GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA

SECTORAL REPORT

VOL. 3

GROUNDWATER RESOURCES

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA

SECTORAL REPORT

VOL. 3

GROUNDWATER RESOURCES

OCTOBER 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

LIST OF REPORTS

MAIN REPORT

Vol. 1. MASTER ACTION PLAN
Vol. 2. WATER RESOURCES DEVELOPMENT AND USE PLAN

STATE REPORT

Vol. 1. PERLIS/KEDAH/P. PINANG
Vol. 2. PERAK
Vol. 3. SELANGOR
Vol. 4. N. SEMBILAN/MELAKA
Vol. 5. JOHOR
Vol. 6. PAHANG
Vol. 7. TRENGGANU
Vol. 8. KELANTAN
Vol. 9. SABAH
Vol. 10. SARAWAK

SECTORAL REPORT

Vol. 1. SOCIO-ECONOMY
Vol. 2. METEOROLOGY AND HYDROLOGY
Vol. 3. GROUNDWATER RESOURCES
Vol. 4. GEOLOGY
Vol. 5. RIVER CONDITIONS
Vol. 6. WATER QUALITY
Vol. 7. ECOLOGY
Vol. 8. POWER MARKET
Vol. 9. DOMESTIC AND INDUSTRIAL WATER SUPPLY
Vol. 10. AGRICULTURE
Vol. 11. IRRIGATION WATER DEMAND
Vol. 12. INLAND FISHERY
Vol. 13. INLAND NAVIGATION, WATER-RELATED RECREATION
Vol. 14. WATERSHED MANAGEMENT
Vol. 15. WATER RESOURCES ENGINEERING
Vol. 16. WATER SOURCE AND HYDROPOWER DEVELOPMENT PLANNING
Vol. 17. PUBLIC EXPENDITURE AND BENEFICIAL AND ADVERSE EFFECTS
Vol. 18. WATER RESOURCES MANAGEMENT
Vol. 19. WATER LAWS AND INSTITUTIONS

COMPOSITION OF THIS VOLUME

This Volume consists of two parts: Part 1 deals with the subject matters of Peninsular Malaysia and Part 2 is devoted to the States of Sabah and Sarawak.

ABBREVIATIONS

(1) Plan

FMP	:	First Malaysia Plan
SMP	:	Second Malaysia Plan
TMP	:	Third Malaysia Plan
4MP	:	Fourth Malaysia Plan
5MP	:	Fifth Malaysia Plan
6MP	:	Sixth Malaysia Plan
7MP	:	Seventh Malaysia Plan
NEP	:	New Economic Policy
OPP	:	Outline Perspective Plan
RESP	:	Rural Environmental Sanitation Program

(2) Domestic Organization

DID (JPT)	:	Drainage and Irrigation Department
DOA	:	Department of Agriculture
DOE	:	Division of Environment
DOF	:	Department of Forestry
DOFS	:	Department of Fishery
DOM	:	Department of Mines
DOS	:	Department of Statistics
EPU	:	Economic Planning Unit
FAMA	:	Federal Agricultural Marketing Authority
FELCRA	:	Federal Land Consolidation and Rehabilitation Authority
FELDA	:	Federal Land Development Authority
ICU	:	Implementation and Coordination Unit
MARDI	:	Malaysian Agricultural Research and Development Institute
MIDA	:	Malaysian Industrial Development Authority
MLRD	:	Ministry of Land and Regional Development
MMS	:	Malaysian Meteorological Service
MOA	:	Ministry of Agriculture
MOF	:	Ministry of Finance

MOH	:	Ministry of Health
MOPI	:	Ministry of Primary Industries
MRRDB	:	Malaysia Rubber Research and Development Board
NDPC	:	National Development Planning Committee
NEB (LLN)	:	National Electricity Board
PORIM	:	Palm Oil Research Institute of Malaysia
PWD (JKR)	:	Public Works Department
RDA	:	Regional Development Authority
RISDA	:	Rubber Industry Small-holders Development Authority
RRIM	:	Rubber Research Institute of Malaysia
SEB	:	Sabah Electricity Board
SEBC	:	State Economic Development Corporation
S(E)PU	:	State (Economic) Planning Unit
SESCO	:	Sarawak Electricity Supply Corporation
UDA	:	Urban Development Authority

(3) International or Foreign Organization

ADAA	:	Australian Development Assistance Agency
ADB	:	Asian Development Bank
ASCE	:	American Society of Civil Engineers
FAO	:	Food and Agriculture Organization of the United Nations
IBRD	:	International Bank for Reconstruction and Development
ILO	:	International Labour Organization
IMF	:	International Monetary Fund
IRRI	:	International Rice Research Institute
JICA	:	Japan International Cooperation Agency
JSCE	:	Japan Society of Civil Engineers
MOC	:	Ministry of Construction, Japan
OECD	:	Organization for Economic Cooperation and Development
OECF	:	Overseas Economic Cooperation Fund, Japan
UK	:	United Kingdom
UNDP	:	United Nations Development Program

UNSF	:	United Nations Special Fund
US or USA	:	United States of America
US/AID	:	United States Agency for International Development
USBR	:	United States Bureau of Reclamation
WHO	:	World Health Organization
WMO	:	World Meteorological Organization

(4) Others

B	:	Benefit
BOD	:	Biochemical Oxygen Demand
C	:	Cost
CIF	:	Cost, Insurance and Freight
COD	:	Chemical Oxygen Demand
D&I	:	Domestic and Industrial
dia	:	Diameter
EIRR	:	Economic Internal Rate of Return
El.	:	Elevation above mean sea level
Eq.	:	Equation
Fig.	:	Figure
FOB	:	Free on Board
FSL	:	Full Supply Level
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
H	:	Height, or Water Head
HWL	:	Reservoir High Water Level
LWL	:	Reservoir Low Water Level
O&M	:	Operation and Maintenance
Q	:	Discharge
Ref.	:	Reference
SITC	:	Standard International Trade Classification
SS	:	Suspended Solid
V	:	Volume
W	:	Width

ABBREVIATIONS OF MEASUREMENT

Length

mm = millimeter
cm = centimeter
m = meter
km = kilometer
ft = foot
yd = yard

Area

cm^2 = square centimeter
m^2 = square meter
ha = hectare
km^2 = square kilometer

Volume

cm^3 = cubic centimeter
l = lit = liter
kl = kiloliter
m^3 = cubic meter
gal. = gallon

Weight

mg = milligram
g = gram
kg = kilogram
ton = metric ton
lb = pound

Time

s = second
min = minute
h = hour
d = day
y = year

Electrical Measures

V = Volt
A = Ampere
Hz = Hertz (cycle)
W = Watt
kW = Kilowatt
MW = Megawatt
GW = Gigawatt

Other Measures

% = percent
PS = horsepower
° = degree
' = minute
" = second
°C = degree in centigrade
10^3 = thousand
10^6 = million
10^9 = billion (milliard)

Derived Measures

m^3/s = cubic meter per second
cusec = cubic feet per second
mgd = million gallon per day
kWh = kilowatt hour
MWh = Megawatt hour
GWh = Gigawatt hour
kWh/y = kilowatt hour per year
kVA = kilovolt ampere
BTU = British thermal unit
psi = pound per square inch

Money

M$ = Malaysian ringgit
US$ = US dollar
¥ = Japanese Yen

CONVERSION FACTORS

	From Metric System	To Metric System
Length	1 cm = 0.394 inch 1 m = 3.28 ft = 1.094 yd 1 km = 0.621 mile	1 inch = 2.54 cm 1 ft = 30.48 cm 1 yd = 91.44 cm 1 mile = 1.609 km
Area	1 cm^2 = 0.155 sq.in 1 m^2 = 10.76 sq.ft 1 ha = 2.471 acres 1 km^2 = 0.386 sq.mile	1 sq.ft = 0.0929 m^2 1sq.yd = 0.835 m^2 1 acre = 0.4047 ha 1 sq.mile = 2.59 km^2
Volume	1 cm^3 = 0.0610 cu.in 1 lit = 0.220 gal.(imp.) 1 kl = 6.29 barrels 1 m^3 = 35.3 cu.ft 10^6 m^3 = 811 acre-ft	1 cu.ft = 28.32 lit 1 cu.yd = 0.765 m^3 1 gal.(imp.) = 4.55 lit 1 gal.(US) = 3.79 lit 1 acre-ft = 1,233.5 m^2
Weight	1 g = 0.0353 ounce 1 kg = 2.20 lb 1 ton = 0.984 long ton = 1.102 short ton	1 ounce = 28.35 g 1 lb = 0.4536 kg 1 long ton = 1.016 ton 1 short ton = 0.907 ton
Energy	1 kWh = 3,413 BTU	1 BTU = 0.293 Wh
Temperature	°C = (°F - 32)·5/9	°F = 1.8°C + 32
Derived Measures	1 m^3/s = 35.3 cusec 1 kg/cm^2 = 14.2 psi 1 ton/ha = 891 lb/acre 10^6 m^3 = 810.7 acre-ft 1 m^3/s = 19.0 mgd	1 cusec = 0.0283 m^3/s 1 psi = 0.703 kg/cm^2 1 lb/acre = 1.12 kg/ha 1 acre-ft = 1,233.5 m^3 1 mgd = 0.0526 m^3/s
Local Measures	1 lit = 0.220 gantang 1 kg = 1.65 kati 1 ton = 16.5 pikul	1 gantang = 4.55 lit 1 kati = 0.606 kg 1 pikul = 60.6 kg

Exchange Rate
(as average between July and December 1980)

\$1 = M\$2.22
¥100 = M\$1.03

PART 1

PENINSULAR MALAYSIA

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SPECIAL ABBREVIATIONS

(1) Domestic Organization

GSD	:	Geological Survey Department

(2) Others

Mc	:	Malaysian Cent
gpd	:	gallon per day
mgd	:	million gallon per day
Kg	:	Kampong
Pg	:	Pengkalen (local name)
Sg	:	Sungai
PS	:	Horsepower
mm/d	:	mm/day
mm/y	:	mm/year
m^3/d	:	m^3/day
m^3/M	:	m^3/month
m^3/y	:	m^3/year
dia.	:	diameter

1. INTRODUCTION

This ANNEX presents the results of groundwater resources study including the present condition of groundwater use, inventory of tubewell, delineation of potential aquifer, cost analysis and plan for groundwater basin management.

The data of existing tubewells were collected from GSD and drilling companies. Hydrogeologic data of geologic logs, geological cross sections, well loggings and pumping test results were either provided by GSD or taken from previous studies.

Hydrogeological land classification was made for estimation of the potential of groundwater development.

The costs of well construction and water source were estimated based on the recent contract amount and the previous engineer's estimate. The cost of the groundwater development was estimated based on the aquifer potential in order to estimate the unit water source cost.

The concept of the systematic groundwater basin management plan was studies to facilitate for the maximum development of groundwater resources for beneficial use without producing the undesired results such as sea water intrusion and land subsidence.

2. PRESENT CONDITION

2.1 Inventory of Tubewell

GSD has just started the compilation of inventory of tubewells and existing drilled logs in Peninsular Malaysia. Tables 1 to 3 show indicative inventory of pumping yield in Peninsular Malaysia in 1979 specially prepared by GSD for the Study.

Tables 4 to 11 show inventory of tubewells in Peninsular Malaysia in 1980 rearranged and compiled by the Study from the registered drilling record in GSD. The purpose of this inventory is to distinguish the hydrogeological conditions showing the location, depth, diameter, purpose, screen length, drawdown, pumping discharge, specific capacity, transmissivity coefficient and permeability coefficient. Tables 4 to 7 include the tubewells of 62 in number constructed by GSD, PWD and DID before 1980. Tables 8 to 11 include 44 test production tubewells constructed by the Kedah/Perlis Water Resources Management Study (EPU) in 1980 (Ref. 11).

Tubewell records in 3 private drilling companies are collected by the Study. They include 15 wells for agriculture use, 120 wells for domestic use, 108 wells for industry use and 45 exploratory boreholes. Table 12 shows the summary of inventory including the tubewells and boreholes recorded in GSD and 3 drilling companies. Distribution of the production tubewells is shown in Fig. 1. If the average pumping yield of production tubewell in Table 12 is assumed to be 500 m^3/d, total output of 348 wells is calculated to be 174 x 10^3 m^3/d (63.5 x 10^6 m^3/y).

2.2 Domestic Groundwater Supply

Among 61 wells excluding one not working, 57 tubewells are supplying 66.6 x 10^3 m^3/d, or 24.3 x 10^6 m^3/y for the domestic use being located at 21 places (see Table 1). This output corresponds to 4% of PWD's total supply of 589 x 10^6 m^3/y in 1978. Among the tubewell supply, 41.6 x 10^3 m^3/d, or 15.2 x 10^6 m^3/y is regarded as urban supply for Kota Bharu, Kuala Trengganu and Kuantan/Cheratomg. The remaining 24.96 x 10^3 m^3/d, or 9.3 x 10^6 m^3/y is rural supply. It is noted that Kota Bharu district are wholly supplied with groundwater. Total tubewell supply for domestic purpose is estimated to be 100 x 10^6 m^3/y, if the tubewells recorded in the private companies are taken into account.

PWD estimated that the pipe-served population was 6.5 x 10^6 against the total population of 11 x 10^6 in Peninsular Malaysia in 1978 (Ref. 47). The remaining 4.5 x 10^6 are regarded to depend on some local sources such as driven wells, dug wells and rivers. An estimate indicated that 70% of non-pipe-served population depended on groundwater in Malaysia in 1975 (Ref. 5). If this figure is applied, 3 x 10^6 people are depending on the driven wells and dug wells. The groundwater use by non-pipe-served people is roughly estimated to be 50 x 10^6 m^3/y, assuming a per capita consumption of 46 lit/d (10 gpd).

In summary, the groundwater supply for the domestic use is about 150×10^6 m^3/y, comprising 100×10^6 m^3/y by tubewells and 50×10^6 m^3/y by driven and dug wells.

2.3 Agriculture Groundwater Use

The agriculture groundwater use is recognized in the coastal alluvial plain in Kelantan State. There is a tubewell of the 96 m in dpeth and many dug wells less than 10 m in depth in the perched water in Kemasin-Semerak area of 2,895 ha in which main crops are tobacco, watermelon, vegetables, groundnut and occasionally corn (Ref. 6). These wells are utilized for irrigation of certain part of the upland field and conducted by sprinkler and hand held hose.

Based on the result of Kelantan River basin study 1977 (Ref. 7), DID constructed and operated two pilot schemes in 1978 and 1979. The Bris Lallang scheme of 0.4 ha was located on the coastal sand dune in Kemasin-Semerak area. A shallow production well was drilled for pumping of irrigation water on upland during the dry periods of the year. The Kg. Kandis pilot irrigation project of 180 ha is located on the coastal sand dune in southern Kelantan. Pilot cultivation of tobacco is being practiced by well point system in shallow aquifer of less than 5 m. With success of this pilot project, southern Kandis area is selected to be a next alternative groundwater irrigation project. The Meranti pilot scheme of 64 ha was located in the alluvial plain on the right bank of the Kelantan river, where single cropping of rice has been practiced during the main raining season. A production well of 50 m in depth was drilled and pumped water was utilized for supplemental irrigation in 20 ha of paddy in September to October.

The groundwater supply for irrigation so far appearing in Table 1 is 4.9×10^3 m^3/d, or 0.4×10^6 to 0.5×10^6 m^3/y if 80 to 100-day operation is assumed. Referring to Table 12, total supply is estimated to be 2×10^6 m^3/y.

2.4 Industrial Water Use

The tubewells of 108 in number are recognized in the industrial park, oil palm factories, rubber factories and other factories (see Table 12). This fact indicates that substantial volume of groundwater is used for the industrial purpose, but no yield data is available.

2.5 Types of Tubewells

Three types of tubewells are recognized: (1) PWD old type, (2) German type and (3) PWD new type (see Figs. 2 to 4).

The PWD old type well is a shallow tubewell less than 20 meters in depth in alluvial aquifer, which has been developed by PWD at Kota Bharu district since 1935. The wells are screened by slotted pipes of steel or PVC with 25 cm dia.

The German type well is a shallow or deep tubewell of 20 to 100 m in depth in either alluvium or hard rocks, which has been constructed by PWD, DID and GSD all over the country since 1975. The wells are screened by slotted PVC pipe or steel pipe with 20 to 25 cm dia.

The PWD new type well is a shallow or deep tubewell applicable to 10 to 100 m in depth in any type of aquifer. The construction of this type of well started in 1980 at Kota Bharu district by PWD. The well is cased by wire wrapped type of screen (Johnson type) with 20 to 35 cm dia.

German type wells have been constructing all over the country. However some deep tubewells were abandoned in the Kota Bharu district, because of the collapse of the PVC screen pipe. All the PWD old type and German type of tubewells 32 in number in the Kota Bharu district are being replaced by the PWD new type (Ref. 9).

2.6 Types of Pumps

Centrifugal and the submersible pumps are used in Kota Bharu district (Ref. 9). The centrifugal pumps are installed in the pits of JKR old type wells (see Fig. 3). The pumps rated 20 PS delivering 1,100 to 1,700 m^3/d are equipped for the shallow tubewells in alluvial aquifer. They are affected by the seasonal fluctuation of water level of 1.5 to 6.5 m. The submersible pumps rated 25 to 30 PS delivering 2,000 to 2,200 m^3/d are installed in German type wells and PWD old type wells. They are less sensitive to the seasonal change of water level than the centrifugal pump.

2.7 Yield of Tubewells

GSD and German Hydrogeological Mission carried out pumping test of 7 German type wells in alluvial aquifer at Kota Bharu district and estimated the maximum available yield from each well to be 2,700 m^3/d (Ref. 10). The Kota Bharu Headworks (PWD) also performed pumping test of 3 German type wells in alluvial aquifer at Kota Bharu district and estimated the pumping yield of 2,000 to 2,200 m^3/d. Kedah/Perlis Water Resources Study assisted by GSD carried out pumping test of 38 German type wells in rock aquifer at Kedah and Perlis. This pumping test was the first systematic groundwater development feasibility study in rock aquifer in mountainous area of Peninsular Malaysia. The pumping yield was 216 to 276 m^3/d with an average of 258 m^3/d in silurian rocks, 24 to 300 m^3/d with an average of 153 m^3/d in carboniferous rocks, 168 to 960 m^3/d with an average of 473 m^3/d in triassic rocks and 432 to 1,032 m^3/d with an average of 673 m^3/d in limestone (see Tables 10 & 11).

PWD new type wells of 32 in number were proposed to replace the existing tubewells at Kota Bharu by PWD. Purpose of the replacement is to keep the long well life and increase the unit pumping yield. The maximum pumping yield was expected to be 3,300 m^3/d (Ref. 12).

2.8 Groundwater Exploration

The GSD has implemented systematic groundwater exploration programs since 1975 at requests by PWD, EPU, DOA and DID. The drilling companies drilled the exploratory boreholes based on requests by the above-mentioned departments and private companies.

The Kedah/Perlis Water Resources Management Study implemented a systematic groundwater development feasibility study in 1980 (Ref. 8). Test wells of 64 in total number were drilled in the two States. Test wells of 20 in number were abandoned after drilling because no sufficient water was found. Test wells of 44 in number have been used for production well after pumping test. The geology of the studied area is silurian to traissic including limestones, sandstones, shales, mudstones, hornfels and others. The aquifers are recognized in the fissures of rocks between 20 to 30 m in depth. The aquifers more than 50 m in depth have not been explored, but there may be more potential in deep aquifer. The hydrogeological columns of 44 test wells are shown in Figs. 5 and 6. Location of the test wells is shown in Fig. 7. Transmissivity coefficients of the limestone and other rocks were measured to be 1 m^2/d to 467 m^2/d (see Tables 10 & 11).

2.9 The Kota Bharu Water Supply Scheme

The Kota Bharu Water Supply Scheme (Ref. 10) was envisaged by PWD in 1978 to upgrade the existing domestic water supply capacity of 18.5×10^3 m^3/d (4.06 mgd) to 49.4×10^3 m^3/d (10.86 mgd) in Kota Bharu district by construction of 32 new and related storage, treatment and distribution facilities, which would replace all old existing wells.

Under this scheme, 44 cm (18 inches) dia. boreholes were drilled in total length of 725 m in the first and second aquifers of less than 50 m in depth. The tubewells constructed were of PWD new type with 20 cm (8 inches) dia. wire wrapped screen. The contract amount of the well construction was M$988 x 10^3 in 1979 as broken down in Table 13 (Ref. 9).

The third aquifer has been convinced in the depth of 50 - 150 m. It is likely more promising than the overlying aquifers and could be considered for further exploitation.

The total construction cost of the scheme had been estimated to be M$18 x 10^6 in 1978 including the water source, storage, treatment and distributing facilities, assuming German type wells with PVC screen. Taking into account the design change from German type wells to PWD new type wells, the cost is updated to M$18.5 x 10^6 as shown in Table 14.

3. DEVELOPMENT POSSIBILITIES

3.1 Classification of Groundwater Potential

Aquifers are recognized in the alluvial sands and gravels, and the fissures of limestones and other rocks. Alluvial deposits are clays, silts, sands and gravels. Their alternating layers in the alluvial sedimentary basin constitute multi-layered semi-confined aquifer system. The hydrogeological cross sections of alluvial coastal aquifers are reproduced from existing reports (Refs. 14 to 40) in Figs. 9 to 14. Their locations are shown in Fig. 5. The maximum depth of alluvial sediment is 150 m in Kota Bharu district, more than 70 m at Kuala Trengganu, 25 m in Kuantan region and 32 m at Alor Setar. The maximum thickness of the alluvial aquifer is 90 m in Kota Bharu district, more than 30 m at Kuala Trengganu, 20 m in Kuantan region and 6 m at Alor Setar. Transmissivity coefficients of the potential alluvial aquifers were measured to be 146 m^2/d to 12,600 m^2/d (see Tables 6 & 7).

Brackish to saline groundwater is recognized in some tubewells along the coast of Kedah, Selangor, Johor, Trengganu, and Pahang States.

The rocks in Peninsular Malaysia are limestones, sandstones, conglomerates, shales, mudstones, granites, schists, hornfels, volcanic flows, volcanic tuffs, pyroclastics and others. The aquifers are recognized more or less in the faulting zones of all rocks. Very few data is available to distinguish the aquifer characteristics in rocks (Refs. 8, 16 and 38).

Based on the aquifer parameters of thickness, specific yield, pumping discharge, transmissivity coefficient and drawdown in the previous study, potential areas are classified into 8. The range of specific yield was assumed, though there is no data available.

(1) Alluvial Class I

This is the excellent aquifer with large thickness being located in the downstream areas of large river basins, especially the Kelantan, Trengganu, Pahang, Klang, Selangor and Perak river basins. Schematic hydrogeological profile is shown in Figs. 8 to 13. Aquifer parameters are assumed as follows:

Thickness of Aquifer	:	10 - 40 m
Specific Yield	:	15 - 25%
Pumping Discharge	:	500 - 3,000 m^3/d
Transmissivity Coefficient	:	100 - 1,000 m^2/d
Drawdown	:	1 - 10 m

(2) Alluvial Class II

This is the good aquifer with moderate thickness being located in coastal alluvial plains. Schematic hydrogeological profile is shown in Figs. 10 to 13. Aquifer parameters are assumed as follows:

Thickness of Aquifer	:	8 - 15 m
Specific Yield	:	10 - 20%
Pumping Discharge	:	200 - 500 m^3/d
Transmissivity Coefficient	:	50 - 150 m^2/d
Drawdown	:	2 - 10 m

(3) Alluvial Class III

This is the fair aquifer with moderate thickness less than alluvial class II being located at the foothills of the highlands. Schematic hydrogeological profile is shown in Figs. 11 to 13. Aquifer parameters are assumed as follows:

Thickness of Aquifer	:	2 - 8 m
Specific Yield	:	10 - 15%
Pumping Discharge	:	50 - 200 m^3/d
Transmissivity Coefficient	:	10 - 50 m^2/d
Drawdown	:	3 - 10 m

(4) Alluvial Class IV

This is the poor aquifer with very thin thickness less than 2 m being located at the foothills of the highlands or sea coast. Schematic hydrogeological profile is shown in Figs. 8 to 13. Aquifer parameters are assumed as follows:

Thickness of Aquifer	:	0 - 2 m
Specific Yield	:	5 - 15%
Pumping Discharge	:	0 - 50 m^3/d
Transmissivity Coefficient	:	0 - 10 m^2/d
Drawdown	:	4 - 10 m

(5) Alluvial Class V

This is the very poor aquifer with thickness nearly equal to zero or intruded by sea water being located at the sea coast. Schematic hydrogeological profile is shown in Fig. 8. No groundwater development is expected in this class.

(6) Rock Class I

This is the excellent aquifer with large to moderate thickness being located in the limestones of crystalline and of karst type. Schematic log is shown in Fig. 5. Aquifer parameters are assumed as follows:

Thickness of Aquifer	:	10 - 25 m
Specific Yield	:	5 - 10%
Pumping Discharge	:	300 - 1,500 m^3/d
Transmissivity Coefficient	:	50 - 500 m2/d
Drawdown	:	1 - 10 m

(7) Rock Class II

This is the good to fair aquifer with moderate thickness being located in the sandstones and conglomerates with intensive fissures. Schematic log is shown in Figs. 5 and 6. Aquifer parameters are assumed as follows:

Thickness of Aquifer	:	5 - 15 m
Specific Yield	:	2 - 8%
Pumping Discharge	:	100 - 300 m^3/d
Transmissivity Coefficient	:	10 - 50 m^2/d
Drawdown	:	5 - 10 m

(8) Rock Class III

This is the fair to poor aquifer with moderate thickness being located in other rocks with fissures. Schematic log is shown in Figs. 5 and 6. Aquifer parameters are assumed as follows:

Thickness of Aquifer	:	5 - 15 m
Specific Yield	:	2 - 5%
Pumping Discharge	:	0 - 100 m^3/d
Transmissivity Coefficient	:	0 - 15 m^2/d
Drawdown	:	10 - 25 m

Probability of occurrence of non-productive field is assumed to be 10% in alluvial class I, 30% in alluvial class II, 50% in alluvial class III, 80% in alluvial class IV, 100% in alluvial class V, 50% in rock class I, 70% in rock class II and 90% in rock class III depending on some experiences in water well development which were carried out by contractor. Hydrogeological land classification map is shown in Fig. 14.

3.2 Storage Potential

Storage potential is the groundwater storage volume in the aquifer. It is estimated as follows:

$$SP = A \times b \times Sy \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

where, SP: Storage potential
A : Area
b : Thickness of aquifer
Sy: Specific yield (effective porosity)

Assuming the average thickness and average specific yield by hydrogeological land class as shown in Table 16, the storage potential by class by basin was calculated as shown in Table 17.

3.3 Groundwater Recharge

Very few study on deep percolation or groundwater recharge is recognized in hydrogeological study. According to the recent study on deep percolation in Japan, linear relation between deep percolation and precipitation is recognized by a field investigation and water balance analysis. The deep percolation is estimated to be 15 to 25% of the annual precipitation (Ref. 48). Based on this study, annual deep percolation in alluvial plain is assumed to be 22% of annual precipitation. According to Ref. 42, deep percolation in mountain area of granitic rocks is estimated to be 90 mm/y by a water balance analysis. Annual precipitation in the studied area in Selangor State is estimated to be 2,300 mm/y. Accordingly, annual deep percolation in the mountain area is assumed to be 3% of annual precipitation. The deep percolation rates in the 41 basins were calculated with the above-mentioned assumptions as shown in Table 18. Average daily groundwater recharge was estimated by hydrogeological land class by basin as shown in Table 19.

3.4 Preliminary Estimate of Safe Yield

Assuming probability of occurrence of non-productive field 0.1 to 0.9 safe yield was preliminarily estimated by class by basin as shown in Table 20 that it is not larger than the storage potential and groundwater recharge.

3.5 Cost Analysis

Unit cost of water source was estimated to compare the cost of groundwater and surface water. Corresponding to hydrogeological land classification, 7 cases were assumed with the aquifer type, average well depth, average pumping discharge, average drawdown, well type and pump capacity as shown in Tables 21 and 22.

Regarding the power source and electric supply from power system, the power generator by diesel engine was assumed because the groundwater development is regarded to be conducted mostly in rural areas.

Economic life of the facilities are assumed as follows:

Well .... 25 years
Pump and generator .... 8 years
Other facilities .... 50 years

Estimated cost stream for 50 years of the assumed groundwater source facilities is shown in Table 23.

Unit cost of water source was estimated assuming discount rates of 6-20% as shown in Table 24.

4. SOME COMMENTS ON GROUNDWATER DEVELOPMENT AND MANAGEMENT

4.1 General

Present groundwater use is limited to the very small amount compared with the groundwater potential in Peninsular Malaysia. Groundwater is only the water source where surface water is not available. No treatment except the chlorination will be required for groundwater supply. Small scale groundwater development scheme in the potential areas will be estimated to be low cost of water resources development. It is anticipated that the groundwater will be used especially in rural water supply. No statistics are available for industry groundwater use. However the most beneficial use will be the industry use because of that high water quality is not required and distribution cost is less if the drilled well is located near the factory in owner's land.

Neither the legal regulations nor the government control have been performed to provide the maximum development of groundwater resources for beneficial use. The safe yield of a groundwater basin is the amount of water which can be withdrawn from it annually without producing undesired result (Ref. 41). Sea water intrusion and land subsidence may be anticipated at alluvial aquifer especially in alluvial class I which located near sea coast when the groundwater extraction from the groundwater storage exceeds the safe yield. It is seldom that any single value of safe yield from a groundwater basin can be correct for an extended time. Any determination of safe yield is based upon specific conditions, either existing or assumed, and any changes in these conditions will change the safe yield.

It is unfortunate, perhaps, that most investigations to ascertain the safe yield are not initiated until the basin development have produced overdrafts. The utilization of groundwater by one landowner affects the water supply of all other landowners. No groundwater law has been established for the control and the management of groundwater resources except for Geological Survey Act 129.

4.2 An Example of Groundwater Development and Management

Sand dune which is developed in local along the east coast of Malaysia is a distinct hydrogeological land in some alluvial classes I to IV. This area is distinguished in high pervious sands with high infiltration rates, however, careful groundwater management is requested to avoid sea water intrusion resulting in over pumping. The occurrence of fresh groundwater is recognized in shallow unconfined aquifer which is perched on saline water, and it is replenished directly by rainfall during wet season. Safe yield of optimum pumping yield in this area is preliminary estimated to forecast the groundwater level depending on Ghyben-Hertzberg law which indicates the critical water level of elevation zero to permit sea water intrusion into aquifer of sands. Kg. Kandis pilot irrigation of 180 ha in sand dune of Kelantan is selected to be an example of case study for small scale groundwater management.

Monthly change in groundwater level is preliminary predicted by hydrogeological tank model method assuming the monthly water requirement of 20×10^3 to 160×10^3 m^3/M in dry season. Lowest groundwater level is estimated to be 0.3 m in the year of 1978 which has a probability of 1/5 drought year as shown in Fig. 15.

A proposed procedure of the regional groundwater management for the artesian alluvial groundwater basin (especially for Class I area) is shown in Fig. 16. This flow chart will be used for a part of regional water resources development and management program in the stage of planning.

REFERENCES

1. SEMENANJUNG MALAYSIA, 1979, OOI JIN BEE

2. AVERAGE ANNUAL SURFACE WATER RESOURCES OF PENINSULAR MALAYSIA, WATER RESOURCES PUB. NO. 6, 1976, JPT

3. UNITED NATIONS WATER CONFERENCE COUNTRY REPORT ESCAP REGIONAL PREPARATORY MEETING BANGKOK, 1976, GOVERNMENT OF SELANGOR

4. INVESTIGATIONS FOR A SUITABLE SOURCE OF WATER SUPPLY FOR THE KLANG VALLEY INTERIM REPORT GROUNDWATER STUDY, 1979, GOM

5. RAPID ASSESSMENT OF WATER SUPPLY AND SANITATION MALAYSIA, 1978, GOM

6. KEMASIN-SEMERAK INTEGRATED RURAL DEVELOPMENT PROJECT VOL. 1 DRAFT REPORT, 1979, GOM

7. THE KELANTAN RIVER BASIN STUDY VOL. 1, 1977, EPU & DID

8. KEDAH/PERLIS WATER RESOURCES MANAGEMENT STUDY VOL. 2, 1980, GOM

9. KOTA BHARU WATER SUPPLY SCHEME CONTRACT NO. 6, 1979, PWD

10. KOTA BHARU WATER SUPPLY SCHEME KELANTAN, 1978, PWD

11. KEDAH/PERLIS WATER RESOURCES MANAGEMENT STUDY APPENDIX 2, 1980, GOM

12. ACCORDING TO THE INFORMATION FROM KOTA BHARU WATER SUPPLY, 1980, PWD

13. GEOLOGICAL MAP OF PENINSULAR MALAYSIA, 1973, GSD

14. GROUNDWATER EXPLORATION IN KOTA BHARU, GPH 1, 1974, GSD

15. GROUNDWATER EXPLORATION IN KOTA BHARU, GPH 2, 1974, GSD

16. GROUNDWATER EXPLORATION IN THE JENGKA TRIANGLE, PAHANG, GPH 1, 1975, GSD

17. GEOLOGIC LOGS OF EXPLORATION BOREHOLES DRILLED IN 1975 IN THE KOTA BHARU AREA, GPH 2, 1975, GSD

18. HYDROGEOLOGICAL REPORT - KAMPONG RAJA, TRENGGANU, GPH 3, 1975, GSD

19. GEOELECTRICAL INVESTIGATIONS IN KUALA TRENGGANU, TRENGGANU, GPH 5, 1975, GSD

20. GEOELECTRICAL INVESTIGATIONS IN KOTA BHARU, KELANTAN, GPH 6, 1975, GSD

21. REPORT OF GEOELECTRICAL INVESTIGATIONS IN THE KUANTAN - CHUKAI AREA, PAHANG/TRENGGANU, GPH 7, 1975, GSD

22. REPORT OF GEOELECTRICAL INVESTIGATIONS IN CHUPING AREA, PERLIS, GPH 8, 1975, GSD

23. HYDROGEOLOGICAL REPORT ON GROUNDWATER INVESTIGATIONS IN PASIR PUTEH, KELANTAN, GPH 1, 1976, GSD

24. GEOLOGIC LOGS OF EXPLORATION BOREHOLES DRILLED IN TRENGGANU, GPH 2, 1976, GSD

25. HYDROGEOLOGICAL REPORT - KG. PENGKALAN KUBOR, KELANTAN, GPH 3, 1976, GSD

26. HYDROGEOLOGICAL REPORT - TUMPAT, KELANTAN, GPH 4, 1976, GSD

27. INVESTIGATIONS ABOUT "SUBTERRANEOUS DEFERRIZATION OF GROUNDWATER" IN THE TUMPAT WATERWORKS, KELANTAN, GPH 5, 1976, GSD

28. HYDROGEOLOGICAL REPORT - PENGKALAN CHEPA, KOTA BHARU, KELANTAN, GPH 1, 1977, GSD

29. TUMPAT WATERWORKS, KELANTAN - SUBTERRANEOUS DEFERRIZATION TESTS, GPH 2, 1977, GSD

30. HYDROGEOLOGICAL REPORT - BACHOK, KELANTAN, GPH 3, 1977, GSD

31. HYDROGEOLOGICAL INVESTIGATIONS IN THE NEW PORT AREA NORTH OF KUANTAN, PAHANG, GPH 5, 1977, GSD

32. HYDROGEOLOGICAL REPORT - WAKAF BHARU, KOTA BHARU, KELANTAN, GPH 6, 1977, GSD

33. HYDROGEOLOGICAL INVESTIGATIONS IN CHUPING FELDA SUGARCANE PLANTATION, PERLIS, GPH 7, 1977, GSD

34. HYDROGEOLOGICAL INVESTIGATIONS IN THE KUALA BESUT AREA, TRENGGANU, GPH 8, 1977, GSD

35. HYDROGEOLOGICAL INVESTIGATIONS IN KUALA TRENGGANU, TRENGGANU, GPH 9, 1977, GSD

36. SUPPLEMENTARY HYDROGEOLOGICAL REPORT - KG. RAJA, TRENGGANU, GPH 10, 1977, GSD

37. HYDROGEOLOGICAL REPORT - CITY WATERWORKS, KOTA BHARU, KELANTAN, GPH 11, 1977, GSD

38. GROUNDWATER EXPLORATION IN THE JENGKA TRIANGLE, PAHANG - REPORT NO. 2, GPH 12, 1977, GSD

39. HYDROGEOLOGICAL INVESTIGATIONS AT PROPOSED DID (DRAINAGE AND IRRIGATION DEPARTMENT) WATER MANAGEMENT CENTRE, KG. RANJI, KOTA BHARU, KELANTAN, GPH 1, 1978, GSD

40. INTERIM REPORT - GROUNDWATER INVESTIGATIONS IN PULAU LANGKAWI, KEDAH, GPH 2, 1978, GSD

41. GROUNDWATER HYDROLOGY, 1959, JOHN WILEY & SON

42. SG. LUI REPRESENTATIVE BASIN REPORT WATER RESOURCES PUBLICATION NO. 9, 1978, DID

43. GROUNDWATER RESOURCES STUDY, 1973, JAPANESE

44. LAND SUBSIDENCE RESEARCH AND REGIONAL WATER RESOURCES PLANNING OF THE NANAO BASIN, 1976, IASH

45. INFORMATION FROM NEB, 1980, NEB

46. INFORMATION FROM SELANGOR WATERWORKS PWD

47. DATA BAGI PENYEDIAAN RANCANGAN MALAYSIA KEEMPAT, FEB. 1980, PWD

48. HYDROLOGICAL CYCLE OF HILLY LAND AND EFFECTS ON URBANIZATION ON IT, 1981, JAPANESE

49. CROP WATER REQUIREMENTS, 1977, FAO

50. KAMPONG KANDIS PILOT IRRIGATION PROJECT, 1981, DID

TABLES

Table 1 INVENTORY OF PUMPING DISCHARGE BY GSD (1/2)

Location	No. of Wells	Pumping Discharge/1 (m^3/d)	Present Output/2 (m^3/d)	Use For	Remarks Number (Table 2)
Kelantan					
Kota Bharu town	8	22,680	10,000	Domestic	1
Pintu Geng.	1	2,000	2,000	Domestic	2
Wakat Bharu	2	8,000	8,000	Domestic	2
Pengkalen Cepa	7	2,800	2,800	Domestic	3
Tanjong Mas	3	9,000	9,000	Domestic	3
Bachok	1	3,000	500	Domestic	4
Tumpat	2	4,000	200	Domestic	5
Pasir Putih	1	2,400	2,400	Agriculture	6
Pengkalan Kubur	2	500	150	Domestic	7
Machang	2	1,200	150	Domestic	7
Meranti	1	500	500	Domestic	8
Pantai Panjang	1	800	800	Domestic	8
Tanah Merah	1	1,500	1,500	Domestic	8
Repek	1	700	700	Domestic	8
Chetok	1	1,000	1,000	Domestic	9
Panji	1	1,600	1,500	Agriculture	10
Sub-total	35	61,680	41,200		
Trengganu					
Kuala Trengganu	6	16,600	16,600	Domestic	11
Kampung Raja	4	6,700	2,000	Domestic	12
Besut	2	450	-	Agriculture	13
Marang	2	1,000	1,000	Domestic	14
Buloh-Penarik	(1)	-	-	-	15
Sub-total	15	24,750	19,600		
Pahang					
Kuantan/Cherating	5	5,000	5,000	Domestic	16
Jenka Triangle	3	1,500	1,500	Domestic	17
Sub-total	8	6,500	6,500		
Perlis					
Chuping Felda	3	2,160	2,160	Domestic	18
Arau	1	1,000	1,000	Domestic	
Sub-total	4	3,160	3,160		
Total	61	96,090	70,460		

Remarks; /1: Maximum yield of well

/2: Daily yield of well for actual use

Source; Geological Survey Department, 1979

Table 2 INVENTORY OF PUMPING DISCHARGE BY GSD (2/2)

Remarks to Table 1

1. Present output is only 10,000 m^3/d; with this additional 22,680 m^3/d, the supply to the town up to 1985 is assured. Demand by 1985 is about 32,000 m^3/d. Based on GSD's investigations, JKR has designed a new waterworks for K.B. Third aquifer can also be exploited if demand increases.
2. For additional supply to KB town.
3. For supply to P. Cepa area.
4. Sufficient for present requirement of 500 m^3/d. For 1985 requirement of 4,500 m^3/d, one more well is needed.
5. Sufficient for present requirement of 200 m^3/d, and 1985 requirement of 600 m^3/d.
6. This test-well indicated that the requirement of 500 m^3/hr by the DID can be obtained by constructing more wells.
7. Sufficient to meet daily requirement of 150 m^3.
8. For Kelantan Rural Water Supply Scheme.
9. For Kelantan Rural Water Supply Scheme.
10. For DID. Daily requirement of 1,500 m^3.
11. This is sufficient to meet the additional daily demand of the K.T. area. A new waterworks has been proposed at the well-site.
12. These are sufficient to meet the combined requirements of Besut, Kg. Raja, Alor Lintang Area, amounting to 2,000 m^3/d.
13. Sufficient for supply to chicken farm project.
14. A new waterwork site has been established; to provide the Cherating area, including Club Mediteranee. An annual yield of 2 million m^3 possible from this aquifer.
15. Aquifer was found to be salty.
16. With 4 wells, it is possible to provide the requirements of village No. 15-17, amounting 1,700 m^3/d.
17. This is sufficient to provide the daily needs of the settlers. Further work is in progress to locate more groundwater for sugarance irrigation.
18. For additional output from the present waterworks.

Table 3 INVENTORY OF TUBEWELLS BY GSD (GEOLOGICAL SURVEY DEPARTMENT) (1/4)

Well No.	Location (State/City/Town/Village)	Depth (m)	Diameter (inch)			Purpose
			Drilling	Casing	Screen	
1	Perlis, Chuping	42.0	16.5	8	8	D
2	Perlis, Chuping	45.5	16.5	8	8	D
3	Perlis, Chuping	39.0	16.5	8	8	D
4	Pahang, Kuantan, Sg. Ular	13.3	20.5	12	12	D
5	Pahang, Kuantan, Bachok	21.0	20.5	12	12	D
6	Pahang, Kuantan, Cherating	21.0	20.5	12	12	D
7	Trengganu, K.Trengg., Kg.Kepong	23.3	20.5	12	12	D
8	Trengganu, K.Trengg., Kg.Kepong	14.0	20.5	12	12	D
9	Trengganu, K.Trengg., Kg.Kepong	14.2	20.5	12	12	D
10	Trengganu, K.Trengg., Kg.Kepong	13.1	20.5	12	12	-
11	Trengganu, K.Trengg., Kg.Kepong	12.5	20.5	12	12	D
12	Trengganu, Jerteh, Kg. Raja	40.0	20.5	12	8	D
13	Trengganu, Jerteh, Kg. Raja	33.5	20.5	12	8	D
14	Trengganu, Jerteh, Kg. Raja	34.5	20.5	12	8	D
15	Trengganu, Jerteh, Kg. Baru	38.7	20.5	12	8	D
16	Trengganu, Jerteh, Kg. Lampu	12.5	20.5	12	12	D
17	Kelantan, Pasir, Kg. Sg. Petai	16.7	20.5	12	12	D
18	Kelantan, Bachok, Kg. Chap	32.4	16.5	8	8	D
19	Kelantan, Kota Bharu, W. Bharu	12.0	20.5	12	12	D
20	Kelantan, Kota Bharu, W. Bharu	12.0	20.5	12	12	D
21	Kelantan, Kota Bharu, K. Krian	6.0	-	10	10	D
22	Kelantan, Kota Bharu, K. Krian	6.0	-	10	10	D
23	Kelantan, Kota Bharu, Tg. Mas	94.0	20.5	12	8	D
24	Kelantan, Kota Bharu, Tg. Mas	94.0	20.5	12	8	D
25	Kelantan, Kota Bharu, Tg. Mas	95.1	20.5	12	8	D
26	Kelantan, Kota Bharu, Tg. Mas	94.8	20.5	12	8	D
27	Kelantan, Kota Bharu, Cabang Tiga	10.1	20.5	12	12	D
28	Kelantan, Kota Bharu, Pg. Cepa	7.0	20.5	8	8	D
29	Kelantan, Kota Bharu, Pg. Cepa	6.8	20.5	8	8	D
30	Kelantan, Kota Bharu, Pg. Cepa	6.8	20.5	8	8	D
31	Kelantan, Kota Bharu, Pg. Cepa	6.8	20.5	8	8	D
32	Kelantan, Kota Bharu, Pg. Cepa	6.5	20.5	8	8	D
33	Kelantan, Kota Bharu, Pg. Cepa	9.4	20.5	8	8	D
34	Kelantan, Kota Bharu, Pg. Cepa	6.7	20.5	8	8	D
35	Kelantan, Kota Bharu, Pg. Cepa	7.0	20.5	8	8	D
36	Kelantan, Pasir Puteh, Kg. Petai	96.0	20.5	12	8	A

Remarks; Purpose: A: Agriculture, D: Domestic, I: Industry
T: Test Well

The data source of this GSD's inventory is different from Table 1. However almost all the wells in this table coincide with the wells in Table 1.

Well type: German type well & old PWD type well

Table 4 INVENTORY OF TUBEWELLS BY GSD (GEOLOGICAL SURVEY DEPARTMENT) (2/4)

Well No.	Location (State/City/Town/Village)	Depth (m)	Diameter (inch) Drilling	Casing	Screen	Purpose
37	Kelantan, Tumpat, Kg. Sedar	38.4	20.5	12	12	D
38	Kelantan, Tumpat, Kg. Sedar	36.0	20.5	12	8	D
39	Kelantan, Tumpat, Kg. Ketil	12.4	20.5	8	8	D
40	Kelantan, Tumpat, Kg. Ketil	11.3	20.5	8	8	D
41	Kelantan, Kota Bharu, Kg. Puteh	12.1	20.5	12	12	D
42	Kelantan, Kota Bharu, Kg. Puteh	14.1	20.5	12	12	D
43	Kelantan, Kota Bharu, Kg. Puteh	14.1	20.5	12	12	D
44	Kelantan, Kota Bharu, Kg. Puteh	14.0	20.5	12	12	D
45	Kelantan, Kota Bharu, Kg. Puteh	13.9	20.5	12	12	D
46	Kelantan, Kota Bharu, Kg. Puteh	11.2	20.5	12	12	D
47	Kelantan, Kota Bharu, Kg. Puteh	13.1	20.5	12	12	D
48	Kelantan, Kota Bharu, Kg. Puteh	52.0	20.5	10	10	D
49	Kelantan, Kota Bharu, Kg. Puteh	11.7	20.5	12	12	T
50	Kelantan, Kota Bharu, Kg. Puteh	12.9	20.5	12	12	T
51	Trengganu, Kuala Trengganu, Buloh	9.1	20.5	12	12	T
52	Trengganu, Kuala Trengganu, Marang	8.4	20.5	12	12	I
53	Trengganu, Kuala Trengganu, Marang	8.4	20.5	12	12	I
54	Trengganu, Pasir Mas, Kg. Repek	31.5	20.5	12	8	D
55	Trengganu, Pasir Mas, Chetok	18.6	20.5	12	12	D
56	Trengganu, Tanah Merah	20.5	20.5	12	12	D
57	Trengganu, Rantau Panjang	26.8	20.5	8	8	D
58	Trengganu, Pasir Mas, Meranti	29.2	20.5	12	12	D
59	Trengganu, Machang	8.3	20.5	12	12	D
60	Trengganu, Machang	8.3	20.5	12	12	D
61	Trengganu, Kota Bharu, Pintu Geng	12.8	20.5	12	12	D
62	Perak, Sg. Siput Perlop	45.0	18.5	8	8	T

Remarks; Purpose: A: Agriculture, D: Domestic, I: Industry
T: Test Well

Well type: German type well & old PWD type well

Table 5 INVENTORY OF TUBEWELLS BY GSD (GEOLOGICAL SURVEY DEPARTMENT) (3/4)

Well No.	(1) Screen Length (m)	(2) Drawdown (m)	(3) Pumping Discharge (m^3/d)	(3)/(2) Specific Capacity ($m^3/d/m$)	Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/s)
1	28.5	9.3	886	93	223	9.1×10^{-3}
2	36.0	-	-	-	-	-
3	21.0	-	-	-	-	-
4	7.7	5.1	2,016	395	508	5.4×10^{-2}
5	6.7	11.9	168	14	-	-
6	10.5	9.0	1,872	208	146	1.7×10^{-2}
7	12.0	0.8	3,072	3,840	12,600	1.1×10^{0}
8	7.7	2.7	2,880	1,067	-	-
9	9.8	2.0	2,760	1,380	-	-
10	8.6	1.6	2,736	1,710	-	-
11	9.0	-	-	-	-	-
12	14.0	2.2	2,400	1,091	2,328	7.0×10^{-1}
13	12.4	2.9	4,080	1,407	-	-
14	10.5	4.4	3,744	851	-	-
15	11.5	2.1	1,440	686	840	6.9×10^{-2}
16	6.0	3.2	432	135	151	2.3×10^{-2}
17	9.5	4.2	2,880	686	600	5.8×10^{-1}
18	15.4	2.1	3,240	1,543	2,736	3.0×10^{-1}
19	5.7	2.2	4,896	2,225	7,656	1.0×10^{0}
20	5.8	2.2	5,040	2,291	-	-
21	3.0	-	720	-	-	-
22	3.0	0.8	1,896	2,370	-	1.0×10^{-1}
23	20.2	10.5	2,256	215	1,433	8.2×10^{-2}
24	20.2	9.1	2,760	303	-	-
25	21.1	11.3	1,812	160	1,145	6.3×10^{-2}
26	21.9	-	-	-	-	-
27	4.5	6.7	1,352	202	192	4.0×10^{-2}
28	3.6	2.7	180	67	-	-
29	6.8	1.2	420	350	-	-
30	6.8	0.8	360	450	-	-
31	6.8	0.7	295	421	-	-
32	6.5	0.6	252	420	-	-
33	9.4	1.3	780	600	509	9.5×10^{-2}
34	6.7	1.0	360	360	-	-
35	7.0	0.5	254	508	-	-
36	96.0	18.6	1,920	103	1,630	9.4×10^{-2}
37	7.4	3.7	3,480	940	2,280	2.4×10^{-1}
38	7.6	6.4	2,280	356	-	5.2×10^{-2}
39	8.8	1.5	288	192	-	-
40	8.6	1.8	192	107	-	-
41	3.8	1.2	7,992	6,660	7,440	1.2×10^{0}
42	3.8	0.8	2,160	2,700	-	-
43	3.8	0.8	2,880	3,600	-	-
44	3.8	0.6	2,880	4,800	-	-
45	5.7	1.1	2,880	2,618	-	-

Table 6 INVENTORY OF TUBEWELLS BY GSD (GEOLOGICAL SURVEY DEPARTMENT) (4/4)

Well No.	(1) Screen Length (m)	(2) Drawdown (m)	(3) Pumping Discharge (m^3/d)	(3)/(2) Specific Capacity ($m^3/d/m$)	Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/s)
46	5.9	2.6	1,872	720	-	-
47	5.0	2.2	4,200	1,909	-	-
48	5.0	18.3	1,980	108	-	-
49	5.6	4.6	960	209	-	1.8×10^{-1}
50	3.8	5.2	856	165	-	-
51	6.6	5.6	480	86	-	-
52	3.9	-	667	-	768	2.3×10^{-1}
53	3.9	-	-	-	-	-
54	9.5	7.8	1,128	145	-	-
55	7.7	0.3	1,128	3,760	-	-
56	9.6	3.7	2,400	649	-	-
57	13.3	10.1	1,128	112	-	-
58	13.4	9.5	600	63	-	-
59	4.8	1.4	1,128	806	-	-
60	4.8	1.2	1,200	1,000	-	-
61	5.7	-	1,200	-	-	-

Table 7 INVENTORY OF TUBEWELLS BY KEDAH/PERLIS WATER RESOURCES MANAGEMENT STUDY (1/4)

Well No.	Location (State/City/Town/Village)	Depth (m)	Diameter (inch)			Pur-pose
			Drilling	Casing	Screen	
SILURIN						
GS 528	Kedah, Kuala Muda, Lubok Kawa	33.0	-	6	6	T
GS 522	Kedah, Baling, Sira Ko.	48.0	-	6	6	T
GS 525	Kedah, Sik, Fima Estate	39.0	-	6	6	T
CARBONIFEROUS						
GS 465	Kedah, Kubang Pusu, Darat	38.0	-	6	4-6	T
GS 536	Kedah, Kubang Pasu, Darat	54.0	-	6	6	T
GS 466	Kedah, Kubang Pasu, Che Harun	36.5	-	6	4	T
GS 467	Kedah, Padang Temesu	46.3	-	6	6	T
GS 468	Kedah, Kubang Pasu, Fisheries Jitra	50.0	-	6	6	T
GS 483	Kedah, Kubang Pasu, Fisheries Jitra	42.0	-	6	6	T
GS 474	Perlis, Ulu Pauh	53.0	-	6	6	T
GS 564	Kedah, Langkawi, Golf Club	24.0	-	6	6	T
GS 570	Kedah, Langkawi, Kisap Estate	24.0	-	6	6	T
GS 571	Kedah, Langkawi, Mashuri School	40.5	-	-	-	T
GS 574	Kedah, Langkawi, Kisap Upstream	34.0	-	-	-	T
GS 576	Kedah, Langkawi, Kisap Batu Dua	31.0	-	-	-	T
GS 587	Kedah, Kubang Pasu, Kota Mengkuang	42.0	-	6	6	T
TRIASSIC						
GS 471	Kedah, Kota Setar, Whatt Lampan	56.0	-	6	6	T
GS 531	Kedah, Padang Terap, Naka	36.0	-	6	6	T
GS 473	Kedah, Padang Terap, Naka	56.0	-	6	6	T
GS 475	Kedah, Padang Terap, Masjid Lama	45.0	-	6	6	T
GS 477	Kedah, Kota Setar, Bukit Tembaga	36.0	-	6	6	T
GS 478	Kedah, Baling, Padang Sanai	36.0	-	6	6	T
GS 537	Kedah, Padang Terap, Sugar Cane Plantation (F21)	33.0	-	6	6	T
GS 538	Kedah, Padang Terap, Sugar Cane Plantation (D65)	24.0	-	6	6	T
GS 539	Kedah, Padang Terap, Sugar Cane Plantation (D30)	49.0	-	6	6	T
GS 540	Kedah, Padang Terap, Sugar Cane Plantation (A38)	49.5	-	6	6	T
GS 487	Kedah, Kubang Pasu, Kodiang Town	50.0	-	6	6	T
GS 488	Kedah, Kubang Pasu, Kodiang Quarry	33.0	-	6	6	T
GS 526	Kedah, Kubang Pasu, Kodiang Quarry	18.0	-	8	8	T

Remarks; T: Test Well
Well type: German type well

Table 8 INVENTORY OF TUBEWELLS BY KEDAH/PERLIS WATER RESOURCES MANAGEMENT STUDY (2/4)

Well No.	Location (State/City/Town/Village)	Depth (m)	Diameter (inch) Drilling	Casing	Screen	Purpose
GS 547	Kedah, Kulim, Industrial Area	55.5	-	6	6	T
GS 548	Kedah, Kulim, Industrial Area	55.5	-	6	6	T
GS 543	Kedah, Padang Terap, Nami	37.0	-	6	6	T
GS 552	Kedah, Baling, Kuala Ketil	30.0	-	6	6	T
GS 577	Kedah, Baling, Kuala Ketil	33.0	-	6	6	T
GS 583	Kedah, Baling, Padang Geh	35.0	-	6	6	T
LIMESTONE						
GS 535	Kedah, Kota Setar, Gunong Keriang	11.0	-	6	6	T
GS 480	Kedah, Kota Setar, Gunong Keriang	12.0	-	6	6	T
GS 481	Kedah, Kota Setar, Gunong Keriang	46.0	-	6	6	T
GS 489	Perlis, Sungai Gial	51.0	-	6	6	T
GS 519	Perlis, Tambun Tulang	51.0	-	6	6	T
GS 560	Perlis, Batu Pahat Golf Club	42.0	-	6	6	T
GS 563	Perlis, Arau Treatment Plant	29.0	-	12	12	T
ALLUVIUM						
GS 491	Kedah, Langkawi, Nyor Chabang	33.0	-	6	6	T
GS 492	Kedah, Langkawi, Padang Masirat	35.0	-	6	6	T

Remarks; T: Test Well
Well type: German type well

Table 9 INVENTORY OF TUBEWELLS BY KEDAH/PERLIS WATER RESOURCES MANAGEMENT STUDY (3/4)

Well No.	(1) Screen Length (m)	(2) Drawdown (m)	(3) Pumping Discharge (m^3/d)	(3)/(2) Specific Capacity ($m^3/d/m$)	Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/s)
SILURIAN						
GS 528	-	13.0	276	21	-	-
GS 522	18.0	25.0	283	11	8	-
GS 525	12.0	20.5	216	11	52	-
CARBONIFEROUS						
GS 465	13.0	12.5	132	11	8	-
GS 536	18.0	29.0	300	10	9	-
GS 466	19.5	19.5	216	11	86	-
GS 467	18.3	18.0	108	6	3	-
GS 468	-	28.0	48	2	-	-
GS 463	12.0	28.0	55	2	1	-
GS 474	18.0	23.0	132	6	4	-
GS 564	-	14.0	24	2	1	-
GS 570	-	12.0	288	24	17	-
GS 571	-	24.0	174	7	5	-
GS 574	-	20.0	240	12	10	-
GS 576	-	13.0	132	10	12	-
GS 587	-	25.0	144	6	6	-
TRIASSIC						
GS 471	18.0	30.0	324	11	11	-
GS 531	-	18.0	960	53	-	-
GS 473	18.0	21.0	806	38	38	-
GS 475	12.0	20.0	384	19	26	-
GS 477	24.0	18.0	288	16	31	-
GS 478	12.0	16.5	307	19	35	-
GS 537	-	15.0	-	-	3	-
GS 538	-	15.0	-	-	-	-
GS 539	-	27.0	648	24	26	-
GS 540	18.0	23.0	516	22	49	-
GS 487	12.0	31.0	379	12	6	-
GS 488	-	21.0	518	25	49	-
GS 526	-	11.0	-	-	-	-
GS 547	10.0	11.0	648	59	-	-
GS 548	14.0	16.0	768	48	121	-
GS 543	6.0	21.0	233	11	11	-
GS 552	6.0	17.0	168	10	-	-
GS 577	-	22.0	336	15	-	-
GS 583	-	13.0	281	22	-	-

Table 10 INVENTORY OF TUBEWELLS BY KEDAH/PERLIS WATER RESOURCES MANAGEMENT STUDY (4/4)

Well No.	(1) Screen Length (m)	(2) Drawdown (m)	(3) Pumping Discharge (m^3/d)	(3)/(2) Specific Capacity ($m^3/d/m$)	Transmissivity Coefficient (m^2/d)	Permeability Coefficient (cm/s)
LIMESTONE						
GS 535	11.0	5.8	768	132	467	-
GS 480	12.0	5.0	432	86	86	-
GS 481	-	20.5	-	-	-	-
GS 489	12.0	19.5	552	28	156	-
GS 519	12.0	11.0	1,032	94	121	-
GS 560	30.0	21.0	391	19	37	-
GS 563	18.0	7.0	864	123	112	-
ALLUVIAL						
GS 491	-	16.0	65	4	14	-
GS 492	-	15.0	216	14	12	-

Table 11 INVENTORY OF TUBEWELLS

Unit: Number

Tubewell For	GSD/1	Federal Drillers/2	Pacific Industry And Mining/3	United Drillers/4	Total
Agriculture use	4	7	7	1	19
Domestic Use	57+(44)/5	67	45	8	177+(44)
Industry Use	-	52	34	22	108
Sub-total	61+(44)	126	86	31	304+(44)
Test Well	((20)/6)	-	-	-	20
Exploratory bore hole	242	-	14	31	256
Total	368+(44)	126	100	31	580+(44)

Remarks; /1: GSD's inventory includes the number of wells before 1979 (see Table 1).

/2: Federal Driller's inventory includes the number between 1974 and 1980.

/3: Pacific Industry and Mining's inventory includes the number between 1971 and 1979.

/4: United Driller's inventory includes the number between 1969 and 1980.

/5: Number of test wells drilled by Kedah/Perlis Water Resources Management Study in 1979 (Ref. 8). All the test wells are used as production well after completion of the pumping test.

/6: Number of the test wells abandoned after drilling, because of no sufficient pumping yield was recognized.

Table 12 WELL CONSTRUCTION COST OF KOTA BHARU WATER SUPPLY SCHEME

Unit: $M\$10^3$

Item No.	Description	Amount
1.	Transportation and mobilization (32 nos.)	197
2.	Drilling (725 m)	134
3.	Casing and screen (including installation)	230
4.	Gravel packing and clay plugging	36
5.	Well development	52
6.	Pumping test (32 nos.)	131
7.	Sample testing and others	48
8.	Administration and general	101
9.	Contingency	51
10.	Particulars for local and imported good	8
Total		988

Table 13 INVESTMENT COST OF WATER SOURCE, STORAGE, TREATMENT, AND DISTRIBUTION FACILITIES

Unit: M$$10^3$

	Description	Amount
I.	Water Source	
1.	Well construction (32 nos.)/1	988
2.	Pumpsets (Submersible and centrifugal)	820
3.	Generator set	450
4.	Pump houses and buildings	300
5.	Quarters	225
6.	Land acquisition	250
7.	Survey and investigation	110
Sub-total		3,143
II.	Storage	
1.	Booster station	30
2.	Pressure filters	210
3.	Elevated tanks	2,500
4.	Reservoirs	800
Sub-total		3,540
III.	Treatment	
1.	Chemical dozers (Chlorinator, lime dozers and fluoridators)	310
2.	Aerator for iron removal	230
3.	Clear water tank	230
Sub-total		770
IV.	Distribution (trunk and reticulation pipelines)	9,500
V.	Contingencies (9% of the total cost)	1,526
Total		18,479

Remarks; /1: Engineering estimate cost of well construction 32 in number had been estimated to be M$400 x 10^3 in 1978 (Ref. 10). However the design criteria had been changed from the PVC type of screen well (German Type) to the wire wrapped type of screen well in 1979. (Ref. 9) The new well construction cost was estimated to be M$988 x 10^3. Only the well construction cost is replaced from M$400 x 10^3 to M$988 x 10^3 in the original table in Ref. 10.

Table 14 HYDROGEOLOGICAL LAND CLASSIFICATION

Unit: km^2

Basin No.	Alluvial Class I	Alluvial Class II	Alluvial Class III	Alluvial Class IV	Rock Class I	Rock Class II	Rock Class III	Total
1	-	-	-	73	155	-	524	752
2	-	-	-	-	-	-	475	475
3	-	-	-	621	-	37	2,623	3,281
4	-	-	35	-	-	94	338	467
5	-	-	90	-	86	-	4,042	4,218
6	18	152	170	-	-	-	420	760
7	-	-	-	-	-	-	300	300
8	-	17	57	99	-	114	1,022	1,309
9	13	228	716	98	-	-	1,042	2,097
10	882	441	588	-	735	1,323	10,731	14,700
11	192	467	500	133	-	334	1,134	2,760
12	62	108	108	73	-	119	23	493
13	7	69	36	-	-	583	1,092	1,787
14	-	27	134	-	-	230	62	453
15	-	9	114	-	256	442	527	1,348
16	58	180	182	-	54	36	1,053	1,563
17	2	138	141	-	-	-	231	512
18	-	-	-	-	-	128	1,292	1,420
19	-	-	-	-	-	-	1,010	1,010
20	-	-	-	120	-	169	416	705
21	-	-	-	416	-	1,715	4,286	6,417
22	-	-	-	586	-	-	1,534	2,120
23	-	-	-	655	-	-	1,569	2,224
24	-	-	-	293	-	130	2,632	3,055
25	-	-	-	175	-	-	1,529	1,704
26	-	-	-	-	-	-	880	880
27	-	47	142	806	-	474	3,271	4,740
28	22	154	214	129	-	986	2,742	4,247
29	-	625	549	-	-	-	683	1,857
30	586	293	293	-	586	6,153	21,389	29,300
31	20	142	243	81	-	61	1,478	2,025
32	51	51	77	-	-	694	1,697	2,570
33	-	-	-	-	-	-	850	850
34	-	-	-	-	-	169	1,706	1,875
35	-	23	8	-	-	-	729	760
36	93	93	47	47	-	976	3,394	4,650
37	-	6	207	-	-	104	631	948
38	62	74	86	-	-	283	725	1,230
39	286	224	184	-	-	-	326	1,020
40	393	131	131	-	655	1,048	10,742	13,100
41	90	72	90	-	-	-	663	915
Total	2,837	3,771	5,142	4,405	2,527	16,402	91,513	126,597

Remarks; Alluvial Class V is excluded.

Table 15 THICKNESS AND SPECIFIC YIELD USED FOR POTENTIAL ANALYSIS

Aquifer	Class	Average Thickness of Aquifer (m)	Average Specific Yield
Alluvial	I	30	0.17
Alluvial	II	10	0.15
Alluvial	III	5	0.13
Alluvial	IV	1	0.10
Rock	I	15	0.08
Rock	II	10	0.05
Rock	III	10	0.03

Table 16 ESTIMATED STORAGE POTENTIAL

Unit: $10^6 m^3$

Basin No.	Alluvial Class I	Alluvial Class II	Alluvial Class III	Alluvial Class IV	Rock Class I	Rock Class II	Rock Class III	Total
1	-	-	-	5	186	-	160	351
2	-	-	-	-	-	-	140	140
3	-	-	-	60	-	20	790	870
4	-	-	22	-	-	47	100	169
5	-	-	58	-	104	-	1,210	1,372
6	92	227	112	-	-	-	130	561
7	-	-	-	-	-	-	90	90
8	-	26	38	10	-	57	310	441
9	66	343	466	10	-	-	310	1,195
10	4,498	663	382	-	882	663	3,220	10,308
11	979	701	326	15	-	167	340	2,528
12	316	163	80	5	-	60	10	634
13	36	104	22	-	-	293	330	785
14	-	41	88	-	-	117	20	266
15	-	14	74	-	308	223	160	779
16	251	270	118	-	66	17	320	1,042
17	10	207	92	-	-	-	70	379
18	-	-	-	-	-	63	390	453
19	-	-	-	-	-	-	300	300
20	-	-	-	10	-	87	130	227
21	-	-	-	40	-	857	1,290	2,187
22	-	-	-	60	-	-	460	520
23	-	-	-	65	-	-	470	535
24	-	-	-	30	-	67	790	887
25	-	-	-	20	-	-	460	480
26	-	-	-	-	-	-	260	260
27	-	71	92	80	-	237	980	1,460
28	112	231	138	15	-	493	820	1,809
29	-	937	358	-	-	-	210	1,505
30	2,989	440	190	-	704	3,077	6,420	13,820
31	102	213	158	10	-	33	440	956
32	260	77	50	-	-	347	510	1,244
33	-	-	-	-	-	-	260	260
34	-	-	-	-	-	87	510	597
35	-	36	6	-	-	-	220	262
36	474	140	32	5	-	487	1,020	2,158
37	-	9	136	-	-	53	190	388
38	316	111	56	-	-	143	220	846
39	1,459	336	120	-	-	-	100	2,015
40	2,004	197	86	-	786	523	3,220	6,816
41	459	107	58	-	-	-	200	824
Total	14,423	5,664	3,358	440	3,036	8,218	27,580	62,719

Table 17 PRECIPITATION AND ESTIMATED DEEP PERCOLATION RATE

Basin No.	Precipitation (mm/y)	Deep Percolation in Alluvial Plain (mm/d)	Deep Percolation in Mountain Area (mm/d)
1	1,901	1.2	0.16
2	2,050	1.3	0.17
3	2,245	1.4	0.18
4	2,463	1.6	0.20
5	2,530	1.6	0.21
6	2,319	1.5	0.19
7	2,786	1.8	0.23
8	2,792	1.8	0.23
9	2,655	1.7	0.22
10	2,339	1.5	0.19
11	2,498	1.6	0.21
12	2,154	1.4	0.18
13	2,498	1.6	0.21
14	2,071	1.3	0.17
15	2,249	1.4	0.18
16	2,214	1.4	0.18
17	2,203	1.4	0.18
18	2,094	1.3	0.17
19	1,912	1.2	0.16
20	1,795	1.1	0.15
21	1,812	1.1	0.15
22	2,112	1.3	0.17
23	2,451	1.6	0.20
24	2,418	1.5	0.20
25	2,554	1.6	0.21
26	2,824	1.8	0.23
27	2,618	1.7	0.22
28	2,365	1.5	0.19
29	2,684	1.7	0.22
30	2,126	1.3	0.17
31	2,659	1.7	0.22
32	3,102	2.0	0.25
33	2,973	1.9	0.27
34	3,287	2.1	0.27
35	3,427	2.2	0.28
36	3,566	2.3	0.29
37	3,277	2.1	0.30
38	3,268	2.1	0.27
39	2,786	1.8	0.23
40	2,540	1.6	0.21
41	2,945	1.9	0.24
Peninsular Malaysia	2,364	1.4	0.19

Table 18 ESTIMATED GROUNDWATER RECHARGE

Unit: $10^6 m^3/d$

Basin	Alluvial Class				Rock Class			
No.	I	II	III	IV	I	II	III	Total
1	-	-	-	0.09	0.02	-	0.08	0.19
2	-	-	-	-	-	-	0.08	0.08
3	-	-	-	0.87	-	0.01	0.47	1.35
4	-	-	0.06	-	-	0.02	0.07	0.15
5	-	-	0.14	-	0.02	-	0.85	1.01
6	0.03	0.23	0.26	-	-	-	0.08	0.60
7	-	-	-	-	-	-	0.07	0.07
8	-	0.03	0.10	0.18	-	0.03	0.24	0.58
9	0.02	0.39	1.22	0.17	-	-	0.23	2.03
10	1.32	0.66	0.88	-	0.14	0.25	2.04	5.29
11	0.31	0.75	0.80	0.21	-	0.07	0.24	2.38
12	0.09	0.15	0.15	0.10	-	0.02	nil	0.51
13	0.01	0.11	0.06	-	-	0.12	0.23	0.53
14	-	0.04	0.17	-	-	0.04	0.01	0.26
15	-	0.01	0.16	-	0.05	0.08	0.09	0.39
16	0.08	0.25	0.25	-	0.01	0.01	0.19	0.79
17	nil	0.19	0.20	-	-	-	0.04	0.43
18	-	-	-	-	-	0.02	0.22	0.24
19	-	-	-	-	-	-	0.16	0.16
20	-	-	-	0.13	-	0.03	0.06	0.22
21	-	-	-	0.46	-	0.26	0.64	1.36
22	-	-	-	0.76	-	-	0.26	1.02
23	-	-	-	1.05	-	-	0.31	1.36
24	-	-	-	0.44	-	0.03	0.53	1.00
25	-	-	-	0.28	-	-	0.32	0.60
26	-	-	-	-	-	-	0.20	0.20
27	-	0.08	0.24	1.37	-	0.10	0.72	2.51
28	0.03	0.23	0.32	0.19	-	0.19	0.52	1.48
29	-	1.06	0.93	-	-	-	0.15	2.14
30	0.76	0.38	0.38	-	0.10	1.05	3.64	6.31
31	0.03	0.24	0.41	0.14	-	0.01	0.33	1.16
32	0.10	0.10	0.15	-	-	0.17	0.42	0.94
33	-	-	-	-	-	-	0.23	0.23
34	-	-	-	-	-	0.05	0.46	0.51
35	-	0.05	0.02	-	-	-	0.20	0.27
36	0.21	0.21	0.11	0.11	-	0.28	0.98	1.90
37	-	0.01	0.43	-	-	0.03	0.19	0.66
38	0.13	0.16	0.18	-	-	0.08	0.20	0.75
39	0.51	0.40	0.33	-	-	-	0.07	1.31
40	0.63	0.21	0.21	-	0.14	0.22	2.26	3.67
41	0.17	0.14	0.17	-	-	-	0.16	0.64
Total	4.43	6.08	8.33	6.55	0.48	3.17	18.24	47.28

Table 19 PRELIMINARY ESTIMATE OF SAFE YIELD

Basin No.	Alluvial Class I	Alluvial Class II	Alluvial Class III	Alluvial Class IV	Rock Class I	Rock Class II	Rock Class III	Total
1	-	-	-	nil	0.01	-	0.01	0.02
2	-	-	-	-	-	-	0.01	0.01
3	-	-	-	0.03	-	nil	0.05	0.08
4	-	-	0.03	-	-	0.01	0.01	0.05
5	-	-	0.07	-	0.01	-	0.09	0.17
6	0.03	0.16	0.13	-	-	-	0.01	0.33
7	-	-	-	-	-	-	0.01	0.01
8	-	0.02	0.05	0.01	-	0.01	0.02	0.11
9	0.02	0.27	0.61	0.01	-	-	0.02	0.93
10	1.19	0.46	0.44	-	0.07	0.08	0.20	2.44
11	0.28	0.52	0.40	0.01	-	0.02	0.02	1.25
12	0.08	0.11	0.08	nil	-	0.01	nil	0.28
13	0.01	0.08	0.03	-	-	0.04	0.02	0.18
14	-	0.03	0.09	-	-	0.02	nil	0.14
15	-	0.01	0.08	-	0.03	nil	0.01	0.13
16	0.07	0.18	0.13	-	0.01	0.01	0.02	0.42
17	nil	0.13	0.10	-	-	-	nil	0.23
18	-	-	-	-	-	0.01	0.02	0.03
19	-	-	-	-	-	-	0.02	0.02
20	-	-	-	0.01	-	0.01	0.01	0.03
21	-	-	-	0.02	-	0.08	0.06	0.16
22	-	-	-	0.03	-	-	0.03	0.06
23	-	-	-	0.04	-	-	0.03	0.07
24	-	-	-	0.02	-	0.01	0.05	0.08
25	-	-	-	0.01	-	-	0.03	0.04
26	-	-	-	-	-	-	0.02	0.02
27	-	0.06	0.12	0.04	-	0.03	0.07	0.32
28	0.03	0.16	0.16	0.01	-	0.06	0.05	1.47
29	-	0.74	0.47	-	-	-	0.02	1.23
30	0.68	0.27	0.19	-	0.05	0.32	0.36	1.87
31	0.03	0.17	0.21	0.01	-	nil	0.03	0.45
32	0.09	0.07	0.07	-	-	0.05	0.04	0.32
33	-	-	-	-	-	-	0.02	0.02
34	-	-	-	-	-	0.02	0.05	0.07
35	-	0.04	0.01	-	-	-	0.02	0.07
36	0.19	0.15	0.04	nil	-	0.08	0.10	0.56
37	-	0.01	0.19	-	-	0.01	0.02	0.23
38	0.12	0.11	0.08	-	-	0.02	0.02	0.35
39	0.46	0.28	0.16	-	-	-	0.01	0.91
40	0.57	0.15	0.11	-	0.07	0.07	0.23	1.20
41	0.15	0.10	0.08	-	-	-	0.02	0.35
Total	4.00	4.28	4.13	0.25	0.25	0.97	1.83	15.71

Table 20 PRINCIPAL FEATURE AND COST ESTIMATE OF ASSUMED GROUNDWATER SOURCE FACILITIES (1/2)

Item	Case No. 1	2	3	4	5	6	7
Aquifer	Alluvial	Alluvial	Alluvial	Alluvial	Rock	Rock	Rock
Class	I	II	III	IV	I	II	III
Depth of well (m)/1	50	50	50	20	50	50	50
Pumping discharge: Q (m^3/d)	1,460	330	150	30	660	230	70
Drawdown (m)	5	5	5	5	5	10	15
Transmissivity: T (m^2/d)	350	70	30	5	150	25	5
Well type	PWD New	PWD New	PWD New	PWD New	PWD New	PWD New	PWD New
Pump Capacity (PS)	10	2	2	0.5	10	4	1.5
Motor Capacity (kW)	7.5	2.2	1.5	0.4	7.5	3.0	1.1
Water Source Investment Cost							
1. Well construction (M$$10^3$)/2	54	54	54	30	61	61	61
2. Submersible pump (M$$10^3$)	10	7	5	4	10	8	5
3. Diesel generator set (M$$10^3$)/3	15	8	7	7	15	9	7
4. Building (M$$10^3$)/4	12	12	12	12	12	12	12
5. Quarter (M$$10^3$)/4	10	10	10	10	10	10	10
6. Land aquisition (M$$10^3$)/4	10	10	10	10	10	10	10
7. Engineering (M$$10^3$)/4	4	4	4	4	4	4	4
8. Physical Contingency (M$$10^3$)/5	12	11	10	8	12	11	11
Total (M$$10^3$)	127	116	112	85	134	125	120
O & M Cost							
1. Power generation (10^3M$/y)/6	6.6	1.9	1.3	0.4	6.6	2.6	0.9
2. Chlolination (10^3M$/y)/7	5.3	1.2	0.5	0.1	2.4	0.8	0.3
3. Well cleaning (10^3M$/y)	0.5	0.5	0.5	0.5	0.5	0.5	0.5
4. Other cost (10^3M$/y)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total (10^3M$/y)	13.4	4.6	3.3	2.0	10.5	4.9	2.7

Remarks; Remarks are shown in Table 21.

Table 21 PRINCIPAL FEATURE AND COST ESTIMATE OF ASSUMED GROUNDWATER SOURCE FACILITIES (2/2)

Remarks to Table 20

All the costs are at price level of 1980.

/1: Radius of well is assumed to be 0.1 m.

/2: According to the Ref. PO 9 (1979 price). Annual escalation rate of foreign portion from 1979 to 1980 is assumed to be 10%.

/3: This item includes a standby generator unit.

/4: According to the Ref. PO 10 (1978 price). Escalation rate of domestic portion from 1978 to 1980 is assumed to be 30%.

/5: Assumed to be 10% of total cost of 1 to 7.

/6: Electric charge (M\$/y) = M\$0.15 x kW x 16 hours per day x 365/y.

/7: Unit cost is assumed to be M\$0.01/m^3.

Table 22: ESTIMATED COST STREAM OF ASSUMED GROUNDWATER SOURCE FACILITIES

Year in Order	Capital Cost							O & M Cost						
	Case							Case						
	1	2	3	4	5	6	7	1	2	3	4	5	6	7
1	127	116	112	85	134	125	120	-	-	-	-	-	-	-
2-7	-	-	-	-	-	-	-	13.4	4.6	3.3	2.0	10.5	4.9	2.7
8	25	15	12	11	25	17	12	13.4	4.6	3.3	2.0	10.5	4.9	2.7
9-15	-	-	-	-	-	-	-	13.4	4.6	3.3	2.0	10.5	4.9	2.7
16	25	15	12	11	25	17	12	13.4	4.6	3.3	2.0	10.5	4.9	2.7
17-23	-	-	-	-	-	-	-	13.4	4.6	3.3	2.0	10.5	4.9	2.7
24	25	15	12	11	25	17	12	13.4	4.6	3.3	2.0	10.5	4.9	2.7
25	49	49	49	27	55	55	55	13.4	4.6	3.3	2.0	10.5	4.9	2.7
26-31	-	-	-	-	-	-	-	13.4	4.6	3.3	2.0	10.5	4.9	2.7
32	25	15	12	11	25	17	12	13.4	4.6	3.3	2.0	10.5	4.9	2.7
33-39	-	-	-	-	-	-	-	13.4	4.6	3.3	2.0	10.5	4.9	2.7
40	25	15	12	11	25	17	12	13.4	4.6	3.3	2.0	10.5	4.9	2.7
41-47	-	-	-	-	-	-	-	13.4	4.6	3.3	2.0	10.5	4.9	2.7
48	25	15	12	11	25	17	12	13.4	4.6	3.3	2.0	10.5	4.9	2.7
49-50	-	-	-	-	-	-	-	13.4	4.6	3.3	2.0	10.5	4.9	2.7

Table 23 ESTIMATED UNIT COST OF WATER SOURCE

Unit: M$

Discount Rate (%)	Case						
	1	2	3	4	5	6	7
6	0.045	0.114	0.224	0.785	0.088	0.178	0.461
8	0.049	0.128	0.246	0.888	0.098	0.198	0.522
10	0.052	0.143	0.277	0.991	0.106	0.220	0.589
12	0.055	0.155	0.302	1.121	0.113	0.240	0.648
14	0.058	0.169	0.334	1.205	0.121	0.260	0.719
16	0.062	0.183	0.355	1.304	0.129	0.280	0.778
18	0.065	0.195	0.387	1.426	0.135	0.300	0.840
20	0.067	0.207	0.411	1.527	0.142	0.321	0.908

Table 24 GROUNDWATER BUDGET IN SAND DUNE AREA (1/2)

Item		Month J	F	M	A	M	J
Precipitation	(mm)	68.4	28.5	66.7	1.5	103.5	109.0
Surface runoff	(mm)/1	0	0	5.7	0	3.7	2.6
Surface/subsurface retension loss	(m)/2	15.9	11.5	5.2	1.5	14.0	17.5
Average ET tobacco	(mm)/3	36.5	60.5	129.5	127.0	93.0	66.5
Average ET grass	(mm)/3	-	-	-	-	-	-
Groundwater runoff	(mm)/4	34.7	33.8	30.6	25.9	18.7	16.5
Pumping discharge	(mm)/5	19.0	60.0	100.0	159.0	66.0	36.0
Groundwater storage	(mm)	-37.7	-137.3	-204.3	-311.9	-91.9	-30.1
Change of groundwater level	(m)/6	-0.13	-0.46	-0.68	-1.04	-0.31	-0.10
Groundwater level	(m)/7	2.87	2.41	1.73	0.69	0.38	0.28

Item		Month J	A	S	O	N	D	Total
Precipitation	(mm)	125.0	254.0	366.2	314.0	395.5	207.5	2,039.8
Surface runoff	(mm)/1	3.3	17.9	29.2	23.8	28.8	14.7	129.6
Surface/subsurcace retension loss	(m)/2	15.5	15.5	3.2	14.7	10.5	8.5	133.5
Average ET tobacco	(mm)/3	-	-	-	-	-	-	-
Average ET grass	(mm)/3	61.0	62.0	62.5	57.0	48.5	47.5	338.5
Groundwater runoff	(mm)/4	15.8	16.5	19.8	25.6	30.1	36.6	304.6
Pumping discharge	(mm)/5	-	-	-	-	-	-	440.0
Groundwater storage	(mm)	29.4	142.1	256.4	192.9	277.6	100.2	185.4
Change of groundwater level	(m)/6	0.10	0.47	0.85	0.64	0.93	0.33	-
Groundwater level	(m)/7	0.38	0.85	1.70	2.34	3.27	3.60	

Remarks; Calculation method and Remarks to this table are shown in Table 25.

Table 25 GROUNDWATER BUDGET IN SAND DUNE AREA (2/2)

(1) Calculation method in Table 24

Following equations were used to estimate the change in groundwater level.

$$Sgw = P - Roff - Los - ET - Goff - Q \quad (1)$$

$$h = Sgw/Sy \quad (2)$$

$$H = Ho - h \quad (3)$$

where,

Sgw : Change in groundwater storage
P : Precipitation
Roff: Surface runoff
Los : Surface/subsurface retension loss
ET : Evapotranspiration
Goff: Groundwater runoff
Q : Pumping discharge
h : Change in groundwater level
H : Elevation of groundwater level
Ho : Initial groundwater level above the sea water level./7

(2) Remarks to Table 24

/1: Coefficient of surface runoff is assumed to be 0.1 for the rainfall 20 to 200 mm/d and zero for the rainfall less than 20 mm/d due to the high infiltration rate of the sand dune.

/2: The loss is assumed to be the rain 0 to 5 mm/d.

/3: Evapotranspiration (ET) is calculated by penman method (Ref. 49)

/4: Groundwater runoff is calculated as follows.

$$Goff = 4\ A\ (Ho + h')ki$$

where,

A : Area
b : Saturated thickness of aquifer (5 m is assumed)
h': Change in groundwater level per month
k : Coefficient of permeability is estimated to be 1.8×10^{-2} cm/s (Ref. 50)
i : Grandient of water table is assumed to be 1/200 (Ref. 50)

/5: Water requirement is calculated by USDA method as shown in Ref. 49.

/6: Specific yield of sands (medium sand) is assumed to be 0.3 (Ref. 41)

/7: Initial groundwater level is assumed to be 3 m above the sea water level (Ref. 50)

FIGURES

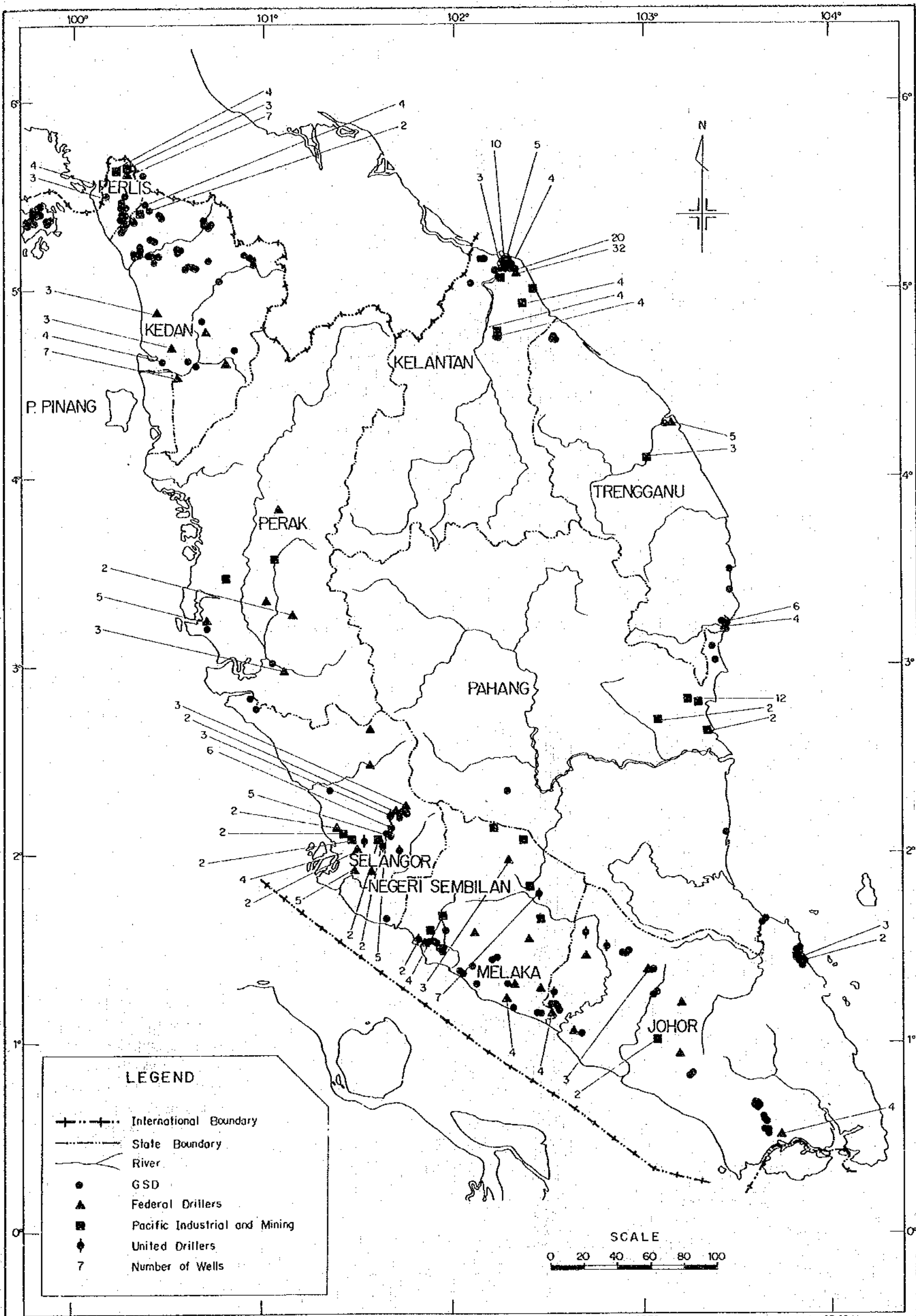


Fig. I Location Map of Tubewell

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

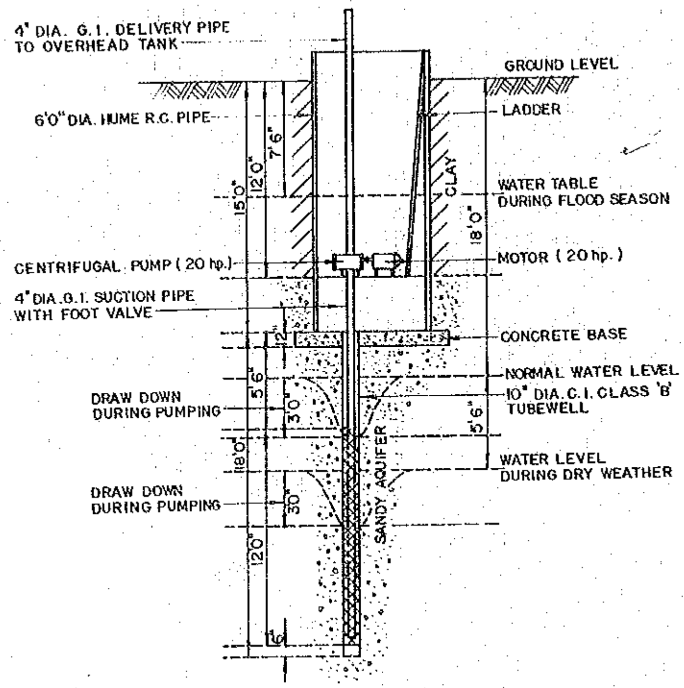
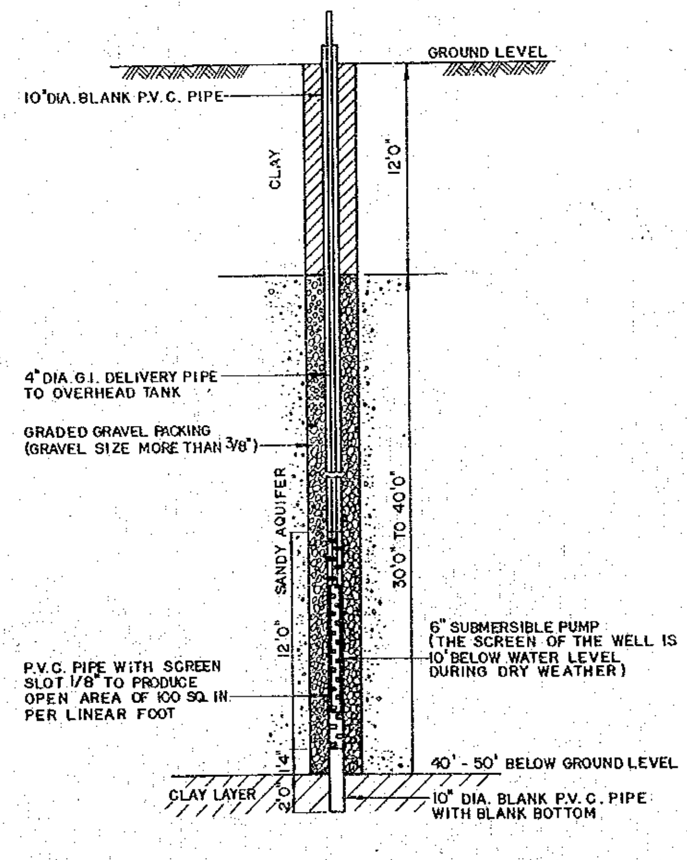


Fig. 2 Typical Example of the PWD Old Type Well



NOTE :

THE NORMAL WATER LEVEL, WATER LEVEL DURING DRY SEASON WATER LEVEL DURING FLOOD SEASON AND THE DRAW DOWN DURING PUMPING IS THE SAME FOR BOTH THE GERMAN WELL AND THE J.K.R TYPE WELL

Fig. 3 Typical Example of the German Type Well

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

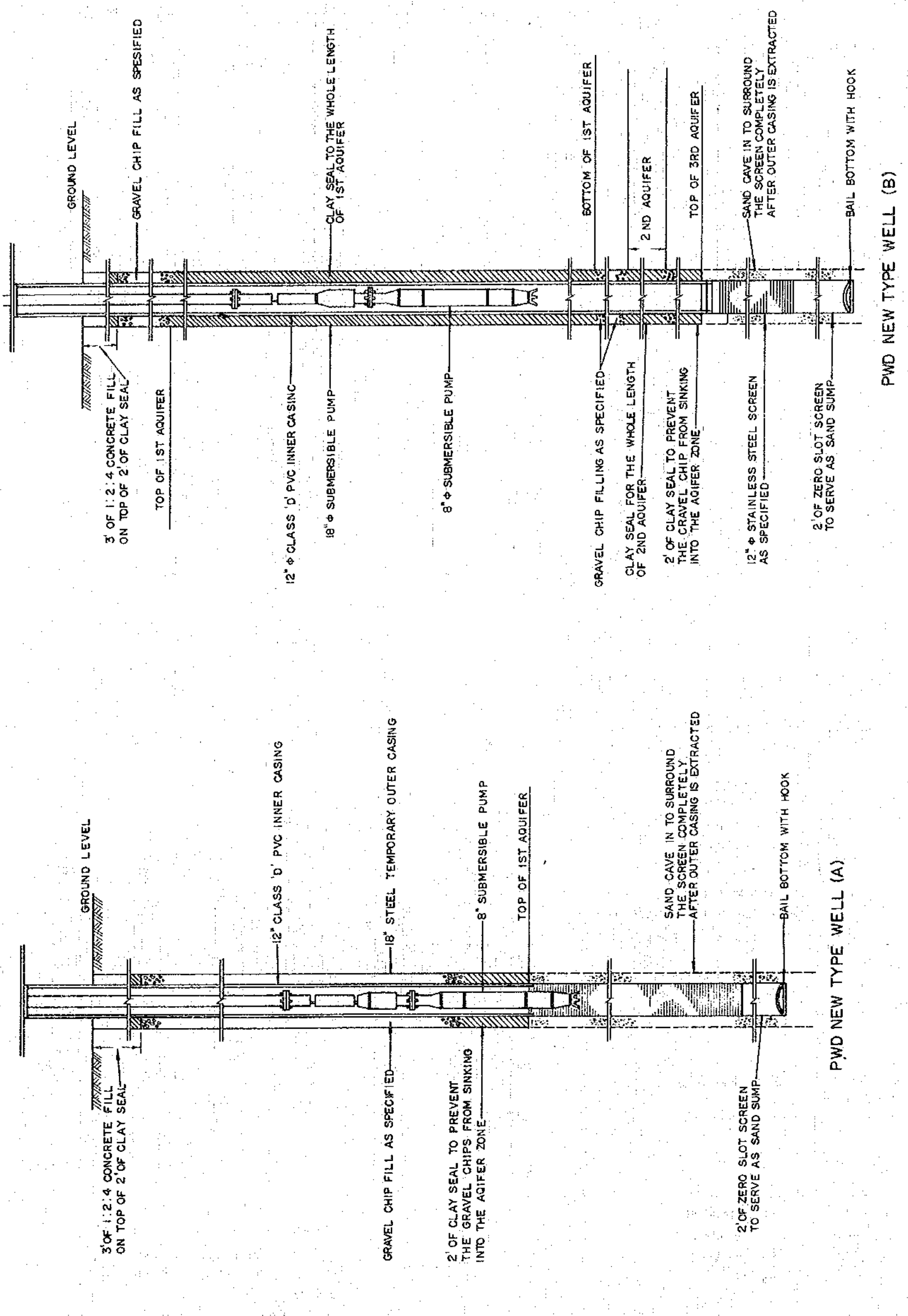


Fig. 4 Typical Example of the PWD New Type Well

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

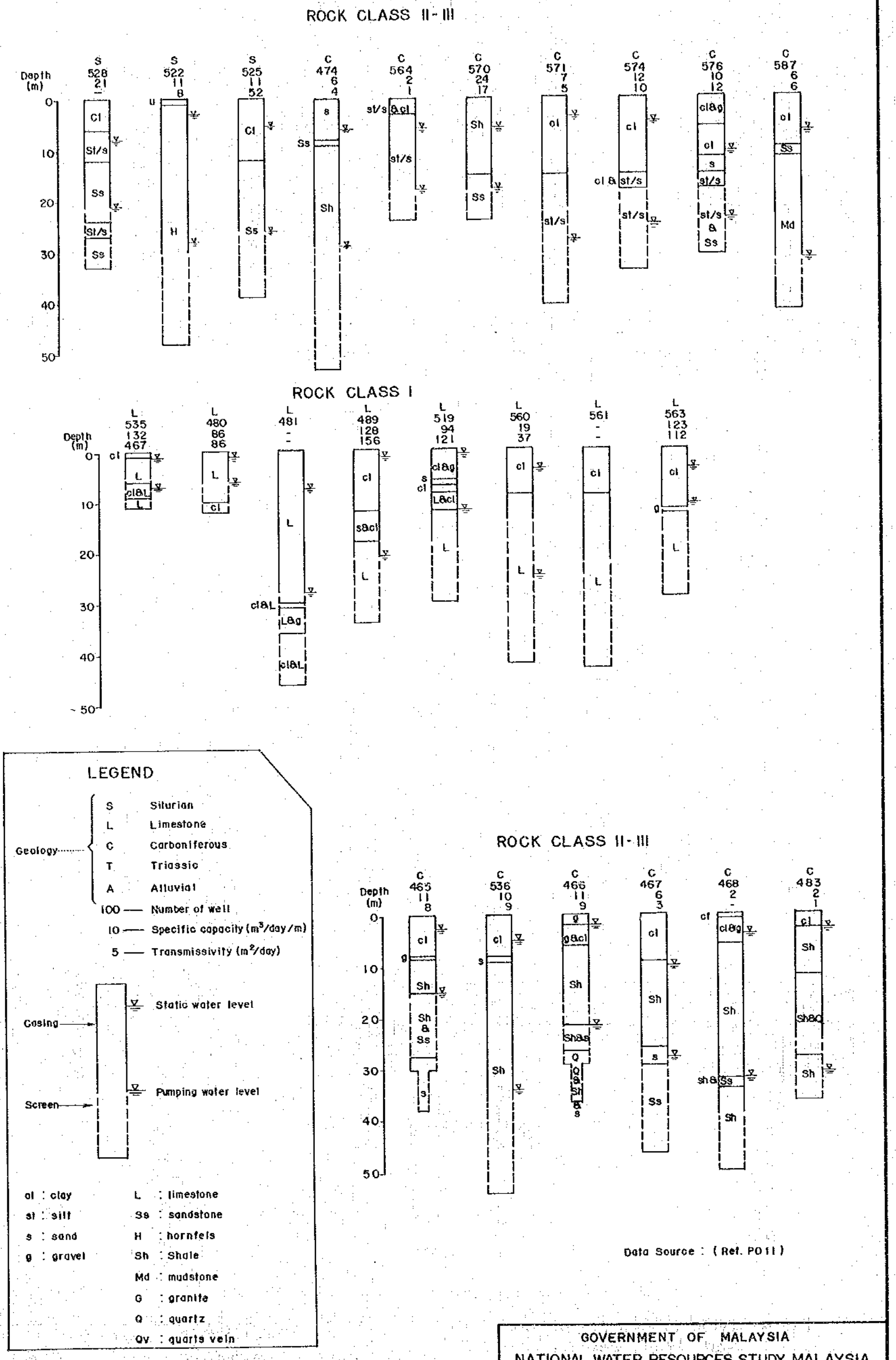


Fig. 5 Test Well in Hard Rocks (1/2)

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

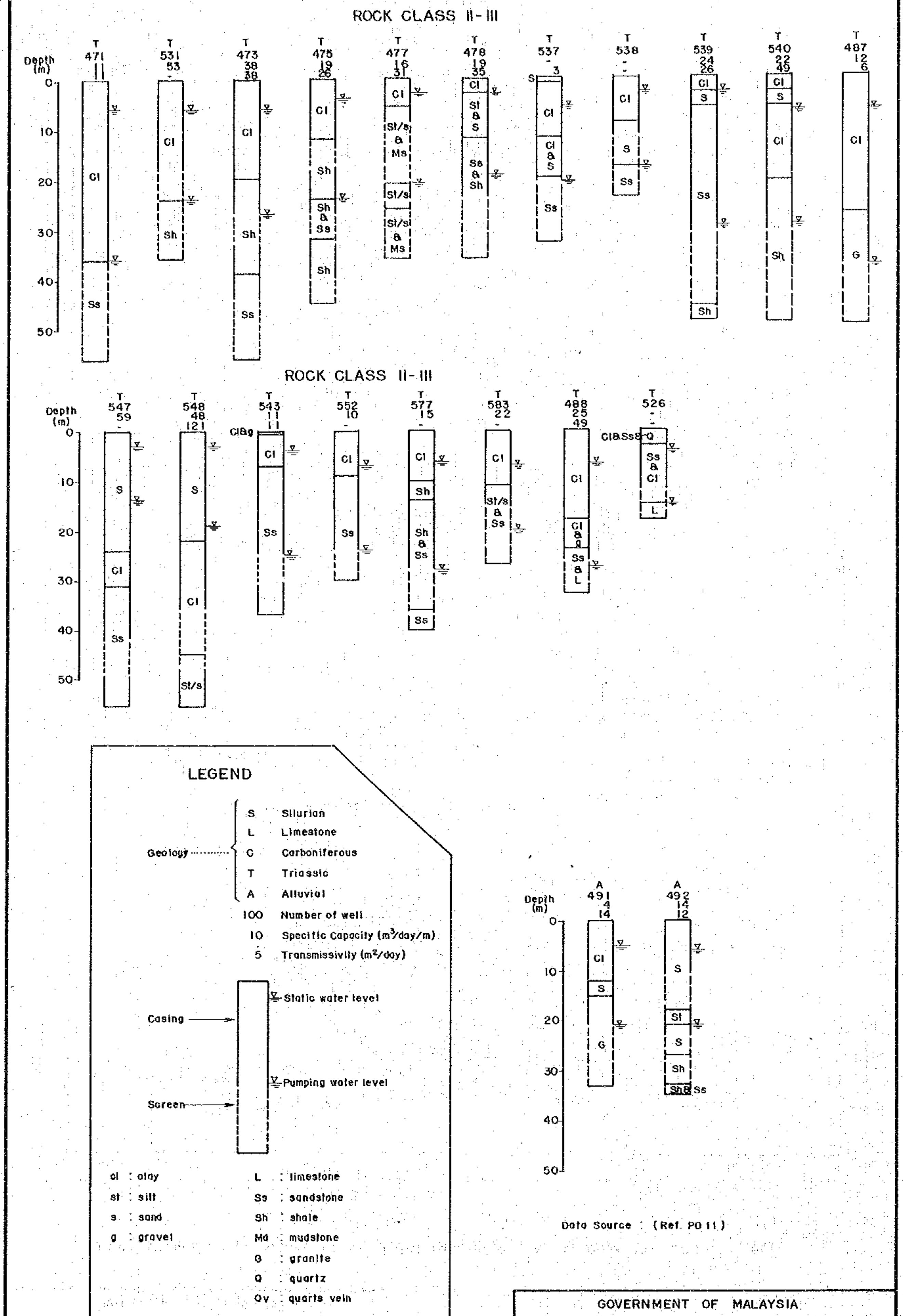


Fig. 6 Test Well in Hard Rocks (2/2)

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

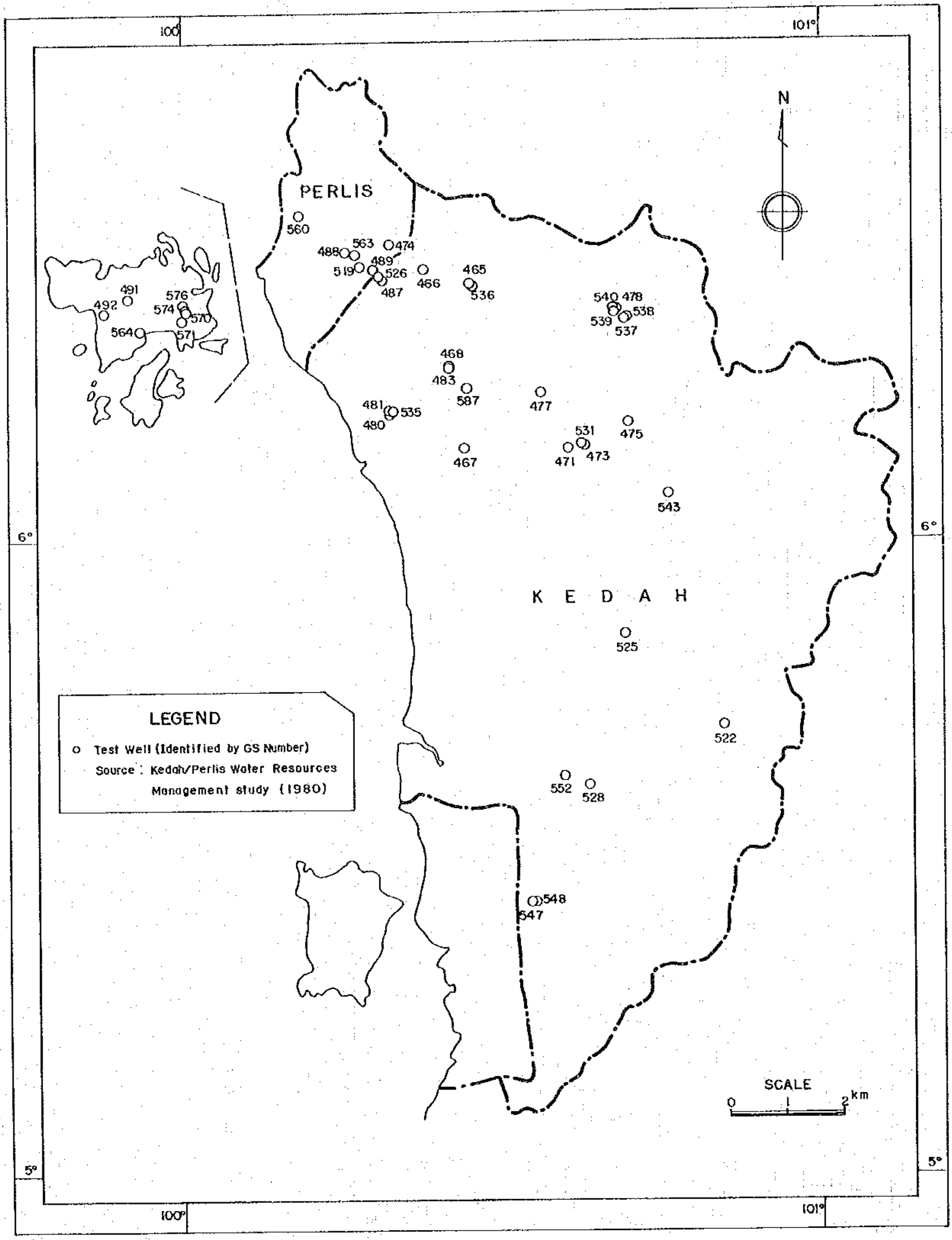
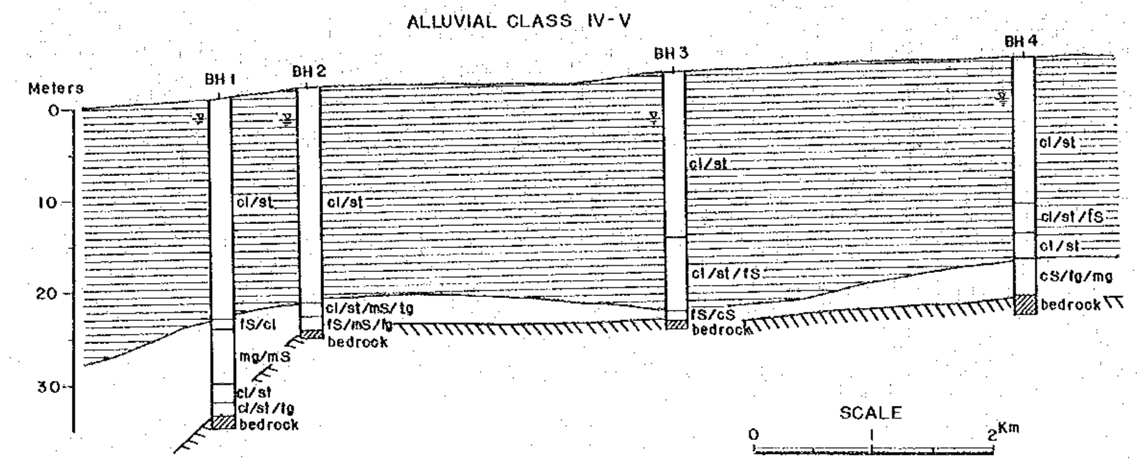


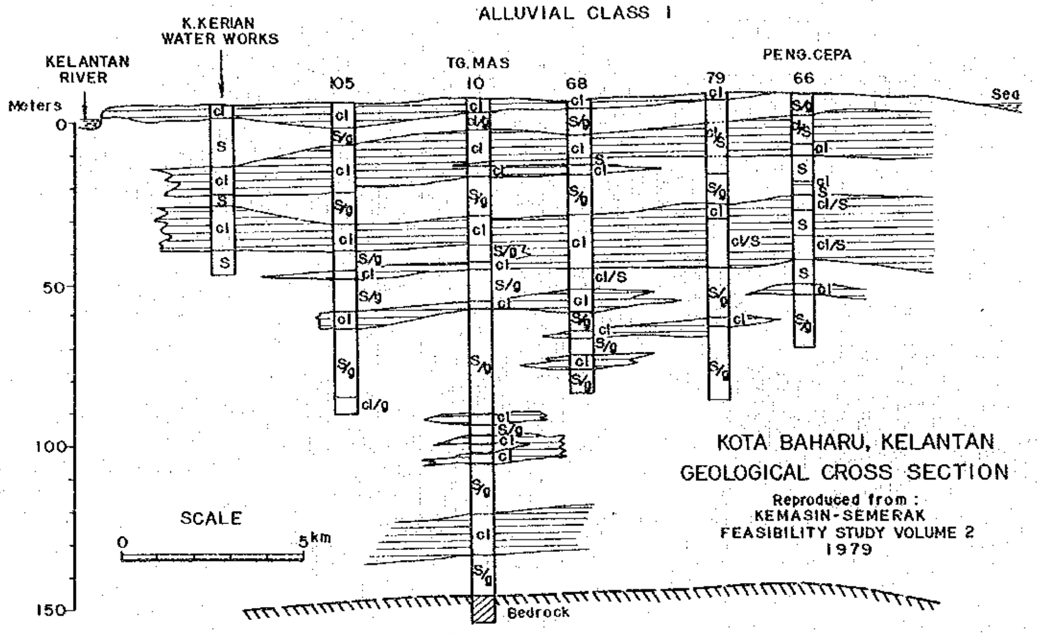
Fig. 7 Location Map of Test Well (Kedah / Perlis Water Management Study)

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

KUALA KEDAH, KEDAH
GEOLOGICAL CROSS SECTION

Reproduced from : GSD No. MP. KB/E/003/15





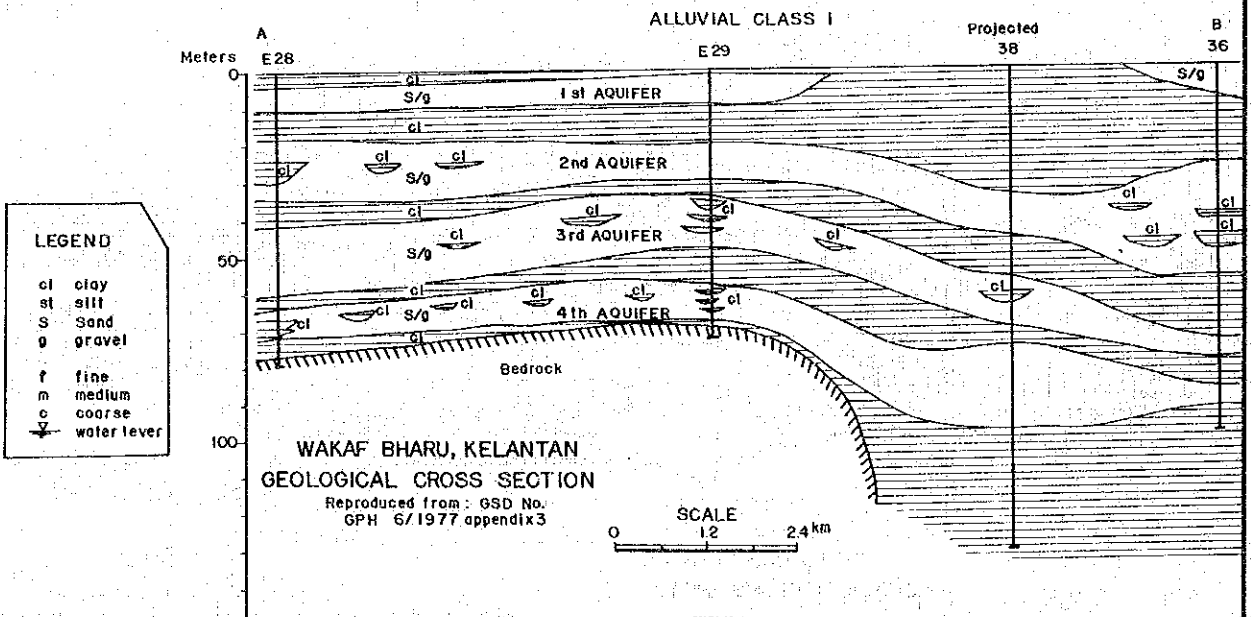


Fig. 8 Hydrogeological Cross Section (1/6)

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

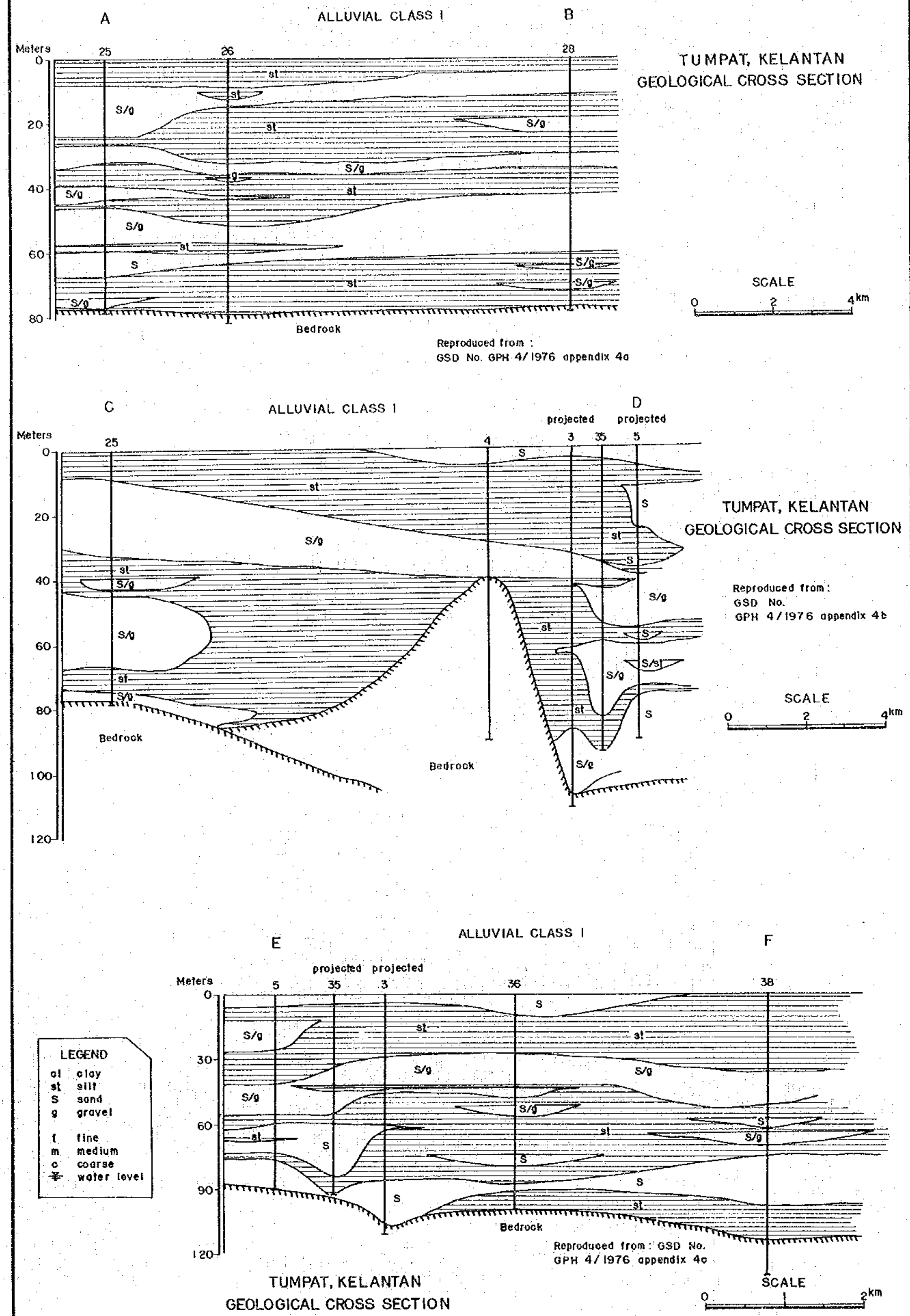


Fig. 9 Hydrogeological Cross Section (2/6)

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

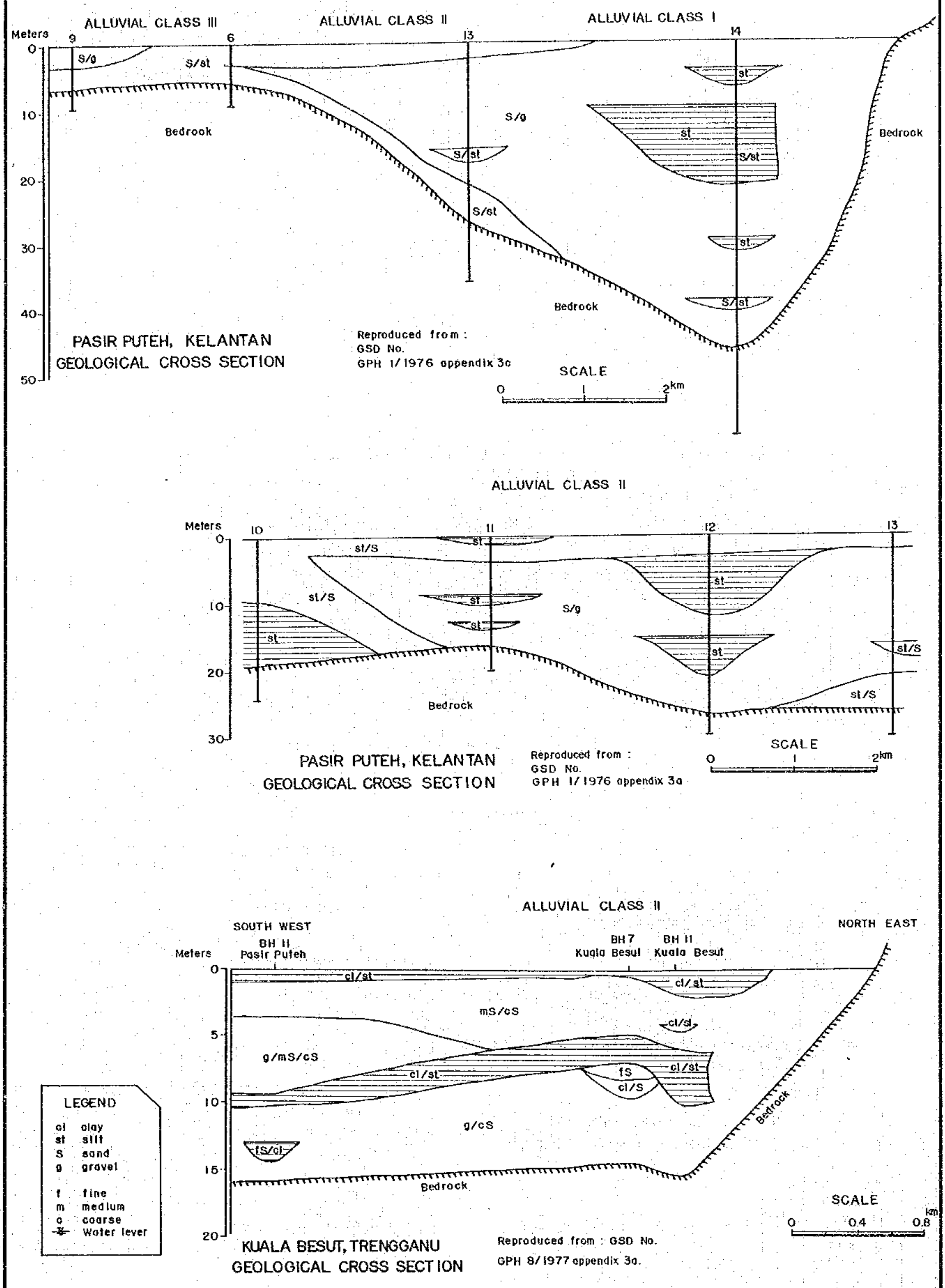
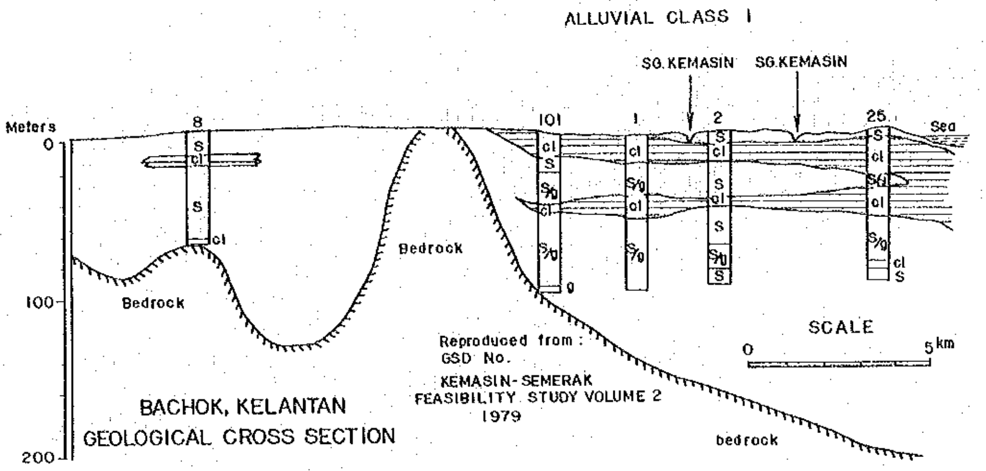
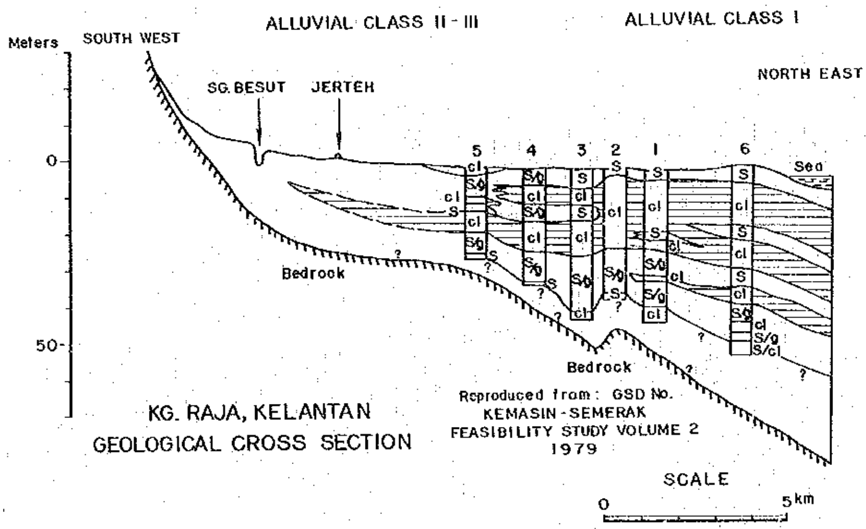
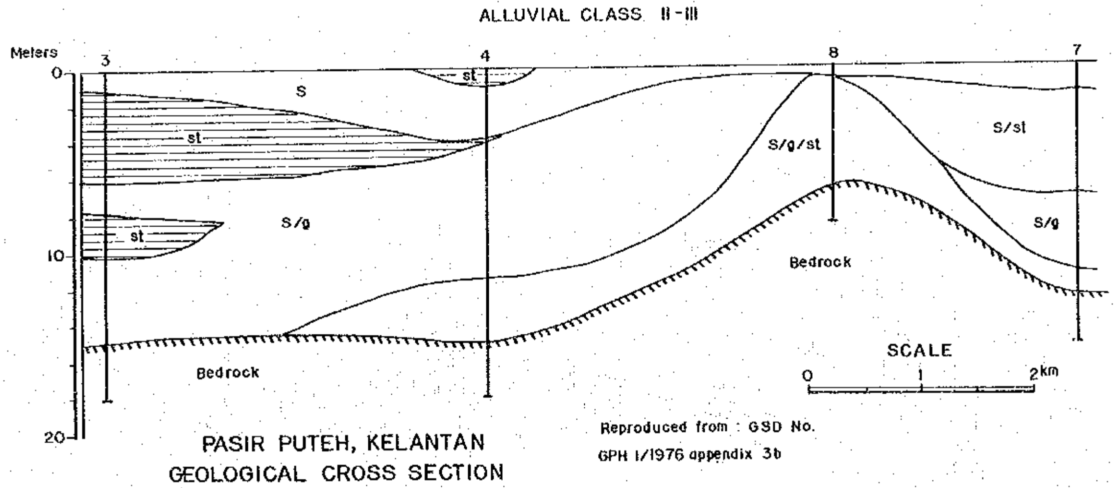


Fig. 10 Hydrogeological Cross Section (3/6)

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY







LEGEND

cl clay
st silt
S Sand
g gravel

f fine
m medium
c coarse
▼ water level

Fig. 11 Hydrogeological Cross Section (4/6)

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

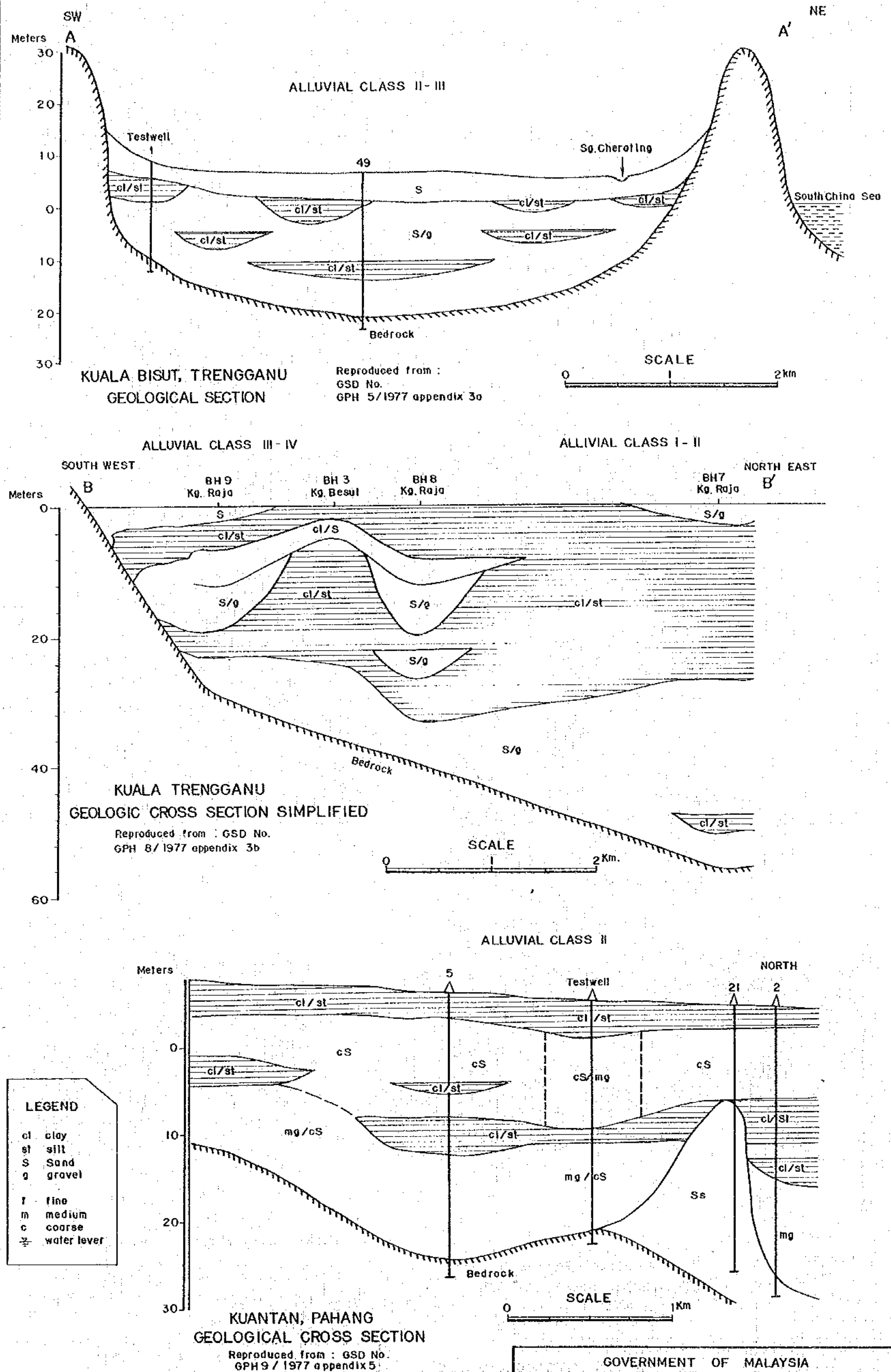


Fig. 12 Hydrogeological Cross Section (5/6)

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

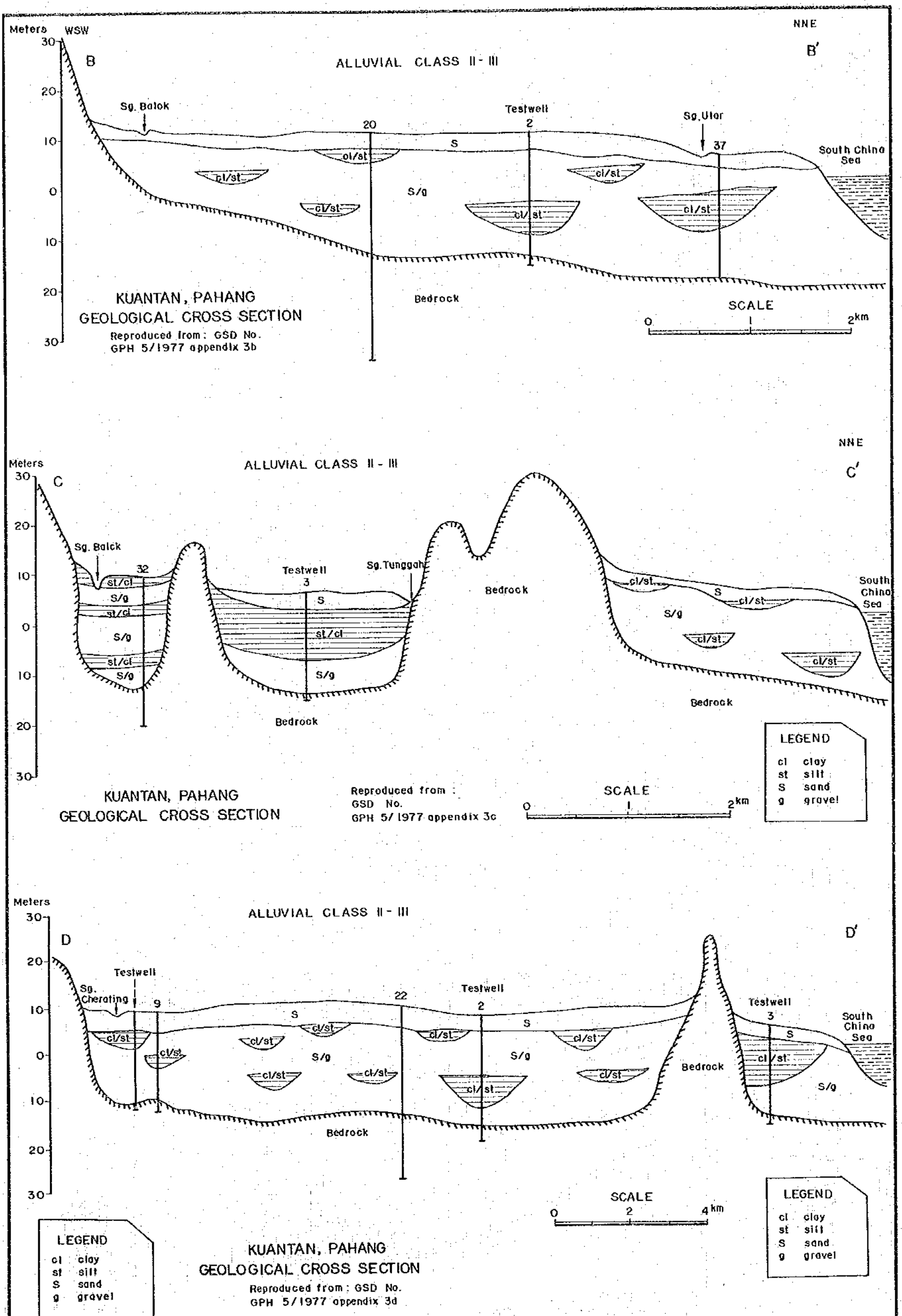
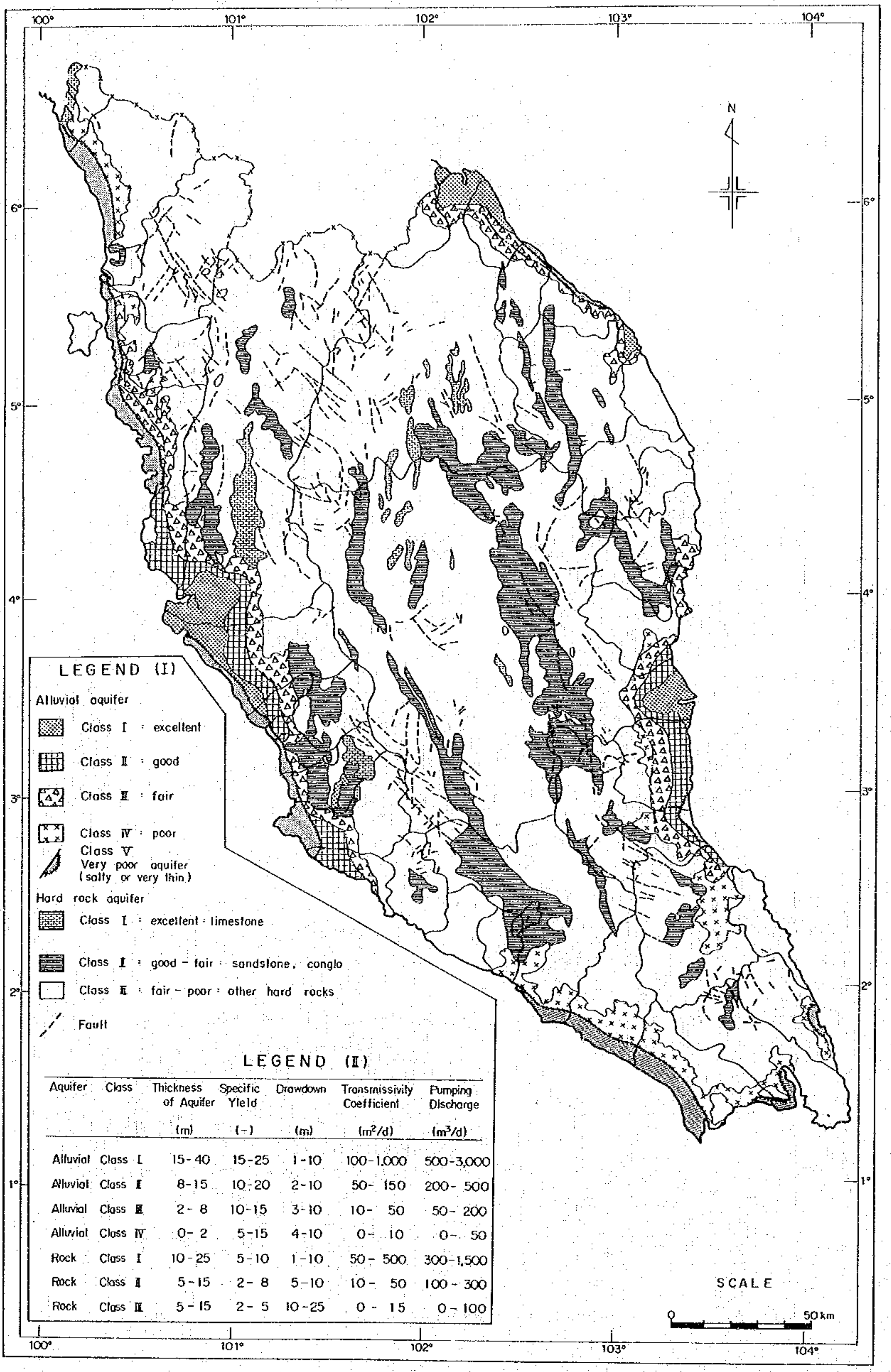


Fig. 13 Hydrogeological Cross Section (6/6)

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

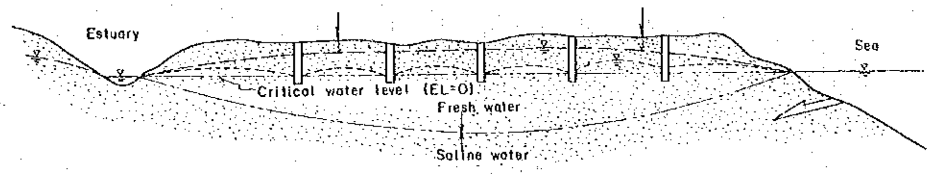
JAPAN INTERNATIONAL COOPERATION AGENCY



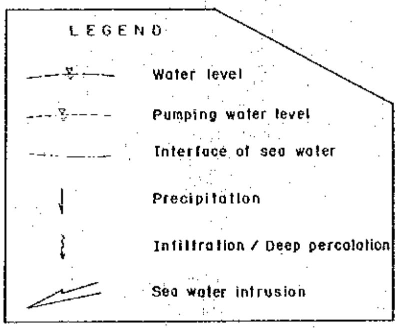
Aquifer	Class	Thickness of Aquifer (m)	Specific Yield (-)	Drawdown (m)	Transmissivity Coefficient (m²/d)	Pumping Discharge (m³/d)
Alluvial	Class I	15-40	15-25	1-10	100-1,000	500-3,000
Alluvial	Class II	8-15	10-20	2-10	50-150	200-500
Alluvial	Class III	2-8	10-15	3-10	10-50	50-200
Alluvial	Class IV	0-2	5-15	4-10	0-10	0-50
Rock	Class I	10-25	5-10	1-10	50-500	300-1,500
Rock	Class II	5-15	2-8	5-10	10-50	100-300
Rock	Class III	5-15	2-5	10-25	0-15	0-100

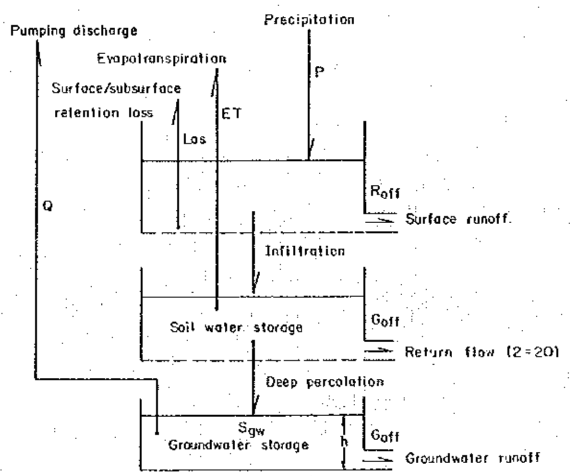
Fig. 14 Hydrogeological Land Classification Map

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

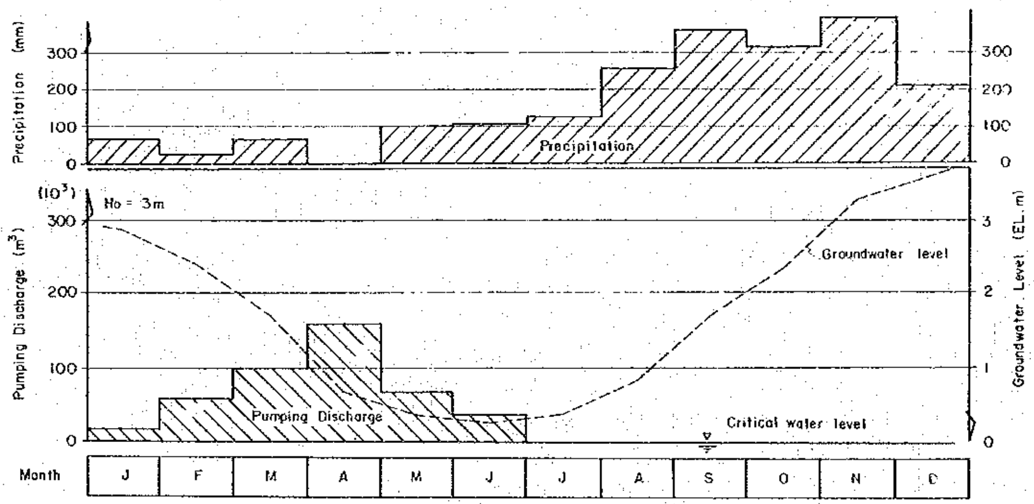


Schematics of Hydrogeological Land at Sand Dune





Hydrogeologic Model of Sand Dune



Change in Groundwater Level and Pumping Discharge

Fig. 15 An Example of Groundwater Management for Unconfined Aquifer in Sand Dune Area

GOVERNMENT OF MALAYSIA
NATIONAL WATER RESOURCES STUDY MALAYSIA
JAPAN INTERNATIONAL COOPERATION AGENCY

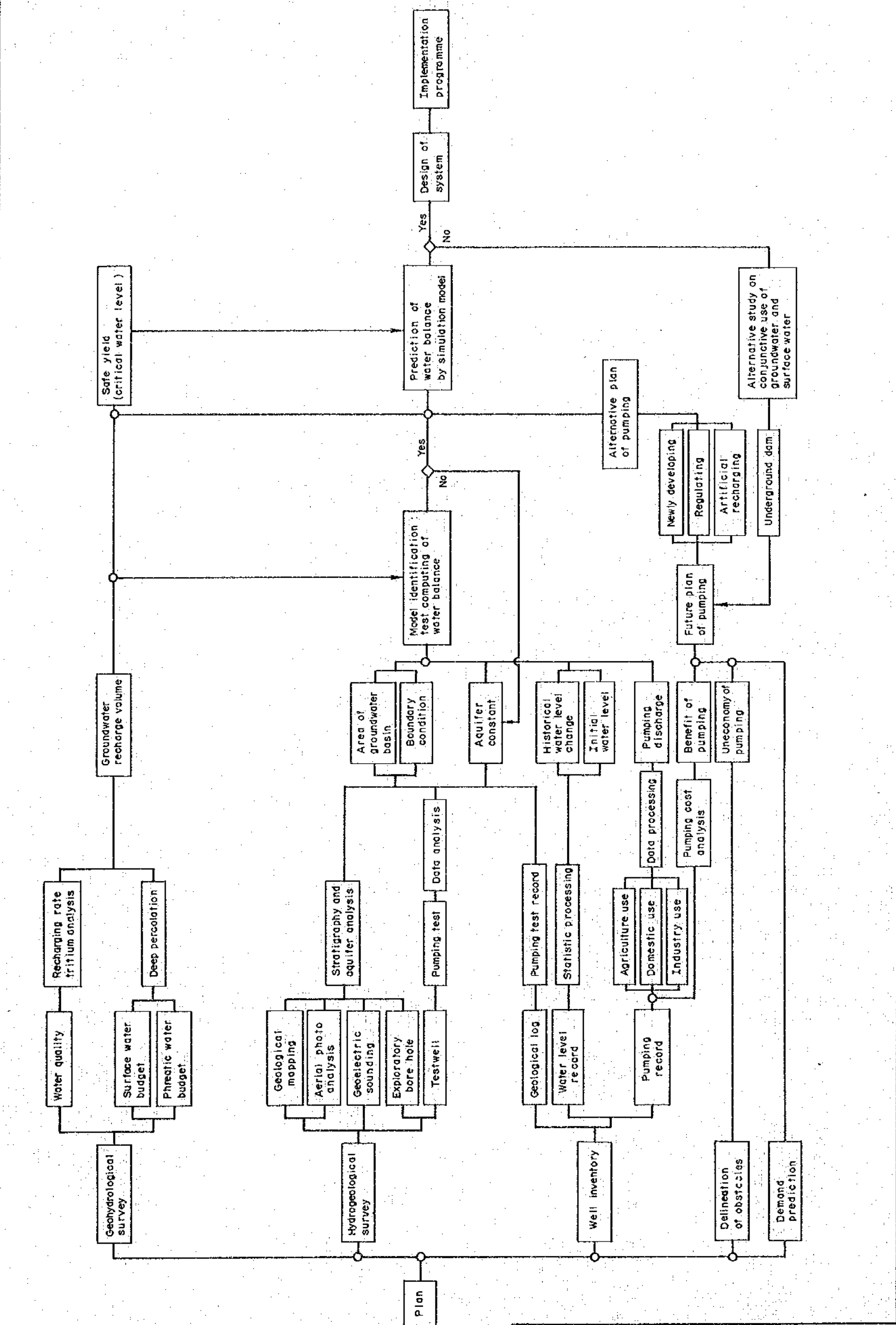


Fig. 16 Flow Chart of Management Plan for Alluvial Artesian Groundwater Basin

GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY MALAYSIA

JAPAN INTERNATIONAL COOPERATION AGENCY

PART 2

SABAH AND SARAWAK

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

This Report presents the results of groundwater resources study including the present condition of groundwater use, inventory of production tubewells, delineation of potential aquifers, cost analysis and plan for groundwater basin management.

The data of existing production tubewells were collected from Sabah PWD and Sarawak GSD. Hydrogeologic data of geologic logs, geological cross sections, well logging and pumping test results were provided by Sabah PWD and Sarawak GSD.

Based on the analysis of the collected data, hydrogeological land classification was made for estimating the potentials of groundwater development.

The cost of well construction and water source was estimated based on the recent contracted amount. The cost of the groundwater development was estimated based on the types of wells and aquifer potentials to evaluate the unit water source cost.

The preliminary study on monitoring and management of the groundwater basin was made to facilitate the optimum development of groundwater resources for beneficial use without producing undesired results such as sea water intrusion and land subsidence. Some recommendations and comments on conjunctive water use of groundwater and surface water were included in this study.

2. PRESENT CONDITION

2.1 Groundwater Use in Sabah

Groundwater is used in five PWD's water works at Sandakan, Labuan, Semporna, Kota Belud and Kuala Penyu. Groundwater use in 1980 is estimated to be 23 x 10^3 m^3/d corresponding to 22% of the total water supply of 105 x 10^3 m^3/d by PWD.

Fifty four (54) boreholes were drilled in both the confined and semi-confined aquifers of sandstone with alternating shale. These are used in the water supply to Sandakan, Labuan and Kuala Penjua. Three (3) dug wells were sunk in the unconfined shallow aquifer of alluvial sand, being used in the water supply to Semporna and Kota Belud. They are as shown in Table 1.

Groundwater is used for the water supply to town areas for domestic and industrial purposes. Groundwater use for agriculture is not known. No statistics are available to distinguish the different purposes between domestic and industry. Area where groundwater is exploited is as shown in Fig. 1.

(1) Groundwater use in Sandakan

Production wells of 21 in number are being used by the PWD for water supply to Sandakan. All the boreholes are sunk in the Sandstones with alternating shales ranging from 30 to 190 m in depth. Aquifers are noted at the fissures and cracks of sandstones in Sandakan formation. Groundwater extracted in 1980 is estimated to be 16.5 x 10^3 m^3/d which is equivalent to 82% of the total water supply of 20 x 10^3 m^3/d (Ref. 1). The ratio of the groundwater use increases to 85% during dry season from March to May when the flow intake discharge from the two small rivers, Batu Lima and Sibuga, begins to trickle.

The supply capacity of 20 x 10^3 m^3/d is lower than the present water demand estimated of 27 x 10^3 m^3/d. Rapid assessment of water supply was carried out to meet the estimated water demand in 1984. According to the Interim Improvement Scheme of the PWD, an additional groundwater development scheme which includes 13 new production boreholes, six redrilling and three replacement of screen pipes of the existing boreholes was proposed so as to meet the estimated water demand in 1984 (Ref. 1).

The drilling program of the 13 new production wells has just commenced in 1981. However, the first drilled borehole was abandoned due to low productivity. PWD intends to increase the number of boreholes until the total yield from the wells meets the estimated demand. No alternatives to meet the water demand in future are given to PWD except for the groundwater development, so long as the proposed long term scheme of Meliau intake/dam project remains incomplete (Ref. 1).

Conjunctive use of groundwater and surface water is recommended for a period of 15 to 20 years in accordance with the proposed stage development plan which includes Meliau river intake and pipeline scheme by the year 1985 and Meliau dam scheme by the year 1995. Groundwater should be phased out by the year 2000, if the rapid increase in the demand projection to the year 2000 is not affected by any modification and no delay of the accepted implementation program which was proposed by the PWD in 1980 (Ref. 1). However, the first target year, 1985, of the completion of the Meliau river intake and concomitant 120-km pipeline could be delayed until 1987 or 1988 due to the delay of the final decision on selecting the alternative surface water source point in the Meliau or Kinabatangan river.

Sustained yield of the existing well field at the east of the Seguntor river is estimated to be 39 x 10^3 m^3/d, which corresponds to approximately more than double of the present withdrawal of 16.5 x 10^3 m^3/d. The west side of the Seguntor river is selected to be the next new well field and its sustained yield is preliminarily estimated to be 11 x 10^3 m^3/d (Ref. 1). Total sustained yield of 50 x 10^3 m^3/d in Sandakan area concludes that the groundwater development still has possibilities to satisfy the water demand by the year 1988.

(2) Groundwater use in Labuan

Production wells of 31 in number are being used in PWD's Labuan water supply. All the boreholes are sunk in the sandstones with alternating shale ranging from 50 to 150 m in depth. Aquifers are recognized in the fissures and the cracks of sandstone in Belait formation.

The wells were constructed in the air field and housing area in the eastern zone of the island where the Belait formation covers the whole well field.

Groundwater of 5 x 10^3 m^3/d was extracted from the 22 boreholes in 1980. Additional boreholes of 16 in number including the replacement of six old wells were constructed in 1980. Reliable yield of groundwater is estimated to be 10 x 10^3 m^3/d in 1981.

Further groundwater development is proposed to satisfy some of the future demand, which includes artificial recharging and groundwater development of the northern Belait formation. The expected yield of these two schemes is 9 x 10^3 m^3/d.

Total reliable yield in Labuan Island is estimated to be 31 x 10^3 m^3/d including 19 x 10^3 m^3/d of groundwater and 12 x 10^3 m^3/d of surface water by the year of 2000 (Ref. 10). Groundwater will be used until the completion of the proposed submarine pipeline scheme which can supply with raw water of 45 x 10^3 m^3/d from the Padas river.

(3) Groundwater use in Kota Belud

Three dug wells are used in PWD's Kota Belud water works, supplying 1.7×10^3 m^3/d in 1981. The wells are sunk in alluvial sediment of 5 m in depth. Aquifers are recognized in fine to medium sandy layers in the alluvial deposits. The maximum thickness of the alluvial sediments is expected to be 30 m in the alluvial flood plain.

According to the preliminary study of groundwater resources in this area in 1980, the exploitation of the alluvial aquifers with higher permeability and depth more than 10 m has an advantage for future water resources development compared with the surface water scheme. Nine boreholes are recommended to be drilled in the potential alluvial aquifers to satisfy the water demand by the year 2000 including replacement of three existing dug wells due to the limited productivity and the water quality which has high content of iron, manganese and bacteria (Ref. 18).

(4) Groundwater use in Kuala Penyu

Two boreholes are used by PWD at the Kuala Penyu water works, supplying 0.1 m^3/d in 1980. A new surface water development scheme is recommended to satisfy the water demand after the year 1982 because of the limited productivity and poor water quality with higher content of salinity, iron and manganese of the existing boreholes. The two boreholes will be closed when the surface water scheme is completed.

2.2 Groundwater Use in Sarawak

Groundwater is only used in one of PWD's rural domestic water supply systems to the towns of Belawai and Rajang. Groundwater use of 1,000 m^3/d in Sarawak occupies a very minor portion of PWD's total water supply of 35×10^3 m^3/d in 1980. It was supplied by six shallow boreholes with 15 m in depth which were sunk in alluvial sediments. The well field which is located at the estuary of the Rajang river is as shown in Fig. 1. Careful monitoring is executed to avoid salt water intrusion during dry season due to over-pumping from the aquifer of sands. Groundwater in the shallow alluvial aquifer is directly replenished by the rain. A well field of 20 ha including a recharging area was acquired to conserve the land by PWD.

The success of the groundwater development of the Belawai scheme would encourage PWD's rural water scheme. No alternative is given to PWD's rural water supply program except for the groundwater exploitation at the coastal areas along the South China Sea where all the rivers are subjected to frequent salt water intrusion.

Groundwater exploitation scheme is being carried out at the town of Kabong by PWD. The hydrogeological condition is similar to that of alluvial aquifers in Belawai. This scheme could be completed by the end of 1984 including the construction of seven boreholes producing 400 m^3/d of raw water. But at present groundwater use is still in the preliminary stage.

2.3 Groundwater Exploration in Sabah

A systematic groundwater exploration has been carried out in the area of Sandakan and Labuan by PWD. A small scheme of groundwater exploration is being executed at Pangi Island by PWD in 1981.

Groundwater exploration has been performed by the consultant of PWD with some assistance from GSD Sabah Office which provides the general geological information. The objective of this exploration scheme is to evaluate the aquifer potentials of hard rocks in hilly areas and some alluvial sediments in coastal plains. Exploratory boreholes including some observation holes have been drilled; 38 in number at Sandakan and 15 at Labuan since 1975.

(1) Sandakan

Preliminary evaluation of groundwater potentials in the west of the Seguntor river was carried out by PWD to find the new source area of groundwater exploitation in 1980. No exploratory boreholes were available. In this study, however, the field geological investigation concluded that the sandstone outcrops with a prominent faulting system are similar to the structural condition of the east of Seguntor river where 38 existing exploratory/observation boreholes are located. The preliminary investigation suggests a possibility of groundwater exploitation in this area.

Further investigation scheme including six exploratory borehole drilling is recommended to assess the quantitative potentials of the sandstone aquifers in the west of the Seguntor river. The location of the recommended exploration area is as shown in Fig. 6.

(2) Labuan

A systematic groundwater exploration program was carried out to evaluate the aquifer potentials of the Belait formation in Labuan Island by PWD in 1976. A series of 12 exploratory boreholes ranging from 33 to 305 m in depth were drilled in all the island's geological formations including the Berite, Temburong, Croker and Alluvial as illustrated in Fig. 7. The eastern zone of the Berite formation is a more productive source of groundwater and the northern zone of the Belait formation is expected to be a secondary potential source after the development of groundwater resources in the eastern zone is fully carried out. Though the preliminary result of the investigation shows that the northern zone of the Belait formation could be considered to be a possible development, it could be less productive than the eastern zone. The other geological formations offer little scope for groundwater development.

(3) Pangi Island

Groundwater exploration in Pangi Island has just started to assess the possibility of groundwater exploitation for water supply by PWD in 1981. Groundwater development is also expected to be carried out at the small isolated island where the river water trickles during the dry season.

2.4 Groundwater Exploration in Sarawak

A systematic groundwater exploration has been carried out by GSD Sarawak Office together with some assistance by the German Hydrogeological Mission and the headquarters of GSD since 1974. Six groundwater exploration schemes were carried out during TMP period on the basis of request by PWD to find a source of water supply for domestic purposes, particularly in the coastal areas where the rivers are subjected to prominent salt water intrusion. These areas are Kuala Lawas, Matu, Belawai-Rajang, Kabong, Tambirat and Bako.

Groundwater exploration in the coastal areas are being executed to evaluate the potentials of alluvial aquifers by GSD Sarawak under the request by PWD for rural water supply program under 4MP. The places of nominated exploration schemes are Kampong Sundar, Punang, Bawang, Tran, Igan, Pusa, Malu dam, Sebongan, Semera and Nanok. Groundwater explorations of hard rocks which consist of volcanics and sandstones with alternating shales are being planned to assess the potentials of rock aquifers. The proposed exploration schemes include 14 drilling programs of 120 m in depth, which are located at Bacho, Sedon, Serian, Sarikas, Binatang, Mukah and Punang.

2.5 Types of Wells

Three types of production well are recognized. They are: (1) Shallow tubewell, (2) Deep tubewell, and (3) Dug well.

The shallow tubewell has been developed by GSD Sarawak to exploit the groundwater in alluvial aquifers which are less than 30 m in depth. Since 1974 the wells have been screened by slotted pipes of steel or PVC with 20 to 35 cm in diameter. The PVC or fibre glass pipe is being recommended for the well field where higher concentration of iron ion or iron bacteria is detected.

Since 1953 deep tubewells have been constructed by GSD Sarawak and PWD in Sabah to exploit the groundwater in rock aquifers of sandstones with alternating shale, ranging 30 to 90 m in depth. The wells are screened by slotted steel pipes, fibre glass pipes and stainless steel pipes with 20 to 30 cm in diameter.

Some tubewells were abandoned due to the corrosion of steel pipes caused by the high content of iron ion and iron bacteria in deep aquifers.

The dug well was sunk in alluvial sediments less than 6 m in depth by PWD in Sabah for the town water supply. The wells are cased by concrete pipes with 2.5 m in diameter.