No.51

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINERALS AND GEOSCIENCE DEPARTMENT MALAYSIA

THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

FINAL REPORT

VOLUME 1 EXECUTIVE SUMMARY

MARCH 2002

CTI Engineering International Co., Ltd.

OYO CORPORATION

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All the Malaysian Ringgit amounts including project costs shown in this report are indicated in 2001 price unless otherwise indicated. Those amount are estimated based on the foreign prices by applying currency exchange rates as of 30th of November 2001; namely, US$1 = RM3.8000 = 123.98 Japanese Yen.

PREFACE

In response to a request from the Government of Malaysia, the Government of Japan decided to conduct a Study on the Sustainable Groundwater Resources and Environmental Management for the Langat Basin and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Keiji Sasabe of CTI Engineering International Co., Ltd. and consisting of CTI Engineering International Co., Ltd. and Oyo Corporation to Malaysia, four times between March 2000 and March 2002.

The team held discussions with the officials concerned of the Government of Malaysia and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Malaysia for their close cooperation extended to the team.

March 2002

Takao Kawakami
President
Japan International Cooperation Agency

March, 2002

Mr. Takao Kawakami
President
Japan International Cooperation Agency
Tokyo, Japan

Sir:

LETTER OF TRANSMITTAL

We are pleased to submit herewith the Final Report on *the Study on the Sustainable Groundwater Resources and Environmental Management for the Langat Basin in Malaysia*.

The study was conducted by CTI Engineering International Co., Ltd. in association with Oyo Corporation, under contracts with Japan International Cooperation Agency (JICA) during the period from March 2000 to March 2002. In conducting the study, particular attention was paid to the formulation of a management plan for sustainable groundwater resources development and conservation for the Langat Basin. The management plan is composed of the Monitoring Plan that is to obtain data and information on the objectives, Management Information System (MIS) that is a tool with Information Technology (IT) and Human Resources and Institutional Development Plan that is a prerequisite for operation and management of the management plan.

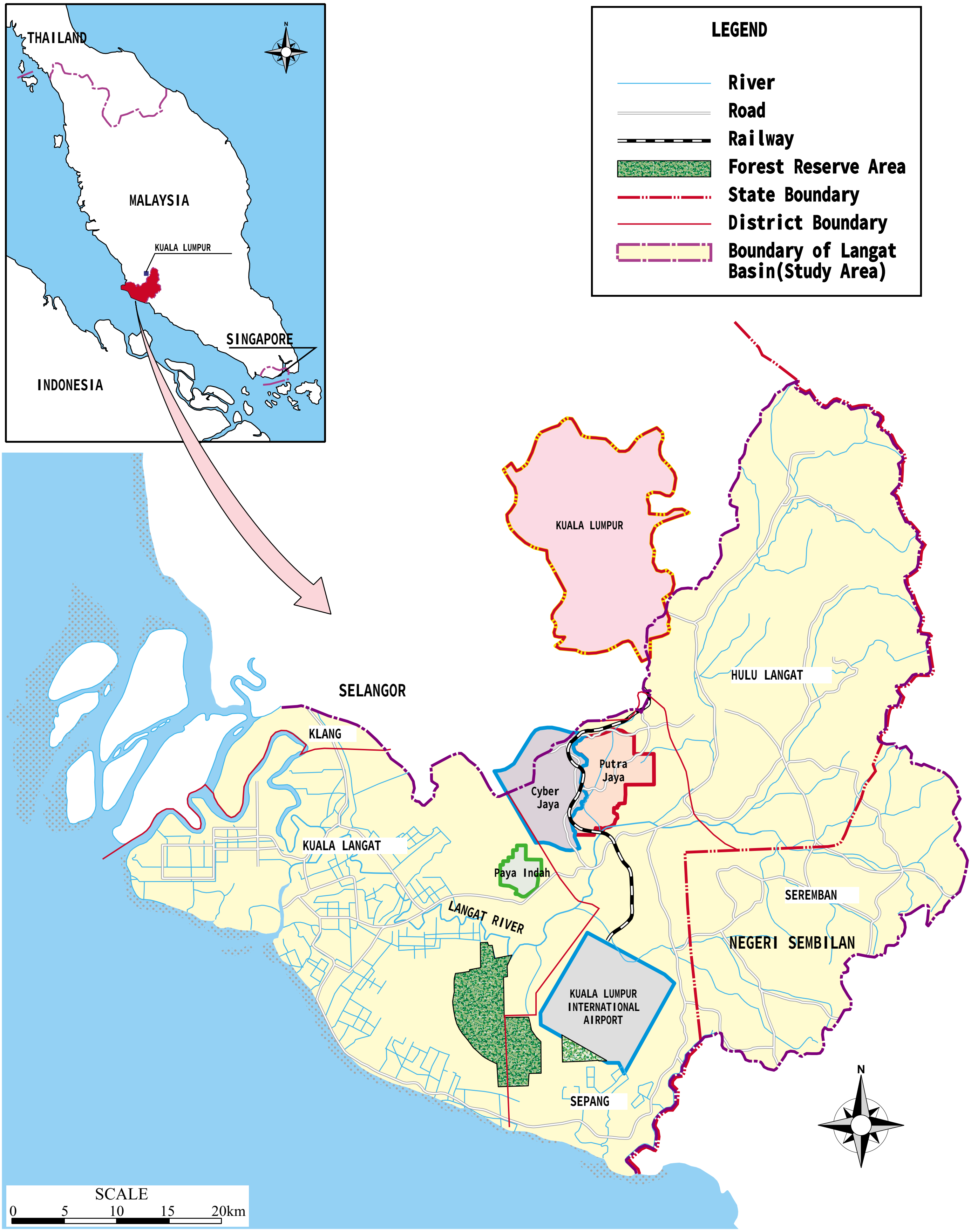
We wish to take this opportunity to express our sincere gratitude to the Government of Japan, particularly, JICA, the Ministry of Foreign Affairs, and other offices concerned. We also wish to express our deep appreciation to the Minerals and Geoscience Department Malaysia, the Ministry of Primary Industries, and other authorities concerned of the Government of Malaysia for their close cooperation and assistance extended to the JICA study team during the study.

Finally, we hope that this report will contribute to the further promotion of the project.

Very truly yours,

Keiji Sasabe
Leader, JICA Study Team
CTI Engineering International Co., Ltd.

Encl. : a/s



LOCATION MAP

Discussion on Inception Report 31/3/2000

Signing of Minutes of Inception Report 31/3/2000

Technical Meeting 21/6/2000

Establishment of Land Subsidence Monitoring Benchmarks 7/8/2000

Workshop (1) 14/10/2000

Drilling of Monitoring Well at Kajibumi WF2 23/10/2000

Water Level Gauge at Paya Indah 22/11/2000

Pumping Test at Kanchong Darat 13/2/2001

PHOTOGRAPHS OF THE STUDY EVENTS (1)

Drilling of Monitoring Well along the ELITE Highway 13/2/2001

Drilling of Monitoring Well at Kanchong Darat 13/2/20**01**

Sampling of Surface Water (Canal in a plantation) 17/2/2001

Sampling of Surface Water (Inflow to Paya Indah) 17/2/2001

Groundwater Level/Quality Measurement at Existing Well 23/2/2001

Groundwater Level/Quality Measurement at New Well 14/3/2001

Workshop (2) 20/3/2001

Project Committee Meeting on Interim Report 23/8/2001

PHOTOGRAPHS OF THE STUDY EVENTS (2)

Field Observation/Sampling at New Monitoring Well 29/8/2001

Field Observation/Sampling at Existing Monitoring Well 29/8/2001

One of Monitoring Wells equipped with Data Logger 29/8/2001

One of New Monitoring Wells 13/9/2001

Workshop (3) 10/9/2001

Project Committee Meeting on Draft Final Report 12/1/2002

Seminar 17/1/2002

Datuk Seri Dr. Lim, Minister of Primary Industries and Mr. Konishi, Ambassador of Japan, seeing exhibitions at the Seminar, Mandarin Oriental Kuala Lumpur 17/1/2002

PHOTOGRAPHS OF THE STUDY EVENTS (3)

COMPOSITION OF FINAL REPORT

Volume 1	**EXECUTIVE SUMMARY**
Volume 2	**MAIN REPORT**
Volume 3	**SUPPORTING REPORT**
Sector A	**Socioeconomy**
Sector B	**Land Use**
Sector C	**Water Demand and Supply**
Sector D	**Surface Water Status**
Sector E	**Groundwater Quality**
Sector F	**Physical Characteristics of Groundwater Basin**
Sector G	**Groundwater Modelling**
Sector H	**Groundwater Monitoring**
Sector I	**Management Information System**
Sector J	**Institutional Aspects of Groundwater Management**
Sector K	**Initial Environmental Assessment (IEA)**
Volume 4	**DATA BOOK**

SUMMARY

1. Background of the Study

Rapid and ultra-large scale development is progressing in the national capital of Kuala Lumpur and the adjoining areas in Selangor State, Malaysia. To cope with the water deficit in Selangor State, the groundwater is considered as a possible supplementary of alternative water source, and some factories already started shifting their water source from surface water to groundwater. Uncontrolled use of groundwater, however, may induce serious environmental problems, e.g. land subsidence, saltwater intrusion to the aquifer. The establishment of a balanced, multi-sector and integrated groundwater resources and environmental management plan is deemed urgent to attain a sustainable groundwater resources use and to maintain a favourable groundwater quality in the Langat Basin.

In response to the request from the Government of Malaysia on the above background, the Government of Japan dispatched through the Japan International Cooperation Agency (JICA) a Study Team to conduct “The Study on the Sustainable Groundwater Resources and Environmental Management for the Langat Basin in Malaysia” (hereinafter referred to “the JICA Study”) for the period from March 2000 to March 2002. The Management Plan was thus formulated, as a result of the JICA Study, in close cooperation with the Minerals and Geoscience Department of Malaysia and other relevant agencies.

The **objectives of the Study** include: (i) formulation of a sustainable groundwater resources and environmental management plan for the Langat Basin; (ii) establishment of a monitoring system and Geographic Information System to support the Management Plan; and (iii) formulation of human resources and institutional development plan for the implementation of the Management Plan, and to be able to utilise the Management Plan for other basins.

2. General Condition of the Langat Basin

2.1 Socioeconomic Conditions

Seventh Malaysia Plan sets fourteen targets as development thrust. Of these, “Sustainable development” means that economic, social and environmental aspects are integrated into the development process. The environment should be improved and resources utilised more efficiently to ensure that improvements in living standards are made without compromising the needs, interest and welfare of future generations. **Eighth Malaysia Plan** says that the Government will adopt early preventive measures and will apply the precautionary principle to environment and resources issues in order to ensure that the development is sustainable and resilient. Measures to address such issues include: Enhancement of the database for environmental decision making; and, Formulation of a National Water Policy to ensure that water resources will be managed more efficiently and effectively.

The **Malaysian economy** had been growing at a high speed in the 1980s up to mid-1990s. The average growth rate in 1980-1990 reached 5.2% annually and growth rate in 1991-1996 exceeded 9% every year. Malaysia recovered in 1999 the damage by economic crisis in 1997. Economic research institutes predict favourable prospects on the Malaysian economy in the near future. The **population of Malaysia** is estimated at 22.7 million in 1999.

Due to its strategic location and economic development, **Selangor State** has set a target to achieve the status of a developed state 15 years earlier than the country's target of Vision 2020. This target is incorporated into Vision 2005 for Selangor. Selangor's development strategies towards Vision 2005 include: increasing development towards areas outside of the Klang Valley; and, conservation of natural environment and implementation of sustainable development.

The total **GDP of Selangor** accounts for around 20% of the national GDP. Selangor's GDP growth rate remarkably reversed from minus 1.54% in 1998 to plus 5.2% in 1999 in accordance with the trend seen in the nation. GDP shares of the industrial and services sectors are 59.0% and 38.5% in 1999 while the agriculture sector has 2.5%. Total **population of Selangor** State is estimated at more than 3 million in 1998 or 13.6% of the nation.

Langat Basin includes Kuala Langat District, Sepang District and Hulu Langat District of Selangor State, and the western part of Seremban District of Negeri Sembilan State. The industrial sector will play an important role in the development of **Kuala Langat District**. Three development corridors are proposed in the development plan of Kuala Langat District; namely, Telok Panglima Garang - Banting - Olak Lempit; Morib-Tg. Gabang - Tg. Tumbuk; and Pulau Carey. The Multimedia Super Corridor (MSC) is the largest and the only urban development plan in **Sepang District.** Its establishment is expected to greatly influence development not only of the district but the State and the whole nation as well. The MSC will also influence the land use development pattern in **Hulu Langat District**. Nilai City in the western part of **Seremban District** is planned to grow as a semi-state centre in 2020 with Mantin and Labu as growth centres.

2.2 Topography, River System and General Geology

The **Langat River** and its left bank tributary, the Semenyih River, originate in the western slope of the mountain ridge penetrating the Malay Peninsula. Both rivers collect water in the mountainous areas and generally flow southwestward in the mountainous terrain. They gradually change their direction to the west after flowing in the hilly areas near Kajang and Bangi, respectively. The two rivers then join, enter the flat land near Kg. Dengkil and flows westward. In some locations the river heavily meanders and finally flows into the Straits of Malacca. The total catchment area of the Langat Basin including the neighboring basins is 2,750 km^2.

From the **topography**, the Langat Basin can be broadly divided into three; namely, mountainous areas, hilly areas and flat lowlands, from the upstream to the downstream. Groundwater recharging areas are in the upstream mountainous and hilly areas, and an aquifer distributes widely in the flat lowlands.

Bedrock in the mountain area consists of schist and phyllite of Howthornden Formation and granitic rock of Permian that forms the mountain bone of the peninsula and extends around the hilly areas near Kg. Cheras. Layers of the hilly areas are called Kenny Hill Formation and Kajang Formation, consisting of shale and quartzite. The upper part of the bedrock including those of intruded granite is weathered.

In the low flatlands, thick **Quaternary layers** are deposited on the bedrock. The Quaternary layer, from the top to the bottom, consists of 0.5 to 5.5 m thick Beruas Formation with peat layer at the top, clayey Gula Formation and Kempadang Formation starting in the hilly areas and having a 40 to 50 m thick layer near the seacoast. Lying underneath is the Simpang Formation of sand and gravel with thickness of several metres in the hilly area and about 40 m in the low flatlands. The Simpang Formation of sand and gravel layer is the subject aquifer of the present study. This aquifer distributes continuously around 15-20 m below the ground with the thickness of 20 to more than 100 m, and thus it is generally considered that groundwater can be developed economically in this area.

2.3 Land Use

Topographic and land use maps are the basis for various analysis in the present study and for implementation of the management plan. Digital topographic maps of DSMM (1991/92) at a scale of 1:50,000 in DXF-data format available at JMG were converted into ARC/INFO format to prepare relevant data such as contours, roads, rivers, etc.

The Study Team had digitised the hard copy **land use maps** for 1995 prepared by DOA. The digitised DOA land use maps were updated by using Landsat TM image of 1998 and aerial photos taken from 1992 to 1999. The comparison of the land cover between 1995 and 1998 for the total Langat Basin of 2,750.2 km^2 revealed increases of Built-up Area and Plantation by 255.5 km^2 and 31.7 km^2, respectively, and decreases of Oil Palm, Swamps, Rubber and Grassland by 102.5, 92.7, 75.5 and 36.6 km^2, respectively.

2.4 Meteorology and Hydrology

The Langat River Basin has two monsoons a year. The northeast monsoon occurs from November to March while the southwest monsoon occurs from May to September. In between the two monsoons are the two inter-monsoon periods. The average **annual rainfall** ranges from approximately 2,200 to 2700 mm. It gradually increases from the coast towards the mountain areas. Monthly rainfall patterns generally show two peaks in the year, namely, around March to April and around September to October with the amount of approximately 300 mm. The temperature throughout the year is quite constant with a mean of 27°C, and the variation of the relative humidity throughout the year is also small with an average value of 82%. The evaporation depth for open water is measured to be around 1,500 mm per year.

Annual water balance study has been conducted for the Langat River Basin for the total basin of Upper Langat, Semenyih and Middle Langat with the catchment area of 1,281 km^2. Annual groundwater recharge height was estimated at 108 mm as a balance of the annual rainfall of 2,238 mm and the estimated annual evaporation of 1,284 mm and the annual discharge height of 846 mm. The volume of groundwater recharge at 108 mm a year is 4.8% of the annual rainfall. The groundwater recharge height at 108 mm can be converted to the total amount of 139 million m^3 from the area of the catchment basin at 1,281.1 km^2.

2.5 Water Demand and Supply

Major surface water sources in the Langat Basin are the Langat and Semenyih treatment plants with 93% of the total water treatment capacity of 1,003.8 Mld for the Langat Basin. Most of the groundwater is used for industrial purposes. The National Water Resources Study (NWRS) was carried out for planning, development and management up to 2050 of the overall water resources of Peninsular Malaysia. **Water demand in the Langat Basin** is increasing steadily. The future demands of the three districts of Selangor State in the Langat Basin are fulfilled with the water sources of Langat Basin including Langat and Semenyih treatment plants. Its supply is to be powered by the Southern Interstate Transfer from Pahang from 2007. The construction of Kelau Dam is very critical for the demand-supply balance in the Langat Basin.

The Klang Valley suffered from a severe water shortage in 1998, which was caused by a drought due to abnormal weather. The Mid-term Review of the Seventh Malaysia Plan 1996-2000 describes the necessity of sustainable **development of groundwater** as an alternative source in case of emergency. As NWRS shows, on the condition that the new water source schemes are implemented as scheduled all the demand from industries will be covered by the surface water in the Langat Basin. Presently, however, the Government does not restrict groundwater development and private companies behave in an economic manner. In other words, private companies will dig wells as long as the cost of groundwater development is lower than using surface water.

2.6 Information Technology

With the establishment of National Infrastructure for Land Information System (**NaLIS**), all land related agencies, which have been developing standalone information systems since the 1970s, were linked together in a network for communication. JMG is one of the member agencies and responsible for geological, mining and geo-technical information.

The five-year strategic plan of JMG includes the use of IT to enhance planning and implementation capabilities of the Department. **Data information strategy** is mentioned as follows: Data gathering will be client and needs driven; agency-owned data and information will be organised and efficiently managed; and IT-driven systems will be utilised for delivery of information to satisfy the wide range of client's needs. HIDRODAT is an updated version of a Groundwater Database. A data input and updating tool has been developed in the Oracle based Client/Server system environment.

2.7 Institutional Aspects

The Federal State's jurisdiction over water is governed by the Constitution. "Water" falls under the State List. The law on groundwater management and control is currently not consolidated into a single comprehensive legislation. Provisions on groundwater are found in the SWMAE, the Geological Survey Act (GSA), etc. Minerals and Geoscience Department (JMG) is the technical department responsible for groundwater. The main functions of the department among others is to advise the Federal and State Government Agencies on policies and technical matters relating to minerals and geosciences.

The Selangor Waters Management Authority (**SWMA**) was established by way of a state enactment. The Enactment (SWMAE) provides for the management and protection of river basins, water bodies, groundwater, coastal waters and wetlands, and for the sustainable development of water sources. Minerals and Geoscience Department, Selangor is a branch of the Federal department. Groundwater development is part of the functions of the Geoscience Unit.

The 7th Malaysia Plan had recognised that in order to meet the increasing demand for domestic and industrial water, the building of dams further upstream and the increased use of groundwater are necessary. The Government established the National Water Resources Council in 1998. This council is entrusted with the responsibility of formulating the **National Water Policy**. Included in the policy directions is "Explore opportunities for the development of groundwater resources." The National Economic Recovery Plan had also expressed strong recommendations on the conservation of water and the sustainable utilisation of groundwater.

The SWMA is looking into the prospect of imposing a charge of about 4 sen/m^3 for raw water abstraction. Similarly, it is also possible to impose a charge for raw groundwater abstraction and a separate charge for treated groundwater.

3. Groundwater Status

3.1 Groundwater Quality

Groundwater quality was analysed for 34 wells. The surface water quality was also measured at 10 locations. Low pH values ranging from 3.9 to 4.7 were observed mainly in surface water near Paya Indah area. In terms of groundwater in this area, it is assumed that the highly acidic surface water has significantly reduced the pH values of the groundwater to the range of 4.5 - 4.7.

Total iron values mostly exceed the mandatory level of iron values specified in the Malaysian National Drinking Water Guidelines, i.e., 0.3 mg/l, generally ranging from 1 to 10 mg/l. One of the outstanding characteristics of heavy metals is widely detected **arsenic** although almost all were under drinking standard of 0.05 mg/l. As a result of the field survey, the higher concentration of arsenic is found in shallower wells. Four wells gave five kinds of **organic compounds**. They are; m&p-Xylene, o-Xylene, 1,2,4-Trimethylbenzene, Napthalene and 2-Methylnapthaline. This is observed only one time of observation out of three except one case, further monitoring is thus necessary.

As a result of the **water classification**, Na_2SO_4 or NaCl Type and Intermediate Type of water is dominant for the groundwater in this basin. It may be more or less the influence of the seawater and marine origin sediments. While six locations out of nine of the surface water are classified into $CaSO_4$ or $CaCl_2$ Type. It is assumed that the surface water quality is affected by surrounding mining activities.

Potential sources of groundwater pollution are as follows: There are a total of 30 industrial estates in the Langat Basin. The main activity of agriculture is dominated by palm oil plantation, followed by rubber, piggery, poultry, aquaculture, cattle and orchards. Other potential pollution sources include mines, solid waste landfill site, wastewater treatment plants, and petroleum storage tanks of the petrol station.

3.2 Groundwater Usage

The existing wells in three districts in the Langat Basin, Hulu Langat, Kuala Langat and Sepang, are divided into 5 different categories; namely, domestic, industry, observation, test well and unknown. **Usage of groundwater** during 1999 was estimated as 2,845 m^3/hour. Industrial activities utilised 1,385 m^3/hour, followed by domestic 1,341 m^3/hour.

The total number of wells surveyed in the Hydro Census is 121 while JMG well database keeps a register of 103 wells. Agricultural and commercial usage is an absolute minimum at only 1% of the total, respectively. Of the total 121, 33 are active, 18 are abandoned and 70 are unknown. The **main well fields** in the subject groundwater basin is located in the Megasteel/Amsteel II property (wells PWM-1, PWM-2, PWM-3, PWM-4, PWS-1, TW-4) at Brooklands Estate in Kuala Langat District. The smaller capacity well fields are in Brooklands Estate (Kajibumi WF1, 4 wells) and in Olak Lempit (Kajibumi WF2, TU/B). The natural groundwater flow is affected by abstraction of water from the Imuda Tin Mine.

3.3 Land Subsidence Status

Elevations of twenty shallow benchmarks were measured by first-order levelling in July and November 2000, and March and August 2001 to monitor the land subsidence. Records of 15 and 11 out of 20 benchmarks show a tendency to subside in the second and third measurement, respectively, while 19 benchmarks sank in the fourth one. In comparison with the difference between the first and the fourth measurements, 19 benchmarks also have sunk since the beginning of the installation.

A total of eight benchmarks, namely BM3, 4, 7, 12, 14, 15, 16 and 20, indicates continuous settlement. Benchmarks situated near the Langat River such as BM7, 15 and 16 have sunk from around 11 to 16 mm for one year period since July 2000. These benchmarks are located in the area where much groundwater is extracted presently. Consolidation by draining of peat/peaty clay layer and clayey soil layer that are widely spread over the Basin may result in the subsidence around the area.

3.4 Physical Characteristics of the Groundwater Basin

<u>Topographical Boundary of the Groundwater Basin</u>

The Groundwater Basin in the north and the east is bounded by the hills. In the west, no distinct topographical feature is observed, except a granite hill, Bt. Jugra, and the western boundary of the Groundwater Basin should be defined by the subsurface conditions. The Groundwater Basin is bounded by the sea in the south.

Bedrock Surface

According to the developed bedrock surface contour lines, two major valleys, which are running from the north (Klang Basin) to the south, can be recognised. From the east, valleys formed by the Langat and Labu rivers and other small channels can be expected. Three major valleys from the north and the east seem to meet at the centre of the Groundwater Basin and to form a single deep valley that flows down towards the sea. Depth of the bedrock increases as the valleys approaches toward the sea. In the north, the elevation at the centre of the valleys ranges -20 to -30 m from the m.s.l. The elevation near the seacoast was estimated at around -130 m.

General Conditions of Groundwater Basin

The Quaternary sediments in the subject groundwater basin are divided into four layers, namely from the ground surface peat/peaty clay layer (Layer 1), clayey soil layer (Layer 2a and 2b), sandy and gravelly soil layer (Layer 3) and the bedrock (Layer 4).

Very soft peaty soils (Layer 1) of Beruas Formation consist mainly of peat with a total thickness of about 1 to 5 metres. Soft clayey soils (Layer 2a) consist of light/greenish grey to grey marine silty clay of Gula Formation. The thickness of the layer increases from several metres at the northern part of the Basin to more than 20 m at the seacoast. The thickness also increases towards the west side of the Basin. Medium to stiff clayey soils (Layer 2b) mainly consist of light grey to grey clay with thickness varying between several metres to over 10 metres. This layer is also considered as Gula Formation.

Layer 3 consists mainly of sandy and gravelly soils of the Lower Member of Simpang Formation and widely spread over the Groundwater Basin. The thickness of the layer varies considerably, ranging from several metres in the northern part of the Basin to over 100 metres at the seacoast. Although the sandy/gravelly soil layers are grouped in a single unit, alternating clayey soil layers and sandy/gravelly soil layers are common features of Layer 3.

3.5 Groundwater Modelling

Model Grid

The modelling domain was selected according to natural hydrogeological boundaries, over an area with x coordinate 378,000 – 418,000 m, and y coordinate 285,000 – 330,000 m (area 40×45 km). Inside the modelling domain rectangular model grid with different length and width of cells has been set-up (37240 cells). The model has a 70×76 cell grid in horizontal direction; with minimum cell size 250×250 m and maximum cell size 2,000×2,000 m. The model has been set up with seven layers in vertical direction.

Aquifer Parameters

Hydraulic parameters of each layer of the model are determined based on the results of pumping tests and laboratory soil tests.

Model Application

A total of nine cases of groundwater extraction, Simulation Variant 0 (SV0) to SV8, was considered to evaluate the influence of the groundwater extraction. SV0 assumes no groundwater abstraction for use and only the Imuda Tin Mine with the extraction of 27,028 m^3/day is under operation. The SV1 corresponds more or less to the groundwater status during the field investigation. Kajibumi WF 1 and WF 2 are not operated, the wells at Megasteel are simulated according to logged data. Total extraction volume is 45,654 m^3/day.

Simulated contour lines of piezometric head and directions of groundwater flow in SV1 indicate, that there exists a large cone of depression around the Megasteel/Amsteel II area and Imuda Mine. The regional groundwater flow is oriented towards this exploitation area. The main inflow of fresh groundwater is coming from northwest and east. The elevation of groundwater level reaches about –10 m.s.l. in the centre of depression (Imuda Mine). The simulated groundwater divide is located very near the seacoast.

The pumping rate scenario in steady-state SV2 is similar to that in SV1; it differs only with consideration of water abstraction from Kajibumi WF 1 and Kajibumi WF 2. This means a small increase of total amount of abstracted water from recent 45,000 to 60,000 m^3/day. SV3 and SV5 assume significantly increased (full) pumping rate from existing well PWM-1 and pumping of two additional wells with pumping rate similar to PWM-1 in Megasteel/Amsteel II property (total amount of abstracted water about 90,000 m^3/day).

An increase of pumping rate in SV2 causes the movement of groundwater divide towards seacoast and creates more suitable conditions for seawater intrusion. Significantly increased pumping with duration for 3 years (SV5) changed the head equipotentials and direction of flow in the main aquifer significantly. Larger cone of depression cause the movement of groundwater divide towards seacoast and creates conditions suitable for intensive seawater intrusion.

Other simulations include, impact of dry season (SV4), impact of reduced groundwater abstraction from Imuda Tin Mine (SV6 and SV7), impact of industrial development (SV8) and pollution transportation (SV2(b)). Simulation was conducted also for land subsidence. Status of seawater intrusion was also analysed.

The results of the simulation show that the present extraction volume is somewhat close to the allowable extraction volume. When the additional extraction is made, there will be influence of seawater intrusion and land subsidence.

4. Significant Pressures and Impacts

For the sustainable groundwater resources and environmental conservation of the Langat Basin, significant pressures were identified, as follows:

- Existence of Industrial Development Corridor along the Langat River in the subject groundwater basin.
- Historical unstable water supply from surface water during extraordinary drought.
- Large-scale groundwater abstraction for industry in Telok Datok - Olak Lempit area, and Large-scale groundwater withdrawal at the Imuda Tin Mine.
- Generally higher iron contents of groundwater of few mg/l and generally high electric conductivity.

Significant impacts on the sustainable groundwater resources and environmental conservation were identified, as follows:

- Arsenic is widely detected in the subject basin especially in the shallower wells, though almost all are under the drinking standard.
- Five (5) kinds of organic compounds were detected by one measurement only out of three (3).
- Wells in coastal area show more than 10,000 μS/cm of electric conductivity. Groundwater in the coastal area is probably not suitable for domestic use. Extent of seawater intrusion to the groundwater basin is still not clear and need further monitoring.
- Notable data of land subsidence for the one year period from June 2000 to August 2001 is 16.46 mm in BM7, 11.10 mm in BM15 and 13.24 mm in BM16. All of these locations are in the area along the Langat River, and near the large consumers of groundwater (Megasteel) and the dewatering process to keep the pit dry for sand mining (Imuda Tin Mine).
- As a result of the groundwater simulation, no effect to the water level in lakes in Paya Indah Wetland Sanctuary are expected. These lakes are assumed sealed by impermeable soils.

5. Environmental Objectives

Environmental objectives of the Sustainable Groundwater Resources and Environmental Management Plan have been set as below, but they should be revised in accordance with the monitoring results.

- Although the sustainable groundwater yield depends upon the mode of groundwater extraction (few large extractions at deeper locations versus scattered smaller extractions at shallower wells), the present level of extraction at around 45,000 m^3/day for large consumers seems close to the sustainable yield at the time of study.

- Organic Compounds should not be detected from groundwater.
- Concentration of heavy metals should be under the drinking water standards.
- Electric conductivity of J7-1-4 at Kanchong Darat should maintain the present level of around 2,000-2,500 μS/cm.
- Annual land subsidence should be less than 15mm (present level). Special attention should be paid to the land subsidence at BM7, BM15 and BM16.

6. Formulation of Sustainable Groundwater Resources and Environmental Management Plan

To achieve the above objectives, the Sustainable Groundwater Resources and Environmental Management Plan has been established. This management plan is composed of the Monitoring Plan that is to obtain data and information on the objectives, Management Information System (MIS) that is a tool with Information Technology (IT) and Human Resources and Institutional Development Plan that is a prerequisite for operation and management of the management plan.

6.1 Monitoring Plan

The objective of the monitoring is to obtain data and information necessary for the execution of the Management Plan.

Regular monitoring proposed for the Sustainable Groundwater Resources and Environmental Management for the Langat Basin consists of the periodical monitoring for the following items: Groundwater Abstraction Volume; Static Groundwater Table; Groundwater Quality; Land Subsidence; and Surface Water Level. Detailed monitoring will be ad hoc monitoring. When some unusual changes occur or some values exceed the given limit, detailed monitoring will be conducted for the specific purpose, location, and item. Though the methodology applied for the detailed monitoring will be the same with those of the regular monitoring, monitoring contents will be determined ad hoc.

6.2 Management Information System (MIS)

The proposed Management Information System (MIS) will include the following four major modules, namely, (i) Data Input and Maintenance, (ii) Monitoring, (iii) Evaluation; and (iv) Dissemination of Information to the Public by Annual Status Report.

Possible users will include: JMG Staff; Staff of Relevant Agencies, i.e., SWMA, DOE, DID, Paya Indah Wetland Sanctuary; and General Public. The level of access to each of the modules will be controlled by the process management part of the system. Functionally, the Annual Report module will be able to access by any internet user.

The Internet Web-application by using ArcIMS (Arc Internet Map Server) has been developed for the MIS. Topographic and thematic maps as well as the other relevant maps have been digitised and prepared in ArcView shapefile format. The available well data are converted into Oracle database and compatible with HIDRODAT that is a database developed by JMG. As hardware environment, ArcIMS Server was newly introduced. PCs used in the study were utilised as Data Server and ArcSDE Server.

6.3 Human Resources and Institutional Development Plan

Organisation

The policy and regulatory function for Selangor State on groundwater will be carried out by LUAS assisted by JMG, the main technical department responsible for groundwater development and management. It is also recommended in this study that JMG be the main depository for information on groundwater development and management.

Pollution control functions on groundwater are vested with DOE. However it is important that the development programme on monitoring wells by DOE is coordinated with that of JMG. In the areas of public awareness programme, research and training, it is expected that JMG will also play an important role. It is also recommended in this study that hydrogeology and groundwater development be prescribed as one of the functions of JMG in the Ministers of the Federal Government order under the Ministerial Functions Act 1969.

Human Resources Development

The main function of the JMG (HQ) will include the policy and programme related matters. It will also be the national centre and depository for groundwater information. The Technical services division in Ipoh will provide specialist groundwater expertise, undertake research and development as well as provide laboratory services. In order to better emphasis and carry out these functions it may be necessary to establish a new hydrogeology unit in both JMG (HQ) and in the Technical Services Division (Ipoh).

The Selangor State JMG will be the main technical agency for groundwater development in the State. It will carry out comprehensive monitoring for groundwater management purposes as well as undertake groundwater development works. It will also advise LUAS on licensing matters and evaluate proposals submitted by private licencees and concessionaires. In order to carry out these functions a new hydrogeology unit is proposed with adequate professional staff to undertake both development work and groundwater management functions.

Institutional Development

Under the proposed amendments to the Geological Survey Act, reference shall be made to the Director General (DG) before commencing work if any persons intends to sink, enlarge, deepen or close a well with an abstraction rate of 2,500 litres per day (l/d) regardless of the purpose of usage. Record of works and test should also be sent to the DG in the prescribed manner. However the approving authority to license a well in Selangor is LUAS. It may also be possible to amend the SWMAE to provide that the

State JMG be consulted before the Authority (LUAS) issues a licence for wells and that records of works and other necessary information on the wells be sent to the State JMG from time to time.

It may also be necessary to have a common definition for purposes of imposing charges for groundwater abstraction. The JMG's proposed definition of a well with an abstraction rate exceeding 2,500 l/d could be used as a common platform.

7. Conclusion and Recommendation

The importance of groundwater resources in the Langat Basin has been increasingly recognised in helping to cope with the water deficit in Selangor State. Thick Quaternary layers are deposited in the flat lowlands spreading the downstream of the Langat Basin. The subject aquifer for the Study, i.e., Simpang Formation of sand and gravel layer, is distributed continuously around 15-20 m below the ground with a depth of 20 to more than 100 m in the lowlands. From topographical and hydrogeological points of view, it is therefore generally viewed that groundwater can be developed economically in this area.

Presently, however, the Government does not restrict groundwater development and private companies can pump up the groundwater at their own risk. Groundwater abstraction through wells construction and dewatering activities in the Basin is estimated to be 45,000 m^3 per day, which is nearly equivalent to the sustainable groundwater yield of the Basin. Groundwater monitoring and modelling reveals that the groundwater abstraction results in lowering the groundwater level around the pumping area.

While groundwater quality in the basin has not been deteriorated yet, the future monitoring especially for heavy metals, such as lead and arsenic, and organic compounds will be of great importance. In addition, seawater intrusion and land subsidence that may affect the environment in the Basin significantly as well as water level in Paya Indah lakes should also be monitored closely as one of the environmental objectives of the Management Plan.

The JICA Study Team recommends that the Government of Malaysia and the Minerals and Geoscience Department Malaysia (JMG) should carry out the Management Plan proposed in the Study to attain the sustainable development and safeguard of the groundwater resources in the Langat Basin. To achieve this aim, the following actions are earnestly recommended:

(1) Establishment of the institutional framework and securing financing for the implementation of periodical and reliable monitoring work;

(2) Establishment of the institutional framework and securing financing for the operation and maintenance of the Management Information System; and

(3) Preparation for establishment of comprehensive standards for groundwater management.

THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

FINAL REPORT

VOLUME 1

EXECUTIVE SUMMARY

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ABBREVIATIONS AND ACRONYMS

1. ORGANISATIONS

ASMA	:	Alam Sekitar Malaysia Sdn. Bhd.
DID	:	Drainage and Irrigation Department (JPS: *Jabatan Pengairan dan Saliran*)
DOA	:	Department of Agriculture
DOE	:	Department of Environment
DSMM	:	Department of Survey and Mapping Malaysia
DWNP	:	Department of Wildlife and Natural Parks
EIU	:	Economist Intelligence Unit
EPU	:	Economic Planning Unit
FOMCA	:	Federal Organisation of Malaysia Consumers Association
IDK	:	*Indah Water Konsortium*
IMF	:	International Monetary Fund
IUCN	:	International Union for Conservation of Nature and Natural Resources
JICA	:	Japan International Cooperation Agency
JMG	:	Minerals and Geoscience Department Malaysia (*Jabatan Mineral dan Geosains*)
JPBD	:	Selangor Town and Country Planning Department (*Jabatan Perancang Bandar dan Desa*)
KLIA	:	Kuala Lumpur International Airport
LESTARI	:	Institute for Environment and Development (*Institut Alam Sekitar dan Pembangunan*)
MACRES	:	Malaysian Centre for Remote Sensing
MIDA	:	Malaysia Industry Development Authority
MLCD	:	Ministry of Land and Co-Operative Development
MMS	:	Malaysian Meteorological Services Department
MOA	:	Ministry of Agriculture
MOH	:	Ministry of Health
MPI	:	Ministry of Primary Industry
MWF	:	Malaysian Wetlands Foundation
MWSS	:	Malaysia Wetland Sanctuary Selangor
NEAC	:	National Economic Action Council
NAHRIM	:	National Hydraulic Research Institute of Malaysia
NWRC	:	National Water Resources Council
PORLA	:	Palm Oil Registration and Licensing Authority
PWD	:	Public Works Department
RISDA	:	Rubber Industry Small Holders Development Authority
SPC	:	State Planning Committee
SSC	:	Swedish Space Corporation
SWD	:	Selangor Waterworks Department (JBA Selangor: *Jabatan Bekalan Air Selangor*)
SWMA	:	Selangor Waters Management Authority (LUAS: *Lembaga Urus Air Selangor*)
UKM	:	*Universiti Kebangsaan Malaysia*
WHO	:	World Health Organisation

2. OTHER TERMS

7MP	:	Seventh Malaysia Plan
BOD	:	Biochemical Oxygen Demand
BS	:	British Standards
CACS	:	Computer Assisted Cartographic Subsystems
CAMS	:	Computer Assisted Mapping System
CAPS	:	Computer Assisted Photogrammetric Subsystem
CARDS	:	Computer Assisted Raster Digitizing Subsystem
CEO	:	Chief Executive Officer
CGIM	:	Customized Groundwater Information Management
COD	:	Chemical Oxygen Demand
CWU	:	Commercial Water Use
DEM	:	Digital Elevation Model
DO	:	Oxygen Demand
DWU	:	Domestic Water Use
EIA	:	Environmental Impact Assessment
EQA	:	Environmental Quality Act
ERM	:	Emergency Response Management
FDI	:	Foreign Direct Investment
GDP	:	Gross Domestic Product
GIS	:	Geographic Information System
GITN	:	Government Integrated Telecommunication Network
GNP	:	Gross National Product
GRDP	:	Gross Regional Domestic Product
GRMP	:	Groundwater Resources and Management Plan
GSA	:	Geological Survey Act
IEA	:	Initial Environmental Assessment
IHP	:	International Hydrological Programme
IHRP	:	Institutional and Human Resource Plan
IIS	:	Internet Information Services
IMS	:	Internet Map Server
INWQS	:	Interim National Water Quality Standards for Malaysia
IT	:	Information Technology
IWU	:	Institutional Water Use
KSAN	:	*Kajian Sumber Air Negara* (National Water Resources Study)
KSAS	:	*Kawasan Sensitif Alam Sekitar* (Environmental Sensitive Areas)
LA	:	Local Authority
LCA	:	Land Conservation Act
LGA	:	Local Government Act
LIS	:	Land Information System
LPA	:	Local Planning Authority
MIS	:	Management Information System
MOU	:	Memorandum of Understanding
MSC	:	Multimedia Super Corridor
NaLIS	:	National Land Infrastructure System
NDP	:	New Development Policy
NDWQSP	:	National Drinking Water Quality Surveillance Programme
NERP	:	National Economic Recovery Plan

NEP	:	New Economic Policy
NGDWQ	:	National Guideline for Drinking Water Quality
NGO	:	Non-Governmental Organisation
NIEs:	:	Newly Industrialized Economies
NLC	:	National Land Code
NTU	:	Nephelometric Turbidity Unit
NRW	:	Non-Revenue Water
NWRS	:	National Water Resources Study (Peninsular Malaysia) 2000-2050
OPP1	:	First Outline Perspective Plan
OPP2	:	Second Outline Perspective Plan
PAP	:	Project Affected Persons
R&D	:	Research and Development
RBIS	:	River Basin Information System
RDMS	:	Relational Database Management System
ROW	:	Right-of-way
RSO	:	Rectified Skew Orthomorphic
SA	:	State Authority
SDBA	:	Streets, Drainage and Building Act
SDE	:	Spatial Databese Engine
SS	:	Suspended Solid
SWMAE	:	Selangor Waters Management Authority Enactment
SWSE	:	Selangor Water Supply Enactment
TA	:	Technical Assistance
TCPA	:	Town and Country Planning Act
TEM	:	Transient Electro-magnetic Survey
TSP	:	Total Suspended Particulate
UIWC	:	Unit Industrial Water Consumption
UPS	:	Uninterruptive Power Supply
WAN	:	Wide Area Network
WSE	:	Water Supply Enactment
WTP	:	Water Treatment Plant
YoY	:	Year-on-year

3. UNITS OF MEASUREMENT

(Length)			(Weight)		
mm	:	millimetre(s)	mg	:	milligram(s)
cm	:	centimetre(s)	g, gr	:	gram(s)
m	:	metre(s)	kg	:	kilogram(s)
km	:	kilometre(s)	ton	:	tonne(s)

(Area)			(Time)		
mm^2	:	square millimetre(s)	s, sec	:	second(s)
cm^2	:	square centimetre(s)	min	:	minute(s)
m^2	:	square metre(s)	h(hrs)	:	hour(s)
km^2	:	square kilometre(s)	d(dys)	:	day(s)
ha	:	hectare(s)	y, yr(yrs)	:	year(s)

(Volume)

cm^3	:	cubic centimetre(s)
m^3	:	cubic metre(s)
l	:	litre(s)
G, gallon	:	0.003785 m^3
mcm	:	million cubic metre(s)

(Concentration)

mg/l	:	milligram per litre
µg/l	:	microgram per litre
meq/l	:	milliequivalents per litre

(Speed/Velocity)

cm/sec, cm/s	:	centimetre per second
m/sec, m/s	:	metre per second
km/hr, km/h	:	kilometre per hour

(Stress)

kg/cm^2	:	kilogram per square centimetre
ton/m^2	:	ton per square metre

(Flow/Discharge)

l/sec, l/s	:	litre per second
m^3/sec, m^3/s	:	cubic metre per second
m^3/yr, m^3/y	:	cubic metre per year
Mld	:	million litre per day
MGD	:	million gallons per day (3,785 m^3/day)

(Electrical Units)

W	:	watt(s)
kW	:	kilowatt(s)
MW	:	megawatt(s)
kWh	:	kilowatt-hour
MWh	:	megawatt-hour
GWh	:	gigawatt-hour
V	:	volt(s)
mV	:	millivolt(s)
kV	:	kilovolt(s)

(Sound)

dB	:	decibel

(Conductivity)

mS/cm	:	milli-siemens per centimetre
µS/cm	:	micro-siemens per centimetre

(Proportion)

%	:	percentage (percent)
$^o/_{oo}$	:	permillage (permilli)

4. MONETARY TERMS

¥	:	Japanese Yen
US$	:	United States Dollar
RM	:	Malaysian Ringgit

5. MALAY TERMS

Bhd.	:	*Berhad*, or Limited
Bt.	:	*Bukit*, or Hill, Highland
Jl.	:	*Jalan*, or Street
Kg.	:	*Kampung*, or Village
Sdn.	:	*Sendirian*, or Company
Sg.	:	*Sungai*, or River
Tg.	:	*Tanjung*, or Promontory

CHAPTER 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

1.1 Background of the Establishment of the Management Plan

Rapid and ultra-large scale development is progressing in the national capital of Kuala Lumpur and the adjoining areas in Selangor State, Malaysia. This is exemplified by the Multimedia Super Corridor (MSC), consisting of the new political and administrative centre at Putrajaya, the multimedia industries' intelligent city at Cyberjaya, the new international airport (KLIA), and related development areas. As a result, emerging are social problems, namely, urban environmental deterioration including water deficit and water quality deterioration.

To cope with the water deficit in Selangor State, the groundwater is considered as a possible supplementary of alternative water source, and some factories already started shifting their water source from surface water to groundwater. Uncontrolled use of groundwater, however, may induce serious environmental problems, e.g. land subsidence, saltwater intrusion to the aquifer, and destruction of swamps due to declining groundwater levels.

The Government of Malaysia then amended the Seventh Malaysia Plan to give the highest priority to groundwater development and environmental conservation in the Langat Basin where MSC is located. This policy was carried over to the Eighth Malaysia Plan, which calls for the formulation of a National Water Policy to provide a framework for water conservation and management. The establishment of a balanced, multi-sector and integrated groundwater resources and environmental management plan is thus deemed urgent.

In response to the request from the Government of Malaysia, the Government of Japan dispatched through the Japan International Cooperation Agency (JICA) a Study Team, on March 24, 2000, to conduct "The Study on the Sustainable Groundwater Resources and Environmental Management for the Langat Basin in Malaysia" (hereinafter referred to "the JICA Study"). The Management Plan was thus formulated, as a result of the JICA Study, in close cooperation with the Minerals and Geoscience Department Malaysia and other relevant agencies.

1.2 Objectives of the Study

The objectives of the Study are:

(1) To formulate a sustainable groundwater resources and environmental management plan ("the Management Plan") for the Langat Basin;

(2) To establish a monitoring system and Geographic Information System (GIS) to support the Management Plan;

(3) To formulate a human resources and institutional development plan for the implementation of the Management Plan, and to be able to utilise the Management Plan for other basins; and,

(4) To pursue technology transfer to counterpart personnel in the course of the Study.

1.3 Study Area

The Study covered the entire Langat and neighbouring southern basins with an aggregate area of 2,750.2 km^2 (see Location Map). The area for groundwater models was the flat lowland located in the downstream part of the Langat Basin.

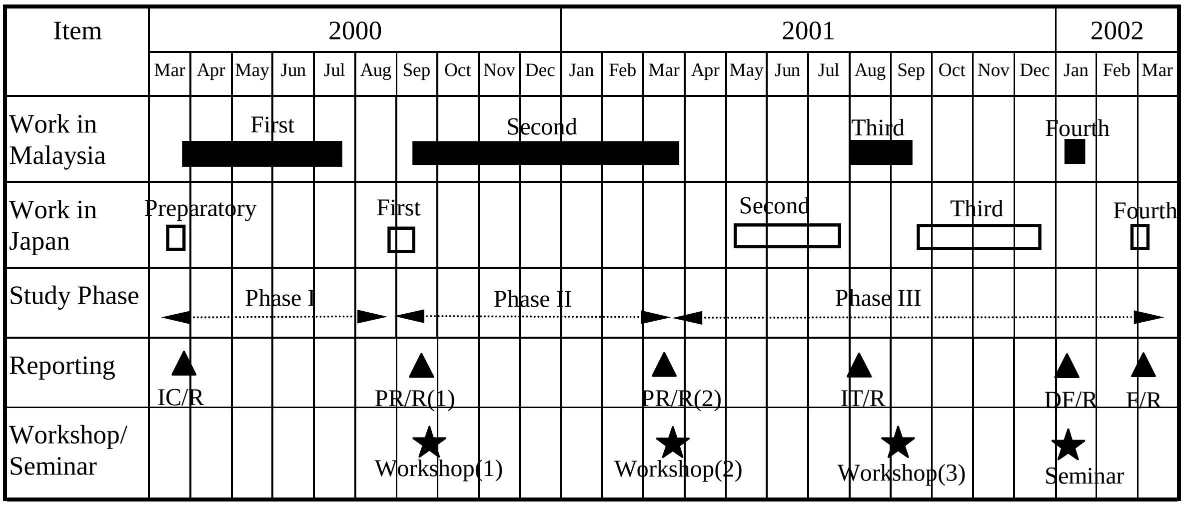
Administratively, the Basin consists of the areas of Kuala Langat District, Sepang District and Hulu Langat District of Selangor State, and the western part of Seremban District of Negeri Sembilan State.

1.4 Implementation Organisation of the Study

A Study Team of thirteen experts organised by JICA had conducted the Study. An Advisory Committee was organised to provide technical advice to JICA. On the Malaysian side, the Minerals and Geoscience Department (JMG) under the Ministry of Primary Industries was the counterpart agency for the Study. JMG established a Project Committee to assist and to deliberate on various issues related to the Study.

1.5 Study Flow

The overall Study flow is as presented in **Figure 1.5.1** below.



Legend: IC/R: Inception Report PR/R: Progress Report IT/R: Interim Report
DF/R: Draft Final Report F/R: Final Report

Figure 1.5.1 Overall Study Flow

CHAPTER 2

GENERAL CONDITION OF THE LANGAT BASIN

CHAPTER 2

GENERAL CONDITION OF THE LANGAT BASIN

2.1 Socioeconomy - Nation to the Basin

2.1.1 National Progress

The 7MP set fourteen targets as development thrust that were deemed to enhance potential output growth, achieve further structural transformation and attain balanced development. Of these, "Sustainable development" means that economic, social and environmental aspects are integrated into the development process. The environment should be improved and resources utilised more efficiently to ensure that improvements in living standards are made without compromising the needs, interest and welfare of future generations.

The Eighth Malaysia Plan (8MP) focuses on achieving sustainable growth with resilience. Strategies has been shifted from the input-driven ones to the knowledge-driven ones in order to enhance the output potentiality, accelerate structural transformation within the manufacturing and services sectors and revitalise the agricultural sector, and strengthen socioeconomic stability. Concerning the environment and resources issues, the 8MP emphasises that they should be treated in an integrated and holistic manner. It is planned that the Government will adopt early preventive measures and will apply the precautionary principle in order to ensure that the development is sustainable and resilient. Measures to address such issues include: Enhancement of the database for environmental decision making by introducing the use of sustainable development indicators; and, Formulation of a National Water Policy to ensure that water resources will be managed more efficiently and effectively.

The Malaysian economy had been growing at a high speed in the 1980s up to mid-1990s. The average growth rate in 1980-1990 reached 5.2% annually and growth rate in 1991-1996 exceeded 9% every year. Malaysia recovered in 1999 the damage by economic crisis in 1997. Economic research institutes predict favourable prospects on the Malaysian economy in the near future. The population of Malaysia is estimated at 22.7 million in 1999. The average annual increases are 2.5% in 1971-1980, 2.7% in 1981-1990, 2.8% in 1991-1995, and 2.4% in 1996-1999.

2.1.2 Selangor State

Due to its strategic location and economic development, Selangor State has set a target to achieve the status of a developed state 15 years earlier than the country's target of Vision 2020. This target is incorporated into Vision 2005 for Selangor. Selangor's development strategies towards Vision 2005 include: increasing development towards areas outside the Klang Valley; and, conservation of natural environment and implementation of sustainable development.

The total GDP of Selangor accounts for around 20% of the national GDP. Selangor's GDP growth rate remarkably reversed from minus 1.54% in 1998 to plus 5.2% in 1999 in accordance with the trend seen in the nation. GDP shares of the industrial and services sectors are 59.0% and 38.5% in 1999 while the agriculture sector has 2.5%. Total population of Selangor State is estimated at more than 3 million in 1998 or 13.6% of the nation. Growth rates are 3.1% in 1997 and 3.3% in 1998, higher than the recent national trend, 2.4%. The development plan is presented in **Figure 2.1.1**.

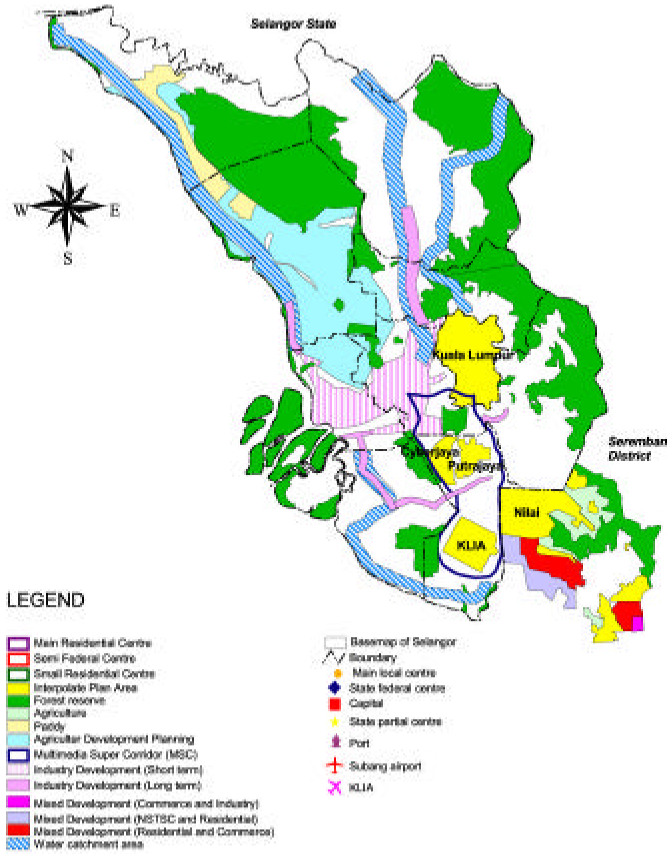


Figure 2.1.1 Development Plan Map of Selangor State and Seremban District

Sources: Town and Country Planning Department of Selangor State, and Seremban District Council

2.1.3 Langat Basin

Langat Basin includes Kuala Langat District, Sepang District and Hulu Langat District of Selangor State, and the western part of Seremban District of Negeri Sembilan State. The industrial sector will play an important role in the development of Kuala Langat District, and three development corridors are proposed in the development plan; namely, Telok Panglima Garang-Banting-Olak Lempit; Morib-Tg. Gabang-Tg. Tumbuk; and Pulau Carey. The development plan also identifies environment sensitive areas that emphasise on low intensity development and green belt to make a balance between physical development and environment. Environmental sensitive areas include preservation of limited and valuable natural resources and potential area for tourism development.

The Multimedia Super Corridor (MSC) is the largest and the only urban development plan in Sepang District and also gives huge influences out of this district to the State as well as the nation. The MSC will also influence the land use development pattern in Hulu Langat District, in addition to the influence made by the development of the Klang Valley. To be emphasised is the development of sectors including high technology related ones, institutional centre, research and development (R&D) centre and tourism. Nilai City, which is in the western part of Seremban District that also include other cities such as Mantin and Labu, is planned to grow as a semi-state centre in 2020 with Mantin and Labu as growth centres. The city is considered to have a potential to develop the "support sector" that gives to other industries services such as banking, insurance, hotels, communications, information technology and transportation.

2.2 Topography, River System and General Geology

2.2.1 Topography

From the topography, the Langat Basin can be broadly divided into three; namely, mountainous areas, hilly areas and flat lowlands from the upstream to the downstream. Groundwater recharging areas are in the upstream mountainous and hilly areas, and an aquifer distributes widely in the flat lowlands.

2.2.2 River System

The Langat River and its left bank tributary, the Semenyih River, originate in the western slope of the mountain ridge penetrating the Malay Peninsula (see **Figure 2.2.1**).

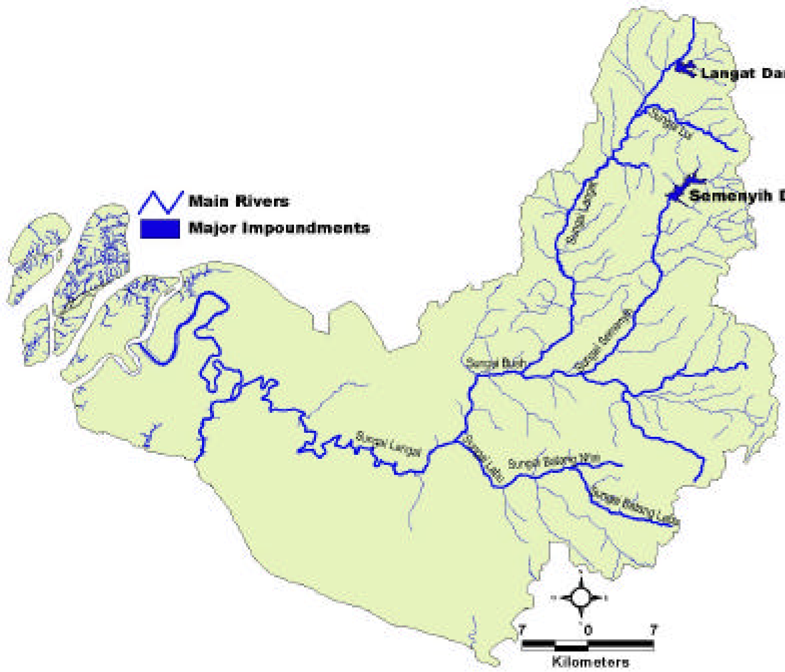


Figure 2.2.1 Main Rivers and its Tributaries in the Langat Basin

Source: LESTARI, 2000.

Both rivers collect water in the mountainous areas and generally flow south-westward in the mountainous terrain. They gradually change their direction to the west after flowing in the hilly areas near Kajang and Bangi, respectively. The two rivers then join, enter the flat land near Kg. Dengkil and flow westward. In some locations the joined river heavily meanders and finally flow into the Straits of Malacca. The total catchment area of the Langat Basin and the neighbouring southern basins is approximately 2,750 km^2.

2.2.3 General Geology

Bedrock in the mountainous area consists of schist and phyllite of Howthornden Formation in Old Silurian and granitic rock of Permian. The granitic rock is mainly found at the upper part of the mountain area. Usually, the granitic rock is covered by 5 to 10 metres thick of highly or completely weathered zone and 5 to 10 metres of lightly weathered zone. (see **Figure 2.2.2**)

Bedrock in the hilly area consists of phyllite, shale and quartzite of Kajang Formation and Kenny Hill Formation. Geology of the lowlands consists of unconsolidated gravel, sand, silt and clay of Simpang Formation of Pleistocene and Gula and Beruas Formations of Holocene. They have been deposited under fluviatile or marine sedimental conditions to fill undulations of the bedrock of Kajang Formation. The lower sand member of Simpang Formation is the Aquifer that is studied in this Study.

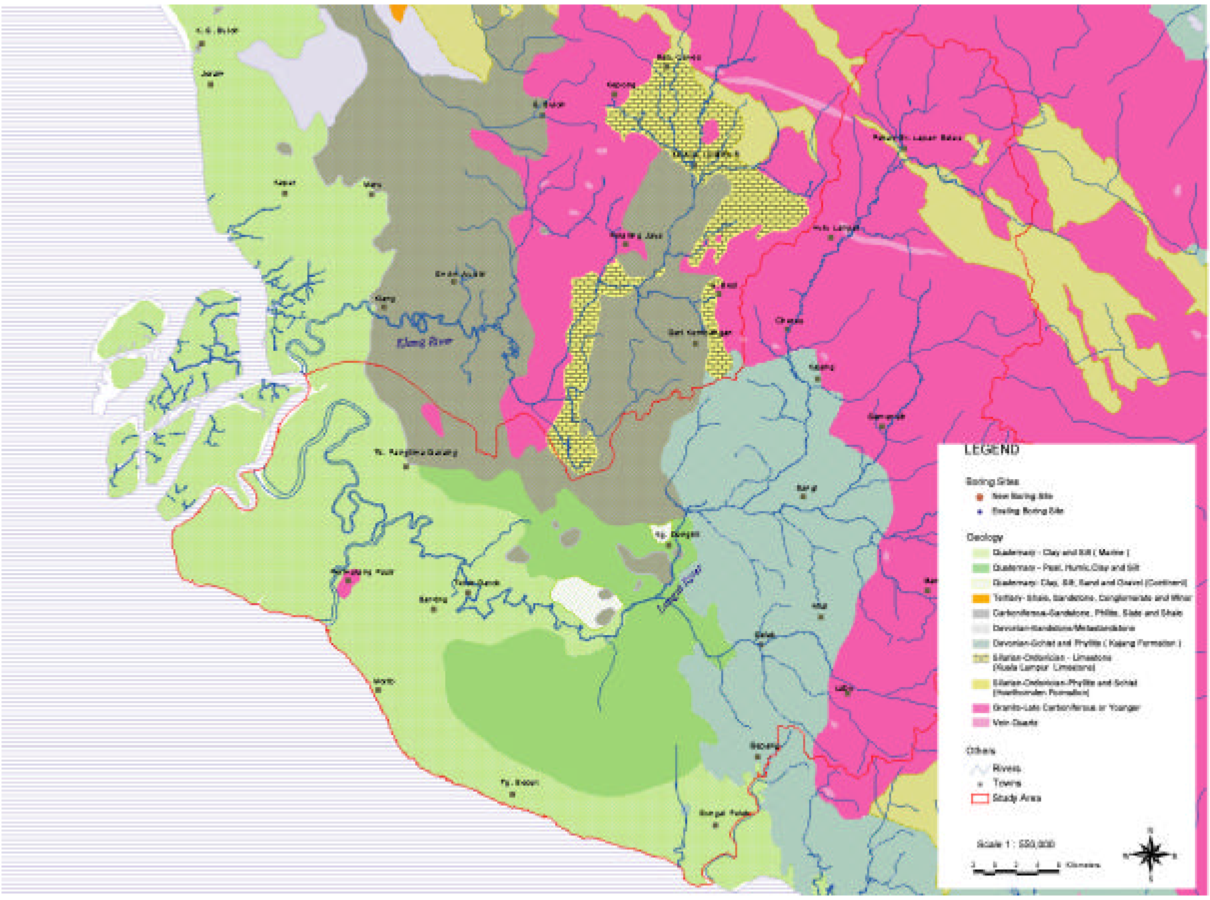


Figure 2.2.2 Geological Map of the Langat Basin

In the low flatlands, thick Quaternary layers are deposited on the bedrock. The Quaternary layer, from the top to the bottom, consists of 0.5 to 5.5 m deep Beruas Formation with peat layer at the top, clayey Gula Formation and Kempadang Formation starting in the hilly areas and having a 40 to 50 m depth near the seacoast. Lying and underneath is the Simpang Formation of sand and gravel with thickness of several metres in the hilly area and about 50 m to more than 100 m in the low flatlands.

The Simpang Formation of sand and gravel layer is the subject aquifer for the present Management Plan. This aquifer distributes continuously around 15-20 m below the ground with the depths of 20 to more than 100 m, and thus it is generally judged that groundwater can be developed economically in this area.

2.3 Land Use and Land Cover

2.3.1 Land Use in 1995

The land use maps published by the Department of Agriculture (DOA) in 1995 at a scale of 1:50,000 covering the whole Langat Basin of 2,750.2 km^2 are digitized and edited through field verification. Present land use is as presented in **Table 2.3.1**.

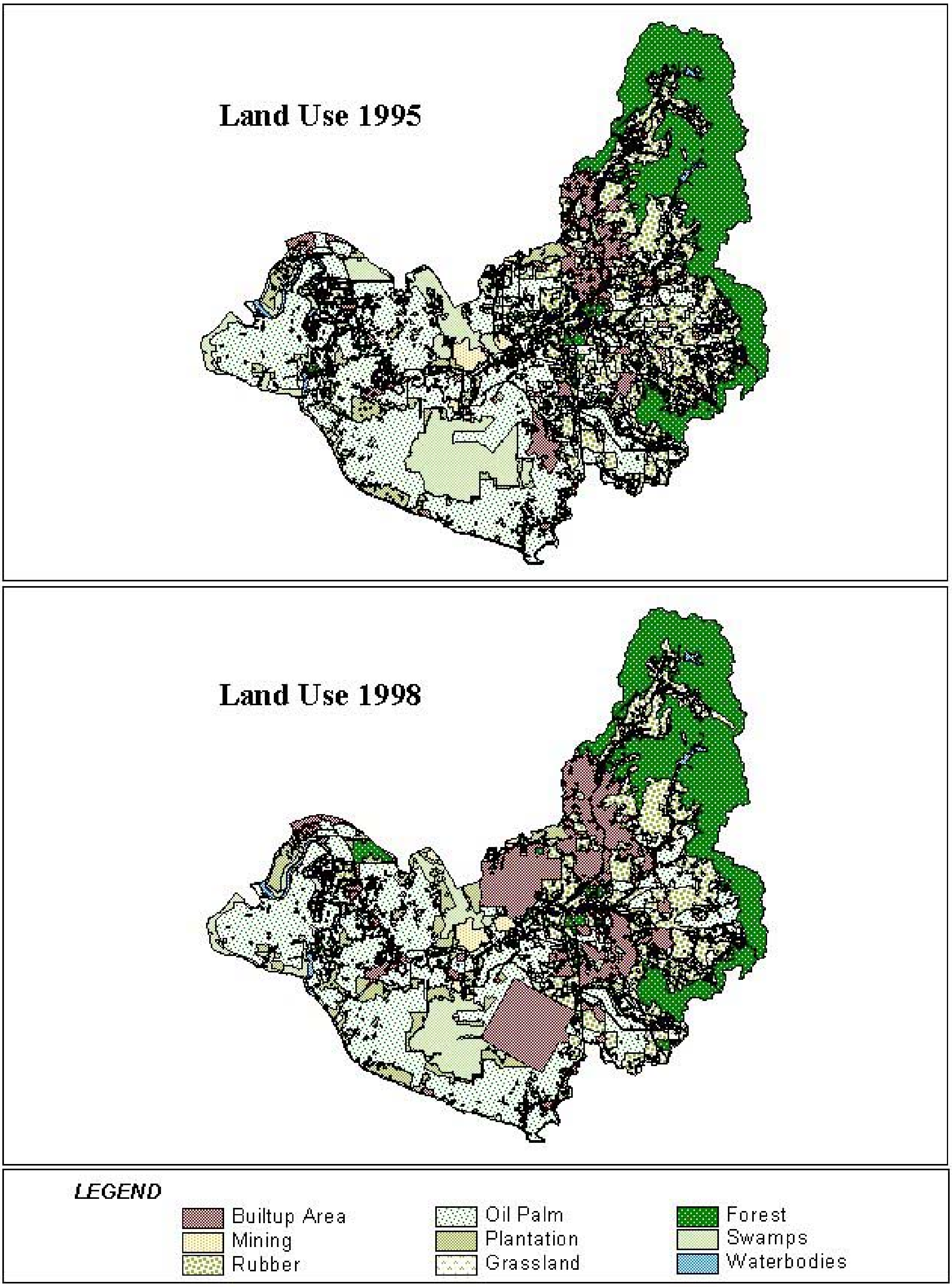
Table 2.3.1 Land Use in the Langat Basin

Land Use Class	LUCODE	No. of Lots	Area (km^2)	Percent (%)
Builtup Areas	1001	530	189.0	6.9
Tin Mining	1002	62	42.4	1.5
Cultivated Land	2001	422	78.6	2.9
Rubber	3001	670	463.9	16.9
Oil Palm	3002	463	929.8	33.8
Coconut	3003	100	39.6	1.4
Other Plantation	3004	329	32.5	1.2
Diversified Crops	4001	96	26.6	1.0
Paddy	4002	24	3.7	0.1
Shifting Cultivation	4003	1	0.1	0.0
Livestock	5001	2	1.1	0.0
Grassland	6001	315	35.3	1.3
Forest	7001	79	478.7	17.4
Shrubs, Bush	7002	173	28.4	1.0
Reclaimed Land	7003	281	32.3	1.2
Swamps	8001	189	275.1	10.0
Unclassified Land	9001	3	1.2	0.0
Water Bodies	9002	140	40.2	1.5
Mixed Use	9999	137	51.7	1.9
TOTAL			**2,750.2**	**100.0**

Source: Digitised Land Use Map of DOA published in 1995

2.3.2 Updated Land Cover for 1998

The digitised DOA Land Use Maps (1995) are updated by using Landsat TM Image of 1998 to produce the Land Cover Map. The Land Cover maps in 1995 and 1998 are compared as presented in **Figure 2.3.1** and the change is listed in **Table 2.3.2**.



Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

Figure 2.3.1

THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

Land Use Changes of the Langat Basin between 1995 and 1998

CTI Engineering International Co., Ltd.

OYO CORPORATION

Table 2.3.2 Land Use /Land Cover Changes in the Langat Basin from 1995 to 1998

(Unit: km^2)

No.	Land Use/Land Cover	1995	1998	Changes
1	Built-up Area	172.2	446.0	255.5
2	Mining	42.4	57.7	15.3
3	Rubber	430.3	350.6	-75.5
4	Oil Palm	929.8	827.3	-102.5
5	Plantation	283.2	300.8	31.7
6	Grassland	69.9	33.3	-36.6
7	Forest	507.1	504.2	-2.9
8	Swamps	275.1	182.4	-92.7
9	Water Bodies	40.2	47.9	7.7
	Total	2,750.2	2,750.2	0.0

2.4 Meteorology and Hydrology

2.4.1 General Meteorology

The Langat River Basin has two monsoons a year, i.e. the northeast and southwest monsoons. The northeast monsoon occurs from November to March while the southwest monsoon occurs from May to September. In between the two monsoons are the two inter-monsoon periods; occurring in April and October. The inter-monsoon months are characterised by variable winds and thunderstorm in the afternoon. The Langat River Basin is on the west coast of Peninsular Malaysia and is generally hot and wet throughout the year without much variation.

The average annual rainfall by station (1985-90) in the Langat Basin ranges from approximately 2,200 to 2,700 mm. It gradually increases from the coast towards the mountain areas (see **Figure 2.4.1**). Although the monthly rainfall patterns are different by location, two peaks in the year are pronounced, namely, around March to April and around September to October with the amount of approximately 300 mm. The monthly rainfall amount in the driest season is around 100 mm.

The temperature throughout the year is quite constant with a mean of 27°C and ranges from 24°C to 32°C. The high temperatures are expected in April and May while the low temperatures are experienced in November and December. Variation of the relative humidity throughout the year is also small with an average value of 82%. Seasonal maximum sunshine occurs in February-March and June-July. The duration of sunshine hours per day is quite constant for the whole year and daily sunshine-hours ranges from 3.5 to 6.7 hours. The evaporation depth for open water is measured to be around 1,500 mm per year and monthly mean of around 125 mm. The highest evaporation occurs in February-March and the lowest evaporation occurs in November-December although the difference is very small.

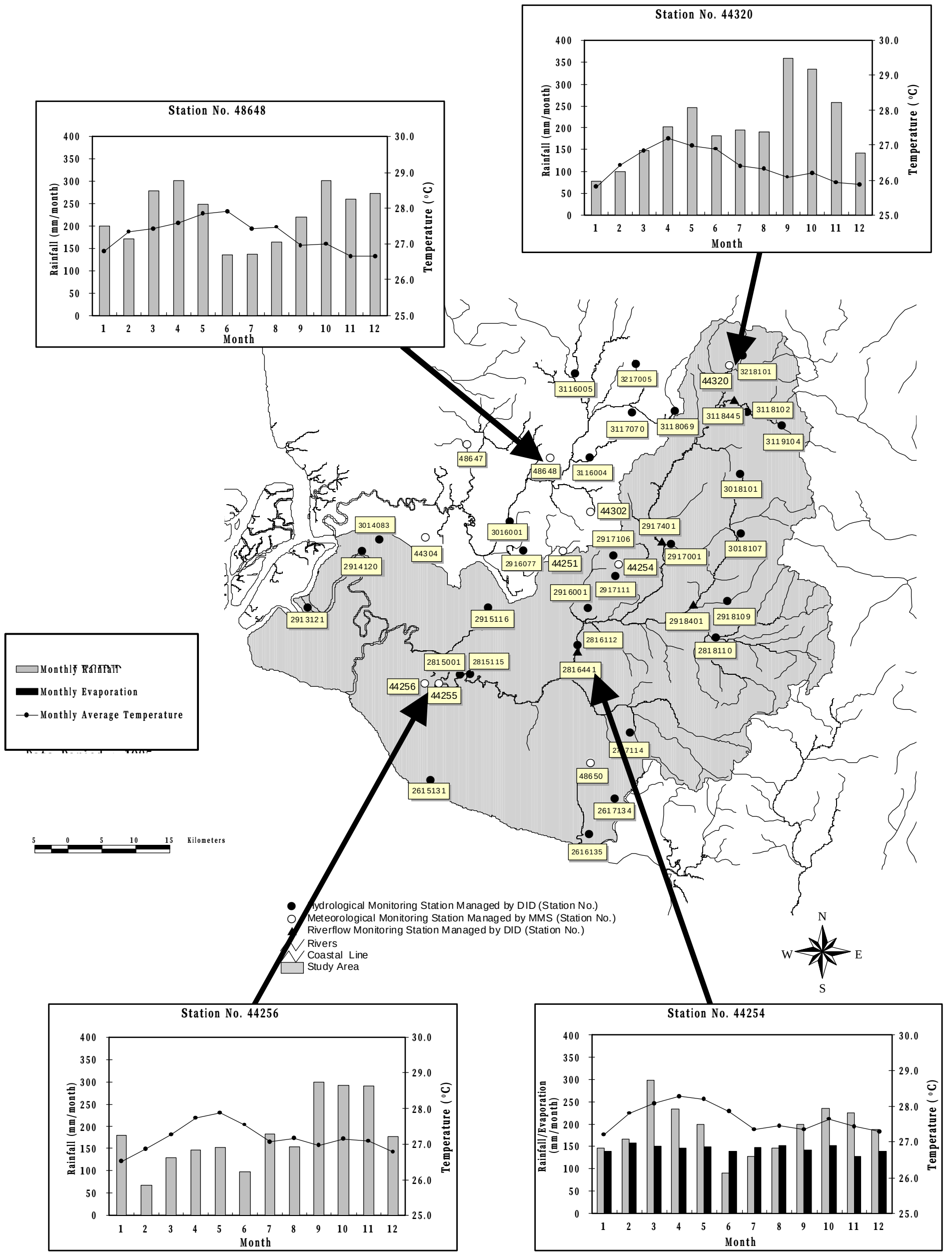


Figure 2.4.1 Monthly Variation of Temperature, Rainfall and Evaporation in the Langat Basin
Source: Data provided by Drainage and Irrigation Department (DID) and Malaysian Meteorological Service (MMS)

2.4.2 Annual Water Balance in the Basin

Annual water balance study has been conducted for the Langat River Basin for the total basin of Upper Langat, Semenyih and Middle Langat with the catchment are of 1,281 km^2.

Annual groundwater recharge height was estimated at 108 mm as a balance of the annual rainfall of 2,238 mm and the estimated annual evaporation of 1,284 mm and the annual discharge height of 846 mm. The volume of groundwater recharge at 108 mm a year is

4.8% of the annual rainfall. The groundwater recharge height at 108 mm can be converted to the total amount of 139 million m^3 from the area of the catchment basin at 1,281.1 km^2.

The volume of groundwater recharge was also simulated using the Tank Model for the same basin and the same period at an annual average of 111.5 mm and equivalent to 142.8 million m^3 or 5% of the total rainfall in the area.

2.5 Water Demand and Supply - Nation to the Basin

2.5.1 National Water Resources Study

The National Water Resources Study (NWRS) was carried out for planning, development and management up to 2050 of the overall water resources of Peninsular Malaysia. The water demand and supply plan was proposed in this study.

2.5.2 Selangor State

NWRS proposes supply/demand scenarios with recommended source works for 2000-2050. Proposed future source works include Sg. Selangor Scheme Phase 3, Southern Interstate Transfer from Pahang, Northern Interstate Transfer from Pahang and Bernam Dam. In drawing up the scenarios, NWRS considers the following conditions:

Water shortages are almost certain to occur after 2004 mainly in the southern part of the State where continuing demands will be generated by the infrastructure development for the Multimedia Super Corridor. Thus, priority is given to the Southern Selangor Transfer from Pahang. Southern Selangor Transfer from Pahang will supply more than enough water to the southern part of the State such as Hulu Langat, Sepang and Kuala Langat. It is also planned to supply water to Negeri Sembilan to cover the shortage in Seremban District and Port Dickson District from 2005. Further, it is also expected to satisfy the shortage in Klang Valley with the Northern Selangor Transfer from Pahang.

2.5.3 Langat Basin

NWRS estimated that the population in the three districts in the Langat Basin would exceed one million in 2005 and two million in 2035. NWRS projected the demands of the three districts in estimating the total demand in the Selangor State, which is necessary to draw up the entire supply plan of the State. In the demand forecast, three scenarios, namely, low, planning and high, were considered as follows: The low scenario is based on the natural population growth. The planning scenario considers the potential high growth rates in population as a result of possible increase in in-migration and development. The high scenario represents the limit that will be assumed in considering possible additional source requirements. It increases the low population growth rates by 1.0% points in 1997-2020 and by 0.4% points in 2020-2050.

In addition, "Pahang-Selangor Raw Water Transfer Project Engineering Services and Detailed Engineering Design" reviewed the demand forecast only for the years of

2000-2020 in August 2000, considering recent economic situations. In this supply plan, the demands of the three districts are fulfilled with the water sources of Langat Basin including Langat WTP, Semenyih WTP and other minor WTPs. Its supply is to be powered by the Southern Interstate Transfer from Pahang from 2007 as expected. The construction of Kelau Dam is very critical for the demand-supply balance in Langat basin. (See **Figure 2.5.1**)

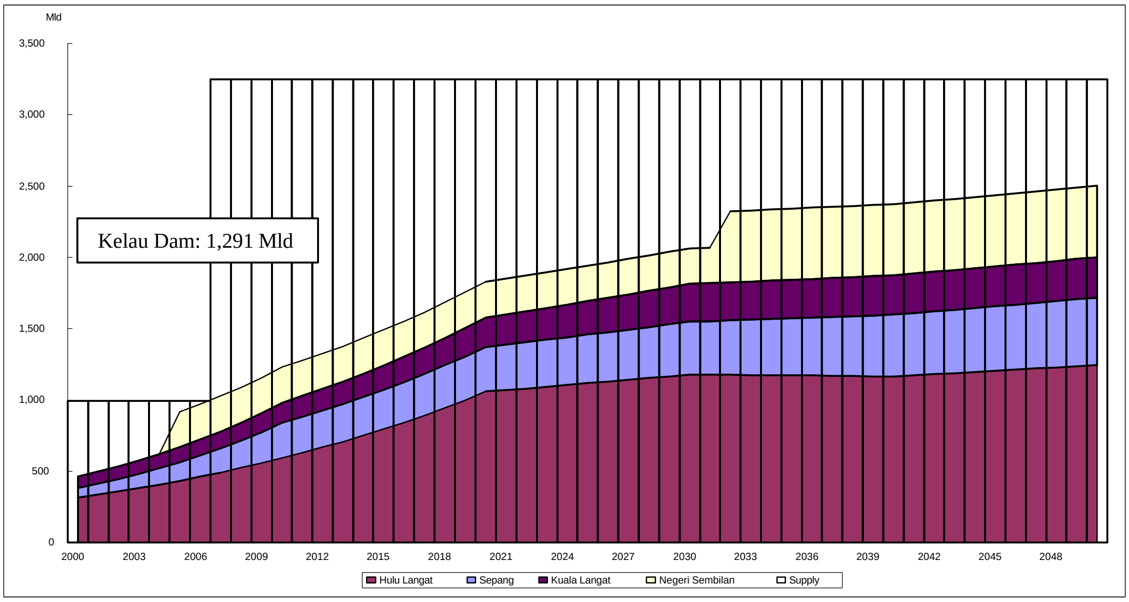


Figure 2.5.1 Demand and Supply Plan in the Langat Basin

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), State Report Volume 12 Selangor*, March 2000, Public Works Department Malaysia and Selangor State Water Supply Department.

Note: NWRS report gives demand figures only in the years of 2000, 2010, 2020, 2030, 2040 and 2050. Those in other years are calculated by interpolation method by the Study Team.

2.6 Information Technology

2.6.1 National Infrastructure for Land Information System (NaLIS)

NaLIS has been established to support the sharing of information among producers and users of land data. With the establishment of NaLIS, all land related agencies, which have been developing standalone information systems since the 1970s, were linked together in a network for communication. The NaLIS Clearinghouse Server was set up in the Land Information Infrastructure Unit, Ministry of Land and Co-Operative Development (MLCD). The management of NaLIS Clearinghouse is handled by the Clearinghouse Technical Committee, comprised of all land related data providers and users. JMG is one of the member agencies, and it is responsible for geological, mining and geo-technical information.

2.6.2 Information Technology (IT) Strategy of JMG

The five-year strategic plan of JMG, includes the use of IT to enhance planning and implementation capabilities of the Department. The plan further addresses international standard quality data and information services strategies, and analyses personnel, hardware/software status. Of these, data information strategy is mentioned as follows: Data gathering will be client and needs driven; agency-owned data/information will be organised and efficiently managed; and IT-driven systems will be utilised for delivery of information to satisfy the wide range of client's needs. The information management activities are the archiving of information; the development, integration and management of databases, particularly in the use of GIS; and the dissemination and delivery of information using advanced IT systems.

2.6.3 Existing Systems of JMG

JMG has set up a GIS Unit in the Head Office in 1994. A Unix version of ARC/INFO 7.2.1 with TIN optional module, and a Windows version of ArcView 3.0a with Spatial Analyst extension are the GIS software used in the GIS Unit. Relational Database software Oracle is installed on the Unix machine and dBase is installed on two PC platforms. The system is connected with the JMG-LAN. Two NaLIS workstations, one with ArcView 3.2 and the other with ArcView IMS (Internet Map Server) are installed in the GIS room. However, ArcView IMS was migrated to ArcIMS at the beginning of the year 2001.

Hydrological Database (HYDAT) and Geochemical Database (GeoCHEM) have been established in JMG. HYDAT consists of Well information and GeoCHEM consists of chemical analysis data from the laboratory. Modifications were made with the objective to develop HYDAT to a Groundwater Database at National level (HIDRODAT). A data input and updating tool (JMG Database Information System Version 4.1.3) has been developed in the Oracle based Client/Server system environment. The JMG Head Office will manage the newly developed HIDRODAT database, and the State offices will maintain their respective data, which are identified in the database by WELL_NO. In the future, a web-based on-line database maintenance system is being considered.

2.6.4 GIS and IT of Other Related Agencies

"Malaysia: the Way Forward (Vision 2020)" was presented in 1991 with an objective to get Malaysia a fully developed country by the year 2020. The State of Selangor has set the target (Vision 2005) to achieve the status of a developed state 15 years earlier than the country's target. Information Technology (IT) is emphasised at Ministerial, Departmental, and States levels. A series of GIS application study projects have been carried out. Internet/Intranet infrastructure is in place in many organisations.

2.7 Institutional Aspects

2.7.1 Laws and Regulations Affecting Groundwater Development and Management

While there are several laws related to the development and management of water in the country, there is at present no comprehensive legislation on groundwater use and management. Relevant aspects of groundwater management and development are found in several pieces of legislation.

The Federal State's jurisdiction over water is governed by the Constitution. Generally, water including water supply, rivers, canals, control of silt and riparian rights fall under the State List except for federal works related to water supply, rivers and canals not wholly within the state or regulated by agreement between states. The Federal Government however has executive authority on matters given in the State List pertaining to inquiries, surveys and statistics, as well as conduct research, provide technical assistance, give advice and inspect a state department. There are a number of provisions in the related legislations that confer ownership of water on the State. These include those in the Federal Constitution, the Waters Act, the National Land Code, the Mining Enactment, and the Selangor Waters Management Authority Enactment (SWMAE).

Legislations that empower the conservation of water resources include provisions in the Land Conservation Act (LCA), Forestry Act, Town and Country Planning Act (TCPA), SWMAE, and Selangor Water Supply Enactment of 1997. There are also a number of provisions in the SWMAE 1999 relating to water resource conservation.

The legal provisions for pollution control are found in a number of related Acts. The principal act governing pollution control is the Environmental Quality Act of 1974. The Act calls for the establishment of the Environmental Quality Council and confers the licencing authority under the Act on the Director General (DG). The Ministry of Health (MOH) first established a committee on water quality surveillance in 1982 for the purpose of developing guidelines for safe potable water. Subsequently, a National Drinking Water Quality Surveillance programme (NDWQSP) was started in 1983, and yearly reports on water quality status were compiled and published.

The law on groundwater management and control is currently not consolidated into a single comprehensive legislation. Provisions on groundwater are found in the SWMAE, the Geological Survey Act (GSA) and the proposed related rules, the Water Supply Enactment of Selangor and the Environmental Quality Order of 1987. Under the Geological Survey Act of 1974, the DG of Geological Survey has to be notified if any person sinks a well to extract water. There is no need for a notification if: the well is less than 30 feet deep without reaching bedrock; yield is less than 500 gal of water/day; and the well is used only for domestic purposes. At present, there are proposals to amend the Geological Survey Act (GSA) to include the following provision:

(1) Any person who intends to sink a well, enlarge, deepen or close a well shall refer to the DG of Geological Survey before commencing work.

(2) A well is defined as one with an abstraction rate exceeding 2,500 litres per day (l/d) regardless of the purpose the water is used. This is more in line with the provisions in the WSE.

(3) Person sinking a well shall keep records of all works and test, and send a copy to the DG in the prescribed manner.

The Department has also prepared draft regulations for well drilling, groundwater abstraction and groundwater monitoring. For both well drilling and groundwater abstraction, the rules require an application for a licence to be first obtained from the government agency.

2.7.2 Federal Level Organisational Framework

Minerals and Geoscience Department (JMG) is the technical department responsible for groundwater. The main functions of the department among others is to advise the Federal and State Government Agencies on policies and technical matters relating to minerals and geosciences. Other specific functions include the following: undertake engineering geology investigations; investigate and develop groundwater resources; and, prepare thematic maps on geological, geochemical, hydrological, geophysical and mineral resource maps.

A Director General heads the Department, assisted by two deputy director generals. The Department has 10 state branches including Sabah and Sarawak. The main divisions in the department are: Coordination, Operations and Implementation; Corporate and Mineral Economics; Technical Services; and Mineral Research Centre. These divisions are further divided into operational units. Logistically, the headquarters, the State offices and the Ipoh Office carry out the functions of the Department. The headquarters is responsible for policy advice, coordination, corporate affairs and mineral economy. The state offices are implementing agencies while technical services and mineral research are carried out at the Ipoh Office.

The Department has the total staff of 1,137, out of which 324 are in the professional and management group. Most of the professionals are geologists, geophysicists, geochemist mining engineers and research officers. The Department has also developed technical competence in the field of hydrogeology. Currently, the groundwater and hydrogeology unit of the Department is located in the Ipoh Office.

There are currently about 10 trained hydro-geologists with the Department. Emphasis on this area in the future will be given to the following issues: Systematic groundwater resource assessment; Exploration and development of groundwater as an alternative water resource in water stress areas; Development of a hydro-geological database; and Preparation of groundwater resource maps and other hydro-geological maps.

Other federal level organisations related to groundwater management include: Economic Planning Unit (EPU), Ministry of Primary Industries, Public Works Department (Water Supply Branch), Department of Environment (DOE), Drainage and Irrigation Department (DID), Malaysian Wetlands Foundation (MWF) and water related councils.

2.7.3 State Level Organisational Framework

The Selangor Waters Management Authority (SWMA) was established by way of a state enactment. The Enactment (SWMAE) provides for the management and protection of river basins, water bodies, groundwater, coastal waters and wetlands, and for the sustainable development of water sources in any designated area including catchment areas and river basins.

Minerals and Geoscience Department, Selangor is a branch of the Federal department. Groundwater development is part of the functions of the Geoscience Unit. There are two posts for hydrogeologist approved for the Department in recognition of the importance of this sector in the Klang Valley, which had faced a water crisis recently. The department will have the total staff strength of 50 personnel out of which 13 will belong to the professional and management group.

2.7.4 Local Level Organisational Framework

Local Authorities are a state responsibility. Local Authorities are responsible for urban drainage, sanitation, town planning and building control. The Local Authority issues the planning permission for any development before the commencement of development. Hence, housing projects, industrial estates, petrol stations and landfill sites have to be approved by the Local Authority, all of which may have an impact on the groundwater regime. The local authorities within the study area are: Kajang Municipal Council; Sepang District Council; Kuala Langat District Council; Seremban District Council; Parts of the Klang Municipal Council area; and Putrajaya. Other important management bodies in the study area include Cyberjaya and the Kuala Lumpur International Airport.

2.7.5 Current Practices on Groundwater Extraction and Management

The government is committed towards the sustainable development of water resources. The 7th Malaysia Plan had recognised that in order to meet the increasing demand for domestic and industrial water, the building of dams further upstream and the increased use of groundwater are necessary. The Government established the National Water Resources Council in 1998 to serve as a coordinating council of water related issues involving both the Federal and State governments. This council is entrusted with the responsibility of formulating the National Water Policy. Included in the policy directions is "Explore opportunities for the development of groundwater resources." The National Economic Recovery Plan had also expressed strong recommendations on the conservation of water and the sustainable utilisation of groundwater.

The charge in Selangor for domestic consumption was 42 sen for the first 15 m^3 of water. This has been increased effective on the 19th day of April 2001 to 57 sen/m^3 for the first 20 m^3 and progressively increased to 91 sen per m^3 for water consumption of 21-35 m^3 and at RM1.70 per m^3 for consumption exceeding 35 m^3. The SA first approves the tariffs before they are implemented. The SWMA is also looking into the prospect of imposing a charge of about 4 sen/m^3 for raw water abstraction. Similarly, it is also possible to impose a charge for raw groundwater abstraction and a separate charge for treated groundwater.

The development budget generally includes budgets for implementing projects and undertaking feasibility studies. Development budget for hydrogeology activities of JMG was only about RM1.37 million in 1999. In view of its enhanced role in groundwater development JMG had requested for a higher development budget for hydrogeological activities to about RM12.1 million under the 8th Plan (2001-2005).

CHAPTER 3

GROUNDWATER STATUS

CHAPTER 3

GROUNDWATER STATUS

3.1 Groundwater Quality

The present status of groundwater quality of the subject groundwater basin obtained through the field and laboratory investigations is summarised as below. (For location of sampling points, see **Figure 6.2.1**).

3.1.1 pH

Values below pH 5 can be observed mainly in surface water near the Paya Indah area. Three observation points in the Kuala Langat North Forest Reserve, namely, S3, S4 and S5 that are located 3km north of Paya Indah showed low pH ranging from 3.9 to 4.7. In terms of groundwater in this area, it is assumed that the highly acidic surface water has significantly reduced the pH values of the groundwater to the range of 4.5 - 4.7.

3.1.2 Electric Conductivity

In the south and along the Langat River, high electric conductivity that is more than 500 μS/cm was observed. Marine sediments in the area such as Gula and Kempadang Formations may cause this high conductivity. Saltwater coming from the river and shoreline may also contribute to conductible condition of the groundwater. Especially, wells in coastal area, i.e., J8-1, J8-2, J9-1 and J9-2, showing more than ten thousand μS/cm, are actually located in the interface between fresh and saline waters. It is estimated that the seawater intrudes at least 2km inside from the shoreline.

3.1.3 Total Iron

All total iron values except for nine samples out of 109 exceed the mandatory level of iron values specified in the Malaysian National Drinking Water Guidelines (October 1983), i.e., 0.3 mg/l. Iron is a common constituent of many primary minerals, such as biotite, pyroxenes and amphiboles. It is assumed that geochemical conditions of the study area may result in predominant distribution of ferrous and ferric irons although it is not confirmed that these minerals clearly exist in the area. While observed values are fluctuated among the three measurements, S1 and S6 that are situated in active mines have relatively low concentrations of iron.

3.1.4 Heavy Metals

In terms of mercury (Hg), arsenic (As), lead (Pb), chromium (Cr), copper (Cu) and zinc (Zn), higher concentrations than the Drinking Water Quality Standards in Malaysia can be observed in arsenic, mercury and chromium, while the copper and zinc values do not exceed the Standards at any well and surface water sample. Well MWD10 shows the lead value of 0.08 mg/l exceeding the Standards of 0.05 mg/l; however, this is a solitary well that has the exceeding limit and is the only one sample out of 86 samples.

Regarding mercury, concentrations of 12 wells (38% of a total of 32 wells) exceed the Standards of 0.001 mg/l. The mercury values are generally high in the Basin. It has been reported that slime in ponds at abandoned mines in the Kinta Valley, Perak, indicates higher concentrations of heavy metals such as mercury and cadmium. It has also been discussed that high arsenic content in the soil could result from the breakdown of pyrites and arsenopyrites in soil. It is another possibility that detection of mercury, lead and zinc, on the other hand, may be related to fertiliser inputs.

There are seven wells (22%) that indicate arsenic values exceeding the Standards of 0.05 mg/l: J2-1-2 and J2-1-3 in Paya Indah; J5-2-2 in Kajibumi Well Field 2; J7-1-2, J7-1-3 and J7-1-4 in Kanchong Darat; and J10-1-1 at the east of Paya Indah. These areas were used for agricultural purposes before or are now used for plantations. Some of the earliest uses of arsenic compounds were as pesticides and herbicides. Lead arsenate was commonly used to control insect pests in orchards and sodium arsenite was employed to defoliate seed potatoes and clear aquatic weeds. Arsenic was widely detected in the study area while some were under the limit for drinking water. Higher concentrations of arsenic come out mostly from shallower wells in the study area. This may be some indication that the arsenic content is infiltrated into the groundwater from the surface. It may be, therefore, considered that use of pesticides and herbicides is associated with the widespread distribution although another possibility may come from natural contribution of pyrites and arsenopyrites in soil.

3.1.5 Organic Compounds

Detected organic compounds are listed in **Table 3.1.1**. Only four wells, namely J7-1-2, J7-1-3, J8-2 and J9-1, gave five (5) kinds of compounds. Due to their toxicity, carcinogenicity and the effects of reaction with the natural system, both natural and man-made organic compounds must not be detected in drinking water even if the detected level is minimal.

Xylenes comprising three isomers exist, i.e., meta (m-), para (p-), and ortho (o-) Xylene, are used for gasoline, solvents, pesticide, and production of polyester resin and medicine. Trimethylbenzene is mainly applied for solvents. Napthalene and methylnapthalene are also used for insecticides. Detection of chlorinated solvents that primarily consist of the aliphatic compounds tetrachloroethene, trichloroethene and 1,1,1-trichloroethene was not made in the measurements. Continuous periodical observation of these compounds will be indispensable because a relatively small amount of chlorinated solvent can impact very large quantities of groundwater and affect a wide area of the aquifer.

Table 3.1.1 Detected Organic Compound in Groundwater and Surface Water

Organic Compound	No. *[2]	Concentration (μg/l)			
		J7-1-2	J7-1-3	J8-2	J9-1
m & p-Xylene	1	ND*[1]	ND	ND	ND
	2	ND	**14**	ND	ND
	3	ND	ND	ND	ND
o-Xylene	1	ND	ND	ND	ND
	2	ND	**6**	ND	ND
	3	ND	ND	ND	ND
1,2,4-Trimethylbenzene	1	ND	ND	ND	ND
	2	**9**	**11**	ND	ND
	3	ND	ND	ND	ND
Napthalene	1	ND	ND	ND	ND
	2	**3**	**4**	ND	ND
	3	ND	ND	ND	**2**
2-Methylnapthalene	1	ND	ND	ND	ND
	2	**4**	**5**	ND	**5**
	3	ND	ND	**3**	**4**

Note: *[1] "ND" stands for not detected.
*[2] "No." means time of measurement.

3.1.6 Water Classification

The composition of dominant ions can be displayed graphically by several methods. **Figure 3.1.1** shows a Piper diagram. Based on the diagram, samples from groundwater and surface water in the study were classified into the types shown in **Table 3.1.2**.

Table 3.1.2 Water Classification of Samples from Groundwater and Surface Water in the Study

Type		Point (Sample) Name	
		Groundwater	Surface Water
I	$Ca(HCO_3)_2$	J2-1-2, J10-1-1	S9
II	$NaHCO_3$	J5-2-2, J7-1-2, LED2, MW14	-
III	$CaSO_4$ or $CaCl_2$	-	S1, S3, S4, S7, S8, S10
IV	Na_2SO_4 or NaCl	J3-1, J3-2, J5-2-3, J7-2, J8-1, J8-2, J9-1, J9-2, MWD1, MWD2, MWD5, MWD6, MWD7, MWD8, MWD9, MWD10	S2, S5, S6
V	Intermediate	J1-1-1, J1-1-2, J2-1-3, J7-1-3, J7-1-4, J10-1-2 MWD4, MW1	-

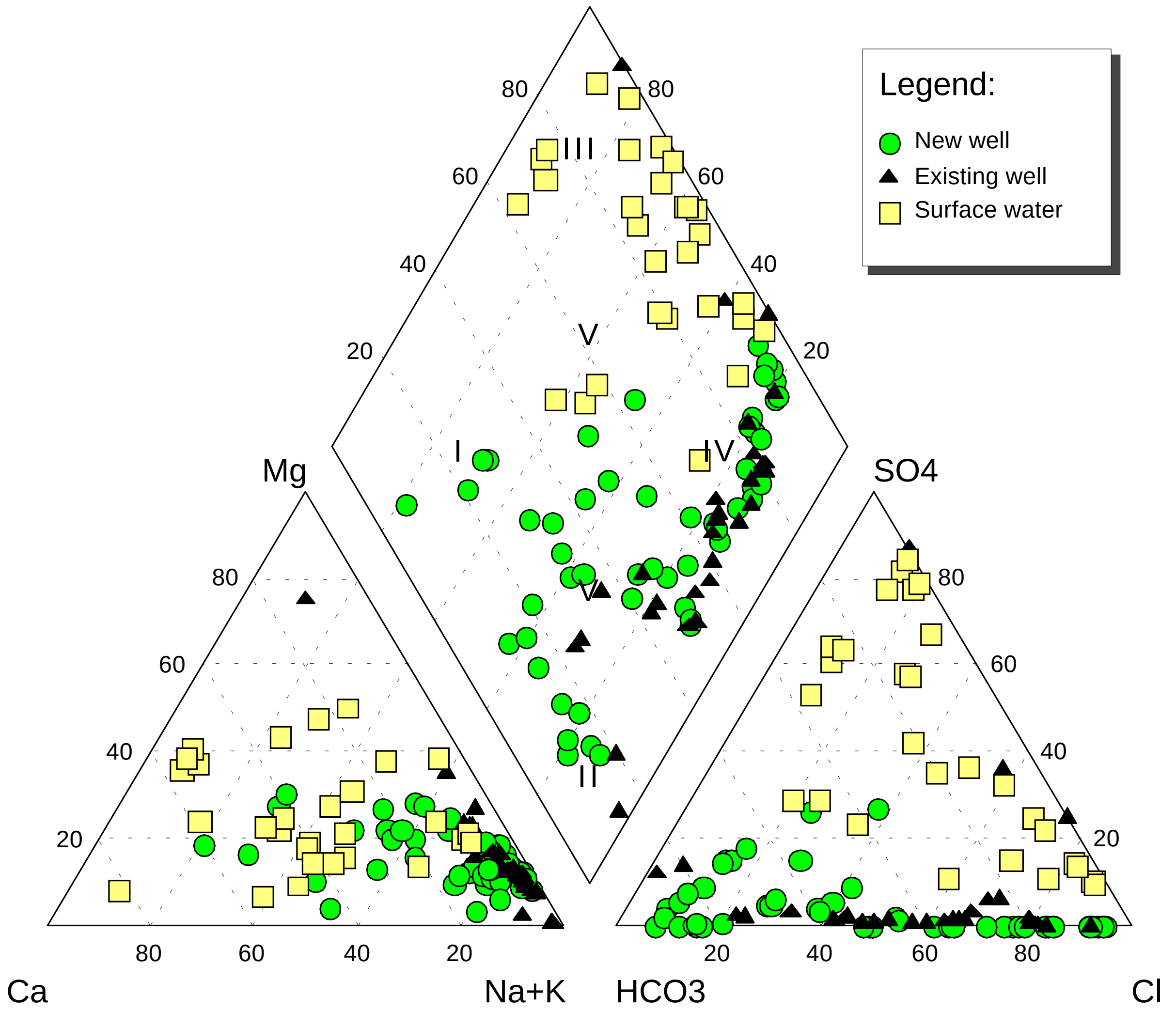
Na_2SO_4 or NaCl type (Type IV) and intermediate type (Type V) of water is dominant for the groundwater, i.e., 80% of the wells, while six locations out of ten are classified into $CaSO_4$ or $CaCl_2$ type (Type III) for the surface water. Na_2SO_4 or NaCl type of groundwater usually can be seen near the coastal area since this kind of water contains seawater in many cases. In addition to wells J8-1&2, and J9-1&2 that are located at about 2km and 500m from the shoreline, respectively, and JMG monitoring wells such as MWD1, MWD2, MWD5, MWD6, MWD7, MWD8, MWD9 and MWD10, may be more or less influenced by seawater.

On the other hand, $CaSO_4$ or $CaCl_2$ type (Type III) of water is categorised into unique surface water or groundwater. This type of water is generally mixed with spring or mineral water as well as industrial wastewater. At the sampling sites of S1, S3, S4 and S5, it is assumed that the water quality is affected by surrounding mining activities.

While most of the groundwater circulating in Japan is classified into $Ca(HCO_3)_2$ type (Type I) of water in general, there are only two (2) wells in this type in the measurement. Groundwater in a limestone aquifer tends to be in this type. $NaHCO_3$ type (Type II) of groundwater typically exists in a stagnant condition, and consequently it can often be derived from a relatively deep well. There are four (4) wells in this type, namely, J5-2-2, MW14, J7-1-2 and LED2. Contrary to this tendency, these wells were built in shallow depths; that is, water from these wells come from sand layers in depths of 10 to 18 metres.

3.1.7 Potential Pollution Sources

There are a total of 30 industrial estates in the Langat Basin. Electric and electronic industries predominate followed by industries manufacturing industrial and engineering products, furniture, textiles and fabrics, and building materials and chemicals. The main activity of agriculture is dominated by palm oil plantation, followed by rubber, piggery, poultry, aquaculture, cattle and orchards. There are many types of pesticides being used mainly to control weeds, insects, rats and other pests. Those composed of Glyphosate isopropylamine are the major biocides used for agriculture. Fertilisers used in the palm oil industry are reported as Guthrie Natural Fertiliser, borate, nitrite acid, rock phosphate (C.I.R.P), etc. Other potential pollution sources include mines, solid waste landfill site, wastewater treatment plants, and petroleum storage tanks of the petrol station.



Water Classification

I: $Ca(HCO_3)_2$ Type

II: $NaHCO_2$ Type

III: $CaSO_4$ or $CaCl_2$ Type

IV: Na_2SO_4 or NaCl Type

V: Intermediate Type

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Figure 3.1.1

Piper Diagram of Major Ions in Groundwater and Surface Water in the Study Area

3.2 Groundwater Usage

The largest abstraction of groundwater for industrial use in the country is at the Megasteel/Amsteel factory at Brooklands Estate in Kuala Langat District. The groundwater potential at this site has been proven and, when the factory is running at full capacity, about 40 Mld would be supplied by the well field comprising 13 wells sunk to a depth of 50 m into the underlying semi-confined alluvial aquifer.

The existing wells in three districts in the Langat Basin, Hulu Langat, Kuala Langat and Sepang, are divided into 5 different categories; namely, domestic, industry, observation, test well and unknown. Usage of groundwater during 1999 was estimated as 2,845 m^3/hour (or 68.3 Mld based on 24 hours pumping). Industrial activities utilised 1,385 m^3/hour (or 33.2 Mld based on 24 hours pumping), followed by domestic 1,341 m^3/hour (or 32.2 Mld based on 24 hours pumping).

The total number of wells surveyed in the Hydro Census is 121 while JMG well database keeps a register of 103 wells. New 18 wells were found in the Census. Approximately 17% of the wells are operating for industry especially for cooling system and cleaning purposes. Agricultural and commercial usage is an absolute minimum at only 1% of the total, respectively. The remaining 81% is used for domestic purposes. Of the total 121, 33 are active, 18 are abandoned and 70 are unknown.

The main well fields in the subject groundwater basin, is located in the Megasteel/Amsteel II property (wells PWM-1, PWM-2, PWM-3, PWM-4, PWS-1, TW-4). The smaller capacity well fields are in Brookland Estate (Kajibumi WF1, 4 wells) and in Olak Lempit (Kajibumi WF2, TU/B). The natural groundwater flow is affected by abstraction of water from the Imuda Tin Mine.

3.3 Land Subsidence Status

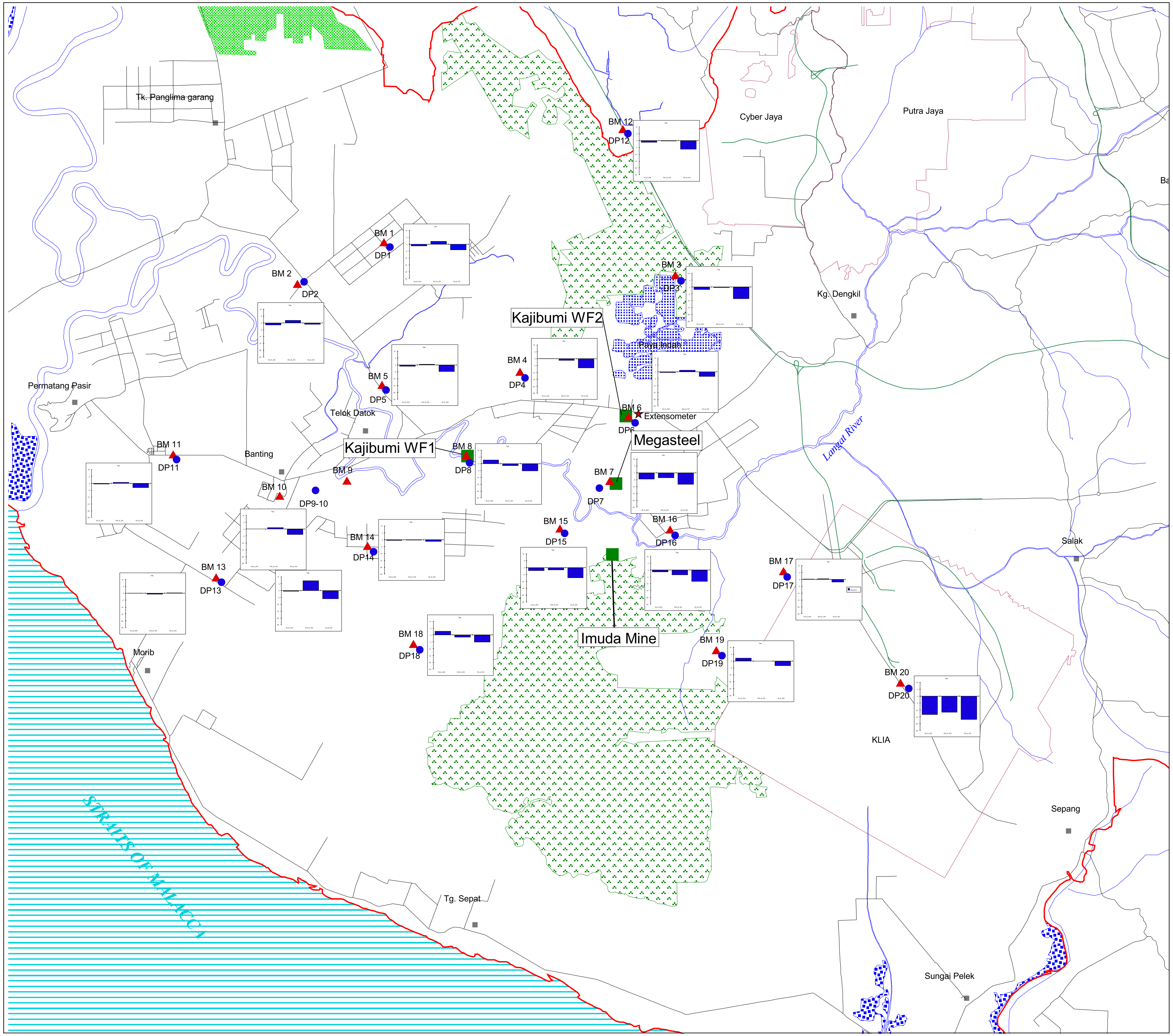
Elevations of twenty shallow benchmarks (see **Figure 3.3.1**) were measured by first-order levelling in July and November 2000, and March and August 2001 to monitor the land subsidence. Then change of thickness of the silty soil was also measured by extensometer installed at Kajibumi WF2. Records of 15 and 11 out of 20 benchmarks show a tendency to subside in the second and third measurement, respectively, while 19 benchmarks sank in the fourth one. In comparison with the difference between the first and the fourth measurements, 19 benchmarks also have sunk since the beginning of the installation.

A total of eight benchmarks, namely BM3, 4, 7, 12, 14, 15, 16 and 20, indicate continuous settlement. Benchmarks situated near the Langat River such as BM7, 15 and 16 have sunk from around 11 to 16 mm since July 2000. BM3 and BM4 in the north of Paya Indah, and BM12 along the express highway also marked sinkage from 7 to 11 mm in total, although relatively small settlement of around 2 mm was recorded at BM14 in the southeast of Banting. In particular, BM20 was recorded at about 42 mm in 15 months, the maximum sinkage of all the benchmarks, because of proximity of a building or backfill nearby.

The same tendency was given by seven benchmarks, i.e., BM1, 2, 5, 6, 8, 10 and 11; that is, firstly settlement arose, secondly these benchmarks were elevated and finally sunk again. Especially, BM10 in the backyard of the Banting Hospital had a record of 7 mm that is the highest rise among twenty benchmarks in the surveys. On the other hand, considering a tolerance of plus-minus 0.15 mm, there is no benchmark that is in continuous rise from the beginning. While it may be assumed, in a short observation period, that the ground level ordinarily gets to sink or rise repeatedly, it can be said that the Lower Langat Basin has a tendency to subside rather than rise in general. Consolidation by draining of peat/peaty clay layer and clayey soil layer that are widely spread over the Basin may result in the subsidence around the area.

Figure 3.3.1

Results of the Land Subsidence Measurement



LEGEND

- Borehole Extensometer
- Bench Mark
- Deep Datum
- Well Field and Dewatering Sites

Forest Reserve

- Inland Forest
- Mangrove Forest
- Swamp Forest
- Highway
- Roads
- Railways
- Rivers
- Towns
- Builtup Area
- Paya Indah
- Study Area

Scale 1 : 200,000

1 0 1 2 3 Kilometers

N W E S

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3.4 Physical Characteristics of the Groundwater Basin

The subject groundwater basin under the present Management Plan is located in the downstream of the Langat Basin. The Study was carried out to identify boundary conditions and geological conditions of the groundwater basin, and physical characteristics of soil layers that consist of the Aquifer.

3.4.1 Topographical Boundary of the Groundwater Basin

Topographically the Langat Basin is divided into three areas, namely, mountainous areas, hilly areas and flat lowlands. Spatial distribution of the subject Groundwater Basin is considered analogues to those of the low lands that are located in the southwest of the Langat Basin.

The Groundwater Basin in the north and the east is bounded by the hills. The boundary between the lowlands and hills was defined firstly by drawing topographical contour lines of 20 metres in height. The boundary was then adjusted by the results of aerial photograph interpretation. The boundary is presented in **Figure 3.4.1**.

In the north, three small but distinct hills are recognised. Three valleys between the hills connect the subject Groundwater Basin and the Klang Basin. In the east, valleys formed by the Langat River, the Labu River and a hypothetical old channel of the Langat River, which run through Dengkil, connect the hill area to the Groundwater Basin.

In the west, no distinct topographical feature is observed, except a granite hill, Bt. Jugra. The western boundary of the Groundwater Basin should be defined by the subsurface conditions. The Groundwater Basin is bounded by the sea to the south.

3.4.2 Bedrock Surface

In the Groundwater Basin, thick Quaternary sediments are aggraded above the eroded older rock surface. The thickest and oldest Quaternary sediments, which are considered as the Aquifer, overlay the bedrock. Contour lines of the bedrock surface were constructed, as shown in **Figure 3.4.1.**

Two major valleys, which run from the north (the Klang River Basin) to the south, can be recognised. From the east, although the borehole data is not sufficient, a valley formed by Langat River, Labu River and other small channels can be expected. Three major valleys from the north and the east seem to meet at the centre of the Groundwater Basin to form a single deep valley that flows down towards the sea.

Depth of bedrock increases as the valleys approach the sea. In the north, the elevation at the centre of the valleys ranges from -20 to -30 m from the mean sea level. The elevation near the seacoast was estimated by the seismic survey at around -130m at Location No. 7, 8 and 9. Contour lines at the centre of the valley near the seacoast were deduced by information at the above three locations.

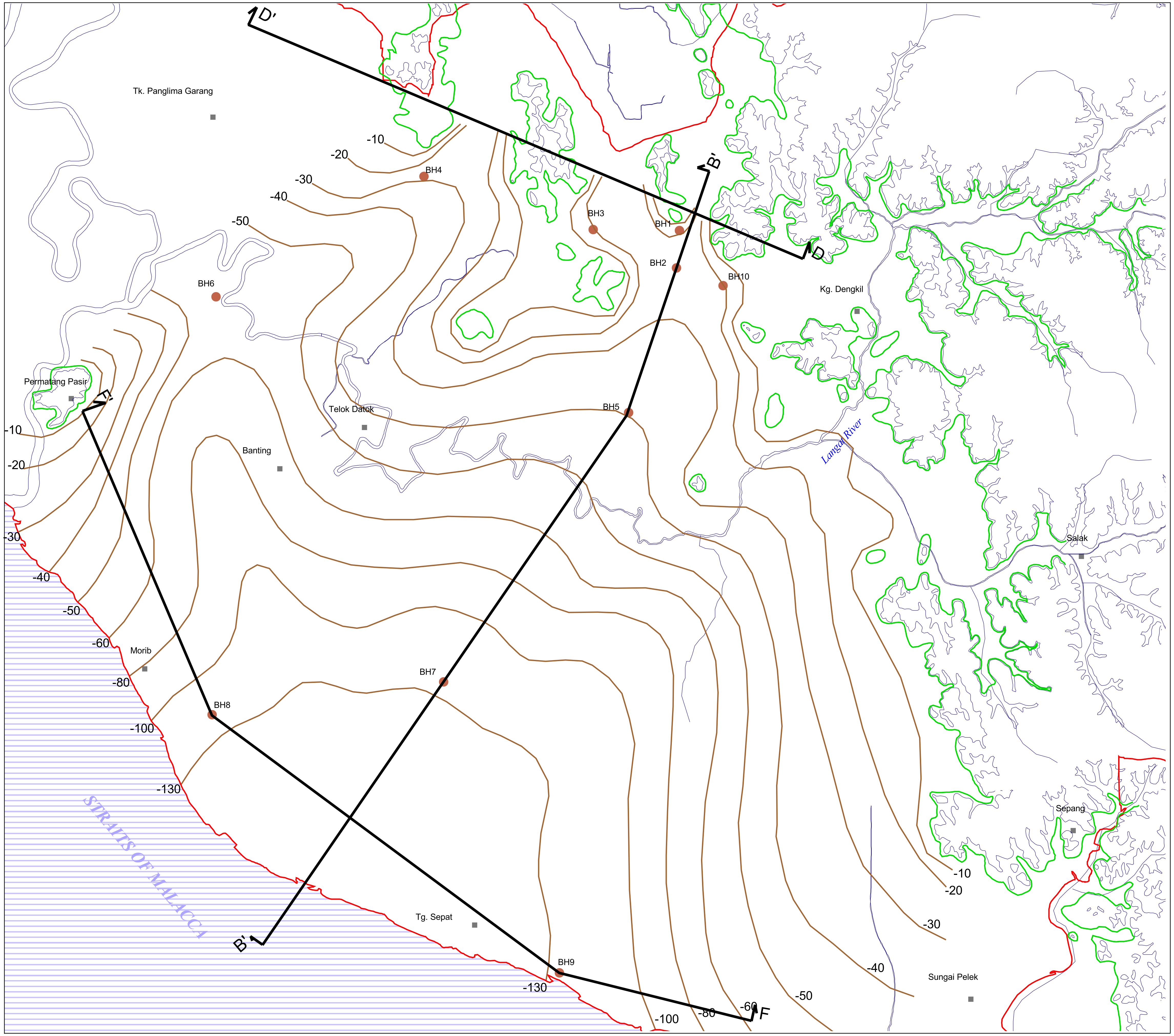

Figure 3.4.1

Topographic Boundary of Lowlands and Contour Map of Bedrock Level

LEGEND

- Location of Geological Profile
- Boring Point (Present Study)
- Topographic Contourline of 20m Height
- Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation
- Contourline of Bedrock Surface
- Rivers
- Towns
- Study Area

N W E S

Scale 1 : 200,000

2 0 2 4 Kilometers

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3.4.3 Geological Conditions of Groundwater Basin

The geological profile (B-B') along the major valley from the north is presented in **Figure 3.4.2.** The same (D-D') along the northern boundary and (E-E') across the Basin at the center are presented in **Figures 3.4.3** and **3.4.4**, respectively.

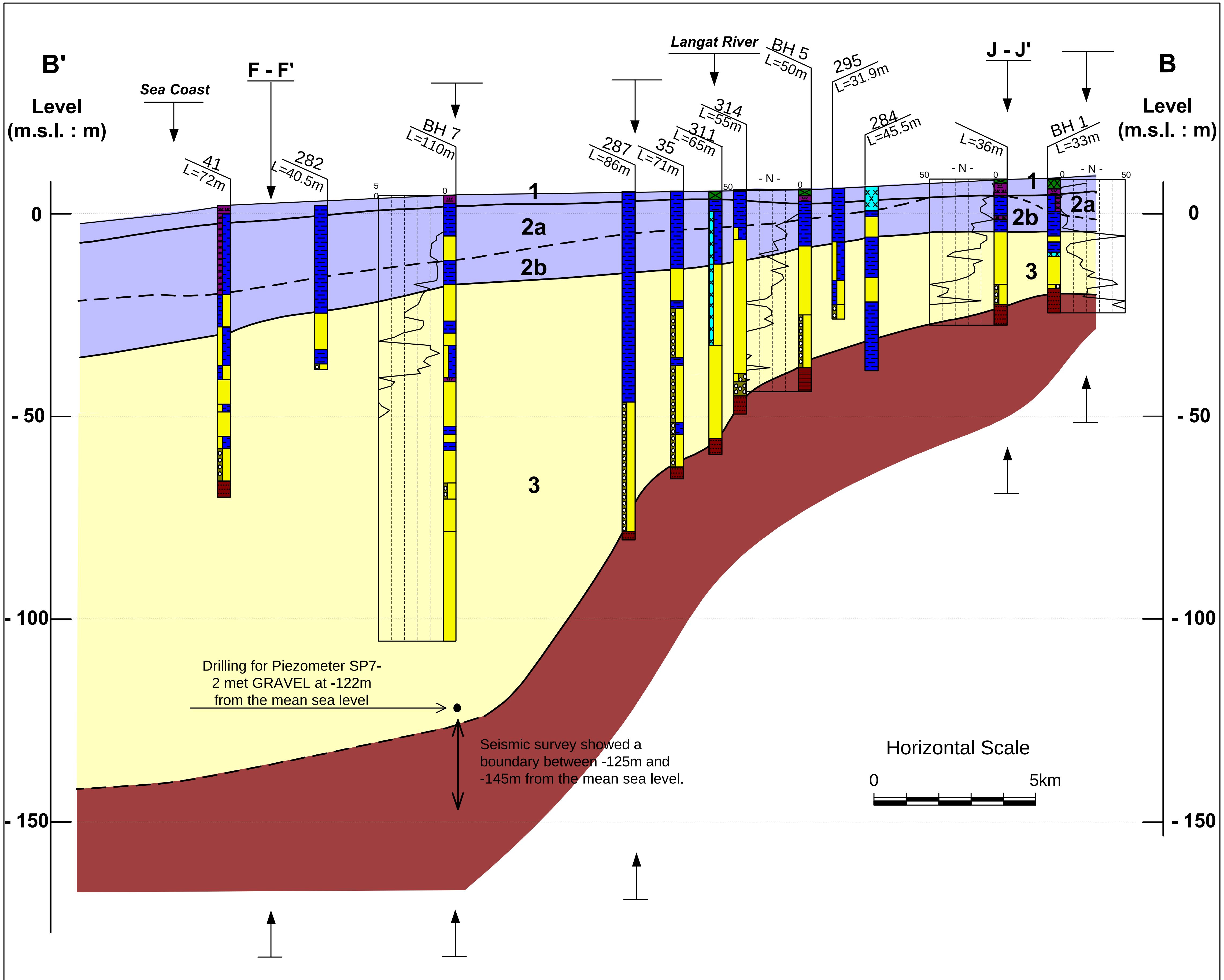
Typical geological conditions in the Groundwater Basin can be seen along Profile B-B'. The Quaternary sediments were divided into four layers, namely from the ground surface peat/peaty clay layer (Layer 1), clayey soil layer (Layer 2a and 2b), sandy and gravelly soil layer (Layer 3), and the bedrock (Layer 4).

Very soft peaty soils cover (Layer 1) most of the Groundwater Basin. The layer consists of peat at the upper part and dark grey coloured peaty clay at the lower part. Thickness of the layer ranges from 3.5 to 5.5 m at the northern part (BH 1, 2, 3 and 10), 1.5 to 1.7 m at the central part (BH 5 and 7), and 0.6 to 1.0 m at the western edge of the Basin. No peat and/or peaty clay are recorded at locations near the coastline (BH 8 and 9). Layer 1 corresponds to Beruas Formation.

Soft clayey soils (Layer 2a) distribute widely in the Groundwater Basin. The layer consists of light/greenish grey to grey-coloured marine silty clay, which is considered as Gula Formation. The thickness of the layer increases from several metres at the northern part of the Basin (Location No. 5) to more than 20 m at the seacoast. The thickness also increases towards the west side of the Basin. Medium dense sand layers, 6 to 7 m thick, are found within the soft clay layer at Location Nos. 6 and 7.

Medium to stiff clayey soils (Layer 2b) also distribute widely in the Basin. Soils mainly consist of light grey to grey coloured clay. The thickness of the layer varies between several metres to over 10 metres. Layers of sandy soils are expected within Layer 2b. This layer is also considered as Gula Formation, except at Location No. 5 where the physical properties are different from other localities. Clayey soils at Location No. 5 seem to be more compact and give low compressibility.

Layer 3 consists mainly of sandy and gravelly soils, and widely spread over the Groundwater Basin. The layer is considered as the Lower Member of Simpang Formation and forms the main aquifer in the Groundwater Basin. The thickness of the layer varies considerably, ranging from several metres in the northern part of the Basin to over 100 metres at the seacoast. Although the sandy/gravelly soil layers are grouped in a single unit, alternating clayey soil layers and sandy/gravelly soil layers are common features of Layer 3. The clayey soil layers in Layer 3 have a thickness of 1m to over 8 metres.



Note that this geological profile was prepared by a limit number of borehole logs. The profile should be modified and improved when additional information is obtained.

Figure 3.4.2

Geological Profiles, B - B'

LEGEND

- PEAT
- CLAY
- SILT
- SAND
- GRAVEL
- LIMESTONE
- SHALE, SLATE, PHYLLITE
- SANDSTONE, QUARTZITE, SCHIST
- GRANITIC ROCK

1 - 3 Layer Number

Boundary of Geology

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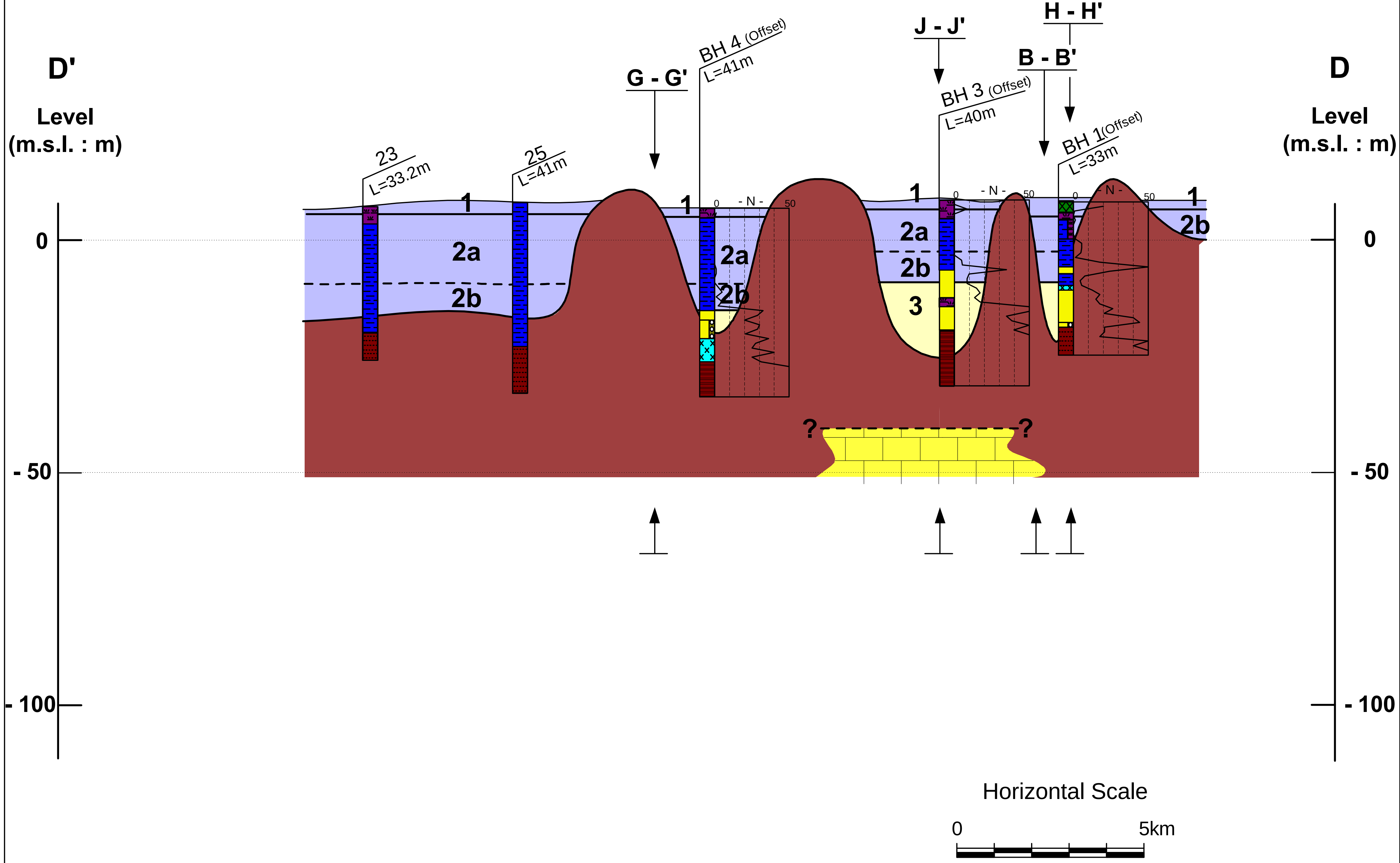
Figure 3.4.3

Geological Profiles, D - D'



Note that this geological profile was prepared by a limited number of borehole logs. The profile should be modified and improved when additional information is obtained.

Vertical and horizontal scales have a ratio of 1 to 125.

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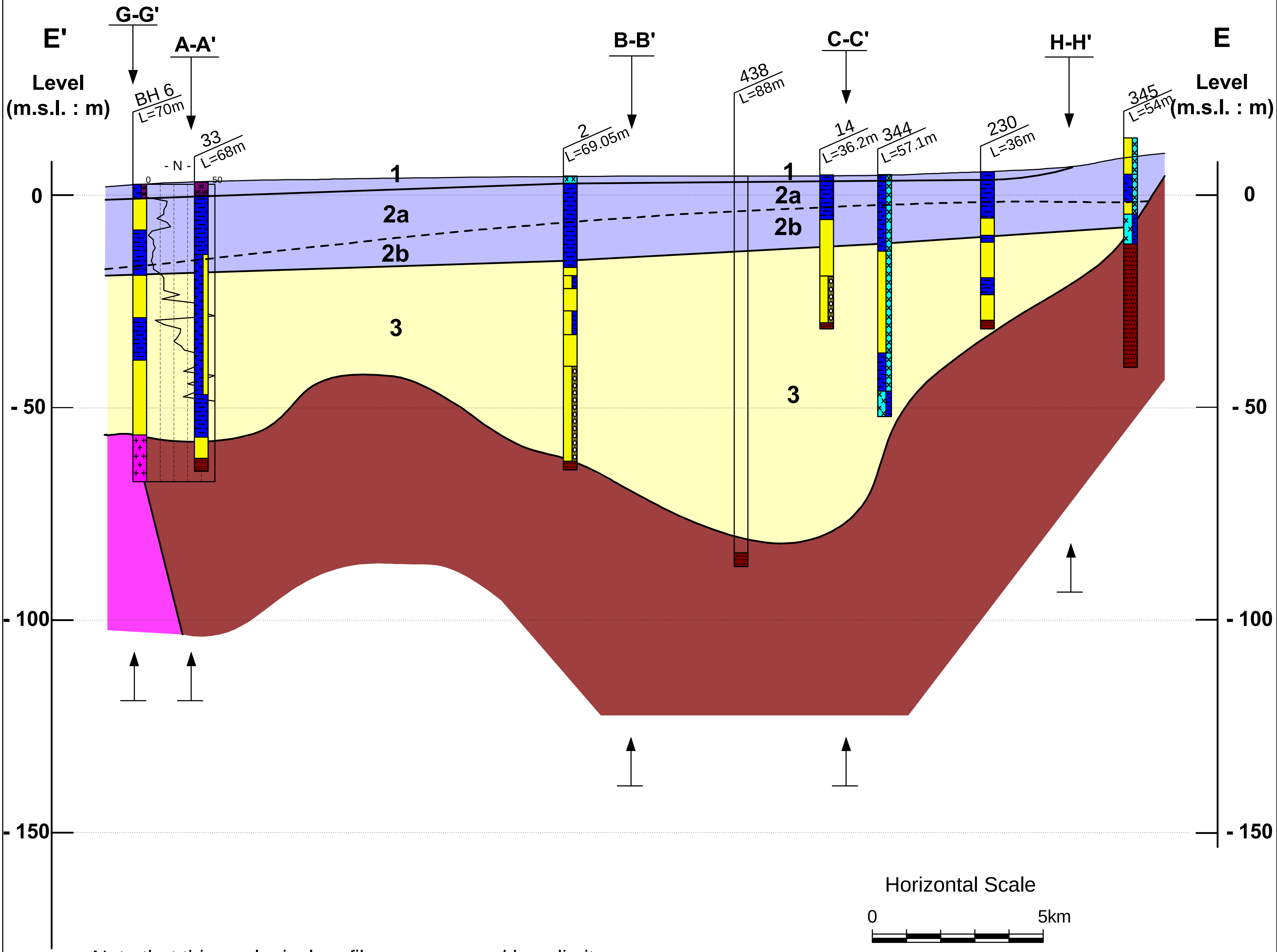
Figure 3.4.4

Geological Profiles, E - E'



Note that this geological profile was prepared by a limit number of borehole logs. The profile should be modified and improved when additional information is obtained.

Vertical and horizontal scales have a ratio of 1 to 125.

LEGEND

- PEAT
- CLAY
- SILT
- SAND
- GRAVEL
- LIMESTONE
- SHALE, SLATE, PHYLLITE
- SANDSTONE, QUARTZITE, SCHIST
- GRANITIC ROCK

1 - 3 Layer Number

Boundary of Geology

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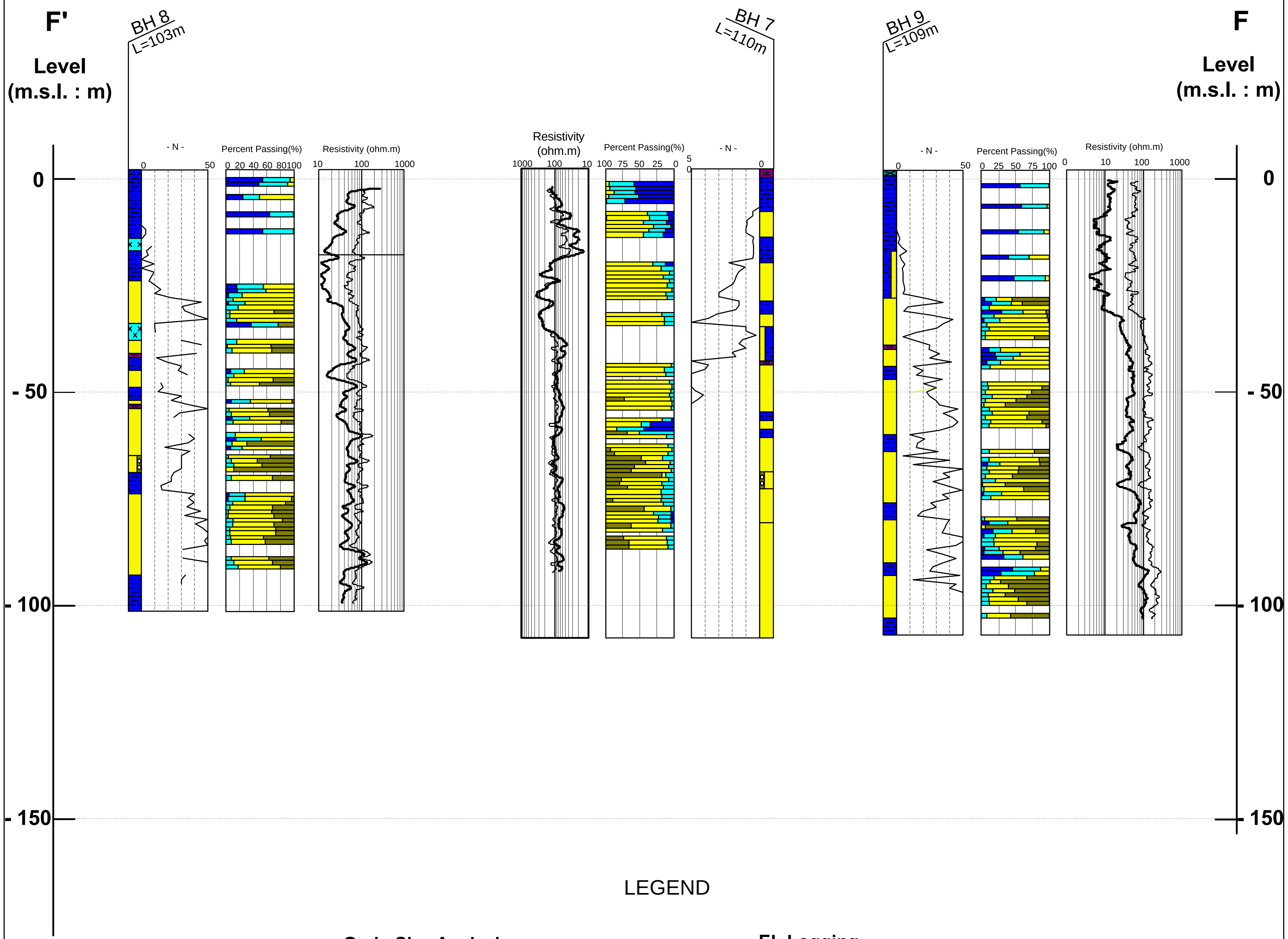
3.4.4 Physical Characteristics of Soil Layers

Based on the plasticity index and liquid limit, the soft clayey soil layer can be divided into three zones and the medium to stiff clay layer into two zones. The highest compressibility in the western part (Zone I), the lowest compressibility in the north eastern part (Zone II), and medium compressibility in the central and southern part (Zone III) of the Groundwater Basin.

Figure 3.4.5 demonstrates characteristics of the Aquifer in the centre and southern parts of the Groundwater Basin. Borehole logs, N values of the standard penetration test, grain-size characteristics and apparent resistivity are presented for Location No. 7, 8 and 9. It can be seen in the figure that the Aquifer, or Layer 4, consists of alternative layers of clayey soils and sand/gravelly soils. Continuity of the clayey soil layers is not certain. Gravel contents of the sandy/gravelly soils vary from location to location, from layer to layer and even within a single layer.

Figure 3.4.5

Characteristics of the Aquifer (Centre and Southern Part



LEGEND

PEAT

CLAY

SILT

SAND

GRAVEL

SHALE, SLATE, PHYLLITE

SANDSTONE, QUARTZITE, SCHIST

GRANITIC ROCK

1 - 4 Layer Number

Boundary of Geology

LEGEND

Grain Size Analysis

0 % 20 % 40 % 60 % 80 % 100 %

Clay | Silt | Sand | Gravel

EL Logging

Pole Distance 100cm

Pole Distance 50cm

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3.5 Simulation Model

The overall objectives of groundwater simulation are to estimate groundwater resources potential and to predict environmental impacts caused by groundwater abstraction. The basis for the modelling of three-dimensional groundwater flow and contaminant transport forms the integrated mathematical modelling package Visual MODFLOW. The modelling package combines MODFLOW, MODPATH, ZoneBudget, MT3D/RT3D, and PEST with the powerful graphical interface.

3.5.1 Boundary Condition

The topographical surface is the place where rain, evaporation, infiltration and surface run-off take place. It is the most important physical model boundary. The bedrock boundary is bottom boundary of the model. Topographical (horizontal) and bedrock (vertical) boundaries of the simulation model were determined based on the boundary conditions, as discussed in the previous section. Dredge ponds of Paya Indah and Imuda Tin Mine were simulated using specific hydraulic parameters defined by the Study. Details of model set up, including model grid, hydraulic parameters, and boundary and initial conditions, are discussed in **Section 4.2 of Volume 3, Supporting Report**.

3.5.2 Properties of the Groundwater Basin Layers

In the model, the aquifer system was divided into 7 layers (including sub-layers).

The aquifer, Layer 3 in geological classification, was subdivided into 4 layers (Layers 3a to 3d) to model alternative nature of the aquifer, namely alternative layers of clayey soil and sand/gravelly soil. Hydrogeological characteristics of each model layer are described as follows:

(1) Peat, represents the subsurface shallow and thin aquifer with the ability of taking rainwater and transmitting the surplus water as a shallow groundwater flow; in this layer the simulation of surface runoff into the drains, canals, or rivers takes place (Layer 1);

(2) Silty and sandy clay, upper low permeable to impermeable aquitard of regional extent (Layer 2);

(3) Silty or clayey sand, usually with minor amount of gravel, represents the upper less permeable aquifer; this layer is rather heterogeneous in thickness and extent, at some places missing, at other places rather thick and interbedded with clayey horizons (Layer 3a);

(4) Sandy clay or clayey silt, lower low permeable to impermeable aquitard of regional extent (Layer 3b);

(5) Silty sand and gravel, sometimes with occurrence of layers of sandy clays, characteristic with higher anisotropy and represents the upper part of the main highly permeable regionally spread aquifer (Layer 3c);

(6) Silty sand and gravel, represents the lower part of the main highly permeable regionally spread aquifer (Layer 3d); and

(7) Bedrock, very low permeable or nearly impermeable, weathered, pre-Quaternary rock (Layer 4).

From the hydrogeological and modelling point of view, Layer No. 3c and 3d are of prime interest. The other layers represent the main aquifer boundaries, affect recharge possibilities, and thus are also important for aquifer management.

3.5.3 Interpretation of Pumping Test Results for 3D Groundwater Model

Three pumping tests were conducted in the model area to study the aquifer characteristics and derive reliable input parameters for set up of 3D groundwater flow model: (i) Paya Indah, (ii) Kajibumi WF2, and (iii) Kanchong Darat.

(1) Pumping Test at Paya Indah

The following important facts were recognised from the long-term pumping test:

- Vertical recharge of aquifer from the surface is negligible.
- No significant changes in shallow groundwater horizon and its regime (peat) are expected.
- Possible distance of recharge area can be expected in a distance of 1200 to 1800 m.
- Lake area (dredge pond) is creating an impermeable barrier for groundwater flow.
- No significant recharge of aquifer from the lake is expected.
- Basic hydraulic parameters of lower sand and gravel aquifer interpreted from pumping test are as follows: transmissivity T is about 4.1×10^{-3} m^2/s, and elastic storage S is about 6.2×10^{-4} (when considering the Main Lake at Paya Indah as impermeable boundary).
- Vertical hydraulic conductivity of aquitard is low, approximately 1.2×10^{-8} or 7×10^{-9} m/s.

Chemically pure water at Paya Indah well PW-2 showed very low electrical conductivities; the values measured during pumping test were in the range of 23-38 μS/cm. The content of chlorides was always below 2 mg/l, pH values fluctuated in the range of 4.7 to 5.2. Low content of dissolved solids indicates either low reactivity of aquifer material or close distance of recharge area, which means short interaction of infiltrated rainwater with aquifer sediments. The aquifer water can be used for water supply. It seems that after proper distribution of a few production wells, only about 5 to 10 l/s could be analised in the area. Protection of main recharge areas should be focused on recharge possibilities and infiltrating water quality.

(2) Pumping Test at Kajibumi WF 2

The following important facts were recognised from the long term pumping test:

- Vertical recharge of aquifer from the surface is negligible. No significant recharge of aquifer from the surface is expected in the pumping test area.
- No changes in shallow groundwater level (peat) and its regime are expected.
- Possible distance of recharge area can be expected in 3000 m or more from the pumping test area.
- Banks and bottom of Paya Indah Lake are considered to be nearly impermeable; they create some barrier for groundwater flow from north direction.
- Dewatering of mine pits in surrounding areas uses water that can be used for water supply purposes.
- Seaside is a boundary condition with possible seawater intrusion.
- Basic hydraulic parameters of lower sand and gravel aquifer interpreted from pumping test are as follows: transmissivity T about 1.7×10^{-2} m^2/s, and elastic storage *S* about 6.0×10^{-4} (when considering lake at Paya Indah as impermeable boundary).
- Vertical hydraulic conductivity of aquitard is low, approximately 6.0×10^{-8} or 9.2×10^{-9} m/s.

The aquifer water can be used for water supply. For estimation of safe yield, 3-D modelling is necessary. It seems that after proper distribution of production wells in the area, the total quantity of water that is at present pumped for water supply and for dewatering of mines could be analised. The problem of aquifer overexploitation and intrusion of seawater will be the main limiting factors of groundwater safe yield estimation.

The groundwater at Kajibumi WF 2 well TU/B is characterised with higher electric conductivities (261-332 μS/cm), pH values 6.6-6.8, and content of chlorides in the range of 28-30 mg/l. Protection of main recharge areas is necessary. This protection should be from the point of view of recharge possibilities and from the point of view of infiltrating water quality. In addition, measures against seawater intrusion based on monitoring should be elaborated.

(3) Pumping Test at Kanchong Darat

The following important facts were recognised from the long-term pumping test:

- Vertical recharge of aquifer from the surface is negligible. No significant recharge of aquifer from the surface is expected in the pumping test area.
- No change in shallow groundwater level (peat) and its regime is expected.
- Possible distance of recharge area can be expected at 4000 m or more
- Seaside is the boundary condition with documented seawater intrusion.
- Basic hydraulic parameters of lower sand and gravel aquifer interpreted from pumping test are as follows: transmissivity T, about 5.1 x 10^{-2} m^2/s; and elastic storage *S*, about 2.5 x 10^{-3}.
- Vertical hydraulic conductivity of aquitards is low, up to 5.0 x 10^{-9} m/s.

In comparison to previous localities, the groundwater from pumping well PW7 at Kanchong Darat showed very high electric conductivities (2050-2230 μS/cm) and pH values of 5.72-6.69. The content of chlorides in the range 407-445 mg/l may indicate the saltwater intrusion from deeper aquifer horizons.

(4) Summary of the Results

Comparison of hydraulic parameters of lower aquifer (Model Layer No. 3c and 3d) with other pumping test localities is given in **Table 3.5.1**. Based on results of pumping test at Kanchong Darat and other localities, the hydraulic parameters for the regional 3D groundwater flow model were derived.

Table 3.5.1 Hydraulic Parameters of Lower Sand and Gravel (Layer No. 3c and 3d)

Locality	Depth (m)	Thick. b (m)	Conduct. K_H ($m.s^{-1}$)	Conduct. K_V ($m.s^{-1}$)	Transm. T ($m^2.s^{-1}$)	Spec. St. S_S (m^{-1})	Stor. S (-)
Paya Indah	16 - 29.8	13.8	2.97e-4	7.27e-6	4.10e-3	4.50e-5	6.21e-4
Kajibumi WF 2	23 – 43	20	8.41e-4	2.04e-5	1.68e-2	3.00e-5	6.00e-4
Kanchong Darat	63 – 120	57	8.98e-4	1.63e-6	5.12e-2	4.36e-5	2.48e-3

3.5.4 Groundwater Flow Model

Visual MODFLOW is applied to groundwater flow model for the present groundwater basin. The procedure of model application involves three steps, namely, model set up, model calibration and model validation.

(1) Model Set Up

Model Grid

The modelling domain was selected according to natural hydrogeological boundaries, over an area with *x* coordinate 378,000–418,000 m, and *y* coordinate 285,000–330,000 m (area 40×45 km). Inside the modelling domain rectangular model grid with different length and width of cells has been set-up (37,240 cells).

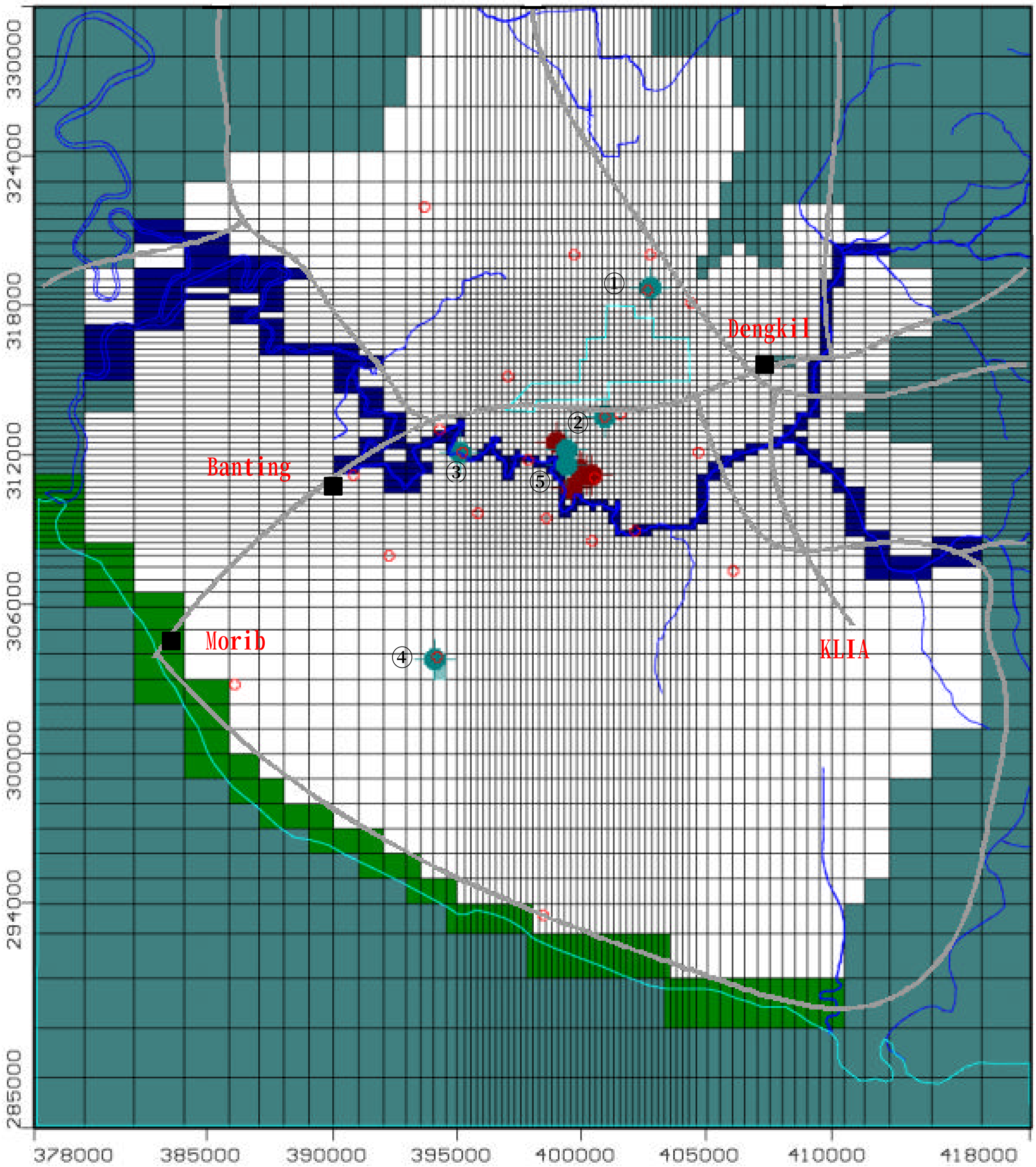
The model has a 70×76 cell grid in horizontal direction; with minimum cell size of 250×250 m and maximum cell size of 2,000×2,000 m. The model has been set up with seven layers in vertical direction. Model Grid and Boundaries are presented in **Figure 3.5.1**, and elevation of ground surface is presented in **Figures 3.5.2**.

Aquifer Parameters

Hydraulic parameters of aquifer used in the 3D model setup are listed in **Table 3.5.2**.

Table 3.5.2 Hydraulic Parameters of Regional 3D Groundwater Flow Model

Layer No.	Zone	Prop. ID	Conduct. K_H ($m.s^{-1}$)	Conduct. K_V ($m.s^{-1}$)	Anisotr. K_H / K_V	S_S (m^{-1})	S_Y (-)	Soil Description
1		18	1.00e-4	1.00e-5	10	1.00e-3	0.3	Peat, laterite soil
2		8	1.20e-8	9.20e-9	1.3	6.00e-6	0.01	Silty clay
3a	A	21	6.00e-5	6.00e-6	10	3.70e-5	0.15	Clayey sand with gravel
	B	1	1.00e-4	1.00e-5	10	6.00e-6	0.15	
	C	28	1.6e-4	4.00e-6	40	6.00e-6	0.15	
3b		9	1.00e-8	7.00e-9	1.4	6.00e-6	0.01	Clayey silt
3c	A	23	4.00e-4	9.60e-6	42	4.50e-5	0.2	Silty sand and gravel, sandy clay
	B	12	1.20e-3	4.80e-5	25	3.00e-5	0.2	
	C	25	1.20e-3	2.40e-5	50	4.10e-5	0.18	
3d	A	38	1.00e-4	5.00e-6	20	4.50e-5	0.2	Silty sand and gravel
	B	15	2.00e-4	1.00e-5	20	3.00e-5	0.2	
	C	40	8.00e-4	3.20e-5	25	4.50e-5	0.2	
4	A	20	3.20e-6	3.20e-6	1	6.00e-6	0.02	Bedrock
	B	24	1.00e-8	1.00e-8	1	6.00e-6	0.02	
Dredge Ponds		2	5.80e-7	5.80e-7	1	4.50e-5	1	Mining areas



LEGEND

- Incativ Cells
- General Head
- River
- Road
- Town

Active Pumping Well
①: Paya Indah
②: Kajibumi Well Field 2
③: Kajibumi Well Field 1
④: Kanchong Darat
⑤: Megasteel

Inactive Pumping Well
Monitoring Well

Scale 5km 5km 0

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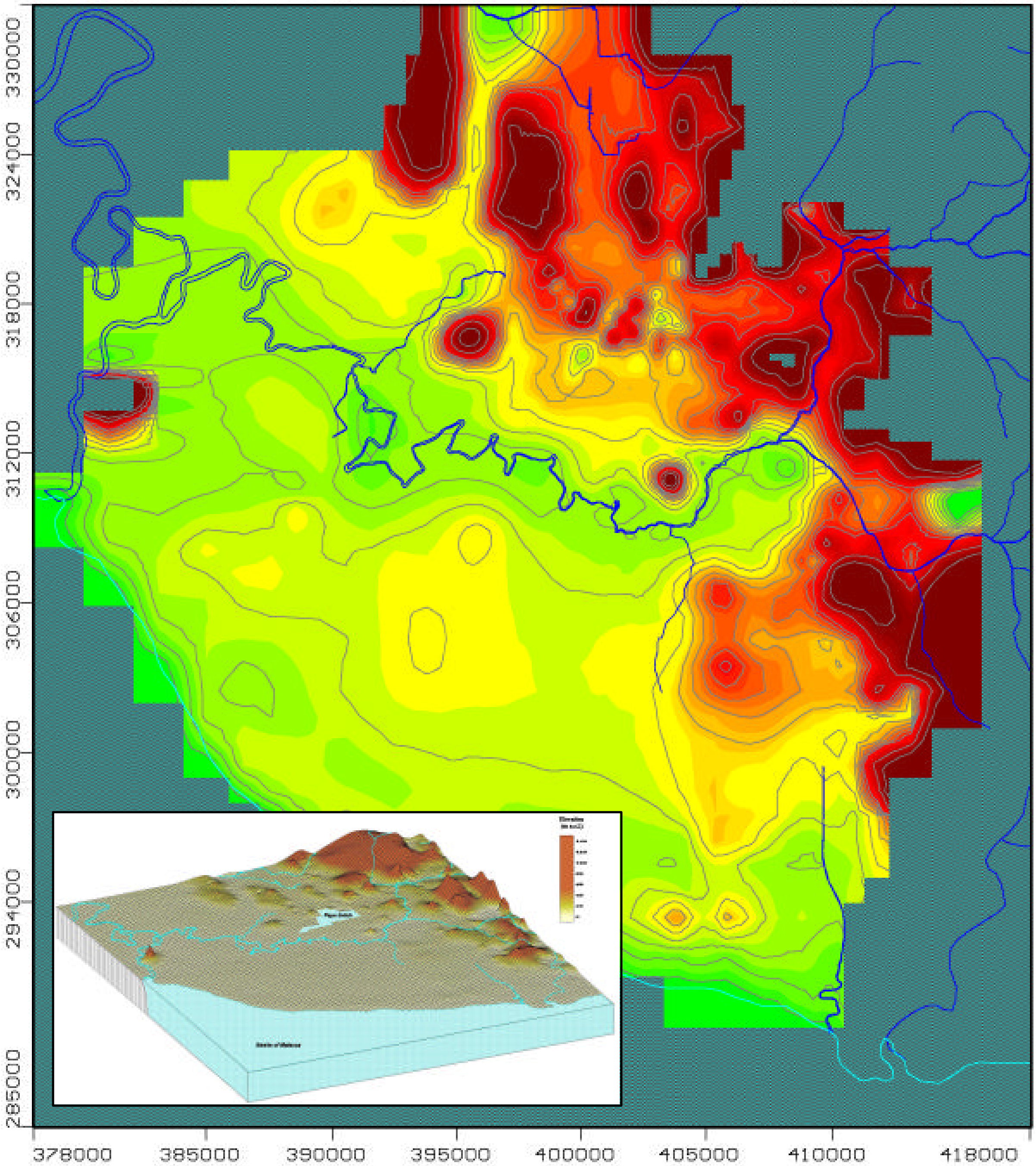
Figure 3.5.1

Model Grid and Boundaries



LEGEND

Inactive cells

Contour lines of ground surface

Elevation (m a. s. l.)

0

5

20

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Figure 3.5.2

THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

Elevation of Ground Surface

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Initial and Boundary Conditions

A no flow boundary (zero-flux, barrier) is a boundary across which there is no flow of groundwater. The bottom of the model, outside of the model domain, and inactive cells are treated as no flow boundaries. Very low permeable dredge ponds, or elevations of bedrock, form another type of partial barriers, which are realised according to properties and configuration of layers.

The recharge from rainfall is restricted to the uppermost layer and is allowed to pass through inactive cells. The value 954 mm/year was used for Simulation Variants 0, 1, 2, 3, and 5. In the Simulation Variant 4 the recharge 0 mm/year was assumed.

Langat River (and Labu River) represents surface water boundary condition in the model. Riverbed conductance reflects the length and width of river in a cell, and hydraulic conductivity and thickness of riverbed material ($k/b=3e^{-8}s^{-1}$).

The boundary of aquifer with sea was represented in the model by General head boundary. The water level elevation was set to 1.0 m a.s.l., to compensate for influence of density. The conductance represents the resistance to flow between the sea (general head boundary) and the groundwater. The values reflect the size of cells, thickness and hydraulic conductivity of sediments ($k/b=5.8e^{-7}s^{-1}$).

The effect of drainage system that holds the subsurface water level below ground surface is simulated with 7334 drain cells in the first model layer. The elevation of drain was set 1 m below the ground surface. The drain conductances reflect the size of cells, hydraulic conductivity near the drain and the head loss between the drain and the groundwater system ($k/b=1.0e^{-7}s^{-1}$).

Imuda tin mine was simulated with 60 drain-cells with the conductance of 250 m^2/d ($k/b=4.63e^{-8}s^{-1}$). The elevation of drain was set at –35 m.s.l.

(2) Model Calibration and Verification

Hydraulic parameters of the 3D groundwater flow model were based on results of realised pumping tests at Paya Indah, Kajibumi WF 2, and Kanchong Darat. For all three localities a local pumping test model was set up, and this model was calibrated and verified against groundwater levels measured during pumping and recovery test. The 3D model was calibrated against groundwater levels in the model area measured on March 9 to 13, 2001. The analysis during calibration confirmed high sensitivity of model to pumping rates from existing well fields and dewatering pits (Imuda tin mine). Unfortunately, only very limited amount and quality of data about pumping rate from Megasteel well field were analised and no information on present or past pumping rates from Imuda tin mine was available. Thus the calibration had to rely on estimated values found in available reports.

(3) Simulation Variant

The definition of scenarios was based on variation of groundwater abstraction from existing well fields and dewatering pits; and change of groundwater recharge from rainfall. **Table 3.5.3** provides an overview of simulated pumping rates and recharge that characterise each model scenario. In brief the characterisation of scenarios is described as follows:

- **Variant 0**: The natural (original) conditions in the past, before putting existing well fields into operation, with active Imuda Tin Mine.
- **Variant 1**: Present conditions, with abstraction of groundwater from existing well fields and dewatering pits.
- **Variant 2**: Near future conditions; increased abstraction of groundwater with putting Kajibumi WF 1 and Kajibumi WF 2 into operation.
- **Variant 3** & **Variant 5**: Future conditions, with increased abstraction of groundwater in the Megasteel/Amsteel II area, with Kajibumi WF 1 and Kajibumi WF 2 in operation.
- **Variant 4**: Present conditions (during field investigation in the Study), with abstraction of groundwater from existing well fields and dewatering pits, similar to Variant 1 but without recharge from rainfall.
- **Variant 6**: The natural conditions in the future, similar to Variant 0 but without any abstraction of water from well fields and dewatering pit at Imuda Tin Mine.
- **Variant 7**: The conditions with increased abstraction of groundwater, after putting Kajibumi WF 1 and Kajibumi WF 2 into operation, similar to Variant 2 but without abstraction of water from existing dewatering pit at Imuda Tin Mine.
- **Variant 8**: Present conditions (during field investigation in the Study), with abstraction of groundwater from existing well fields and dewatering pits, similar to Variant 1 but with reduced effective recharge from rainfall in the Multimedia Super Corridor area.

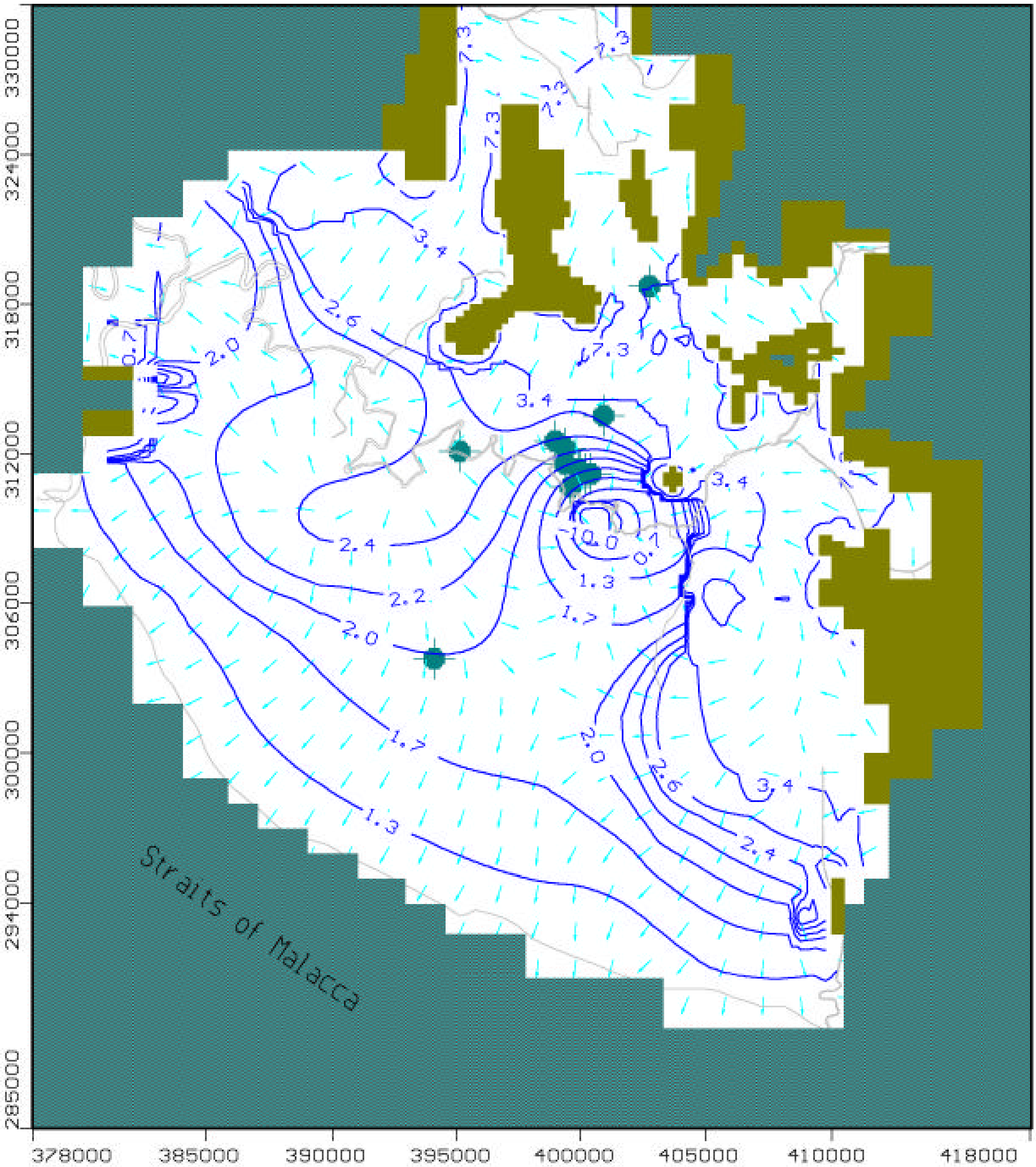
Table 3.5.3 Simulated Daily Pumping Rates from Well Fields and Dewatering Pits

Well Field	Simulation Variant (SV)								
	SV 0 (m^3/d)	SV 1 (m^3/d)	SV 2 (m^3/d)	SV 3 (m^3/d)	SV 4 (m^3/d)	SV 5 (m^3/d)	SV 6 (m^3/d)	SV 7 (m^3/d)	SV 8 (m^3/d)
PWM-1	0	6450	6450	13440	6450	13440	0	6450	6450
Well A (new)	0	0	0	13730	0	13730	0	0	0
Well B (new)	0	0	0	13730	0	13730	0	0	0
PWM-2 (JBA-1)	0	2640	2640	2640	2640	2640	0	2640	2640
PWM-3	0	4440	4440	4440	4440	4440	0	4440	4440
PWM-4	0	4440	4440	4440	4440	4440	0	4440	4440
PWS-1	0	1200	1200	1200	1200	1200	0	1200	1200
TW-4	0	1600	1600	1600	1600	1600	0	1600	1600
Kajibumi WF 1	0	0	9200	9200	0	9200	0	9200	0
Kajibumi WF 2	0	0	6900	6900	0	6900	0	6900	0
Imuda Tin Mine	27028	24884	23756	18933	20619	20931	0	0	24432
Total	**27028**	**45654**	**60626**	**90253**	**41389**	**92251**	**0**	**36870**	**45202**

(4) Natural Groundwater Flow – SV1 and SV0

SV1 represents recent status and calibration variant. The modelling results are presented in **Figure 3.5.4**. **Figure 3.5.5** shows the results of simulation in model cross-section. Simulated contour lines of piezometric head and directions of groundwater flow in **SV1** indicate that there exist a large cone of depression around the Megasteel/Amsteel II area and Imuda Mine. The regional groundwater flow is oriented towards this exploitation area. The main inflow of fresh groundwater is from northwest and east.

SV0 is similar to **SV1**, with difference that it considers only abstraction of water from dewatering pits (see **Figure 3.5.3)**. The stop of groundwater abstraction from existing well fields leads to reduction of depression cone and movement of groundwater divide inlands. The results of simulated water balance in the model area are listed in **Table 3.5.3**.



LEGEND

Contour Lines of Piezometric Head	Inactive Pumping Well
Direction of Groundwater Flow	Active Pumping Well
Inactive cells	Dry cells

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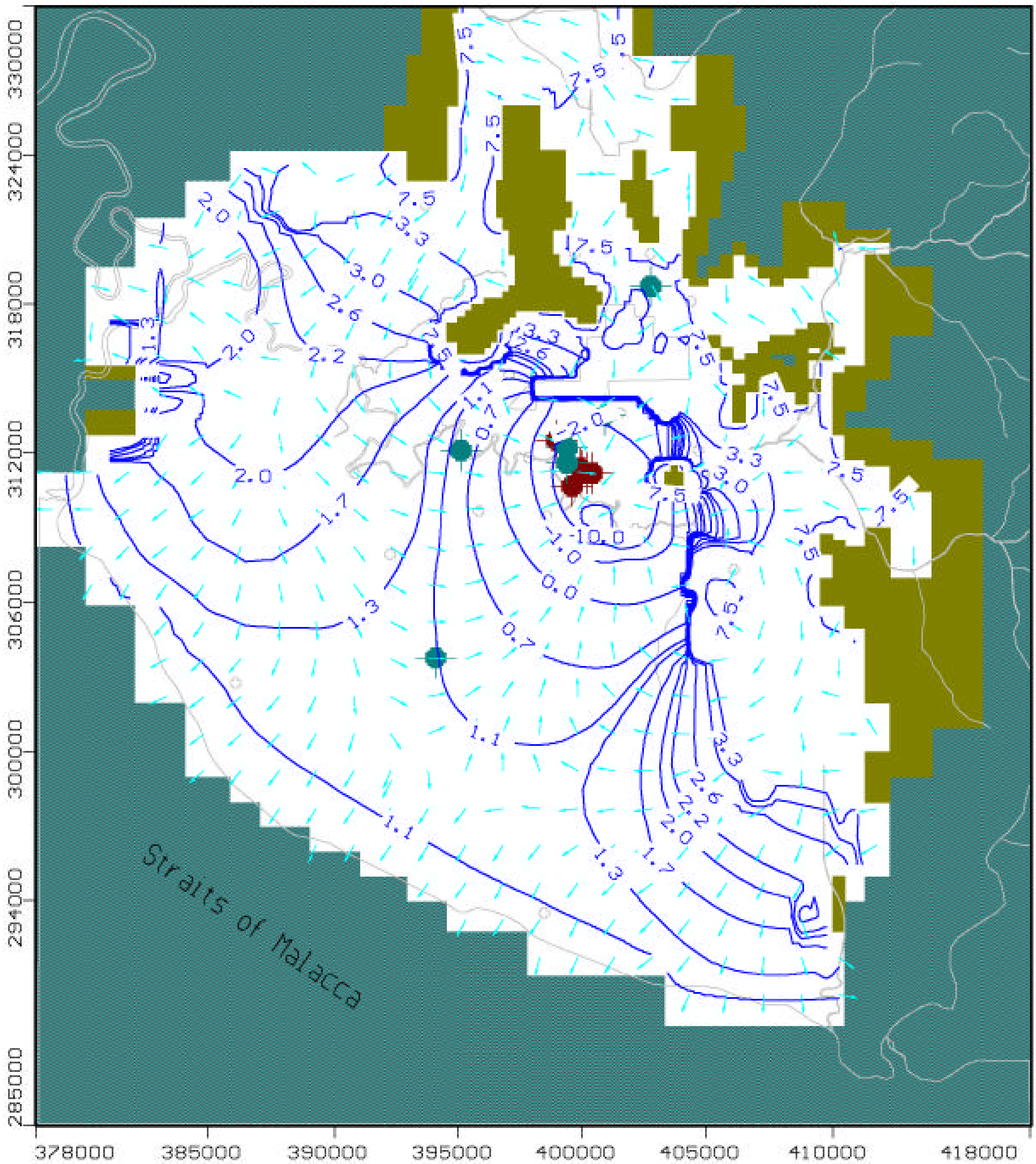
Figure 3.5.3

Solution Variant 0 - Head Equipotentials in Model Layer 3c



LEGEND

- Contour Lines of Piezometric Head
- Direction of Groundwater Flow
- Inactive cells
- Inactive Pumping Well
- Active Pumping Well
- Dry cells

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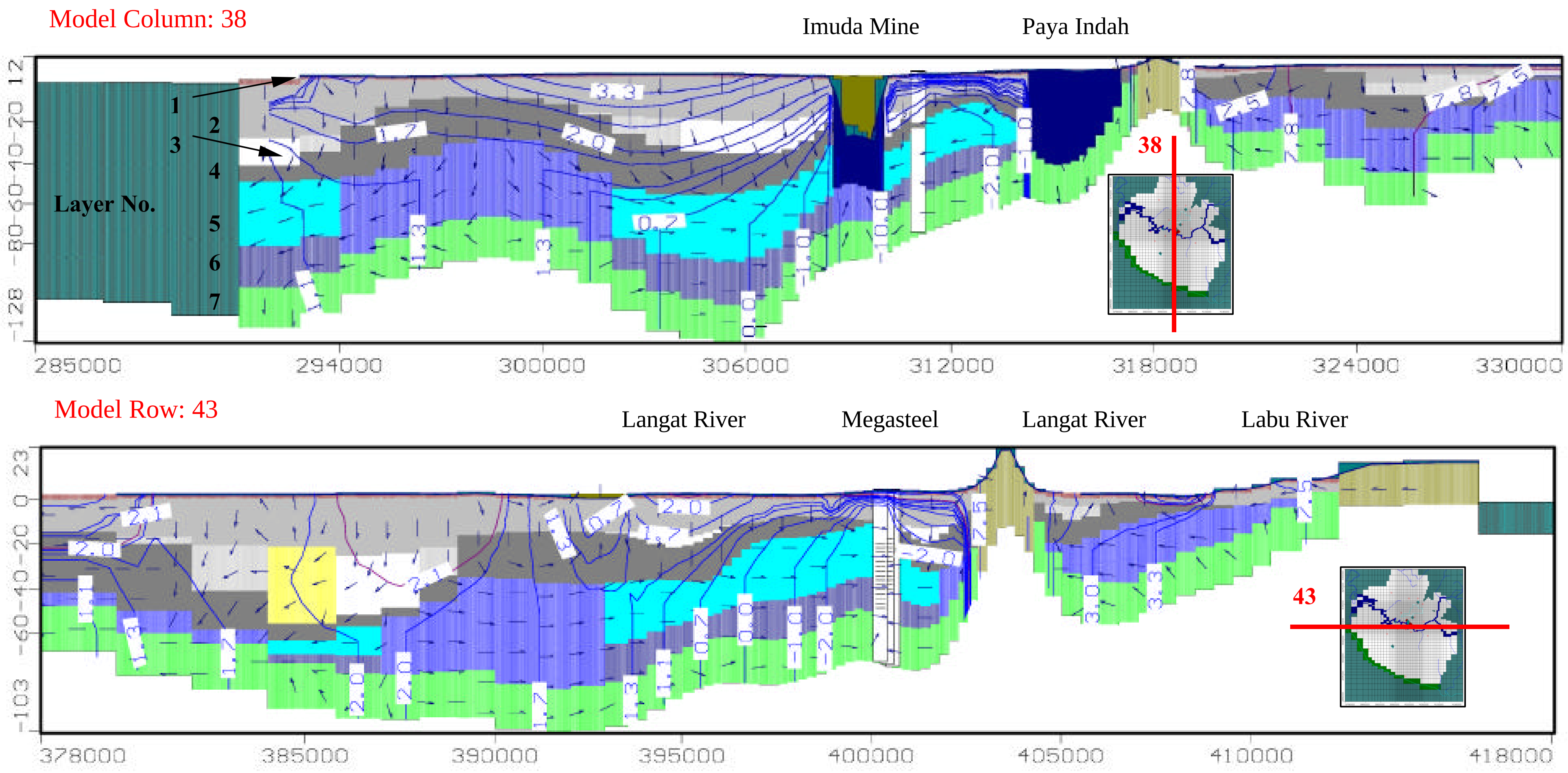
Figure 3.5.4

Solution Variant 1 - Head Equipotentials in Model Layer 3c



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LEGEND

- Contour Lines of Piezometric Head
- Direction of Groundwater Flow
- Inactive Cells

Figure 3.5.5

Solution Variant 1 – Head Equipotentials in Model Cross-Section Column 38 and Row 43

Table 3.5.4 Simulated Water Balance in Model Area

Model (+ Input / - Output)		Simulation Variant (SV)								
		SV0 (m^3/d)	**SV1 (m^3/d)**	**SV2 (m^3/d)**	**SV3 (m^3/d)**	**SV4 (m^3/d)**	**SV5 (m^3/d)**	**SV6 (m^3/d)**	**SV7 (m^3/d)**	**SV8 (m^3/d)**
1. Recharge (rain.-evap.)		2586074	2586074	2586074	2586074	0	2586074	2586074	2586074	1873358
2. Drains, Canals		-2385000	-2374800	-2367300	-2351800	-10631	-2354300	-2394285	-2380796	-1660440
3. Imuda Tin Mine	**GW**	-22454	-20310	-19182	-14359	-20619	-16357	0	0	-19836
	SW	-4574	-4574	-4574	-4574	0	-4574	0	0	-4574
4. Leakage from River		2410	3186	3927	7299	4260	6438	1586	2475	3680
5. Leakage into River		-3576	-3149	-2623	-2040	-2267	-2200	- 647	-2945	-2557
6. Pumping Wells		0	-20770	-36870	-71320	-20770	-71320	0	-36870	-20770
7. Leakage from HB (sea)		0	0	807	15021	348	11538	0	0	0
8. Storage		0	0	0	0	37771	46	0	0	752
GW Recharge from rain (1.–2.–3.^{SW})		196500	206700	214200	229700	0	227200	191789	205278	208344

Simulation parameters:
Variant 0, 1, 2, 3, 6, 7: SOR Solver, InitHead Terrain - 1m, Head CC for Convergence 0.01 m
Variant 4, 5, 8: SOR Solver, InitHead Variant 1, Head CC for Convergence 0.01 m

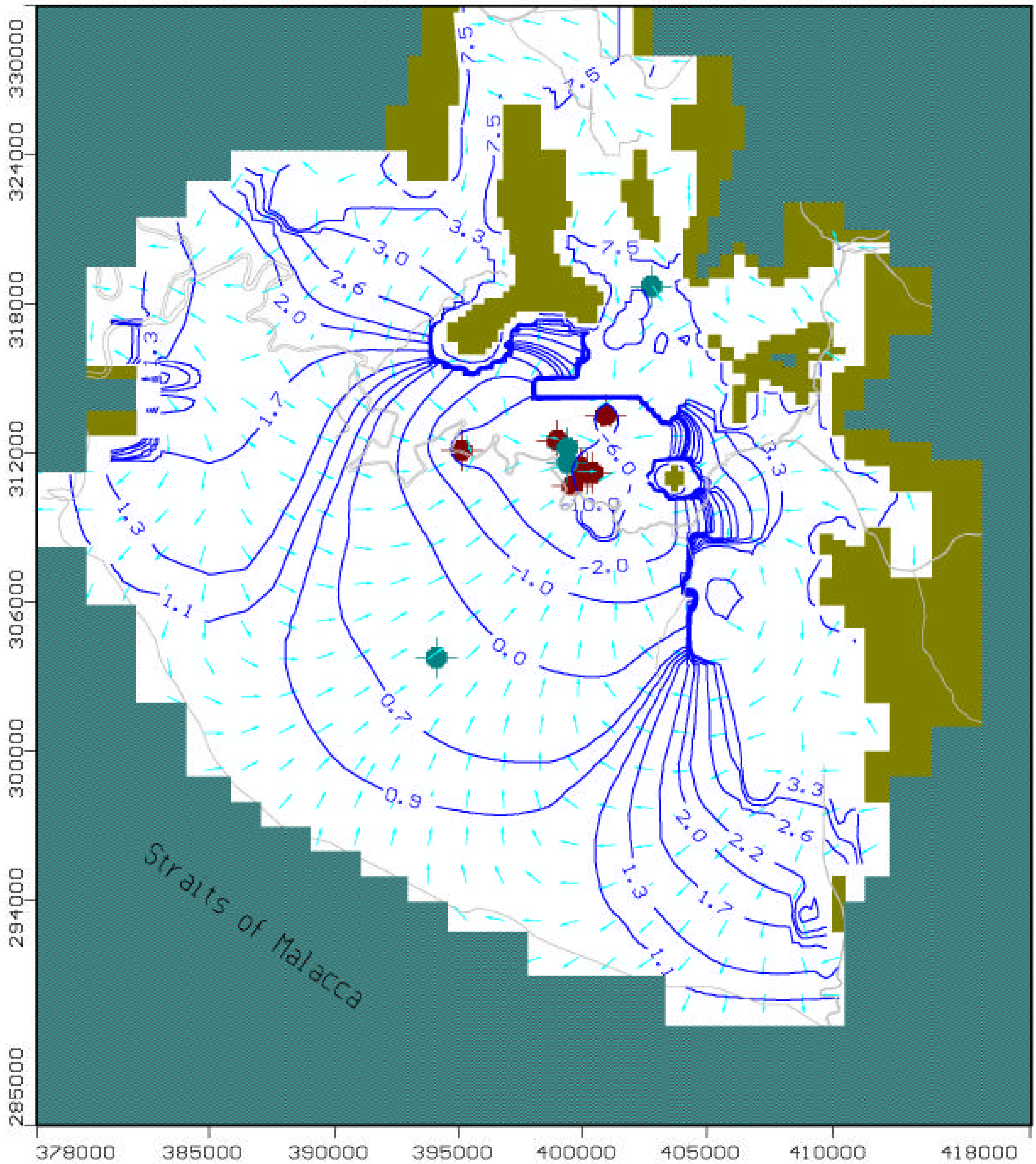
(5) Impact of Increased Groundwater Abstraction – SV2, SV3, SV5

The pumping rate scenario in steady-state **SV2** is similar to that in **SV1**; it differs only with consideration of water abstraction from Kajibumi WF 1 and Kajibumi WF 2. This means a small increase of total amount of abstracted water from recent 45,000 to 60,000 m^3/day. **SV3** and **SV5** assume significantly increased (full) pumping rate from existing well PWM-1 and pumping of two additional wells with pumping rate similar to PWM-1 in Megasteel/Amsteel II property (total amount of abstracted water, about 90,000 m^3/day).

Increased pumping (**SV2**) changed the head equipotentials and direction of flow in the main aquifer significantly (**Figure 3.5.6**). In the case of significant increase of pumping (**SV5**), the calculated drawdown in the area (cells) around Megasteel and Imuda Mine reaches about 10 metres (**Figure 3.5.7**). The drawdown in clayey aquitard (Model Layer 2) reaches 8 metres and spreads over a large area to the south of the Paya Indah Wetland Sanctuary (**Figure 3.5.8**).

(6) Impact of Dry Season – SV4

In the 3 years of zero effective rainfall the head equipotentials and direction of flow in the main aquifer is evidently changed. Larger cone of depression caused the movement of groundwater divide towards seacoast and creates conditions suitable for intensive seawater intrusion. The cut down of recharge caused up to 1.4 m drop of piezometric heads in the area around Megasteel and Imuda Mine.



LEGEND

- Contour Lines of Piezometric Head
- Direction of Groundwater Flow
- Inactive cells
- Inactive Pumping Well
- Active Pumping Well
- Dry cells

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Figure 3.5.6

Solution Variant 2 - Head Equipotentials in Model Layer 3c

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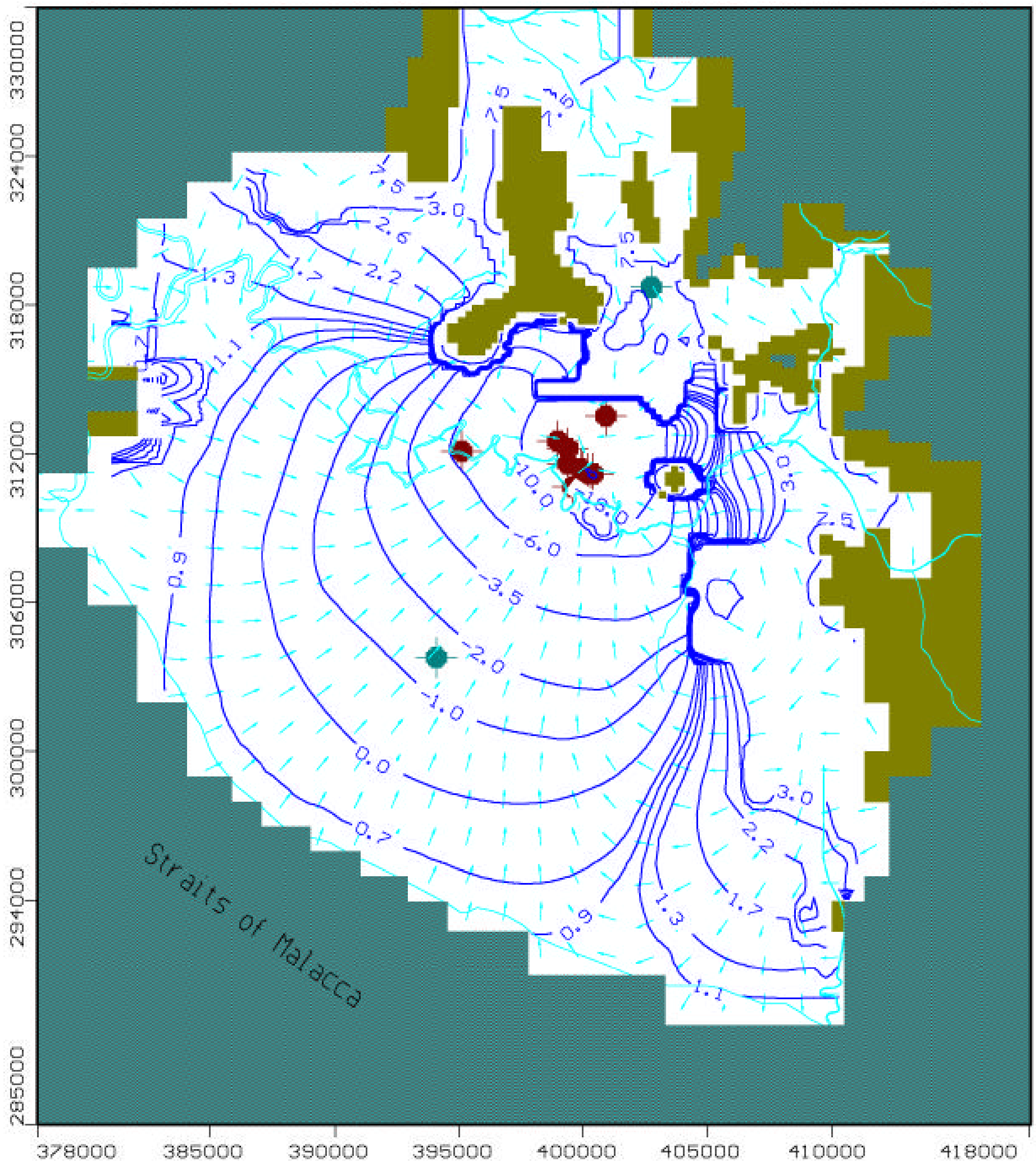

LEGEND

	Contour Lines of Piezometric Head		Inactive Pumping Well
	Direction of Groundwater Flow		Active Pumping Well
	Inactive cells		Dry cells

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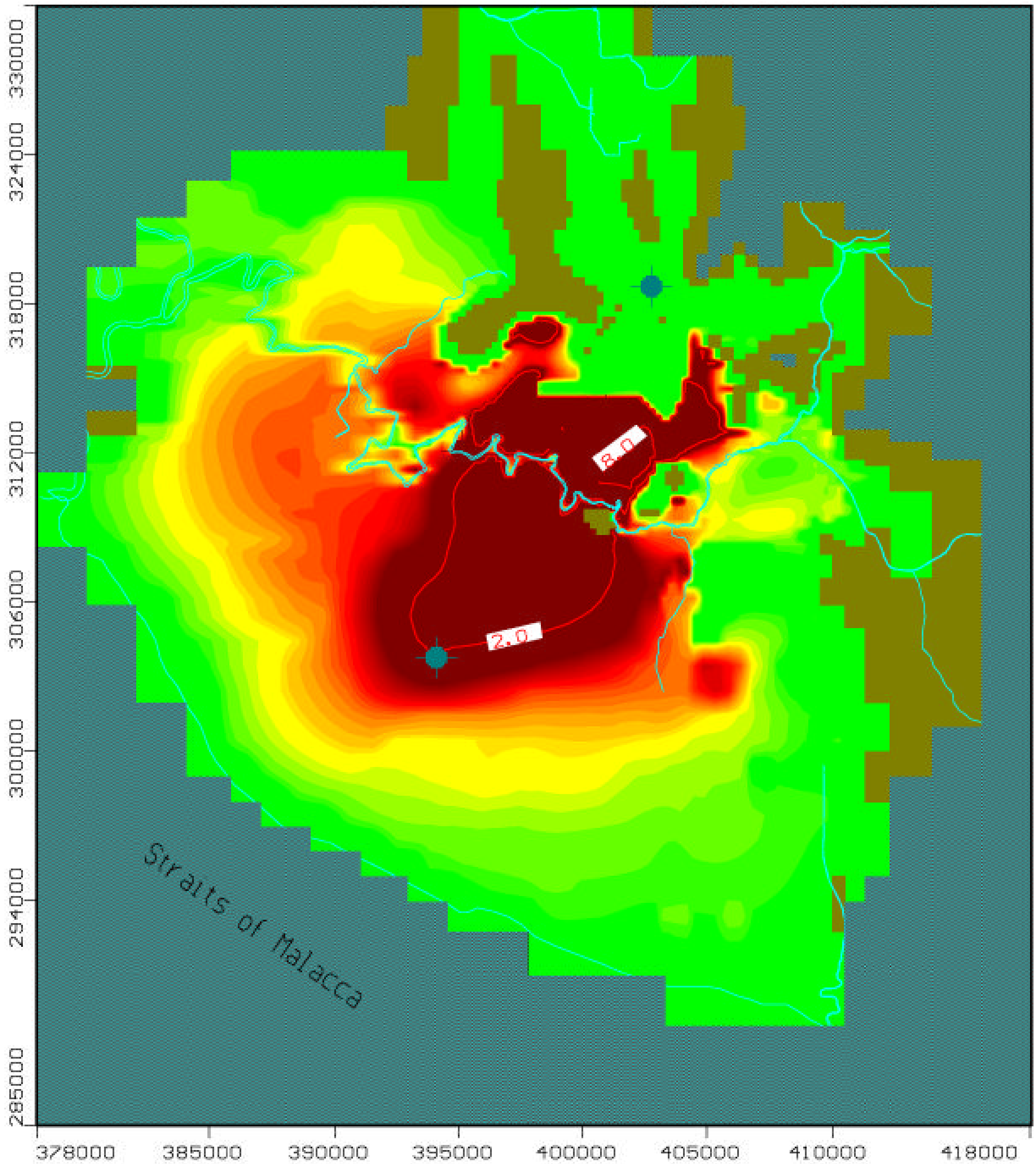
Figure 3.5.7

Solution Variant 5 - Head Equipotentials in Model Layer 3c



LEGEND

Inactive cells	
Dry cells	
General head boundary	

Drawdown (m)

0	0.8
0.2	1.4

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Figure 3.5.8

Solution Variant 5 - Drawdown in Model Layer 2

(7) Impact of Reduced Groundwater Abstraction from Imuda Mine– SV6, SV7

SV6 is a case of a significant decrease of total amount of abstracted water at Imuda Mine from 27,028 to 0 m^3/day. **SV7** assumes pumping from existing pumping wells at Megasteel/Amsteel II and Kajibumi WF, similar to **SV2**. As **Figure 3.5.9** (**SV6)** shows, the abolishment of pumping creates conditions with intensive freshwater supply in the main aquifer. The calculated recovery of groundwater levels in the area around Megasteel and Imuda Mine reaches more than 10 metres. The regional groundwater flow is oriented towards the sea.

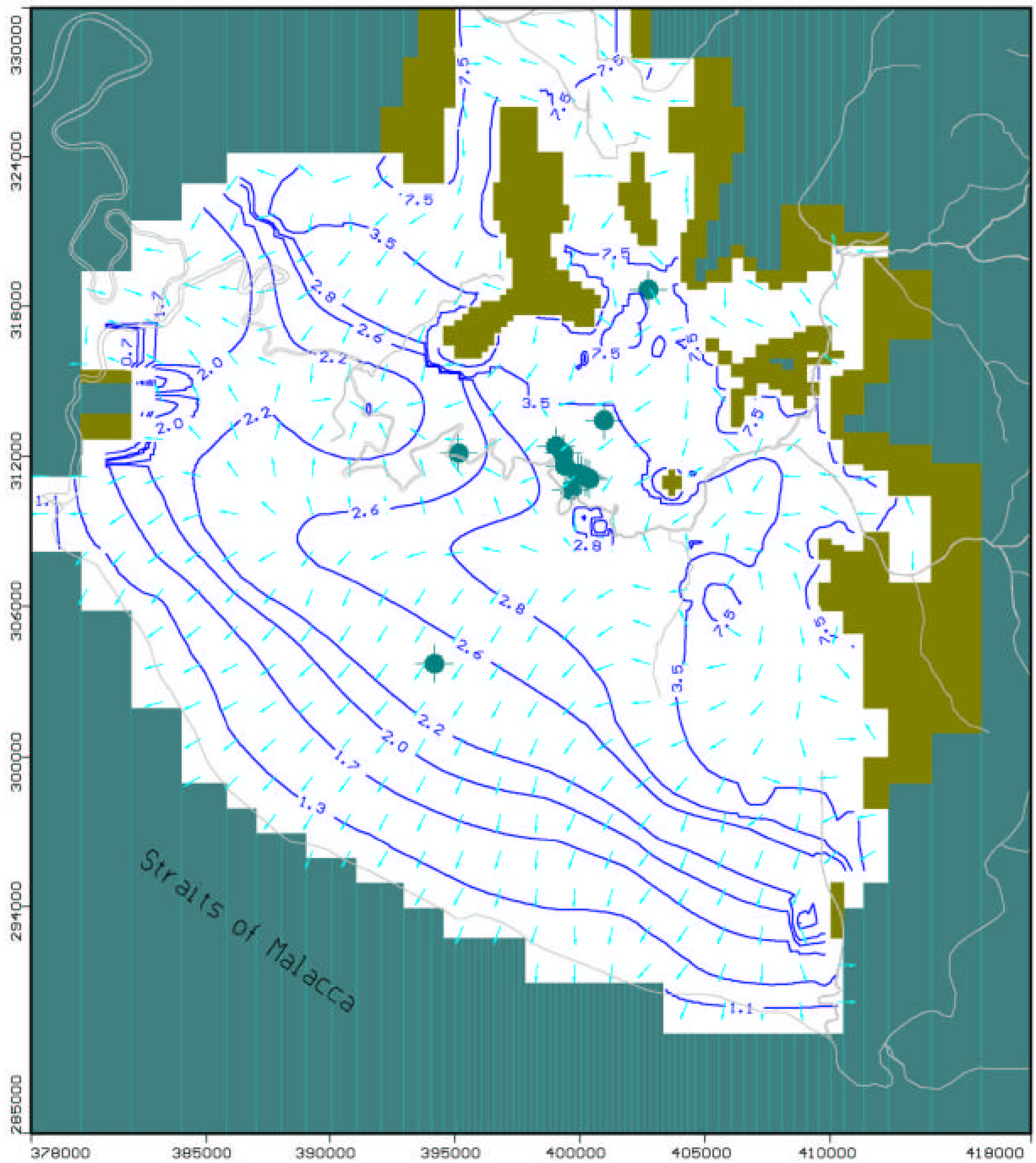
(8) Impact of Industrial Development – SV8

In the 20 years of reduced effective rainfall in MSC area, the head equipotentials and direction of flow in the main aquifer is changed slightly (**Figure 3.5.10**). Larger cone of depression causes the movement of groundwater divide towards seacoast, but does not create conditions suitable for seawater intrusion. The reduction of groundwater recharge caused up to 0.5-1.4 m drop of piezometric heads in the main aquifer around Megasteel and Imuda Mine. Drawdown of water levels (piezometric heads) in the upper peat and clay layer, Model Layer 1 and 2, was less significant; it reached the value of less than 0.2-0.5 m.

(9) Pollution Transport – SV2(b)

Result of three-dimensional particle tracking calculation is presented in the form of map of pathlines (**Figure 3.5.11**). The flow direction is indicated with direction arrows on pathlines. These arrows also serve as time markers to determine the period of 20 years before a particle reaches a certain destination. Because of low hydraulic gradients near the edges of groundwater basin, only very slow movement of pollution may be expected in this area.

The following simple example of local transport model describes the changes in concentration due to advection and dispersion. The pollutant is represented by a conservative tracer, which saturates the first four model layers (peaty, clayey and sandy top horizons). Constant concentration of pollution, 10 g/l, is assigned for every layer in two model cells (column 9, rows 39-40). **Figure 3.5.12** shows the simulated concentration contours of contaminant using the Upstream Finite Difference Method. In 20-year of continuous pollution the contaminant plume would enter the aquifer and reach the production wells at Kajibumi WF 1.



LEGEND

Contour Lines of Piezometric Head	Inactive Pumping Well
Direction of Groundwater Flow	Active Pumping Well
Inactive cells	Dry cells

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Figure 3.5.9

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Solution Variant 6 - Head Equipotentials in Model Layer 3c

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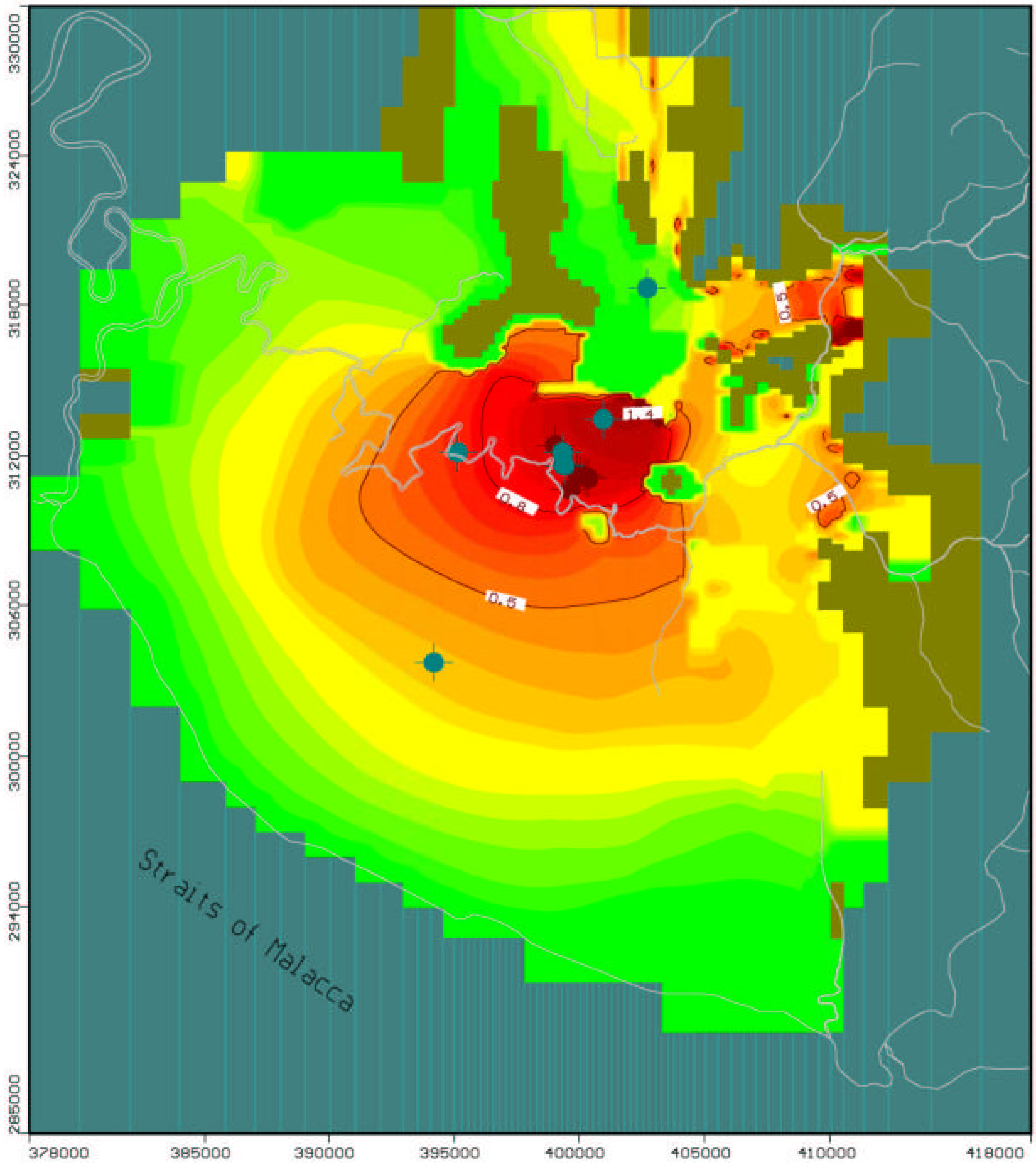

LEGEND

Inactive cells	
Dry cells	
General head boundary	

Drawdown (m)

0	0.8
0.2	1.4

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Figure 3.5.10

THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

Solution Variant 8 - Drawdown in Model Layer 3c

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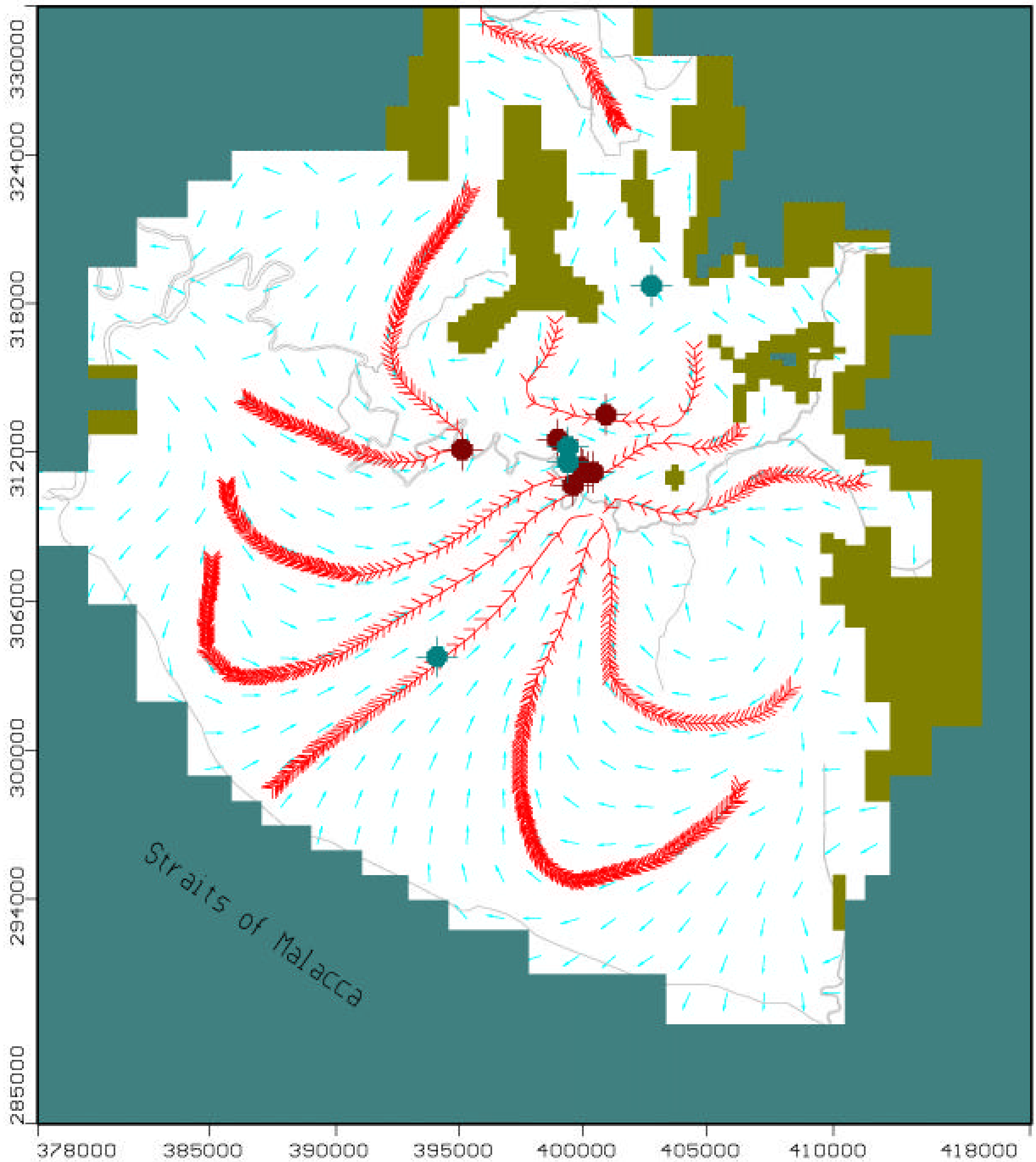

LEGEND

- Pathlines (20-years time markers)
- Direction of Groundwater Flow
- Inactive cells
- Inactive Pumping Well
- Active Pumping Well
- Dry cells

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THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

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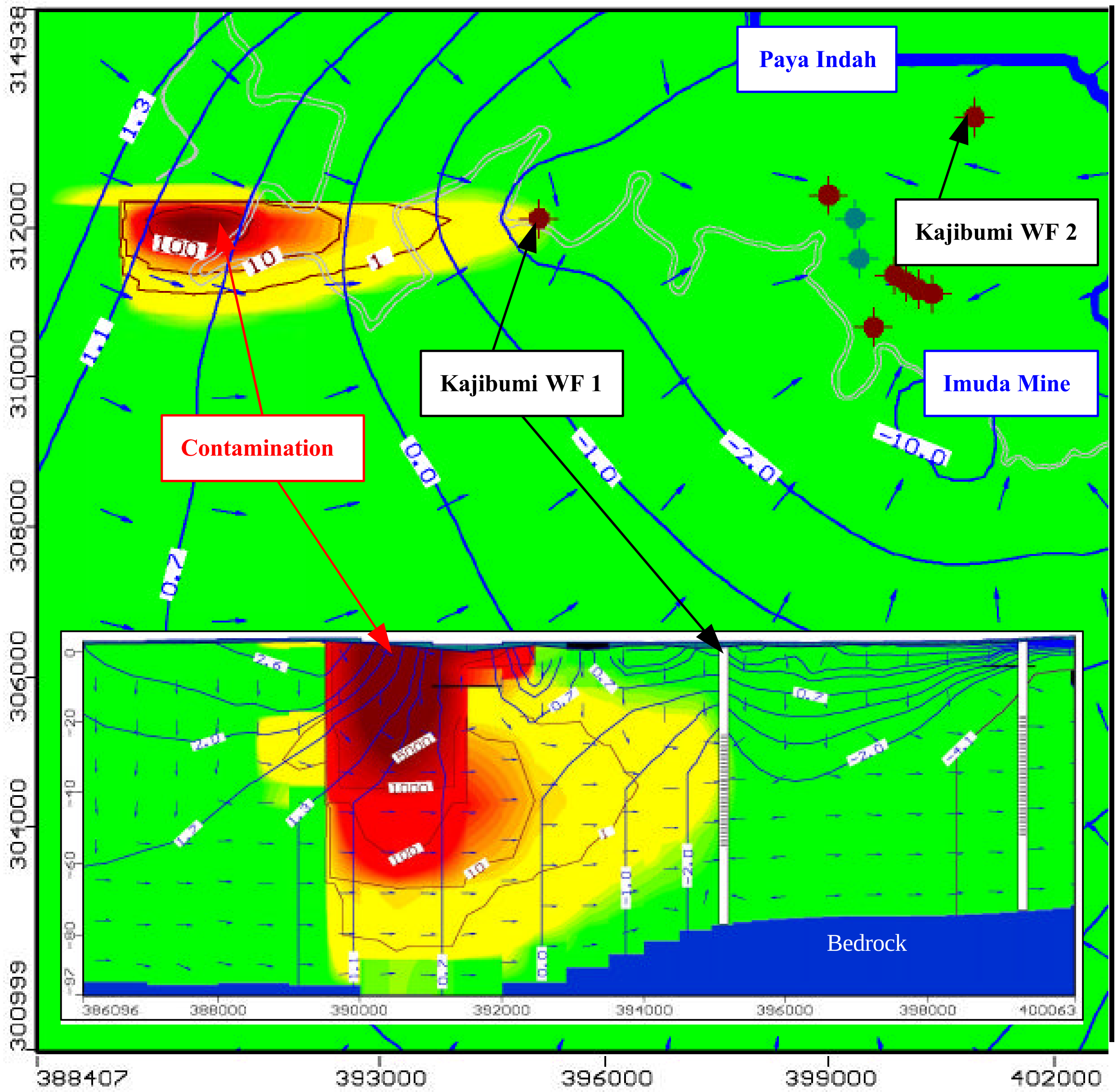
Figure 3.5.11

Solution Variant 2 (b) - Pathlines in Model Layer 3d



LEGEND

- Contour Lines of Piezometric Head
- Direction of Groundwater Flow
- Inactive Pumping Well
- Active Pumping Well

Concentration (mg/l)

0	100
1	10000

Contamination Period: **7300 days**

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Figure 3.5.12

THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

Solution Variant 2 (c) - Contaminant Concentration in Model Layer 5 and Row 39

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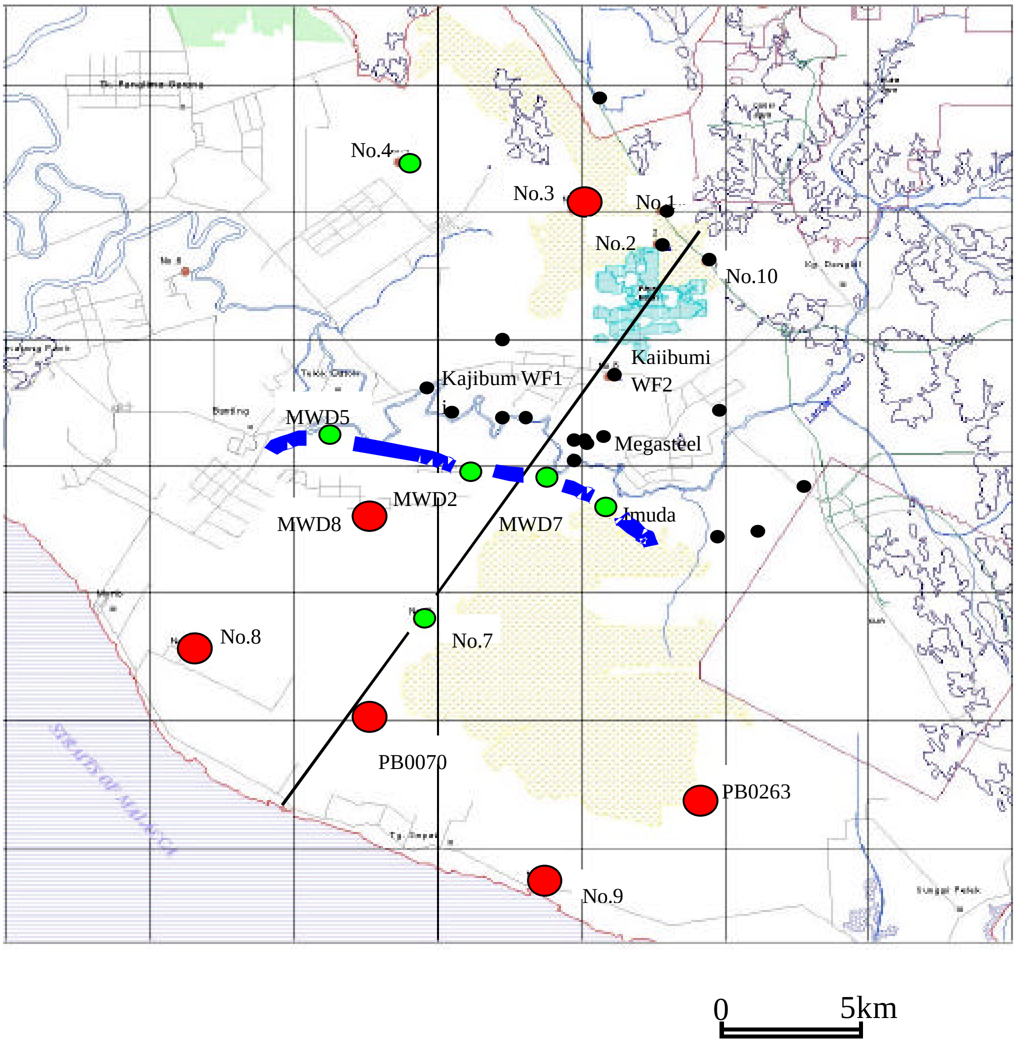
(10) Land Subsidence

The permanent compression – settlement is a major part of land subsidence and occurs in clayey soils by reduction of groundwater level. Additional pumping of groundwater from the current existing wells (**SV2**) expanded the area subjected to the consolidation settlement. The maximum settlement of over 0.2 m was estimated, and the area of 0.05 m settlement expanded to 5 times of Variant 1. A distant area such as Kanchong Darat started to show the sign of settlement.

(11) Saltwater Intrusion

Figure 3.5.13 presents chloride content of groundwater sampled from the monitoring wells distributing over the Groundwater Basin. In the figure, chloride contents are divided into three categories; namely, more than 1,000 mg per litre (mg/l), 250 to 1,000 mg/l, and less than 250 mg/l. The figure demonstrates that groundwater of high salinity can be found deep in the Groundwater Basin. A line that divides the Basin by the standard, 250 mg/l, can be drawn along the southern bank of the Langat River. Sources of high salinity at location No. 3 and No. 4 are unknown.

Distribution of chloride contents along a profile crossing the centre of the Groundwater Basin is presented in **Figure 3.5.14**. The chloride content is as high as 2,300 to 5,800 mg/l near the seacoast, and then decreases gradually towards inland. At the boundary to the hilly area, the chloride content drops to below around 10 mg/l. Contour lines of selected values may be drawn as shown in **Figure 3.5.14** as well.



Legend

Freshwater- Saltwater Interface; Line of Chloride Content of 250mg/l

Profile Line

Chloride (mg/l)

- more than 1000
- 250 to 1000
- less than 250

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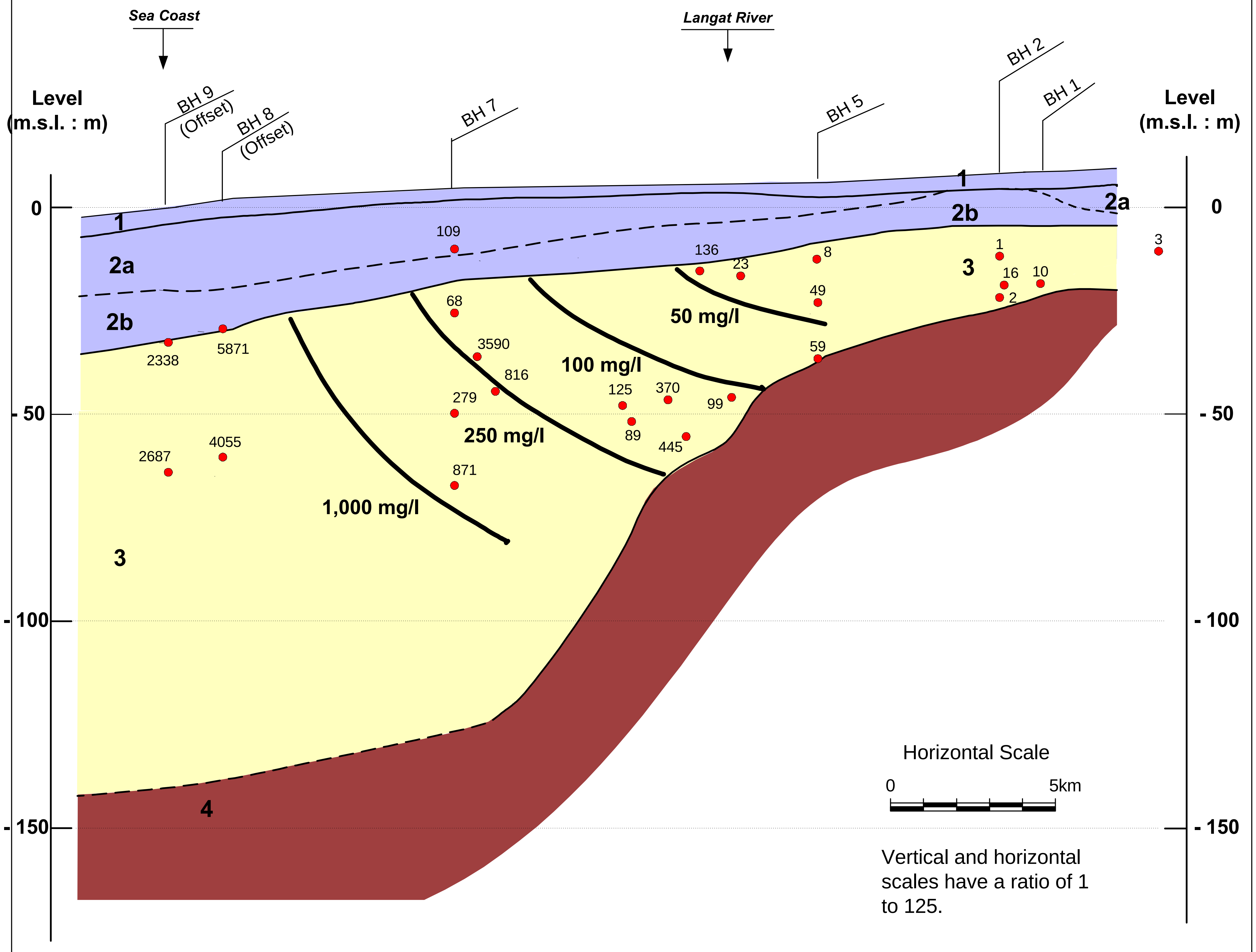
Figure 3.5.13

Current Status of Saltwater Intrusion

Figure 3.5.14

Distribution of Chloride Content within the Aquifer



LEGEND

Piezometer

59 Chloride Content (mg/l)

Location of Piezometer

Key of Borehole Log

- PEAT
- CLAY
- SILT
- SAND
- GRAVEL
- LIMESTONE
- SHALE, SLATE, PHYLLITE
- SANDSTONE, QUARTZITE, SCHIST
- Granitic rock

1 - 4 Layer Number

Boundary of Geology

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THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

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CHAPTER 4

SIGNIFICANT PRESSURES AND IMPACTS

CHAPTER 4

SIGNIFICANT PRESSURES AND IMPACTS

4.1 Significant Pressures

For the sustainable groundwater resources and environmental conservation of the Langat Basin, significant pressures were identified, as follows:

(1) Identified Pressures

Non-point source

- Historical unstable water supply with surface water resources during extraordinary drought.
- The groundwater in the subject groundwater basin is characterised by higher iron contents of few milligram per litre (normally around 1.0 to 4.0 mg/l and sometimes over 10 mg/l) compared to the drinking water standards of 0.3 mg/l.
- Electric conductivity is also generally high.

Point source

- Existence of Industrial Development Corridor along the Langat River in the subject groundwater basin.
- Large-scale groundwater abstraction for industrial purpose in the Telok Datok - Olak Lempit area.
- Large-scale groundwater withdrawal at the Imuda Tin Mine.

(2) Potential Pressures but not Identified

Non-point source

- Use of pesticides in large-scale plantation areas.
- Influence of large-scale development in the middle hilly basin, e.g., Putrajaya, Cyberjaya and other industrial estates.

4.2 Significant Impacts

Significant impacts on the sustainable groundwater resources and environmental conservation were identified, as follows:

(1) Groundwater Pollution

Although the number of data was not sufficient to judge the impacts and its possible causes, the following has been identified.

- Heavy Metals: Only one sample (MWD10 at Kajibumi WF1) out of 35 samples showed high contents of lead (Pb) at 0.08 mg/l against the drinking standard of 0.05 mg/l. Arsenic (As) exceeded the drinking standards at several wells (J2-1-2&3 in Paya Indah, J5-2-2 in Kajibumi WF2, J7-1-2&3&4 at Kanchong Darat, and J10-1-1 at east of Paya Indah). Arsenic is widely detected in the subject basin especially in the shallower wells, though almost all are under the drinking standard.
- Organic Compounds: Five kinds of organic compounds (m & p-Xylene, o-Xylene, 1,2,4-Trimethylbenzene, Napthalene, and 2-Methylnapthalene) were detected in J7-1-2, J7-1-3, J8-2, J9-1). Though it was detected by one measurement only out of three except one well (J9-1), attention should be paid for the future monitoring.

(2) Seawater Intrusion

Wells in coastal area, i.e., J8 and J9, show more than 10,000 μS/cm of electric conductivity (that of seawater is around 45,000 μS/cm). Groundwater in the coastal area is probably not suitable for domestic use. Extent of seawater intrusion to the groundwater basin is still not clear and need further monitoring.

(3) Land Subsidence

Notable data of land subsidence for the nine months period from June 2000 to August 2001 is 16.46 mm in BM7, 11.10 mm in BM15 and 13.24 mm in BM16. All of these locations are in the area along the Langat River, and near the large consumers of groundwater (Megasteel) and the dewatering process to keep the pit dry for sand mining (Imuda Tin Mine).

(4) Drawdown of Water Level in Wetlands

As a result of the groundwater simulation, no effect to the water level in lakes in Paya Indah Wetland Sanctuary are expected. These lakes are assumed sealed by impermeable soils.

CHAPTER 5

ENVIRONMENTAL OBJECTIVES

CHAPTER 5

ENVIRONMENTAL OBJECTIVES

5.1 General

Environmental objectives of the Management Plan of Sustainable Groundwater Resources Use and Environmental Conservation have been set as below, but they were revised in accordance with the monitoring results.

5.2 Environmental Objectives

The environmental objectives were set as follows:

(1) Sustainable Groundwater Yield

Although the sustainable groundwater yield depends upon the mode of groundwater extraction (few large extractions at deeper locations versus scattered smaller extractions at shallower wells), the present level of extraction at around 45,000 m^3/day for large consumers seems close to the sustainable yield at the time of study.

(2) Groundwater Quality

- Organic Compounds should not be detected from groundwater.
- Concentration of heavy metals should be under the drinking water standards.

(3) Seawater Intrusion

- Electric conductivity of J7-1-4 at Kanchong Darat should maintain the present level of around 2,000-2,500 μS/cm.

(4) Land Subsidence

- Annual land subsidence should be less than 15mm (present level). Special attention should be paid to the land subsidence at BM7, BM15 and BM16.

(5) Drawdown of Water Level of Lakes in Paya Indah

- Unusual drawdown should be avoided in the lakes in Paya Indah.

CHAPTER 6

FORMULATION OF SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT PLAN

CHAPTER 6

FORMULATION OF SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT

6.1 Introduction

To achieve the Environmental Objectives, the Sustainable Groundwater Resources and Environmental Management Plan has been established. This management plan is composed of the Monitoring Plan that is to obtain data and information on the objectives, Management Information System (MIS) that is a tool with Information Technology (IT) and Human Resources and Institutional Development Plan that is a prerequisite for operation and management of the management plan.

6.2 Monitoring Plan

6.2.1 Objective and Principles

The objective of the monitoring is to obtain data and information necessary for execution of the Management Plan. Since the Langat Basin has few accumulations of data and information necessary for the execution of the groundwater management, the monitoring to be conducted in the future is the only way to know changes in groundwater environment.

6.2.2 General Procedure of Monitoring

The monitoring work under the proposed Management Plan is divided into two; namely, "Regular Monitoring" and "Detailed Monitoring".

Regular monitoring is to be conducted for the purpose of obtaining periodical and continuous data and information, and realising historical changes of the groundwater environment. Detailed monitoring, on the other hand, will be ad hoc monitoring. When some unusual changes occur or some values exceed the given limit, detailed monitoring will be conducted for the specific purpose, location, and item. Although the methodology applied for the detailed monitoring will be the same with those of the regular monitoring, monitoring contents will be determined ad hoc.

6.2.3 Regular Monitoring

Regular monitoring proposed for the Sustainable Groundwater Resources and Environmental Management for the Langat Basin consists of the periodical monitoring of the following items:

- Groundwater Abstraction Volume;
- Static Groundwater Table;

- Groundwater Quality;
- Land Subsidence; and,
- Surface Water Level.

A summary of work item, required group/manpower, etc. is presented in **Table 6.2.1**. Detailed explanation of the monitoring work is presented in Subsections.

Table 6.2.1 Summary of Work Items for the Regular Monitoring

Work Items	Frequency of Implementation	Group/ Manpower	Equipment	Budget for Subcontract*
Groundwater Level				
1. Retrieval of Data from Data Logger New observation well: 13 Existing observation well: 7 Total 20	Every 2 months	Monitoring group	1. Vehicle 2. Receiver of data logger 3. Laptop P/C	N.A.
2. Manual measurement New observation well: 10 Existing observation well: 4 Total 14	Every 2 months	Monitoring Group	1. Vehicle 2. GW level measurement device	N.A.
3. Well Maintenance	Twice a year	Monitoring Group	Equipment for maintenance	N.A.
Groundwater and Surface Water Quality				
1. Measurement of GW and SW quality New observation well: 19 Existing observation well: 11 Surface water 10 Total 40	Twice a year	1. Monitoring Group 2. JMG Ipoh laboratory 3. Private laboratory	1. Vehicle 2. Portable WQ tester 3. Equipment for on-site measurement	For private laboratory RM67,000 /1-time RM134,000 /year
Land Subsidence				
1. Retrieval of Data from Data Logger Extensometer at Kajibumi WF2:	Every 2 months	Monitoring Group	1. Vehicle 2. Receiver of data logger	N.A.
2. First Order Levelling Land Subsidence BM at 20 Locations	Once a year	Private survey company	Vehicle	For private survey company RM10,000 /year
3. BM Maintenance	Every 4 months	Monitoring Group	1. Vehicle 2. Equipment for site clearing	N.A.
Surface Water Level				
1. Retrieval of Data from Data Loggers WL Gauge for Inflow to Paya Indah: 3 WL Gauge for Outflow from Paya Indah: 2 WL Gauge for Langat River: 1 Total 6	Every 2 months	Monitoring Group	1. Vehicle 2. Laptop P/C	N.A.

“N.A.” stands for Not Applicable.
*Budget required for the subcontracted work shall be confirmed by requesting quotations from several contractors before planning.

(1) Groundwater Abstraction Volume

The volume of groundwater abstraction is one of the basic information for the groundwater management. At present, no actual record is available for any type of wells although the pumping capacity is available from the well development application. Possible way of obtaining the information will include the collection of data on daily volume of groundwater abstraction.

(2) Static Groundwater Table

The objective of the observation is to identify regional variations and long-term changes of groundwater level in the Langat Aquifer. For the future long-term monitoring, different frequencies will be applied to the monitoring of groundwater table and groundwater quality.

A total of 34 wells has been selected and developed for the long-term groundwater level measurement. Of the 34 wells, an automatic data logger with sensor for the static groundwater table has been installed at 20 wells. Retrieval of the data from the data logger and manual measurement will be conducted in every 2-months. Location of the observation points for groundwater level and quality is illustrated in **Figure 6.2.1**.

(3) Groundwater Quality

Groundwater quality monitoring will be conducted to identify regional variations and long-term changes of groundwater quality in the target Aquifer. In addition, surface water quality will be measured as the background information.

Of the total of 34 wells developed for the long term monitoring for groundwater level, 30 wells have been selected for groundwater quality monitoring. The surface water quality is to be measured at 10 locations such as mine lakes, canals in plantations and the Langat River. Measurement of water quality will be conducted in four modes, namely, in-situ, on-site, at JMG Ipoh Laboratory, and at a private laboratory. Measurement interval will be twice a year.

(4) Land Subsidence

The established network for land subsidence monitoring consists of a total of 20 shallow benchmarks with 20 corresponding datum points for the monitoring of land surface subsidence, and one borehole extensometer for monitoring of the change in upper clayey layer thickness.

First order leveling survey for the shallow benchmarks of 20 locations from each corresponding datum point will be conducted once a year. Retrieval of data from data logger of the extensometer will be conducted in every two months. The location of the shallow benchmarks, datum points and borehole extensometer is illustrated in **Figure 6.2.2**.

(5) Surface Water Level

Surface water level measurement devices have been installed to monitor the inflow to and outflow from the Paya Indah Wetland Sanctuary and at the Langat River. The monitoring work will be conducted to obtain the basic hydrological information to be used in the future groundwater simulation.

Five sets of TD-Diver have been installed at Paya Indah, and one set of SEBA PS-Insider has been installed in the Langat River. Retrieval of the data from the data logger will be carried out using the laptop computer used for the Study, every two months.

6.2.4 Detailed Monitoring

Detailed monitoring will be ad hoc monitoring. When some unusual changes occur or some values exceed the given limit, detailed monitoring will be conducted for the specific purpose, location, and item. Although the methodology applied for the detailed monitoring will be the same as those of the regular monitoring, monitoring contents will be determined ad hoc.

The necessity of the detailed monitoring will be proposed by the Manager of the Groundwater Management Section and reported to the Director of Regional JMG (see proposed organisation of Groundwater Management). The Director of the Regional JMG will judge the necessity of the detailed monitoring and give necessary instructions to the Manager of the Groundwater Management Section.

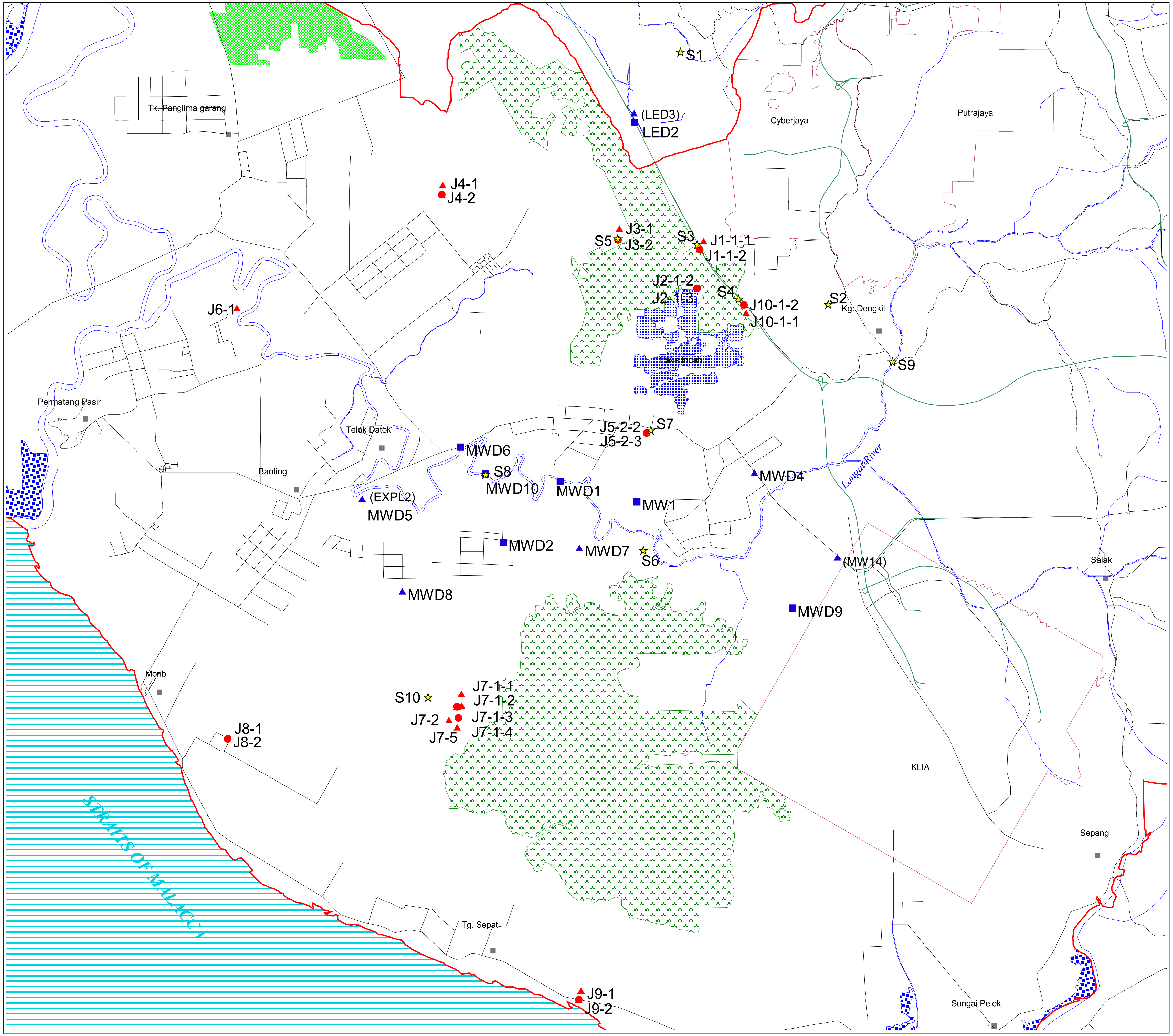

Figure 6.2.1

Location of Groundwater Level and Quality Observation

LEGEND

- ● New well measured by logger
- ▲ New well measured by manual
- ■ Existing well measured by logger
- ▲ Existing well measured by manual
- ☆ Surface water sampling

Forest Reserve

- Inland Forest
- Mangrove Forest
- Swamp Forest

- Highway
- Roads
- Railways
- Rivers

- Towns

- Builtup Area
- Paya Indah
- Study Area

Scale 1 : 200,000

1 0 1 2 3 Kilometers

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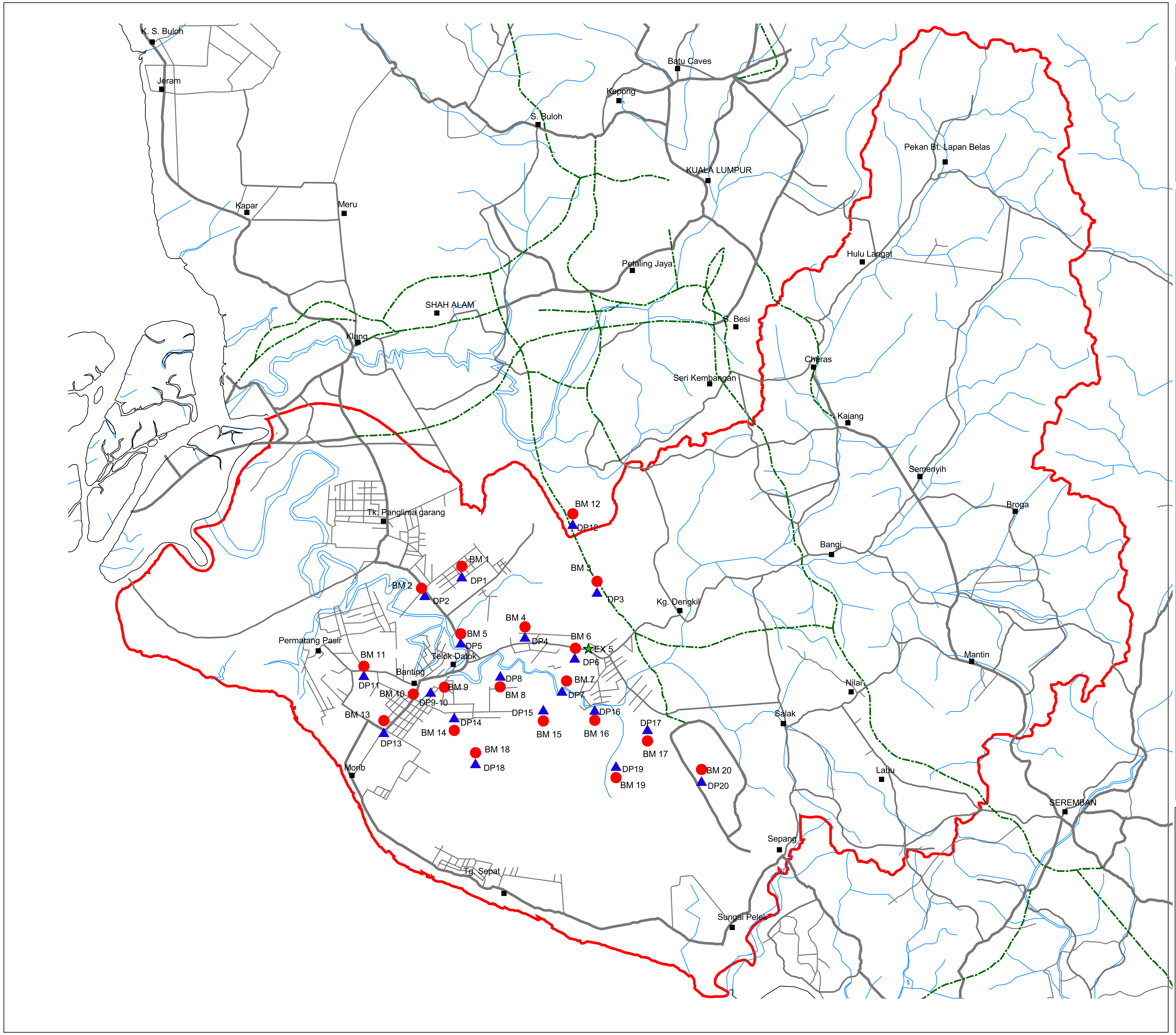

Figure 6.2.2

Location of Land Subsidence Measurement

LEGEND

- Benchmark Station
- Deep Datum
- Extensometer
- Town
- Coastal line
- Major Sealed Federal Road
- Other Sealed Federal Road
- Major Sealed State Road
- Other Sealed State Road
- Toll Expressway
- River
- Langat Basin

3000 0 3000 6000 Meters

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6.3 Management Information System (MIS)

6.3.1 Objective for the Establishment of MIS

For the establishment of the Sustainable Groundwater Resources and Environment Management Plan in the present study, various kinds of information have been collected and developed as ArcView shapefile format utilising the Geographical Information System (GIS). Various numerical data have also been compiled and stored in database files.

JMG has been promoting further utilisation of the GIS and IT environment as well as the updating of database environment utilising Internet environment. The five-year strategic plan of JMG includes the use of Information Technology (IT) to enhance the planning and implementation capabilities of the Department. The plan further addresses international standard quality data and information services strategy.

Sustainable utilisation of the information as well as the smooth implementation of monitoring work is important for the execution of the Management Plan. The Management Information System (MIS) proposed in this chapter is a tool with IT for the execution of the Management Plan.

6.3.2 Principles of MIS Establishment

(1) Major Functions

The proposed Management Information System will include four major functions; namely, Data Input and Maintenance; Monitoring; Evaluation; and Dissemination of Information to the Public by Annual Status Report.

(2) Users

Possible users will include: JMG Staff; Staff of relevant agencies, i.e., SWMA, DOE, DID, Paya Indah Wetland Sanctuary; and General Public.

The level of access to each of the functions mentioned above will be controlled by the Process Management part of the system. Functionally, any Internet user can access the Annual Report function. For the other functions, a user will need a password, which can be obtained from JMG via e-mail. JMG will then approve the level of access for each applicant and issue the corresponding password. This procedure will be performed electronically.

(3) Basic Structure

The Internet Web-application by using ArcIMS (Arc Internet Map Server) has been developed for the MIS. Topographic and thematic maps as well as the other relevant maps have been digitised and prepared in ArcView shapefile format. The available Well data have been converted into Oracle database.

Utilisation of digital maps and database has been taken into consideration and necessary software has been determined.

As hardware environment, ArcIMS Server has been newly introduced. PCs used in the study have been utilised as ArcSDE Server and for data processing.

6.3.3 Functions

Functions of each module are as presented hereafter.

(1) Data Input and Maintenance

For the purpose of identifying regional variations and long-term changes of groundwater level and quality, observations have been made regularly at the long-term monitoring wells in this Study. The Data Input and Maintenance system will allow a user to browse, input, and manage the observed data for monitoring purposes.

The proposed Sub-Modules under Data Input and Maintenance will be the following three:

- Groundwater Level and Quality;
- Surface Water Level; and,
- Topsoil Subsidence and Benchmark Elevation.

(2) Monitoring

Groundwater level, water quality, land subsidence and the lowering of water level in reserve areas within the Langat Basin are the items to be monitored. The measurements at the monitoring wells for groundwater level and quality, the levelling results of benchmark stations, are the main data sources, which would be supplemented by the Thematic Maps prepared in this Study.

(3) Evaluation

This module will allow authorised users to visualise the evaluation maps such as Distribution of Clayey Soil and Boundary of Aquifer, as well as those derived from the evaluation of Groundwater Model simulation results such as Impacts of Extracting Groundwater.

Both pre-processing and post-processing of data to and from MODFLOW, is performed using Visual MODFLOW software. Based on topographical data such as DEM (Digital Elevation Model), contour lines are generated, and all the positional data required for modelling are geo-referenced in GIS. Data transfer between GIS and VM is performed in DXF (AutoCAD standard interchange file) and ASCII (Text file) formats. All simulation results, as well as the derived data, are stored in ArcView shapefile, which are ready to use for display by ArcIMS.

The JICA Study Team had conducted land subsidence simulations and the resulting contour lines were digitised to produce Land Subsidence maps using GIS. Similarly, maps of distribution of Clayey Soil, Aquifer, etc. have also been produced.

Those Evaluation Maps are prepared by model variant. The user of this module is assumed to be familiar with the model variants, and can selectively display each concerning Evaluation Map referring to the corresponding model variants. The examples are shown in **Figure 6.3.1**.

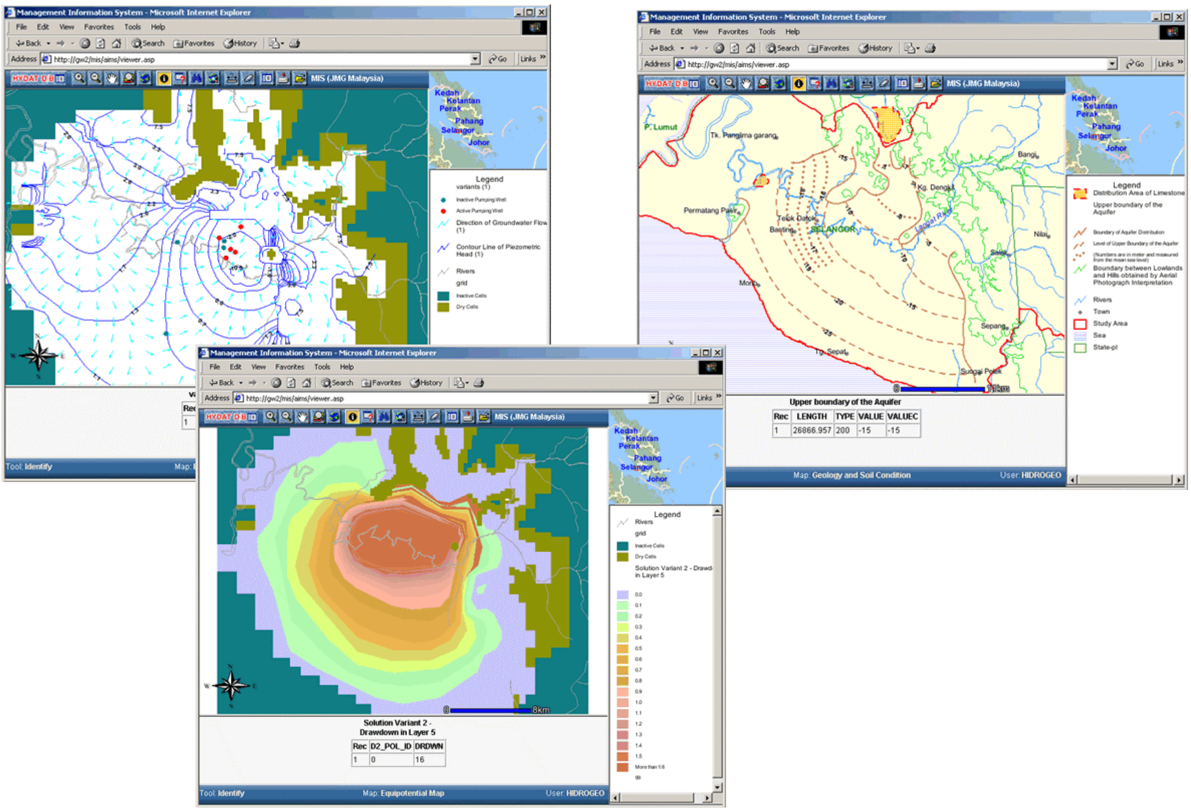

Figure 6.3.1 Examples of Viewing MODFLOW Model Simulation

(4) Annual Report

This module is thought for general Internet users, no Password is necessary for access. The proposed major items are: (i) Features of Langat Basin, (ii) Monitoring Results in 2001, (iii) Change from Year 2000, (iv) Measures Taken, (v) Achievement of Environmental Objectives, and so on. The information to be disseminated on the web is basically in textural form, supplemented by figures (graphics, scanned image) and tables. Examples of Annual Report Page are shown in **Figure 6.3.2** below.

Figure 6.3.2 Examples of Annual Report Page

6.3.4 Structure with ArcIMS

(1) System Architecture

The system employs a web-based three-tier architecture; namely, Client Front-End (User Interface), ArcIMS Middle Tier (Process Management), and Database Back-End (Database Management).

(a) Client Front-End

A client will send request to the server, and receive reply from the server through a given Internet connection by a web browser. It is termed as Client Front-End Tier. The system will utilise a thin client design, the existing Internet connection at JMG, and the Internet Explorer Version 4 and higher. The bandwidth of the existing Internet connection is 64kbps and the communicator is Netscape Version 4.

(b) ArcIMS – Middle Tier

This middle tier of the system will have a Process Management component. It will determine what kind of data is to be sent to the user, depending on the type of Password. For the “Input and Maintenance Module”, the password will be issued for JMG internal use only. As for Monitoring and Evaluation modules, the user will be requested to enter a Password.

The system utilises Microsoft Internet Information Services (MS IIS), which is the default web service of Windows NT and Windows 2000, to integrate all the middle-tier applications. All components of ArcIMS, namely, ArcIMS Application Server, ArcIMS Spatial Server, and ArcIMS Manager, are installed on a single server. ArcIMS has the capability to provide five Internet map services; namely, Image Rendering, Query, Data Extraction, Feature Streaming and Geocoding, among which the latter two are not applied for application development.

(c) Database Back-End

The Oracle database design of HIDRODAT has been adapted and it works with the JMGM Database Information System Version 3.4.1. The master database provided by JMG consists of two schemes, IDIS01 and IDIS02. The application development will utilise the scheme IDIS01.

Further, two database schemes, IDIS03 and IDIS04, have been created. IDIS03 is a SDE database scheme. Shapefiles, which feature attributes will be queried from the Oracle database, are managed in this database scheme. The water level and water quality observations, including time-series data from automatic data logger and first-order levelling, are stored in IDIS04. This database design will allow query procedures of the system to be effective.

(2) Hardware and Software

The Hardware and Software configuration basically has no change, as depicted in **Figure 6.3.3**.

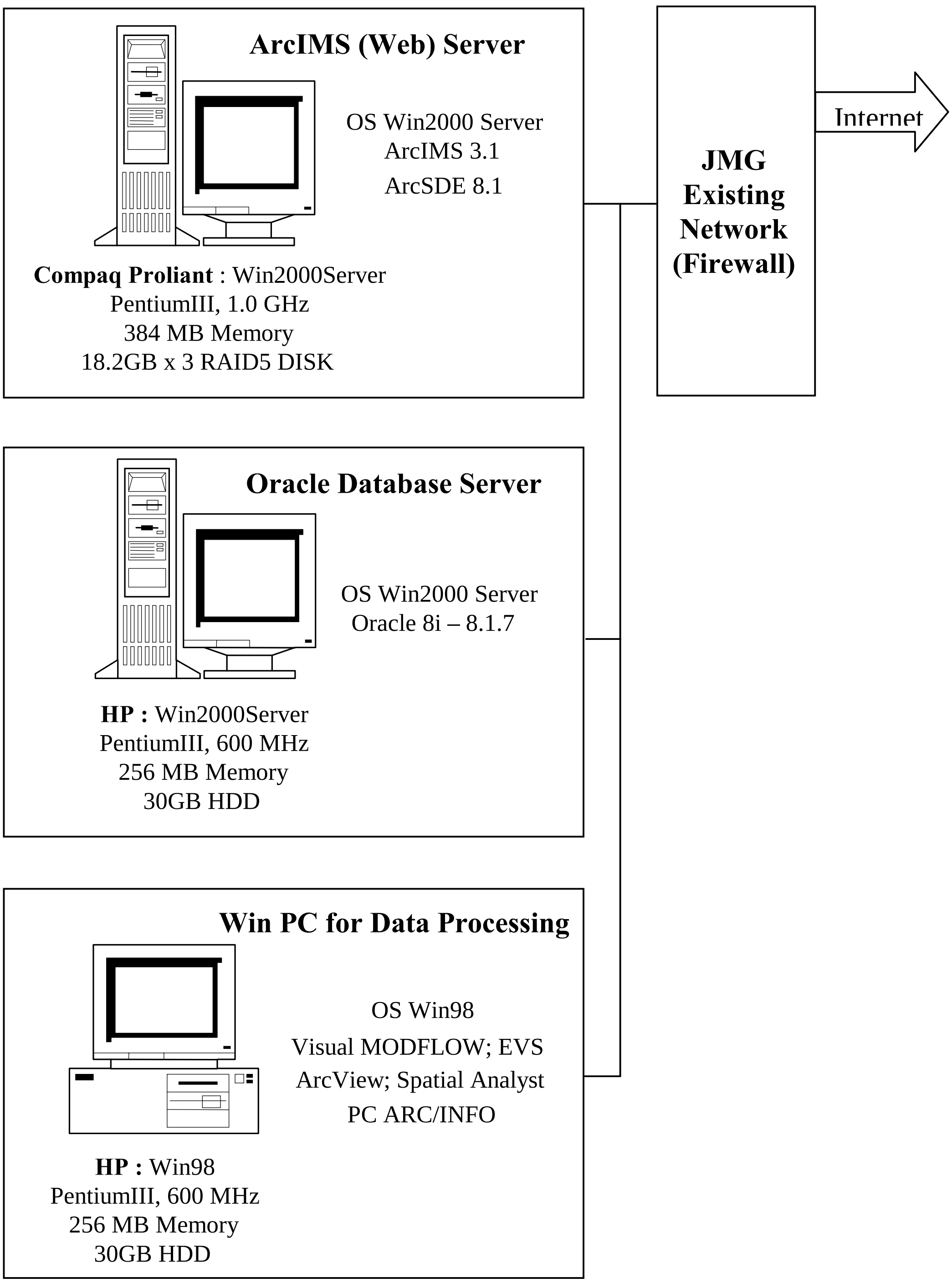

Figure 6.3.3 Hardware and Software Configuration

6.4 Human Resources and Institutional Development Plan

6.4.1 Organisational Framework

There are several agencies involved in different components of groundwater development and management. The overall organisational framework for groundwater development in the Langat Basin is shown in **Figure 6.4.1,** while the roles of these agencies involved are summarised in **Table 6.4.1**. These aspects are further elaborated below:

Table 6.4.1 Proposed Roles of Agencies Related to Sustainable Groundwater Development

Aspect	Agency
Policy, Programme, Plan	
1. National Groundwater Policy	**National Water Resources Council (NWRC)**
2. Groundwater Development Programme (5yr. Malaysia Plans)	**NWRC, EPU, Treasury, JMG, LUAS**
3. Master Plan and Feasibility Studies	**JMG**, LUAS, Private Concessionaires
4. Langat Basin Management Plan	**LUAS**, JMG, DID, JPBD, Local Authorities, Forestry Dept. PTG, Paya Indah, DOE
Infrastructure Development (planning, design, construction and maintenance)	
1. Groundwater production well	**JMG**, JBAS, Private Concessionaires
2. Groundwater Distribution	**JBAS**, Private Licencees
Laws/Enforcement	
1. Laws and regulations on groundwater development and management	State Authority, **LUAS**
2. Licencing for well drilling, groundwater abstraction and monitoring	**LUAS**
3. Pollution Control Enforcement	**DOE**, LUAS
4. Guidelines and Standards	**JMG**, LUAS
Monitoring	
1. Groundwater Monitoring (comprehensive monitoring, water quality, land subsidence, water level, inflow and outflow)	**JMG**, LUAS
2. Pollution Control Monitoring	**DOE**, LUAS
3. Drinking Water Quality Monitoring	**MOH**, NDWQSP
Education and Research	
1. Public Awareness / Education	**JMG**, Local Authority, LUAS, Schools, DOE, NGO (MWA, Malaysian Wetland Foundation)
2. Emergency Response Management (ERM)	**JMG**, Local Authority, DOE, District Office, LUAS, JBA
3. Research and Development	**JMG, University**, NAHRIM, JPS
4. Training	**JMG**, NAHRIM, LUAS, IKLAS, University

Note : Lead agencies are presented in bold letters.

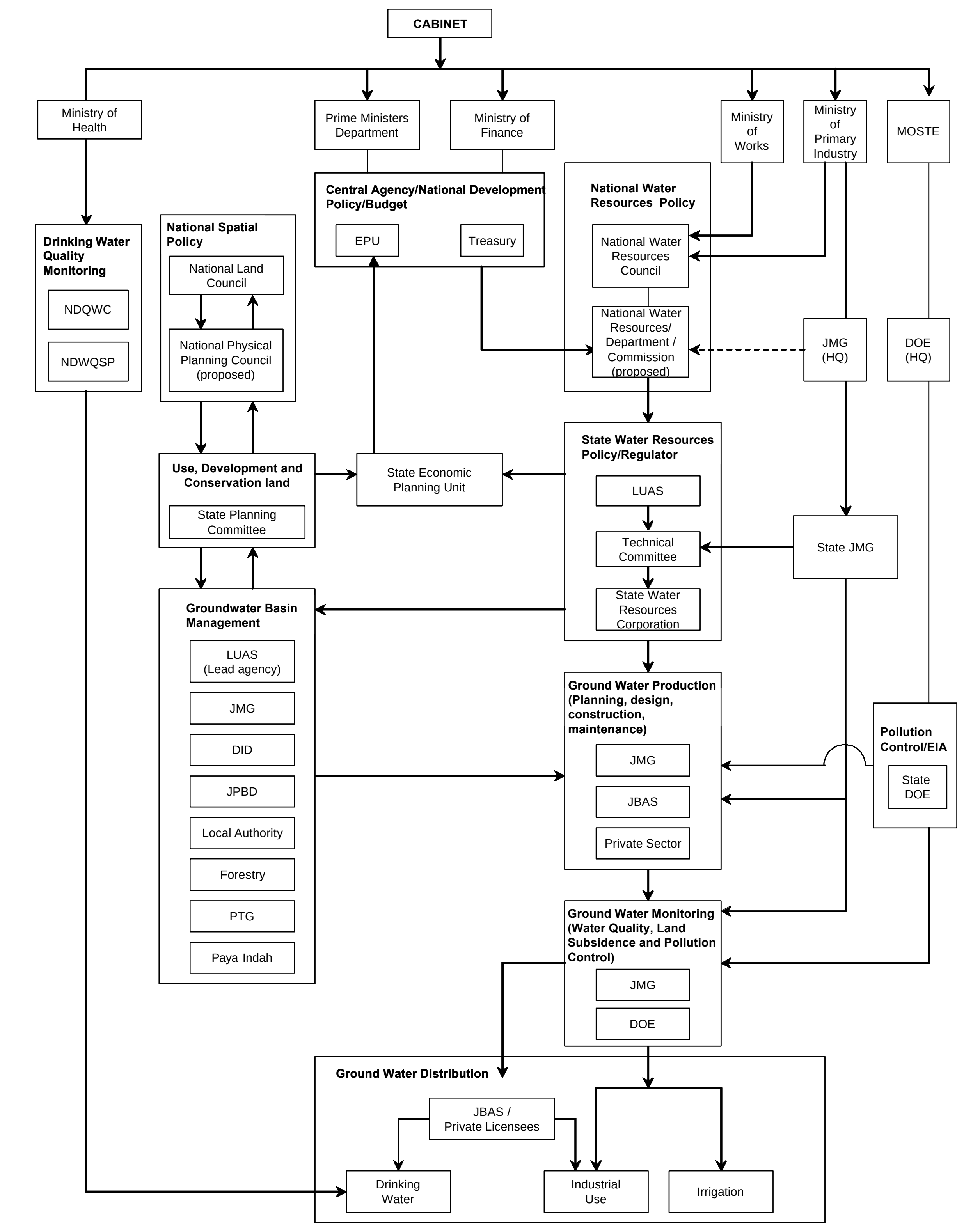

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Figure 6.4.1

Proposed Organisational Framework for Sustainable Groundwater Management / Development in the Langat Basin

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(1) Policy, Programme and Plans

The national groundwater policy should be a constituent component of the proposed National Water Resources Policy. The National Water Resources Council (NWRC) will be an important forum to deliberate on policy matters regarding groundwater and on issues relating to groundwater regimes that transcend state boundaries.

The development programmes of government departments and agencies are normally incorporated into the 5-year Malaysia Plans. The principal agencies that will be responsible in formulating an overall programme for groundwater development is JMG and expected to include NWRC, EPU, Treasury and LUAS.

It is suggested that JMG be entrusted to prepare more specific master plans for areas with good groundwater potential to complement the National Water Resources Master Plan. In the case of Selangor, the task could also be carried out by LUAS with assistance from JMG.

The management and protection of the river basin should be led by LUAS, which has wide reaching powers to advise the State on the declaration of designated areas, protected areas and river reserves, and on the formulate and implement development and management plans for the area.

(2) Infrastructure Development

Infrastructure development will involve well drilling, related soil investigation works, pumping tests and reticulation system. In the state of Selangor the production and the distribution functions of potable water are divided between JBAS and the privatised companies with the former being responsible for the distribution aspects. In line with this trend, it is likely that groundwater production wells could be privatised under licence. The main agency responsible for infrastructure development for production wells will be JMG if it is government funded and private concessionaires if the project is privatised. Most of the groundwater pumped is used on site for industrial purposes. Some of the wells developed by JBAS and private water companies are used to supply drinking water and are distributed by the JBAS water reticulation system. Most of the groundwater in the Langat Basin is expected for on-site industrial use or as drinking water.

(3) Regulatory Aspects

Provisions on groundwater are found in the SWMAE, the Geological Survey Act and the Environmental Quality Act (EQA). In the case of Selangor, the principal law on groundwater is the SWMAE. The law defines groundwater and allows the imposition of charges for abstraction and declaration of designated groundwater areas. The principal authorities for the making of laws and regulations on groundwater in Selangor are the State Authority and LUAS.

In the case of Selangor, the licencing powers with respect to the above are given to LUAS under the SWMAE. The enactment also states that no licence is required and consequently no charges may be imposed for the private right to take and use water for domestic and subsistence agricultural purposes.

The main enforcement powers on pollution of watercourses are with DOE and LUAS. Both of these agencies are empowered by respective laws, i.e., EQA and SWMAE. Prohibition of pollution of watercourses is also found in a number of related legislations including the Waters Act.

JMG being the principal technical department on groundwater may prescribe uniform standards and guidelines on groundwater management. These could be first deliberated at the NWRC before they are subsequently adopted by the respective states.

(4) Monitoring

JMG and DOE currently manage the monitoring of wells. The more comprehensive range of monitoring functions is carried out by JMG. It is suggested that JMG be the main central depository of information obtained from all monitoring wells.

Safe drinking water is an important public health concern. Obviously, if groundwater is to be used for dinking purposes, then it has to satisfy the National Drinking Water Quality Standards (NDWQS). It is proposed in this study that the JMG be made a permanent member of the National Drinking Water Quality Surveillance Programme (NDWQSP) as well as the National Drinking Water Quality Committee.

(5) Education and Research

Public awareness and education on groundwater resources and the need to protect these resources are an important component of a management plan. Emergency Response Management (ERM) arises if there is major catastrophe relating to groundwater pollution or accident. Such ERM response measures are important for river flooding and may be extended to include the groundwater sector as well. The importance of research and development (R&D) on groundwater is already spelled out in the 8th Malaysia Plan. The main agencies involved in this will include JMG, universities, NAHRIM (National Hydraulic Research Institute of Malaysia), and DID.

6.4.2 Human Resources Development Plan

(1) Roles and Functions

(a) Minerals and Geoscience Department (HQ)

JMG will be the main technical department for groundwater development and management. Except for laws and regulations that are clearly within the jurisdiction of the State, JMG has an important role in programme formulation, planning and development, monitoring, public awareness programme and research. Hence it is important at the organisational level that the groundwater and hydrogeological functions of the Department are better emphasised. At the headquarters level there may be a need to establish groundwater functions under the Geoscience Unit to better emphasise the hydrogeological functions of the department.

The Technical Services Division in Ipoh will support the Headquarters. A new unit on groundwater is proposed, headed by a hydrogeologist. The main function of this unit is to provide specialist groundwater expertise particularly researchers and modellers to State JMGs that do not have a Hydrogeology Unit as well as State Water Resource Authorities. This unit may also conduct training courses and undertake research and development on groundwater development and management. This unit will also undertake data management and MIS functions of State JMGs. The Technical Services Division will also provide Laboratory services for water quality analysis as well as system administration support to the Groundwater Unit. It may also be necessary to enhance the laboratory services for water quality analysis in order to reduce outsourcing to private laboratories. The proposed organisation structure for Headquarters is shown in **Figure 6.4.2**.

(b) Selangor State JMG

The Selangor State JMG will be the main technical agency on groundwater development in the State. It will also be the principal advisor to LUAS on matters pertaining to groundwater development and management in Selangor.

The proposed organisational structure for State JMGs is shown in **Figure 6.4.3**. A new hydrogeology unit is proposed, headed by a senior hydrogeologist. Hydrological functions will be subsumed under the Geoscience Unit. The main functional sections will include (i) groundwater development, (ii) groundwater monitoring, and (iii) MIS and Data Management. The groundwater development section will be mainly responsible for infrastructure development pertaining to the planning, design, construction and maintenance of wells. This section will also evaluate technical reports and feasibility studies submitted by private concessionaires and licencees.

Other aspects of development work relates to development programmes and advisory services relating to licencing and carrying out public awareness campaigns. The Manager could assume these functions. The other section of the unit relates to groundwater monitoring, which will mainly involve gathering field information, while the MIS function will include building a database and GIS of the spatial attributes of the wells. The Information Management Unit of the Department will provide system support to the Unit.

(c) Department of Environment (DOE)

DOE is the principal agency with respect to pollution control. It does so by administering and enforcing the provisions of the Environmental Quality Act (EQA) 1974 and the various regulations enacted under the Act. The Monitoring Unit of the Control Division at DOE (HQ) currently undertakes the groundwater functions. The objective of this monitoring programme is to detect contamination to groundwater.

(d) Selangor Waters Management Authority (LUAS)

LUAS was established under a state enactment for the better management and protection of water resources in the State. In fact the 8th Plan suggests that such models be replicated in all states. Despite its wide powers, both its technical and financial capabilities are quite limited at the moment. However, under the proposed manpower planning of the Department, the current staff strength of 5 is proposed to increase to 200.

The current main programmes for the agency under the 8th Plan are the planning and management of catchment Areas, cleansing and rehabilitation, water pollution control and public awareness and education. The focus of these programmes is more related to surface water than groundwater. Adequate financial and staff resources have to be allotted to LUAS before it can effectively carry out its functions.

(2) Training

Training and development are part of the functions of a number of agencies including JMG and this function could be further developed at the Ipoh Branch. Other relevant agencies include NAHRIM, LUAS and IKLAS (the research institute under DOE). These agencies could conduct in-service short-term training on different aspects of groundwater development and management. Both long term and short-term academic courses could also be conducted at the universities to enhance knowledge on groundwater development and management.

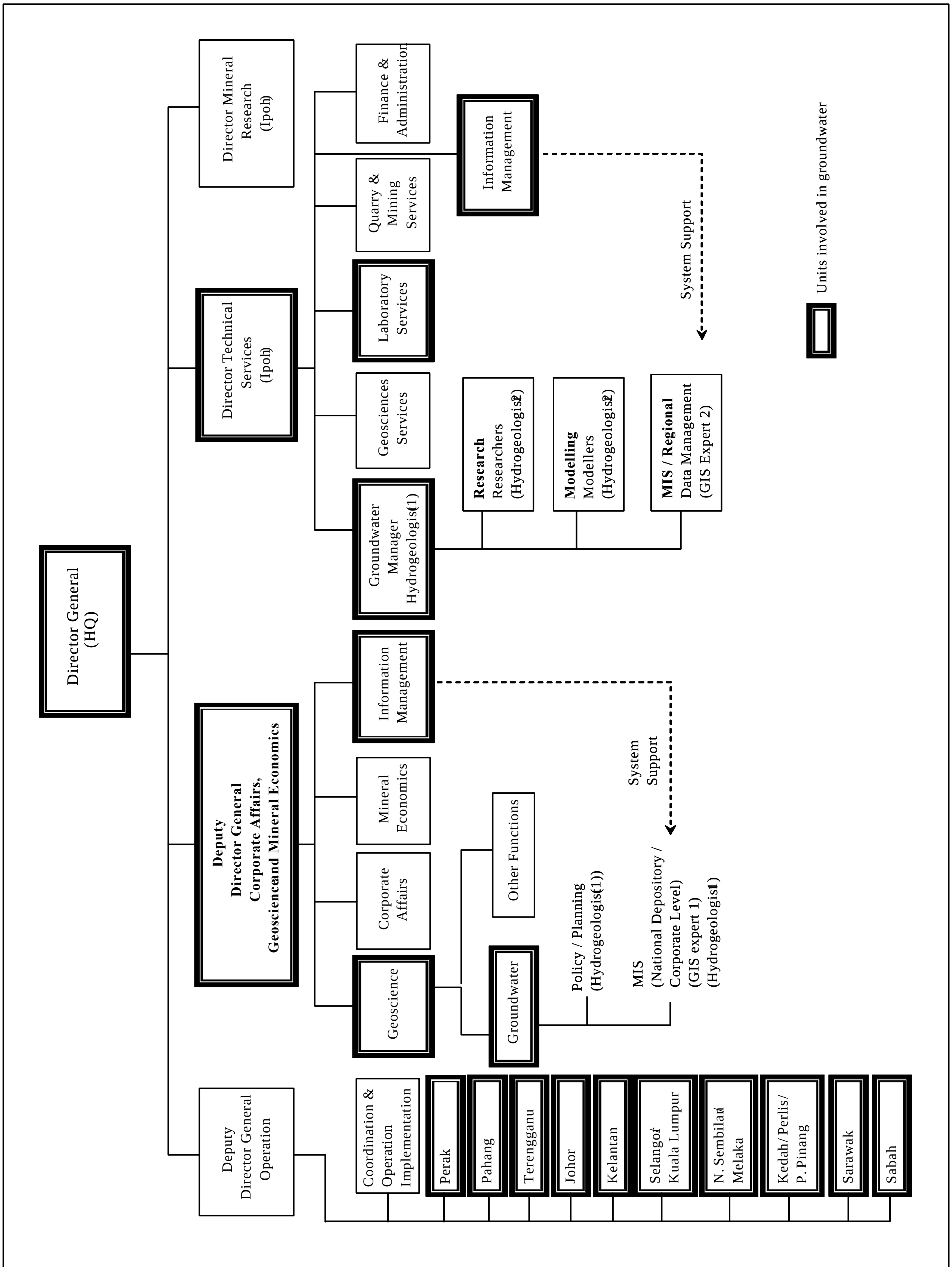

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Figure 6.4.2

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Proposed Organisation of Minerals and Geoscience Department for Groundwater Management

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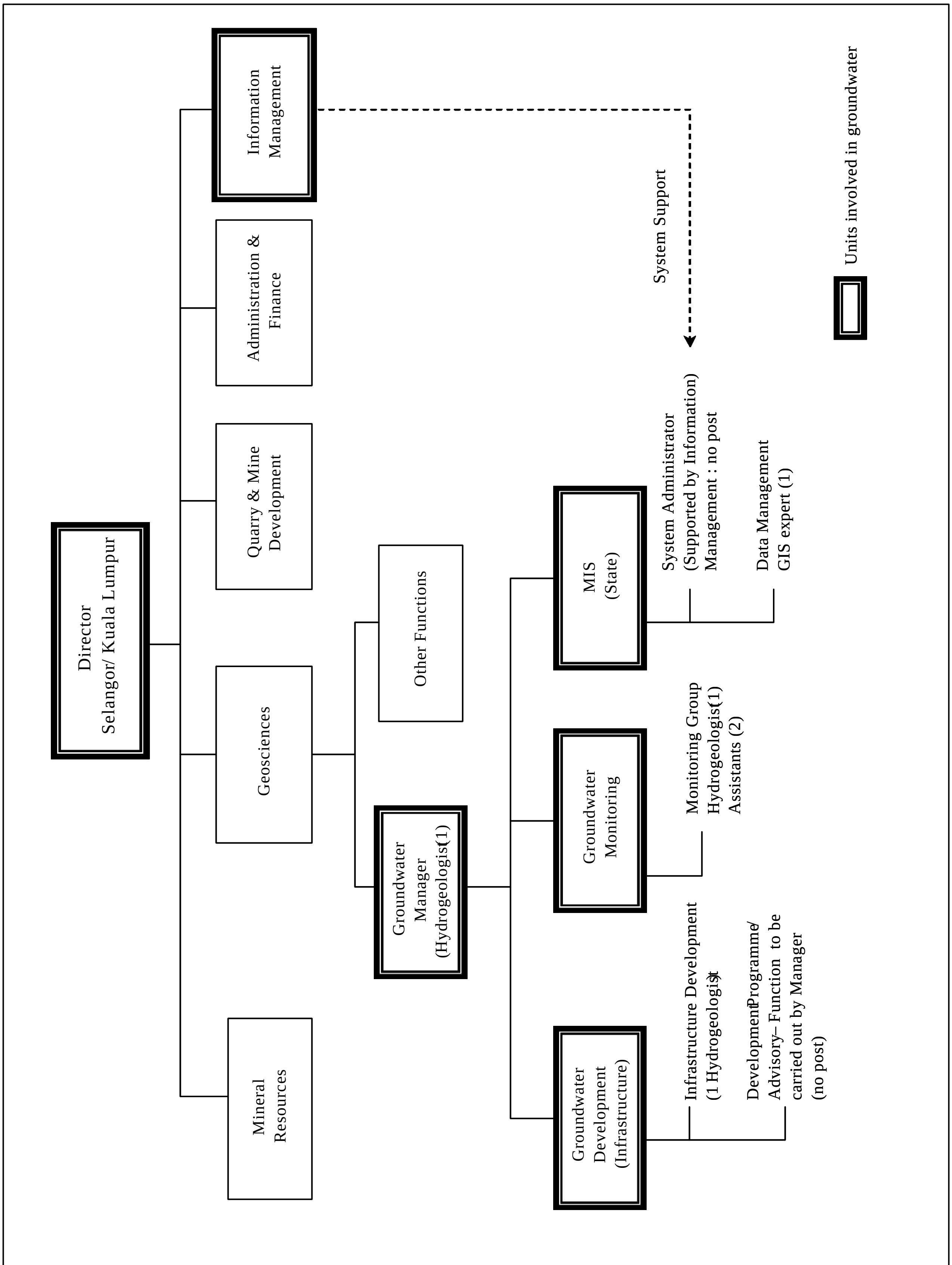

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Figure 6.4.3

Proposed Organisation of Selangor Minerals and Geoscience Department for Groundwater Management

6.4.3 Improvements to the Legal Framework

(1) Comprehensive Act on Groundwater

At the Federal level it is possible to have a comprehensive Act on groundwater, but only for purposes of uniformity since water resources are within the State List under the Constitution. Alternatively the scope of the Waters Act 1920 could be amended to include groundwater. The Waters Act however does not apply in Selangor as it has been repealed by the Selangor Waters Management Authority Enactment 1999. In line with current trends and national policies, it is more likely that State Governments enact their own Water Resources Enactment similar to the SWMAE in the future.

(2) Geological Survey Act 1974

Under the Geological Survey Act (GSA) 1974, there is a duty to notify the Director of Geological Survey, if any person intends to sink a well. The well need to be more than 30ft deep with a yield of more than 500 gal/day and not exclusively used for domestic purposes. Under the proposed amendments to the GSA, JMG has suggested: Any person who intends to sink a well, enlarge, deepen or close a well shall refer to the Director General of Geological Survey before commencing work; A well is defined as one with an abstraction rate exceeding 2,500 litres per day (l/d) regardless of the purpose the water is used; and, The person sinking the well shall keep records of all works and test and send a copy to the DG in the prescribed manner.

Under the Act, JMG is not an approving or licencing authority. The approval for the project will have to be obtained from the relevant state authorised agency, i.e., LUAS. Not withstanding this there is a need to consult the Director General of JMG before the relevant State Authority gives its approval. This provision could be included in the proposed amendments of the GSA.

(3) Environmental Quality Act

DOE is currently preparing comprehensive standards for groundwater quality control. Wide powers are also given to DOE to require occupiers of any premise that is likely to emit or discharge pollutants to install control equipment. This would suggest that control equipment could be enforced on any premise that is a potential source of groundwater pollution.

(4) Selangor Waters Management Authority Enactment

There is a need to provide a set of rules for the management, regulation and control of groundwater in the SWMAE. These rules should also be consistent with the draft regulations proposed by JMG with respect to well drilling, monitoring and abstraction of water. The JMG's proposed definition of a well as being one 'with an abstraction rate exceeding 2,500 l/d regardless of the purpose the water is used' could be used as a common platform.

(5) Enforcement Provisions for Basin Wide Control and Management

While the SWMAE provides for wide ranging provisions to ensure proper management of the River Basin, there are several other related provisions found in the National Land Code, etc. It is necessary that the relevant agencies empowered by these legislations carry out the necessary enforcement to ensure sustainable development of water resources in the basin.

(6) The Proposed 'Safe Drinking Water Act'

The Ministry of Health (MOH) has proposed the drafting of a Safe Drinking Water Act to control the quality of drinking water supplied to the public. Under the proposed Act it would be an offence to supply drinking water that does not specify specific standards. It may be possible to codify these standards and guidelines under the respective State Water Supply or Water Resources Enactment. If groundwater has to be used for drinking purposes it would additionally have to comply with these standards.

6.4.4 Establishing a Levy for Groundwater

Groundwater is a natural resource that needs to be conserved and efficiently managed. Currently groundwater is abstracted free of charge with no revenue to the State and often resulting in over exploitation of the resource. Most of the groundwater abstracted in the Langat Basin is for industrial use.

(1) Basis for Charging

The basis of charging for groundwater abstraction is provided under s44 SWMAE where LUAS with the approval of the SA may impose a charge on the abstraction of water from any source. In practice, a well has to be licenced before charges are imposed. In order to use a common basis for licencing and charging, this study has recommended using JMG's definition of a well i.e. "with an abstraction rate exceeding 2500 l/d regardless of the purpose"

(2) Existing Charge Rates

There are no levies implemented on groundwater in the country. There are however proposals for imposing charge rates ranging from 6.7 sen/m^3 (RM 0.30/thousand gallon) in Johor for groundwater and 4 sen/m^3 for surface water in Selangor.

(3) Establishing Principles for Imposing Charge Rates

There are no hard and fast rules for imposing charges. Some of the principles that could be considered are as follows:

Differential rates could be utilised for different users, for example a higher industrial rate may be imposed to subsidize agriculture rates. This essentially depends on what the market is willing to pay for the raw water. In situations where the development of water supply is privatised to licenced operators, the charge should reflect the cost of managing the water resources in the basin. In view of the higher economic value of groundwater to surface water, it may be appropriate to charge a higher rate for groundwater to surface water.

(4) Financing the Groundwater Management Programme in the Langat Basin

The Langat Basin has a sustainable daily yield of about 45,000 m^3. The total revenue to the state using 4 sen/m^3 is estimated at RM 657,000 per year. This could be increased to RM 986,000 per year if the levy is increased to 6 sen/m^3. Other sources of income will be from the annual licencing fee.

The basic assumptions used are as follows: The revenue generated should at least meet cost of groundwater management in the Langat Basin. Infrastructure development cost of drilling and maintaining the wells will be met by private concessionaires and licenced operators. Capital cost including equipment, vehicles, computers are not included in the management cost.

The main components of the groundwater management cost are; monitoring/retrieval of data, water quality analysis and land subsidence monitoring which amounts to RM 190,000/yr, staff cost at RM 230,000/yr, research, evaluation and studies at RM 120,000/yr giving an estimated total of RM 540,000/yr.

From the analysis it appears that a minimum charge of 4 sen/m^3 is sufficient to meet groundwater management cost in the Langat Basin. However, if LUAS plans to charge 4 sen/m^3 for surface water, it appears justified to charge a higher rate since groundwater in the Langat Basin is of better quality than surface water. However, the final indicator of charge should be based on the willingness of the user to pay without unduly causing economic hardship. A socio-economic impact assessment has to be carried out by LUAS to ascertain the market for raw water before a final rate is decided.

6.4.5 Implementation of the Human Resources and Institutional Development Plan

The possible implementation mode of the proposed Human Resources and Institutional Development Plan is presented in **Table 6.4.2**. For formulating the implementation mode, consideration was made that some work items need urgent implementation, some work item needs sustainable implementation, and some other work items need implementation in a long range.

Table 6.4.2 Implementation Mode of the Proposed Human Resources and Institutional Development Plan

Work Item	Responsible Agency	8MP				9MP		10MP	
		2002	2003	2004	2005	2006	…	2011	…
Execution of the GW Management in the Langat Basin	JMG, LUAS								
Monitoring	JMG, DOE	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
Monitoring of GW abstraction volume	LUAS		▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
Maintenance of MIS	JMG	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
Review of Annual Report	JMG		∇	∇	∇	∇	…	∇	…
Pollution control	DOE	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
Increase public awareness	JMG	▪▪▪	▪▪▪						
Emergency response management	DOE	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
Research and Development, and Training	JMG, etc.	▪▪▪	▪▪▪						
Development of GW Management Plan in other basins	JMG LUAS	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
Organisational Setup									
Join of JMG to National Drinking Water Quality Committee	JMG, NDWQC	━━━	━━━						
Establishment of water management authority in other States	State Government	━━━	━━━	━━━	━━━	━━━	━━━	━━━	━━━
Plans and Programmes									
Formulation of National Policy on GW	NWRC	━━━	━━━						
Preparation of 5-year Development Program for GW	JMG, NWRC, EPU, Treasury, LUAS				━━━		━━━		━━━
National Drinking Water Quality Surveillance Programme	MOH	━━━	━━━						
GW development and management policy of Selangor State	LUAS, JMG	━━━	━━━						
Laws and Regulations									
Definition of organisational framework in various laws and regulations	Related agencies	▪▪▪	▪▪▪						
Formulation of overall guidelines and standards for licencing	JMG	━━━	━━━						
Develop laws and regulations for licencing of wells	LUAS	━━━							
Hydrogeology and GW development be prescribed as one of functions of JMG in the Ministers of the Federal Government Order	EPU	━━━							
Improvement of SWMAE for GW	LUAS	━━━							
Amendments of Geological Survey Act	JMG	━━━							
Licencing of GW wells	LUAS, JMG	━━━	━━━						
Imposing of charges for GW use	LUAS, JMG		━━━	━━━	━━━				
Establishment of comprehensive standards for GW quality control under Environmental Quality Act	DOE	━━━	━━━						
Strengthening of Organisation									
JMG HQ	JMG	━━━							
Technical Services Division (Ipoh), JMG	JMG	━━━							
Selangor State JMG	JMG	━━━							

Note: 8MP; 8th Malaysia Plan, 9MP; 9th Malaysia Plan, 10MP; 10th Malaysia Plan.

CHAPTER 7

CONCLUSION AND RECOMMENDATION

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The importance of groundwater resources in the Langat Basin has been increasingly recognised in helping to cope with the water deficit in Selangor State. Thick Quaternary layers are deposited in the flat lowlands spreading the downstream of the Langat Basin. The subject aquifer for the Study, i.e., Simpang Formation of sand and gravel layer, is distributed continuously around 15-20 m below the ground with a depth of 20 to more than 100 m in the lowlands. From topographical and hydrogeological points of view, it is therefore generally viewed that groundwater can be developed economically in this area.

Presently, however, the Government does not restrict groundwater development and private companies can pump up the groundwater at their own risk. Groundwater abstraction through wells construction and dewatering activities in the Basin is estimated to be 45,000 m^3 per day, which is nearly equivalent to the sustainable groundwater yield of the Basin. Groundwater monitoring and modelling reveals that the groundwater abstraction results in lowering the groundwater level around the pumping area.

While groundwater quality in the basin has not been deteriorated yet, the future monitoring especially for heavy metals, such as lead and arsenic, and organic compounds will be of great importance. In addition, seawater intrusion and land subsidence that may affect the environment in the Basin significantly as well as water level in Paya Indah lakes should also be monitored closely as one of the environmental objectives of the Management Plan.

The JICA Study Team recommends that the Government of Malaysia and the Minerals and Geoscience Department Malaysia (JMG) should carry out the Management Plan proposed in the Study to attain the sustainable development and safeguard of the groundwater resources in the Langat Basin. To achieve this aim, the following actions are earnestly recommended:

(1) Establishment of the institutional framework and securing financing for the implementation of periodical and reliable monitoring work;

(2) Establishment of the institutional framework and securing financing for the operation and maintenance of the Management Information System; and

(3) Preparation for establishment of comprehensive standards for groundwater management.