)),(A(2401),HDGL(1),NX(1))
     3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,MET1
      IC1=0
C IF   DOWN STREAM HGL IS LOWER THAN UPSTR
C  SET   PRV SET POINT
      DO 10 I=1,NOBP
      LP=NRN(I)
      IF(COBO(I).GT.0.) GO TO 10
     READ(8'LP) LT,NO2,NO1
      DO 26 IJ=1,NOPRV
      K=NOJT(IJ)
      IF(K.EQ.NO1) GO TO 27
26    CONTINUE
27    K=IJ
      IF(HDGL(NO1).LT.COR4S(K) GO TO 22
      IC1=1
      NORS=NORS+1
      COR4(NORS)=COR4S(K)
      NOJUC(NORS)=NO1
      1FIRST=2
      GO TO 10
22    CONTINUE
     WRITE(IOUT,31) NO1,HDGL(NO1)
31   FORMAT(1H ,'HGL AT ',I5,' IS',F10.1)
      COBO(I)=0.
10   CONTINUE
     NRES=NORS+1
     WRITE(IOUT,50) NRES
50   FORMAT(1H ,'NO OF RESERVOIRS PLUS FIXED HEAD JUNCTIONS = ',I5)
     RETURN
     END
```

```
      SUBROUTINE DIA(IDIA,IDIAC)
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
     7IDEX,NORS,NIM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,IC1,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),(NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1),IPL(1)),(A(1201),LLIN(1),NNST(1)),
     2(A(1601),JUNCL(1)),(A(2001),IL(1)),(A(2401),HDGL(1),NX(1))
     3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILT(400),IPL(400),LLIN(400),NNST(400),
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,COM(20),MET1
      DMIN=20
      FQL=0
      IDIA=1
      IDIAC=IDIAC+1
      IF(IDIAC.GT.15) RETURN
      DO 150 I=1,LINES
      II=I
      READ(8'II) LT,NO1,NO2,COMPR,D1,DO,C,T1,RC,Q,NEW
      TEMP=10.41*MET1*(COMPR+EQL)
      IF(D1.GT.DMAX) GO TO 150
      PERCE=RC*Q*ABS(Q)**.8518
      UL=ABS(PERCE)/COMPR*1000.
      IF(UL.LT.SMIN.OR.UL.GT.SMAX) GO TO 160
      GO TO 150
160   ADD=DINCL
200   FORMAT(' LINE ',I5,' ADJUSTED  DIA.= ',F6.0,' UL = ',F8.2)
      IF(D1.LT.DIAT) ADD=DINCS
      IF(UL.LT.SMIN) GO TO 170
      D1=D1+ADD
      IDIA=0
      WRITE(IOUT,200) LT,D1,UL
      RC=TEMP/(C*D1**2.63)**1.8518
      WRITE(8'II)LT,NO1,NO2,COMPR,D1,DO,C,T1,RC,Q,NEW
      GO TO 150
170   IF(NEW.EQ.0) GO TO 150
      D1=D1-ADD
      IF(D1.LT.DMIN) GO TO 180
      IDIA=0
      GO TO 181
180   D1=20.
```

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181     WRITE(IOUT,200) LT,D1,UL
        RC=TEMP/(C*D1**2.63)**1.8518
        WRITE(8'II) LT,NO1,NO2,COMPR,D1,DO,C,T1,RC,Q,NEW
150     CONTINUE
        RETURN
        END
```

```
      SUBROUTINE MATRIX
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIR,IC,IC1,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1),IPL(1)),(A(1201),LLIN(1),NNST(1)),
     2(A(1601),JUNCL(1)),(a(2001),IL(1)),(A(2401),HDGL(1),NX(1))
     3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,C(5),MET1
      CNTR=1./1.8518
      WRITE(IOUT,1)
1     FORMAT(1H ,'SET UP MATRIX')
1825  ICOUT=0
      ICTEST=0
1827  DO 42 I=1,20
      NRV1(I)=0
42    NRV(I)=0
      ITER=0
1826  DO 111 I=1,LNTH
111   A(I)=0.0
      DO 114 I=1,N
114   DELP(I)=0.
      DO 116 I=1,LINES
      L1=NOSD1(I)
      L2=NOSD1(I+1)-1
      IF(L1.GT.L2) GO TO 116
     READ(8'I) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,PRQ,NEW
      RC=COEF*ABD(PRQ)**.8518
      BMQ=RC*PRQ
      GO TO 1410
130   IF(L1.GT.L2) GO TO 116
1410  J=NOLAL(L1)
      JJ=IABS(J)
      S=1.0
      IF(J.GT.0) S=1.0
      DELP(JJ)=DELP(JJ)+BMQ*S
      KKK=(JJ-1)*NODI+1
      DO 131 L=L1,L2
      K=NOLAL(L)
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      KK=IABD(K)
     IDEX=KKK+KK-JJ
      S=1.0
      IF(J*K.LT.0) S=-1.0
      A(IDEX)=A(IDEX)+S*RC
131   CONTINUE
      L1=L1+1
      GO TO 130
116   CONTINUE
     IF(NORS.EQ.0) GO TO 4021
      D=D/RP
      ABD=ABS(D)
      T=HEAD*(1.0+D*(RP1+ABD*(RP2+ABD*RP3)))+RHD
      D=D*RP
      DO 1703 I=1,NORS
      K=NIL(I)
      L=NOJUC(I)
     READ(4'L) NOXYT,(C(I1),I1=1,5),EL,DEMAND
     DND=DEMAND
      ABD=ABD(DND)
     DELP(K)=DELP(K)+T-COR4(I)
      IIS=(K-1)*NODI +1
     A(IIS)=A(IIS)+RP1*HEAD
1703  CONTINUE
4021 CONTINUE
      IF(NOBP.EQ.0) GO TO 1716
      DO 1717 I=1,NOBP
      T=0.
      RC=0.
      IF(COBO(I).LT.)..AND.IFIRST.EQ.1) GO TO 1720
      LP=NRN(I)
     READ(8'LP) LT,NO1.NO2,COMPR,D1,DO,HW,T1,COEF,Q,NEW
      PRQ=Q
      ABQ=ABS(PRQ)
      T=-(COBO(I)*(1.-PRQ*(COB1(I)+ABQ*(COB2(I)+ABQ*(COB3(I))))))
     T1=-T
     WRITE(8'LP) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,Q,NEW
      RC=COBO(I)*(COB1(I)+ABQ*(2.*COB2(I)+ABQ*(3.*COB3(I))))
      RC=RC*CNTR
1720  L1=NOSD1(LP)
      L2=NOSD1(LP+1)-1
1719  IF(L1.GT.L2) GO TO 1717
      J=NOLAL(L1)
      JJ=IABS(J)
      S=1.0
      IF(J.GT.0) S=-1.0
      DELP(JJ)=DELP(JJ)+S*T
      KKK=(JJ-1)*NODI+1
      DO 1718 L=L1,L2
      K=NOLAL(L)
      KK=IABS(K)
      S=1.0
```

```
      IF(J*K.LT.0) S=-1.0
      IDEX=KKK+KK-JJ
      A(IDEX)=A(IDEX)+S*RC
1718  CONTINUE
      L1=L1+1
      GO TO 1719
1717  CONTINUE
1716  CONTINUE
      DO 1704 I=1,N
      DELP(I)=DELP(I)*CNTR
1704  CONTINUE
      CALL COMP(A,DELP,N,NODI,IOUT)
      DOM=0.0
      DO 1707 I=1,N
      DQ=ABS(DELP(I))
      IF(DQ.GT.DQM) DQM=DQ
1707  CONTINUE
      DO 1705 I=1,LINES
      L1=NOSD1(I)
      L2=NOSD1(I+1)-1
      IF(L1.GT.L2) GO TO 1705
      T=0.0.
      DO 1706 L=L1,L2
      J=NOLAL(L)
      S=1.0
      IF(J.LT.0) S=-1.0
      J=IABS(J)
      T=T+S*DELP(J)
1706  CONTINUE
      READ(8'1) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,Q,NEW
      Q=Q+T
      WRITE(8'I) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,Q,NEW
1705  CONTINUE
      IF(NORS.EQ.0) GO TO 1708
      DO 1709 I=1,
      K=NOJUC(I)
      J=NIL(I)
      DQ=DELP(J)
      READ(4'K) NOXYT,(C(I1),L1=1,5),EL,DEMAND
      DEMAND-DEMAND+DQ
      WRITE(4'K)NOXYT,(C(I1),I1=1,5),EL,DEMAND
      D=D-DQ
1709  CONTINUE
      READ(4'NR) NOXYT,(C(I1),I1=1,5),EL,DEMAND
      WRITE(4"NR) NOXYT,(C(I1),I1=1,5),EL,D
1708  CONTINUE
      ITER=ITER+1
      IF(ITER.GT.MAXIT) GO TO 2
      IF(DQM.GT.MAXQ) GO TO 1826
2     WRITE(IOUT,1984) ITER
1984  FORMAT(1HO,50X,'NUMBER OF ITERATIONS=',I5//)
      IF(NOBP.EQ.0) GO TO 3815
      IF(NOPRV.EQ.0) GO TO 1828
```


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```
      IF(IFIRST.NE.1) GO TO 1828
      RETURN
1828    IFIRST=3
      IC=0
      IC1=0
C FIND LINES WITH REVERSE FLOW
      DD 2000 J=1,NOBP
      LP=NRN(J)
      IF(COBO(J).NE.0.) GO TO 2101
      IC1=IC1+1
      NRV1(IC1)=LP
      GO TO 2000
2101   READ(8'LP) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,Q,NEW
      IF(Q.GT.0.) GO TO 2000
      IC=IC+1
      NRV(J)=LP
2000  CONTINUE
      IF(IC.EQ.0) GO TO 2002
      ICTEST =1CTEST+1
      IF(ICTEST.GT.20) GO TO 4815
       WRITE(IOUT,29)
  29  FORMAT(1H ,'PRESSURE DROP (LOSS) HAS BEEN ADJUSTED IN THE FOLLOWING
      LINES')
C ADJUST PRESS. DROP IN REVERSE FLOW LINES
      DO 28 I=1,NOBP
      L=NRV(I)
       IF(L.EQ.0) GO TO 28
      LP=L
      COBO(I)=COBO(I)+1.
      IF(ABS(COBO(I)).LT.2.) COBO(I)=0.
      WRITE(IOUT,27) LP
27    FORMAT(1H ,15)
 28   CONTINUE
      GO TO 1827
2002   CONTINUE
C RETURN IF THERE IS REVERSE FLOW AND COBO HAS BEEN REDUCED TO ZERO
C SO COEF CAN BE SET = 1 USING SUBROUTINE CHNG
      IF(IC1.GE.IC1S) RETURN
      ICOUT=ICOUT+1
      IF(ICOUT.GT.8) GO TO 4815
      ICOUNT=0
      IF(NOPRV.EQ.0) GO TO 3815
      DO 30 IJ=1,NOPRV
      NO1=NOJT(IJ)
      DO 50 J=1,NORS
      NO2=NOJUC(J)
      IF(NO1.EQ.NO2) GO TO 51
50    CONTINUE
      GO TO 30
51    K=J
C ADJUST PRV SET POINTS TO REDUCE FLOW
      READ(4'NO1) NOXYT,(C(I1),I1=1,5),EL,DEMAND
```


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```
      IF(DEMAND.GT.300.) GO TO 32
      GO TO 31
32     COR4(K)=COR4(K)+2.
      WRITE(IDUT,7000) NO1,COR4(K),DEMAND
      ICOUNT=1
31    CONTINUE
      READ(4'NO1) NOXYT,(C(I1),I1=1,5),EL,DEMA
      IF(DEMAND.LT.-300.) GO TO 33
      GO TO 30
33     COR4(K)=COR4(K)-2.
      WRITE(IOUT,7000) NO1,COR4(K),DEMAND
7000  FORMAT(1H ,'PRV SET POINT AT JUNCTION ',I5,' HAS BEEN ADJUSTED TO'
     1,F12.1,' BECAUSE DEMAND = ',F12.1)
      ICOUNT=1
30    CONTINUE
      IF(ICOUNT.EQ.1) GO TO 1827
      GO TO 3815
 4815   WRITE(IOUT,4816)
4816  FORMAT(1H ,'THER IS EITHER NEGATIVE FLOW OR TOO HIGH DEMAND AT A
     1FIXED HEAD JUNCTION')
3815  IF(NOPT.EQ.0) GO TO 3816
      CALL DIA(IDIA,IDIAC)
      IF(IDIA.EQ.0) GO TO 1825
3816  IC1=0
      RETURN
      END
```

```
      SUBROUTINE PROFIL
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,IC1,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSP(2),NOSD1(3)),NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1),IPL(1)),(A(1201),LLIN(1),NNST(1)),
     2(a(1601),JUNCL(1)),(A(2001),IL(1)),(A(2401),HDGL(1),NX(1))
     3,(a(2801),INDK(1)),(a(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      DATA FL/' US ','IMP '/
      REAL MAXQ,MET1,FL(2)
      TEMP=3.5368
      TEMP1=1.
      IF(IMETER.EQ.1) GO TO 3
      TEMP=.4085
      TEMP1=.433
      IK=1
      IF(IMETER.EQ.0) GO TO 3
      TEMP=.49059
      TEMP1=.433
      IK=2
3     CONTINUE
      I=0
      KK=(JUNCS-1)/22+1
      DO 2 KKK=1,KK
      IDEX=JUNCS-I
      IF(IDEX.GT.22) IDEX=22
      WRITE(IOUT,1001)
1001  FORMAT(1H1,////,37X,'JUNCTION OUTPUT DATA')
      WRITE(IOUT,1002)
1002  FORMAT(1HO,'JUNCTION',T17,"ADDRESS',T33,'GROUND    ELEVATION
     1  PRESSURE     OUTFLOW')
      IF(IMETER.EQ.1) GO TO 7
6     WRITE(IOUT,8) FL(IK)
8     FORMAT(1HO,T3,'NUMBER',T31,' LEVEL-FT    OF HGL-FT',9X,'PSIG',
     17X,A4,'GPM')
      GO TO 9
7     WRITE(IOUT,1003)
1003  FORMAT(1HO,T3,'NUMBER',T31,' LEVEL-M     OF HGL-M ',8X,'METERS',
     16X,' CMH   ')
```

```
9         CONTINUE
          DO 146 JJ=1,IDEX
          I=I+1
         READ(4'I) NX1,(COB1(I1),I1=1,5),RC,DEMAND
         NLNJ(I)=NX1
          PRESH=(HDGL(I)-RC)*TEMP1
          WRITE(IOUT,900) NX1,(COB1(I1),I1=1,5),RC,HDGL(I),PRESH,DEMAND
146       CONTINUE
 900      FORMAT(1HO,T1,I5,T11,5A4,T33,F6.0, 5X,F6.0,9X,F7.1,6X,F8.0)
 2        CONTINUE
          I=0
          KK=(LINES-1)/22+1
          DO 1 KKK=1,KK
          IDEX=LINES-I
          IF(IDEX.GT.22) IDEX=22
          WRITE(IOUT,910)
 910      FORMAT(1H1,////,49X,'LINE DATA OUTPUT')
          WRITE(IOUT,911)
911       FORMAT(1HO,3X,'LINE',6X,'FROM',9X,'TO',9X,'H-W',5X,'DIAMETER',
        13X,'LENGTH',5X,'FLOW',5X,'VELOCITY',5X,'HEAD',5X,'UNIT LOSS',
        23X,'BOOSTER')
          IF(IMETER.EQ.1) GO TO 4
         WRITE(IOUT,5) FL(IK)
          GO TO 10
5         FORMAT(1HO,4X,'NO.',4X,'JUNCTION',4X,'JUNCTION',5X,'COEF.',
        17X,'IN',8X,'FT',5X,A4,'GPM',7X,'FPS',6X,'LOSS-FT',3X,'FT/1000FT',
        3'   HEAD-FT')
4         WRITE(IOUT,912)
912       FORMAT(1HO,4X,'NO.',4X,'JUNCTION',4X
        17X,'CM',6X,'METERS',3X,'  CMH  ' ,5X,
        1    HEAD-M')
10        CONTINUE
          DO 150 JJ=1,IDEX
          I=I+1
         READ(8'I) LT,NO1,NO2,COMPR,D1,DO,C,T1,RC,PRQ,NEW
          IF(NO1.EQ.0) GO TO 150
          NX1=NLNJ(NO1)
          NX2=NLNJ(NO2)
         V=PRQ*TEMP  /(D1*D1)
          PERCE=RC*PRQ*ABS(PRQ)**.8518
          PERCE=PERCE-T1
          UL=PERCE/COMPR*1000.
          WRITE(IOUT,800) LT,NX1,NX2,C,D1,COMPR,PRQ,V,PERCE,UL,T1
150       CONTINUE
 800      FORMAT(1HO,1X,I5,6X,I5,7X,I5,8X,
        1F4.0,4X,F6.0,6X,F6.0,
        12X,F8.1,4X,F7.2,5X,F6.1,2X,F9.1,5X,F6.1)
 1        CONTINUE
          SMAX=0.0
          IF(NORS.EQ.0)GO TO 2021
          DO 2020 I=1,NORS
          K=NOJUC(I)
```


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```
            IF(K.LE.O.OR.K.GT.700) WRITE(IOUT,9001) I,K
9001        FORMAT(1X,2I5)
       READ(4'K) NOXYT,(COB1(I1),I1=1,5),RC,DEMAND
        DND=DEMAND
        ABD=ABD(DND)
        HGL=COR4(I)
        S=ABD(HGL-HDGL(K))
        IF(S.GT.SMAX) SMAX=S
2020    CONTINUE
2021      CONTINUE
        IF(NL.EQ.0) GO TO 3317
        DO 1712 I=1,N
       DELP(I)=0.
1712    CONTINUE
        DO 1710 I=1,LINES
        L1=NOSD1(I)
        L2=NOSD1(I+1)-1
        IF(L1.GT.L2) GO TO 1710
        RC=QTJU(I)
        DO 1711 L=L1,L2
        J=NOLAL(L)
        S=1.0
        IF(J.LT.0) S=1.0
        J=IABS(J)
       DELP(J)=DELP(J)+S*RC
1711    CONTINUE
1710    CONTINUE
       IF(NORS.EQ.0) GO TO 2453
       DO 2454 I=1,NORS
       J=NIL(I)
      DELP(J)=0.
2454   CONTINUE
2453   CONTINUE
       DO 1713 I=1,N
      S=ABS(DELP(I))
       IF(S.GT.SMAX) SMAX=S
1713   CONTINUE
3317   WRITE(IOUT,2173) SMAX
2173   FORMAT(1H1,   29HMAXIMUM UNBALANCED HEAD LOSS=,E12.5)
       WRITE(IOUT,9000)
9000   FORMAT(1H1)
       REUTRN
       END
```

```
      SUBROUTINE INPUT(NSTOP)
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(2o),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,IC1,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),(NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1),IPL(1),(A(1201),LLIN(1),NNST(1)),
     2(A(1601),JUNCL(1)),(A(2001),IL(1)),(A(2401),HDGL(1),NX(1))
     3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,COM(20),MET1
      LDIM=400
      IF(IFIRST.EQ.2) GO TO 410
      IF(IC1.LE.0) GO TO 411
      GO TO 410
411   READ(IIN,2,END=3) COM
      NSTOP=0
      WRITE(IOUT,5) COM
2     FORMAT(20A4)
5     FORMAT(T10,20A4)
      IDEX=1
      READ(IIN,6) MAXQ,PERCE,MAXIT,IRIT,IMETER,SMIN,SMAX
     1,DINCS,DINCL,DIAT,DMAX,NOPT
6     FORMAT (2F6.0,I4,2I2,6F6.0,I2)
      MET1=1.
      IF(IMETER.EQ.1) MET1=1081.72
      IF(IMETER.EQ.2) MET1=1.4037
      NRES=0
      JUNCS=0
      SUM=0.
      J=0
C READ JUNCTION DATA
      DO 12 I=1,1000
      READ(IIN,13,ERR=600) NOXYT,(A(I1),I1=1,5),RC,D,TEMP
13    FORMAT(I5,5A4,3F7.0)
      IF(NOXYT.LT.1) GO TO 15
      IF(D.EQ.-1.) GO TO 38
      D=D*PERCE
      SUM=SUM+D
      GO TO 300
```

```
 38.     NRES=NRES+1
         NRN(NRES)=I
300      JUNCS=JUNCS+1
        WRITE(4'I) NOXYT,(A(I1),I1=1,5),RC,D
         NLNJ(I)=NOXYT
         IF(TEMP.LT.1.) GO TO 12
         J=J+1
         NOJT(J)=I
         COR4S(J)=TEMP
 12      CONTINUE
 15        CONTINUE
         DO 9 1=1,LDIM
         NOLJ(I)=0
9        CONTINUE
         NOPRV=J
          RC=SUM/FLOAT(NRES)
         DO 301 I=1,NRES
         L=NRN(I)
        READ(4'L) NOXYT,(A(I1),I1=1,5),EL,D
        D=-RC
        WRITE(4'L) NOXYT,(A(I1),I1=1,5),EL,D
301      CONTINUE
         LINES=0
        Q=0.
         T1=0.
C  READ LINE DATA
         DO 21 L=1,1000
         READ(IIN,14,ERR=602) LT,NO1,NO2,COMPR,D,C,EQL,NEW
 14      FORMAT(3I5,4F6.0,I5)
         IF(LT.LT.1) GO TO 25
         LINES=LINES+1
         COEF=10.41/(C*D**@.63)**1.85*MET1*(COMPR+EQL)
         DO 29 M1=1,JUNCS
         IF(NLNJ(M1)-NO1) 29,33,29
 29      CONTINUE
          WRITE(IOUT,17) LT,NO1
         IDEX=0
 33      DO 35 M2=1,JUNCS
         IF(NLNJ(M2)-NO2) 35,37,35
35       CONTINUE
          WRITE(IOUT,17) LT,NO2
         IDEX=0
17       FORMAT(1H ,'MATCH NOT FOUND',2I5)
37       CONTINUE
         WRITE(8'L) LT,M1,M2,COMPR,D,D,C,T1,COEF,Q,NEW
         NOLJ(M1)=NOLJ(M1)+1
         NOLJ(M2)=NOLJ(M2)+1
 21      CONTINUE
 25      CONTINUE
         WRITE(IOUT2) (NOLJ(J),J=1,LDIM)
         J1=0
         DO 403 I=1,JUNCS
         DO 401 J=1,LINES
```


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```
        READ(8'J) LT,NO1,NO2
        IF(NO1.EQ.I) GO TO 403
        IF(NO2.EQ.I) GO TO 403
401       CONTINUE
         J1=J1+1
         ISAVE(J1)=I
403      CONTINUE
         IF(J1.EQ.0) GO TO 410
         WRITE(IOUT,3318)
3318     FORMAT(1HO,'THE FOLLOWING JUNCTIONS ARE NOT CONNECTED')
         DO 420 J=1,J1
         I=ISAVE(J)
         WRITE(IOUT,3319( NLNJ(I
3319     FORMAT(1HO,I8)
420         CONTINUE
410      CONTINUE
        REWIND IOUT2
        READ(IOUT2) (NOLJ(J),J=1,LDIM)
         IF(IDEX.EQ.0) GO TO 18
         IF(IRIT.GT.0) GO TO 16
 18      CONTINUE
         DO 11 I=1,LINES
        READ(8'I) LT,NO1,NO2
11      WRITE(IOUT,10) LT,NLNJ(NO1),NLNJ(NO2)
         IF(IDEX.EQ.0) STOP 'ERROR IN DATA'
16       CONTINUE
10       FORMAT(1H, 3I5)
       NNUM=JUNCS+1
        DO 7 I=1,NNUM
7       NLNJ(I)=0
        NNUM=LINES*2
        DO 8 I=1,NNUM
8       LNJ(I)=0
        NLNJ(1)=1
        NTM=1
        J=1
        JUNCS=JUNCS+1
        DO 200 I=2,JUNCS
        NTM=NTM+NOLJ(J)
        J=1
200     NLNJ(I)=NTM
        JUNCS=JUNCS-1
       Q=0.
        DO 201 I=1,LINES
       READ(8'I) LT,NO1,NO2,COMPR,D1,DO,C,T1,COEF,D,NEW
       WRITE(8'I) LT,NO1,NO2,COMPR,D1,DO,C,T1,COEF,Q,NEW
        IF(NO1.EQ.0) GO TO 201
        ITM1=NLNJ(NO1)
        ITM2=NLNJ(NO2)
        NLNJ(NO1)=ITM1+1
        NLNJ(NO2)=ITM2+1
```


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```
 38.     NRES=NRES+1
         NRN(NRES)=I
300      JUNCS=JUNCS+1
        WRITE(4'I) NOXYT,(A(I1),I1=1,5),RC,D
         NLNJ(I)=NOXYT
         IF(TEMP.LT.1.) GO TO 12
         J=J+1
         NOJT(J)=I
         COR4S(J)=TEMP
 12      CONTINUE
 15        CONTINUE
         DO 9 1=1,LDIM
         NOLJ(I)=0
9        CONTINUE
         NOPRV=J
          RC=SUM/FLOAT(NRES)
         DO 301 I=1,NRES
         L=NRN(I)
        READ(4'L) NOXYT,(A(I1),I1=1,5),EL,D
        D=-RC
        WRITE(4'L) NOXYT,(A(I1),I1=1,5),EL,D
301      CONTINUE
         LINES=0
        Q=0.
         T1=0.
C  READ LINE DATA
         DO 21 L=1,1000
         READ(IIN,14,ERR=602) LT,NO1,NO2,COMPR,D,C,EQL,NEW
 14      FORMAT(3I5,4F6.0,I5)
         IF(LT.LT.1) GO TO 25
         LINES=LINES+1
         COEF=10.41/(C*D**@.63)**1.85*MET1*(COMPR+EQL)
         DO 29 M1=1,JUNCS
         IF(NLNJ(M1)-NO1) 29,33,29
 29      CONTINUE
          WRITE(IOUT,17) LT,NO1
         IDEX=0
 33      DO 35 M2=1,JUNCS
         IF(NLNJ(M2)-NO2) 35,37,35
35       CONTINUE
          WRITE(IOUT,17) LT,NO2
         IDEX=0
17       FORMAT(1H ,'MATCH NOT FOUND',2I5)
37       CONTINUE
         WRITE(8'L) LT,M1,M2,COMPR,D,D,C,T1,COEF,Q,NEW
         NOLJ(M1)=NOLJ(M1)+1
         NOLJ(M2)=NOLJ(M2)+1
 21      CONTINUE
 25      CONTINUE
         WRITE(IOUT2) (NOLJ(J),J=1,LDIM)
         J1=0
         DO 403 I=1,JUNCS
         DO 401 J=1,LINES
```


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```
        READ(8'J) LT,NO1,NO2
        IF(NO1.EQ.I) GO TO 403
        IF(NO2.EQ.I) GO TO 403
401       CONTINUE
         J1=J1+1
         ISAVE(J1)=I
403      CONTINUE
         IF(J1.EQ.0) GO TO 410
         WRITE(IOUT,3318)
3318     FORMAT(1HO,'THE FOLLOWING JUNCTIONS ARE NOT CONNECTED')
         DO 420 J=1,J1
         I=ISAVE(J)
         WRITE(IOUT,3319( NLNJ(I)
3319     FORMAT(1HO,I8)
420         CONTINUE
410      CONTINUE
        REWIND IOUT2
        READ(IOUT2) (NOLJ(J),J=1,LDIM)
         IF(IDEX.EQ.0) GO TO 18
         IF(IRIT.GT.0) GO TO 16
 18      CONTINUE
         DO 11 I=1,LINES
        READ(8'I) LT,NO1,NO2
11      WRITE(IOUT,10) LT,NLNJ(NO1),NLNJ(NO2)
         IF(IDEX.EQ.0) STOP 'ERROR IN DATA'
16       CONTINUE
10       FORMAT(1H, 3I5)
       NNUM=JUNCS+1
        DO 7 I=1,NNUM
7       NLNJ(I)=0
        NNUM=LINES*2
        DO 8 I=1,NNUM
8       LNJ(I)=0
        NLNJ(1)=1
        NTM=1
        J=1
        JUNCS=JUNCS+1
        DO 200 I=2,JUNCS
        NTM=NTM+NOLJ(J)
        J=1
200     NLNJ(I)=NTM
        JUNCS=JUNCS-1
       Q=0.
        DO 201 I=1,LINES
       READ(8'I) LT,NO1,NO2,COMPR,D1,DO,C,T1,COEF,D,NEW
       WRITE(8'I) LT,NO1,NO2,COMPR,D1,DO,C,T1,COEF,Q,NEW
        IF(NO1.EQ.0) GO TO 201
        ITM1=NLNJ(NO1)
        ITM2=NLNJ(NO2)
        NLNJ(NO1)=ITM1+1
        NLNJ(NO2)=ITM2+1
```


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```
      LNJ(ITM1)=1
      LNJ(ITM2)=1
201   CONTINUE
      DO 203 I=1,JUNCS
 203  NLNJ(I)=NLNJ(I)-NOLJ(I)
      WRITE(IOUT,305) JUNCS,LINES
305   FORMAT(1HO,'NO OF JUNCTIONS = ',I5,'   NO OF LINES = ',I5)
      WRITE(IOUT,306) SUM
306   FORMAT(1HO,'TOTAL SYSTEM FLOW = ',F10.1,' GPM OR CMH')
     RETURN
3    NSTOP=1
     REUTRN
600  WRITE(IOUT,601) NOXYT
601  FORMAT(' CONVERSION ERROR IN DATA NEAR JUNCTION ',I5)
     NSTO=1
     RETURN
602  WRITE(IOUT,603) LT
603  FORMAT(' CONVERSION ERROR IN DATA NEAR LINE ',I5)
     NSTOP=1
     END
```


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```
C SUBROUTINE NEEDED
C  INPUT
C  TREE
C  LOOP
C  PARAM
C  NUMBER
C  MATRIX
C  PROFIL
C  HYDGL
C  ZERO
C  CHNG
C  COMP
C  DIA
C  COMPAR
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,IC1,IFIRST,NOPRV,IC1s
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),(NOPIP(1),LPRP(1),NOLAL(1)
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1),IPL(1)),(A(1201),LLIN(1),NNST(1)),
     2(A(1601),JUNCL(1)),(A(2001),IL(1)),(A(2401),HDGL(1),NX(1))
     3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,MET1
      IC1=0
      IOUT=6
      IIN=5
      IC1S=1
      CALL ASSIGN(4,'TEMP',4,'SCR',NC,1)
     DEFINE FILE 4(1000,15,U,NREC)
      TYPE 414
414   FORMAT(' ENTER SAVE FILE NAME'/)
       CALL ASSIGN(9,SAVE,-23,'NEW',NC,1)
      IOUT2=3
      TYPE 412
412   FORMAT(' ENTER DATA FILE NAME'/)
      CALL ASSIGN(IIN,FILE,-23)
     TYPE 413
413  FORMAT(' ENTER DATA OUTPUT FILE NAME'/)
     CALL ASSIGN(IOUT,OUTPUT,-23)
```


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```
      CALL ASSIGN(IOUT2,'TEMP1',5,'SCR',NC,1)
      CALL ASSIGN(8,'TEMP2',5,'SCR',NC,1)
      DEFINE FILE 8(1000,18,U,NREC)
       IFIRST=1
1     CONTINUE
       GO TO 3
2     CALL CHNG
3      CALL INPUT(NSTOP)
      IF(NSTOP.EQ.1) GO TO 5
      CALL TREE
      CALL LOOP
      CALL PARAM
       IF(LPKT.NE.0) GO TO 315
      CALL HYDGL
      CALL COMPAR
      CALL PROFIL
      STOP 'TREE NETWORK'
315     CONTINUE
      CALL NUMBER
      CALL MATRIX
       IF(IC1.GE.IC1S) GO TO 2
      CALL HYDGL
      IF(NOBP.EQ.0) GO TO 316
      IF(IFIRST.NE.1) GO TO 316
      IF(NOPRV.NE.0) CALL ZERO
      IFIRST=2
      IF(IC1.EQ.1) GO TO 1
      IC1=1
      IF(NOBP.GT.NOPRV) GO TO 1
316   CALL COMPAR
      CALL PROFIL
        GO TO 1
5     STOP 'END OF RUN'
       END
```

```
      SUBROUTINE TREE
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,IC1,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),(NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1)),(A(1201),LLIN(1),NNST(1)),
     2(A(1601),JUNCL(1)),(A(2001),IL(1)),(A(2401),HDGL(1),NX(1)),
     3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400)
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,C(5),MET1
      DO 16 I=1,LINES
16    ILI(I)=1
      DO 14 I=1,JUNCS
      NLT(I)=0
14    NX(I)=1000
      NX(JUNCS)=0
      K-0
      L2=JUNCS
      IF(NOLJ(JUNCS).ESQ.0) GO TO 3315
      NTM=JUNCS-1
      DO 20 L-1,NTM
      IDEX=NLNJ(L2)
      L1=IDEX+NOLJ(L2)-1
      DO 18 1=IDEX,L1
      LP=LNJ(I)
     READ(8'LP) LT,NU,ND,COMPR,D1,DO,HW,T1,COEF,Q,NEW
     NO1=NO
      IF(NO1.EQ.L2) NO1=ND
      J=NX(NO1)
      IF(J.EQ.0) GO TO 18
      IF(J.NE.1000) GO TO 19
      K=K+1
      NX(NO1)=K
      NOPIP(K)=LP
     QTJU(K)=COEF
      GO TO 18
19   RC=COEF
     IF(QTJU(J).LE.RC)GO TO 18
     QTJU(J)=RC
     NOPIP(J)=LP
```


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```
:18      CONTINUE
         TEMP=1.E20
         IF(K.EQ.0) GO TO 3315
         DO 17 I=1,K
         RC=QTJU(I)
         IF(RC.GE.TEMP) GO TO 17
         TEMP=RC
         IM=I
17       CONTINUE
         LP=NOPIP(IM)
        READ(8'LP) LT,NO1,NO2
         L1=NO1
         IF(NX(NO1).NE.0) L1=NO2
          L2=NO1+NO2-L1
         ILI(LP)=0
         NLT(L1)=NLT(L1)+1
         NLT(L2)=1
         NX(L2)=0
         IF(K.EQ.IM) GO TO 21
         LP=NOPIP(K)
        READ(8'LP) LT,NU,ND
        NO1=NU
        IF(NX(NO1).EQ.0) NO1=ND
         NX(NO1)=IM
         NPIP(IM)=LP
         QTJU(IM)=QTJU(K)
21       K=K-1
20       CONTINUE
          WRITE(IOUT,2024)
2024     FORMAT(' CALCULATE INITIAL FLOWS')
          DO 1918 I=1,JUNCS
        READ(4'I) NOXYT,(C(I1),I1=1,5),EL,DEMAND
1918    QTJU(I)=DEMAND
         K=0
         DO 23 I=1,JUNCS
         IF(NLT(I).NE.1) GO TO 23
         K=K+1
         NOST(K)=I
23       CONTINUE
         DO 25 L=1,NTM
29       L1=NOST(K)
         K=K-1
         IDEX=NLNJ(L1)
         J=IDEX+NOLJ(L1)-1
         DO 26 I-IDEX,J
         LP=LNJ(I)
         IF(ILI(LP).EQ.0) GO TO 27
26       CONTINUE
         GO TO 29
27       ILI(LP)=1
        READ(8'LP) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,Q,NEW
         L2=NO1
```


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```
      IF(L2.EQ.L1) L2=NO2
      J=NLT(L2)-1
      NLT(L2)=J
      IF(J.NE.1) GO TO 28
      K=K+1
      NOST(K)=L2
28    FLO=QTJU(L1)
      T=FLO
      IF(NO1.EQ.L1) FLO=-FLO
     WRITE(8'LP) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,FLO,NEW
      QTJU(L2)=QTJU(L2)+T
25    CONTINUE
      WRITE(IOUT,367) QTJU(L2)
 367  FORMAT(' NETWORK FLOW BALANCE =',F10.3)
      RETURN
3315  WRITE(IOUT,36)
36    FORMAT(1HO,' NETWORK NOT CONTINUOUS')
     STOP 'STOPPED IN LOOP'
      END
```

```
      SUBROUTINE HYDGL
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOP1,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,IC1,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),(NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1),IPL(1)),(A(1201),LLIN(1),NNST(1)),
     2(A(1601),JUNCL(1)),(A(2001),IL(1)),(A(2401),HDGL(1),NX(1))
     3,(A(2801),INDK(1)),(a(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
     2NLNJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,MET1
      DO 150 I=1,LINES
      READ(8'I) LT,NO1,NO2,COMPR,D1,DO,C,T1,RC,PRQ,NEW
      IF(NO1.EQ.0) GO TO 150
      PERCE=RC*PRQ*ABS(PRQ)**.8518
      PERCE=PERCE-T1
      QTJU(I)=PERCE
150   CONTINUE
      D=D/RP
      ABD=ABS(D)
      HGL=HEAD*(1.0+D*(RP1+ABD*(RP2+ABD*RP3)))+RHD
      HDGL(NR)=HGL
      NOST(1)=NR
      K=1
      L=1
      J=1
      DO 140 I=1,JUNCS
140   IDL(I)=0
      IDL(NR)=1
144   NO1=NOST(K)
      K=K+1
      L1=NLNJ(NO1)
      L2=NLNJ(NO1+1)-1
      DO 141 I-L1,L2
      LP=LNJ(I)
      READ(8'LP) LT,NU,ND
      NO2=NU
      AJJ=-1.0
      IF(NO1.NE.NO2) GO TO 143
      NO2=ND
      AJJ=1.0
```


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```
 143     IF(ID:(NO2).EQ.0) GO TO 142
1141     CONTINUE
141     CONTINUE
         IF(J.LT.JUNCS) GO TO 144
        GO TO 145
 142     IDL(NO2)=1
         L=L+1
         NOST(L)=NO2
         HDGL(NO2)=HDGL(NO1)-AJJ*QTJU(LP)
        J=J+1
         GO TO 1141
 145     CONTINUE
         RETURN
         END
```


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```
      SUBROUTINE NUMBER
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOUT,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,IC1,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),(NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1),IPL(1)),(A(1201),LLIN(1),NNST(1)),
     2(a(1601),JUNCL(1)),(a(2001),IL(1)),(a(2401),HDGL(1),NX(1))
     3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,C(5),MET1
      WRITE(IOUT,1)
1     FORMAT(1H ,'NUMBER LOOPS')
      KK=KKK
      JJ=KK
      LMAX=9000
      NODI=0
94    DO 69 J-1,N
69    IL(J)=0
      K=1
      IF(JJ.EQ.0) GO TO 70
      I=IPL(JJ)
      IL(I)=1
      IP(1)=1
      L=1
73    NLP=IP(K)
      L1=NLT(NLP)
      L2=NLT(NLP+1)-1
      IF(LI.GT.L2) GO TO 70
      J=0
      DO 71 I=L1,L2
      LP=INDK(I)
      IF(IL(LP).NE.0) GO TO 71
      J=J+1
      NOST(J)=LP
71    CONTINUE
      IF(J.NE.0) GO TO 72
70    K=K+1
      IF(K.LE.L) GO TO 73
      IF(K.EQ.NOLJ1) GO TO 88
77    IF(KKK.NE.0) GO TO 76
```


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```
      DO 1432 I=1,N
      IF(IL(1).EQ.0) GO TO 81
1432  CONTINUE
76    I=IPL(KKK)
      KKK=KKK-1
      IF(IL(I).NE.0) GO TO 77
81    L=K
      IP(K)=I
      IL(I)=K
      GO TO 73
72    IF(J.EQ.1) GO TO 82
      DO 83 I=1,J
      LP=NOST(1)
      L1=NLT(LP)
      L2=NLT(LP+1)-1
      MAX=0
      DO 84 L3=L1,L2
      NO1=INDK(L3)
      IF(IL(NO1).EQ.0) MAX=MAX+1
84    CONTINUE
83    NOST1(I)=MAX
      IM=1
      IM1=1
      DO 85 I=2,J
      MAX=NOST1(IM)
      DO 86 L3=I,J
      ITM1=NOST1(L3)
      IF(ITM1.GE.MAX) GO TO 86
      IM=L3
      MAX=ITM1
86    CONTINUE
      ITM1=NOST1(IM)
      ITM2=NOST(IM)
      NOST1(IM)=NOST1(IM1)
      NOST(IM)=NOST(IM1)
      NOST1(IM1)=ITM1
      NOST(IM1)=ITM2
      IM=I
      IM1=I
85    CONTINUE
82    DO 87 I=1,J
      L=L+1
      NO1=NOST(I)
      IP(L)=NO1
87    IL(NO1)=L
      K=K+1
      GO TO 73
88    IF(LMAX.EQ.0) GO TO 92
      IM1=1
      L1=1
      MAX=0
      DO 95 I=2,N
      L2=NLT(I)-1
```

```
        IF(11.GT.L2) GO TO 91
        LP=IL(1M1)
        DO 96 L=L1,L2
        L3=INDK(L)
        K=IABS(LP-IL(L3))
96      IF(K.GT.MAX) MAX=K
91      IM1=I
95      L1=L2+1
        IF(MAX.GE.LMAX) GO TO 93
        LMAX=MAX
        KMAX=JJ
93      JJ=JJ-1
        KKK=KK
        IF(JJ.GT.0) GO TO 94
        JJ=KMAX
        NODI=LMAX
        LMAX=0
        IF(JJ.GT.1) GO TO 94
92      CONTINUE
       NODI=NODI+1
       LNTH=NODT*N
       WRITE(IOUT,1870) LNTH
1870   FORMAT(1H ,'LENGTH OF VECTOR A = ',I5)
        IF(IRIT.NE.0) GO TO 360
       WRITE(IOUT,1869)
        DO 1867 I=1,N
        K=IP(I)
        L1=ILOP(K)
        L2=ILOP(K+1)-1
1867       WRITE(IOUT,1868)I,(NUM(J),J=L1,L2)
1869   FORMAT(5X,'LOOP          PIPES')
1868    FORMAT(3X,I5,8X,20I5,/18X,20I5)
360     CONTINUE
        ITM1=NOSD1(LINES+1)-1
        DO 110 I=1,ITM1
        LP=NOLAL(I)
        J=IABS(LP)
        J=IL(J)
 110    NOLAL(1)=ISIGN(J,LP)
C TEST FOR LOOPS WITH INITIAL FLOW = 0. IN ALL LINES
C  IN THE LOOP. SET FLOW TO 1. FOR ALL SUCH LINES
        AK=1.0
        L1=1
        DO 1820 I=1,N
        L2=ILOP(1+1)-1
        DO 1821 L=L1,L2
        LP=NUM(L)
        LP=IABS(LP)
       READ(8'LP) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,Q,NEW
        IF(Q.NE.0.0) GO TO 1820
1821    CONTINUE
        IF(I.GT.NL) GO TO 1824
1825    DO 1823 L=L1,L2
```


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```
      LP=NUM(L)
      J=IABS(LP)
     READ(8'J) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,Q,NEW
      Q=AK*SIGN(1.0,FLOAT(LP))
1823 WRITE(8'J) LT,NO1,NO2,COMPR,D1,DO,HW,T1,COEF,Q,NEW
      GO TO 1820
C   PSEUDO LOOPS
1824  AK=D/2.0
      D=AK
      K=I-NL
      K=NOJUC(K)
     READ(4'K) NOXYT,(C(I1),I1=1,5),EL,DEMAND
     DEMAND=DEMAND+D
     WRITE(4'K) NOXYT,(C(I1),I1=1,5),EL,DEMAND
      GO TO 1825
1820  L1=L2+1
      LK=1
      NL=NL+1
      IF(NL.GT.N) GO TO 1700
      K=1
      DO 1701 I=NL,N
      NIL(K)=IL(I)
      K=K+1
1701  CONTINUE
1700  NL=NL-1
      DO 112 I=1,LINES
      J=NOSD1(I)
      L2=NOSD1(I+1)-1
      L1=J+1
      K=J
115   IF(L1.GT.L2) GO TO 112
      MIN=IABS(NOLAL(J))
      DO 113 L=L1,L2
      IF(MIN.LE.IABS(NOLAL(L))) GO TO 113
      MIN=IABS(NOLAL(L))
      J=L
113   CONTINUE
      KK=NOLAL(K)
      NOLAL(K)=NOLAL(J)
      NOLAL(J)=KK
      K=L1
      J=K
      L1=L1+1
      GO TO 115
112   CONTINUE
      RETURN
      END
```


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```
      SUBROUTINE PARAM
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,IC1,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),(NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1),IPL(1)),(A(1201),LLIN(1),NNST(1)),
     2(a(1601),JUNCL(1)),(A(2001),IL(1)),(a(2401),HDGL(1),NX(1))
     3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,C(5),MET1
      WRITE(IOUT,1)
1     FORMAT(' ','READ RESERVOIR DATA')
      IF(IC1.GT.0) GO TO 20
      DO 30 I=1,JUNCS
      READ(4'I) IP(I),(COB1(I1),I1=1,5),RC,DEMAND
30    CONTINUE
      READ(IIN,102) NR,L,RHD,HEAD,RP1,RP2,RP3
102     FORMAT(2I5,5F10.0)
      IF(L.EQ.0) L=1
      RP=L
      DO 2 I=1,JUNCS
      IF(IP(I).EQ.NR) GO TO 3
2     CONTINUE
3     NR=1
20    CONTINUE
      DO 1300 I=1,JUNCS
      LLIN(I)=9000
1300  JUNCL(I)=0
      LLIN(NR)=0
      NOST(1)=NR
      K=1
      L=1
1305  NO1=NOST(K)
      K=K+1
      L1=NLNJ(NO1)
      L2=NLNJ(NO1+1)-1
      JJ=LLIN(NO1)
      DO 1301 I=L1,L2
      LP=LNJ(I)
      KK=1
```


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```
      READ(8'LP) LT,NU,NO2
      IF(NO2.NE.NU1) GO TO 1306
      NO2=NU
       KK=-1
1306   J=NOLJ(LP)
       JJJ=J+JJ
       IF(JJJ.GE.LLIN(NO2)) GO TO 1301
       LLIN(NO2)=JJJ
       IF(JUNCL(NO2).NE.0) GO TO 1304
       L=L+1
       NOST(L)=NO2
1304   NLJJ(NO2)=KK*LP
       JUNCL(NO2)=NO1
1301    CONTINUE
       IF(K.LE.L) GO TO 1305
       IF(L.EQ.JUNCS) GO TO 1213
       WRITE(IOUT,1214)
       STOP'IN PARAM'
1214   FORMAT(1H1,'SECOND NETWORK NOT CONTINUOUS')
1213   NORS=NRES-1
       ITM1=KKK+NORS
       KKK=KKK+1
       IF(KKK.GT.ITM1) GO TO 2001
       DO 2000 I=KKK,ITM1
2000   IPL(I)=NL+1+I-KKK
2001   KKK=ITM1
       IF(NORS.EQ.00 GO TO 100
       DO 101 I=1,NORS
       IF(IC1.GT.0) GO TO 21
       READ(IIN,102) K,L,COR4(I)
       DO 6 I1=1,JUNCS
       IF(IP(I1).EQ.K) GO TO 7
   6   CONTINUE
      WRITE(IOUT,1700) K
      STOP
1700   FORMAT(' RESERVOIR',I5,' IS NOT NUMBERED CORRECTLY'
 7     K=I1
       NOJUC(1)=K
21     CONTINUE
       K=NOJUC(I)
1310   LP=NLJJ(K)
       K=JUNCL(K)
       NUM(LPKT)=LP
       LPKT=LPKT+1
       IF(K.NE.NR) GO TO 1310
       NOLJ1=NOLJ1+1
       ILOP(NOLJ1)=LPKT
101    CONTINUE
100    N=NL+NORS
       IF(IC1.GT.0) GO TO 1714
       NOBP=0
       DO 31 I=1,LINES
```

```
      READ(8'I) IP(I)
31     CONTINUE
       DO 1715 I=1,40
       READ(IIN,102) LPB,L,COBO(I),COB1(I),COB2(I),COB3(I)
        IF(LPB.LT.1) GO TO 1714
        DO 4 I1=1,LINES
       IF(IP(I1).EQ.LPB) GO TO 5
4     CONTINUE
      WRITE(IOUT,1701) LPB
      STOP
1701  FORMAT(' BOOSTER PUMP',I5,' IS NOT NUMBERED CORRECTLY')
 5     NRN(I)=I1
       NOBP=NOBP+1
1715   CONTINUE
1714   CONTINUE
      READ(4'NR) NOXYT,(C(I1),I1=1,5),EL,D
       LPKT=LPKT-1
       DO 61 I=1,LINES
61     NOLJ(1)=0
       IF(LPKT.NE.0) GO TO 3314
       RETURN
3314   DO 62 I=1,LPKT
       J=IABS(NUM(I))
 62    NOLJ(J)=NOLJ(J)+1
       J=1
       NOSD(1)=1
       DO 63 I=2,LINES
       NOSD(I)=NOSD(J)+NOLJ(J)
 63    J=I
       KM1=1
       K=2
       LP=ILOP(2)
       DO 64 I=1,LPKT
       JJ=NUM(I)
       J=IABS(JJ)
       L=NOSD(J)
       NOSD(J)=L+1
       IF(I.LT.LP) GO TO 65
       KM1=K
       K=K+1
       LP=ILOP(K)
65     NOLAL(L)=ISIGN(KM1,JJ)
64     CONTINUE
       NOSD1(1)=1
       LPKT=1
       J=1
       DO 66 I=1,N
       NLT(I)=LPKT
       KPS=LPKT
       K=ILOP9I+1)-1
       DO 68 L=J,K
       LP=IABS(NUM(L))
```

```
      L1=NOSD1(LP)
      L2=NOSD1(LP+1)-1
      DO 67 L3=L1,L2
      NO1=IABS(NOLAL(L3))
      IF(NO1.EQ.I) GO TO 67
      IF(KPS.EQ.LPKT) GO TO 9991
      ITM2=LPKT-1
      DO 999 NO2=KPS,ITM2
      IF(INDK(NO2).EQ.NO1) GO TO 67
999   CONTINUE
9991  UNDK(LPKT)=NO1
      LPKT=LPKT+1
67    CONTINUE
68    CONTINUE
      J=K+1
66    CONTINUE
      NLT(N+1)=LPKT
      RETURN
      END
```


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```
      SUBROUTINE LOOP
      COMMON COR4S(20),SMIN,SMAX,DINCS,DINCL,COR4(20),DELP(200),
     2COB1(20),COB2(20),COB3(20),COBO(20),A(6400),MAXQ,D,
     3RP,HEAD,RP1,RP2,RP3,RHD,MET1,DIAT,DMAX,
     4NOLAL(1200),J,K,JJ,IOUT,IIN,NRES,NOJUC(20),NRV(20),NRV1(20),
     5NIL(20),NOSD1(402),NLNJ(401),LNJ(800),
     6NOJT(20),NRN(20),N,LINES,JUNCS,NO1,NO2,NOPT,
     7IDEX,NORS,NTM,ITM1,ITM2,LPKT,NL,ITJ1,ITJ2,KKK,NOBP,
     8NR,NODI,L1,L2,L3,KK,LP,LNTH,NOLJ1,IRIT,IMETER,IOUT2,
     9MAXIT,IC,IC1,IFIRST,NOPRV,IC1S
      EQUIVALENCE(NOLJ(1),NOSD(2),NOSD1(3)),(NOPIP(1),LPRP(1),NOLAL(1))
     1,(NOLAL(401),NLJJ(1))
      EQUIVALENCE (A(1),QTJU(1),IP(1)),(A(401),NLT(1),IDL(1)),
     1(A(801),ILI(1),IPL(1)),(A(1201),LLIN(1),NNST(1)),
     2(A(1601),JUNCL(1)),(A(2001),IL(1)),(A(2401),HDGL(1),NX(1))
     3,(A(2801),INDK(1)),(A(4001),NUM(1)),(A(5201),ILOP(1))
     4,(A(5401),NOST(1)),(A(5801),NOST1(1))
      DIMENSION NOLJ(400),NOSD(401),QTJU(400),HDGL(400),NOST1(200),
     1IP(400),IDL(400),NLT(400),ILI(400),IPL(400),LLIN(400),NNST(400),
     2NLJJ(400),JUNCL(400),IL(400),NX(400),LPRP(400),ISAVE(20),
     3NOPIP(400),INDK(1200),NUM(1200),ILOP(200),NOST(400)
      REAL MAXQ,MET1
      WRITE(IOUT,1)
1     FORMAT(1H,'FIND LOOPS')
      DO 2 I=1,LINES
      LPRP(I)=1
2     CONTINUE
      K=0
      I=3
      DO 55 JTR=1,JUNCS
      IF(NOLJ(JTR).NE.1) GO TO 54
      ITJ1=JTR
      NOLJ(ITJ1)=0
      GO TO 60
52    CONTINUE
54    IF(NOLJ(JTR).NE.2) GO TO 55
      K=K+1
      NOST(K)=JTR
55    CONTINUE
      NL=LINES-JUNCS+1
      LPKT=1
      KKK=0
      IF(NL) 33,33,3316
3316  DO 51 NLP=1,NL
      ILOP(NLP)=LPKT
4114  DO 59 I=1,JUNCS
 59   JUNCL(I)=0
53    IF(K.NE.0) GO TO 34
      NDL1=1000
      DO 35 I=1,JUNCS
      IF(NOLJ(I).EQ.0.OR.NOLJ(I).GE.NDL1) GO TO 35
      L1=I
```

```
        NDL1=NOLJ(I)
35      CONTINUE
        ITJ2=L1
        NOLJ(L1)=NDL1-1
        GO TO 1435
34      L1=NOST(K)
        K=K-1
        IF(NOLJ(L1).NE.2) GO TO 53
        NOLJ(L1)=0
1435    IDEX=NLNJ(L1)
57      LP=LNJ(IDEX)
        ITT=1
        IDEX=IDEX+1
        IF(LPRP(LP).NE.0) GO TO 56
        GO TO 57
56      LPRP(LP)=0
        KM1=0
       READ(8'LP) L1,NO1,NO2
       ITJ1=NO2
        J=1
        IF(ITJ1.NE.L1) GO TO 58
        J=-1
       ITJ1=NO1
58      NUM(LPKT)=J*LP
        LPKT=LPKT+1
        NOLJ(ITJ1)=NOLJ(ITJ1)-1
        IF(NOLJ(L1).NE.0) GO TO 1436
37      LP=LNJ(IDEX)
        ITT=2
        IDEX=IDEX+1
        IF(LPRP(LP).EQ.0) GO TO 37
        LPRP(LP)=0
       READ(8'LP) LT,NO1,NO2
        ITJ2=NO1
         J=1
         IF(ITJ2.NE.L1) GO TO 41
        ITJ2=NO2
         J=-1
41      NUM(LPKT)=J*LP
        LPKT=LPKT+1
        NOLJ(ITJ2)=NOLJ(ITJ2)-1
        IF(ITJ1.EQ.ITJ2) GO TO 4115
1436    NNST(1)=ITJ1
        KK=1
        KNT=1
        JUNCL(ITJ1)=L1
 39     NO1=NNST(KK)
        KK=KK+1
        ITM1=NLNJ(NO1)
        ITM2=NLNJ(NO1+1)-1
        DO 40 I=ITM1,ITM2
        LP=LNJ(I)
```


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```
        ITT=3
        IF(LPRP(LP).EQ.0) GO TO 40
       READ(8'LP) LT,NU,ND
       NO2=NU
        J=-1
        IF(NO2.NE.NO1) GO TO 42
        J=1
       NO2=ND
 42     IF(JUNCL(NO2).NE.0) GO TO 40
        JUNCL(NO2)=NO1
        KNT=KNT+1
        NNST(KNT)=NO2
        NLST(KNT)=NO2
        NLJJ(NO2)=LP*J
 40     CONTINUE
        IF(JUNCL(ITJ2).NE.0) GO TO 38
        IF(KK.LE.KNT) GO TO 39
        LPKT=LPKT-2
        IF(NOLJ(L1).NE.0) LPKT=LPKT+1
        I=4
        GO TO 49
 43     ITJ1=ITJ2
        I=5
        GO TO 49
44      GO TO 4114
38      J=ITJ2
4113    LP=NLJJ(J)
        IF(NLNJ(J+1)-NLNJ(J).EQ.2) KM1=1
        J=JUNCL(J)
        NUM(LPKT)=LP
        LPKT=LPKT+1
        IF(J.NE.ITJ1) GO TO 4113
        IF(NLNJ(L1+1)-NLNJ(L1).EQ.2.OR.LPKT-ILOP(NLP).GT.7) KM1=1
        IF(KM1.EQ.0) GO TO 4115
        KKK=KKK+1
        IPL(KKK)=NLP
4115    I=1
        GO TO 49
 62     CONTINUE
51      CONTINUE
        GO TO 33
49      J=NOLJ(ITJ1)
        IF(J.NE.2) GO TO 45
        K=K+1
        NOST(K)=ITJ1
        GO TO 46
45      IF(J.NE.1) GO TO $¢
        NOLJ(ITJ1)=0
 60     IDEX=NLNJ(ITJ1)
48      LP=LNJ(IDEX)
        ITT=4
        IF(LPRP(LP).NE.0) GO TO 47
        IDEX=IDEX+1
```


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```
      GO TO 48
47    LPRP(LP)=0
     READ(8'LP) LT,NU,ND
     L1=NU
      IF(L1.EQ.ITJ1) L1=ND
      ITJ1=L1
      NOLJ(ITJ1)=NOLJ(ITJ1)-1
      GO TO 49
46    GO TO (50,62,52,43,44),I
50    I=2
      ITJ1=ITJ2
      GO TO 49
33    CONTINUE
      NOLJ1=NL+1
      ILOP(NOLJ1)=LPKT
     RETURN
      STOP'STOPPED IN LOOP'
      END
```

APPENDIX G

ENVIRONMENTAL ASSESSMENT

G.1 INTRODUCTION

The objective of an environmental assessment is to provide an evaluation of the effects which proposed facilities and operations will produce within the project study area. Since the level of detail for recommended projects developed under these investigations is much more general than that provided for actual construction projects, the assessment of environmental effects will focus on major effects. Most project effects will be largely beneficial but some will be adverse.

The major impacts of the recommended plans are focused on improved urban development and housing and on the development of water supply, drainage, wastewater collection, and solid waste management systems to support these recommended urban improvements. The combined effects of the plans will be to improve urban aesthetic values, support more coordinated and compatible land uses, and improve the standards of urban life and public health within Medan.

Adverse effects will arise primarily from urban expansion, withdrawal of large amounts of water from the rivers and groundwater basins, discharge of greater quantities of drain water and sewage, and collection and disposal of large volumes of solid wastes. Improvements of local living standards and expanding employment opportunities will increase the attraction of Medan for citizens of the secondary communities and the rural areas of North Sumatra. Induced attraction of population and resulting growth may exceed projections used in plans, and the recommended infrastructure may not be able to adequately reach the proposed levels of service and benefits.

The Medan Urban Development Study (MUDS) has conducted a coordinated study of the development of overall urban growth, major low and middle income housing and residential improvements, and the major urban utilities which support both the urban growth and housing for the urban poor. The study has not included provision of energy from electricity and natural gas.

Urban growth for the study area was projected from historic trends and the influences of planned and funded projects and population growth. Locations of housing projects have reflected the projected improvements and new housing needs over the next five, ten and twenty years. Utility requirements have been largely determined by the projections of urban

and population growth to the year 2000. The location and size of water supply, sewerage, drainage, and sanitation facilities were determined by the projected requirements, existing facilities, and physical limitations and characteristics of the area.

G.2 SCOPE OF THE ASSESSMENT

As defined in the regulations for U.S. Agency for International Development (USAID), the scope and level of detail in an environmental assessment are more limited than those of an environmental impact statement. Generally, the scope of the assessment is directed toward the major adverse effects of various recommended projects and their operations. The level of detail within this environmental assessment has been limited by the existing and available data which are few and often of questionable accuracy or reliability.

This environmental assessment has been organized to be integrated within the Master Plan report, and it is not intended to stand alone. Several of the standard elements of an environmental assessment (project description, alternatives to the proposed action, beneficial effects of the proposed action) are described in detail in the previous sections and such details are not repeated in this section.

G.3 PROJECT ELEMENTS

The recommended projects have been developed to improve existing poor urban conditions to provide better urban life for the Medan citizens. Major project aspects which relate to environmental effects are presented below.

G.3.1 Urban Development Plan

The recommended urban development plan has focused on the projection of existing trends for the next five years and on a recommended development strategy for 1985 and to the year 2000. The projections and recommended strategy diverge from the existing year 2000 Master Plan with its diffused residential development by concentrating the urban growth. The MUDS projection of a year 2000 population of 1.9 million is significantly lower than the previously projected level of 2.4 million. The urban plan projects an expansion of land use in commerce by 95 percent, in industry by 44 percent, and in institutions by 78 percent with an additional non-residential area of about 7.7 sq km. An expanded employment base is indicated by construction of more than 28 sq km of new urban structure in addition to many major public works projects. Capital facilities projects will create employment and stimulate economic activity. Public works projects which will provide employment and greater importance to Medan include:

- Belawan Port expansion
- Trans-Sumatra Highway, Medan-Belawan Toll Road, and Ring Road

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- Airport relocation

- Railroad improvements and urban transit

- Major public works projects recommended in the MUDS Master Plans for Medan (housing, pipelines, drainage channels treatment plants)

The recommended urban development plan used the following guidelines for defining development and reserved areas. Expansion of Medan should be concentrated within a few kilometres of the planned Ring Road and Toll Road except along the Tanjung Morawa - P.Siantar road, the Deli Tua road, and the Brastagi road. Urban expansion should be extended west of the Belawan river and outside of the Belawan corridor (between the Deli River and Toll Road).

Several guidelines reflect potential development costs for many areas and potential government costs for providing utility services and flood protection. Watershed protection for the Sunggal Water Plant involves both water quality or public health conditions for potable water supplies and costs for additional treatment requirements for removing urban pollutants.

G.3.2 Housing

Several housing projects have been developed during the Medan study for improvement of existing low income housing and for development of a new housing project. The Kampung Improvement Program (KIP) will improve roads, paths, drainage, water supply and solid waste collection for 244 ha of low income housing in seven districts of central Medan. The KIP will add new health, educational, and financial services to the recommended areas and to the adjacent UNDP area. These recommended areas have a population of about 80,000 which is expected to grow to over 100,000 by the year 2000.

The Low Cost Housing/Sites and Services Program will develop a new housing site of 160 ha near the Brastagi road. The site will contain about 7,500 lots for an eventual resident population of 50,000 (gross density: 313 persons/ha). Parcels will vary in size, degree of improvement, and conditions of acquisition (e.g. government service, private sale or rental). Utilities and public services will be within the site, but major commercial and transportation facilities will develop along the Brastagi road.

G.3.3 Water Supply

Development of the future water supply incorporated the projections of urban growth and distribution, significant users, water demands, and the governmental goals for service. These were then compared with the supply capacity of existing facilities, and the net requirements were used to determine recommended supply and distribution facilities:

1. Expanded Sunggal Water Plant (130,000 cu m/d).

2. A new Deli Tua Water Plant (150,000 cu m/d).

3. Sibolangit Springs (46,000 cu m/d).

4. 100 deep water wells.

5. Six ground level reservoirs with booster pumps.

6. 290 km of new major pipeline construction (300 mm or larger).

7. Administrative and technical buildings and housing for employees.

Operations would include normal requirements for such facilities, training programs and extensive water flow and quality monitoring in the four major rivers, the groundwater aquifers, and throughout the supply system.

The service objectives of the recommended water system are to quadruple the service population with building connections and increase public standpipe supply to at least 20 percent of the year 2000 population. Total served population will reach 1.5 million (or 80 percent of the total study area population). Service would also be improved by increasing water pressure throughout the expanded service area and providing normal operating pressures throughout the average day and in most areas during the maximum day demand. Storage would provide for peak hour demands and for emergency supplies.

G.3.4 Wastewater

Existing sanitary waste disposal involves individual treatment of sanitary wastes, which are separated from general wastewaters. Septic tanks with subsurface soil absorption and pit latrine systems are widely used in residential areas. In the central area, some commercial and institutional buildings provide onsite treatment (septic tanks) before disposal to the storm drains, but some sanitary wastes are discharge directly to the sewers. Existing practises will be allowed to continue in many areas because costs of water-borne sanitary waste collection, treatment and disposal are beyond the local financial capacity.

The recommended wastewater system will provide collection, transmission, treatment, and disposal for about 90,000 cu m/d of sewage from a service area in central Medan of about 21.4 sq km. About 175 km of street sewers will collect sewage and discharge it into about 30 km of major interceptor sewers. A regional sewer will convey the sewage to the treatment facility north of the existing urban area. The facilities will consist of 90 to 130 ha of waste stabilization lagoons. Secondary treated effluent will be discharge to the Deli River.

G.3.5 Drainage

Development of drainage projects largely reflects the types and intensity of land use rather than population levels. Existing drains are often clogged with solid wastes and other debris or are of insufficient

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size to remove rainfall, and flooding in many areas causes unundation of residences and roads. Urban development typically increases the runoff and the rapid urban runoff and high flows in the Deli and Babura rivers may cause river flow to spill over the banks and flood the surrounding areas. Recommended drainage projects will reduce ponding within the drainage system area and reduce overbank flooding along the river for storms of 1 to 5 year return frequency.

Recommended drainage projects include:

1. Clenaing of drains along 520 km of city street in 57 sq km in Medan.

2. Cleaning channels of the Deli, Babura, Sikambing, and Kera rivers within the urban area, and

3. Long-term cleaning, bank protection and in some areas, dredging of the Deli, Babura, and Percut rivers and along main and major drains.

Maintenance of two to five year flood flows through existing drains and stream channels has been the primary goal of this recommended system. In the phased program, flow monitoring of the cleaned channels would provide more representative data on flood flows; these flow data would then be used to define where selected improvements should be made.

G.3.6 Solid Wastes

Recommended solid waste collection and disposal will be vastly improved throughout all of Medan. About 300 sq km will be served by daily collection by trucks or carts. Cart collection from about 3000 neighbourhood storage sites will convey refuse to about 290 truck loading facilities, one per square kilometre. Refuse collected by or transferred to trucks will be delivered to a recommended Belawan disposal site, unless a closer site with similar land and development costs can be found. By the year 2000, up to 8,000,000 cu m of disposal site capacity would be filled with compacted refuse.

Daily solid waste collection will increase from 150-200 tonnes up to 1,850 tonnes. The effective collection area will expand from about 25 sq km to about 250 sq km. A fleet of about 325 trucks will be required.

G.4 ENVIRONMENTAL EFFECTS

Environmental impacts of the recommended plans involve both beneficial and adverse effects. Benefits largely arise form the improvement of the urban life for almost two million people in Medan by the year 2000. Significance of this improvement is enhanced since about 75 percent of those benefitting will be the urban poor who have the least personal means of improving their standard of living.

Adverse effects primarily result from effects of construction. However, some adverse effects may result from the operation of the water

supply and the drainage and solid waste systems in conformance with the recommended urban plan. Knowledge of these adverse effects and planning for their mitigation or elimination will depend upon data derived from recommended monitoring programs. Sufficient flexibility in the physical capability of resources and engineering will allow reduction of adverse effects, once monitoring has indicate their occurrence.

G.4.1 Beneficial Effects

Beneficial effects of the recommended plans generally involve the improvement of Medan's urban environment, of the urban services to the low income residents of Medan, and of the public health of more than 1.9 million people by the year 2000. Since the plans would be implemented in an integrated fashion, many projects will have related effects and should reinforce the improvement of the low income population's standard of living. Other income groups will also benefit directly and indirectly, but benefits to these groups, although important, are not the major objective of the recommended projects.

Beneficial effects of each plan have been discussed in each section of this report and are summarized below :

- Urban Plan

  - Maintain greenbelts and agricultural open space.

  - Protect approaches to Polonia Airport from urban encroachment.

  - Protect the Belawan river watershed above Sunggal Water Plant.

  - Reduce the rate of increase in public costs for urban services, make maximum use of existing and planned facilities, and allow development where natural advantages are greatest.

  Housing

  - Improve 260 ha of existing low income areas by provision of water, drainage, solid waste collection and urban services.

  - Locate 160 ha of land for a new low income housing project for 40,000 residents.

  - Support existing low income improvement projects by integrating new services with ongoing projects.

  Water Supply

  - Meet 60 percent of projected domestic water demands by 1985 and serve more than 80 percent with safe potable water supply by 2000.

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- Reduce dependency upon shallow wells or rivers for water supply.

- Reduce need for individual building water storage systems which become contaminated.

- Improve the condition of remaining shallow wells.

- Reduce or eliminate need for private deep wells and surface water treatment facilities.

Wastewater

- Minimize contamination of the Deli, Babura, and Kera rivers.

- Reduce public health hazards from contact with untreated sewage.

- Improve visual appearance of urban rivers within Medan.

Drainage

- Reduce flooding frequency and duration in urban areas either from ponding of rainfall or from overbank inundation by rivers.

- Reduce ponding of contaminated wastewater.

- Reduce public health hazards due to exposure of residents to contaminated water during flooding.

- Improve visual aesthetics of streets and general urban area.

- Reduce water logging of roads and structures, contamination of shallow wells and groundwater, and damage and disruption of normal urban activities.

Solid Waste

- Reduce habitat for disease vectors and reduce public contact with refuse.

- Reduce organic loading and septic conditions in drains and improve quality of wastewaters.

- Improve drainage and diminish flooding by collection of debris before it enters drains.

- Enchance general urban visual impression and waterway appearance.

- Reduce local burning of refuse and resulting air pollutants.

- Increase resources recovery and composting.

- Protect general surface water and the shallow groundwater table from contamination by uncontrolled leachate discharge and runoff from disposal sites.

- General

  - Significant increase in employment in construction and operations.

  - Stimulate local economy in construction materials and equipment.

G.4.2 Adverse and Other Effects

G.4.2.1 Urban Plan

The urban plan represents a projection of the urban environment that will develop during the next 20 years rather than a plan as to how it should develop. Therefore the projected urban setting in the future without the plan is virtually identical to that of the "recommended" plan. Numerous projects are already underway which will establish urban growth trends, and some undesireable effects of these trends would be expensive and administratively difficult to overcome.

Adverse effects of projected growth and the plan are :

- Isolation of residential areas northeast of the proposed Toll Road

- Maintenance of services to Medan II housing project without incorporation in the city

- Urban sprawl along Tanjung Morawa and Brastagi roads

- Need for new bridges on the Babura and Deli rivers to serve low density areas along the southerly perimeter, while new bridges are needed to replace old bridges with very high traffic volumes.

- Partial encirclement of Polonia Airport and encouragement of urban development under southwestern approach path (Pancur Batu and Medan III).

The recommended plan has incorporated the ring road and the new Toll Road which may encourage urban development producing adverse effects on other plans. Adverse effects will largely arise from increased urban runoff upstream of the city and the creation of higher flows which will exceed drainage capacity more frequently.

Urban growth in the Tuntungan-Pancur Batu - Sunggal areas will increase runoff into the Sikambing, Putih and Bekala (Babura) rivers. Although the middle to high income-low density areas along these rivers will have good drainage, the runoff will increase the frequency of flooding along the downstream channels and at their confluences with the main stream of the Deli River.

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Diversion of drainage from the areas south of the planned Ring Road and Toll Road may cause flooding upstream of their east-west aligned segments and along the drains and river channels downstream of road culverts. The roads will encourage urban expansion and higher storm run-off along the roads, while the roadways will disrupt general drainage.

G.4.2.2 Housing

Recommended housing projects will directly improve housing conditions for 140,000 people by the year 2000. The Kampung Improvement Program does not induce additional growth in the project areas. The turnover of existing owners and renters is expected to be low, although some replacements will occur. Improvements of services and living conditions will encourage vehicle traffic in and out of each area and thereby increase congestion on Singamangaraja Street.

The new low income housing project will radically change the rural plantation setting to a definite urban residential character. Similarly, surrounding areas will be stimulated to convert to urban uses. Growth of more than 5,000 families in the southwestern-Brastagi road sector will greatly increase traffic loading at the new ring road intersection and at the three major access points of western traffic to the central and eastern employment areas. Two existing congested bridge crossings will be further congested by increased traffic to housing sites, or the ring road will carry traffic to the congested Singamangaraja Street.

Development of the Brastagi Road housing and the associated urban development will increase runoff to the Bekala River and ultimately of the Deli River. With an average annual rainfall of about 2.0 m, 90 percent development will annually contribute 2,250,000 cu m of runoff to the Bekala-Babura basins, or about 11,000 cu m/d during the high rainfall months. This runoff and runoff from surrounding developments will increase flooding (marginally) in the Bekala and downstream reaches of the Babura river.

Dry weather flows from the housing area may include percolation of septic tank effluents or treated discharges from a wastewater lagoon sanitary system which would contaminate the Babura River. These flows may have better quality than typical urban drainage, but with flows from less controlled developments, the quality of dry weather flows in the Bekala and Babura could be degraded. Although no municipal water supply is now taken from the Babura RIver, future water resources development may require diversion of low, dry weather flows from the Babura to the Deli Tua Plant. The urban plant recommended constraining urban development above the Sunggal Water Plant, and new water intakes on the Deli or Percut are recommended to be above urban development (at the Deli Tua Plant this requires 6.0 km of additional pipeline). Therefore, the increased urban drainage from project and urban expansion along the Babura watershed will require additional treatment of the Babura River water for municipal water supply.

The significance of this effect is somewhat lessened by the unknown safe yield of the river and the high costs (low development potential) for use of this source with the Deli Tua Plant. If water

quality of the Bekala-Babura is further degraded, the additional costs of water source development above the housing project and urban development may be too high or production losses too great for diversion of the Babura subbasins to remain a feasible municipal source.

G.4.2.3 Water Supply

The recommended water supply projects will have construction and operational effects, and these will be of different types and durations. Construction effects of water supply projects will be similar to those of sewer construction and of construction of the sewage and solid waste treatment/disposal facilities.

Construction of Source Facilities: Expansion of the Sunggal Water Plant and construction of deep well facilities will not significantly alter existing or planned land uses or cause disturbances to surrounding areas. The Sunggal expansion will occur at the existing isolated site and on a parcel designated for this expansion. Truck haulage of equipment and construction materials will add to congestion and will further damage the Sunggal Road. Increased equipment haulage, may be compensated for by use of local aggregate production for the project and corresponding reduction of aggregate hauling into Medan.

Continued use of the springs at Sibolangit will eventually require replacement and renovation of the existing pipelines probably with larger diameter pipes. Such construction will lie along existing pipeline routes and should have few adverse effects. Good construction management should be employed to reduce the soil erosion and runoff to the Deli River; slopes should be replanted, and removal of trees should be avoided.

Construction of each deep water well will have effects similar to the construction of a large single family residence. Widely scattered well sites will be selected based upon compatible or beneficial land uses, and construction should have little adverse effects. During drilling, work schedules may be adjusted to minimize night-time disturbance to adjacent residences.

Construction of a new plant on the Deli River will produce the most significant construction effects for water source projects. Potential sites are located near Deli Tua and south of the Medan urban area. The sites consist of agricultural lands which have been cleared of most natural and bankside vegetation. Construction of the water level control weir and diversion structure will increase local water turbidity and generally disturb the shoreline along about 100 m of the river. Bankside and terrace excavations have the highest potential for encountering archeological and historic remains. Aggregate will be imported from nearby quarries, but trucks will bring other construction materials and equipment to the site along the two roads to the town of Deli Tua and then the single road to the plant site. As at the Sunggal Plant, diversion of aggregate to the plant construction will reduce truck trips on the main roads, while plant construction will generate an equal or greater number of trips, therefore net traffic on the Deli Tua Road will increase by only a percentage of the total number of trips to the plant site. Congestion and road damage along the Deli Tua Road and in Deli Tua will be increased.

Pipeline Construction: Pipeline construction will cause disruption of traffic and normal urban activity along the pipeline route for at least three months. Major adverse effects largely relate to the following factors:

1. Narrow streets and rights-of-way.

2. Numerous pipelines already in place.

3. Deep ditches along each side of the roadways.

4. High traffic loading and poorly controlled traffic movement.

5. Long distances between major intersections and few alternative routings.

6. Predominately hand labor, short working hours, and poorly coordinated opening-closing of trenches and pavement repair.

7. On-site storage of trench debris, pipe, equipment, aggregate, and fill materials.

These factors will be compounded by the magnitude of pipeline construction: 290 km of major pipelines and quadrupling of street-building pipelines. Although only about half of the major pipelines will be in the existing urban area with congested streets, these 150 km of pipeline will be installed at the same time as 26 km of major sewers and about 100 km of street sewers in the central business district (east of the Deli River). Simultaneous pipeline construction for water mains and sewers will have a significant adverse effect upon the intense urban environment of the eastern district. During the first five year period, more than 100 km of water pipe and 40 km of sewers will be installed in the eastern dense urban sector.

Few other adverse effects arise from pipeline construction in urban areas. One potential adverse effect may occur from disruption or damage to archeologically significant remains buried along the rivers. Pipeline construction requires trench excavation to at least 1.3 m depth and up to 4.0 m depth for some sewers and associated facilities. Such excavation will reach well below existing disturbed soils and may encounter archeological remains. The highest potential for such remains exist along the old river channels of the Deli, Babura, Sikambing, Belawan, and Percut rivers (usually within 50-100 m of the water). Since most major roads and utility routes either cross the rivers or lie beyond the 100 m zone of the river channels, most recommended pipelines will not have high potentials for encountering significant archeological or historic remains. Recommended pipelines between Medan and Belawan will have the highest potential for encountering and damaging archeological remains. About 15 rivers crossings by major water and sewer pipelines will also have relatively high potential for disturbing archeological or historic remains.

Reservoirs: The water plan recommends six large new storage reservoirs, three each in western and eastern Medan. The ground level

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reservoirs will have little adverse effect because of their general low physical profile (less than a two storied building) and low activity (only electric motors in pump houses). Such features will allow use of sites within residential areas. The reservoirs on Belawan Road, near Polonia Airport, and in Medan Baru will have to be located in highly valued commercial, residential, or recreational or institutional lands. The larger reservoirs will require up to one hectare of land. Other new reservoirs will be located in more peripheral areas with lower land use values.

Mitigation of Construction Effects: Mitigation of significant construction effects should focus on minimizing traffic disruption and congestion. This can be done with the following measures :

1. On-site traffic control during construction.

2. Multiple shifts and night shifts for construction.

3. Night-time delivery of equipment and material to sites in non-residential areas.

4. Daily closing of trenches, removal of all excavated debris, import of fill material.

Archeological mitigation should include on-site archeological inspection of excavations at the Deli Tua Plant, and along pipelines at river crossing or along the Belawan road.

Operational Effects: Operational effects include possible adverse effects upon the groundwater aquifers and the surface waters below Medan. The potential adverse effects generally relate to the quantity of water extracted from the aquifers or the streams compared to the safe yields of the sources.

Adverse effects upon water sources can be avoided by adequate monitoring of the groundwater aquifers and the low flow conditions within the streams. Such monitoring will indicate the safe yield from both aquifers and surface streams.

If a decision is made to allow dewatering of the intermediate and deep aquifers or if uncontrolled private extraction continued and expanded, then some adverse environmental effects may occur. Similarly, if the surface water treatment plants are sized to greater capacity than the streams can maintain for all basin users, adverse environmental effects will occur during low flows, expected once every 10 to 20 years. These adverse effects generally involve:

Groundwater:

- Infiltration of polluted water from other aquifers and decline in water quality

- Increased costs of operations for higher pumping lifts

- Saline water intrusion in Belawan

- Compaction and reduction of capacity of the deep aquifers, and subsidence of the land surface

Surface waters:

- Reduced mixing volumes for pollutants in wastewaters

- Lowered production by other users and losses of income and employment

- Saline water intrusion in the lower Belawan and lower Percut rivers.

Assuming that the projected water supplies are adequate, private diversion of surface waters and pumping of the aquifers should diminish. However, monitoring and allocations will have to be supported by inspection and control measures.

Water Quality Effects: Indirect effects on downstream water quality will result from two aspects of increased water supply within Medan: basin transfers and wastewater discharges. Water is and will continue to be taken for water supply from the Belawan River and transported into Deli, Babura, Kera, and Percut basins. Water quality in the Belawan river will decline with reduced flow.

During the low flows on the Deli River (200-300,000 cu m/d), 30 to 50 percent of the river flow will be withdrawn from the river at the Deli Tua Plant. This withdrawal plus Sunggal production and production from wells and springs will equal about 400,000 cu m on an average day. Of this, 90,000 cu m/d will be collect by the recommended sewerage system. Therefore, a net volume of 210,000 cu m/d will re-enter the five major urban streams. If 75 percent returns to the Deli River near Glugur, the 158,000 cu m/d will mix with about 100,000 cu m/d of natural flow. This will degrade the water quality of the Deli and its tributaries.

G.4.2.4 Wastewater

The recommended wastewater plan will result in significant adverse construction effects on traffic and the general urban setting which will be reinforced by simultaneous construction of water pipelines. The construction effects will extend over a 20 years period and therefore become an on-going effect.

Construction of the treatment lagoon along the Belawan road will destroy agricultural lands and some natural wet lands. These effects are largely unavoidable.

Operational effects relate to the influence of the treatment facilities. The most apparent effect will be the odors from occasional malfunctions of the lagoon. Such odors will be blown into small residential/commercial areas in the Belawan corridor and across the new Toll Road.

Mitigation of odor control could also include :

- A treatment site further east of the Belawan corridor or on the west side of the Deli River.

- Greater aeration and backup power for lagoons in order to maintain aerobic conditions.

Normal operations will discharge treated wastewater into the Deli River or smaller coastal waterways. Although the absolute level of Deli River pollution will be reduced over that expected in the year 2000 without treatment, untreated drainage flow will be about four times the treated discharges and about twice the existing flows. Therefore, discharge of even the treated wastewater to the Deli River will add an increment of organic load to a badly polluted river. Discharge to the Kera River would have a similar effect, since this stream will be more polluted than the Deli River. Direct discharge to the coastal marshes and estuaries will create freshwater conditions and cause major replacement of saline marshes by freshwater marshes. The organic load near a single discharge point may create toxic anaerobic conditions, although more dispersed discharges could stimulate algal and invertebrate biota, possibly to the benefit of nearshore fisheries.

The only way to mitigate discharge effects would be use of an offshore discharge with suitable diffusers. Shallow coastal waters would require a very long pumped discharge pipeline in order to reach depths needed for adequate diffusion.

G.4.2.5 Drainage

The recommended drainage activities will remove large quantities of debris and bank sediments from the drains and river channels in the Medan urban area. The removal and disposal of the excavated debris will temporarily disrupt the bankside land uses, increase turbidity in the rivers, create substantial increases in truck traffic loading of city streets, and require land disposal for more than five million cubic metres of debris during the next 20 years.

Debris cleaned from the drains and channels will not be suitable for land fills or structural uses. The material should be placed in sanitary land fills where surface runoff and leachate percolation will be controlled. These materials will have very high levels of pollutants, especially oils and other organic rich liquids.

In addition, the removal of debris will require truck haulage from the drains and rivers through the urban area to the recommended land fill site near Belawan. About 90 truck round/trips per working day for five years (260 d/yr) will pass through the northern urban area of Medan and along the Belawan road. The trucks, dripping fluids, and odors will cause adverse effects for the traffic and residents along the haul routes. If appropriate sites are found closer to the city center, these effects along the haul routes would be reduced but considerable care must be used to ensure that the runoff and leachates are controlled.

The second phase of the drainage plan may include channel enlargement and protection of channel banks. This will be defined after monitoring the results of the cleaning program in improving drainage flows. The total volume of excavations may be about 4.4 million cu m from more than 100 km of drains and river channels. Bank excavations will destroy most vegetation along the channels and convert the existing waterways to typical urban drains, some unlined and others lined with concrete and rock walls. Loss of vegetation along river and major drains will continue to degrade the visual impression of the city, while increasing structural dominance.

Bankside excavations will also have the greatest potential for encountering historic and archeologic remains in the undisturbed soils. This will be most likely along the Babura, Percut, and Deli rivers, with little probability along the artificial drains.

Disposal of excavated bank sediments will not require the degree of control that should be used in disposal of refuse and debris in the first phase, but the anticipated volume indicates potential adverse effects may arise from its disposal. Along small drains many local residents may desire the excavated soil in order to improve local grades, or the amount of sediment may be small enough to spread along the adjacent banks with little adverse effects. However, along major drains and river channels, the excavated sediment will probably exceed the requirements of local residents. Truck haulage of one half of the excavated materials (two million cubic metres) would require about 100 truck trips per day for 15 years (260 d/yr). Such traffic and truck loadings of the roads will cause further congestion of and damage to roads in the Medan urban area and along the Belawan Road.

The Belawan land fill site will require inorganic cover materials to properly control sanitary conditions of the landfill. The excavated bank sediments may be a good cover for the solid waste and fill, although they may be too fine for properly engineered land-fills for structural uses. Beneficial uses of the excavated materials at the land fill site compensate for the additional truck traffic on the Belawan road, because some cover material from other sources would have to be trucked into the land fill site under normal operation.

G.4.2.6 Solid Wastes

The recommended solid waste facilities will produce adverse effects at the very large land fill site, adjacent to truck loading facilities, and along the haul routes for over 600 daily roundtrips by 2000. Significant effects will be centered on the land fill site and the Belawan road, while minor disruptions and disturbances will occur around the truck loading facilities.

Construction of the solid waste landfill at the potential Belawan site will alter the drainage in the coastal zone, and destroy large amounts of marshlands. The construction will require enclosure and draining of marshes as each cell becomes filled with solid waste.

Drainage changes and discharge of runoff and leachates from the landfill will adversely affect surrounding marshes not directly destroyed

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by the landfill construction. Some degradation of coastal water quality will probably occur either due to leachate migration from the land fill or from changes in drainage and storm runoff.

Operating effects of the landfill will include some visual degradation of the access roads and Belawan road from debris falling from trucks, from dust and exhaust of the trucks, and from the large number of trucks travelling along the road. Truck traffic for solid waste disposal will be added to that for disposal of drainage debris and for haulage of construction materials and equipment to other planned housing and utility developments.

G.4.3 Overall Effects

As indicated in each of the above sections, recommended facilities and operations will create beneficial and adverse effects.

Adverse traffic effects of each plan will be aggravated by truck hauling of other plans. Combined traffic effects will be most adverse in the eastern commercial area and to the north. Sewer and water pipe installation and cleaning of street drains will interfere with traffic; already congested traffic will be increased by trucks carrying the solid waste and the drain and channel debris and by trucks carrying construction materials and equipment to and from the Port of Belawan. The planned Belawan Toll Road and western Ring Road can reduce some local traffic load, but the wide spacing of Medan interchanges and long distance from the city to the eastern interchanges will inhibit the use of this road.

Heavy truck traffic has badly damaged many Medan roads. Expanded truck haulage for solid waste, excavated drainage materials, excavated and back fill materials for water pipelines and sewers, and construction materials and equipment will increase damage to the city's roads. Such damage will be further aggravated by pipeline excavations and enlargements of road culverts. Reduction of the compounded effects of street excavations and damage from heavy truck traffic will require extensive coordination with road resurfacing programs and with the construction of new roads (the Toll Road and the Ring Road).

Coordination of pipeline construction and routing should avoid placing several large water pipelines adjacent to local distribution water mains and large sewers. Leakage from one pipe may damage the beds of other pipelines and damage other pipelines. Parallel laying of numerous pipelines along narrow roads will increase the danger of damaging adjacent pipelines during new excavation. Most streets have very small rights-of-way and numerous excavations along the some streets will prolong and accentuate adverse effects for adjacent residents.

G.4.4 Energy

All major utility projects require large quantities of energy during construction and operation. However, the general worldwide concern for energy conservation, for potential reduction of available petroleum in Indonesia, and for substantial cost increases emphasizes the need for further consideration of this aspect.

The plan includes expansion of residentail areas into areas which cannot be served adequately by urban rail transit and does not promote expansion along potential urban rail transit routes. Such trends reduce the effectiveness of more energy-efficient urban transit. The recommended urban plan concentrates more residentail areas and increases residential density up to 300 to 400 persons per hectare. This density or even higher density (e.g. 500 to 700 persons/ha) would reduce distribution costs and would allow better transit and utility service.

APPENDIX H

WATER SUPPLY CAPITAL COSTS:
1980/81 - 1983/84