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 3 SUPPORTING REPORT

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.

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SOCIOECONOMY

1. NATIONAL PROGRESS

1.1 Development Plans and Policies

1.1.1 New Economic Policy/OPP1

The Government introduced the New Economic Policy (NEP) in 1970 after the racial riots in 1969, to promote growth with equity with the objective of fostering national unity among the various races. The First Outline Perspective Plan (OPP1), covering the period 1970-1990, was formulated based on NEP. Under OPP1, the Government implemented four development plans from the Second Malaysia Plan (1971-1975) to the Fifth Malaysia Plan (1986-1990).

Economic policy changed from liberalism to one in which the Government aggressively intervenes for the attainment of national objectives. Major policies implemented in NEP/OPP1 are outlined as follows[1)]*:

- Ethnic structure of employment in any job of any industry should be the same with the ratios of ethnic groups in the country (Malay 50% and Chinese 40%);
- Capital share of a domestic corporation by Malays was to increase to 30% in 1990;
- Export-oriented manufacturing industries were aggressively fostered by the Government leadership as well as brought up import-substitute industries;
- Heavy and chemical industries were set up as national projects in the Fourth Malaysia Plan (1981-1985); and
- Public corporations had an important role for the industrialisation of the economy.

Note: * Number in close parenthesis attached to a text refer to the reference number in References at the end of the sector. The following sectors are described as the same as this manner unless otherwise indicated.

1.1.2 Vision 2020

"Malaysia: the Way Forward (Vision 2020)" was presented by the Prime Minister, Dr. Mahathir Bin Mohamad, in the inaugural meeting of the Malaysian Business Council on February 28, 1991. In short, Vision 2020's objective is to get Malaysia a fully developed country by the year 2020. It means almost doubling its real gross domestic product every ten years between 1990 and 2020 or $115 billion in 1990 and about $920 billion in 2020, at 1990 prices. This rapid growth will require that the economy grow by about 7% (in real terms) annually on the average.

In Vision 2020, however, "developed" does not mean only in the economic sense. Malaysia must be a nation that is fully developed along all the dimensions:

economically, politically, socially, spiritually, psychologically and culturally. In other words, Malaysia should become a united nation with a confident Malaysian society. It also clarifies the following nine strategic challenges to be overcome for attaining the objective:

- Establishing a united Malaysian nation with a sense of common and shared destiny
- Creating a psychologically liberated, secure, and developed Malaysian Society with faith and confidence in itself
- Fostering and developing a mature democratic society practising a form of mature consensual, community-oriented Malaysian democracy
- Establishing a fully moral and ethical society
- Establishing a mature, liberal and tolerant society
- Establishing a scientific and progressive society
- Establishing a fully caring society
- Ensuring an economically-just society
- Establishing a prosperous society, with an economy that is fully competitive, dynamic, robust and resilient

1.1.3 New Development Policy/OPP2

OPP1 had ended, and the Second Outline Perspective Plan (OPP2) covering 1991-2000 was formulated based on a policy, which was called the New Development Policy (NDP). The NDP was built on the achievements during the OPP1 to accelerate the process of eradicating poverty and restructuring society to correct social and economic imbalances. Major principles of NDP are as follows:

- Continue building a united nation.
- Continue correcting economic imbalances.
- As the overall poverty situation in the country is improving rapidly, poverty eradication efforts will focus more sharply on the hardcore poor.
- The restructuring of equity capital will continue to achieve 30% ownership of Malays.
- The Government has relaxed considerably the foreign equity guidelines. In order to maintain the favourable climate for attracting private investment and for stimulating growth, the Government will continue the liberal policy with regard to equity requirements for foreign investments in the manufacturing and tourism sectors.
- In order to ensure public sector efficiency, privatisation of Government services and public sector-owned commercial enterprises will be accelerated.

1.1.4 Seventh Malaysia Plan (1996-2000)

With the launching of the Seventh Malaysia Plan (7MP), 1996-2000, the Malaysian economy entered the second phase of the Second Outline Perspective Plan (OPP2), 1991-2000. With the strong fundamentals underlying the rapid expansion in the economy already in place, the nation enters the second phase of development under the OPP2. The 7MP provides the stage for the Government to accelerate the attainment of the objectives of balanced development as envisaged under the National Development Policy (NDP), with the overriding objective of creating a more united and just society.

To support and sustain the development process, the following fourteen targets are set as development thrust which are deemed to enhance potential output growth, achieve further structural transformation and attain balanced development:

- Macroeconomic stability
- Poverty alleviation and restructuring of society
- Productivity-driven growth
- Enhancement of competitiveness
- Industrialisation for the future
- Human resource development
- Technology development
- Information technology
- Privatisation
- Sustainable development
- Quality of life
- Address of social problem
- Moral and ethical value
- Administrative improvement

Among them, "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. Thus, the Government is required to balance growth objectives with environmental concerns, which should be integrated into land use planning to ensure that land is properly utilised and watershed and catchment areas will be protected. Soil conservation efforts will be implemented systematically and integrated with physical planning in order to prevent indiscriminate land-clearing as well as provide adequate control of development on land.

On the other hand, the 7MP focuses on the following macroeconomic analyses. Although the Malaysian economy had been expanding rapidly based on the inflow of foreign funds, capital market participants, especially foreign investors, were increasing concerns on the soundness of the Malaysian economy. Such concerns were summarised as follows[2)]:

- **Overheating economy**: Growth rates recorded high levels while current account deficits increased (8.3% of GDP in 1995), which might mean an overheating economy resulting from excess demands.
- **Limited capacity for further development**: Population is small (about 1.9 million). Its employment is already nearly full and future labour supply should be limited.
- **Foreign direct investment hitting its peak**: Foreign direct investment, which had been the driving force of past economic growth, seemed hitting its peak.

Following the macroeconomic analyses, 7MP also presents economic policies to improve productivity, which should be the driving force of future economic growth. Its target in the planning period is 3.3% (total factor productivity, annual). Measures for improving productivity are listed up as follows[1)]:

- **Promotion of technical transfer from abroad**: Favourable treatment of taxes to investment in hi-tech industries, selection of joint partners for public corporations
- **Promotion of R&D at home**: Increase R&D expenditures to 1.0% of GDP from 0.4%, several favourable treatments to attract engineers living in foreign countries
- **Improving efficiency of resource distribution**: Privatisation of infrastructure development and public corporations
- **Improving human resources**: Expansion of scientific and technological education

1.1.5 National Economic Recovery Plan

The National Economic Action Council (NEAC) was established on the 7th of January 1998 as a consultative body to the Cabinet to deal with the economic crisis. As one of its primary tasks, the NEAC had taken upon itself to prepare the National Economic Recovery Plan (NERP), which presents a comprehensive framework for action for national economic recovery.

NERP analyses the cause of the crisis in the Asia Pacific region including Malaysia appropriately, some of which had been already pointed out in the Seventh Malaysia Plan. NERP says as follows:

- **Economic performance**: The unusually successful economic performance in the region attracted large inflows of foreign portfolio funds into the Asia Pacific region, which became a root cause for the currency crisis. During the early to mid-1990s, Malaysia experienced high annual growth rates that ranged between 7-12%.
- **Saving-investment gap**: While there were sizeable current account deficits for some countries, especially for Malaysia and Thailand, these were the outcome of the shortfalls of private savings to match private investment, not public sector dis-saving. Foreign capital inflows made up for the shortfall in national savings to meet the very high national investment.
- **Private inflows of fund**: While the net private inflows for China and Vietnam were foreign direct investment (FDI) dominated, short-term inflows were substantial for Indonesia, South Korea, Malaysia, and the Philippines. During 1995-96, Malaysia's short-term capital was 4-4.5% of GDP, while its FDI was at 5% of GDP.
- **Changes in external environment**: The decline in asset yields in the industrial economies prompted fund managers to invest into the Asian emerging assets, which gave higher returns. On the other hand, the rapid economic growth of the ASEAN economies was accompanied by rapid credit growth to the private sector and asset price inflation, including in real estate markets and in equity markets, raising the concern that their exchange rates were not sustainable.
- **Weakness in the financial sector**: Weakness in the financial sector compounded the problem. Inadequate disclosure of information and data deficiencies increased uncertainty and adversely affected confidence. The Malaysian financial sector was much stronger than those of the neighbouring counties, but there was the problem of rapid credit expansion to the private sector, especially during 1995-97.

With the above analysis, NERP presents the following prescription, "Plan for Action":

(i) Stabilising the Ringgit

(ii) Restoring Market Confidence

(iii) Maintaining Financial Market Stability

(iv) Strengthening Economic Fundamentals

(v) Continuing the Equity and Socio-Economic Agenda

(vi) Revitalising Affected Sectors

See **Table A.1.1** below for the details of the "Plan for Action".

Table A.1.1 "Plan for Action" of the National Economic Recovery Plan (NERP)

Action Plan

Objective 1: Stabilising the Ringgit

- Appropriate Choice of Exchange Rate Regime
- Reduce Over-Dependence on the US Dollar
- Increase External Reserves
- Adopt a Balanced Interest Rate Policy

Objective 2: Restoring Market Confidence

- Improve Transparency and Regulatory Environment
- Establish Rules for Assisting Industries and Companies in toruble
- Increase Consistency of Policies
- Adopt Liberal and Market-Based Policies
- Improve Public Relations
- Improve the Dissemination of Economic information

Objective3: Maintaining Financial Market Stability

- Preserve the Integrity of the Banking System
- Establish Agencies Along the Lines of FDIC/RTC
- Recapitalise the Banking Sector
- Monitor Closely Overall Credit Expansion
- Improve the Capital Market
- Develop the PDS Market

Objective 4: Strengthening Economic Fundamentals

- Increase the Quality of Investments
- Improve the Balance of Payments
- Maintain a Balanced Public Sector Financial Position
- Maintain an Appropriate Monetary Policy
- Maintain Price Stability

Objective 5: Continuing the Equity and Socio-Economic Agenda

- Ameliorate the Hardship from Poverty
- Address the Issues on Bumiputera Equity Ownership
- Expand Employment Opportunities
- Meet the Challenge of Expanding Tertiary Education
- Address the Problem of Graduate Unemployment
- Control the Influx of Foreign Workers
- Gear Up State Corporations to Face the Crisis
- Revamp Cooperatives and Cooperative Banks
- Protect Environment for Sustainable Development

Objective 6: Revitalising Affected Sectors

- Primary commodities and Resource-Based Industries
- Mining and Petroleum
- Manufacturing
- Information Technology and the Multimedia super Corridor
- Motor Industry
- Construction
- Property
- Infrastructure
- Transportation
- Freight Forwarding
- Tourism
- Industrial Development Finance Institutions
- Insurance and Reinsurance

Source: National Economic Action Council, *National Economic Recovery Plan*, August 1998, p.45.

1.1.6 National Vision Policy/OPP3

The Third Outline Perspective Plan (OPP3), which is based on the National Vision Policy (NVP), was announced in the Parliament by the Prime Minster on April 3, 2001. OPP3 appreciates the results of OPP2 as follows:

The strategies and policies of the OPP2 contributed towards strengthening and modernizing the industrial base of the country. The nation achieved rapid economic growth despite being affected by the 1997-1998 financial crisis. This was accompanied by significant improvements in the level of income and enhancement in the quality of life of all Malaysians with significant progress made in reducing the incidence of poverty. (Chapter 2, Review of the Second Outline Perspective Plan, 1991-2000, p. 56)

In turn, OPP3 outlines the policies and direction of Malaysia's development in the next ten years, following such achievements of OPP2. NVP/OPP3 is summarised as follows:

- Developing Malaysia into a knowledge-based society;
- Generating endogenously-driven growth through strengthening domestic investment and developing indigenous capability, while continuing to attract foreign direct investment (FDI) in strategic areas;
- Increasing the dynamism of the agriculture, manufacturing and services sectors through greater infusion of knowledge;
- Addressing pockets of poverty in remote areas and among Orang Asli and Bumiputera minorities in Sabah and Sarawak as well as increasing the income and quality of life of those in the lowest 30 per cent income category;
- Achieving effective Bumiputera participation as well as equity ownership of at least 30 per cent by 2010;
- Increasing the participation of Bumiputera in the leading sectors of the economy; and
- Reorientating human resource development to support a knowledge-based society.

1.1.7 The Eighth Malaysia Plan 2001-2005

The Eighth Malaysia Plan focuses on achieving sustainable growth with resilience. Strategies have 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. The Plan will put greater emphasis on private sector initiatives, while the public sector will undertake a facilitating role providing an institutional framework and quality service. In order to enhance Malaysia's competitive edge, special emphasis will be given on increasing productivity and efficiency through human resource development, encouraging R&D activities as well as utilising the latest technologies, particularly information and communication technology (ICT).

The Plan's key strategies are as follows:

- Pursuing sound macroeconomic management, and ensuring prudent fiscal and monetary policies as well as enhancing efforts to develop a knowledge-based economy;
- Strengthening and streamlining distributional strategies and programes to ensure balanced participation among and within ethnic and income groups as well as regions;
- Enhancing productivity growth through improvement in workers' knowledge, skills and expertise as well as upgrading of R&D and science and technology (S&T);
- Increasing competitiveness and economic resilience through accelerating the shift of the key economic sectors towards more efficient production processes and high value-added activities;
- Expanding the usage of ICT within and across sectors to accelerate the growth process;
- Strengthening the human resource base to ensure the availability of manpower with higher levels of knowledge, technical and thinking skills;
- Adopting an integrated and holistic approach in addressing environmental and resource issues to attain sustainable development;
- Enhancing further the quality of life through improving accessibility to social services as well as developing the aesthetic aspects of life; and
- Intensifying efforts to nurture and inculcate positive values and attributes among Malaysians through the education system, social and religious organisations and the media.

Concerning the environmental and resources issues, the Eighth Malaysia Plan 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,
- Formulation of a National Water Policy to ensure that water resources will be managed more efficiently and effectively,
- Introduction of a comprehensive waste management policy to address issues of waste reduction, reuse and recycling,
- Enhancement of land use planning and introduction of regulations to control access to biological resources, and

- Review of overall management of marine affairs to alleviate pressure on the marine environment and to enhance marine and coastal biological diversity.

1.2 Economic Development up to Mid-1990s

Malaysian economy had been growing at a high speed in the 1980s and 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. (See **Figure A.1.1**.)

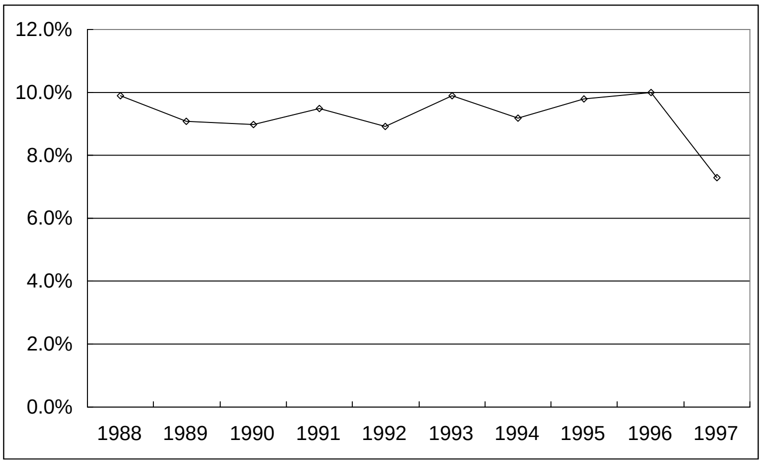


Figure A.1.1 GDP Growth Rates of Malaysia

Source: Central Bank of Malaysia

Its economic structure had also transformed to that of secondary and tertiary industries from an economy exporting primary products in the course of development progress. Shares of manufacturing sector and non-governmental services sector in GDP exceeded 27% and 40% respectively in 1995, while that of agriculture sector and mining and quarrying sector went down to 10.3% and 8.2% in the same period. (See **Figure A.1.2**.)

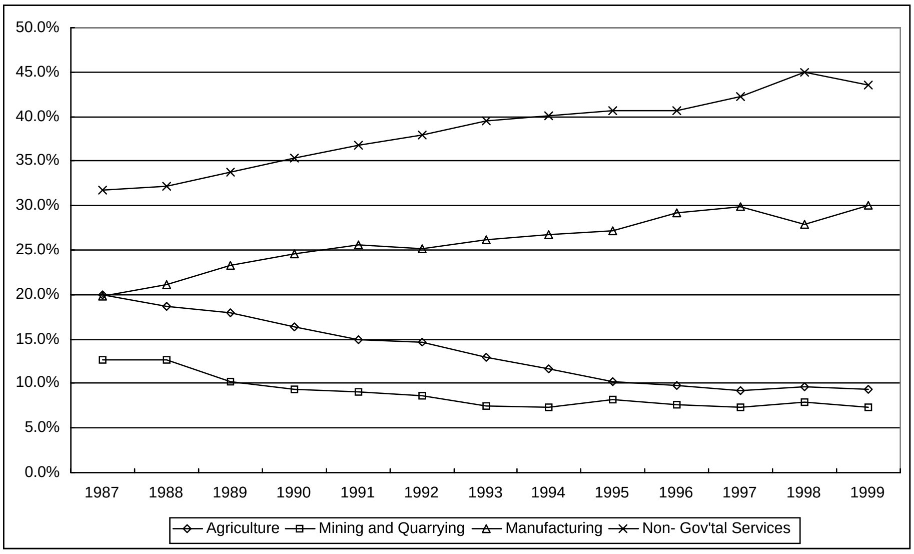


Figure A.1.2 Changes in Sector Shares of GDP, Malaysia

Source: Central Bank of Malaysia

In addition, the share of manufacturing sector in exports recorded more than 75% in 1995 (See **Figure A.1.3**). It is true that "Malaysia is the first country which successfully changed to an industrialised economy from a plantation economy".[1)]

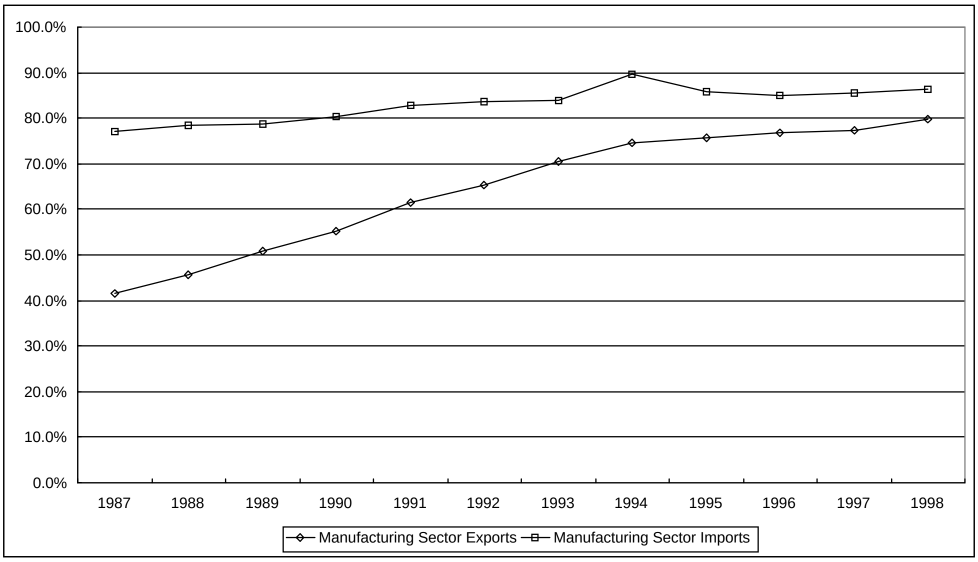


Figure A.1.3 External Trade Share of Manufacturing Sector, Malaysia

Source: Central Bank of Malaysia

1.3 Recovery from the Economic Crisis

The economic crisis in East Asia damaged seriously five countries – Indonesia, Korea, Malaysia, the Philippines and Thailand in 1998. Now they seem to have gained momentum of economic activities. Especially, Malaysia and Korea are showing relatively good performance even in comparing with those before the crisis. Has Malaysia really gained the power to develop further? We will examine this question in this subsection.

The five countries can be divided into two groups in terms of the GDP growth rate recoveries after the crisis. Korea and Malaysia are gaining more than 10% on quarterly year-on-year (YoY) basis, which exceed those in 1997. Thailand, Indonesia and the Philippines could not keep the momentum of recovery. (See **Figure A.1.4**.)

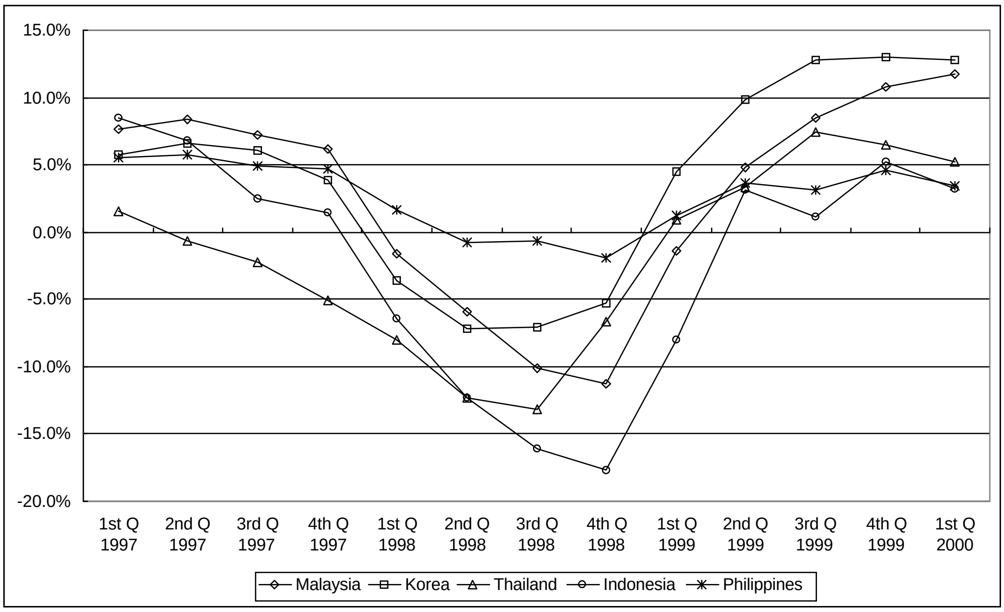


Figure A.1.4 GDP Growth Rates (YoY) of the Five Countries

Source: the Japan Research Institute, *Monthly Country Review of Asia*

The main reason why Malaysia is showing favourable performance is the drastic expansion of capital investments led by the global demand for information technology (IT) related products as well as high level of education, development of urban middle classes and subcontractors, and relatively narrow difference of income. On the other hand, Korea's recovery resulted from the completion of the severe structural reform conditioned by IMF.[3)]

When we look at the Malaysian economy in detail, we find that industrial production is expanding rapidly. Index of industrial production has increased by 33.4 points in a year and exceeded 1997 level in the 3rd Quarter of 1999. (See **Figure A.1.5**.)

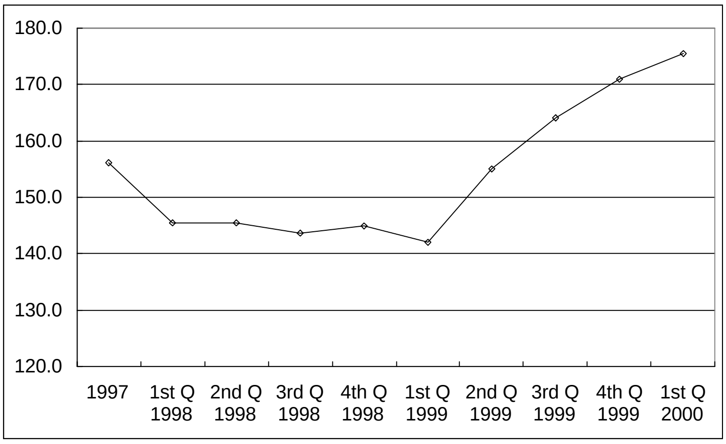


Figure A.1.5 Index of Industrial Production (1985=100) in Malaysia

Source: Central Bank of Malaysia

As we see private investment indicators, it can be found that rapid expansion of industrial production has been supported by firm increase of private investments. Although vehicle sales were stimulated by Governmental economic policy, import of investment goods is increasing after vehicle sales lost the momentum in the second half of 1999. (See **Figure A.1.6**.)

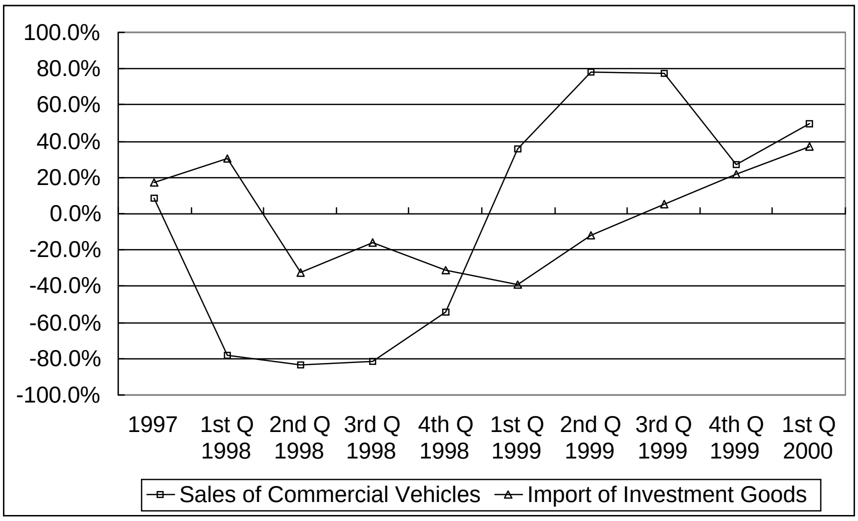


Figure A.1.6 Private Investment Indicators (YoY) in Malaysia

Source: Central Bank of Malaysia

It should be understood in turn, when we examine private consumption indicators, that firm increase in private investments has been supported by increase in private consumption. (Private consumption has a strong influence on the economic activity because private consumption accounts for around 45% of the total GDP in Malaysia.) The indicators changed to positive in the 2nd Quarter of 1999 and they are keeping more than 20% increase thereafter. (See **Figure A.1.7**.)

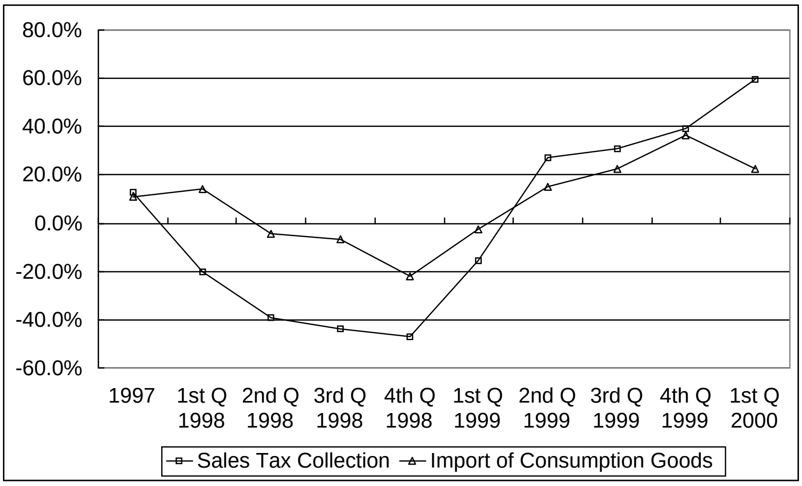


Figure A.1.7 Private Consumption Indicators (YoY) in Malaysia

Source: Central Bank of Malaysia

Finally, we look at the data of the external sector. It also confirms our argument that the momentum of recovery arose from the 2nd Quarter of 1999. (See **Figure A.1.8**.)

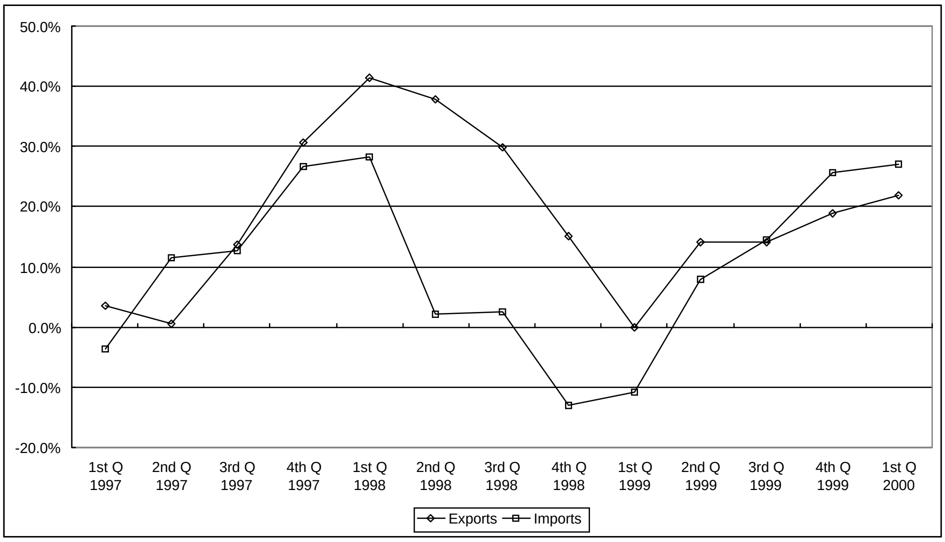


Figure A.1.8 Expansion of External Trade (YoY) in Malaysia

Source: Central Bank of Malaysia

1.4 Post-recovery Situations of Malaysian Economy

Malaysian economy has entered a sustainable growth process from the V-shaped rapid recovery as it has been showing such quarterly year on year GDP growth rates as 7.8% in the third quarter of 2000 and 6.5% in the fourth quarter since it peaked out with 11.8% in the first quarter. Reduction in exports and consumption has been contributing to such change in the economy. Exports has been declining with the following factors: 1) economic slowdown in the US and European countries, and 2) slackness of IT-related demands. On the other hand, consumption has been dropping with the following factors: 1) long-lasting stagnation of the stock market following the adjustment in the US stock market, and 2) deteriorating employment in accordance with the declining export. (See **Figure A.1.9**.)

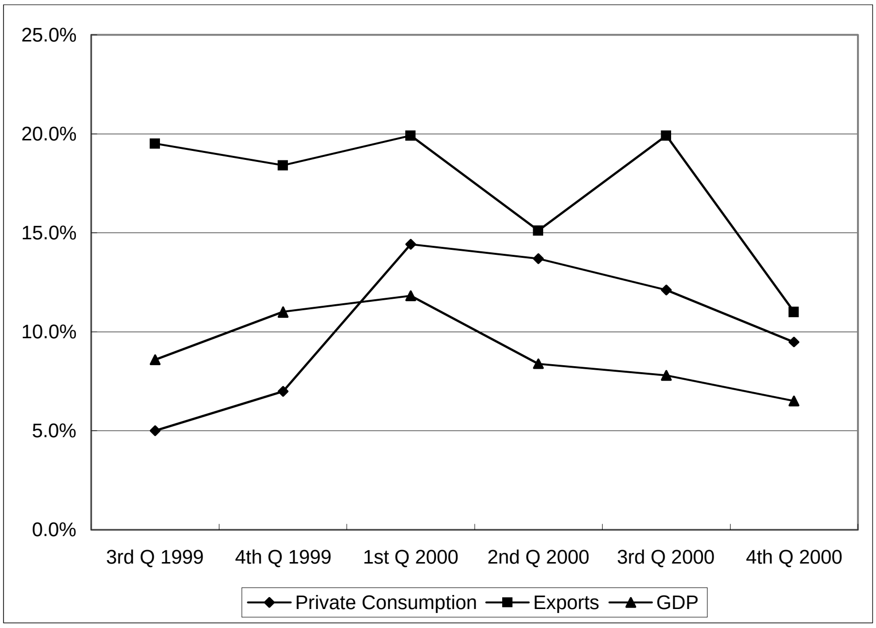


Figure A.1.9 Percent Changes of Real GDP (YoY) in Malaysia

Source: Department of Statistics, Malaysia

The Economist Intelligence Unit (EIU) forecasts 4.1% for 2001. EIU also expects that GDP growth rate will recover to 6.1% in 2002 because the public spending is likely to be boosted if the slowdown turn out to be prolonged as well as the growth rate resulted to achieve higher 8.5% in 2000[4)].

1.5 Population

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. The dependency ratio (the number under the age of 15 and over the age of 64 divided by the rest of the population) has been declining: 91.7% in 1970, 76.9% in 1980, 69.7% in 1990, 64.2% in 1995, and 59.6% in 1999. (See **Figure A.1.10**.)

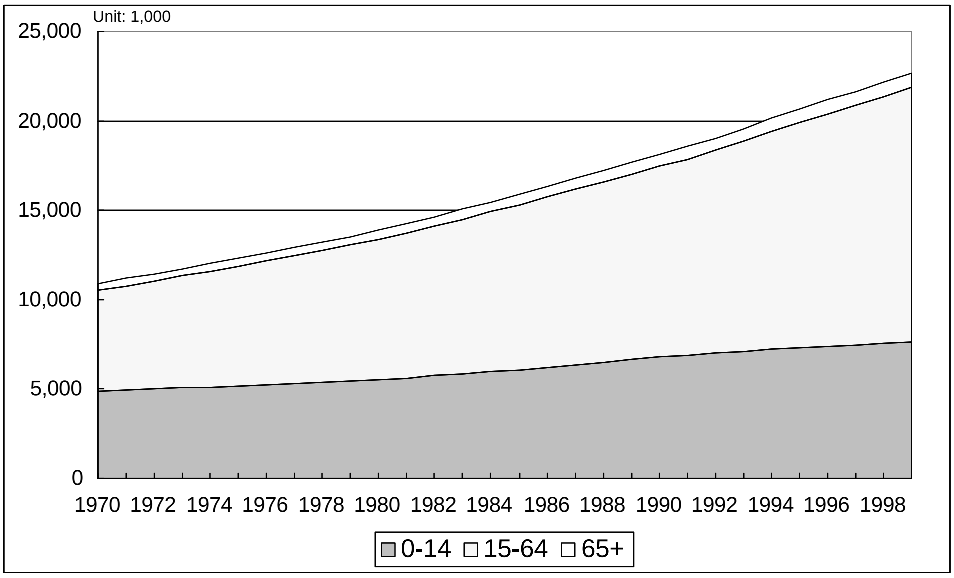


Figure A.1.10 Population Estimates by Age Group, Malaysia

Source: Department of Statistics, Malaysia

Rates of population growth vary between the main ethnic groups. During 1991-1995, the annual rates of growth of the Malay, Chinese and Indian communities were 2.7%, 1.3% and 1.5%. The Chinese, long urbanised and enjoying higher average incomes, now have smaller families.[5)]

2. SELANGOR STATE

2.1 General Conditions

Bernam River forms the northern boundary of Selangor State with Perak State while the Sepang River forms the southern border with Negeri Sembilan State. On the other hand, the watershed line of the Main Range (Banjaran Titiwangsa) forms the boundary between Selangor State and Pahang State. Selangor covers a total area of 8,200 km^2. It is divided into nine districts - Klang, Petaling, Sepang, Kuala Langat, Hulu Langat, Gombak, Kuala Selangor, Hulu Selangor and Sabak Bernam.

In the late 1980s, Selangor made major changes to its Economic Policy with preference given to industrial, housing and recreational development. For the 2000s a new direction in the industrial policy was directed towards capital-intensive and high-tech industries. To set a new direction for industrial development, the state government had outlined, and encourages the following[6)]:

- Quality projects that are skill-intensive and have high-value capital
- Industries that encourage the development of R&D sectors
- Industries that possess the potential to develop the state by using local natural resources
- Priority given to hi-tech industries, aerospace and information technology industries, capital intensive industries utilising skilled labour and marine activities
- Priority given to eco-friendly industries that preserves and protects the environment (Non-polluting industries and industries that consume low power and water)
- Industries that offer business opportunities to local entrepreneurs
- Industries that are non-labour intensive
- To achieve the above objectives, the state government is planning to set up Research and Development facilities to enhance the standard of Industrial products.

2.2 Development Plans and Policies

2.2.1 Vision 2005 for Selangor

Due to Selangor's strategic location and economic development, the Chief Minister of Selangor has set a target for Selangor 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.

The aim of Vision 2005 is not merely to enhance the economic development of Selangor, but to ensure total development in social, politics, culture, arts, etc., as mentioned in Vision 2020. GDP share of service sector remains the same and that of agriculture sector increases slightly in 2000-2005 in the projected economic structure. (See **Table A.2.1**.)

Table A.2.1 Target of Projected Economic Structure in Vision 2005 for Selangor

Sector	1990	2000	2005
Industry	54%	61%	60%
Services	39%	35%	35%
Agriculture	7%	4%	5%
Total GDP (RM Billion, at 1987 prices)	18.60	41.2	91.4

Source: Selangor State Government, *Selangor Darul Ehsan,*, March 2000.

Selangor's development strategies towards Vision 2005 are summarised as follows:

- Increasing development towards areas outside of the Klang Valley,
- Developing effective and efficient communication systems in Selangor like all mode of transports,
- Providing skilled labour force for the industries such as high technology and information technology,
- Increasing food production,
- Conserving natural environment and implementing sustainable development, and
- Increasing the productivity of information technology (IT).

With these strategies, the corridor concept was established to bring about development to all corners of Selangor and the State government has begun to construct new industrial sites and growth centres outside the Klang Valley towards this end.[6)]

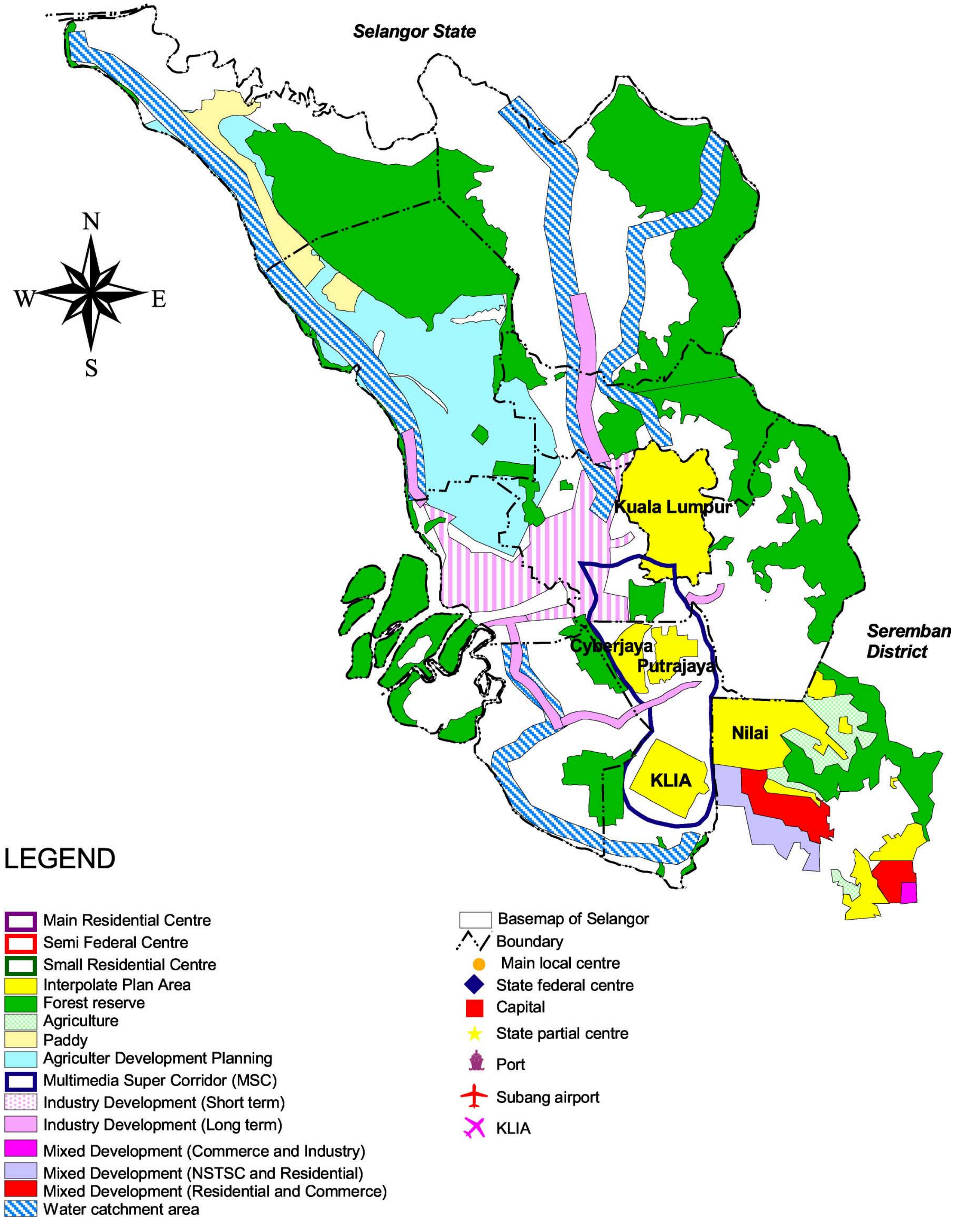
The nine corridors have been identified. They are:

- Klang Valley Development Corridor
- Multimedia Super Corridor
- Southern Coastal Corridor
- Sungai Buluh -Ulu Bernam Corridor
- Rawang-Kuala Kubu Baru Corridor
- Northern Coastal Corridor
- Sungai Besar-Ulu Bernam Corridor
- Kuala Selangor-Kuala Kubu Baru Corridor
- Banting-Bagan Terap Corridor

The following are planned for border and regional development:

- Alliance with the State of Perak for Bernam Valley Development (Serendah, Tanjong Malim and border area between Perak and Selangor)
- Alliance with the State of Negeri Sembilan and Malacca for Southern Regional Development (Sepang, Nilai, Port Dickson and Melaka)

A development plan map of Selangor State and Seremban District is presented in **Figure A.2.1**.



Source: Town and Country Planning Departmnet of Selangor State, and Seremban District Council

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Figure A.2.1

Development Plan Map of Selangor State and Seremban District

2.2.2 Sustainable Development Strategy and Agenda 21, Selangor

Sustainable Development Strategy and Agenda 21, Selangor presents development principles in Environmental Sensitive Areas (KSAS). In accordance with the development principles for KSAS, State Government had framed development corridors. Besides development corridors, Selangor had identified short-term industrial development areas such as areas covering Petaling and Klang, and long-term industrial development area especially the Gombak District area. Meanwhile, priority location for industrial development will cover the following areas: South Petaling Jaya, Hicom Valley, Balakong, Sungai Buloh, Selayang, Puchong, Seri Kembangan, Rawang, Batu Arang, Bandar Baru Kuala Selangor, Salak Tinggi, Batang Kali, Banting, Shah Alam, Klang, Bangi and Telok Panglima Garang.

KSAS is one of the following:

- Areas which have heritage value
- Areas where development increases disaster risks
- Areas which are important for life support system

Development in all KSAS must be based on three major principles, which outline the process of decision making of whether to develop or not. Those principles are:

- All development in KSAS should be placed in Development in Restricted Development Area category (explained hereinafter);
- Development in KSAS should guarantee not to lose endangered life and properties, nor endangered local society health; and
- Development in KSAS should simultaneously increase socio-economic and environmental sustainability of the area.

Restricted Development Area concept is introduced to land use plans in numerous Structure Plans of Districts in Selangor. In the Proposed Amendment of Land Use Planning Guidelines for Kuala Lumpur International Airport (KLIA) in Sepang Restricted Development Area, Selangor Town and Country Planning Department (JPBD), it is stated that Restricted Development Area needs thorough standardisation on usage and land use activity (JPBD, 1997). Especially for KLIA, usage allowed is low intensity land usage related to airport, existing settlement, recreation and agro-tourism, forest reserve and agriculture.

Development in KSAS with high disaster risk needs to be fully avoided. Natural or development effect on disaster incidence could not be precisely forecasted because of influence from environmental and seasonal conditions. An example is safety development in sloppy area, influenced by rainfall rate. Even though it is safe during dry season, extreme rainy season will increase the possibility of unwanted landslide disaster.

Only KSAS with potentiality to bring socio-economic and environmental benefit to local society is considered for development. Development of amenity facilities in natural rivers or mountainous areas are examples of suitable development in KSAS and increase its value as recreational area and at the same time provide opportunity for local society to improve their socio-economic status. The construction of dams to increase fresh water storage in hilly area is another example of development in KSAS for ensuring natural resources supply.[7)]

2.3 GDP

The total GDP of Selangor accounts for around 20% of the national GDP. Selangor's GDP growth rate remarkably reversed to positive, 5.8% in 2000 and 5.2% in 1999 from -1.54% in 1998 in accordance with the trend seen in the nation. However, not all sectors showed the same trend. Manufacturing and Utility sectors recorded higher 15.3% and 7.2% in 2000 respectively, while Agriculture sector presented negative figures, -0.1%. (See **Table A.2.2**.)

Considering the State development plan, Vision 2005 for Selangor, GDP target in 2000 (RM 41.2 billion) was well attained as the result is RM 44.3 billion due to the recent robust economy in Malaysia and Selangor.

Table A.2.2 Real GDP of Selangor (at 1987 prices)

SECTOR	1999		2000		Growth
	Amount	Share	Amount	Share	
Agriculture, Forestry, Livestock and Fishing	1,059.63	2.6%	1,058.06	2.4%	-0.1%
Mining and Quarrying	297.61	0.7%	309.49	0.7%	4.0%
Manufacturing	20,961.15	51.5%	24,165.72	54.5%	15.3%
Electricity, Gas and Water	1,819.70	4.5%	1,949.82	4.4%	7.2%
Construction	2,015.84	5.0%	2,046.73	4.6%	1.5%
Wholesale and Retail Trade, Hotels and Restaurants	3,679.87	9.0%	3,780.20	8.5%	2.7%
Transport, Storage and Communications	5,486.04	13.5%	5,562.22	12.5%	1.4%
Finance, Real Estate and Business Services	3,298.52	8.1%	3,372.75	7.6%	2.3%
Other Services	967.41	2.4%	982.44	2.2%	1.6%
Government Services	2,911.38	7.2%	3,046.34	6.9%	4.6%
TOTAL (RM million)	42,497.15	-	46,273.77	-	8.9%
(Deduct) Banking Service Payment	3,153.52	-7.8%	3,250.34	-7.3%	3.1%
(Add) Import Tax	1,329.50	3.3%	1,317.54	3.0%	-0.9%
GDP At Purchases Value (RM Million)	40,673.13	100%	44,340.97	100%	9.0%
Number of Residents ('ooo)	3,185.58	-	3,281.15	-	3.0%
GDP per Capita (RM)	12,767.89	-	13,513.85	-	5.8%

Source: R&D Centre, Selangor, *Selangore Sate Economic Report, 2000/2001*.

2.4 Industrial Structure

GDP shares of Industrial sector and Services sector are 59.0% and 38.5% in 1999, while Agriculture sector 2.5% on the basis excluding adjustment items such as Banking Service Payment and Import Tax. Considering the Projected Economic Structure in 2000 of the State development plan, Vision 2005 for Selangor, Agriculture sector has already gone down below the the projection of 4%. Services sector has not reached the projection of 35%. Industrial sector shows 2% points lower than the projection. Generally, higher services sector share affects the actual industrial structure. (See **Tables A.2.1 and A.2.2**.)

As mentioned in the previous subsection, the GDP of Selangor accounts for around 20% of the national GDP. Sectors whose percentage to the nation exceeds 20% are Manufacturing (33.4%, 1997) and Transport, Storage and Communication (34.1%, 1997). On the other hand, Agriculture and Mining sectors show very low figures, 5.1% and 3.4% respectively. These facts fully characterise the State's industrial structure. (See **Table A.2.3**.)

Table A.2.3 GDP of Selangor to Malaysia

SECTOR	1995	1996	1997
Agriculture, Forestry, Livestock and Fishing	7.0%	6.7%	5.1%
Mining and Quarrying	1.2%	1.0%	3.4%
Manufacturing	35.5%	35.7%	33.4%
Electricity, Gas and Water	12.2%	12.3%	10.5%
Construction	19.1%	18.7%	18.2%
Wholesale and Retail Trade, Hotels and Restaurants	16.8%	16.9%	17.8%
Transport, Storage and Communications	27.8%	27.9%	34.1%
Finance, Real Estate and Business Services	14.9%	14.7%	17.9%
Other Services	19.2%	19.3%	17.3%
Government Services	10.3%	10.4%	8.7%
TOTAL	20.4%	20.8%	20.9%
GDP At Purchases Value	20.1%	20.6%	21.9%

Source: Ministry of Finance, *Economic Report, 1997/1998*.

2.5 Population

Total population of Selangor State is estimated at more than 3 million in 1998 or 13.6% of Malaysia. Growth rates are 3.1% in 1997 and 3.3% in 1998, higher than the recent national trend, 2.4%. The dependency ratio in 1997 is 52.6% (the number under the age of 15 and over the age of 64: 974,200, the rest of the population: 2,025,600), lower than the 61.8% of the nation. (See **Table A.2.4**.)

Table A.2.4 Population Estimates of Selangor

1996	1997	1998
2,909,700	2,999,800	3,098,800

Source: Department of Statistics, Malaysia, *Population and Housing Census of Malaysia 1970, 1980, 1991 Estimates*.

2.6 Others

2.6.1 Household Income

Average monthly household income in Selangor is estimated at RM 3,135 in 1995. It has been ranked at the second compared with other States in Malaysia. When it is compared with Kuala Lumpur, it was 87.0% in 1987, 88.5% in 1990 and 89.2% in 1995. Although the difference has been reducing gradually, it is still lower by 10%. (See **Table A.2.5**.)

Table A.2.5 Average Monthly Household Income Compared with Other States (RM, Current Prices)

State	1987	1990	1995*
Johor	1,060	1,148	2,111
Kedah	718	748	1,287
Kelantan	667	708	1,081
Melaka	1,034	1,088	1,861
Negeri Sembilan	908	1,078	1,771
Pahang	900	956	1,439
Perak	863	972	1,461
Perlis	711	831	1,159
Pulau Pinang	1,130	1,332	2,214
Selangor	1,558	1,659	3,135
Sabah	1,116	1,148	1,444
Sarawak	1,141	1,208	1,923
Terengganu Wilayah Persekutuan	694	756	1,113
Kuala Lumpur	1,790	1,875	3,515

Source: R&D Centre, *Basic Information on the State of Selangor, 1997/1998.*
*) Estimates

2.6.2 Employment

Selangor has been enjoying very low unemployment rates until 1996. They seem to be near the natural unemployment rate and also supporting that the economy is overheated. The economic crisis raised the rates suddenly to three times higher in 1997. Although data in 1998 and 1999 are not available at this time, unemployment rate might have decreased, as we consider the economic recovery after the crisis. (See **Table A.2.6**.)

Table A.2.6 Estimated Employment and Unemployment Rate in Selangor

Item	1990	1995	1996	1997
Nomber of Employed Persons	934,1000	1,199,800	1,243,800	1,100,600
Unemployment Rate	4.1%	2.8%	2.0%	6.0%

Source: R&D Centre, Selangor, *Basic Information on the State of Selangor, 1997/1998*.

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 (about 46% of the State). This section clarifies present and future conditions of the study area by depicting development plans, which are proceeding, and population characteristics.

3.1 Development Plans

3.1.1 Kuala Langat District

(1) Development Corridors

The industrial sector will play an important role in the development of Kuala Langat district. Small and medium-sized industry is important in creating more local and Malay businessmen as well as for strengthening relations with major industries in Sepang. More emphasis will be given on industrial sectors employing fewer workers such as technology and capital-intensive ones as well as manufacturing with high value added.

In order to attain balanced development in economy and physical structure, three development corridors were proposed in the development plan of Kuala Langat District, namely:

- Telok Panglima Garang – Banting – Olak Lempit
- Morib – Tg Gabang –Tg. Tumbuk
- Pulau Carey

Each development corridor will have a strategic growth centre which will be the focus and catalyst of development and investment. The growth centres will have certain functions that correlate with each other. Strategic growth centres will be supported by (main) settlement centres. The purpose of (main) settlement centres is to integrate town development and infrastructure development as well as socio-economic facilities.[8)] (See **Table A.3.1**.)

Table A.3.1 Development Corridors of Kuala Langat District

Corridor	Strategic Growth Centre	Main Settlement Centre	Settlement Centre
Telok Panglima Garang – Banting – Olak Lempit	Banting (District Main Industrial Centre)	1. Telok Panglima Garang 2. Olak Lempit	1. Kg. Sijangkang Telok 2. Pekan Sg, Jarom 3. Kg. Sg. Manggis 4. Kg. Bukit Cheedaing 5. Labohan Dagang 6. Bandar
Morib – Tg. Gabang – Tg. Tumbuk	Batu Laut (Port City)	1. Morib 2. Tg. Sepat	1. Kg. Endah 2. Kg. Kundang
Pulau Carey	Pulau Carey (Vision City, District Administration and Tourism Centre)		1. Tg. Rhu

Source: Kuala Langat District Council, *Kuala Langat Structure Plan*, November 1998

(2) Environmental Sensitive Area

The development plan also identifies environment sensitive areas that emphasise low intensity development and greenbelt to make a balance between physical development and environment. Environmentally sensitive areas include those requiring preservation of limited and valuable natural resources and potential areas for tourism development. Areas that must be kept and preserved are[8)]:

- KLIA Buffer Zone including KLIA critical risk and noise control area
- Forest area
- Coastal area
- Riverbank area
- Ex-mines and swamp for flood detention
- Paya Indah area
- Highland with above 150 meters height and 20 degree slope
- Existing agriculture area and high productivity agricultural land
- Areas with historical and /or cultural value

3.1.2 Sepang District (Multimedia Super Corridor, MSC)

Multimedia Super Corridor (MSC) is the largest and the only urban development plan in Sepang District. It also gives large influences to the State as well as the nation.

MSC was conceived a vision to guide Malaysia to the 21st Century of Information Technology (IT) and Multimedia. The MSC is planned to develop with world class living and business environment, providing the latest and most up to date information infrastructure, telecommunication network, transportation system and utilities.[9)]

(1) Boundaries

The MSC area covers approximately 57,500ha, and is bordered by KESAS Highway (E5) on the north, North-South Central Link (E6) on the West, KL-Seremban Highway (E2) on the East and the southern boundaries of Kuala Lumpur International Airport (KLIA). Kuala Lumpur City Centre (KLCC) is also included in the MSC as an enclave from the viewpoint of its functions.

The MSC area falls totally or partially in five administrative areas including Kuala Lumpur, Suban Jaya, Sepang District, Kuala Langat District and Putra Jaya.

(2) Land Use Strategic Plan

The land use zone concept proposes five land use development corridors:

- **IT Enterprise Corridor**: With the nucleus at Cyberjaya, running north through Silicon Valley of UPM, Taman Teknologi and on to KLCC and Menara KL, and southwards through Bukit Damar/Dengki as part of Cyber Village and onto KLIA.
- **Manufacturing Enterprise Corridor**: Comprising the existing industrial areas of Puchong, Sime USJ in the northwest and a new corridor in the south, centred at the airport city of Salak Tinggi with non-polluting, capital intensive aviation related industrial enterprises.
- **Institutional/Government Corridor**: Centred at Putrajaya, to be loosely linked to Bangi and Kajang on the northeast and Bandar Baru Salak Tinggi in the south
- **Residential Corridors**: These form the main land use of the MSC and will occur as buffers separating the other corridors mentioned above.
- **Recreation and Green Corridors**: These are the main green network in the MSC, linking the forest reserves, the wetlands, the steep slopes, riverine areas, proposed parklands and other green reserves.

The residential areas, together with the committed areas and potential land to be developed, are expected to accommodate about 2.6 million people (estimates, see below) when fully developed. The proposed settlements in the MSC are as follows:

- Strategic Growth Centres: Putrajaya, Cyberjaya, KLIA and Taman Tknologi
- Major Urban Centres: USJ, Bandar Baru Salak Tinggi
- Urban Centres: Puchong, Puchong Utama, Putra Perdana, Seri Kembangan, Dengkil, Sepang, Sg. Merab, Salak Tinggi.

(3) Population

The estimated population in the MSC is about 648,900 in 1998 and it is expected to grow to 2,223,400 in 2020 (5.8% annually). This projection was made based on existing developments, committed developments, physical availability and an assumed gross density.

As mentioned by the development plan, the projected annual growth rate of 5.8% in 1998-2020 is slightly on the high side to continue for twenty years ahead. It should be treated as a target rate to keep the development speed for attaining the objective of Vision 2020. (See **Table A.3.2**.)

Table A.3.2 Population Projection for MSC

Sub-Panning Area	Year			Optimum Capacity	Growth Rate (%)		
	1998	2015	2020		1998-2015	2015-2020	1998-2020
Bukit Jalil	12,100	120,000	123,000	123,000			
MPSJ	574,400	728,600	786,600	786,600			
- Sderi Kembangan	95,200	156,500	181,200	181,200			
- Puchong	209,400	293,700	324,400	324,400			
- Damansara	269,800	278,400	281,000	281,000			
Sub-Total	**586,500**	**848,600**	**909,600**		**2.2**	**1.4**	**2.0**
Putrajaya	-	300,000	330,000	330,000			
Cyberjaya (Flagship Zone)	-	100,000	120,000	120,000			
Cyberjaya (Outside Flagship Zone)	4,100	217,500	250,000	276,900			
Tele Suburb	13,700	97,000	180,000	440,000			
Airport City	10,200	97,800	129,800	132,100			
Cyber Village	17,800	94,800	157,700	248,600			
Outer KLIA	16,600	80,000	146,300	180,000			
Sub-Total	**62,400**	**987,100**	**1,313,800**		**17.6**	**5.9**	**14.9**
Total	**648,900**	**1,835,700**	**2,223,400**	**2,637,200**	**6.3**	**3.9**	**5.8**

Source: Federal Department of Town and Country Planning, *Multimedia Super Corridor Physical Development Plan Study*, October 1999

3.1.3 Hulu Langat District

The land use development pattern in Hulu Langat will be influenced by the development of Klang Valley and Multimedia Super Corridor (MSC). Emphasised will be development of sectors including high technology related, institutional centre, research and development (R&D) centre and tourism.

At the southwest area, Cheras and Kajang will become parts of MSC area. This situation will provide a development chance of information technology and other hi-tech industries.

Bandar Baru Bangi, located in Kuala Lumpur-Cheras-Kajang-Bangi Corridor, will become a district growth centre, which accommodate institutional centres like Universiti Kebangsaan Malaysia (UKM) and become an R&D centre. In addition, a new city based on eco-media, which is in planning, will also be placed near Bandar Baru Bangi.

Development is accelerated also by abundant development of the Klang Valley Corridor area. In this area, involved is the city-edge area such as Ampang Jaya Municipal Council, which will become a major residential area in Selangor State.[10)]

3.1.4 Western Part of Seremban District

The western part of Seremban District includes those cities as Nilai, Mantin and Labu. Nilai City is planned to grow as a semi-State centre in 2020 with Mantin and Labu as growth centres. This is because so many giant projects are proceeding near the city area including Kuala Lumpur International Airport (KLIA), Putrajaya Federal Administration Centre and Multimedia Super Corridor (MSC). In accordance with these developments, upgrading effort on North-South Highway network and twin railway up to Seremban City (State Territory Centre) will increase the role of Nilai. Thus, Nilai as well as Mantin and Labu have a potential to develop the "support sector" that gives to other industries services such as banking, insurance, hotels, communications, information technology and transportation.

The Seremban District Development Plan proposes six corridor development strategies. Three of them are related to this area. They are as follows[11)]:

- **Nilai-Pajam-Mantin Corridor**: Intensive development will be executed in Nilai area to form an "Airport City". This corridor will support industrial development. Industrial development along Nilai Corridor will expand the development around Lenggeng, Pantai and Broga. In this corridor, emphasis will be given to electronic industrial development.
- **Nilai-Salak Tinggi Corridor**: KLIA, Bandar Baru Salak Tinggi in Sepang, Putrajaya Federal Administration Centre and MSC forms a potential corridor. This corridor will support industrial development growth especially high technology industries for both Negeri Sembilan and Selangor borders.
- **Nilai-Labu-Seremban Corridor**: This corridor is located along the North-South Highway, and will serve abundant development in the Nilai and Seremban areas. The focus of this development corridor is on the industrial sector such as electronics and transportation equipment industry.

3.2 Population

The total population in the study area is estimated at 975,600 in 1998, where the population in the western part of Seremban is estimated in proportion to the area size utilising figures published by the authorities of statistics. This population size amounts to more than 30% of that of Selangor. It is larger than that of Negeri Sembilan State. It is quite important to manage this area for the consistent development of these States.

Hulu Langat, which is the second largest District in Selangor, has the largest population size in the area with 596,800 in 1998, following Petalin with 860,700. It has also the highest growth rate of 5.1%, 2.7% points higher than the national average rate while other Districts show much lower growth rates. In consideration of the above data as well as highest density and lowest dependency rate, Hulu Langat can be seen as the most active in the study area in terms of population and other related indicators. (See **Table A.3.3**.)

Table A.3.3 Population and Other Indicators

Location	Area (ha)	Population[2] (1998)	Density (per km^2, 1998)	Dependency Ratio (1997)	Growth Rate (1998)	Rate of Natural Increase[5] (1997)
Kuala Langat	85,775	164,800	192.1	66.3%	1.4%	10.7
Sepang	59,996	68,100	113.5	61.2%	0.7%	12.4
Hulu Langat	82,620	596,800	722.3	50.3%	5.1%	26.4
Seremban	95,133	317,100	333.3	61.0%[3]	-	21.6
Western Part of Seremban	43,800[1]	145,900[1]	-	-	-	-
Study Area	275,040	975,600	358.4	54.2%[4]	4.0%[4]	-
Selangor State	796,114	3,098,800	389.2	52.6%	3.3%	23.5
Negeri Sembilan State	664,591	823,400	123.9	73.1%[3]	1.6%	17.9
Malaysia	32,973,300	22,179,000	67.3	61.8%	2.4%	20.3

Source: R&D Centre, Selangor, *Basic Information on the State of Selangor, 1997/1998*.
Department of Statistics, Malaysia, *Population and Housing Census of Malaysia 1991*.

1) Tentative estimates by the Study Team
2) Estimates by the Department of Statistics, Malaysia
3) Data in 1991
4) Western Part of Seremban is not included due to data availability.
5) Number of births minus deaths per 1,000 persons

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10) R&D Center, Selangor, *Vision 2005 for Selangor*, 1998 (Malaysian)

11) Seremban District Council, *Seremban District Structure Plan 1995-2020* (Malaysian)

SECTOR B

LAND USE

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

FINAL REPORT

SECTOR B

LAND USE

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LAND USE

1. PRESENT LAND USE

1.1 Land Use Classification

Land Use maps published in 1995 at a scale of 1:50,000 were collected from the Department of Agriculture (DOA). In the DOA map legend, there are nine (9) major classes and forty-five (45) sub-classes. The Land Use maps were digitised and feature coded by a local subcontractor according to the specification in **Table B.1.1**. To minimise difficulty in digitising small areas, Land Use classes were re-categorised as described below.

(1) Built-up Areas and Mining

DOA Land Use Class "Settlements and Associated Non-Agricultural Areas" consists of twelve (12) sub-classes. All urbanised areas in the DOA legend, including Right-of-Way, are combined into Built-up Area, and the two mining areas are treated separately due to their importance in the Study.

(2) Cultivated Areas

All three (3) DOA sub-classes of Horticultural Lands are combined into one, and termed as Cultivated Land.

(3) Rubber, Oil Palm, Coconut and Other Plantation

Various trees, Palms and Other Permanent Crops in the DOA Land Use legend are categorised into four (4) classes: Rubber, Oil Palm, Coconut, and Other Plantation such as Pineapple, Cocoa, Banana, Coffee, and so on. The first three (3) classes are separately categorised in the DOA Land Use Map, the Topographic Map of the Department of Survey and Mapping, Malaysia (DSMM) and the Land Cover Classification of Malaysian Centre for Remote Sensing (MACRES).

(4) Diversified Crops, Paddy, and Shifting Cultivation

Although these croplands on the Land Use Map are small in area, Paddy, Shifting Cultivation and other crops are separately classified. This type of Land Use is assumed to be more intensive in using chemical fertilizer, compared to other vegetation.

Table B.1.1 Layer Specification for Digitizing Land Use Maps

Class	Subclass	Class Description	DOA Code	Re-categorised Class	LUCODE
1	**SETTLEMENT AND ASSOCIATED NON-AGRICULTURAL AREAS**				
	1	Urban & Associated Area	1U	Builtup Areas	1001
	2	Cemetery	1U[C]		
	3	Recreational Area	1U[R]		
	4	Poultry (Chicken Firm)	1U[P]		
	5	Highway	1U[J]		
	6	Railway	1U[K]		
	7	Timber Storage Site	1U[T]		
	8	Gas Pipe Right of Way	1U[B]		
	9	Estate Building	1E		
	12	Power Line Right of Way	1P		
	10	Tin Mining Area	1T	Tin Mining	1002
	11	Other Mining Area	1X	Other Mining	1003
2	**HORTICULTURAL LANDS**				
	1	Agricultural Stations	2E	Cultivated Land	2001
	2	Mixed Horticulture	2H		
	3	Market Gardening	2M		
3	**TREE, PALM AND OTHER PERMANENT CROPS**				
	1	Rubber	3G	Rubber	3001
	2	Oil Palm	3O	Oil Palm	3002
	3	Coconut	3C	Coconut	3003
	4	Pineapple	3N	Other Plantation	3004
	5	Cocoa	3A		
	6	Banana	3B		
	8	Coffee	3K		
	9	Pepper	3P		
	10	Arecanut (Palm)	3R		
	11	Sago	3S		
	12	Tea	3T		
	13	Orchards	3X		
	14	Sugar-Cane	3Y		
4	**CROPLAND**				
	1	Diversified Crops	4C	Diversified Crops	4001
	2	Tobacco	4T		
	3	Paddy	4P	Paddy	4002
	4	Shifting Cultivation	4X	Shifting Cultivation	4003
5	**IMPROVED PERMANENT PASTURE**				
	1	Livestock	5	Livestock	5001
6	**GRASSLANDS**				
	1	Lalang, Grass	6	Grassland	6001
	2	Grass / Erosion Land	6E		
7	**FOREST LAND**				
	1	Forest	7F	Forest	7001
	2	Shrubs, Bush	7S	Shrubs, Bush	7002
	3	Mixed Shrubs and Trees	7F/7S		
	4	Newly cleared Land	7C	Reclaimed Land	7003
	5	Reclaimed Areas	7T		
8	**SWAMPS, MARSHLAND AND WETLAND FOREST**				
	1	Swamps (Mangrove, ..)	8	Swamps	8001
9	**UNUSED LAND**				
	1	Unused Land	9	Unclassified Land	9001
	2	Unclassified Land	UN		
	3	Water	W	Water Bodies	9002
3	7	Fish & Hyacinth Ponds	3H		

Source: Land Use Map Legend of DOA published in 1995

(5) Livestock, Grassland

Livestock and Grassland are classified under the same classification as in the DOA Land Use Map legend: "Improved Permanent Pasture" and "Grasslands". These Land Use classes are supposed to be useful as reference for interpretation of land cover from the Landsat TM.

(6) Forest, Shrubs/Bush, and Reclaimed Land

The DOA Land Use legend of 1995 for 1:50,000 scale map has only the Forest Lands category instead of the Primary and Secondary Forests classifications in "The Present Land Use of Peninsular Malaysia, 1973". The DOA Forest Lands are reclassified into three: Forest, Shrubs/Bush, and Reclaimed Lands. Newly cleared land or reclaimed land might be the area where land use changes are expected in the future.

(7) Water Bodies

Fishponds are categorised in the Major DOA Land Use Category 3, that is, "Tree, Palm and Other Permanent Crops". These fishponds, together with the lakes, are classified in this Study as Water Bodies.

(8) Swamps

In the DOA legend, swamps (Mangrove, etc.), Marshland and Wetland Forests are categorised into one Land Use class. This type of land use is classified in this Study as Swamps.

(9) Unclassified Land and Mixed Use

The areas in the Land Use maps described as "Unclassified" or "Unused" in the DOA legend are termed in this Study as Unclassified Lands. There are a series of mixed-use categories among such classes as, Timber Storage Site, Orchards, Horticulture, and so on. All these together are combined into one, and termed as Mixed-Use.

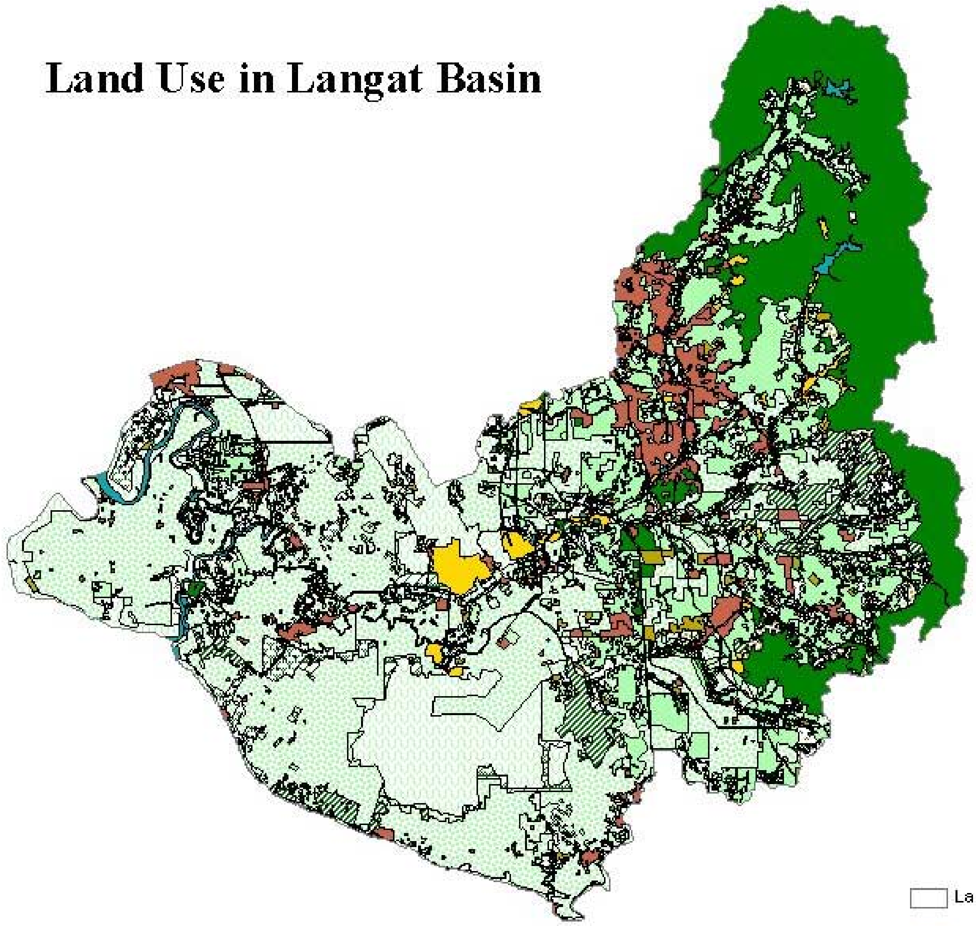
1.2 Existing Land Use Map

1.2.1 Land Use Map collected from DOA

The existing land use maps at a scale of 1:50,000 collected from DOA, covering the whole Langat Basin of 2,750.2 sq. km., are digitalised. The data in ARC/INFO format are plotted, as shown in **Figure B.1.1**.

Oil Palm plantation is dominating Land Use in the Langat Basin, followed by Forest Areas, Rubber, Swamps, and Urban Built-up Areas.

Land Use in Langat Basin



lucode	landuse	frequency	sq_km	percent
1001	Builtup Areas	556	172.2	6.5
1002	Mining	62	42.4	1.5
2001	Cultivated Land	422	78.6	2.8
3001	Rubber	670	436.5	15.6
3002	Oil Palm	465	928.8	33.8
3003	Coconut	100	38.6	1.4
3004	Other Plantation	528	32.5	1.2
4001	Diversified Crops	86	26.6	1.0
4002	Paddy	24	3.7	0.1
4003	Shifting Cultivatio	1	0.1	0.0
5001	Livestock	2	1.1	0.0
6001	Grassland	315	35.3	1.3
7001	Forest	78	478.7	17.4
7002	Shrubs, Bush	173	28.4	1.0
7003	Reclaimed Land	281	32.9	1.2
8001	Swamps	188	275.1	10.0
9001	Unclassified Land	3	1.2	0.0
9002	Water Bodies	140	40.2	1.5
9999	Mixed Use	157	102.1	3.7

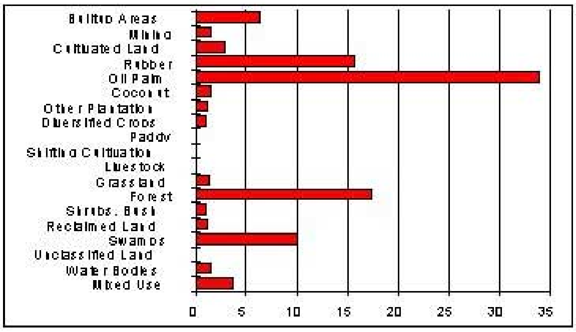


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Figure B.1.1

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

Land Use in the Langat Basin

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1.2.2 Review of Land Use by Field Verification

Coconut plantation areas are preliminarily specified in Table B.1.1, to be consistent with the classification of DSMM and MACRES. However, interpretation of these areas, as well as the Mixed Areas on the Landsat image is expected to be difficult. These areas were reviewed by field verification and the results are as described below. A summary of the field works is given in **Figure B.1.2**.

(1) Mixed Areas

There are a series of mixed-use categories among the classes such as, Timber Storage Site, Orchards, Horticulture and so on in the DOA Land Use Map. The pattern of these mixed areas were studied through a two-day field survey, and photos were taken on representative areas as shown on the leftmost column of **Figure B.1.2**.

The photos show a mixture of houses, roads, coconuts, open spaces and other vegetation. A few coconut trees near an isolated house or a group of houses is very common in the western part of the Study Area. Temporary plantation, such as ginger, is also said to be a common occurrence. A large portion of mixed areas is covered by different kinds of trees and vegetation. After discussing the situation with the other experts of the Study Team, the classification of mixed areas into “Plantation” was maintained.

(2) Coconut Plantation

The coconut plantation areas on the DOA land use map are digitised. Large coconut plantation areas are found along the seaside of the Study Area.

One area in the western seaside was observed, as indicated on the overview map in **Figure B.1.2**, where photos of these areas are shown in the middle column. Even though the other vegetation, houses and roads are mixed, coconut trees are the majority. Oil palms can also be found there. In comparison with the oil palms, coconut trees are tall and easy to differentiate on the ground although their leaves are similar. An extensive field survey might be needed to verify the coconut areas in order to update the land use data by Landsat TM. The situation was also discussed with the other experts, and the coconut areas are combined into Plantation.

(3) Updated Areas

Two mixed-use areas were edited through field verification; one was edited into the Builtup area (about 17 sq. km.) and the other into Rubber (about 34 sq. km.), as indicated on the overview map in **Figure B.1.2**. These are the largest two among mixed areas. About twenty (20) other areas are five (5) to six (6) sq. km, and the remaining ones are less than one (1) sq. km.

Field Verification Summary

Mixed Areas

Houses, Roads, Coconuts and other vegetation

A few Coconuts and other vegetation

Open Space, Coconuts, Oil Palm & other vegetation

Newly planted Oil Palm, and temporary planting of Ginger

Coconut Plantation

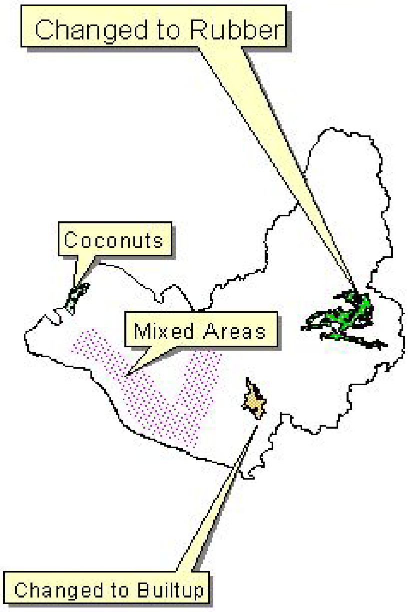
Coconut Areas, still mixed other land cover classes

Identifiable Coconut Area besides a major Road

Coconuts may be identified but, Land cover is complex.

Oil Palm beside a major Road

Updated Areas



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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 B.1.2

Summary of Land Use Field Verification

The area that was edited into Builtup area was originally coded as mixed use with urban, and it totally falls within KLIA. It may be incorrect to assign this area as mixed use, because mixed use areas, unlike this specific case, are more or less vegetated and are classified as Plantation in this Study.

The other area that was edited into Rubber concerns the largest mixed area. Careful observations were made along the passable paths within this area and it was found that Rubber is the dominating plantation in this area. In one place, it was found that the rubber trees were cut and young palm trees were planted. The photos are given in **Figure B.1.2**.

After the above area, the investigation was continued to the northern areas where rubber plantations were also found. Rubber, Oil Palm and other trees in the East, and Oil Palm, Coconut and other trees in the West may be the pattern of vegetation in the Study Area.

1.2.3 Land Use in 1995

The land use data were edited according to the field verification results. The wide rivers and lakes were combined into Water Bodies in Phase-I. These are now coded separately as the sub-classes of Water Bodies. The edited Land Use in Langat Basin in the Year 1995 is as summarised in **Table B.1.2**.

Table B.1.2 Land Use in the Langat Basin

Land Use Class	LUCODE	No. of Lots	Area in Sq.Km	Percent[%]
Builtup Are as	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			**2750.2**	**100**

Source: Digitised Land Use Map of DOA published in 1995

2. UPDATING LAND COVER

2.1 Land Cover Classification

Topographic maps of 1991/92 at a scale of 1:50,000 in DXF data format were made available by JMG. These data are converted into ARC/INFO format and listed in the "Converted Topo-Map" column of **Table B.2.1**. The column "Reclassified Land Use" in that table shows the reclassified DOA Land Use Map legend of 1:50,000 scale (refer to **Section 1.1**).

Due to limitation of visibility in the Landsat TM imageries (30 m resolution), the land use/land cover classes were combined into nine (9) classes, as shown in the table below, for land cover updating purposes.

Table B.2.1 Land Use / Land Cover Classification

No.	Re-Classified Land Use	Converted Topo-Map	Land Use / Land Cover
1	Builtup Area	Urban Areas	BUILTUP AREA
		Airfield	
		Cemetery	
2	Tin Mining	Mining Area	MINING
3	Rubber	Rubber	RUBBER
4	Oil Palm	Oil Palm	OIL PALM
5	Coconut	Coconut	PLANTATION
	Other plantation	Sundry Tree	
	Diversified crops	Sundry (Non-Tree)	
	Paddy	Paddy	
	Cultivated Land		
	Shifting Cultivation		
	Mixed use		
6	Grassland	Grass	GRASSLAND
	Unclassified land		
	Reclaimed land		
	Livestock		
7	Forest	Primary forest	FOREST
	Shrubs, Bush		
8	Swamps	Sand, Mud	SWAMPS
		Swamps	
9	Water Bodies	Wide rivers	WATER BODIES
		Lake, Reservoir	
		Lake (seasonal)	

2.2 Updating Method

The digitised DOA Land Use maps (1995) covering the whole Langat Basin area are updated by using the Landsat TM image of 1998 to produce the Land Use/Land Cover map, as classified in **Table B.2.1**. The digital topographic maps of DSMM (1991/92) in DXF-format are converted into ARC/INFO to prepare other relevant data such as contour, roads, rivers, etc. for the Study. These data are also referred in geo-referencing

Landsat TM scene, as well as in interpretation of the Land Cover from TM images. Aerial photos taken from 1992 to 1999 further supplement the image interpretation.

A total of twelve (12) Ground Control Points (GCP), which are identified on both topographic map and Landsat image, are used to rectify Landsat TM scene, which has seven (7) spectral bands. Different composite of three (3) bands in the order of Red, Green and Blue (RGB) show the objects differently on the image; for example, vegetation appears red, and water appears black on 4,3,2 composite. Those are green and yellow, respectively, on the composite image of TM bands 5,4,2. A comparison of different composite images will help to clarify confused objects on an image. For this reason, three combinations of TM spectral bands in RGB order; (4,3,2), (5,4,2) and (4,1,7), are printed for land cover interpretation.

All the data conversion, land use map digitising and land cover updating works were subcontracted to a local firm.

The areas under different stages of construction were interpreted as built-up area. However, the administrative boundary and the KLIA border were taken from other sources.

2.3 Land Use Map and Land Use/Land Cover Changes

Using the revised data mentioned above, a Land Cover Map at a scale of 1:125,000 is produced. ArcView program file is provided for later reproduction in A-0 Size.

From the Existing and Updated Land Use in Langat Basin, which are shown in **Figure B.2.1**, land use changes during 1995 and 1998 are computed, and summarised in **Table B.2.2**.

Table B.2.2 Land Use / Land Cover Changes (Unit: km^2)

No.	Land Use/Land Cover	1995	1998	Changes
1	Builtup 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

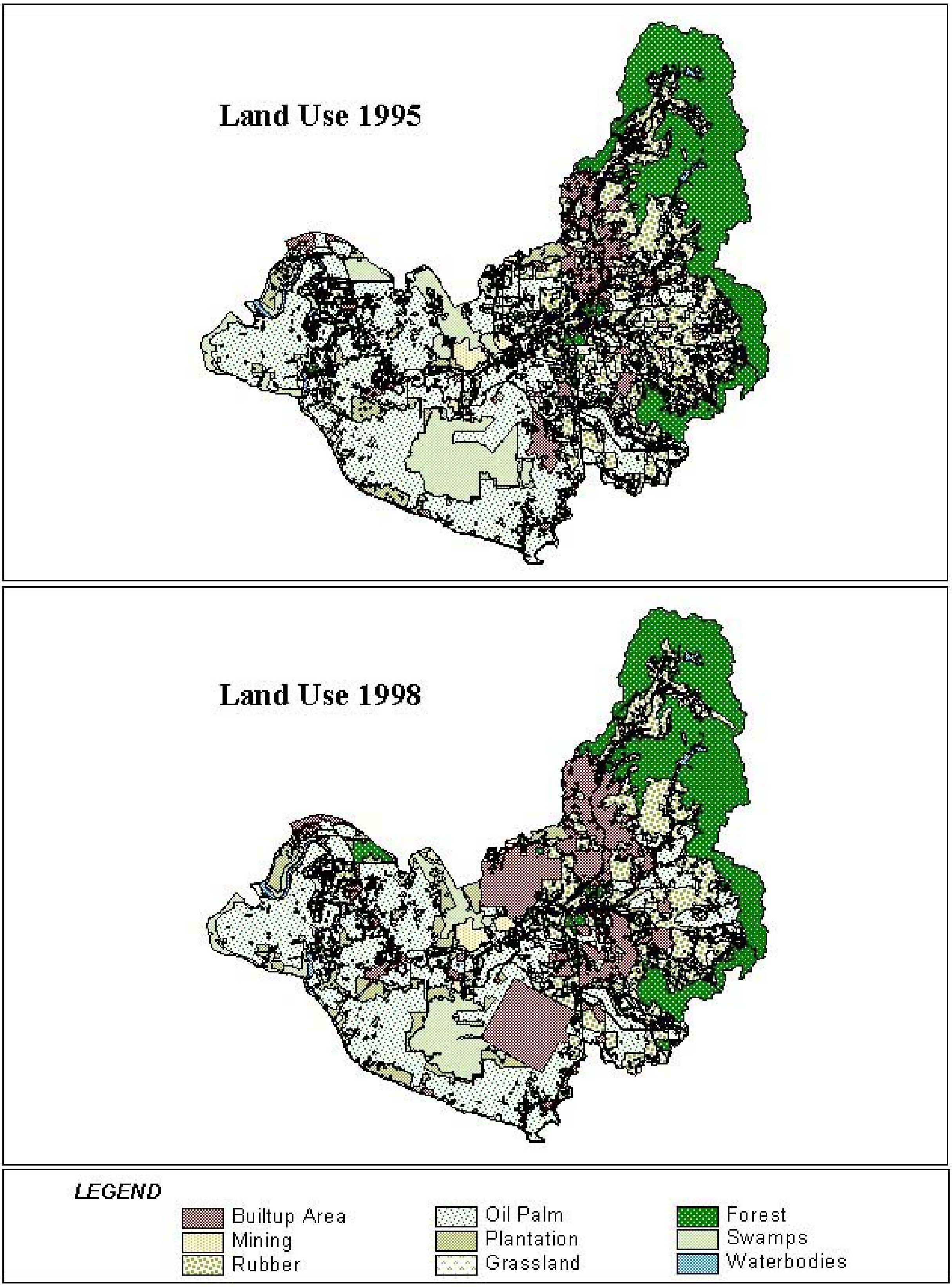

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Figure B.2.1

Land Use Changes of the Langat Basin between 1995 and 1998

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

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SECTOR C

WATER DEMAND AND SUPPLY

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

FINAL REPORT

SECTOR C

WATER DEMAND AND SUPPLY

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SECTOR C

WATER DEMAND AND SUPPLY

1. NATIONAL WATER RESOURCES STUDY (PENINSULAR MALAYSIA) 2000-2050

1.1 Background

In recent years, the available water resources have been under pressure due to increasing demand by industry and domestic water consumption as well as the deterioration in water quality caused by pollution. Further, the population of Peninsular Malaysia had continued to grow rapidly and it is expected to increase in 2050 to more than double of that in 2000. It should also be noted that the Malaysian economy has already changed from agricultural to an industrial one and is projected to grow at a fast speed to the target of Vision 2020. This momentum of growth in population and economy will require much more water supply.[1)]

Considering the above-mentioned situations in Peninsular Malaysia, the National Water Resources Study (NWRS) was carried out on planning, development and management up to 2050 for the overall water resources of Peninsular Malaysia under the sponsorship of the Economic Planning Unit. The final report was issued in March 2000 in two forms, i.e., Sector study reports and State reports. The study objectives and scope of work are closely relevant to this present study. Its data and analysis are frequently made as reference with some amendments to incorporate the results of this present study.

1.2 Demand Forecasting

Water demand is defined as the quantity of water that has to be put into a distribution system so as to satisfy the requirements of household use, commerce, institutional services, industry, recreation and tourism, meet losses that occur through leakage, and satisfy other unaccounted water components. By first making projections on the various components of water demand, a preliminary forecast for each state was made. It should be noted that the forecast was based on the foreseeable pace of development in the respective states, not on the development plans or structure plans that generally forecast higher growth rates of water demand. The State Water Authority in each state had discussed these demands.

Typical econometric models on water demand forecasting employ variables such as price and income levels. NWRS, however, did not use such models saying that in general they cannot predict the impact of factors affecting water demand that are not reflected in the historical data. In addition, in Malaysia, models with water demand relationship that is statistically acceptable have not been practised. NWRS employs a much simpler model, which is intuitively acceptable. Considering the very long time span of the present study, it is agreeable to employ a simple model and not a complicated one that is suitable for short time frame and requires many assumptions for long-term projection.

Described below are the bases of forecasting of each demand component, where domestic and industrial water demands are divided into the five categories.

1.2.1 Domestic

Domestic water use (*DWU*) is estimated with the following formula:

DWU = (*Population*) x (*Service Factor*) x (*per capita DWU*)

Demographic projections are made based on the 1991 national census and then projected for 1995, 1997 and for every decade to 2050 (Details of demographic projections are mentioned below). The service factor for most States in Peninsular Malaysia is expected to approach 100% between years 2000 and 2010. Per capita *DWU* are assumed to grow steadily from 230 ℓ/c/d in 1997 to around 270 ℓ/c/d in 2020 and slower to 300 ℓ/c/d in 2050.

1.2.2 Commercial

Commercial water use (*CWU*) is estimated with the following formula:

CWU = (*Population*) x (*per capita CWU*)

Per capita *CWU* are assumed to grow steadily from 40-50 ℓ/c/d in 1997 to 50-100 ℓ/c/d in 2050 in capital regions and from 10-40 ℓ/c/d to 40-90 ℓ/c/d in outer districts.

1.2.3 Institutional

Institutional water use (*IWU*) is estimated with the following formula:

IWU = (*Population*) x (*per capita IWU*)

Per capita *IWU* are assumed to grow steadily from 20-50 ℓ/c/d in 1997 to 40-100 ℓ/c/d in 2050.

1.2.4 Industrial

NWRS assumes the inter-relationship between (1) per capita GDP, (2) gross value of manufacturing output, and (3) industrial water demand. Based on this assumption, future industrial water demand is estimated as follows:

- Step 1: Determine national GDP growth for 2000-2050.
- Step 2: Project per capita GDP using the demographic projection.
- Step 3: Estimate GDP by State.

- Step 4: Forecast manufacturing value-added by State.
- Step 5: Convert these values to the gross value of manufacturing output.
- Step 6: Estimate future industrial water demand by State based on its manufacturing output projections.

In the calculation process, industrial water use in terms of manufacturing output or Unit Industrial Water Consumption (*UIWC*) is estimated. *UIWC* is expressed as follows:

$$UIWC = TIW \div MO$$

Where, *TIW*: the State's total industrial water use in million m^3 per annum

MO: the State's manufacturing output of the same year in billion RM.

UIWC varies over a wide range from a low of 0.6 in Kelantan State to a high of 8.0 in Terengganu State. NWRS assumes that *UIWC* is to increase generally in the medium term until 2020 and decline thereafter. The increase in *UIWC* means that the efficiency of water use has declined, and the NWRS report does not explain the reason. It can be assumed that since Vision 2020 plans to enhance the growth of the hi-tech sector, which consumes much water, water use efficiency may be lower in the whole industrial sector.

1.2.5 Non-Revenue Water (NRW) or Leakage

NRW is expressed as a percentage of total production. NRW rates are assumed to decrease because privatisation of water supply is expected, and management will try to reduce losses as a condition of the required operating agreements, or try to increase benefits to increase efficiency. NRW rates are assumed to decrease to 10-15% in 2050.

1.3 Demographic Projection

Future population is forecasted at the district level. The population of each district is estimated at 5-year intervals from 1991 to 2050. The estimation uses the standard procedure as follows:

$$P_t = P_0 e^{rt}$$

Where, P_0: population in the base year (National Census in 1991)

P_t: population at time t

r: population growth rate

t: time period

This formula is called the exponential model, which means that the population grows on compound basis, continuously in the period. It grows fastest among models with the same growth rate. It is assumed that the natural growth rate gradually stabilises until it finally reaches the replacement level. Migration factors are estimated based on the information from previous studies.

As a projection result, the average annual growth rate for Peninsular Malaysia is expected to decline from 2.30% in 1995-2000 to 0.86% in 2050. (See **Table C.1.1**.)

Table C.1.1 Population Projection of Peninsular Malaysia

Item	1991	2000	2020	2050
Population ('000)	14,672	18,096	26,653	37,991
Annual Growth Rate (five year average*)	-	2.30%	1.69%	0.86%

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia) 2000-2050, Sector Report Volume 2, Chapter3 Basis for Water Demand Estimation*, March 2000.

*: Averages in 1996-2000, 2016-2020 and 2046-2050

1.4 National GDP Projection

The national GDP growth for the period 2000-2050 is projected with assumed growth rates, considering the development plans and other factors. NWRS did not construct a multi-sector economic model, which incorporates interactions between the labour market and the real and monetary sectors of the economy, arguing that it is beyond the scope and purpose of the study. NWRS also mentions that it did not incorporate data on the external sector such as foreign income and exchange rates because they are not available for the period 2000-2050, although it recognises the importance of those data for determining the national GDP growth.

1.4.1 For the Period 1998-2000

NWRS projects that a positive growth rate of 1.0% in 1999, 3.0% in 2000 and a recovery to about 7.0% in 2002 is attainable. As mentioned in 2.2, Socio-economic Conditions, the Malaysian economy showed a steady growth in 1999 and has entered a sustainable growth process since 2000. Although 7.0% in 2002 seems a little higher, the NWRS estimation for the near future will hit the target very well in average.

1.4.2 For the Period 2001-2010 and Beyond

The average annual growth rate is estimated at 7.12% for the period 2001-2010. NWRS forecasts that in order to keep the industrialisation process on track, the Government will undertake measures to target economic growth at the 7.70% rate from 2006 to 2010. Growth estimates mentioned here and the following should be conceived as Government targets, not projections.

Beyond 2011, NWRS assumes that GDP will grow but at a declining rate of 0.48 percentage points every five years until 2050.

Table C.1.2 summarises the GDP forecasts. As mentioned in the NWRS report, Malaysia's economic growth shows 3.86% on average by 2050, which would be very close to the pace experienced by Japan prior to the economic problems in the 1990s.

Table C.1.2 GDP Projection of Malaysia

Year	Population of Malaysia* ('000)	Population Growth	GDP in 1978 prices (RM Million)	GDP Growth	Per Capita GDP in 1978 prices (RM)	Per Capita GDP Growth
2000	22,620	2.34%	142,422	3.00%	6,296	0.65%
2005	25,243	2.23%	200,845	7.70%	7,956	5.35%
2010	27,932	2.05%	291,031	7.70%	10,419	5.54%
2015	30,615	1.85%	412,400	7.22%	13,471	5.27%
2020	33,316	1.71%	571,418	6.74%	17,151	4.95%
2025	35,958	1.54%	774,111	6.26%	21,528	4.65%
2030	38,494	1.37%	1,025,230	5.78%	26,634	4.35%
2035	40,965	1.25%	1,327,281	5.30%	32,400	3.99%
2040	43,301	1.12%	1,679,514	4.82%	38,787	3.66%
2045	45,493	1.00%	2,077,007	4.34%	45,655	3.31%
2050	47,488	0.86%	2,510,033	3.86%	52,856	2.97%

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia) 2000-2050 Sector Report Volume 2, Chapter 3 Basis of Water Demand Estimation*, March 2000.

*: The national population is estimated by dividing the population projection for Peninsular Malaysia by a factor of 0.8, which represents the ratio of the Peninsular to the national population in 1991 and it is assumed to remain constant in the future.

1.5 Demand Forecasting Results

The total per capita water consumption in 1997 and 2050 for the States are presented in NWRS. Detailed consumption and supply plans are described in the State Reports. (See **Table C.1.3**.)

Table C.1.3 Total Per Capita Water Consumption (l/c/d)

State	1997	2050
Perlis	313	447
Kedah	358	557
P. Pinang	474	663
Perak	352	519
Selangor & KL	431	816
N. Sembilan	397	610
Melaka	349	582
Johor	405	614
Pahang	398	680
Terengganu	272	570
Kelantan	206	378

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia) 2000-2050 Sector Report Volume 3, Chapter 4 Domestic and Industrial Water Demand Forecasting*, March 2000.

1.6 Groundwater Conditions in Peninsular Malaysia

NWRS[2),3)] describes groundwater usage in Peninsular Malaysia as follows:

In Malaysia the evolution of groundwater use from shallow hand-dug wells to the present sophisticated tube wells started nearly 70 years ago. Kelantan, which is the most important State where groundwater is utilised for public supply, started exploiting its rich groundwater basin as early as 1935.

At present, water supply for domestic, agricultural and industrial purposes is mainly sourced from surface water such as rivers and streams. Only in areas where surface supplies are inadequate or non-existent does groundwater come into use on a conjunctive basis or as the only source of water supply.

Kelantan takes the lead as far as groundwater abstraction for public supply is concerned followed by Terengganu, Pahang, Selangor and Perilis. Groundwater usage for industrial purposes is mostly exploited in the State of Selangor especially in the Klang Valley for use in mineral water bottling, breweries, steel mills, ceramic and rubber processing factories. Groundwater usage for agricultural purposes is most prevalent in the State of Kelantan, Terengganu, Pahang, Perlis and Kedah.

2. SELANGOR STATE

2.1 Demand and Supply Plan

2.1.1 Water Demand Estimates of Multimedia Super Corridor

Based on the development plans in sub-areas, the Structure Plan Study of the Multimedia Super Corridor (MSC) estimates the following water demands of MSC in 2020.

Table C.2.1 Water Demand Estimates of MSC in 2020

Sub-Area	Water Demand (Mld)
Kuala Lumpur City Hall	47.19
MPSJ	
- Seri Kembangan Zone	80.37
- Puchong Zone	135.61
-Damansara Zone	112.42
Putrajaya	209.12
Cyberjaya	
- Flagship Zone	118.20
- Outer Flagship Zone	59.10
KLIA	45.46
Outer Area of Cyberjaya and Putrajaya (Petaling District and Sepang Boundaries)	41.69
Cyber Village (Dengkil Area)	69.06
Tele Suburb (Sg. Merab Area)	97.38
Airport City (Salak Tinggi Area)	50.82
KLIA Surrounding Area	46.55
TOTAL	**1,112.97**

Source: Federal Department of Town and Country Planning, *Multimedia Super Corridor Physical Development Plan Study*, October 1999

Note: Water demand is calculated based on the average water consumption (320 litre/person/day) and factor 1.2 is used for development purposes in case population estimates are available. For other calculation bases, see the Development Plan.

The present production capacity of the Semenyih Water Treatment Plant is only 636.44 Mld. Total current needs can be fulfilled by the existing water source. As for the future, the Development Plan described by the Water Supply Plan of Selangor Water Supply Department will cover the future balance. Additional production is planned initially from the Selangor River Scheme when the current production is fully utilised and also from the Interstate Water Transfer Scheme that transfers water from Pahang to Selangor.[4)]

Unfortunately, when the Development Plan described the water balance, it considered the water demand only from the MSC while it mentioned all the supply to Selangor. It did not examine the total water balance in calculating the total demand forecast in the whole Selangor. The final water balance should have been examined together with all the water resource development plans and demand in the area.

2.1.2 State Report of National Water Resources Study (Peninsular Malaysia) 2000-2050

Selangor State contains the Federal Territory of Kuala Lumpur within its boundaries. Thus, many prestigious development projects are planned in this area. Since Selangor and KL have a close relationship with each other geographically and economically, the State Report of NWRS has drawn up a water demand and supply plan that includes both territories.

(1) Demographic Projection

In estimating growth rates, it is assumed that the natural growth rate would tend to decline and reach replacement level in 2080. The demographic projection based on the formula used in the National population or the "low growth forecast" does not include the factor of in-migration, which might be initiated by new developments in the State. Thus, it needs an adjustment with the in-migration factor for water resource development planning purposes. As a result, it is expected that the Selangor population for planning will be about 8.3 million in 2050 while KL will be 2.5 million. (See **Table C.2.2**.)

Table C.2.2 Population Projection of Selangor and KL

Year	Selangor			Kuala Lumpur		
	Low Growth ('000)	Planning ('000)	Annual Growth Rate in Previous Ten Years	Low Growth ('000)	Planning ('000)	Annual Growth Rate in Previous Ten Years
1991	2,372	-	-	1,190	-	-
1995	2,780	-	-	1,282	-	-
2000	3,331	3,805	-	1,398	1,677	-
2010	4,453	5,442	3.6%	1,630	2,286	3.1%
2020	5,496	7,172	2.8%	1,851	2,314	0.1%
2030	6,344	7,700	0.7%	2,070	2,401	0.4%
2040	7,022	7,962	0.3%	2,254	2,435	0.1%
2050	7,509	8,308	0.4%	2,395	2,467	0.1%

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), State Report Volume 12 Selangor, Chapter 4 Basis of Water Demand Estimation*, March 2000.

(2) Regional GDP Estimation

For the calculation of industrial water demand, regional GDPs are estimated. Both Selangor State and Kuala Lumpur show gradual decline of growth rates from higher rates of 6.5% and 8.0% in 2000-2010 to 3.5% and 3.6% in 2050. For this estimation, it is considered that Selangor is the third most favoured location for manufacturing investment, having the largest population in 1998 and being the most industrialised State in Peninsular Malaysia. Kuala Lumpur is expected to remain as a growth centre in the future.

Table C.2.3 GDP and Manufacturing Projection of Selangor and KL

Year	Selangor			Kuala Lumpur		
	GDP (RM million, 1978 Prices)	Growth Rates in Previous Five Years	Manufacturing Value-Added in GDP	GDP (RM million, 1978 Prices)	Growth Rates in Previous Five Years	Manufacturing Value-Added in GDP
2000	30,113	-	57.46%	17,668	-	11.93%
2005	44,006	7.9%	51.96%	23,898	6.2%	11.60%
2010	65,053	8.1%	46.98%	33,286	6.9%	11.28%
2015	92,725	7.3%	42.48%	45,472	6.4%	10.96%
2020	129,050	6.8%	38.42%	60,779	6.0%	10.66%
2025	173,475	6.1%	34.74%	79,964	5.6%	10.36%
2030	225,856	5.4%	31.41%	103,016	5.2%	10.07%
2035	287,257	4.9%	28.40%	129,651	4.7%	9.79%
2040	355,383	4.3%	25.68%	159,524	4.2%	9.52%
2045	429,322	3.9%	23.22%	191,829	3.8%	9.26%
2050	505,465	3.3%	21.00%	225,406	3.3%	9.00%

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), Sector Report Volume 2, Chapter 3 Basis of Water Demand Estimation*, March 2000.

(3) Demand Projection Results

Population base consumption is forecasted to increase steadily. Domestic consumption will increase from 265-275 ℓ/c/d in 1997 to 310-330 ℓ/c/d in 2050, commercial from 25 ℓ/c/d to 60 ℓ/c/d, and institutional from 17 ℓ/c/d to 88 ℓ/c/d. Industrial uses are projected to expand from 395 Mld for capital regions and 15 Mld for outer districts in 1997 to 2,300 Mld and 264 Mld in 2050, respectively. Concerning losses, they are assumed to decrease from 18% in 1997 to 15% in 2050. (See **Table C.2.4**.)

Table C.2.4 Projected Water Demand of Selangor and KL

Year	Population Served ('000)	Domestic (Mld)	Industrial (Mld)	Commercial (Mld)	Institutional (Mld)	Losses (Mld)	Total (Mld)
1995	4,027	1,007	350	123	96	349	1,925
2000	5,482	1,556	607	242	184	450	3,039
2010	7,728	2,287	1,330	551	534	787	5,489
2020	9,486	3,013	2,097	741	741	937	7,529
2030	10,100	3,244	2,368	838	835	1,022	8,307
2040	10,397	3,335	2,518	909	909	942	8,613
2050	10,774	3,452	2,564	942	942	892	8,792

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), State Report Volume 12 Selangor, Chapter 5 Domestic and Industrial Water Demand Forecasting*, March 2000.

(4) Existing Water Sources

There are four major river basins in Selangor State; namely, Sg. Langat, Sg. Klang, Sg. Selangor and Sg. Bernam. A number of water source works have been supplying water to the area. Source works with reliable net yields are listed in **Table C.2.5**. The total water yield is 3,407 Mld as of July 2000.

The largest source works is the Sg. Selangor Scheme (SS) with 3-Phase programs. Phase 2 was completed in 2000 and the scheme is now supplying 1,900 Mld in total. Phase 3 is planned to increase the supply by 1,100 Mld in 2005.

Table C.2.5 Output of Existing Sources/WTPs in Selangor and KL

Source Works	Storage Capacity (million m^3)	Net Reliable Yield (Mld)	District	Remarks
Major Sources				
Klang Gates dam (Bukit Nanas)	22.6	145.0	Kuala Lumpur	Direct supply reservoir
Langat dam	36.4	386.0	Hulu Langat	Regulating reservoir. Output restricted by WTP capacity. Compensation release 90 Mld.
Smenyih dam	60.4	545.0	Hulu Langat	Regulating reservoirs. Output restricted by WTP capacity. Compensation release 90 Mld.
Batu dam	27.5	114.0	Gombak	Direct supply reservoirs
Selangor scheme	-	1,900.0	Kuala Selangor	SS1(Sg. Selangor Phase I): 950 Mld SS2-1: 475 Mld, SS2-2: 475 Mld
Sg. Tinggi dam (Sg. Buloh) *(part of Sg. Selangor Scheme)*	95.0	-	Petaling	Regulating reservoir. Compensation release 300 Mld
Wangsa Maju		45.5	Gombak	
Minor Sources				
Ampang dam/intake		18.0	Gombak	
Sg. Gombak intake		22.5	Gombak	
Sg. Langat (Cheras)		27.0	Hulu Langat	27 Mld WTP. Shut down during droughts due to pollution.
Sg. Langat (Tampoi)		31.5	Hulu Langat	28 Mld WTP. Shut down during droughts due to pollution.
Subang dam	3.5	23.0	Klang	Direct supply reservoirs
Batang Kali intake		20.0	Hulu Selangor	
Kelumpang intake		7.0	Hulu Selangor	
Kuala Kubu Bahru intake		7.0	Hulu Selangor	
Rantau Panjang intake		32.0	Kuala Selangor	
Tanjung Karang inake		27.0	Kuala Selangor	
Bernam River Headworks		21.0	Sabak Bernam	
Sg. Buaya		0.9	Hulu Selangor	
Sg.Dusun		1.3	Hulu Selangor	
Sg. Selisik		1.3	Hulu Selangor	
Sg. Tengi		1.3	Hulu Selangor	
Kepong		2.3	Gombak	
Sg. Keroh		0.5	Gombak	
Sg. Pusu		0.1	Gombak	
Sg. Rangkap		9.0	Gombak	
Sg. Rumput		4.5	Gombak	
Salak Tinggi		10.8	Sepang	
Sg. Lolo		0.3	Hulu Langat	
Sg. Pangsoon		2.3	Hulu Langat	
Sg. Serai		0.9	Hulu Langat	
Total		**3,407.0**		

Source: Selangor Water Supply Department

(5) Future Water Supply Plan

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. These major works are described in detail in following subsections of this sector report. 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, which will be 250 Mld in 2005-2031, and 500 Mld in 2032-2050.
- Further, it is also expected to satisfy the shortage in Klang Valley with the Northern Selangor Transfer from Pahang.

Concerning the Southern Transfer Tunnel, its construction plan has been revised in "Pahang-Selangor Raw Water Transfer Project Engineering Services and Detailed Engineering Design." The new plan is formulated as follows: the construction of Kelau dam is planned to finish in 2007 with increased capacity of 2,259 Mld, while the construction of Telemong Dam is cancelled because of the minimisation of environmental impacts.

Total demand forecasts including that from Negeri Sembilan and the revised schedule of source works implementation are shown in **Tables C.2.6 and C.2.7**.

Table C.2.6 Total Demand Forecast

State	2000	2005	2010	2020	2032	2040	2050
Selangor (Mld)	3,039	4,264	5,489	7,529	8,368	8,613	8,792
Negeri Sembilan (Mld)	0	250	250	250	500	500	500
Total	3,039	4,514	5,739	7,779	8,868	9,113	9,292

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), State Report Volume 12 Selangor Chapter 8 Supply, Planning and Development Works*, March 2000.

Table C.2.7 Proposed Schedule of Source Works Implementation

Year	Source Works	Incremental Yield (Mld)	Total Supply (Mld)
2002	Rasa Stage 1 of Selangor Scheme Phase 3	125	3,532
2003	Sg. Selangor Scheme Phase 3 Stage 1	400	3,932
2004	Rasa Stage 2 of Sg. Selangor Scheme Phase 3	125	4,057
2005	Sg. Selangor Scheme Phase 3 Stage 2	400	4,457
2007	Kelau Dam of Southern Transfer from Pahang	2,259	6,716
2008	Rasa Stage 3 of Sg. Selangor Scheme Phase 3	50	6,766
2013	Liang Dam of Northern Transfer from Pahang	610	7,376
2016	Lipis Dam of Northern Transfer from Pahang	1,090	8,466
2020	Bernam Dam	868	9,334
2032	Sempam Dam of Northern Transfer from Pahang	230	9,564
2040	Kenong Dam of Northern Transfer from Pahang	120	9,684

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), State Report Volume 12, Chapter 8 Supply, Planning and Development Works*, March 2000, Public Works Department Malaysia and Selangor State Water Supply Department.

2.2 Sg. Selangor Scheme

The Sg. Selangor scheme was proposed to obtain a yield of 3,000 Mld from Sg. Selangor (Selangor River) for water supply to the north Selangor region in 1986. It has three implementation phases. Phase 2 was finished in 2000 and the scheme is now in Phase 3. **Table C.2.8** shows the phasing of the works.

Table C.2.8 Phasing of Sg. Selangor Scheme

Phase		Year Commissioned	Incremental Yield (Mld)	Total Capacity (Mld)	Remarks
Phase 1	Sage 1	1993	475	475	Run-of-river yield
	Stage 2	1995	475	950	With Tinggi Dam
Phase 2	Stage 1	1998	475	1,425	
	Stage 2	2000	475	1,900	
Phase 3	Stage 1 (Rasa Intake)	2002	125	2,025	
	Stage 1 (Batang Berjuntai Intake)	2003	400	2,425	
	Stage 1 (Selangor Dam)	2003	-	2,425	Selangor Dam Completed
	Stage 2 (Rasa Intake)	2004	125	2,550	
	Stage 2 (Batang Berjuntai Intake)	2005	400	2,950	
	Stage 3 (Rasa Intake)	2008	50	3,000	

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), State Report Volume 12 Selangor, Chapter 8 Supply, Planning and Development Works*, March 2000.

As the scheme progresses, the supply area will be extended further south in the State to cover the shortages in the districts using southern sources. After completion of the scheme, there will be no other source to be developed in the State. Thus, interstate transfer should be proposed for the future increase of demands.

2.3 Pahang-Selangor Interstate Transfer

As mentioned in the previous subsection, there will be no other available water source in the Selangor State after the completion of Sg. Selangor Scheme, and it is inevitable to develop other interstate transfer schemes. The proposed works are the two tunnels from western Pahang. The southern tunnel discharges into the Sg. Langat and the northern one onto the Sg. Kerling, a tributary of the Sg. Selangor. It is planned that up to 500 Mld from the Southern tunnel is to be sent to Negeri Sembilan State. Sources in Pahang for the transfers are summarised in **Table C.2.9**.

Table C.2.9 Sources in Pahang

Sources	Regulated Yield (Mld)	Remarks
Kelau Dam/Intake	2,259	Water released from reservoir for abstraction and pumping to the tunnel
Total to Southern Transfer Tunnel	**2,259**	**Design capacity for tunnel**
Liang	610	
Lipis/Sia	1,090	Including tunnel between reservoirs
Sempam	230	
Kenong	120	
Total to Northern Tranfer Tunnel	**2,050**	**Design capacity for tunnel**

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), State Report Volume 12 Selangor, Chapter 8 Supply, Planning and Development Works*, March 2000 and Public Works Department Malaysia.

2.4 Other Water Resources Development Plans

A dam can be constructed on the Sg. Bernam in Perak State. It is planned to supply water by interstate transfer in 2020 for expanding the northern transfer scheme.

2.5 Groundwater Conditions in Selangor State

Most of the groundwater abstracted in the State is utilised for industrial purposes. Only at Olak Lempit and Wangsa Maju, JBA Selangor is abstracting groundwater for public water supply. The usage of groundwater for agricultural purposes is minimal and only two wells are documented in Kuala Selangor district.

The JGM (Kajibumi) well field at Olak Lempit comprises six wells tapping an alluvial aquifer. Five wells can produce 2,300 m^3/s each while the remaining well, which is installed with a 24 m length of 300 mm diameter stainless steel screen, can produce 4,560 m^3/d giving a total production of 16 Mld (million litres per day) from this well field.

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 Wangsa Maju well field is managed by Puncak Niaga Sdn Bhd and consists of three wells, which give a total yield of 3 Mld.

Agrovation Sdn Bhd and Sime Darby Plantation Sdn Bhd are abstracting about 0.86 Mld and 0.27 Mld, respectively, for agricultural use in Kuala Selangor District. Individual farmers also abstract groundwater from dug wells for vegetable, fruit and livestock farms, which rear chicken and pigs, prawn breeding, etc.

At present, the total groundwater utilisation for industrial, agricultural and public water supply from available data is in excess of 50 Mld based on 24 hours pumping. When the Megasteel factory at Brooklands Estate is fully operational the total groundwater production in the State will exceed 75 Mld.

3. LANGAT BASIN

3.1 Present Water Demand

It is difficult to grasp all water uses of all user categories including domestic, commercial, institutional and industrial. Reliable data is available concerning water supply by Selangor Water Supply Department. Water supply has been increasing steadily so far except in 1997, which requires water source development in timely manner by the water authorities. (See **Table C.3.1**.)

Table C.3.1 Water Supply (Mld) in the Langat Basin from 1995 to 1999

	1995	1996	1997	1998	1999
Kuala Langat	30	29	41	41	44
Sepang	19	24	31	38	54
Hulu Langat	101	134	116	123	129
Sub-total	150	187	188	202	227
Non-Revenue Water	54	67	68	78	84
Total	204	254	256	280	311
Growth	-	24.6%	0.6%	9.5%	11.2%

Source: Selangor State Water Supply Department
Note: The West Part of Seremban is excluded because water is not supplied from the Langat basin at this time.

3.2 Present Conditions of Water Supply Facilities

3.2.1 Surface Water Use

Major surface water sources in the Langat basin are the Langat and Semenyih reservoirs. **Table C.3.2** lists up water treatment plants in the Langat basin. (See also **Table C.2.5**.)

Table C.3.2 Water Treatment Plants in the Langat Basin

Water Treatment Plant	Design Cap. (Mld)	Treatment Process	Raw Water Source	Watershed Area (km^2)	Supply Area
Sg. Langat	386.0	Conventional	Sg. Langat	295.00	Cheras, Kajang, Shah alam, PJ, Keramat, Wardiebun Camp, Wangsa Maju & Taman Kelang Lama
Bkt. Tampoi	31.5	Conventional	Sg. Langat	1,450.00	Dengkil
Cheras Mile 11	27.0	Conventional	Sg. Langat	321.00	Cheras
Salak Tinggi	10.8	Conventional	Sg. Labu	194.50	Salak Tingi & Sepang
Sg. Pangsoon	2.3	Partial	Sg. Pangsoon	-	Pangsoon
Sg. Serai	0.9	Partial	Sg. Serai	-	Hulu Langat to Batu 18
Sg. Lolo	0.3	Partial	Sg. Lolo	-	Sg. Lolo
Sg. Semenyih	545.0	Conventional	Sg. Semenyih	-	

Source: Selangor State Water Supply Department

3.2.2 Groundwater Use

Most of the groundwater is used for industrial purposes. The Selangor Water Supply Department has wells for public use only in Kajibumi Well Field 2, but they are not used for daily supply (See **Table C.3.3**). **Table C.3.4** lists up wells owned by the private sector.[3)]

Table C.3.3 Public Wells of Selangor Water Supply Department

Well Site	Nos. of Wells	Toltal Pumping Volume (Mld)	Description
Olak Lempit	2	10.0	testing purpose, finished pumping and disconnected from public water pipes
Brookland	5	4.5	connected to public water pipes but used sometimes only for maintenance
Megasteel	3	9.0-13.5	pumping everyday but used only for emergency

Source: Selangor State Water Supply Department

Table C.3.4 Wells Owned by the Private Sector

Owner	No. of Wells	Extraction (Mld)	Use
Hulu Langat District			
Tilbury Douglas (M) Sdn Bhd	3	0.240	Industrial
Permanis Sdn Bhd	3	0.240	Industrial
Stenta Films Sdn Bhd	1	0.120	Industrial
Hume Industries (M) Bhd	2	0.120	Industrial
Watta Battery Sdn Bhd	2	0.065	Industrial
San Teh Industires Sdn Bhd	1	n.a.	Industrial
Sri Cinmal Sdn Bhd	1	n.a.	Industrial
LB Aluminium Bhd	1	0.048	Industrial
Kurari Kenneison Brothers Sdn Bhd	1	0.360	Industrial
Sepang District			
Charterfield Dec. Corp. Sdn Bhd	1	0.120	Industrial
Palm Garden Resort Sdn Bhd	7	n.a.	Domestic
Kuala Langat District			
Megasteel Sdn Bhd	5	15.840	Industrial
Jomalia Sdn Bhd	1	1.572	Industrial
West Part of Seremban District	0	0	

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), State Report Volume 12 Selangor, Chapter 10 Groundwater Studies*, March 2000.

3.3 Water Demand Forecast and Supply Plan

3.3.1 Population Projection

NWRS estimated that the population in the three districts in Selangor would exceed one million in 2005 and two million in 2035 (See **Table C.3.5**). As mentioned in the supply plan of Selangor State, the water supply to the Seremban and Port Dickson districts is planned at 250 Mld in 2005 and 500 Mld in 2032 (See **Table C.2.6**) from the South Interstate Transfer from Pahang. The remaining demands from Seremban will be managed by the Negeri Sembilan Water Supply Department without using water sources in Langat Basin. Therefore, it is not necessary to estimate the population of Seremban for the supply plan of Langat Basin.

Table C.3.5 Population Projection for the Three Districts in Selangor

Year	Kuala Langat	Sepang	Hulu Langat	Total
1991	134,746	56,825	423,774	615,345
1995	146,847	61,116	539,369	747,332
2000	162,942	76,232	689,110	928,284
2005	179,988	104,562	832,473	1,117,023
2010	198,124	157,792	950,416	1,306,332
2015	217,107	214,386	1,060,929	1,492,422
2020	236,842	266,208	1,176,619	1,679,669
2025	259,795	311,306	1,264,460	1,835,561
2030	283,126	362,229	1,330,620	1,975,975
2035	306,400	419,380	1,391,170	2,116,950
2040	331,090	459,793	1,438,563	2,229,446
2045	355,275	501,587	1,477,934	2,334,796
2050	378,756	544,450	1,501,771	2,424,977

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), State Report Volume 12 Selangor, Chapter 4 Basis of Water Demand Estimation*, March 2000.

Note: The West Part of Seremban is excluded because its water demand is decided by the water management plan of Negeri Sembilan Water Supply Department.

3.3.2 Demand Forecasts and Supply Plan

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. For water supply planning, low, planning and high demand forecasts were made. 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.

Four cases of demand projections for the total of the three districts are summarised in **Table C.3.6**.

Table C.3.6 Demand Forecasts for the Three Districts in Selangor

Year	Low		Planning		High		D/D Review	
	Population	Demand (Mld)	Population	Demand (Mld)	Population	Demand (Mld)	Population	Demand (Mld)
2000	928,284	435	947,555	465	1,174,181	468	905,200	479
2010	1,306,332	817	1,627,596	981	1,818,958	1,058	1,393,300	883
2020	1,679,669	1,344	2,101,955	1,580	2,298,996	1,691	1,874,200	1,443
2030	1,975,975	1,609	2,297,794	1,813	2,475,513	1,900	N/A	N/A
2040	2,229,446	1,762	2,414,423	1,873	2,642,227	1,997	N/A	N/A
2050	2,424,977	1,883	2,656,128	2,001	2,876,554	2,141	N/A	N/A

Source: Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia 2000-2050), State Report Volume 12 Selangor, Chapter 5 Domestic and Industrial Water Demand Forecasting*, March 2000 and Public Works Department Malaysia, *Pahang-Selangor Raw Water Transfer Project Engineering Services and Detailed Engineering Design*, August 2000.

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 (See **Table C.2.5**). Its supply is to be powered by the Southern Interstate Transfer from Pahang from 2007 as expected (See **Table C.3.7**). As long as the source works are completed as scheduled, the total supply would exceed the demand in all the time frames. (See **Figure C.3.1**)

Table C.3.7 Demand and Supply Plan in the Langat Basin (Mld)

Year	Demand					Demand Total	Supply Total	Supply Surplus	Remarks
	Hulu Langat	Sepang	Kuala Langat	Sub-total	Negeri Sembilan				
2000	316	67	81	464	-	464	993	529	
2005	434	129	106	669	250	919	1,961	74	
2007	560	217	131	908	250	1,158	3,252	2,224	Kelau Dam
2010	597	247	138	982	250	1,232	3,252	2,020	
2015	795	279	169	1,243	250	1,493	3,252	1,759	
2020	1,058	315	207	1,580	250	1,830	3,252	1,422	
2025	1,118	341	233	1,692	250	1,942	3,252	1,310	
2030	1,181	369	262	1,812	250	2,062	3,252	1,190	
2032	1,178	381	264	1,823	500	2,323	3,252	929	
2035	1,173	400	267	1,841	500	2,341	3,252	911	
2040	1,166	433	273	1,872	500	2,372	3,252	880	
2045	1,205	452	278	1,936	500	2,436	3,252	816	
2050	1,246	472	284	2,002	500	2,502	3,252	750	

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.

Water supply in 2000 comes from 386 Mld of Langat WTP, 545 Mld of Semenyih WTP and 62 Mld of other minor WTPs. See **Table C.2.5 Output of Existing Sources/WTPs in Selangor and KL**.

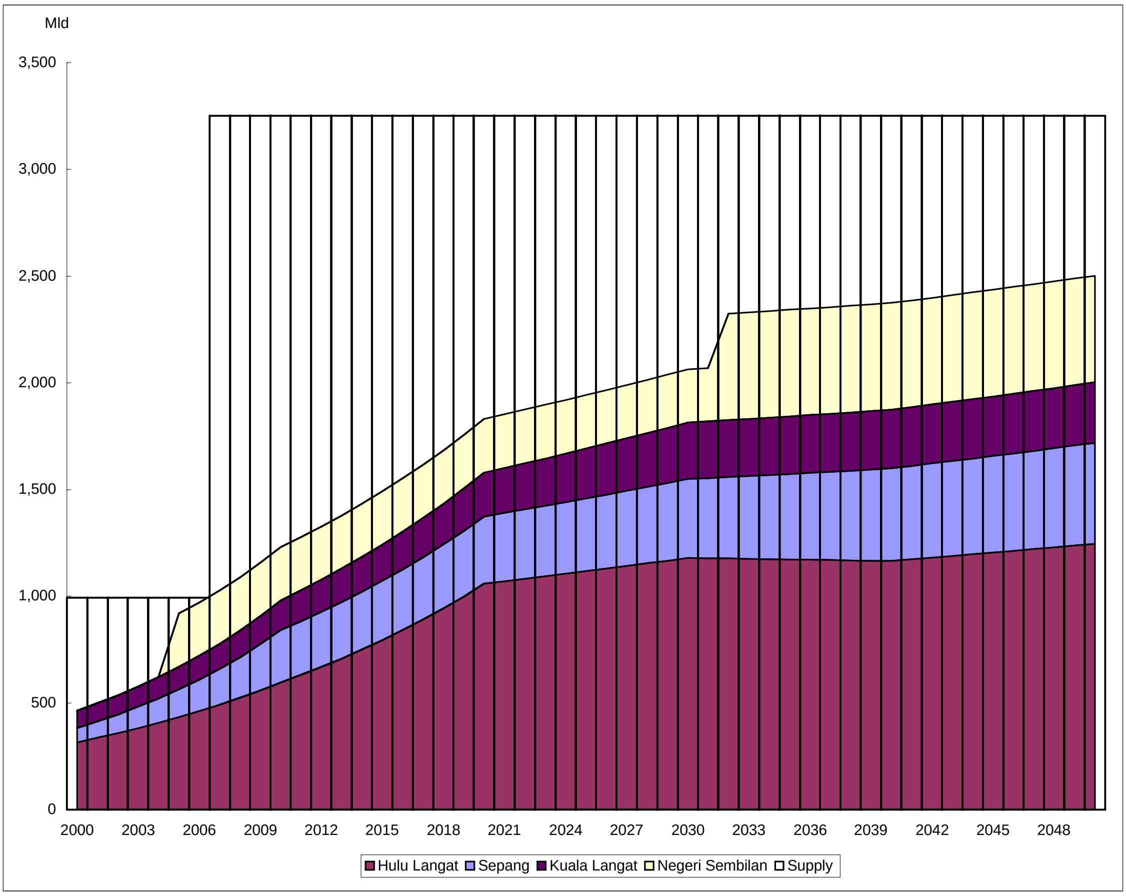


Figure C.3.1 Demand and Supply Plan in the Langat Basin

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.

The following **Figure C.3.2** compares the four demand forecasts with the supply plan. As long as the construction is completed as scheduled, water supply is expected to be enough for the lower three cases. In any case, the construction of Kelau dam is very critical for the demand-supply balance in Langat basin.

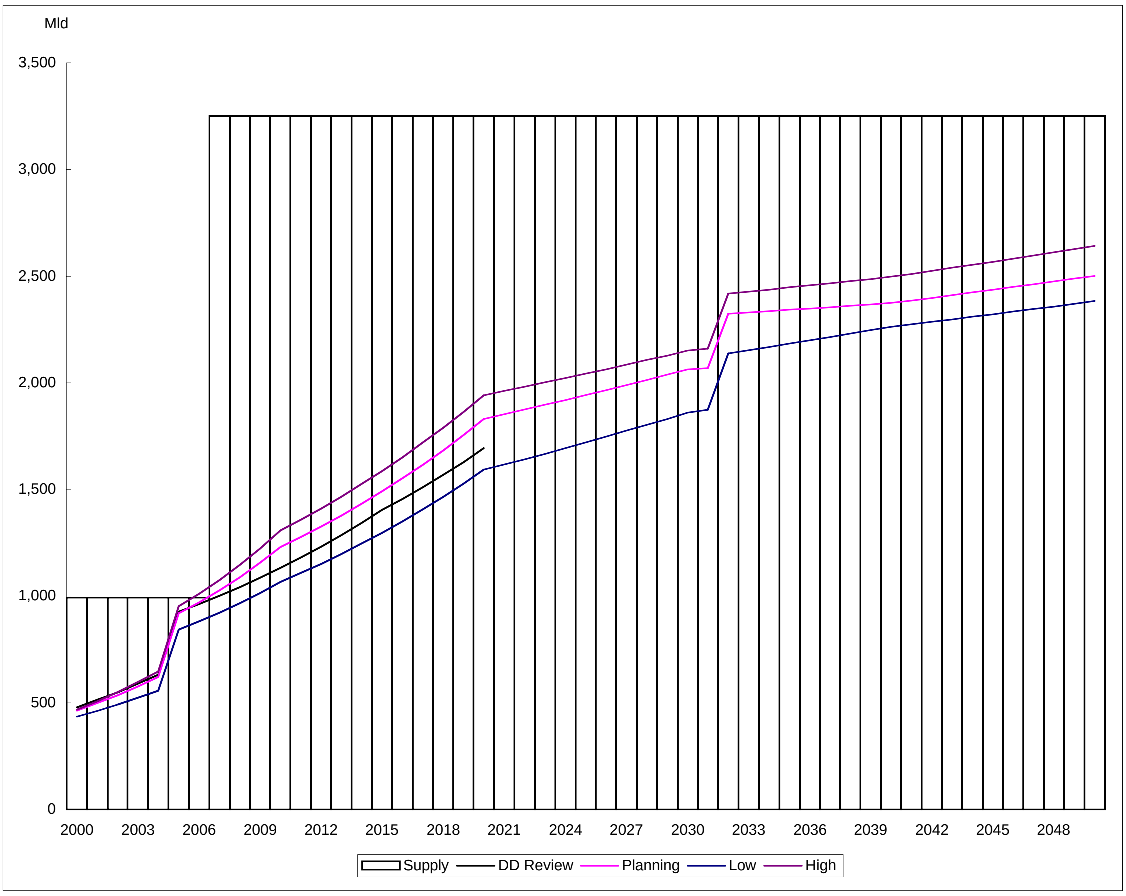


Figure C.3.2 Comparison of the Four Demand Forecasts

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.

3.4 Groundwater

3.4.1 Basic Policy for Groundwater Development

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. (See Water Supply Section of Chapter 11, Infrastructure and Utilities.[5)])

The Eighth Malaysia Plan seems to put more emphasis on environmental protection as it describes the future groundwater exploitation in Natural Resources Management Section of Chapter 19, Environment and Sustainable Resource Management.

19.37 Groundwater exploration will be conducted in the main river basins, to identify potential aquifers and outline protection zones to conserve groundwater resources.

Guidelines and relevant regulations will be formulated to control activities that can pollute groundwater resources. Groundwater research will be intensified and better coordinated to provide a unified database.[6)]

3.4.2 Present Conditions of Groundwater

Hydro Census, described in **Section 3.6**, was conducted to study the groundwater usage in the Langat Basin. A total of 103 wells listed in a well database developed by JMG Selangor[7)] were analysed and some 48 wells were visited to survey the status of the wells. In terms of the groundwater usage, following is a summary of findings of the Hydro Census.

Distribution of the wells in three Districts in the Langat Basin, Hulu Langat, Kuala Langat and Sepang, is presented in **Figure C.3.3**. The wells are divided into 5 different categories; namely, domestic, industrial, observation, test well and unknown.

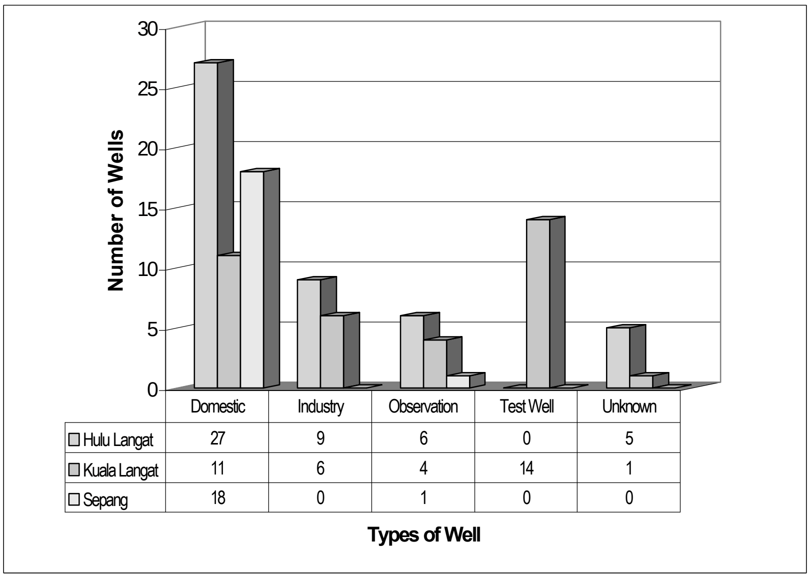


Figure C.3.3 Distribution of Wells in the Langat Basin

Source: JMG's Well Database[7)]

Usage of groundwater during 1999 was estimated as 2,845 m^3/hour (or 68.3 Mld based on 24 hours pumping). **Figure C.3.4** summarises groundwater usage of 1999 by domestic and industry sectors, and others. 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).

Usage in each district is also summarised in **Figure C.3.5** and in **Table C.3.8**.

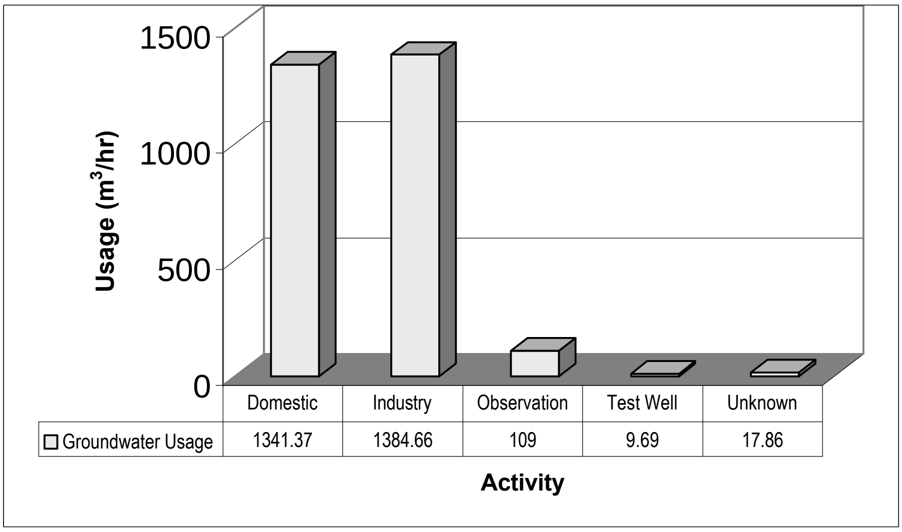


Figure C.3.4 Groundwater Usage in the Langat Basin

Source: JMG's Well Database[7)]

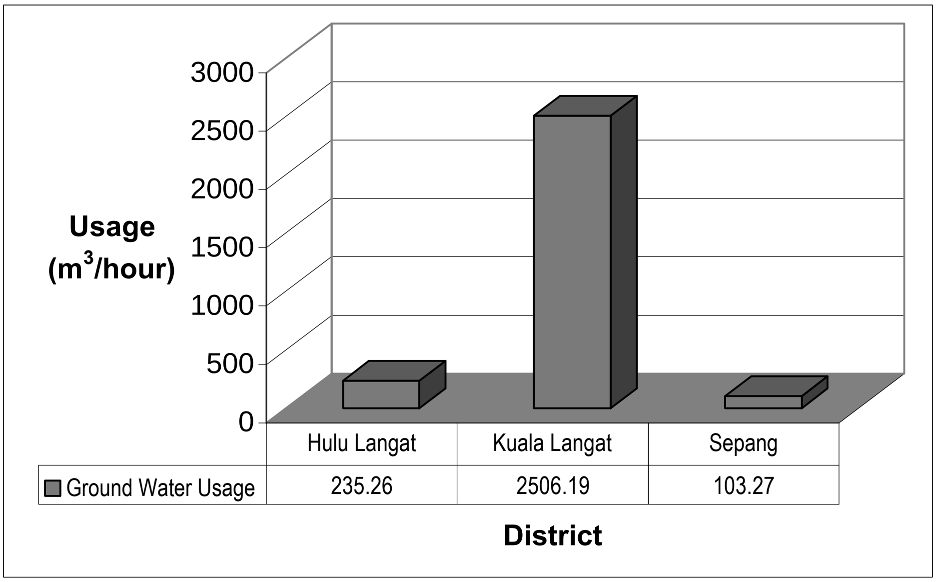


Figure C.3.5 Groundwater Usage in Each District

Sources: JMG's Well Database[7)]

Table C.3.8 Usage of Groundwater in Each District by Sector

District	Usage (m^3/hr)					Total
	Domestic	Industry	Observation	Test Well	Unknown	
Hulu Langat	110.1	125.16	0	0	17.86	**235.26**
Kuala Langat	1128	1259.5	109	9.69	0	**2506.19**
Sepang	103.27	0	0	0	0	**103.27**
Seremban	N.A	N.A	N.A	N.A	N.A	**N.A**
Total	**1341.37**	**1384.66**	**109**	**9.69**	**17.86**	**2844.72**

Source: JMG's Well Database[7)]

3.4.3 Future Use of Groundwater

Three situations can affect large-scale groundwater development in the Langat Basin. They are MSC development, emergent water shortage, and demand from large-scale industrial companies.

Firstly, MSC is planned to use surface water supplied from existing sources. (See **Subsection 2.1.1**, **Water Demand Estimates of Multimedia Super Corridor**)

Secondly, for the situation on emergent water shortage, Selangor State Government has already drawn up a basic policy, which is mentioned above. Efficient and sustainable groundwater development plan is required to be formulated by the State Government.

Thirdly, demand from large-scale industrial companies is a little complicated. According to NWRS, total groundwater extraction by private companies is 18.725 Mld in the three districts (the largest one is 15.840 Mld by Megasteel). It amounts to 24% of the estimated industrial demand in the three districts in 2000. As NWRS shows, all the demand from industries will be covered by the surface water in the Langat Basin on the condition that the new water source schemes are implemented as scheduled (See **Subsection 3.3.2**, **Demand Forecast and Supply Plan**). Private companies, however, behave in an economic manner. In other words, they will dig wells as long as the cost of groundwater development is lower than using surface water in the circumstances that presently the groundwater development is not restricted by the Government. This factor complicates the situation.

Concerning the spatial pattern of groundwater development for industrial use, it is closely related with the industrial development plan or structure plan of the area. The State development plan identifies development corridors that will be new growth centres (See **SUPPORTING REPORT Sector A**, **Subsection 2.2.1**, **Vision 2005 for Selangor**). Among them, Banting-Bagan Terap Corridor is the industrial area, which is in the Langat Basin and has a possibility of groundwater extraction. It is also identified as Telok Panglima Garang – Banting – Olak Lempit Corridor in the Kuala Langat

Structure Plan. This area is to be developed for industries with growth centres and settlement centres along the Langat River. (See **Table A.2.7**)

Thus, the following factors should be clarified for a more precise estimation of future groundwater use:

- Groundwater development plan for emergency by the State Government,
- Groundwater regulation plan by the State Government from the viewpoint of sustainable development,
- Water supply cost by the Water Supply Department, which should include new water source works, and
- Business plans of large scale-companies.

3.5 Well Inventory for the Langat Basin

JMG has developed two databases, Hydrological Database (HYDAT) and Geochemical Database (GeoCHEM). HYDAT consists of Well information and GeoCHEM consists of Groundwater Quality data. Both databases are not linked. HYDAT data have been transferred to a database, CGIM (Customised Groundwater Information Management), which was developed by JMG on dBase software platform. CGIM for the State of Selangor has been continuously updated by adding new well data. For linking Well information with the geochemical data, a new Well-ID numbering scheme has been proposed (KAR project), but not yet approved, except adopting the data exchange standard ISO-TC211 for developing metadata.

The latest version of CGIM (the end of May, 2000) has analysed wells and they have been listed in three categories; namely, Monitoring Wells, Production Wells and Other Wells. These classifications are based on hydro-geological point of view. The lists are attached to the **MAIN REPORT**, **Chapter 3**, **Groundwater Status**.

3.6 Hydro Census for Establishment of a Well Inventory

3.6.1 Methodology of the Census

A hydro census survey was carried out to provide basic information to establish a comprehensive well inventory for the Langat Basin. The survey is composed of three (3) parts; namely, data collection and compilation, field reconnaissance and data verification. The Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia (UKM) conducted the survey on a subcontract basis under the supervision of the JICA Study Team. Each part covers the following items.

(1) Data Collection and Compilation

Data regarding the existing wells in the Langat Basin was collected by reviewing the database and reports of JMG that are presented in the previous **Section 3.5**. The collected data was put into a survey form given by the JICA Study Team and compiled in a spreadsheet as used for a well inventory. The survey form is as shown in **Annex C.3.1**.

The compiled data cover the following items in principle:

(a) Identification

- Name or number of the well, or borehole number;
- Owner of the well (name, address, contact person, telephone number); and
- Source of the well.

(b) Location

- District name;
- Locality; and
- Geographical coordination (latitude, longitude and elevation).

(c) Drilling

- Driller of the well;
- Year of the drilling;
- Bedrock depth and elevation;
- Geological log (raw data if available);
- Grain size curves (raw data if available); and
- Pumping test (raw data if available).

(d) Well

- Depth of the well;
- Inner diameter of the well;
- Well structure (screen top/bottom, top/bottom caps);
- Casing and screen materials; and
- Fill materials.

(e) Usage

- Usage (domestic, commercial, industrial or others);
- Current status (active or abandoned);

- Discharge (daily and yearly); and
- Pumping time (daily and yearly).

(f) Groundwater Level and Quality

- Static groundwater level (seasonal fluctuation if any);
- pH;
- Water temperature;
- Electric conductivity;
- Dissolved oxygen; and
- Other parameters, if any.

(2) Field Reconnaissance

All the wells listed in the JMG database were visited and their conditions were inspected to complete the well inventory covering the above items (a) to (f).

In particular, the groundwater level was measured at each selected well in areas specified by the JICA Study Team. The measurement was made in two different days at the same locations.

Results of the field reconnaissance were incorporated into the well inventory.

(3) Data Verification

The survey data were compared with other data sources, such as JMG reports. A discussion with JMG experts was made to compile the data and to verify discrepancies including possible reasons for variations, etc. for finalisation.

3.6.2 Limitation of the Census

The Census could not cover all of the existing wells in the Langat Basin due to lack of basic data and time constraint. It is presumed that many private-owned wells that are not listed in the database exist in the basin although some new wells were found in the census.

3.6.3 Results of the Census

(1) Number of Surveyed Wells

The total number of wells surveyed in the Census is 121 while the JMG well database keeps a register of 103 wells. This could mean that 18 new wells were found in the Census in addition to the 103 JMG wells. **Data Book C.3.1** shows a list of these wells surveyed, and the location of the wells is plotted in

Figure C.3.6. Among the 121 wells, 48 wells were visited to check the well status. A list of wells visited in the Census is also given in **Data Book C.3.2**.

(2) Current Status of the Wells

Although the census survey was carried out, a large number of wells in the Basin are still under unknown status due to time and budgetary constraints of the survey. The status of more than 50% of the wells was not verified. Among the wells that were investigated, between 20% and 40% of them had been abandoned or demolished. The status of wells is summarised in **Table C.3.9** below, and the status of wells by District is illustrates in **Figure C.3.6**.

Table C.3.9 Status of Wells Visited in the Hydro Census

District	Total well	Status		
		Active	Abandoned	Unknown
Kuala Langat	39	10	3	26
Hulu Langat	63	16	12	35
Sepang	19	7	3	9
Total	121	33	18	70

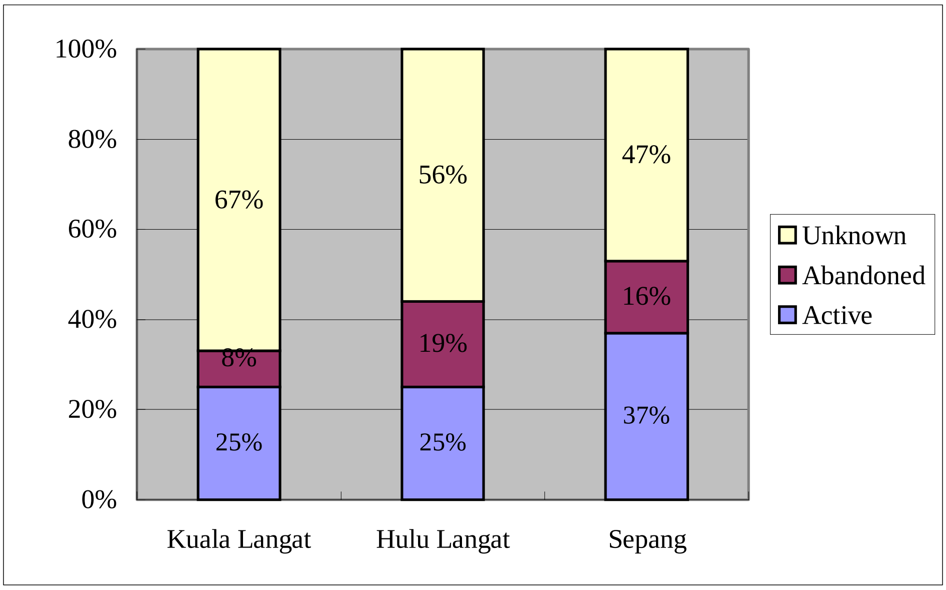
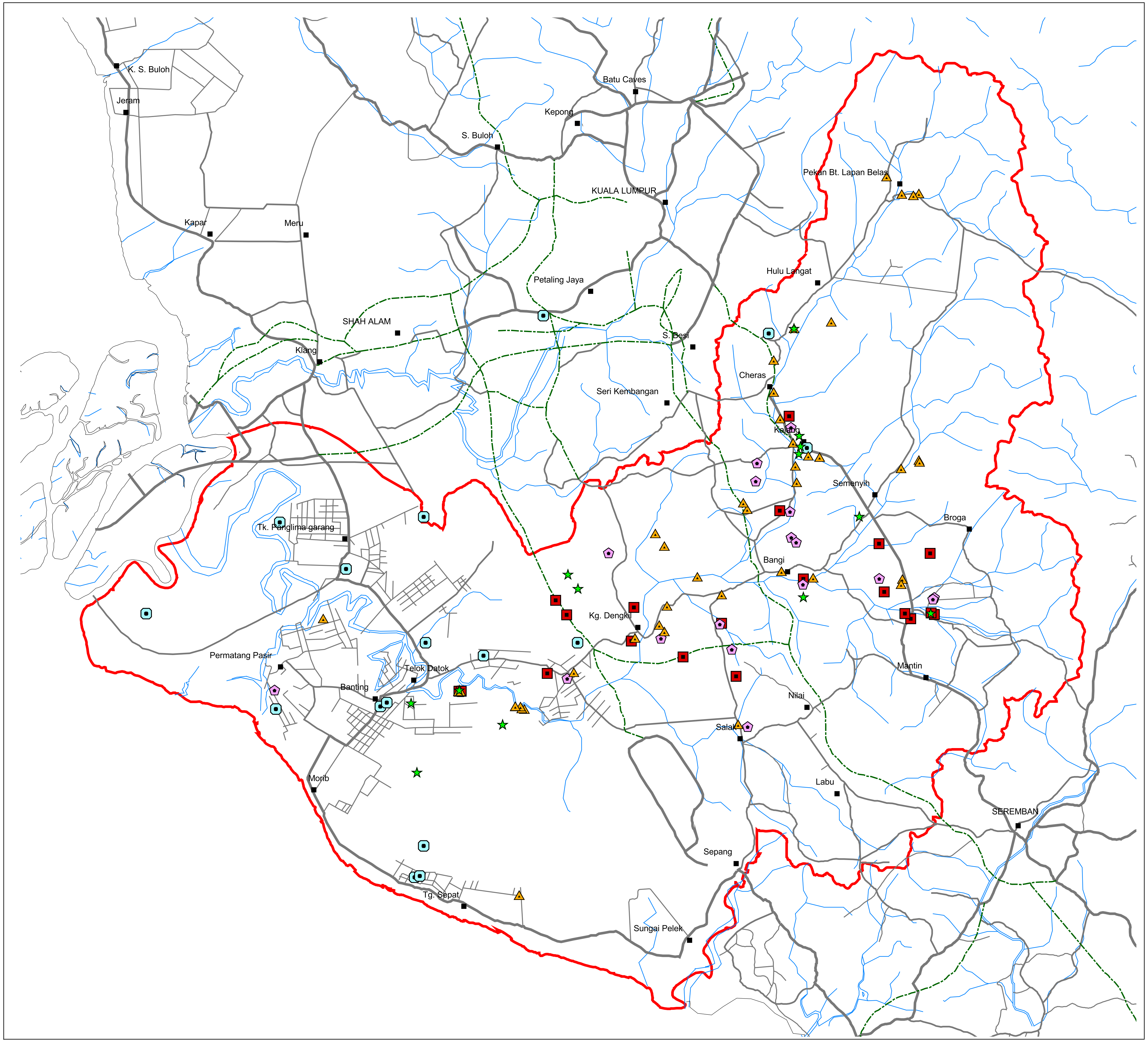


Figure C.3.6 Status of the Surveyed Wells by Each District

Figure C.3.7

Location of Wells for the Hydro Census



LEGEND

- Monitoring Well (Abandoned)
- Monitoring Well (Active)
- Monitoring Well (Unknown)
- Production Well (Abandoned)
- Production Well (Active)
- Production Well (Unknown)
- 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

N E S W

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

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

CTI Engineering International Co., Ltd.

OYO CORPORATION

(3) Types of Well

In the listed 121 wells in the JMG well database, 68% are classified into production wells and 26% are used for monitoring, as shown in **Figure C.3.8**. The type of seven (7) wells, i.e., 6% of the total number, was not identified.

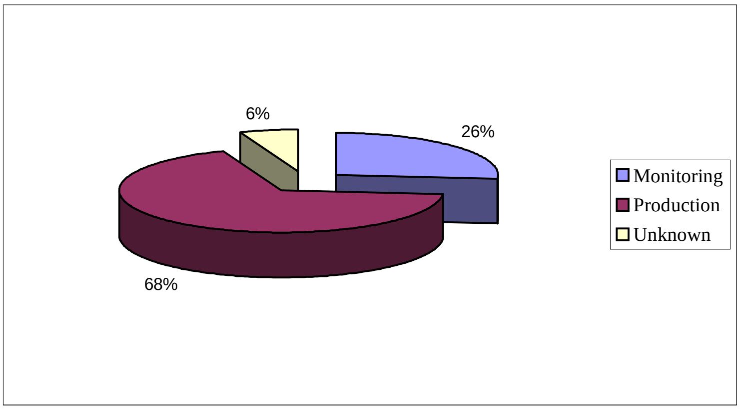


Figure C.3.8 Types of the Surveyed Wells

(4) Groundwater Usage of the Wells

In terms of production wells, most wells, about 81%, are used for domestic purposes, as shown in **Figure C.3.9**. Approximately 17% of the wells are operating for industry. Agricultural and commercial usage is an absolute minimum at only 1% of the total, respectively. Domestic wells are used mainly for washing and cleaning, and only a few are used for drinking. Industries use the groundwater especially for cooling system and cleaning. As for drinking purposes, tap water has replaced well water for the past 25 years. It was very difficult to investigate the usage of wells at the site, and further surveys are required to clarify the specific purposes of each well.

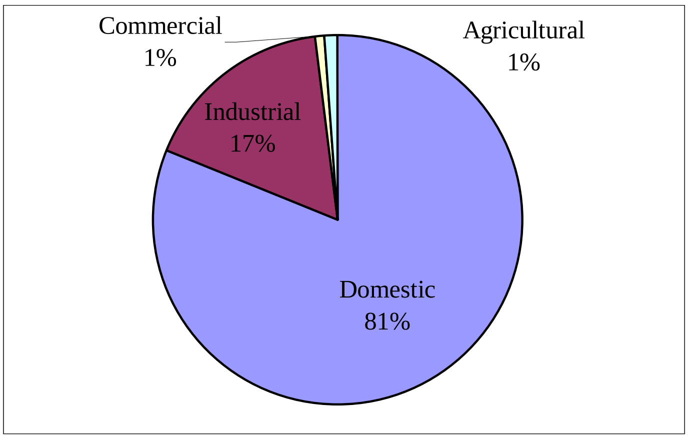


Figure C.3.9 Usage of the Surveyed Production Wells

References

1) Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia) 2000-2050, Sector Report Volume 2*, March 2000

2) Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia) 2000-2050, Sector Report, Volume 4, Chapter 10, Groundwater Studies*, 2000.

3) Economic Planning Unit, *National Water Resource Study (Peninsular Malaysia) 2000-2050, State Report Volume 12*, March 2000

4) Federal Department of Town and Country Planning, *Multimedia Super Corridor Physical Development Plan Study*, October 1999

5) Economic Planning Unit, *Mid-term Review of the Seventh Malaysia Plan 1996-2000*, April 1999

6) Economic Planning Unit, *Eighth Malaysia Plan 2001-2005*, April 2001

7) JMG Selangor, *Well Database CGIM (Customised Groundwater Information Management)*, 2000.

ANNEX C.3.1

HYDRO CENSUS FORM (WELL)

Annex C.3.1

HYDRO CENSUS FORM (WELL)

1. IDENTIFICATION

Well ID (Current) :____

Well ID (New) :____

2. LOCATION

District :____

Locality :____

Site name :____

Coordinate : *N*______________________ *m*

*E*______________________ *m*

Elevation from the mean sea level : __________________ *m msl*

Current general landuse classification :

Metropolitan ( ), Industrial ( ), Resort ( ), Rural ( ), Agricultural ( )

Current landuse : ____

____

Location map : *Yes ( ), No ( ), If Yes, attach a copy.*

3. CONTACTS

<u>Owner of well</u>

Name : ____

Address : ____

____

____

Telephone number : ____

Contract person : ____

<u>Drilling company</u>

Name : ____

Address : ____

____

____

Telephone number : ____

Contract person : ____

4. SOURCE(S) OF INFORMATION

Document used : ____

____

____

____

HYDRO CENSUS FORM (WELL)

(page 2 of 8)

*Well ID (Current) :*__________________________ *Site Name :*__________________________

5. USAGE	*Type of well*	:	*Production ( ), Monitoring ( )*
	Usage	:	*Domestic ( ), Industrial ( ), Agricultural ( ),*
			Other ____________________________________
	Status	:	*Active ( ), Abandoned ( )*
	Discharge	:	______________________ *gallon/hour (gph)*
			______________________ *mega gallon/day (mgd)*
			______________________ m^3*/hour*
			______________________ *(specify other unit)*
	Operation	:	______________________ *hour/day*
			______________________ *day/year*

6. AQUIFER	*Type of Aquifer*	:	*Confined ( ), Unconfined ( )*
	Aquifer Materials	:	*Sand ( ), Gravel ( ), Rock ( ),*
			*Other*______________________________
	If rock, describe rock type and formation name		
	____		
	Top level of aquifer	:	__________________________ *G.L.- m*
	Thickness of aquifer	:	__________________________ *m*
	Transmissivity	:	__________________________ m^2*/day*

7. DRILLING	*Method of drilling*	:	____
			____
	Drilling fluid	:	*Yes ( ), No ( )*
	If Yes, type of drilling fluid	:	__________________________
	Drilling diameter	:	_________________ *m*
	Drilling depth from the ground level	:	_________________ *G.L.- m*
	Bedrock depth from the ground level	:	_________________ *G.L. - m*
	Geological log	:	*Fill in the table in Section 11 and attach raw data (log or description) to this form.*

HYDRO CENSUS FORM (WELL)

(page 3 of 8)

*Well ID (Current) :*___________________________ *Site Name :*___________________________

8. WELL

Well depth from the ground level :___________________ *GL - m*
Inner diameter of the well :___________________ *m*
Casing material :__________________________
Screen material :__________________________
Fill material :__________________________

Structure of well : *Fill in a table in Section 12 and attach raw data to this form.*

Can take groundwater sample from the well ? *Yes ( ), No ( )*
Can measure groundwater level in the well ? *Yes ( ), No ( )*

9. GROUNDWATER LEVEL

GWL during drilling from the ground level :____________ *G.L.- m*
Static GWL from the ground level :____________ *G.L.- m*
Seasonal fluctuation of static GWL, if any :___________________

____

____

Level of measurement point of GWL from the ground level :
_______________ *G.L. m, draw schematic illustration in Section 14.*

10. AVAILABILITY OF TEST DATA

Grain size curve : *Yes ( ), No ( ),* *If Yes, attach raw data.*
Pumping test : *Yes ( ), No ( ),* *If Yes, attach raw data.*
Recovery test : *Yes ( ), No ( ),* *If Yes, attach raw data.*
Groundwater level monitoring : *Yes ( ), No ( ),* *If Yes, attach raw data.*
Chemical test : *Yes ( ), No ( ),* *If Yes, fill in a table in Section 13 and attach raw data.*

HYDRO CENSUS FORM (WELL)

(page 4 of 8)

*Well ID (Current) :*__________________________ *Site Name :*__________________________

11. GEOLOGICAL LOG

Layer No.	*Depth (G.L.-m)*		*Lithology*	*Description*
	from	*to*		
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

12. STRUCTURE OF WELL

Line No.	*Lining Type*	*Lining Depth (G.L. - m)*		*Lining Inner Diameter (m)*	*Lining Material*
		from	*to*		
1	*Casing ( ), Screen ( )*				
2	*Casing ( ), Screen ( )*				
3	*Casing ( ), Screen ( )*				
4	*Casing ( ), Screen ( )*				
5	*Casing ( ), Screen ( )*				
6	*Casing ( ), Screen ( )*				
7	*Casing ( ), Screen ( )*				
8	*Casing ( ), Screen ( )*				
9	*Casing ( ), Screen ( )*				
10	*Casing ( ), Screen ( )*				

HYDRO CENSUS FORM (WELL)

(page 5 of 8)

*Well ID (Current) :*____________________________ *Site Name :*____________________________

13. CHEMICAL ANALYSIS

Water sample no. :____

Date of sampling :____

Laboratory name :____

Sampling method :____

Pumping groundwater before sampling : *Yes ( ), No ( )*

Sampling in the well : *Yes ( ), No ( )*

If Yes, sampling depth ? :

near groundwater level ( ), at casing level ( ), at screen level( )

Parameter	*Value*	*Unit*	*Test Location*		*Test Method*
			Field	*Laboratory*	

HYDRO CENSUS FORM (WELL)

(page 6 of 8)

*Well ID (Current) :*____________________________ *Site Name :*____________________________

14. SKETCH OF THE SITE

Sketch of the location :

Level of measurement point of GWL from the ground level (show by sketch):

HYDRO CENSUS FORM (WELL)

(page 7 of 8)

*Well ID (Current) :*____________________________ *Site Name :*____________________________

15. PHOTOGRAPH

Location :

Well :

HYDRO CENSUS FORM (WELL)

(page 8 of 8)

*Well ID (Current) :*________________________ *Site Name :*________________________

16. SITE VISIT	*Date visited (d/m/y)*	:	____________
	Visited by	:	____________
	Access to Location	:	____________
			____________
			____________
17. PREPARATION OF THE FORM	*Prepared by*	:	____________
	Signature	:	____________
	Date	:	____________
	Checked by	:	____________
	Signature	:	____________
	Date	:	____________

18. ATTACHMENTS	*Location map*	:	*Yes ( ), No ( )*	________*page(s)*
	Borehole log	:	*Yes ( ), No ( )*	________*page(s)*
	Grain size curve	:	*Yes ( ), No ( )*	________*page(s)*
	Pumping test	:	*Yes ( ), No ( )*	________*page(s)*
	Draw down test	:	*Yes ( ), No ( )*	________*page(s)*
	Chemical test	:	*Yes ( ), No ( )*	________*page(s)*

SECTOR D

SURFACE WATER STATUS

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

FINAL REPORT

SECTOR D

SURFACE WATER STATUS

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SECTOR D

SURFACE WATER STATUS

1. METEOROLOGY AND HYDROLOGY

1.1 General Meteorology and Climate

1.1.1 Peninsular Malaysia

Based on the information from the Malaysian Meteorological Service[1)], the general meteorology and climate in Peninsular Malaysia are summarised as follows:

(1) Monsoons

The characteristic features of the climate of Malaysia are the uniform temperature, high humidity and copious rainfall that arise mainly from the maritime exposure of the country. Winds are generally light. Situated at the equatorial doldrums area, it is extremely rare to have a full day with a completely clear sky even in periods of severe drought. On the other hand, it is also rare to have a stretch of a few days with completely no sunshine except during the northeast monsoon seasons.

(2) Wind Flow

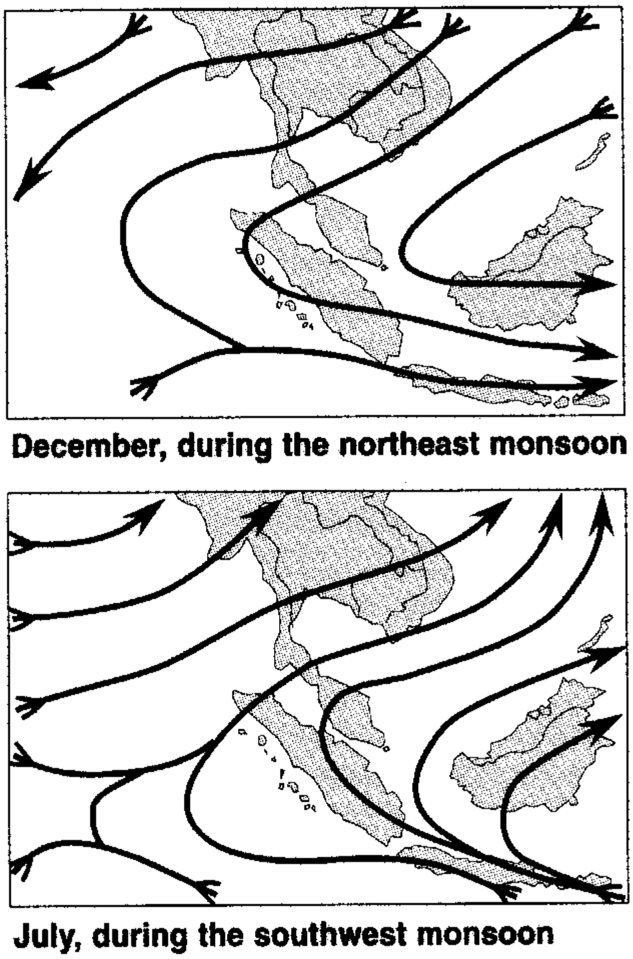
Though the wind over the country is generally light and variable, there are, however, some uniform periodic changes in the wind flow patterns. Based on these, four seasons can be distinguished, namely, the southwest monsoon, northeast monsoon and two shorter intermonsoon seasons.

The southwest monsoon is usually established in the later half of May or early June and ends in September. The prevailing wind flow is generally southwesterly and light, below 15 knots.

The northeast monsoon usually commences in early November and ends in March. During this season, steady easterly or northeasterly winds of 10 to 20 knots prevail. The more severely affected area are the east coast states of Peninsular Malaysia where the wind may reach 30 knots or more during periods of intense surges of cold air from the north (cold surges).

The winds during two seasons of inter-monsoon are generally light and visible. During these seasons, the equatorial trough lies over Malaysia.

From April to November, when typhoons frequently develop over the west Pacific and move westwards across the Philippines, south-westerly winds over the northwest coast of Sabah and Sarawak region may strengthen reaching 20 knots or more.



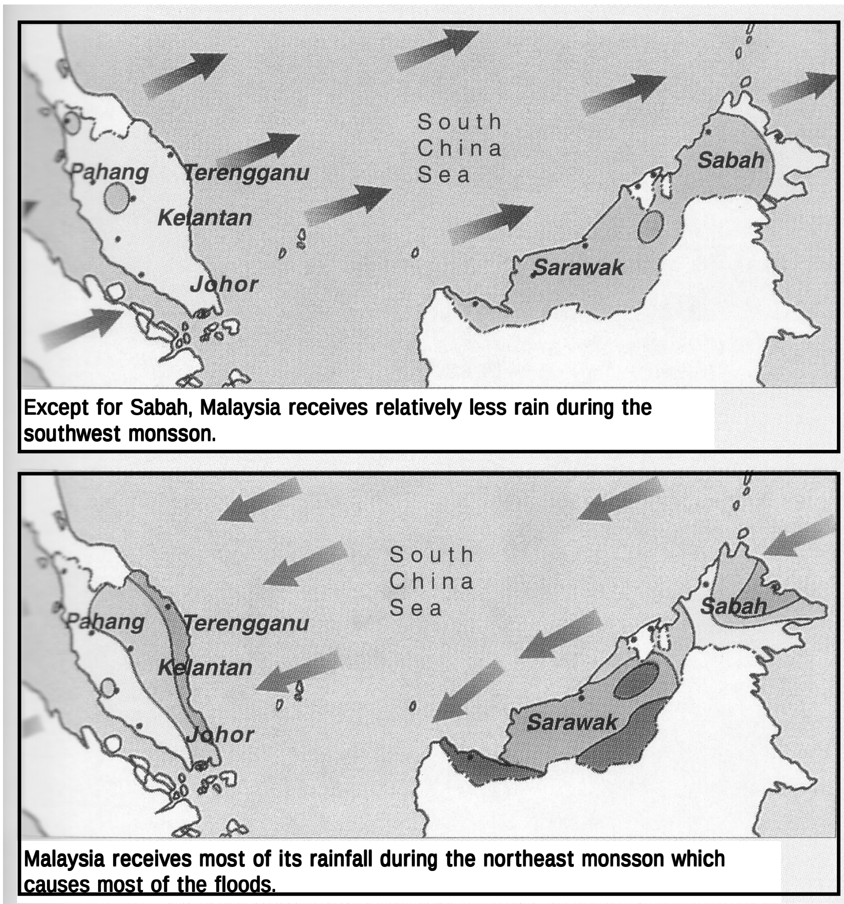
The northeast monsoon: November to early March
The southwest monsoon: June to September or early October

Figure D.1.1 Wind Systems during Monsoons

Source: Malaysian Meteorological Service

(3) Rainfall

The seasonal wind flow patterns coupled with the local topographic features determine the rainfall distribution patterns over the country. The North-East monsoon blows from approximately mid-November till March, and the South-West monsoon between May and September, the periods of change between the two monsoons being marked by heavy rainfall accompanied by lightning and thunderstorms.



Except for Sabah, Malaysia receives relatively less rain during the southwest monsson.

Malaysia receives most of its rainfall during the northeast monsson which causes most of the floods.

Figure D.1.2 Rainfall Distribution during Monsoons

Source: THE ENCYCLOPEDIA OF MALAYSIA, VOLUME 1 THE ENVIRONMENT

The seasonal variation of rainfall in Peninsular Malaysia is of three main types:

(a) Over the east coast districts, November and January are the months with maximum rainfall while June and July are the driest months in most districts.

(b) Over the rest of the Peninsula with the exception of the southwest coastal area, the monthly rainfall pattern shows two periods of maximum rainfall separated by two periods of minimum rainfall. The primary maximum generally occurs between October and November while the secondary maximum generally occurs between April and May. Over the northwestern region, the primary minimum occurs between January and February with the secondary minimum between June and July while elsewhere the primary minimum occurs in June - July with the secondary minimum in February.

(c) The rainfall pattern over the southwest coastal area is much affected by shelter of Sumatra landmass from May to August when the double maximum and minimum pattern is no longer discernible. October and November are the months with maximum rainfall and February the month with minimum rainfall. The March-April-May maximum and the June-July minimum are absent or indistinct.

(4) Temperature and Relative Humidity

Being an equatorial country, Malaysia has uniform temperature throughout the year. The annual variation is less than 2°C except for the east coast areas of Peninsular Malaysia that are often affected by cold surges originating from Siberia during the northeast monsoon. Even there, the annual variation is below 3°C.

The daily range of temperature is large, being from 5°C to 10°C at the coastal stations and from 8°C to 12°C at the inland stations. It may be noted that air temperature of 38°C has very rarely been recorded in Malaysia. Although the days are frequently hot, the nights are reasonably cool everywhere.

However, for every 100 metres increase in altitude, the temperature drops by about 0.6 degrees Celsius.

Malaysia has high humidity. The mean monthly relative humidity falls within 70 to 90%, varying from place to place and from month to month. For any specific area, the range of the mean monthly relative humidity varies from a minimum of 3% to a maximum of about 15%. It is observed that in Peninsular Malaysia, the minimum relative humidity is normally found in the months of January and February except for the east coast states of Kelantan and Terengganu, which have the minimum in March. The maximum is however generally found in the month of November.

(5) Sunshine and Solar Radiation

Being a maritime country close to the equator, Malaysia naturally has abundant sunshine and thus solar radiation. However, it is extremely rare to have a full day with completely clear sky even in periods of severe drought. The cloud cover cuts off a substantial amount of sunshine and thus solar radiation. There are, however, seasonal and spatial variations in the amount of sunshine received.

(6) Evaporation

Among all the factors affecting the rate of evaporation, cloudiness and temperature are two of the most important ones in this country. These two factors are however inter-related. A cloudy day will mean less sunshine and thus less solar radiation and in turn give rise to lower temperature.

An examination of the evaporation data shows that the cloudy or rainy months are the months with lower evaporation rate while the dry months are the months with higher rate. For highland areas such as Cameron Highlands where the air temperature is substantially lower, the evaporation rate is proportionally lower too. While lowland area have an annual average evaporation rate of 4 to 5 mm per day, Cameron Highlands has a rate of only about 2.5 mm per day.

1.1.2 Langat Basin

General meteorology and climate in the Langat River Basin are summarised on the basis of existing report[2) 3)]:

(1) Monsoons

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. Nevertheless, the climate can be vaguely defined by the following seasons:

- The north-east monsoon from December to March;
- A transitional period from April to May;
- The south-west monsoon from June to September; and
- A transitional period from October to November.

In addition, it is also characterised by uniform high temperature, high relative humidity, moderate rainfall and little wind.

(2) Wind

There is no significant prevailing wind direction observed in the Langat River Basin. The daily sea winds and breeze phenomenon is expected but this is more of a diurnal pattern and breezes are in the lower speed limit ranges. A maximum wind speed in this area is in the range of 5.5 to 7.9 m/s and this occurs less than 3% of the time.

The records from the Kuala Lumpur International Airport show significant calm period covering approximately 47% of the time. The predominant winds movement is from direction of northwesterly during November to March (north-east monsoon) and southerly during May to September (south-west monsoon).

Due to the location of the Brooklands estate inland of Kuala Langat, the land-sea breezes lose their strength when advancing further away from the coast.

(3) Rainfall

The average annual rainfall depth in the Study area is about 2,400 mm. There is a tendency for rainfall to gradually increase from the coast towards the hilly areas. The highest rainfall occurs in the month of April and November with a mean of 280 mm. The lowest rainfall occurs in the month of June with a mean of 115 mm. The wet seasons occur in the transitional periods of the monsoons, from March to April and from October to November.

In addition to the rains associated with the monsoons, rainstorms derived from the convection type occur occasionally throughout the year during late afternoons. The rainstorms last for a short duration and are typically in isolated areas and usually with very high intensities. The number of rainy days in a year ranges from 140 to 210 days.

(4) Temperature and Relative Humidity

The temperature throughout the year is quite constant with a mean of 27°C and ranges from 24°C to 32°C. The highest temperature falls at 1:00 p.m. with an average of 32°C and lowest temperature falls at 7:00 p.m. with an average of 24°C. The high temperatures are experienced in April and May while the low temperatures are experienced in November and December.

As the relative humidity is very closely related to the surrounding temperature, its variation throughout the year is also minimal with an average value of 82%. The time of occurrence of the daily high and low values coincide with the low and high temperatures with values of 96% and 62%, respectively. The mean monthly relative humidity exhibits a bimodal distribution with peaks in April-May and October-November, coinciding with periods of heavy rain.

(5) Sunshine and Solar Radiation

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.

(6) Evaporation

The evaporation depth for open water is measured to be around 1,500 mm per year and monthly mean of around 125 mm/month. The highest evaporation occurs in February-March and the lowest evaporation occurs in November-December, although the difference is small.

1.2 Hydrological and Meteorological Stations

Hydrological and meteorological data in the Study Area including both the Langat River Basin and the Klang River Basin were obtained from the following sources:

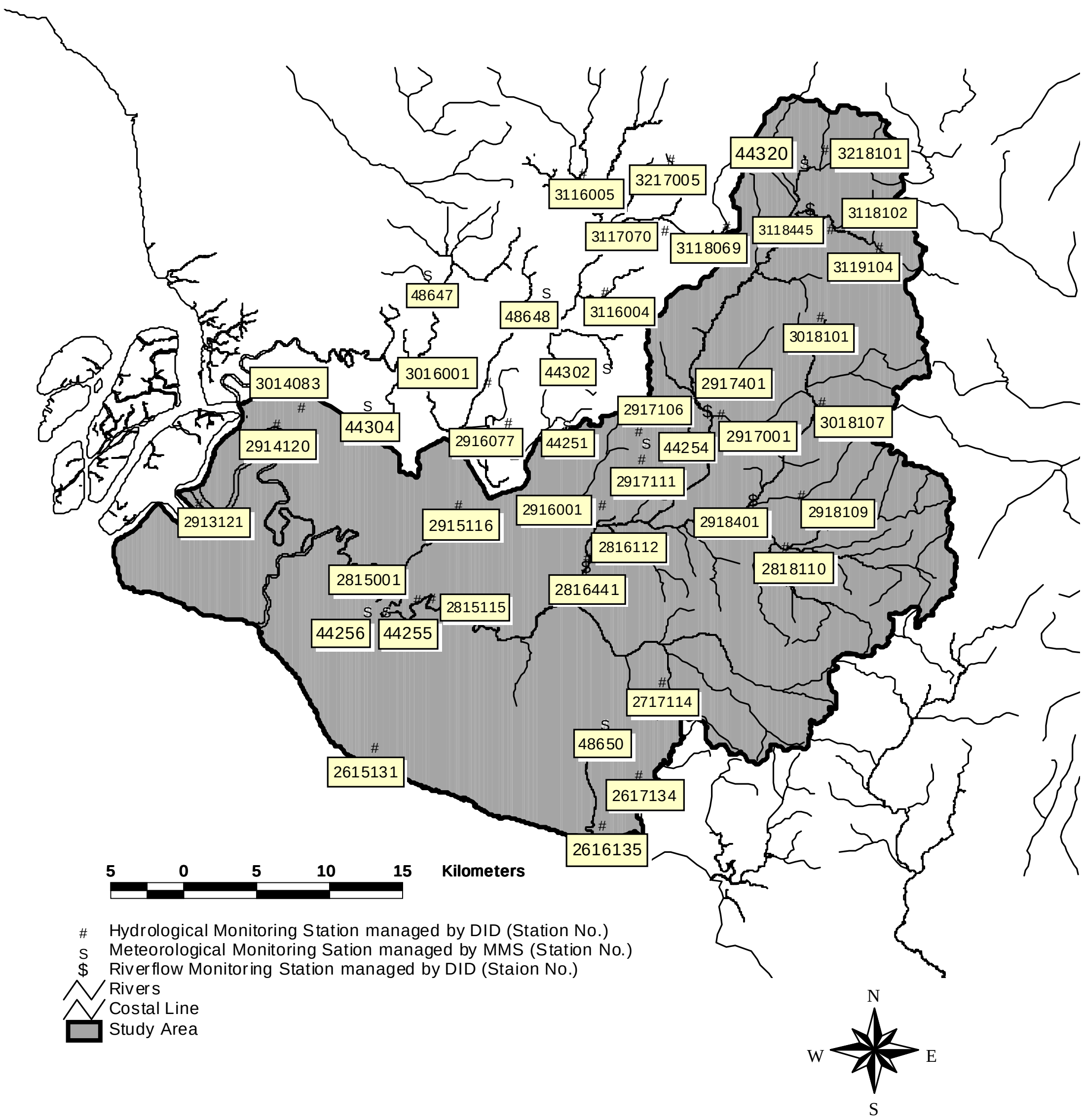
(1) Drainage and Irrigation Department, Ministry of Agriculture (DID)

- Rainfall
- River Water Discharge
- Evaporation
- Tide Level

(2) Malaysian Meteorological Services Department (MMS)

- Rainfall
- Temperature
- Wind
- Sunshine
- Relative Humidity
- Evaporation

The locations of various hydrological and meteorological stations are shown in **Figure D.1.3,** and the inventory is given in **Tables D.1.1 to D.1.2**.



Source: Data provided by Drainage and Irrigation Department (DID) and Malaysian Meteorological Service (MMS)

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Figure D.1.3

Location of Meteorological and Hydrological Monitoring Station

Table D.1.1 Hydrological and Meteorological Stations in the Langat River Basin

Basin			Station Number	Responsible Body	Year Records Available	Location	Latitude	Longitude	Coordinates on GIS Map		Monitering Items
							(D.M.S)	(D.M.S)	X	Y	
Langat	Upper - Middle Langat	U.Langat	3118102	DID	1970 to 1999	SEK. KEB. KG. LUI	03 09 25	101 53 20	432557.700	349296.411	Rainfall
			3119104	DID	1992 to 1999	BT.30 at JALAN GENTING PERES	03 08 25	101 55 47	437091.584	347444.028	Rainfall
			3218101	DID	1946 to 1996	STN. JANALETRIK LLN. at PONSOON	03 13 40	101 53 00	431957.322	357129.194	Rainfall
			44320	MMS	1980 to 1999	AMPANG ULU LANGAT	02 59	101 40	430102.604	355904.786	Rainfall, Temperature
			3118445	DID	1965 to 1997	SG. LUI at KG. LUI SELANGOR	03 10 25	101 52 20	430709.625	351143.125	River Water Discharge
		Semenyih	3018101	DID	1992 to 1999	EMPANGAN SEMENYIH	03 04 43	101 52 50	431612.907	340637.667	Rainfall
			3018107	DID	1929 to 1998	LDG. DOMINION	03 00 13	101 52 55	431749.494	332345.044	Rainfall
			2918401	DID	1975 to 1998	SG. SEMENYIH at KG.RINCHING SELANGOR	02 54 55	101 49 25	425244.125	322592.375	River Water Discharge
			2816112	DID	1930 to 1999	LDG. GALLOWAY	02 53 45	101 39 50	409792.042	316944.987	Rainfall
			2916001	DID	1981 to 1999	PRANG BESAR	02 54 40	101 41 50	411193.714	322163.213	Rainfal, Evaporation (2916301)
			2917001	DID	1975 to 1999	SETOR JPS. KAJANG	02 59 30	101 47 50	422329.732	331044.927	Rainfall
			2917106	DID	1930 to 1995	LDG. WEST COUNTRY at BHG. BARAT	02 58 35	101 43 40	414606.905	329373.145	Rainfall
			2917111	DID	1930 to 1997	LDG. SEDGELEY	02 57 05	101 43 50	414909.339	326608.210	Rainfall
			2818110	DID	1970 to 1999	IBU BEKALAN KG. at JLN. ENAMAKI	02 52 25	101 51 05	428322.330	317978.733	Rainfall
			2918109	DID	1929 to 1996	LDG. SG. RINCHING	02 55 10	101 51 55	429877.067	323043.082	Rainfall
			44254	MMS	1985 to 1999	PORIM BANGI	03 13	101 52	415221.974	328296.754	Rainfall
			2816441	DID	1960 to 1999	SG. LANGAT at DENGKIL SELANGOR	02 51 20	101 41 00	409635.625	316023.906	River Water Discharge
			2917401	DID	1978 to 1998	SG. LANGAT at KAJANG SELANGOR	02 59 40	101 47 10	421095.250	331354.813	River Water Discharge
	Lower Langat		2615131	DID	1936 to 1999	LDG. BATU UNTONG	02 41 40	101 30 25	389981.423	298255.432	Rainfall
			2616135	DID	1930 to 1999	LDG. TELOK MERBAU	02 37 50	101 41 05	411227.292	290613.198	Rainfall
			2617134	DID	1930 to 1999	LDG. SEPANG	02 40 15	101 43 45	414685.114	295586.922	Rainfall
			2717114	DID	1935 to 1999	LDG. BUTE	02 45 15	101 44 55	416867.472	304796.634	Rainfall
			2815001	DID	1970 to 1998	PEJABAT JPS. SG. MANGG	02 49 35	101 32 30	393877.960	312836.372	Rainfall
			2815115	DID	1935 to 1998	LDG. BROOKLANDS	02 49 40	101 33 15	395268.077	312986.544	Rainfall
			2913121	DID	1930 to 1999	LDG. WEST at PULAU CAREY	02 54 40	101 21 30	373519.524	322257.407	Rainfall
			2914120	DID	1936 to 1998	LDG. GOLDEN HOPE	02 58 55	101 25 25	380797.319	330070.830	Rainfall
			2915116	DID	1947 to 1998	LDG. BKT. CHEEDING	02 54 40	101 34 35	397761.134	322195.172	Rainfall
			3014083	DID	1935 to 1999	LDG. HIGHLANDS	02 59 47	101 26 40	383117.414	331661.974	Rainfall
			44255	MMS	1981 to 1999	PUSAT PERTANIAN TELUK DATUK	02 49	101 31	391095.791	311768.172	Rainfall, Temperature, Relative Humidity
			44256	MMS	1981 to 1999	BANTING PALM OIL RESEARCH STATION	02 49	101 30	389242.760	311772.789	Rainfall, Temperature
			48650	MMS	1998 to 1999	SEPANG (KLIA)	03 13	101 52	411453.410	300662.195	Rainfall, Temperature, Wind, Sunshine, Relative Humidity, Evaporation

Source: Data provided by Drainage and Irrigation Department (DID) and Malaysian Meteorological Service (MMS)

Table D.1.2 Hydrological and Meteorological Stations in the Klang River Basin

Basin		Station Number	Responsible Body	Year Records Available	Location	Latitude (D.M.S)	Longitude (D.M.S)	Coordinates on GIS Map X	Coordinates on GIS Map Y	Monitering Items
Klang	Upper Klang	3116005	DID	1980 to 1999	SEK. REN. TAMAN MALURI at W.PERSEKUTUAN	-	-	409376.120	354671.580	Rainfall
		3217005	DID	1982 to 1999	GOMBAK DAMSITE at W.PERSEKUTUAN	-	-	417631.140	356100.330	Rainfall
		3117070	DID	1980 to 1999	PUSAT PENYELIDIKAN at JPS AMPANG	03 09 20	101 45 00	417122.456	349177.367	Rainfall, Evaporation(3117370)
		3118069	DID	1915 to 1995	PEMASOKAN AMPANG	03 09 30	101 48 05	422834.118	349471.439	Rainfall
	Middle Klang	2916077	DID	1935 to 1995	LDG. BKT. HITAM	02 59 00	101 37 05	402412.352	330169.753	Rainfall
		3016001	DID	1976 to 1998	PUCHONG DROP	03 01 10	101 36 05	400569.471	334167.131	Rainfall
		3116004	DID	1980 to 1990	JPS WILAYAH PERSEKUTUAN	-	-	411439.870	343082.810	Rainfall
		44251	MMS	1980 to 1999	MARDE SERDANG	02 59	101 40	407815.826	330156.825	Rainfall, Temperature
		44302	MMS	1980 to 1997	UNIVERSITI PERTANIAN SERDANG	03 02	101 42	411533.936	335676.580	Rainfall, Temperature
		48648	MMS	1980 to 1999	PETALING JAYA	03 06	101 39	405994.163	343061.035	Rainfall, Temperature, Wind, Sunshine, Relative Humidity, Evaporation
	Lower Klang	44304	MMS	1980 to 1999	MARDIKELANG	03 00	101 30	389294.038	332045.294	Rainfall, Temperature
		48647	MMS	1980 to 1999	SUBANG	03 07	101 33	394884.435	344931.352	Rainfall, Temperature, Wind, Sunshine, Relative Humidity, Evaporation

Source: Data provided by Drainage and Irrigation Department (DID) and Malaysian Meteorological Service (MMS)

1.3 Examination of Hydrological and Meteorological Data

Daily hydrological and meteorological data time series were obtained from the Drainage and Irrigation Department (DID) and the Malaysian Meteorological Services Department (MMS). In the Langat and Klang river basins, there are 39 rainfall stations, 5 evaporation stations and 4 river stations and from each station the following time series were extracted.

- Daily rainfall
- Daily evaporation
- Daily water level
- Daily discharge

The quality of these data varies. Some stations have more complete data than others do and all stations have more or less periods of missing data or gaps. For this study, attempts were made to fill in the missing rainfall data to complete the rainfall series for the period from 1980 to 1999 for all stations except for Station No. 3119001 and No. 3119002, which were closed before 1980.

Daily rainfall gaps were filled in by adopting the data from a nearby location. There are many rainfall stations in the Study Area; thus, adopting the daily rainfall from a nearby station is the simplest way of filling in. If data from a nearby station is also missing, then the next nearby station will be used.

Interpolation of discharges by rainfall-runoff analysis

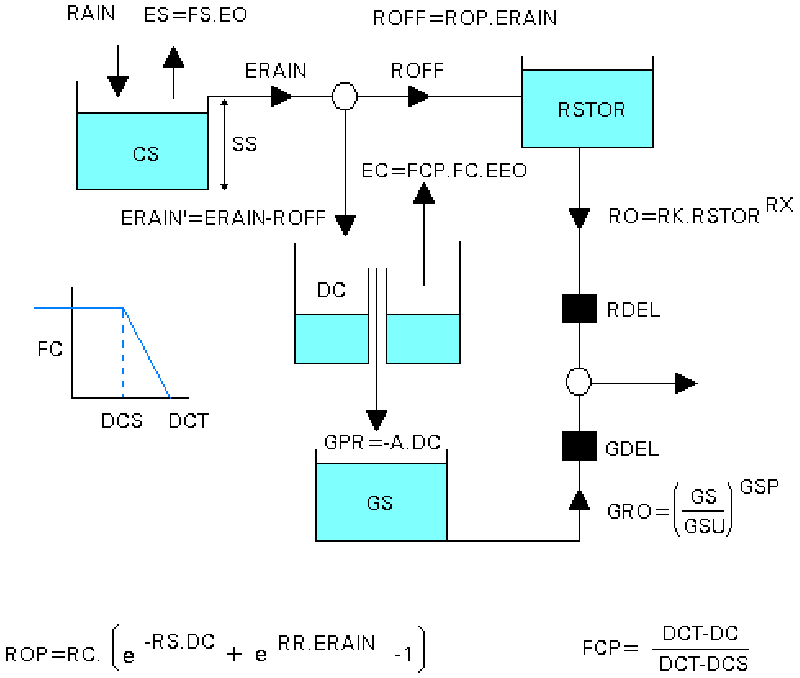
The study also filled in daily runoff data series for Station No. 2816441 which is DID's river station along the Langat River at Dengkil. A rainfall runoff model was used to simulate the daily runoff time series at Dengkil.

The missing observed daily runoff data at Dengkil (Station No. 2826442) was approximately 24% of all from 1980 to 1999. Therefore, the rainfall-runoff model for filled-in data was used only for estimation of annual water balance as described later.

DID recently used the HYRROM software to generate daily flows to fill in the gaps in their daily flow data of river stations in Johore, Malacca and Negeri Sembilan. The rainfall-runoff model used by the HYRROM software for generating runoff is the lumped catchment's model of the Institute of Hydrology, U. K.[4)] A schematic diagram of this model is as shown in **Figure D.1.4**. The same model was used in this study to generate daily flows for the Langat River at Dengkil to fill gaps in the daily flow time series.

Input of daily rainfall and daily evaporation of the Basin is a prerequisite of this model. The daily observed flow at Dengkil is also required for the estimation. The daily rainfall of the basin is computed using the Thiessen Weights (Polygon) method.

Daily Pan-Evaporation was taken from two meteorological stations in the Klang River Basin, i.e., Station No. 2916301 and No. 3117370. An evaporation of the basin is simply an average of the evaporation from these two stations. The problem of data gaps is also found in the evaporation time series. If one evaporation station contains a gap then it is filled in with data from the other evaporation station. However, if both evaporation data are gaps then data from one of the MMS evaporation stations in the basin is used to fill in the missing evaporation data. The calibration exercise attempted to fit the simulated hydrograph to the observed hydrograph. Having obtained the simulated runoff at Dengkil, attempt was then made to locate the periods of missing observed runoff data that are to be filled in by using the simulated runoff data.



Legend

RAIN: Rainfall
ES: Evaporation
FS: A parameter for depleted evaporation
RC: A parameter for soil moisture deficit
RS: A parameter for soil moisture deficit
RR: A parameter for soil moisture deficit
EO: Penman potential evaporation for the hour interval
CS: Store content
SS: A parameter of store capacity
ERAIN: Residual rainfall
ROFF: Volume assigned to surface runoff
ROP: Function of soil moisture deficit
RSTOR: Reservoir content at the start of the interval
EEO: Residual potential evaporative demand (=EO-CS/FS)
EC: A rate for determined by EC=FCP*FC*EEO
FCP: A function of deficit
DC: Soil moisture storage
DCS: A parameter for soil moisture storage at the beginning
DCT: A parameter for soil moisture storage at the ending
A: A parameter of soil moisture store
RO: Surface runoff store
RK: A parameter for surface runoff store
RX: A parameter for surface runoff store
RDEL: A parameter for delayed time interval for surface water
GDEL: A parameter for delayed time interval for groundwater
GSU: A parameter for volume output of groundwater store
GSP: A parameter for volume output of groundwater store
GS: Groundwater store
GRO: Volume output of groundwater store
FC: A Parameter for soil moisture store
GPR: A rate for DC (GPR=-A*DC)

Parameter Value for the Study	
SS	3
FS	0.85
RC	0.3
RS	0
RR	0
RK	0.2
RX	1.2
RDEL	0
FC	1.0
DCS	300
DCT	360
A	0.2
GSU	300
GSP	2
GDEL	0

Figure D.1.4 Rainfall-Runoff Model for Estimation of Daily Flows of the Langat River at Dengkil

1.4 Rainfall

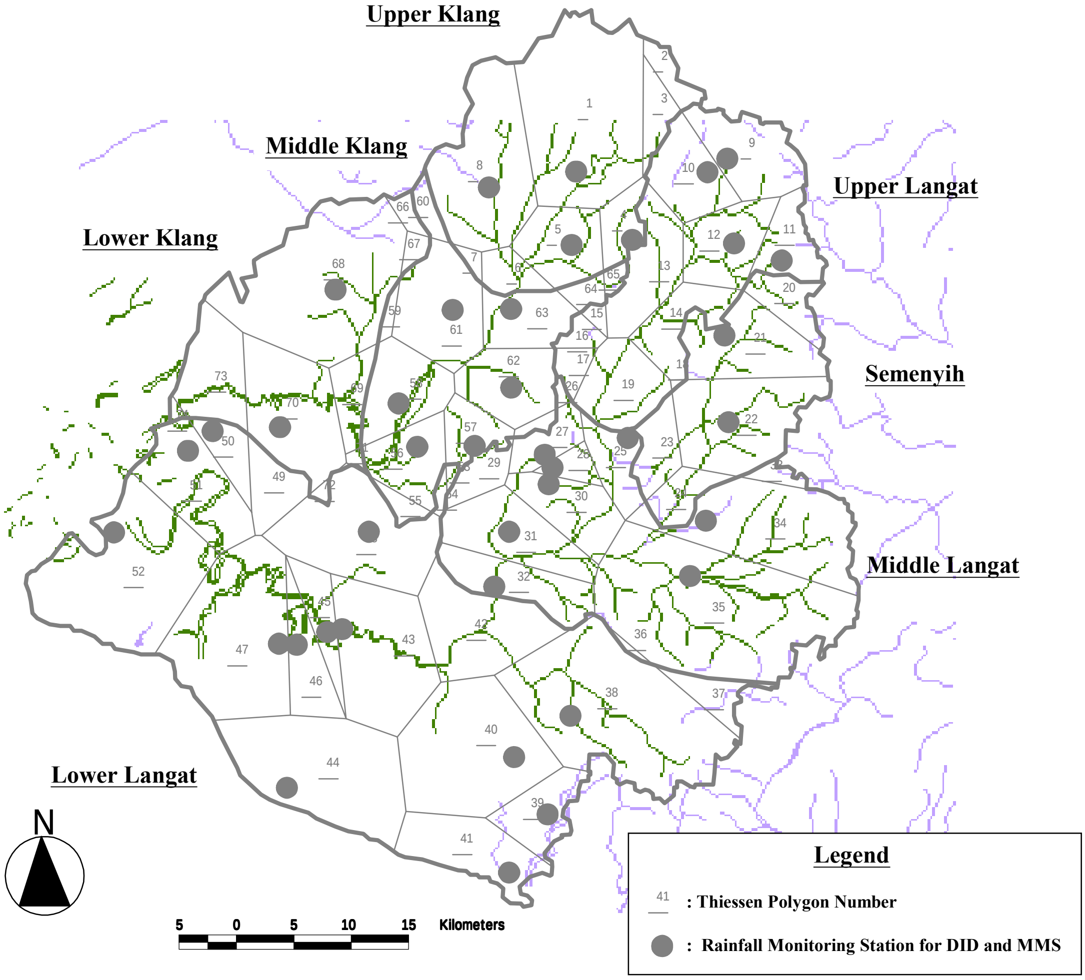
As shown in **Figure D.1.5**, the Langat and Klang river basins can be divided into some sub-basins respectively. Topographical maps determined each sub-basin boundary. **Figure D.1.5** also illustrates the Thiessen Polygon Area that was calculated based on the basin (sub-basin) boundary and location of rainfall station. The annual rainfall of each basin area is given in **Table D.1.3**, together with the ratio of Thiessen Polygon Area and collected data from 1980 to 1999. Monthly rainfall using the Thiessen Polygon Method in the Study Area is as calculated in the **Data Book D.1.1.** In addition, the annual rainfall and monthly average rainfall in the Langat and Klang river basins are shown in **Figures D.1.6 and D.1.7** respectively. These figures indicate rainfall characteristics in the Study Area as follows:

- Annual rainfall both the Langat River Basin and the Klang River Basin is approximately 2,000 mm to 2,500 mm.
- There is no significant difference in annual rainfall among sub-basins.
- Two dry seasons are noted, namely, January to February and June to July, with rainfall below 150 mm per month.
- Two rainy seasons are noted, namely, March to April and October to November, with rainfall above 200 mm per month.

Table D.1.3 Annual Rainfall of the Langat and Klang River Basins from 1980 to 1999

(mm/year)

Year	Rangat River Basin				Klang River Basin			All Langat +All Klang
	Upper Langat	Semenyih	Upper + Semmenyih + Middle Langat	All Langat	Upper Klang	Upper + Middle Klang	All Klang	
1980	2,578	2,631	2,391	2,279	2,683	2,570	2,526	2,349
1981	2,583	2,521	2,297	2,044	2,695	2,569	2,435	2,166
1982	2,676	2,651	2,385	2,082	2,614	2,545	2,538	2,205
1983	2,251	2,305	1,949	1,848	2,434	2,264	2,177	1,956
1984	2,751	2,774	2,624	2,542	2,548	2,526	2,526	2,527
1985	2,384	2,353	2,323	2,275	2,488	2,417	2,342	2,326
1986	2,229	2,390	2,169	1,928	2,189	2,145	2,157	1,993
1987	2,284	2,201	2,163	2,092	2,237	2,356	2,501	2,206
1988	2,193	1,712	2,072	2,222	2,363	2,504	2,692	2,374
1989	2,326	2,329	2,288	2,089	2,333	2,363	2,328	2,163
1990	1,765	1,713	1,772	1,742	1,760	1,839	1,892	1,803
1991	2,618	2,572	2,382	2,259	2,754	2,708	2,737	2,403
1992	2,048	2,433	2,068	2,040	2,133	2,219	2,274	2,108
1993	2,442	2,295	2,616	2,441	2,596	2,676	2,608	2,480
1994	2,236	2,151	2,248	2,417	2,462	2,478	2,488	2,441
1995	2,593	2,565	2,489	2,586	2,949	2,865	2,854	2,654
1996	2,338	2,107	2,162	2,110	2,764	2,735	2,672	2,284
1997	1,992	2,568	1,958	1,871	2,513	2,544	2,517	2,057
1998	1,982	2,064	1,901	1,965	2,164	2,307	2,334	2,083
1999	2,784	2,912	2,500	2,200	2,740	2,715	2,693	2,342
Average	2,353	2,362	2,238	2,152	2,471	2,467	2,465	2,246



Langat River Basin	Thiessen Polygon No. on the map	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	Name of Sub-basin	Upper Langat (382.5km²)											Semeniyh (254.2km²)				
	Area (km²)	62.1	50.3	35.0	54.4	57.8	42.2	4.5	9.6	12.1	0.8	53.8	32.0	73.0	97.6	28.4	23.3

Langat River Basin	Thiessen Polygon No. on the map	25	26	27	28	29	30	31	32	33	34	35	36
	Name of Sub-basin	Middle Langat (644.3km²)											
	Area (km²)	32.0	2.8	25.0	13.4	20.8	50.1	70.3	54.1	8.2	123.4	242.0	2.3

Langat River Basin	Thiessen Polygon No. on the map	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
	Name of Sub-basin	Lower Langat (1469.3km²)																	
	Area (km²)	21.7	210.2	40.6	145.3	66.0	88.0	111.5	147.4	28.0	39.9	154.0	113.8	30.6	23.0	75.2	170.2	2.2	1.8

Klang River Basin	Thiessen Polygon No. on the map	1	2	3	4	5	6	7	8	55	56	57	58	59	60	61	62	63	64	65
	Name of Sub-basin	Upper Klang (458.2km²)								Middle Klang (253.8km²)										
	Area (km²)	188.8	15.4	21.0	25.3	52.4	20.9	4.7	129.8	6.5	33.5	20.2	41.6	3.7	9.0	56.1	41.0	31.2	7.2	3.8

Klang River Basin	Thiessen Polygon No. on the map	66	67	68	69	70	71	72	73	74
	Name of Sub-basin	Lower Klang (576.4km²)								
	Area (km²)	11.2	10.1	278.9	38.4	141.6	4.2	3.9	84.8	3.4

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Figure D.1.5

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Location of Rainfall Station and Thiessen Polygon Area of the Langat River and the Klang River Basins

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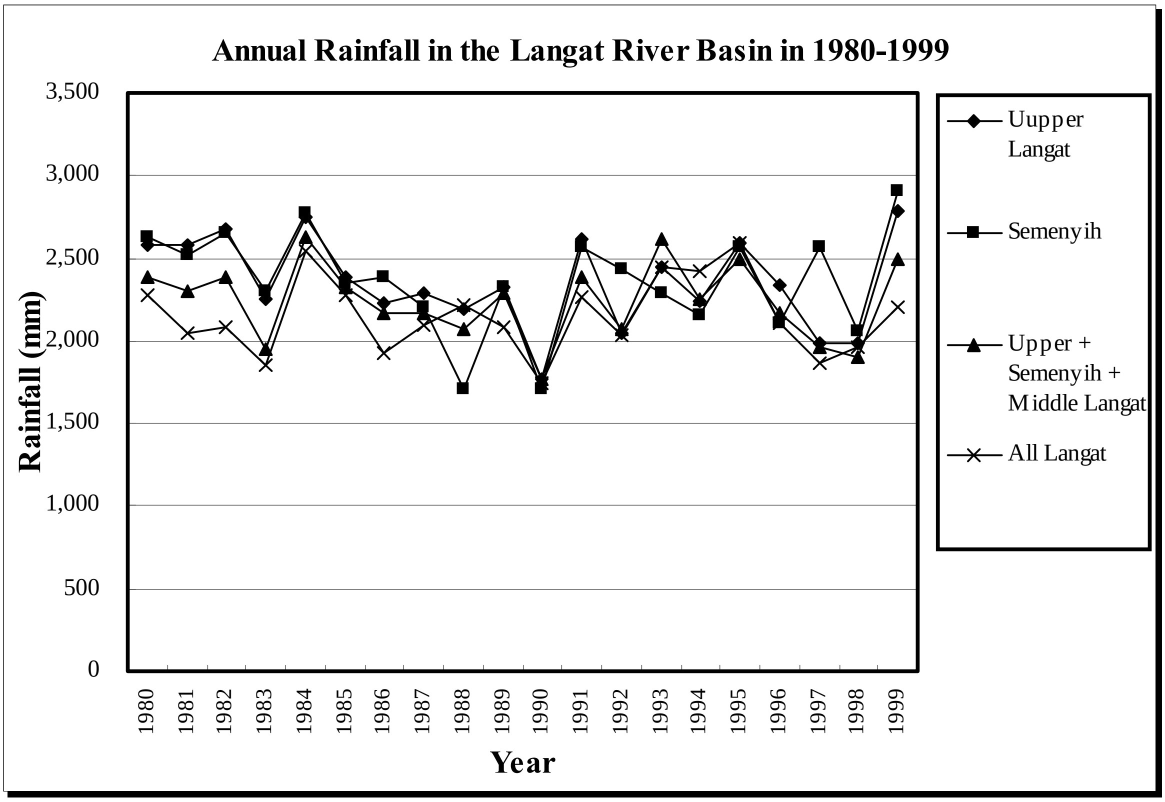

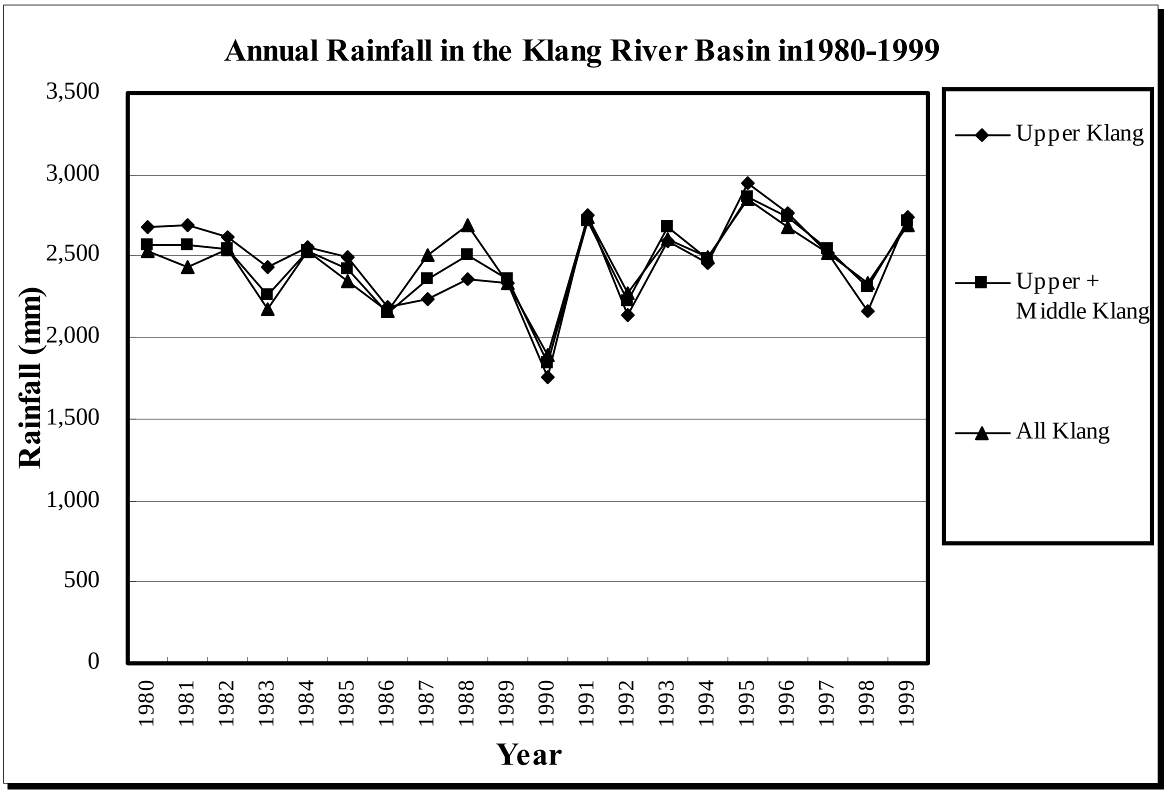

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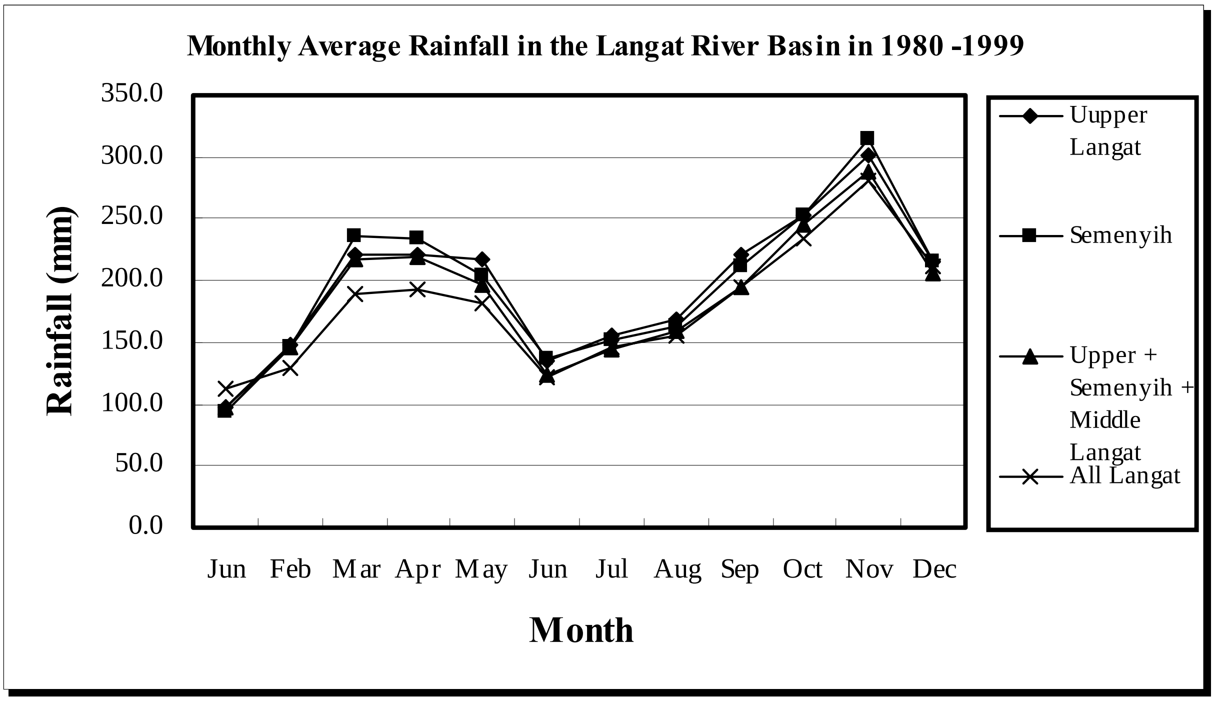
Figure D.1.6

Annual Rainfall in the Langat River and the Klang River Basins from 1980 to 1999



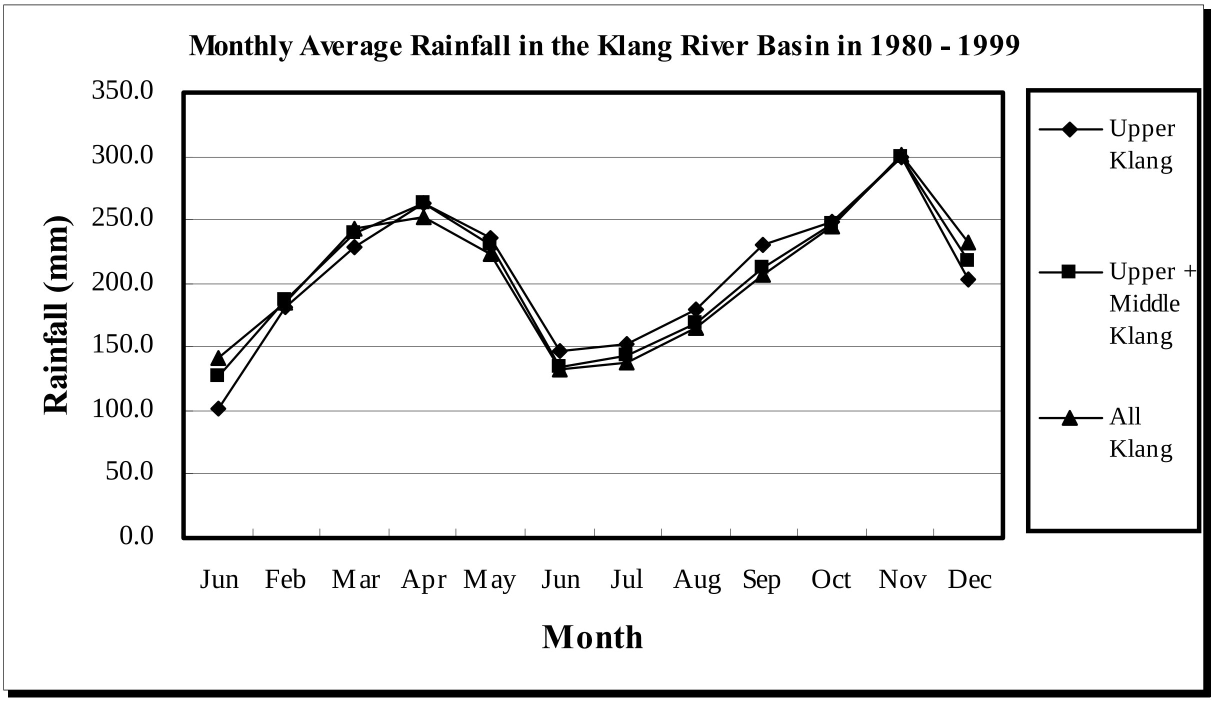


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Figure D.1.7

Monthly Average Rainfall in the Langat River and the Klang River Basins from 1980 to 1999

1.5 Evaporation

As shown in **Figure D.1.10**, there are five (5) monitoring stations for pan-evaporation in the Langat and the Klang river basins. Since three (3) monitoring stations managed by MMS are situated at a slightly distant location from the centre of the Study Area and data is not fully complete, daily pan-evaporation was examined from two (2) hydrological stations managed by DID. The DID stations are Station No. 2916301 (the same location as Station No. 2916001 on **Figure D.1.3**) and Station No. 3117370 (the same location as Station No. 3117370 on **Figure D.1.3**).

According to the interpolated daily evaporation data from 1980 to 1999 at Station No. 2916301 and No. 3117370, as shown in **Figures D.1.8, Figure D.1.9 and Table D.1.4,** there is no significant difference in monthly variation of pan-evaporation. The yearly average evaporation depth is estimated to be around 1,604.7 mm and the monthly average is around 133.7 mm. The highest evaporation occurs in February-March and the lowest evaporation occurs in November-December although the difference is small.

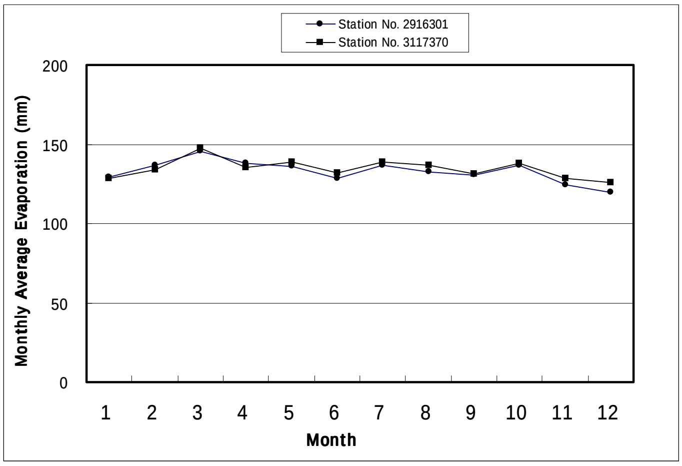


Figure D.1.8 Monthly Average Evaporation in the Study Area in 1980-1999

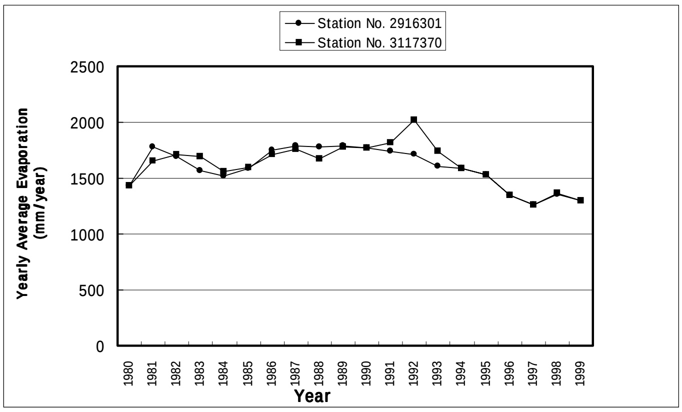
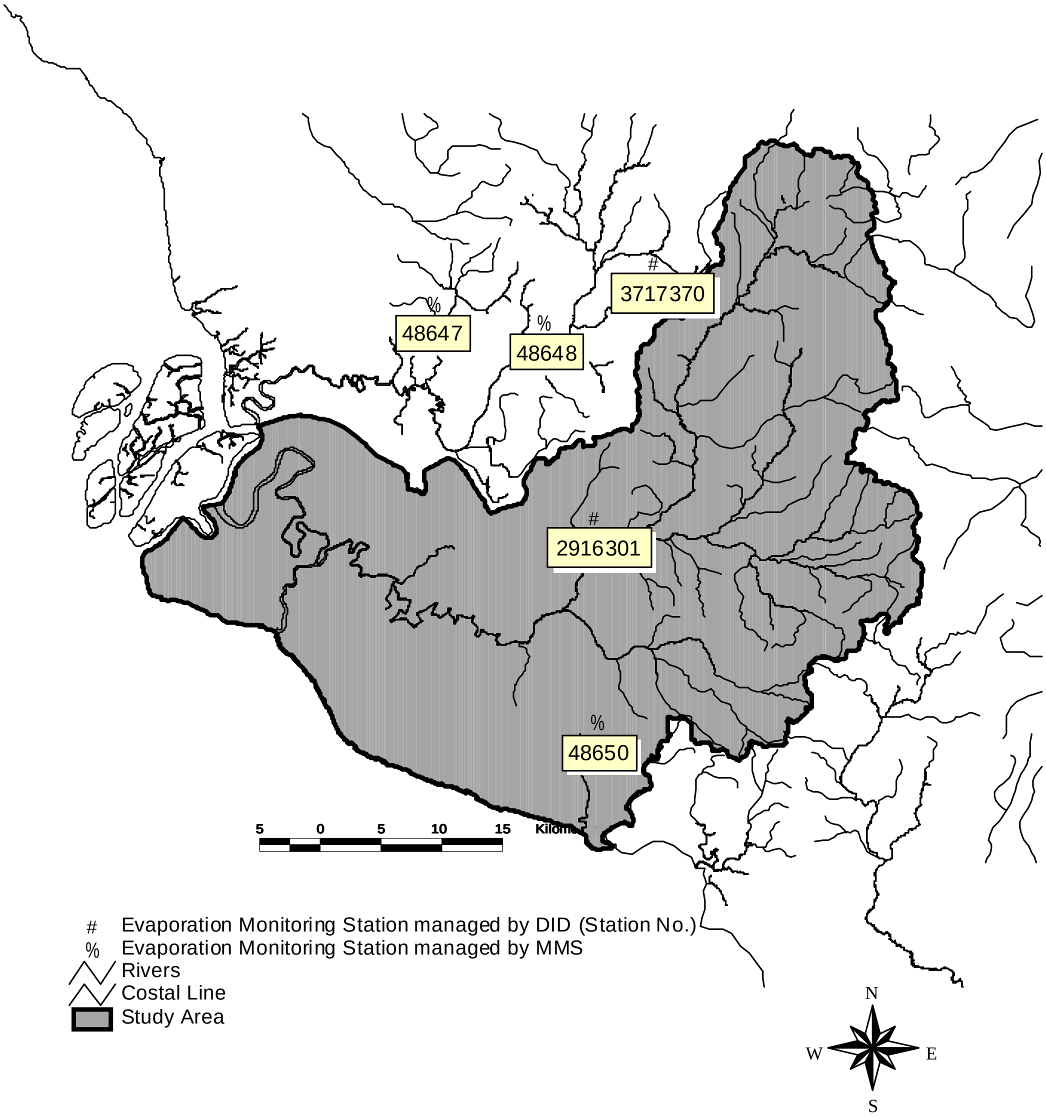


Figure D.1.9 Yearly Average Evaporation in the Study Area in 1980-1999



Source: Data provided by Drainage and Irrigation Department (DID) and Malaysian Meteorological Service (MMS)

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

Figure D.1.10

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

Location of Evaporation Monitoring Station

CTI Engineering International Co., Ltd.

OYO CORPORATION

Table D.1.4 Summary of Evaporation in the Study Area in 1980-1999

Station No. 2916301 (mm)

Year / Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
1980	113.7	131.9	136.8	113.4	139.4	115.8	125.4	106.3	114.9	115.4	104.4	111.6	1429.0
1981	111.3	140.2	180.5	156.2	133.2	140.0	187.5	187.2	131.3	147.9	132.0	131.5	1778.8
1982	130.7	136.2	148.5	154.9	135.2	127.4	148.9	129.2	139.9	158.3	141.1	139.1	1689.4
1983	134.6	137.7	129.6	121.0	131.4	120.5	134.9	129.6	127.7	145.1	150.1	108.5	1570.7
1984	114.1	96.0	133.5	142.8	144.3	122.8	118.1	126.0	119.5	118.7	146.7	138.3	1520.8
1985	139.2	132.8	119.1	102.9	121.2	121.6	149.4	179.1	145.4	137.3	110.4	130.4	1588.8
1986	120.1	143.8	149.2	145.0	166.0	157.7	163.4	153.7	141.1	144.7	122.8	143.1	1750.6
1987	120.1	169.1	189.9	149.8	150.8	136.2	145.8	155.6	148.6	178.6	123.9	122.0	1790.4
1988	161.9	164.7	141.5	159.7	145.5	145.0	144.7	137.7	145.5	157.5	137.2	136.0	1776.9
1989	153.7	168.3	145.4	153.7	153.2	133.1	144.0	147.4	142.9	150.1	151.0	147.4	1790.2
1990	140.6	166.0	162.8	163.1	154.0	140.4	138.5	141.6	135.0	148.6	127.0	153.2	1770.8
1991	156.6	149.2	165.3	155.3	158.7	158.3	151.4	146.6	151.1	124.1	127.5	94.8	1738.9
1992	146.0	155.5	175.0	152.5	153.5	123.0	128.0	133.5	132.0	152.0	133.0	127.8	1711.8
1993	137.0	135.9	161.0	170.2	141.0	143.2	142.5	128.1	130.1	117.2	82.0	114.7	1602.9
1994	135.0	129.1	128.2	122.2	128.1	138.4	143.5	116.4	128.6	142.7	138.2	132.1	1582.5
1995	131.7	122.2	134.9	128.4	132.9	133.4	125.5	112.3	140.7	139.8	125.3	101.3	1528.4
1996	139.2	134.8	156.9	125.9	105.7	102.8	99.9	97.1	112.0	106.1	89.2	79.3	1348.9
1997	105.0	99.5	130.6	104.7	117.3	96.8	93.4	101.2	90.5	103.1	113.6	102.9	1258.5
1998	116.9	127.2	127.9	122.5	123.9	102.6	115.9	99.5	114.3	127.9	109.0	72.9	1360.5
1999	77.6	91.1	100.0	114.5	91.2	106.1	136.0	121.1	118.5	119.3	120.9	104.4	1300.7
Average	129.3	136.6	145.8	137.9	136.3	128.3	136.8	132.5	130.5	136.7	124.3	119.6	1594.5

Station No. 3117370 (mm)

Year / Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
1980	113.7	131.9	136.8	113.4	139.4	115.8	125.4	106.3	114.9	115.4	104.4	111.6	1429.0
1981	86.9	142.3	175.6	136.3	126.1	135.1	143.9	172.9	121.9	139.9	135.8	134.6	1651.3
1982	133.0	140.9	157.4	142.6	138.2	147.5	150.4	144.1	147.8	144.6	130.4	138.6	1715.5
1983	154.7	154.3	162.0	132.4	140.4	129.2	154.4	148.7	125.2	139.8	137.6	115.0	1693.7
1984	125.0	109.5	131.1	131.9	145.6	122.8	137.8	130.3	119.5	118.7	146.7	138.3	1557.2
1985	139.2	132.8	119.1	102.9	121.2	114.1	137.7	173.1	137.2	142.8	129.1	143.3	1592.5
1986	113.0	136.0	155.0	135.1	162.0	145.8	129.3	167.2	125.8	140.8	137.5	160.3	1707.8
1987	120.1	169.1	182.6	173.5	145.7	126.8	146.5	145.3	139.1	167.5	138.2	108.1	1762.5
1988	145.0	146.3	151.1	150.5	151.7	126.0	131.6	123.5	142.4	146.5	128.4	130.2	1673.2
1989	120.1	130.6	141.0	136.9	147.5	158.2	153.3	155.5	154.0	165.0	155.5	165.0	1782.6
1990	140.5	153.4	148.1	154.9	161.2	153.5	136.5	166.7	130.6	154.0	126.2	146.5	1772.1
1991	156.6	146.1	160.8	137.1	156.0	146.3	161.9	147.4	162.0	147.0	155.1	143.3	1819.6
1992	154.0	144.5	179.5	166.5	166.0	169.5	177.0	175.5	170.5	180.5	165.5	169.8	2018.8
1993	166.0	135.9	175.5	176.7	173.5	162.7	180.5	128.1	130.1	117.2	82.0	114.7	1742.9
1994	135.0	129.1	128.2	122.2	128.1	138.4	143.5	116.4	128.6	142.7	138.2	132.1	1582.5
1995	131.7	122.2	134.9	128.4	132.9	133.4	125.5	112.3	140.7	139.8	125.3	101.3	1528.4
1996	139.2	134.8	156.9	125.9	105.7	102.8	99.9	97.1	112.0	106.9	89.2	79.3	1349.7
1997	105.0	99.5	130.6	104.7	117.3	96.8	93.4	101.2	90.1	103.1	114.0	102.9	1258.6
1998	116.9	127.2	127.9	122.5	124.0	102.6	115.9	99.5	114.3	127.9	109.0	72.9	1360.6
1999	77.6	91.1	100.0	114.5	91.2	106.1	136.0	121.1	118.5	119.3	120.9	104.4	1300.7
Average	128.7	133.9	147.7	135.4	138.7	131.7	139.0	136.6	131.3	138.0	128.4	125.6	1615.0

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Station No. 2916301	1429.0	1778.8	1689.4	1570.7	1520.8	1588.8	1750.6	1790.4	1776.9	1790.2
Station No. 3117370	1429.0	1651.3	1715.5	1693.7	1557.2	1592.5	1707.8	1762.5	1673.2	1782.6
Average	1429.0	1715.0	1702.5	1632.2	1539.0	1590.7	1729.2	1776.5	1725.1	1786.4
Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Station No. 2916301	1770.8	1738.9	1711.8	1602.9	1582.5	1528.4	1348.9	1258.5	1360.5	1300.7
Station No. 3117370	1772.1	1819.6	2018.8	1742.9	1582.5	1528.4	1349.7	1258.6	1360.6	1300.7
Average	1771.5	1779.3	1865.3	1672.9	1582.5	1528.4	1349.3	1258.5	1360.6	1300.7

Monthly Average Evaporation 133.7 mm
Yearly Average Evaporation 1604.7 mm

Source: Source data provided by Malaysian Meteorological Service

1.6 Flow Volume

The flow volume (river discharge) of the Langat River and its tributaries are measured by DID. The monitoring stations of flow volume managed by DID are shown in

Figure D.1.13. The records of monthly average discharge and yearly average discharge at the Dengkil (Station No. 2816441) are presented in **Figure D.1.11, Figure D.1.12 and Table D.1.5**. Based on the interpolated daily data from 1980 to 1999 at the Dengkil Station, the yearly average river discharge is estimated to be around 34.84 m^3/sec. The highest discharge occurs in November and December with approximately 57 m^3/sec, subsequently in April and May with approximately 40 m^3/sec. The lowest discharge occurs in February and August with approximately 22 m^3/sec.

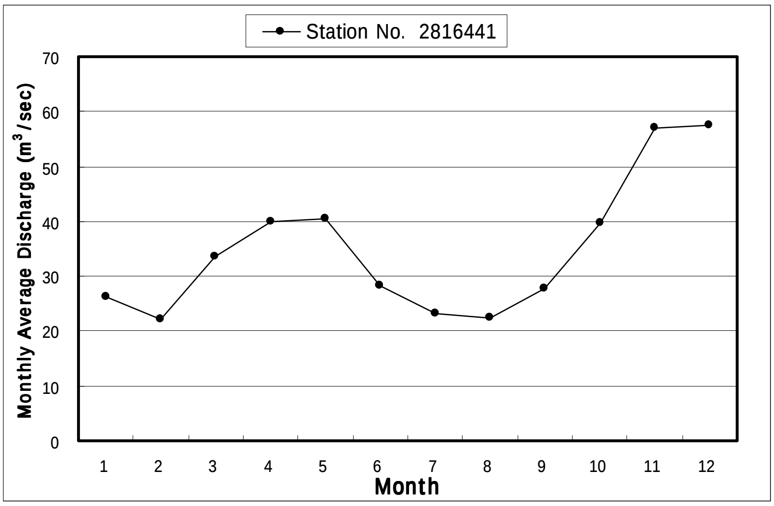


Figure D.1.11 Monthly Average Discharge in 1980-1999 at Dengkil in the Langat River

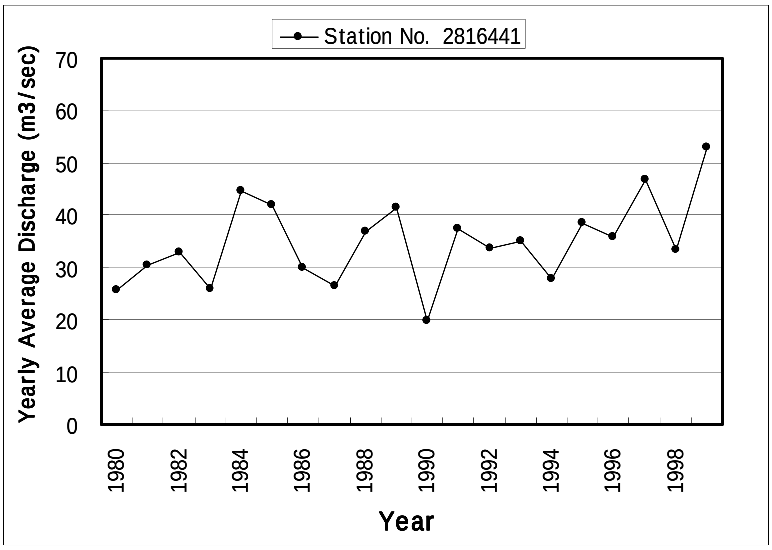
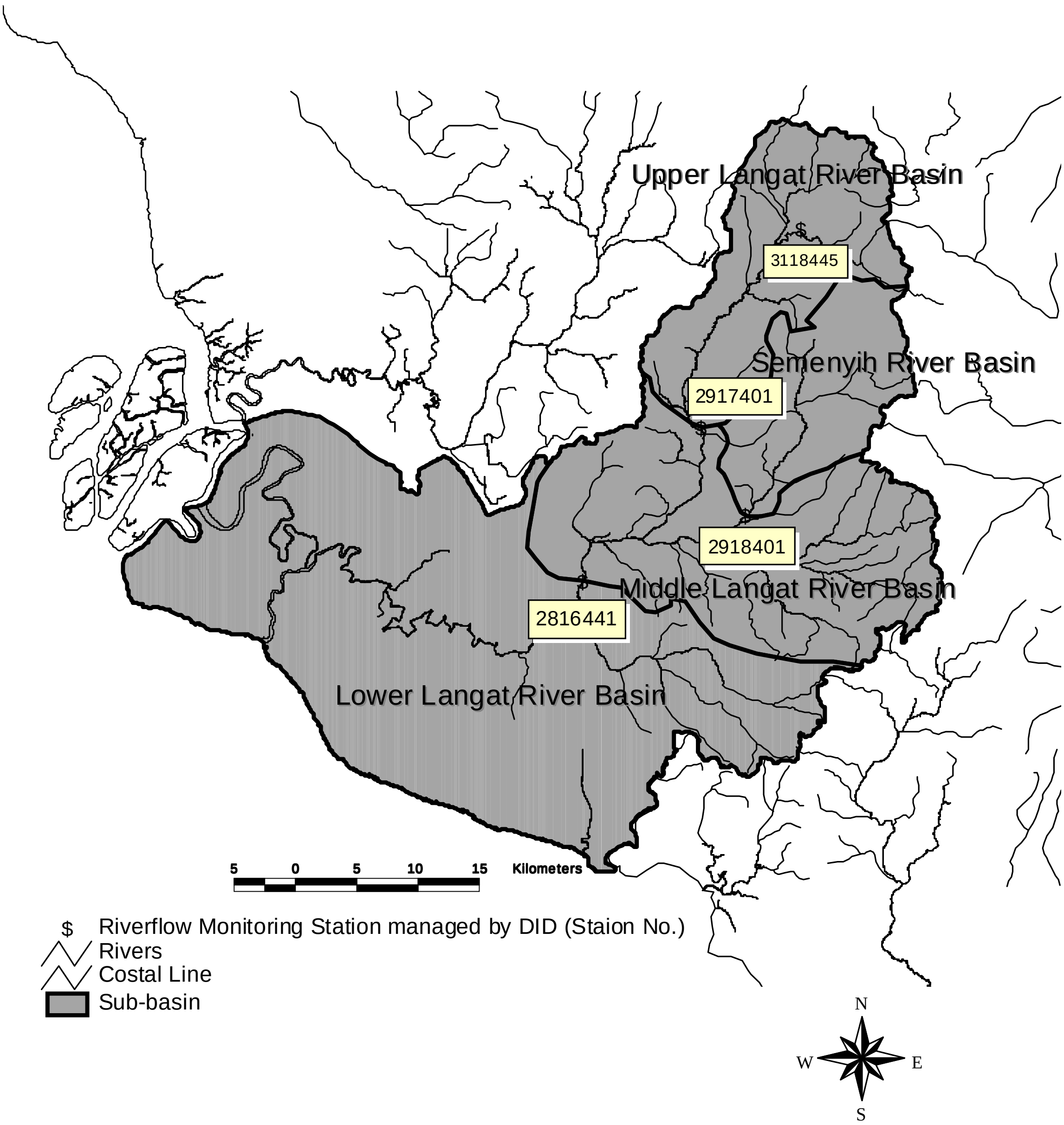


Figure D.1.12 Yearly Average Discharge in 1980-1999 at Dengkil in the Langat River



Source: Data provided by Drainage and Irrigation Department (DID) and Malaysian Meteorological Service (MMS)

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

Figure D.1.13

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

Location of Monitoring Station for Flow Volume in the Langat River Basin

CTI Engineering International Co., Ltd. OYO CORPORATION

Table D.1.5 Summary of Discharge in 1980-1999 at Dengkil in the Langat River

Station No. 2816441 (m^3/sec)

Year/Month	1	2	3	4	5	6	7	8	9	10	11	12	Average
1980	13.02	9.32	27.11	32.10	25.96	24.94	17.04	14.16	15.96	20.94	63.18	45.46	25.77
1981	21.40	35.45	35.93	30.23	78.27	39.29	13.36	10.06	21.48	27.82	25.90	24.73	30.33
1982	11.82	18.30	24.85	27.18	28.79	23.59	17.33	15.27	17.35	38.10	101.68	69.84	32.84
1983	25.04	11.89	24.03	26.36	33.98	15.92	19.63	30.84	45.89	20.03	34.53	22.00	25.85
1984	48.71	59.02	40.48	82.26	31.25	25.99	24.63	14.62	17.61	10.50	95.08	86.46	44.72
1985	24.40	35.32	53.86	29.58	44.45	12.89	14.43	8.91	10.00	32.69	61.85	174.97	41.95
1986	37.52	16.99	49.18	71.74	54.26	19.65	13.45	7.15	8.38	19.67	40.22	21.52	29.98
1987	7.09	5.36	6.33	13.42	15.86	10.78	7.29	20.52	29.56	70.71	75.91	53.84	26.39
1988	21.34	37.06	44.83	46.26	27.73	17.03	24.72	24.50	79.11	24.14	61.88	32.41	36.75
1989	29.10	19.15	34.08	47.02	38.58	35.58	22.33	19.93	50.30	89.36	71.37	40.32	41.43
1990	26.39	14.61	19.70	20.25	25.25	8.14	9.74	8.48	13.50	32.35	37.48	20.37	19.69
1991	12.33	8.19	22.24	24.27	60.43	44.25	16.95	10.01	26.51	72.15	81.94	68.94	37.35
1992	70.19	49.36	35.71	31.14	40.55	18.14	16.09	18.93	14.49	10.14	36.67	63.71	33.76
1993	29.43	18.49	27.68	46.07	55.64	22.46	18.46	6.81	22.46	44.49	69.14	57.84	34.91
1994	25.12	19.51	35.99	44.20	29.72	19.09	7.87	22.40	17.16	24.82	38.01	50.80	27.89
1995	17.36	5.47	35.83	72.91	52.65	66.94	32.33	29.09	5.99	24.07	52.57	65.79	38.42
1996	33.30	21.07	37.01	37.63	18.92	22.83	25.48	33.43	29.98	42.09	25.23	102.98	35.83
1997	16.92	30.47	57.72	58.44	50.24	32.33	40.19	28.51	33.83	92.17	65.11	54.08	46.67
1998	46.09	18.85	38.04	47.70	47.39	36.99	35.66	62.83	36.02	8.29	14.50	9.31	33.47
1999	6.06	8.41	23.91	8.84	50.08	65.98	85.85	60.54	57.52	89.42	89.97	86.96	52.79
Average	26.13	22.12	33.73	39.88	40.50	28.14	23.14	22.35	27.65	39.70	57.11	57.62	34.84

1.7 Tidal Data

In terms of tidal data to be referred[5) 6)], there is only one (1) tidal station at the mouth of the Klang River nearby the Study Area, as follows:

- Station: Pelabuhan Klang
- Location: Dermaga 25 Pelabuhan Utara
- Latitude (N) 03º 03.0', Longitude (E) 101º 21.5'

The monthly tidal data (mean/highest/lowest) and tidal levels during thirteen (13) years observation period at Pelabuhan Klang are shown in **Tables D.1.6 and D.1.7**. All tidal heights and levels in these Tables are referred to the Zero of Tide Gauge at the tidal stations (7.494m below Survey Department brass BMB0169). To predict the tidal effect during pumping test, Tide Table Malaysia in 2000 is available.

Table D.1.6 Tidal Data at Pelabuhan Klang in 1996

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total mean
Mean	3.541	3.516	3.491	3.637	3.742	3.638	3.687	3.678	3.726	3.789	3.822	3.757	3.669
Highest	5.850	5.950	5.940	5.940	6.060	5.820	5.980	6.130	6.310	6.160	6.130	5.940	-
Lowest	0.630	0.680	0.880	1.090	1.350	1.070	0.810	0.950	1.200	1.400	1.330	1.270	-

Source: Laporan Teknikal Jabatan Ukur & Pemetaan, Rekod Cerapan Air Pasang Surut 1996

Table D.1.7 Tidal Levels at Pelabuhan Klang for 13 Years

Levels and Heights	Metre	Comments
Bench Mark No. B0169	7.49	
EHW	6.31	Extreme High Water is the highest level reached during the year
MHWS	5.74	Mean High Water Springs is the average, throughout a year when the moon phase is at full or new, of the heights of two successive high waters during that period of 24 hours when the range of the tide is greatest.
MHWN	4.44	Mean High Water Neaps is the average, throughout a year when the moon phase is at first or last quarter, of the height of two successive high water during that period of 24 hours when the range of the tide is least.
MSL*	3.627	Mean Sea Level, obtained from tidal observation fro a certain period
DTGSM	4.624	Peninsular Malaysia Geodetic Vertical Datum, determined from Tidal Observation at Port Klang (1984-1993)
MLWN	2.92	Mean Low Water Neaps is the average, throughout a year when the moon phase is at first or last quarter, of the height of two successive low water during that period of 24 hours when the range of the tide is least.
MLWS	1.41	Mean Low Water Springs is the average, throughout a year when the moon phase is at full or new, of the heights of two successive low waters during that period of 24 hours when the range of the tide is greatest.
Datum Level	1.282	The Datum Level adopted is that of the Indian Spring Low Water. It is an elevation depressed below MSL by an amount of equal to the sum of the amplitude of the Harmonic Constituents
ELW (Jan. 1996)	0.63	Extreme Low Water is the highest level reached during the year
Zero of Tide Gauge	0.000	

*: Derived from 13 years observation period (1984-1996)
Source: Laporan Teknikal Jabatan Ukur & Pemetaan, Rekod Cerapan Air Pasang Surut 1996

2. INSTALLATION OF SURFACE WATER LEVEL MEASUREMENT INSTRUMENTS

2.1 Objectives of the Work

The installation of surface water level instruments was carried out as a part of the hydrological investigation to monitor the water level of wetland environment at Paya Indah Wetland Sanctuary and the Langat River.

2.2 Scope of the Work

Surechem Marketing Sdn. Bhd. conducted the work as subcontractor under the supervision of the JICA Study Team. The work covered five (5) items, as follows:

(1) Installation of Automatic Surface Water Level Instruments at the Paya Indah Wetland Sanctuary for Water Level Monitoring;

(2) Installation of Automatic Surface Water Level Instruments at the Langat River for Water Level Monitoring;

(3) Preparation of Temporary Bench Mark, including levelling;

(4) Setting of Nameplate; and

(5) Commissioning and Training.

2.3 Technical Specification

2.3.1 Installation of Automatic Surface Water Level Instruments at Paya Indah Wetland Sanctuary for Water Level Monitoring

The total number of automatic surface water instruments installed was five (5). Their locations were selected jointly by the JICA Study Team and the Contractor within the Paya Indah Wetland Sanctuary. Geographical coordinates such as latitude, longitude and elevation of all the automatic surface water level instruments have been measured and recorded.

As specified in the technical specification, the automatic surface water level instruments had allowed continuous monitoring for surface water level with adequate accuracy (with a resolution of 0.2 cm). The structure of the surface water level instruments had allowed easy measurement of water level and were not affected by environmental conditions such as low pH value, climatic conditions such as rain and thunder, clogging by sediment and mischief by people or intruders. The Contractor submitted figures showing profiles and cross sections of the surface water level instruments to the JICA Study Team, prior to the installation, for approval.

2.3.2 Installation of Automatic Surface Water Level Instruments at Langat River for Water Level Monitoring

The number of surface water level instruments installed at Langat River was one (1), and its location was selected jointly by the JICA Study Team and the Contractor at the site. Geographical coordinates such as latitude, longitude and elevation of the automatic surface water level instrument had been measured and recorded.

As specified in the technical specification, the automatic surface water level instrument had allowed continuous monitoring for surface water level with adequate accuracy (with a resolution of 0.5cm in 10m measuring range). The structure of the surface water level instruments had allowed easy measurement of water level and was not affected by climatic conditions at the site such as rain and thunder, clogging by sediment and mischief by people or intruders. The Contractor submitted figures showing profiles and cross sections of the surface water level instrument to the JICA Study Team, prior to the installation, for approval.

2.3.3 Preparation of Temporary Bench Mark including Levelling

To transfer the benchmark value to the actual monitoring stations by levelling, the Contractor provided temporary benchmarks for each of the surface water level instruments mentioned in **Sections 2.1 and 2.2** above. As technically specified, the temporary benchmarks were to be installed on either firm ground or the foundation of buildings or bridges on strong solid bedrock. Where there was no firm ground or building, bridge or other structures that stood on bedrock within fifty metres from the surface water level instrument, temporary benchmarks were placed. Where there were buildings, bridges or other structures that stood on bedrock within fifty metres from the benchmark stations, the temporary benchmark was placed properly on these structures.

As specified, the structure of the temporary benchmark should allow easy carrying out of levelling, and it should not be affected by climatic conditions at the site such as rain and wind, as well as mischief by people or intruders. The Contractor submitted figures showing profiles and cross sections of the temporary benchmarks to the JICA Study Team prior to the installation for approval. Geographical coordinates such as latitude, longitude and elevation of all the temporary benchmarks had been measured and recorded.

The Contractor had carried out precise levelling in accordance with the standards or guidelines of the Department of Survey and National Mapping, Malaysia. After the installation of surface water level instruments, precise levelling was executed from the nearest standard bench mark installed by the Department of Survey and National Mapping, Malaysia to all the temporary benchmarks and the surface water level monitoring instruments.

2.3.4 Setting of Nameplate

The Contractor provided nameplates for the surface water level instruments. The nameplates were six (6) in number at Paya Indah Wetland Sanctuary and Langat River. Nameplates were set on the perforated pipe where the surface water level instruments were installed.

2.3.5 Commissioning and Training

As required in the technical specification, the Contractor provided commissioning and training services to the JICA Study Team upon the completion of installation work and before delivery to JMG and MWF.

2.3.6 Reports and Data Submitted

At the end of the Work period, the Contractor submitted three (3) copies of a final report compiling, but not limited to, the following:

(1) Survey report including the results of levelling and measurement of geographical coordinates;

(2) Backup data regarding initial surface water monitoring inclusive of calibration;

(3) Floppy disks containing a copy of the report submitted; and

(4) On-site photographs showing all survey and installation works on site.

2.3.7 Time Schedule

As specified, the Contractor completed the work within 90 days from the date of signing of the contract.

2.4 Location of Surface Water Level Instrument

Locations and types of surface water level instruments installed are given in **Table D.2.1** and **Figure D.2.1**.

2.4.1 Paya Indah Wetland Sanctuary

The location of surface water level instrument installed was selected based on field investigation in consideration of water balance at the Paya Indah Wetland Sanctuary. The total number of surface water instruments is five (5) as follows:

- **SWL-1**: Inflow (box culvert, at 24.9 km point across the North-South Highway)
- **SWL-2**: Inflow (box culvert, at 27.45 km point across the North-South Highway)
- **SWL-3**: Inflow (box culvert, at 30.3 km point across the North-South Highway)

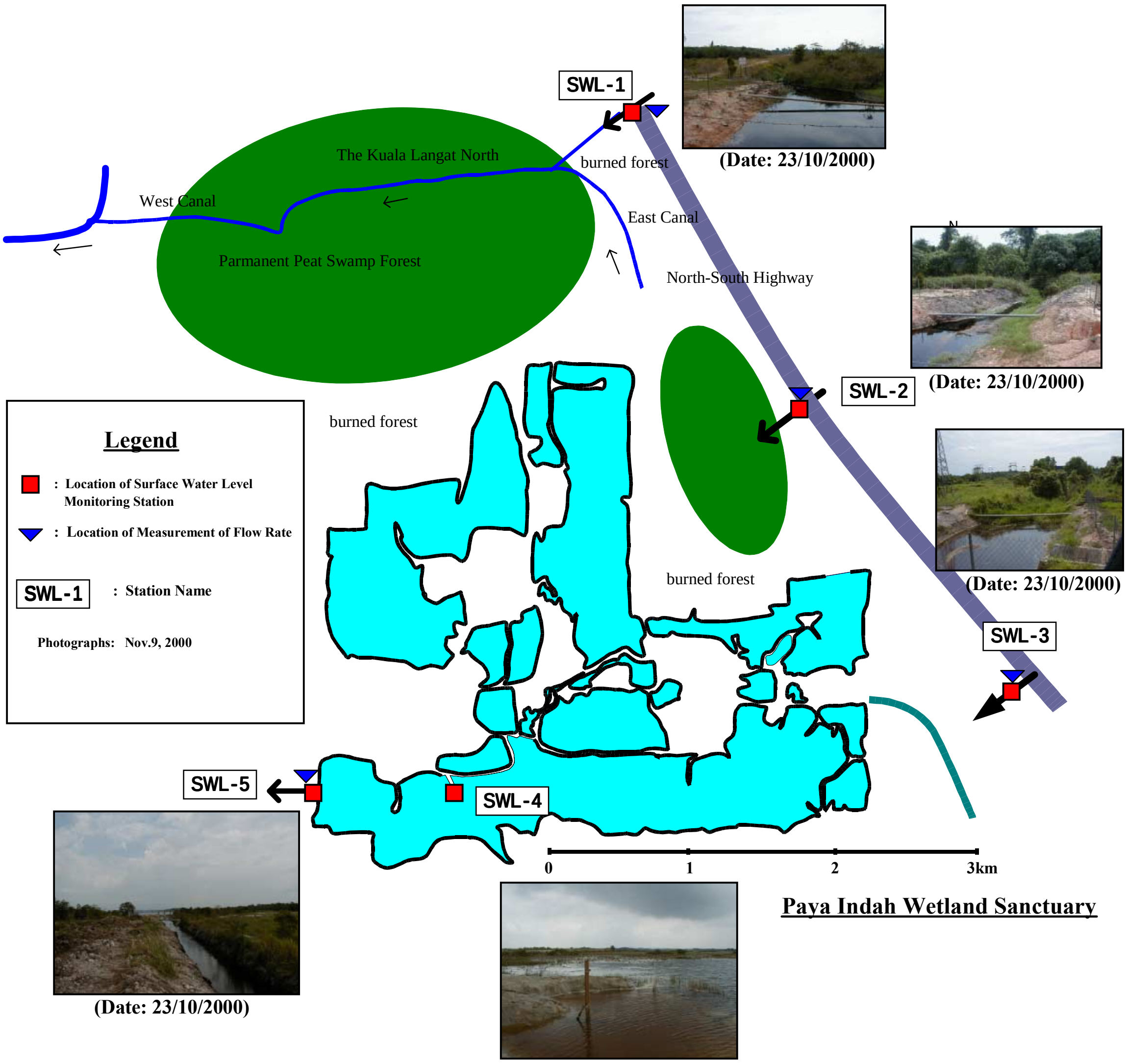
- **SWL-4**: the Lotus Lake
- **SWL-5**: Outflow (downstream side of water gate, outflow from west side edge of the Lotus Lake)

2.4.2 Langat River

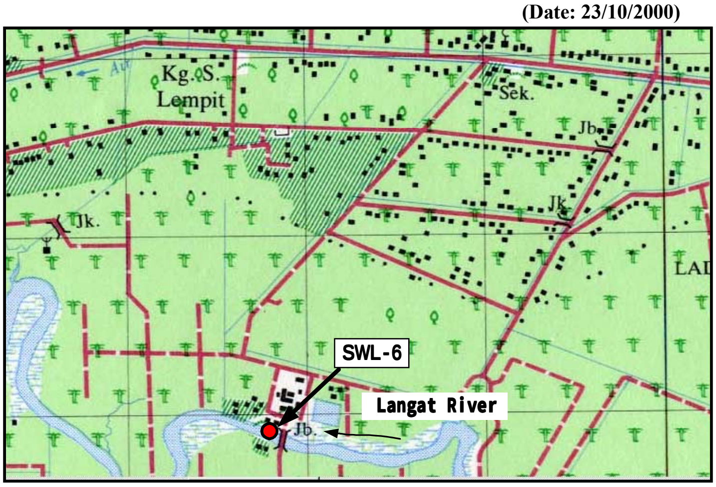
The location of surface water level instrument (**SWL-6**) installed was selected in the Langat River close to the Kajibumi Well Field 1. The tidal stream from the mouth of Langat River comes up to the Dengkil town, and the main aquifer is thought to spread out in the lower Langat Basin including the Kajibumi Well Field 1 and 2. Therefore, the monitoring of the surface water level in the Langat River was significant in consideration of the behaviour of groundwater relating with surface water.

Table D.2.1 Location and Type of Instrument of Surface Water Equipment

Station No.	Location	XY-Coordinate	Relevant organisation at the monitoring site	Instrument type and its serial number	Elevation of Bench Mark (m. s. l.)	Elevation of Water Level Sensor (m. s. l.)
SWL-1	Inflow, west side of ELITE Highway, 24.9 km	N02°53.576” E 101° 37.243”	PPNS DID ELITE	TD-DIVER SN 19665	9.269	7.787
SWL-2	Inflow, west side of ELITE Highway, 27.45 km	N 02° 52.534” E 101° 38.039”	ELITE DID	TD-DIVER SN 19666	9.586	7.326
SWL-3	Inflow, west side of ELITE Highway, 30.3km	N 02° 51.348” E 101° 38.990”	ELITE DID	TD-DIVER SN 19669	8.151	5.590
SWL-4	The Paya Indah Wetland Sanctuary, Lotus Lake	N 02° 51.681” E 101° 37.580”	MWF	TD-DIVER SN 19670 TD-DIVER (Barometric DIVER) SN 19664	6.639	5.610
SWL-5	Outflow, Downstream of sluice gate (West edge of Lotus Lake)	N 02° 51.190", E 101° 35.970"	DID	TD-DIVER SN 19671	7.319	5.141
SWL-6	Langat River (the Kajibumi Well Field 1)	N 02° 49.167”, E 101° 33.170”	DID JBA	SEBA PS-Insider No. 172	2.846	-1.354



Paya Indah Wetland Sanctuary



(Date: 16/11/2000)

Langat River (The Kajibumi Well Field 1)

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Figure D.2.1

Location of Installation of Surface Water Level Instruments

2.5 Type of Instrument

2.5.1 Paya Indah Wetland Sanctuary

The installed surface water level instruments were distributed widely in the Study Area, and high frequency of recording was required such as every thirty (30) minutes during the study period. Therefore, the surface water level instruments installed in the area of Paya Indah Wetland were the self-recording (automatic) water level monitoring equipment by pressure transducer with data logger having adequate accuracy (with a resolution of 0.2 cm). Additionally, the structure of the surface water level instruments should allow easy measurement of water level and shall not be affected by environmental condition such as low pH value, climatic conditions such as rain and thunder, clogging by sediment and mischief by people or intruders. In this consideration, the TD-Diver with the following specifications was selected.

TD-Diver

(1) Outline

The TD-Diver is a self-recording instrument specially developed for the automatic recording of water level and temperature. The TD-Diver uses a built-in pressure transducer and temperature sensor to measure the water level and groundwater temperature accurately within a borehole. The pressure transducer is automatically compensated for the temperature fluctuations giving increased accuracy. The data is stored in its internal memory. The memory can be accessed using a readout unit and a (portable) computer.

(2) Programming

Placing the TD-Diver in the readout unit creates a connection between the computer and the TD-Diver. The user-friendly program EnviroMon (Windows 95 compatible) makes programming the TD-Diver easy. The measurement interval can be adjusted freely.

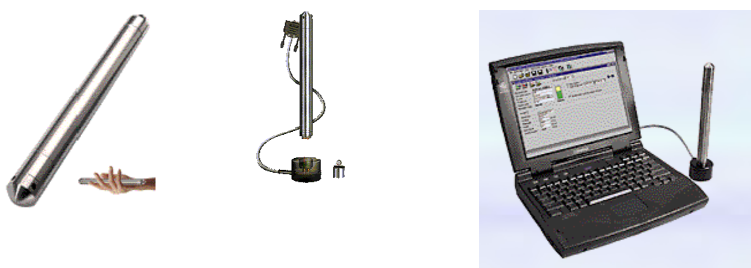

Figure D.2.2 TD-Diver

(3) Measuring

The TD-Diver is attached to a cable (stainless steel) inside water. Using its built-in pressure transducer the TD-Diver accurately measures the fluctuating water levels in the water at any pre-programmed frequency, every 0.5 seconds for instance. At the same time the pressure sensor measures the water temperature. The pressure measurement is automatically compensated for the temperature fluctuations, giving increased accuracy. The data, being the water levels, the temperatures and the times at which these were recorded, are stored in its internal memory up to a maximum of 24,000 measurements per parameter. This is sufficient to monitor the water level and temperature for a long period. During the same period, the barometric pressure in the area should be recorded using a Diver, the TD-Diver for instance. After all, the water level may have been influenced by variations in the barometric pressure. Different sample modes are available, such as linear, logarithmic and event sampling for pump test application for example. The whole system operates on an internal battery with an expected lifetime of 8-10 years. The TD-Diver is made entirely out of stainless steel (316). The TD-Diver is easy to install due to its small size. Vandalism is eliminated due to the anti-vandalism pipe cap, since nothing can be seen from outside the pipe.

(4) Reading

The information stored in the TD-Diver's internal memory can easily be accessed using the readout unit and a (portable) computer. The data is transferred directly into the computer and can be presented in the form of a chart or graph, using EnviroMon. The barometer-wizard in EnviroMon automatically compensates the recorded groundwater levels for the barometric pressures measured in the same period. Facilities for exporting the data to spreadsheet programs are also included. The TD-Diver’s memory can be read out at any chosen time.

(5) Features and Specifications

The features and specifications of equipment are explained in **Tables D.2.2 and D.2.3**:

Table D.2.2 Features of TD-Diver

Size	Ø 22 mm, length 23 cm suitable from 1 inch pipe
Reliability	Stainless steel (316) Internal battery (8-10 years lifetime) Infrared communication Memory capacity for 2 x 24,000 measurements Fully protected against effects of indirect lightning No vented cable required
Accuracy	Temperature compensated pressure transducer Accuracy 0.1% FS (depth) Accuracy 0.1C FS (temperature)
Specific features	Maintenance free Easy installation in borehole Anti-vandalism borehole cap Different sample modes for pump tests
EnviroMon	Windows '95 compatible Barometric compensation wizard Export to spreadsheet programs Direct or future start

Table D.2.3 Technical Specifications of TD-Diver

Products No.	DI220
Calibrated range	500 cm water column
Usable range	400 cm water column
- Accuracy	0.1% FS *
- Resolution	0.2 cm
Temperature range	-20°C to 80°C
- Accuracy	0.1°C
- Resolution	0.01°C
- Compensation range	-10°C to 40°C
Sample rate	0.5 sec tot 99 hrs **
Memory	2x24,000 measurements
Material	Stainless steel (AISI-316L)
Battery life	8-10 years
Dimensions	Ø 22 mm, length 23 cm
* Temperature fully compensated ** Different sample modes available for pump tests	

2.5.2 Langat River

The automatic surface water level instrument installed in the Langat River was a self-recording (automatic) water level monitoring equipment with data logger by pneumatic pressure sensor having adequate accuracy (with a resolution of 0.5 cm in 10 m measuring range). Additionally, the structure of the surface water level instruments should allow easy measurement of water level and should not be affected by climatic conditions such as rain and thunder, clogging by sediment and mischief by people or intruders. In this consideration, the SEBA PS-Insider with the following specifications was selected.

SEBA PS-Insider

(1) Principle of Measurement

The SEBA pressure sensor pneumatic gauge type PS-Insider is used for accurate water level measurements. From an integrated mini-compressor with storage tank, air is directed via a proportioning valve and the pressure transmission pipe into the water. The pressure within the pipe corresponds to the static pressure of the water column (h) above the outlet orifice and thus serves as measured variable for the level position. This static pressure of water column is transmitted to a high precision, temperature compensated pressure sensor. In case of water level fluctuation the pressure sensor sends respectively changed output signal. This output signal, depending on the instrument type, is recorded on a data logger or transferred to an electronically driven servo motor, which moves the connected writing device to the corresponding actual water level.

(2) Technical Specifications

(a) Size of PS-Insider

Housing: steel-plate (IP 65), 205(B) ×180(H) ×440(T) mm

Weight: 7 kg

(b) Recording of measuring values with pressure sensor

Accuracy: 0.05 % = 0.5cm at 10 m measuring range

Measuring range: 0 up to 2.5m, 5m, 7.5m, 10m, and 15m

Output: 0-1 V – temperature compensated with microprocessor

Operation temperature: -20°C up to +50°C

Registration of measuring values: with data logger MDS Insider

(c) Actual measuring value indication

Power supply: battery operation / 12 V

Proportioning valve: with infinite adjustment for adjustment and survey of gas quantity and gas flow

Mini-compressor: integrated with this type

Air storage tank: 3 litre for this type

Pressure transmission pipe: for outside or earth laying, plastic material 11mm in diameter, 6mm in inside diameter. With protective casing, 300m of maximum length

Automatic purging mechanism: regular purging of the pressure transmission pipe prevents silting and mudding up of the outlet orifice. With a rotary switch up to 8 different purging intervals can be selected (i.e., 6, 12, 24h, 2, 4, 8, 16 days)

2.6 Manual of Surface Water Level Instruments

2.6.1 Manual of Data Retrieval for TD-Diver

To retrieve the data from the TD-Diver (SWL1, SWL2, SWL3, SWL4 & SWL5), the following procedure should be carried out.

(1) Check the current water level indicated at the stick gauge, and take note of the water level value.

(2) Remove the Diver from the housing.

(3) Connect the read out unit to the PC/laptop, and turn on the computer.

(4) Prompt to ‘EnviroMon’ software, then open the ‘Logger Setting’ window.

(5) Open the protecting cap of the Diver and plug it on the appropriate place of the read out unit.

(6) Make sure there is no sand or dirt dropped into the protecting cap and the read out unit.

(7) Ensure the read out unit is connected to the correct serial port and select this port in the ‘EnviroMon’.

(8) Press on the ‘Read Logger Setting’ button.

(9) Double-check the instrument’s serial number, which is indicated in this window and at the Diver. (The S.N. should tally)

(10) At the main window, click on the ‘Data Control’ button.

(11) In the 'Data Control' window, press the 'Read Data from Logger' button.

(12) To save the data, press 'file' menu in the main window, and select 'Save Current File As'.

(13) Write the filename in such format as: (Station No.)(Date: day, month). Mon

(14) For example: If you save the data for station SWL4 on 6th December 2000.

(15) The file name should be: SWL40612.Mon

(16) Select 'file' menu in the main window, and select 'exit'.

In order to prevent the overflow of memory, the following procedure should be carried out in case of exceeded period of half a year.

(1) Check the current water level indicated at the stick gauge and take note of the water level value.

(2) Remove the Diver from the housing.

(3) Connect the read out unit to the PC/laptop, and turn on the computer.

(4) Prompt to 'EnviroMon' software, then open the 'Logger Setting' window.

(5) Open the protecting cap of the Diver and plug it on the appropriate place of the read out unit.

(6) Make sure there is no sand or dirt dropped into the protecting cap and the read out unit.

(7) Ensure the read out unit is connected to the correct serial port and select this port in the 'EnviroMon'.

(8) Press on the 'Read Logger Setting' button.

(9) Double-check the instrument's serial number, which is indicated in this window and at the Diver. (The S.N. should tally)

(10) Press the 'stop' button to stop the Diver.

(11) At the main window, click on the 'Data Control' button.

(12) In the 'Data Control' window, press on the 'Read Data From Logger' button.

(13) To save the data, press 'file' menu in the main window, and select 'Save Current File As'.

(14) Write the filename in the following format:

(15) (Station No.)(Date: day, month). Mon

(16) For example: If you save the data for station SWL4 at 6th December 2000.

(17) The file name should be: SWL40612.Mon

(18) Press on the 'Logger Setting' button again, then press 'Start at…' button. And set the time to start the logger.

(19) Select 'file' menu in the main window, and select 'exit'.

2.6.2 Manual of Data Retrieval for SEBA PS-Insider Water Level Data Logger (SWL6)

To retrieve the data from SEBA PS-Insider Water Level Data Logger (SWL6), the following procedure should be carried out.

(1) Plug in the interface-cable to the SEBA PS-Insider and the laptop/PC.

(2) Restart the laptop in MS-DOS mode. (This can be done by pressing F8 key right after the laptop is turned on and before Windows boots up.)

(3) *Never run MS-DOS mode under the Windows background

(4) To start the "Operate" software, type C:\seba\operate\operate, then press 'Enter'.

(5) Move the cursor to menu "read-read and new start", and then press 'Enter'.

(6) Enter to continue.

(7) Key in the filename for output file. The filename should be in this format: SWL6ddmm.152 (dd: date, mm: month)

(8) Press any key. The data now is downloaded to the computer.

(9) Move the cursor to "info-end of program", press 'Enter'.

(10) You can view your retrieved data through the MGMDS and MLMDS.

2.7 Periodic Maintenance of Surface Water Level Equipment

2.7.1 Station SWL-1 to SWL-5 (Paya Indah Wetland)

Periodic maintenance of Station SWL-1 to SWL-5 should be carried out by the following procedure.

(1) Clear the vegetation or rubbish stuck at the water level station.

(2) Check the filter gauge fitted to the HDPE pipe (white pipe). Use a normal soft brush to clear the vegetation (algae) and mud on the filter gauge.

(3) Check the outer PVC pipe (whether it is clogged). If necessary, pull the PVC pipe out from the water and clean it.

(4) Check the sediment accumulated above the concrete base. If the sediment accumulated is too thick, clear the sediment.

(5) Clean the outside and the circulation holes of DIVER with a soft cloth and rinse with freshwater. (DO NOT USE SHARP OBJECT TO CLEAN THE DIVER)

(6) Use acid solutions only when the Diver is extremely dirty and other cleaning methods have failed.

2.7.2 Station SWL-6 (Langat River)

Periodic maintenance of Station SWL-6 should be carried out by the following procedure.

(1) Before retrieving data from the logger, check the battery capacity by pressing the battery indicator button on the PS-Insider. It is recommended to double check the battery voltage and current by using a multi-metre. Replace the battery with the spare battery **(make sure the battery is fully charged)**.

(2) Activate the purging by pressing on the purging button; consequently observe the river where the nozzle is placed. Many bubbles will emerge right after the purging.

(3) (If there is no bubble emerging, it means that the nozzle might be clogged. Clear the objects stuck at the nozzle.)

(4) Check all the G.I. pipe connection to make sure it is well joined.

2.8 Flow Measurement for Data Conversion from Water Level to Flow Rate

2.8.1 Purpose of Flow Measurement

The purpose of flow measurement is to estimate flow rate based on the relation between water level and flow rate. In general, it is difficult to measure the flow rate of stream water directly. Therefore, the flow rate should be estimated by the rating - curve which shows the relation between water level and flow rate, as shown in **Figure D.2.3**.

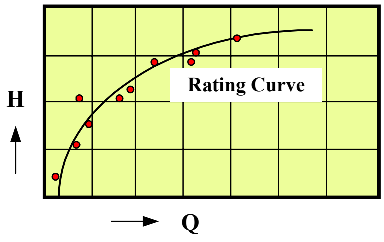

Figure D.2.3 Rating Curve

2.8.2 Methodology

To measure the flow late directly, there are some methods such as volumetric method, flow rate formula using weir, velocity-area method using float (or flow metre), dilution method and so on. In general, the velocity-area method is used. The velocity can be measured by flow metre as shown in **Figure D.2.5**. The depth for measurement of flow metre should be determined according to the water depth in each point (distance of each point is 0.5m). The surface water velocity can be estimate by the average velocity. The area of profile of stream where the surface water velocity was measured should be measured by staff gauge as shown in **Figure D.2.4**. Flow rate can be obtained by the following formula.

$Q=Vm\times(S_1+S_2)/2$; where Vm is average flow velocity, S_1 and S_2 are the areas of profile of the stream.

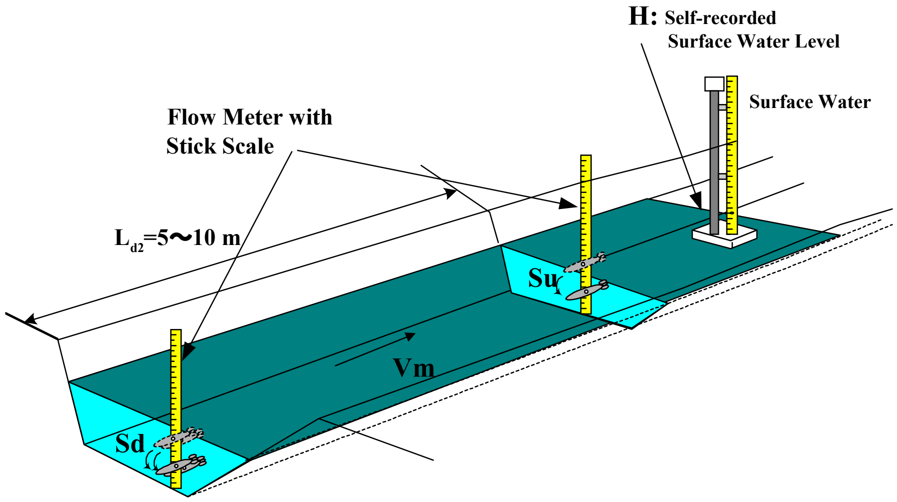

Figure D.2.4 Estimation of Flow Rate

2.8.3 Location of Measurement

- SWL-1 (Inflow)
- SWL-2 (Inflow)
- SWL-3 (Inflow)
- SWL-5 (Outflow)

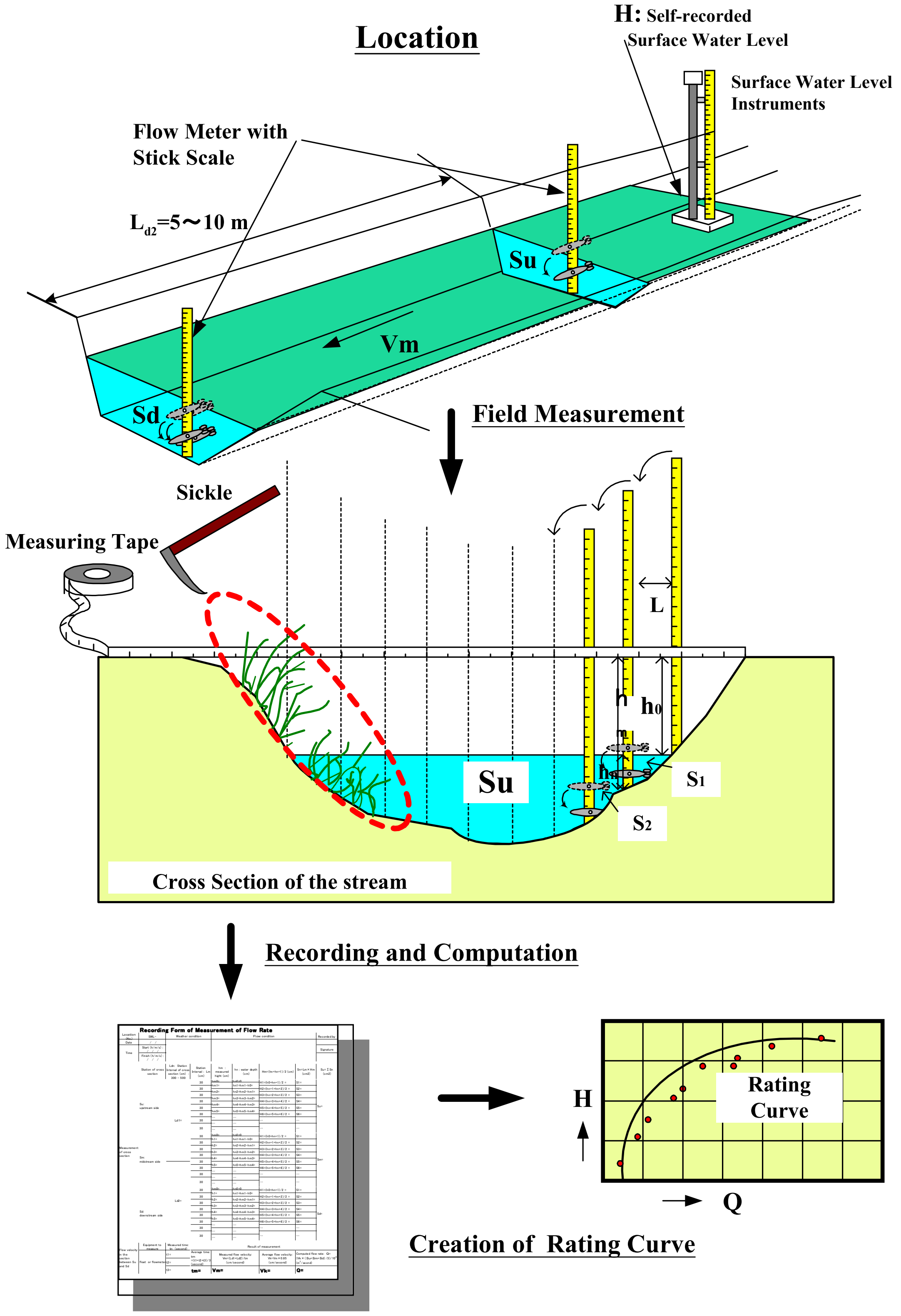

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Figure D.2.5

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Field Measurement of Flow Rate and Creation of Rating Curve

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2.8.4 Frequency of Measurement

To create the rating curve, it is necessary to measure more than ten times during rainy season and draught season after installation work (see **Photograph D.2.1**).

2.8.5 Measurement at SWL-4

SWL-4 (outlet of Lotus Lake) is located in the downstream side of water control gate. To control the water level of Lotus Lake by two (2) sluice gates (outflow of southern edge and outflow of western edge), it is necessary to measure the height of the sluice gate when opened (during rainy season) in relation with the water level of SWL-5 (see **Figure D.2.6**).

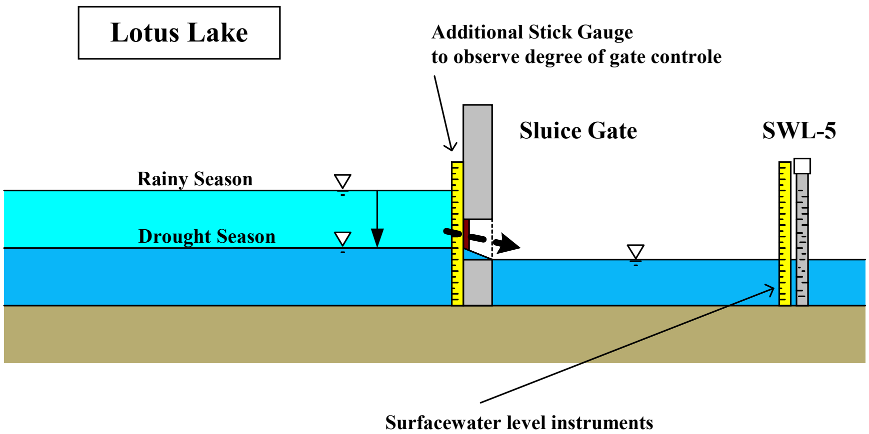


Figure D.2.6 Field Measurement of Flow Rate Creation of Rating Curve

SWL-1

SWL-2

SWL-3

SWL-5

Photograph D.2.1 Measurement of Flow Rate by Cooperation with JPS Gauging Team (Date: 12/12/2000)

The following items relating to installation work of water level equipment and maintenance work are summarised in the **Data Book**. The latest recorded data of surface water level from November 2000 until June 2001 are presented in the **Data Book D.2.4**. Among these items, flow rate measurement is necessary in the sense of estimation of flow rate from the recorded water level, as given in the **Data Book D.2.7 and D.2.8**.

- **Data Book D.2.1 :** Work Schedule for Installation of Surface Water Instruments
- **Data Book D.2.2 :** Location Map and Installation Record
- **Data Book D.2.3 :** Structural Drawing of Surface Water Instruments
- **Data Book D.2.4 :** Data Calibration and Recorded Data by Surface Water Instruments
- **Data Book D.2.5 :** Commissioning and Training on Surface Water Level Instruments
- **Data Book D.2.6 :** Recorded Data of Surface Water Level Instruments
- **Data Book D.2.7 :** Measured Data of Flow Rate by JPS
- **Data Book D.2.8 :** Estimation of Flow Rate

3. CONDITION OF THE BASIN

3.1 Langat River and Its Tributaries

The Langat River Basin occupies the south and southeast parts of the State of Selangor. It is about 78 km long and ranges from 20km to 51.5 km wide. It has a total catchment of 1,987.8 km^2 (The study area including the Sepang River Basin covers approximately 2,750.2 km^2). The source of the Langat River is at the Pahang-Selangor border where hilly terrain reaching up to 1,500 m above mean sea level can be found. It finally drains into the Straits of Malacca on the mangrove coastline of Southwest Selangor. As shown in **Figure D.3.1**, the major tributaries of the Langat River are the Semenyih River and the Labu River. The general flow of the Langat River is north and northeast towards the south and southwest in the eastern half of the basin and westward on the western part.

3.2 Composition of the Basin

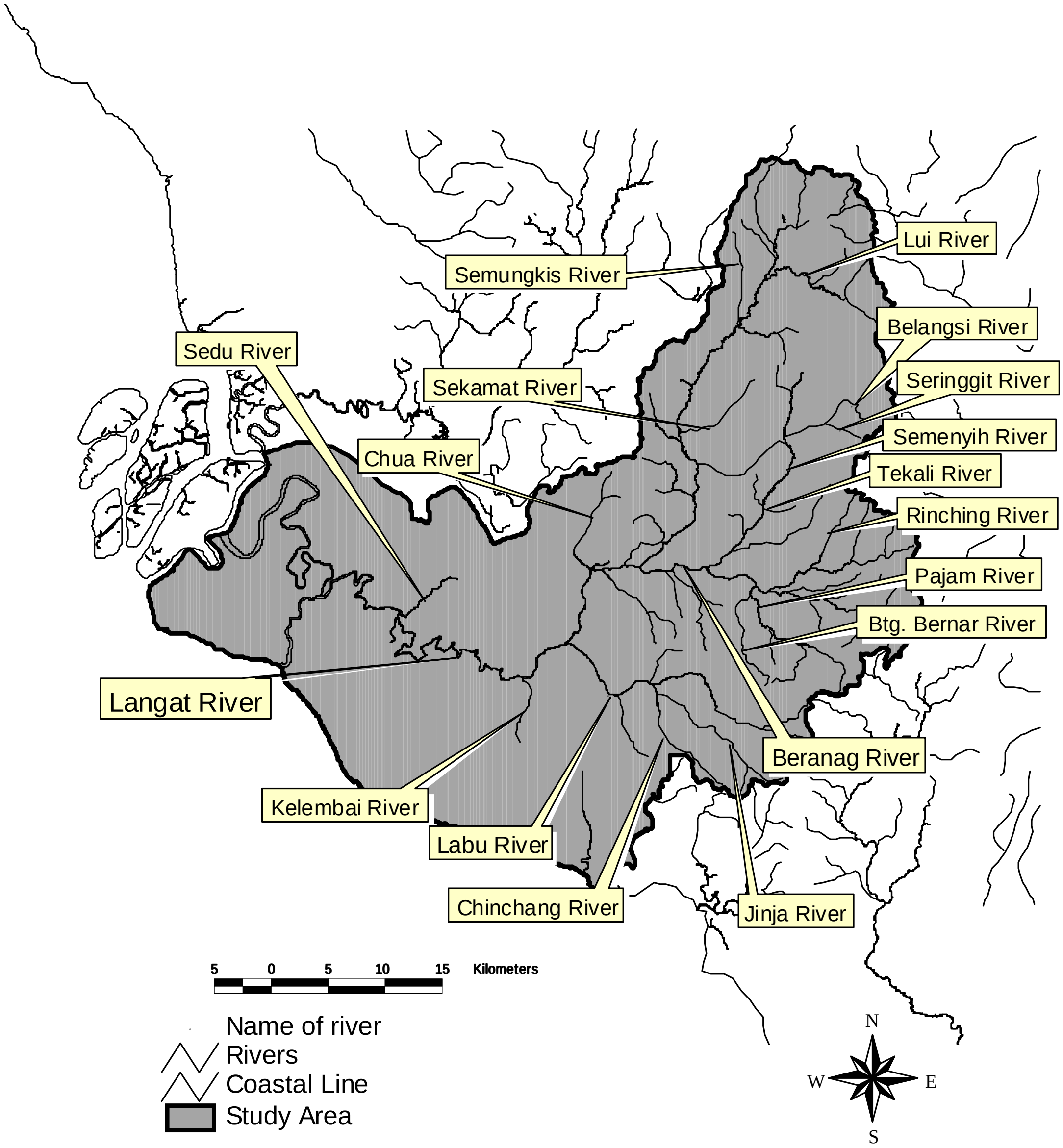
From the morphological point of view, the Langat River Basin can be divided into the eastern part (upper stream) and the western part (lower stream). The eastern part of the basin includes the source of the Langat River where it gathers most of the run-off water from the hilly and mountainous areas. The western part is located in the coastal region where the Langat River meanders in large loops.

According to information from the Drainage and Irrigation Department (DID), there is no authorised data regarding composition of the Langat Basin such as basin boundary. Therefore, the JICA Study Team defined a sub-basin to be covered by several gauging stations based on topographical property and existing documents, as shown in **Figure D.3.2**. In addition, in order to examine the water balance in the Klang River Basin, this river basin was divided into three (3) sub-basins.

3.3 Longitudinal Profile and Cross Section

There is no recent survey data regarding longitudinal profile in the Langat River. As shown in **Figure D.3.3**, the river indicates an almost flat gradient in the lower reach of 90 km from the mouth. In addition, by field reconnaissance, river sediments can be estimated as in **Figure D.3.3**.

Figure D.3.3 shows also changes of cross section based on the measurement data at Kajang and Dengkil for a few years. Naturally formed trapezoidal cross sections dominate.



Source: Information Provide by JPS Ampang.

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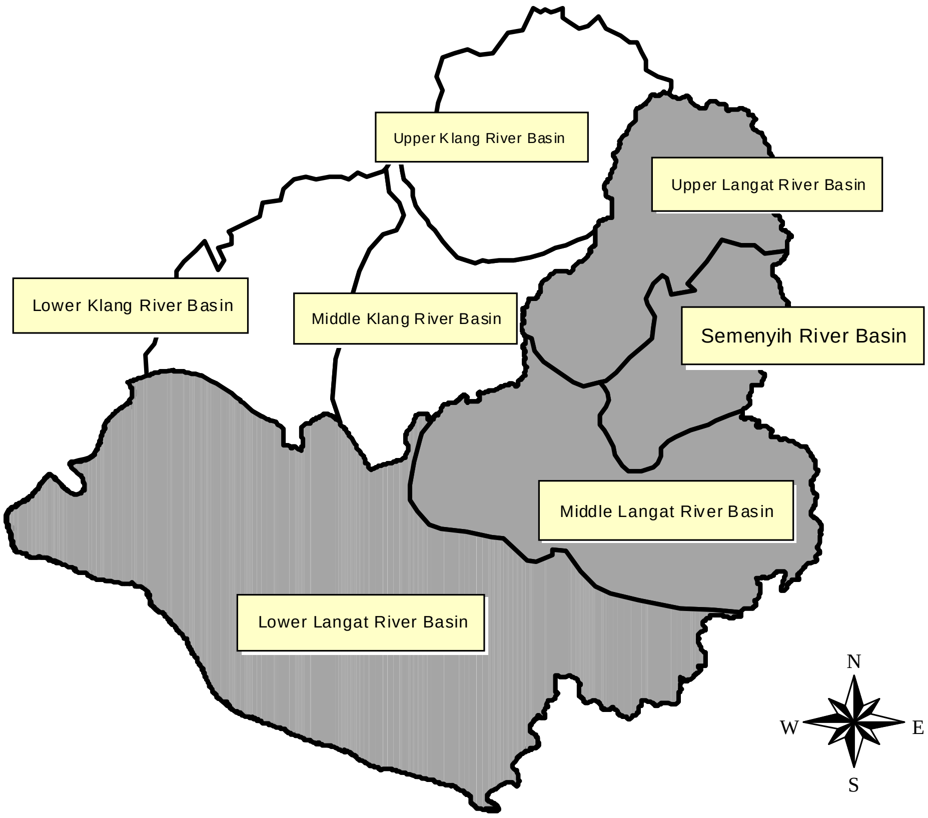
Figure D.3.1

Langat River and its Tributaries



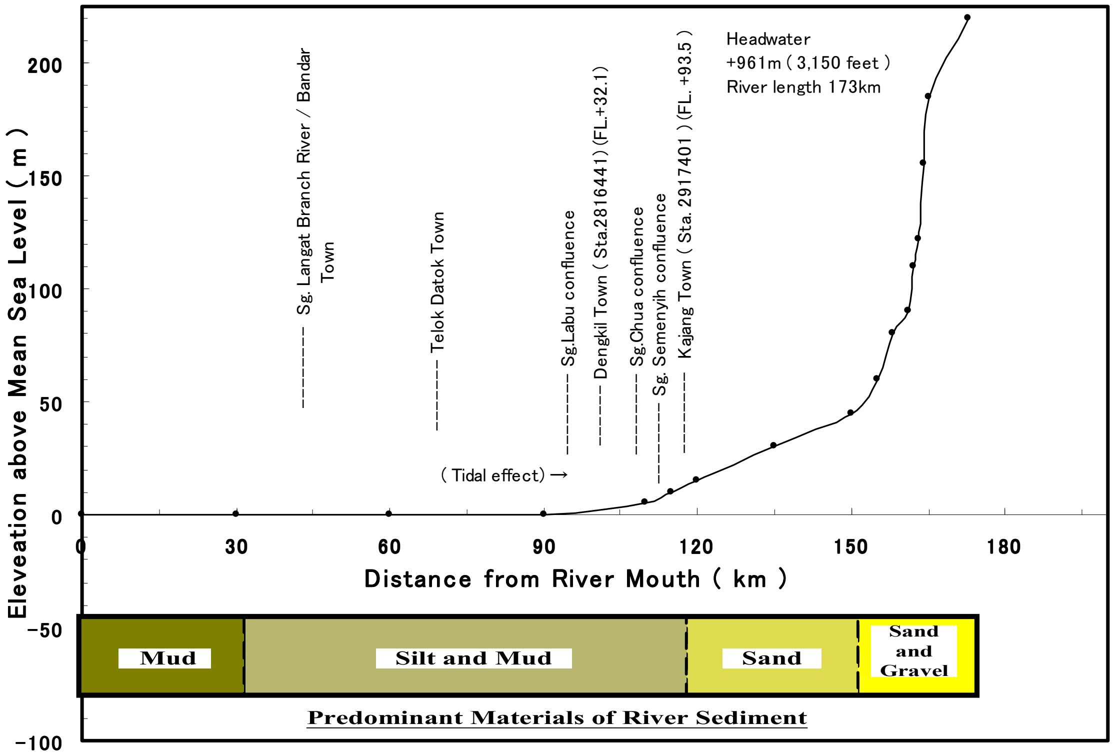
Sub-basin Boundary in the Langat River Basin
Sub-basin Boundary in the Klang River Basin

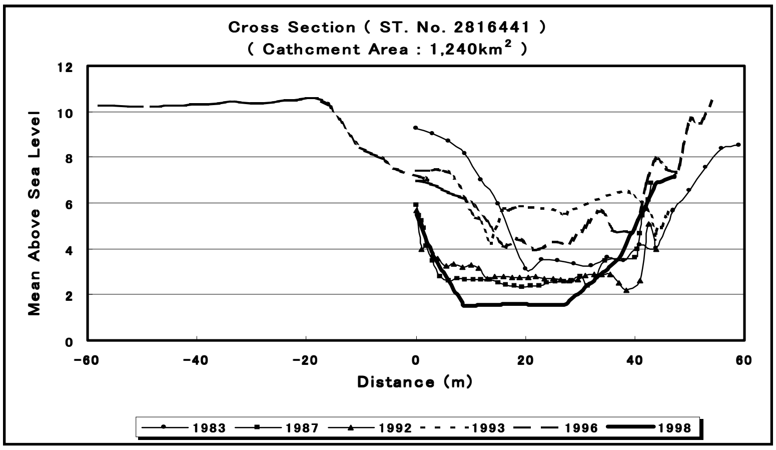
Name of River	Basin Area (km^2)	Name of Sub-Basin	Sub-Basin Area *4) (km^2)
Langat	2750 .1 *1) (2500 *2))	Upper Langat	382.5
		Semenyih	254.2
		Middle Langat	644.3
		Lower Langat	1469.1
Klang	1288.4*3)	Upper Klang	458.2
		Middle Klang	253.8
		Lower Klang	576.4

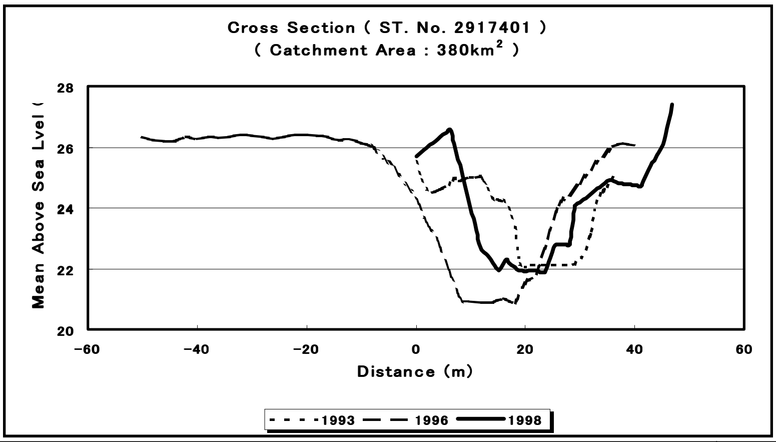
Note:
*1) : Estimated by JICA Study Team, namely " Study Area "
*2) : DID. The Multimedia Super Corridor (MSC) Macro Drainage Master Plan, Chapter 3-5. July. 1999
*3) : JICA. The Study on The Flood Mitigation of the Klan River Basin, Supporting Report Volume 1. 1989
The whole Klang River Basin is divide into the following three aub-catchment areas:
(1) Upper Basin is the upper catchment area covering from the Sulaiman Bridge;
(2) Middle Basin is the middle catchment covering from Puchong Drop to Sulaiman Bridge;
(3) Lower Basin is the lower catchment area from Puchong Drop.
*4) : Estimated by JICA Study Team
*5) : Land use for Klang River was estimated by JICA Study Team based on *3)

Figure D.3.2

Composition of the Langat River Basin







Source:
Longitudinal Profile: JICA, National Water Resources Sectoral Report Vol. 5, 1982.
Cross Sections: Data Provide by JPS Ampang.

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Figure D.3.3

Longitudinal Profile and Cross Sections in the Langat River

3.4 Vegetation, Land Cover and Land Use

In general, agriculture and forest are the dominant types of land use in the Langat River Basin. The classification of land use types (in Sq. km.) in comparison with 1995 and 1998 in the Langat River Basin is shown in **Figure D.3.4**. Oil Palm is the main land use type at 30.1% in 1998, followed by forest at 18.3% in 1998, and Built-up Area at 16.2% in 1998. Built-up area has increased in 1998 in comparison with 1995. On the contrary, Oil Palm, Rubber and Swamps areas tend to decrease in 1998 in comparison with 1995.

3.5 Existing Structures

3.5.1 Dams and Reservoirs

Two dams are located in the Study Area. As shown in **Figure D.3.5**, the Langat Dam located in the upstream of the Langat River has an active storage capacity of 30 million m^3. Semenyih Dam located in the Semenih River has an active storage capacity of 41 million m^3. These dams act as regulated reservoirs and release water whenever water level of the Langat River is low.

3.5.2 Water Intakes

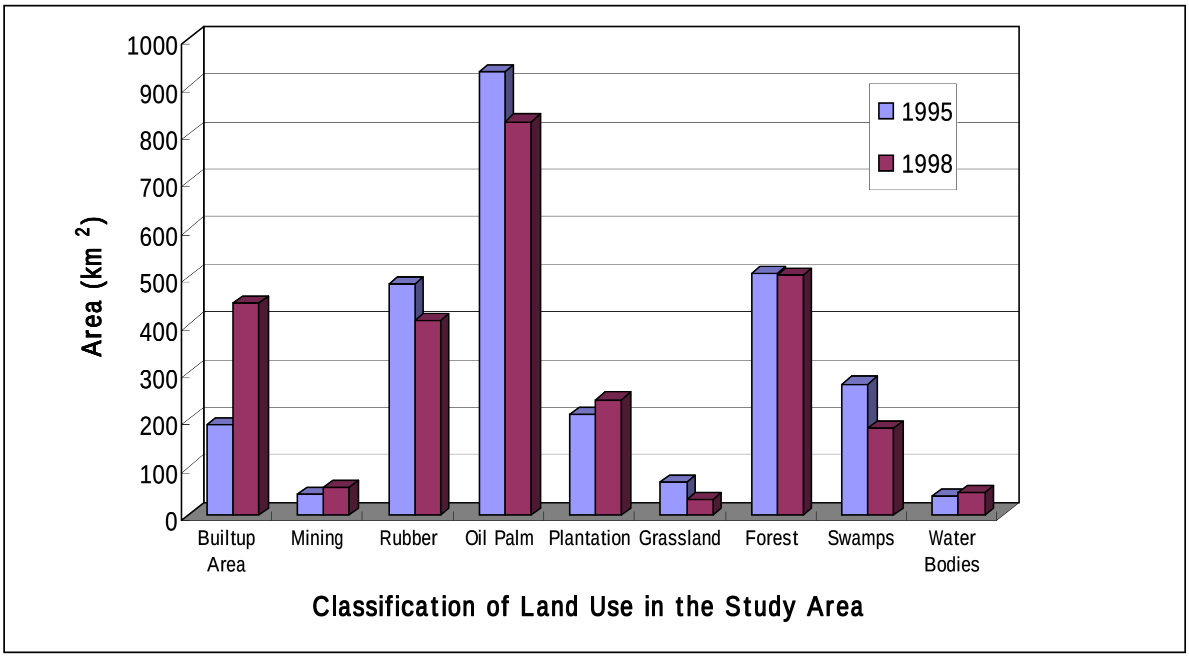
Eight (8) water intakes (water treatment plants) are located in the Study Area and produce more than 200 MGD (million gallons per day) of treated water (see **Figure D.3.6**). The Langat plant supplies 85 MGD of treated water to areas in Cheras, Pandan, and Hulu Langat, while the Cheras Mile 11 plant supplies 6 MGD of treated water to areas in Balakong, parts of Cheras and Kajang. The Bukit Tampoi treatment plant supplies 6.9 MGD of treated water to areas of Dengkil. One water treatment plant is located on Semenyih River with Semenyih dam regulating the flow to the Semenyih treatment plant. The output capacity of this plant is 120 MGD and supplies treated water to areas in Semenyih, Petaling Jaya South, Bukit Gasing, Shah Alam, Klang and Subang Jaya. Salak Tinggi water treatment plant is located at Salak Tinggi and draws raw water from Sungai Labu. The operator of these plants, Puncak Niaga, constantly monitors the quality of the raw water at the intake points.

3.5.3 Lakes and Ponds

According to the previous study, total area of lakes and water bodies, which are mainly located in the lower part of the Langat River Basin, account for 13.13 km^2. A part of lakes and ponds are located in the trace of a former mining area.

3.5.4 Swamp

As presented in **Figure D.3.4**, the swamp area, including marshlands and wetland forest, is mainly located in the lower part of the Langat River Basin, and covers 182.4 km^2 in 1998. Due to urbanisation in the lower part of the Langat River Basin, the swamp area has been drastically decreasing in recent years.



Classification of land use	1995		1998	
	Area (km^2)	%	Area (km^2)	%
Builtup Area	190.5	6.9	446	16.2
Mining	42.4	1.5	57.8	2.1
Rubber	484.6	17.6	409.1	14.9
Oil Palm	929.8	33.8	827.3	30.1
Plantation	210.6	7.7	242.2	8.8
Grassland	69.8	2.5	33.2	1.2
Forest	507.1	18.4	504.2	18.3
Swamps	275.1	10.0	182.4	6.6
Water Bodies	40.2	1.5	47.9	1.7
Total	2750.1	100.0	2750.1	100.0

Source: Land use for the Study Area (the Langat River Basin) was estimated by JICA Study Team based on land use map in 1995 and 1998 by DID

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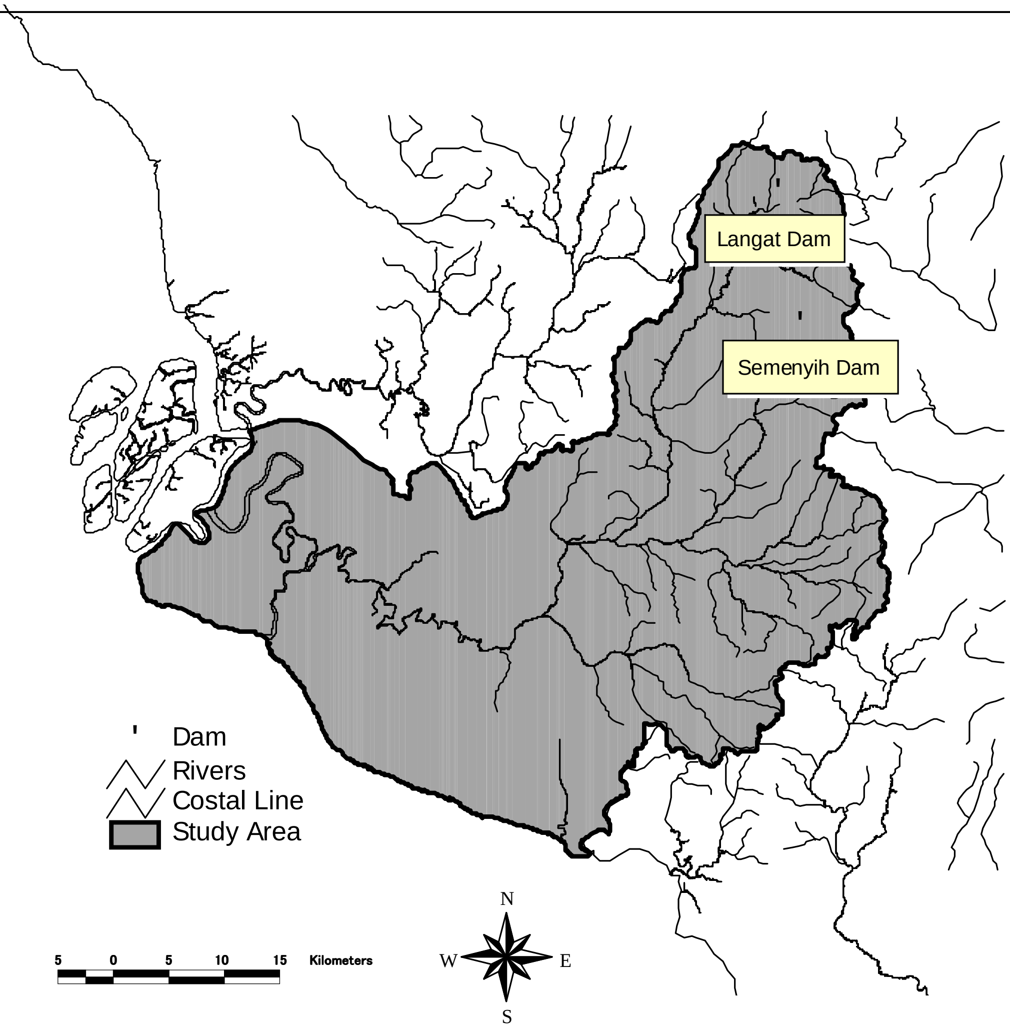
Figure D.3.4

Land Use Type in the Langat River Basin



List of Existing Dam in the Langat River Basin

Name	Langat Dam	Semenyih Dam
River	Langat River	Semeyih River
Purpose	Domestic and industrial water supply	Domestic and industrial water supply
Organisation	SWW	SWW
Catchment Area (km^2)	41	54
Active Storage Capacity (10^6 m^3)	-30	41
Net Supply Capacity (10^3 m^3/y)	32	44

Source: Government of Malaysia, "NATIONAL WATER RESOURCES STUDY, MALAYSIA STATE REPORT VOL.3 SELANGOR ", OCTOBER, 1982. Remarks: ( ) assumed

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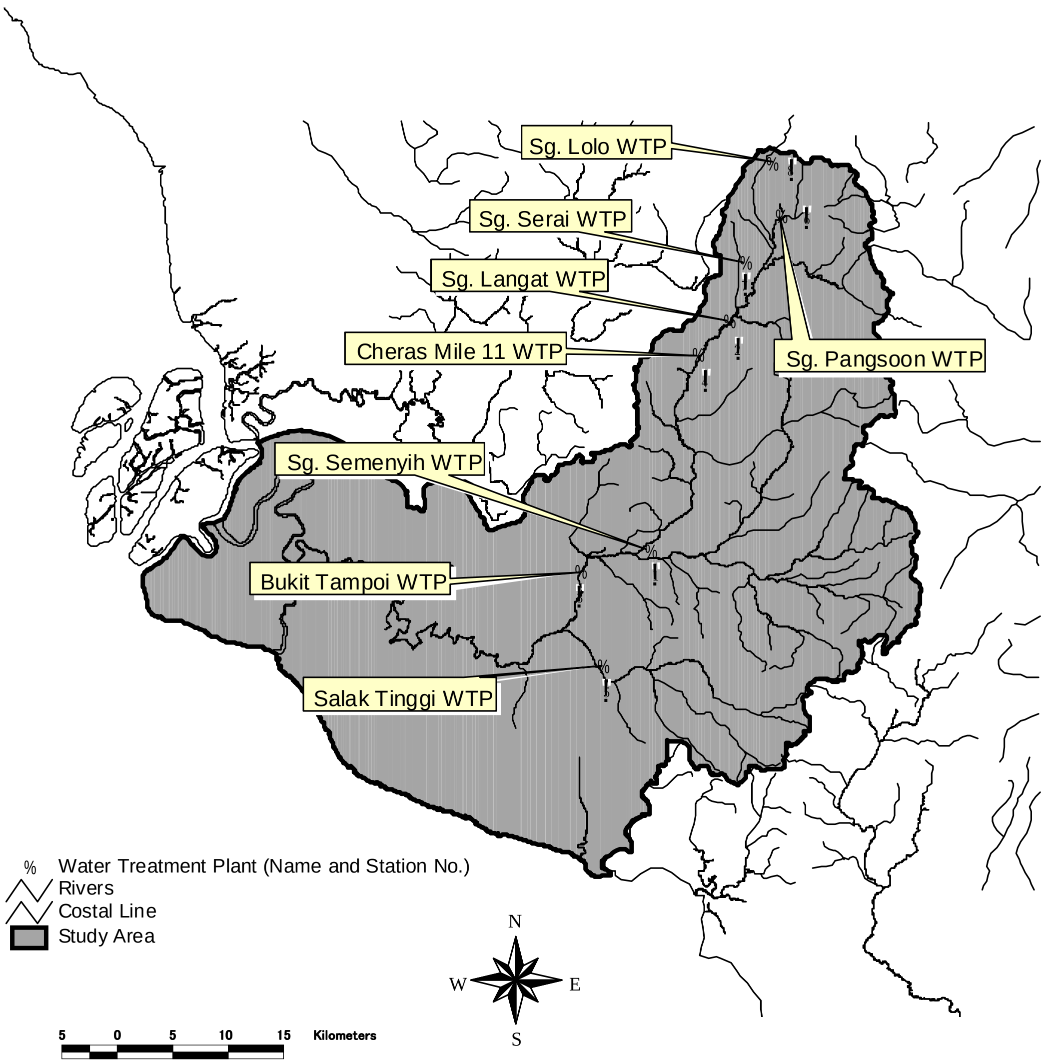
Figure D.3.5

Location of River Facility in the Langat River Basin



List of Water Treatment Plant (Water Intakes) in the Langat River Basin

	Name of Water Treatment Plant (Water Intakes)	Designed Capacity (MGD)
①	Sg. Semenyih WTP	120
②	Sg. Langat WTP	85
③	Bukit Tampoi WTP	6.9
④	Cheras Mile 11 WTP	6
⑤	Salak Tinggi WTP	2.4
⑥	Sg. Pangsoon WTP	0.4
⑦	Sg. Serai WTP	0.2
⑧	Sg. Lolo WTP	0.09

Source: Information from JPS Shah Alam

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Figure D.3.6

Location of Water-Intakes in the Langat River Basin

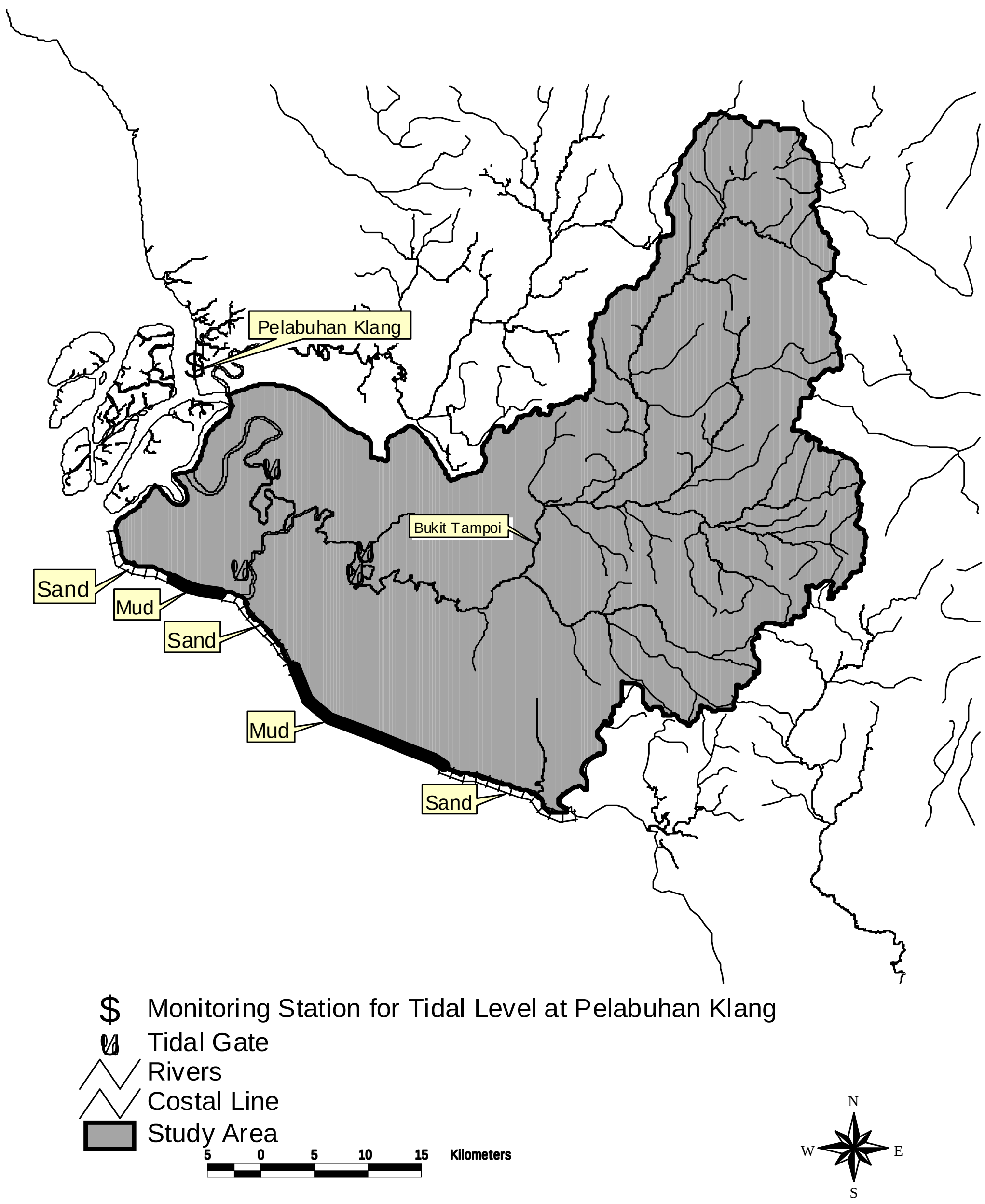
3.6 River Channel and Riverine Conditions

With reference to the previous study, river channel and riverine conditions are as follows:

In the eastern part (upper stream), the Langat river course and several of its large tributaries run in medium-grained crystalline Genting Sempah Micro-granite. It then flows south-west for about 15 km through coarse-grained porphyritic granite terrain of the Kuala Lumpur Granite. Along this stretch, the main Langat river course is largely controlled by the 040° fault zone, which cut the granite. The Langat River then passes through rocks of the Kajang Formation around where Kajang Town is located. It continues to the south and southwest and flow through the terrain occupied by folded sandstone and shale of the Kenny Hill Formation. At this juncture, which is about the mid-point, the Semenyih River and several large tributaries such as Batangsi River, Rinching River, Beranang River, Lenggeng River and Pajam River join it on the right side. All these streams drain areas occupied by the coarse-grained Kuala Lumpur Granite. Along the west and WSW the Langat River drains the terrain occupied by the sandstone and shale of the Kenny Hill Formation after the confluence with the Semenyih River and flows into the Malacca Strait. On reaching the western Langat River Basin, the Langat River enters the coastal alluvial plain, which is flat, and swampy at most places. It meanders in broad loops and with angled turns over terrain occupied by the young alluvial sediment, which are composed mainly of soft clay, and peaty clay and peat. The bedrock underlying the alluvium of the Western Langat Basin is composed either of the weakly metamorphosed sandstone and shale of quartz-mica or graphitic schist of the Hawthornden Formation. The channels of streams that drain the upper reaches of the Langat River Basin are underlain by coarse sediment consisting of sand, pebbles, cobbles and boulders of fresh and weathered rocks. It is common to find granite rocks along the banks as well as along the streambeds. At the lower reaches, the streambeds are covered with sandy clayey sediment, which is part of the Pleistocene Alluvium. The main streams such as those of the sub-basin of Semenyih, Langat, Beranang at the upper and middle reaches often contain cassiterite (tin ore) bearing alluvium. Such cassiterite bearing alluvium has been mined quite extensively in the past (during the 1950's to 1970's). The mainstream channels at the lower reaches and the western part of the Langat River Basin are sites of deposition. Sediments brought down from the upper and middle reaches are in part deposited temporarily or permanently at these sites. Floodwaters often overflow the banks, and leave levee deposits along the banks and along the wide flood plains.

3.7 River Mouth Condition and Tidal Effect

Presently, there is no survey data regarding river mouth condition and tidal effect. However, according to the existing study and related information from the DID Selangor office, tidal effect along the Langat River extends between Kg. Sabohan Bagan (90km from the mouth) and the lower stream of Bt. Tampoi where the water treatment plant (water intake) is located (see **Figure D.3.7**).



Source: Information from DID, National Coastal Erosion Study, Final Report Volume I, August 1985, Unit Perancang Ekonomi Jabatan Perdana Menteri Kuala Lumpur, Malaysia

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Figure D.3.7

Coastal Condition and Tidal Effect in the Langat River Basin

3.8 River Water Quality

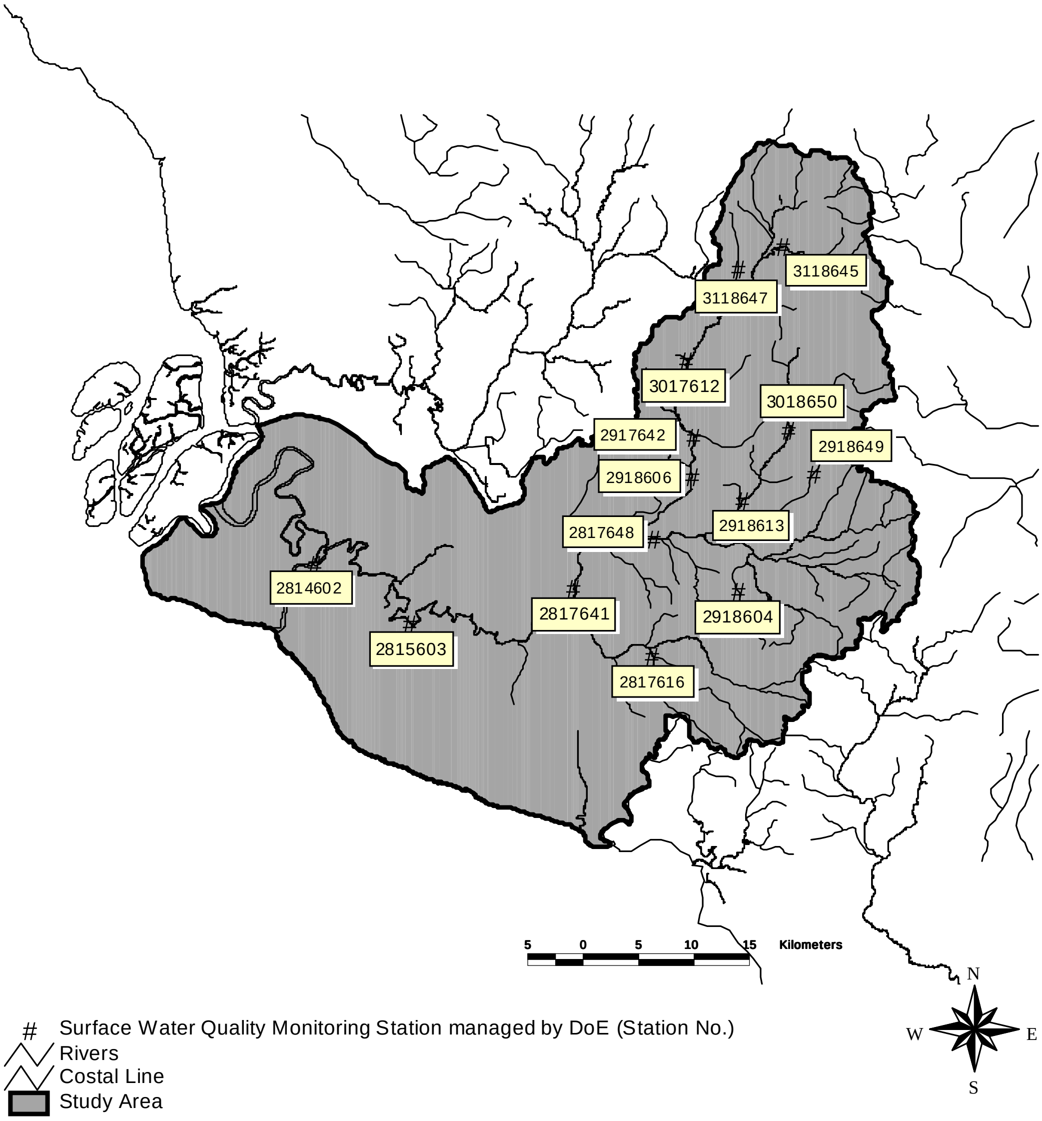
There are fourteen (14) monitoring stations for river water quality established by the DOE in the Study Area. Eight (8) stations are situated in the Langat River Basin, five (5) stations are situated in the Semenyih River Sub-Basin and one is located in the Labu River Sub-Basin (see **Figure D.3.8** and **Table D.3.1**).

Table D.3.1 Water Quality Monitoring Station Managed by DOE in the Langat River

ASMA Code	Station Number	Year Records Available	Location	Distance from Estuary (km)	Latitude	Longitude	Coordinates on GIS Map	
							X	Y
IL01	2814602	1988-1999	Kampung Bandar (end of road)	4.19	N 02 51.940	E 101 26.379	382989.57	317290.11
IL02	2815603	1988-1999	Teluk Datok. Near Banting town.	33.49	N 02 48.936	E 101 30.596	392545.26	310978.64
IL03	2817641	1988-1999	Bridge at Kampung Dengkil	63.43	N 02 51.390	E 101 40.879	409179.23	314694.74
IL04	2918606	1988-1999	Langat River, Bridge near West Country Estate	81.14	N 03 57.846	E 101 47.025	421094.35	326668.84
IL05	2917642	1988-1999	Langat River, Kajang	86.94	-	-	421330.29	330856.83
IL06	3017612	1988-1999	Langat Rvier, Junction to Serdang, Cheras Bt.11	93.38	N 03 02.432	E 101 40.473	420563.48	338937.87
IL07	3118647	1988-1999	Langat River, Bridge near Bt. 18 town	113.99	N 03 09.990	E 101 50.903	425795.51	348764.90
IL08	2817616	1988-1999	Batang Labu River, Near Salak Tinggi, Simpang 3 to Nilai	67.30	N 02 47.243	E 101 45.099	417142.30	307498.48
IL09	2817648	1988-1999	Semenyih River, Jalan Bangi/Dengkil. Ecoville Medeia City. Bukit Ur	80.82	N 03 53.514	E 101 45.734	417319.26	320062.44
IL10	2918613	1988-1999	Semenyih River,	80.50	-	-	426344.08	324132.46
IL11	3018650	1988-1999	Semenyih River, Kampung Pasir. Semenyih	103.80	N 03 00.535	E 101 52.093	431003.95	331564.66
IL12	2918604	1988-1999	Batang Benar River, Kampung Batang Benar	98.82	N 02 50.896	E 101 49.486	425872.19	314399.81
IL13	2918649	1988-1999	Tributary of Semenyih River,	95.82	-	-	433540.34	326904.79
IL14	3118645	1988-1999	Lui River, Bridge at Kampung Masjid	105.00	N 03 10.409	E 101 52.209	430372.80	351171.51

Source: Unit Perundingan Universiti Malaya, "PROJEK KAWALAN PENCEMARAN AIR: KAJLAN MENGKELASKAN SUNGAI-SUNGAI DI MALAYSIA DRAF LAPORAN AKHIR JILID7: SUNGAI LANGAT ", OGOS, 1999.

According to the present study on river water quality by DOE, as shown in **Table D.3.2**, the main pollutants identified as critical for the Langat River Basin are BOD, DO, ammoniacal-N, coliform counts and TSS. Trace metal parameters are generally within the Class II limits and at present do not pose a serious threat to potable water supply. The major sources of pollution in the Langat River Basin include effluents from the agro-industries (palm oil mills, rubber processing plants), animal farm wastewater (pig farms), manufacturing industries, and domestic sewage that contributes predominantly to BOD and ammoniacal-nitrogen pollution.



Source: Unit Perundingan Universiti Malaya, "PROJEK KAWALAN PENCEMARAN AIR: KAJLAN MENGKELASKAN SUNGAI-SUNGAI DI MALAYSIA DRAF LAPORAN AKHIR JILID7: SUNGAI LANGAT ", OGOS, 1999.

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Figure D.3.8

Location of Surface Water Quality Monitoring Station in the Langat River Basin

Table D.3.2 Classification of the Langat River on Water Quality in 1988-1994

ASMA Code	Station Number	Year Records Available	DOE WQI	HARKINS WQI	LIST 1	LIST 2	LIST 3	Classification		Comments
								Period	Overall	
IL01	2814602	1998-1999		Salinity limit classfication not carried						
		1997-1998								
		1995-1996								
IL02	2815603	1998-1999	III	IV	IV	III	II	IV	IV	DO content is quite low.[Mn],[Al] are of concern
		1997-1998	V	V	V	II		V		V. high BOD, ammonia. Low DO content
		1995-1996	IV	IV	V	III/IV	II	V		V. high BOD,[Hg], [Pb] are of concern
IL03	2817641	1998-1999	III	III	III	III/IV	II	IV	IV	high colifrom counts. [Al] is of concern
		1997-1998	IV	V	V	III	II	V		V. high BOD, ammonia, [Pb], [Mn] are of concern
		1995-1996	IV	IV	IV	V	II	V		V. high BOD, E-coliform counts
IL04	2918606	1998-1999	IV	IV	V	V	II	V	V	V. high BOD, coliform counts, [Mn], [Al] are of concern
		1997-1998	IV	V	V	III/IV	II	V		V. high BOD, ammonia, coliform counts, [Mn],[Pb] are of concern
		1995-1996	IV	IV	V	IV	II	V		V. high BOD, E-coliform counts
IL06	3017612	1998-1999	III	III	IV	III	II	IV	IV	high BOD, ammonia and coliform counts, [Al] is of concern
		1997-1998	IV	IV	V	V	II	V		V. high BOD, ammonia, [Mn] is of concern
		1995-1996	III	III	IV	IV	-	IV		high BOD, ammonia and coliform counts
IL07	3118647	1998-1999	III	III	III	III		II	II	coliform counts are of concern
		1997-1998	III	III	III	III	-	III		BOD of Class IV, however, DO of Class I, [Mn] is of concern
		1995-1996	III	III	III	III	-	III		downgraded because of BOD (Class III) and high coliform counts
IL08	2817616	1998-1999	III	III	IV	IV	II	IV	IV	BOD only marginally above Class III limit, however, high ammonia, E.Coli counts
		1997-1998	IV	V	V	III	II	V		V. high ammonia, BOD, [Mn] is of concern
		1995-1996	III	IV	IV	IV	II	IV		maintained Class IV despite high BOD because DO is of Class II
IL09	2817648	1998-1999	III	III	III	III	-	III	III	[Al] is of concern
		1997-1998	III	III	IV	III	II	IV		high BOD. [Mn] is of concern
		1995-1996	III	III	III	III	-	III		
IL11	3018650	1998-1999	III	III	III	II		II	II	coliform counts are of Class III, however, based on 1 measurement only
		1997-1998	III	II	III	III	II	III		ammonia marginally above Class III limit. [Mn] is of concern
		1995-1996	III	II	III	II	-	II		
IL12	2918604	1998-1999	III	III	IV	III	II	IV	IV	BOD V. high during dry period. DO content high. [Mn], [Al] are of concern
		1997-1998	IV	V	V	IV	II	V		V. high BOD, ammonia, [Pb], [Mn] are of concern
		1995-1996	III	III	IV	III/IV	II	IV		V. high ammonia, BOD, [Hg] is of concern
IL14	3118645	1998-1999	II	II	II	III		II	II	BOD and coliform counts only slightly above Class II & III limit resp., DO high
		1997-1998	III	II	III	III	II	III		BOD marginally above Class III limit. [Mn] is of concern.
		1995-1996	II	II	II	III	-	III		BOD only marginally above Class III limit, high total Coli counts

Note:

WQI: A water quality index (WQI) is a method of combining numerous water quality parameters into one concise and objective value representing the state of the water quality trends. Two water quality indices are used in the above table; the opinion poll DOE-WQI and Harkin'sWQI.

List 1: DO, COD, BOD, SS, Ammnonia, Ph

List 2: Colour, Conductivity, Salinity, Oil/Grease, Detergents, Total Coli., E. Coli., Cd, As Hg, Cr, Pb, Mn, Al, Cu, S, CN, NO3-N, P, Pesticides, Phenole

List 3: Sodium, Boron, Chloride

Source: Unit Perundingan Universiti Malaya, "PROJEK KAWALAN PENCEMARAN AIR: KAJLAN MENGKELASKAN SUNGAI-SUNGAI DI MALAYSIA DRAF LAPORAN AKHIR JILID7: SUNGAI LANGAT ", OGOS, 1999.

4. ESTIMATION OF EVAPOTRANSPIRATION

4.1 Objectives

Evapotranspiration value is used to develop the groundwater model and simulation to estimate water balance relating to groundwater recharge in the Study Area. For this purpose, computation of evapotranspiration using the Penman Method was carried out based on collected meteorological data such as temperature, relative humidity, sunshine hour, wind velocity and related specific constant values in Malaysia.

4.2 Methodology

The methodology and use of result concerning estimation of evapotranspiration are summarised as a Work Flow in **Figure D.4.1**. As presented in **Figure D.4.2**, both the Langat River Basin and the Klan River Basin cover the examination of evapotranspiration. The Klang River Basin is to be supposed as an area of groundwater recharge for the Study Area from the hydrological point of view.

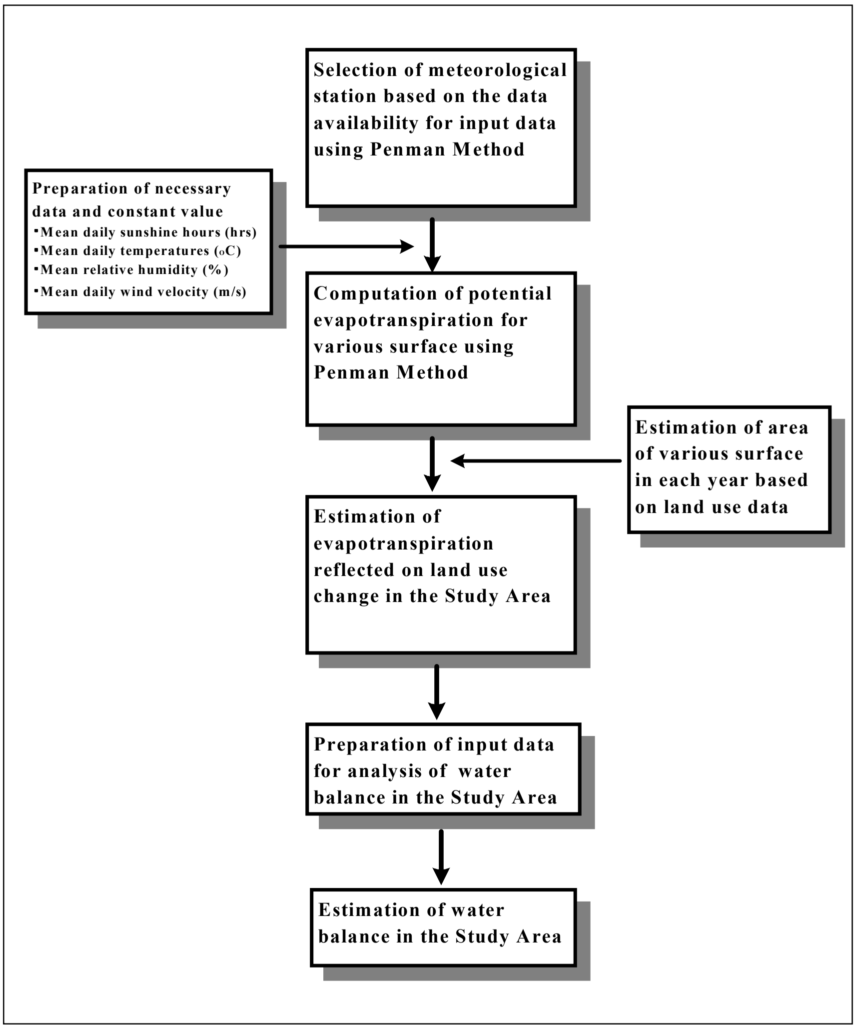
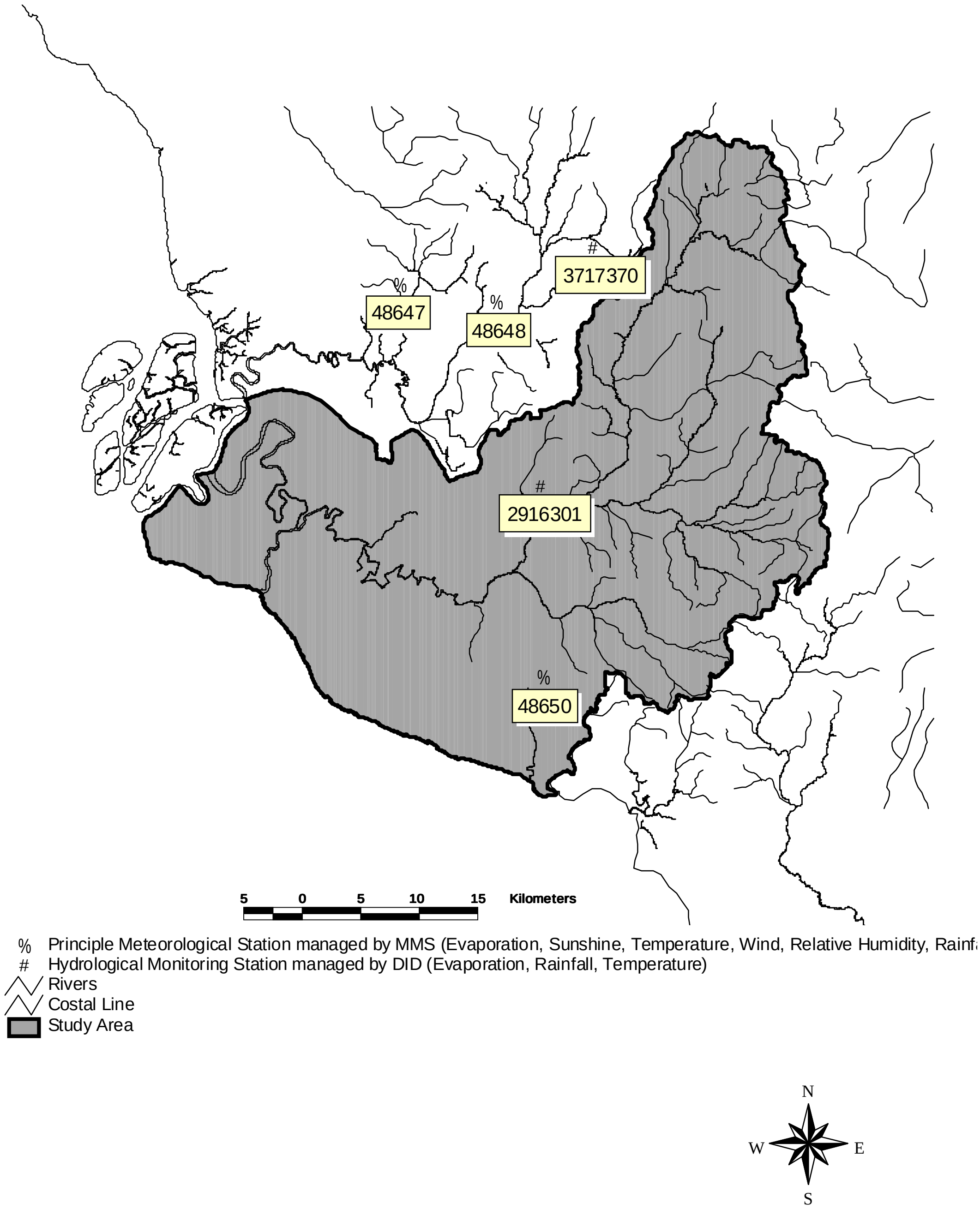


Figure D.4.1 Work Flow for Estimation of Evapotranspiration in the Study Area



Source: Data provided by Drainage and Irrigation Department (DID) and Malaysian Meteorological Service (MMS)

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Figure D.4.2

Selected Meteorological Station for Estimation of Evapotranspiration

4.3 Estimation of Potential Evapotranspiration using Penman Method

4.3.1 Selection of Meteorological Station

With reference to Figure D.4.2, two (2) meteorological stations, Subang (Station No. 48647) and Petaling Jaya (Station No. 48648) are located in the Klang River Basin, and one (1) meteorological station, Sepang/KLIA (Station No. 48650), is located in the Langat River Basin. Although all of these stations have the necessary recorded data for the estimation of evapotranspiration, Sepang/KLIA has the records only from 1998 while Subang is located at the western part of the Klang River Basin. Therefore, Petaling Jaya meteorological station was selected as the most suitable meteorological station for the estimation of evapotranspiration.

4.3.2 Equation of Evapotranspiration by Penman Method

(1) Definition of Evapotranspiration

Evapotranspiration is the sum of evaporation and transpiration where evaporation concerns water evaporating from soils, water surfaces and plants and transpiration concerns water entering the roots and used or transpired by plants. Potential evapotranspiration is defined as the evapotranspiration that would occur if there is adequate soil-moisture supplied at all times, and that is directly related to the amount of radiation energy gained by the evaporating surface corresponding to land use. Among many methods, the Penman Method is used as the most complete theoretical approach for estimation of potential evapotranspiration. The detailed equations and explanations regarding the Penman Method are summarised as follows.

(2) Equation of Evapotranspiration

Due to difficulties associated with direct field measurement of evapotranspiration, many equations of evapotranspiration had been developed such as Blaney-Morin (1942), Thornthwaite (1944), Penman (1948), Blaney-Criddle (1950), Halkias-Veihmeyer-Hendrickson (1955), and Hargreaves (1956). Among them, the Penman equation is based on the most complete theoretical approach, reflecting that evapotranspiration is directly related to the amount of radiation energy gained by the evaporating surface.

Recently, the Penman method is used as a modified Penman method (or Penman equation) in most cases as well as in this study. However, for convenience in preparing this report, the term “Modified Penman Method (or Modified Penman Equation)” will be hereinafter abbreviated as “Penman Method (or Penman Equation).”

(3) Equation of Penman Method

(a) Basic Equation

Penman's equation consists of two terms: the energy of radiation term and the aerodynamic or wind and humidity term. In this equation, the energy term predominates and the aerodynamic term is of less significance under calm weather conditions.

The equation takes the following form:

$LvE = [S(Q - G) + \gamma LvEa) / (S + \gamma)]$

Where:

Lv = Latent heat of evaporation (J/kg)

E = Water vapour flux (kg/m^2/s)

S = Saturation vapour pressure gradient

Q = Budget of radiation (W/m^2)

G = Increasing of heat quantity of water (W/m^2)

Ea = Drying power of air

γ = Psychometric constant

(b) Budget Radiation (Q)

(i) Short Wave Radiation

The amount of energy or extra terrestrial radiation reaching the outer limit of the atmosphere (Budget Radiation: Q) is dependent on latitude and the time of year only. The amount of solar radiation (K↓) that penetrates the atmosphere and reaches the ground is much less than （K０↓） and is largely dependent on cloud cover. It can be estimated by the empirical formula:

$K\downarrow = K0\downarrow (a + b \cdot n / N)$

Where,

K０↓: Short wave radiation

$$K0\downarrow = (S0/\pi d2) \times (H \sin\phi \sin\Delta + \cos\phi \cos\Delta \cdot \sin H)$$

Where,

S0: Solar radiation constant (1353 W/m^2)

ϕ : Latitude at meteorological station

⊿ : Culmination height

H: = 0.5N

d: Standardisation of distance between the sun and the earth

$d = 1+0.017\cos(2\pi(186-m)/365.24)$

a, b: Empirical constants converting sunshine hours to short wave

n: Actual duration of bright sunshine in hours for day

N : Maximum possible mean daily duration of bright sunshine in hours

A part of K↓ is reflected by the evaporating surface as short wave radiation. The net amount of short wave radiation (K↓ - K↑) retained at the evaporating surface is :-

$$K\downarrow - K\uparrow = (1 - \alpha) K0\downarrow (a + b \cdot n / N)$$

Where, α : Reflection coefficient or Albedo

(ii) Long Wave Radiation

Some of the net incoming short wave radiation (K↓ - K↑) is reradiated (day and night) as long wave radiation, and the process is most rapid during cloudless and dry weather. The atmosphere itself radiates but is normally less than the upcoming long wave earth radiation. Empirically, the net outward long wave radiation (L↓ - L↑) can be computed from:

$$L\downarrow - L\uparrow = -\sigma T_m^4(\varepsilon - (C_1+C_2\sqrt{e_a}))(C_3+(1-C_3)n/N)$$

Where;

σ : Stefan-Boltzman constant, 5.67×10^{-8} W/m^2/k

T_m^{4}: Mean air temperature in degrees absolute (°K) for day

ε : Emissivity = 1

C_1: Constant value

C_2: Constant value

C_3: Constant value

e_a: Saturation vapour pressure in mm Hg

(iii) Total Net Radiation

The total net radiation is then,

$Q = (K\downarrow - K\uparrow) + (L\downarrow - L\uparrow)$
$= (1 - \alpha) K_0\downarrow (a + b \cdot n / N) - \sigma T^4(\varepsilon - (C_1+C_2\sqrt{e_a}))(C_3 + (1 - C_3)n/N)$

(c) Drying Power of the Air, i.e., f (u), (T (0) – E (z))

Wind and humidity effects determine removal of water vapour produced from the surface into the atmosphere.

(i) Wind Function f (u) and Wind Conversion

In the publication the effect of wind on Q has been defined as:

$f(u) = (3.7 + 4.0U_2)/Lv$

Where;

U_2: Mean wind velocity in m/sec for day at two metres above ground level.

Lv : Latent heat of evaporation = $(2501 - T \cdot 7/3) \times 10^3$ (J/kg)

(ii) Saturation Vapour Pressure Deficit

Q is also affected by air humidity. Humidity is expressed as saturation vapour pressure deficit. Saturation vapour pressure can be calculated using the following equation:

$Ea = f(u)\,(e_w(T(2)) - e(2))$

Where;

Ea: Drying power of air ($kg/m^2/s$)

f (u): Wind function

$e_w(T(2))$: Saturation vapour pressure at two metre above ground level and at T ℃ of air temperature respectively

e (2): Water vapour pressure at two metres above ground level

(iii) Maximum Possible Mean Daily Duration of Bright Sunshine in Hours (N)

Maximum possible mean daily duration of bright sunshine in hours (N) means the time from sunrise until sunset as calculated by the following equation:

$N = Tr - Ts$

Where;

Tr: the standardised time at sunrise

$= 12 - (12/\pi)\arccos(\tan(\pi\ \zeta / 180)\tan\delta) + \Delta ts$

Where,

ζ : longitude at the meteorological station

δ : Culmination height

$= (23.45\pi/180)\cos(2\pi(172\text{-}i)/365)$

Where,

i: integrated data from January 1

Δts : the difference between the standard time and the time at the Meteorological station

$= (Ls - Lm)\ \varepsilon/15$

Where,

ε : 1 (in case of the longitude east)

Ls: longitude at standardised time

Lm: longitude at the meteorological station

Ts: the standardised time at sunset

$= 24 - Tr - 2\ \Delta ts$

(d) Psychometric Constant (γ) and Slope of the Saturation Vapour Pressure Gradient S

(i) Psychrometric Constant (γ)

The Psychrometric "constant" is dependent on atmospheric pressure and varies with altitude. For sea level and an altitude of 3000 m, the Psychrometric constant is 0.51 and 0.35 mm Hg/°C respectively. The value of γ is non-sensitive and for the normal working range of $0.51 > \gamma > 0.35$ effects a maximum error to Q of less than 1%.

The Psychrometric constant (γ) is given by the following equation:

$\gamma = C_p \times P \quad / \quad L_V \times 5/8$

Where

C_p: Specific heat at constant pressure of air 1005 (J/kg/K)

P: Atmospheric pressure

Lv: Latent heat of evaporation = $(2501 - T \cdot 7/3) \times 10^3$ (J/kg)

(ii) Saturation Vapour Pressure Gradient

The saturation vapour pressure gradient S is approximated by the following equation:

$S = (25880 / (240.97 + T)^2)^{17.502T/(240.97+T)}$

(4) Programmed Calculation

A computer program of the Penman equation using Windows 98 has been developed based on Japanese software and used in various studies, namely, the "Wacos - Penman - Evaporation - Potential Evapotranspiration Model."

4.3.3 Computation of Potential Evapotranspiration using Penman Method

Necessary data and constant value to be used for the computation by Penman Method are sorted as below:

(1) Meteorological Station for Data Input

- Station No. and its location: Station No. 48648, Petaling Jaya
- Longitude and latitude : N03º10' E101º65'
- Latitude at standardised time: 102º67'
- Atmospheric pressure: 1007mb

(2) Necessary Data and Observation Period

- Mean daily air temperature (1995-1998)
- Mean daily relative humidity (1995-1998)
- Mean daily sunshine hours (1995-1998)
- Mean daily wind velocity (1995-1998)

As described hereinafter, the necessary periods for the above data were determined based on the available land use data.

(3) Annual Sunshine Conversion Coefficients

The average annual sunshine conversion coefficients 'a' and 'b' were obtained from an existing document, namely, "Estimating Potential Evapotranspiration Using the Penman Procedure"[8)]. The coefficient values were based on daily meteorological data from 1975 until 1988.

Station No. 48648: a = 0.26; b = 0.41

(4) Albedo Value

Albedo of the evaporating surface is the ratio of the amount of solar radiation reflected by the surface to the amount incident on it. It is a sensitive parameter in the radiation equation and according to Scarf (1976); an Albedo error of 0.01 gives rise to an error of 22mm in the annual evaporation (approx. 1.5%). Albedo values for various surfaces were obtained from an existing document, namely, "Estimating Potential Evapotranspiration Using the Penman Procedure" [8], and major surface types and their Albedo values are presented in **Table D.4.1** below.

Table D.4.1 Albedo Value on Various Surfaces in Malaysia[8)]

Surface type	Albedo value	Surface type	Albedo value
Open water	0.07	Towns	0.17
Grass	0.21	Legumes	0.21
Tropical forest	0.12	Oil Palm	0.18
Crops	0.23	Cocoa	0.19

(5) Constant Values related to Long Term Radiation

Constant values (C_1, C_2, C_3) related to longer radiation are given based on the existing document[8)] as follows:

C_1: Constant value = 0.56

C_2: Constant value = 0.08

C_3: Constant value = 0.1

The computation results of daily potential evapotranspiration at Petaling Jaya (Station No. 48648) in 1995-1998 are given in the **Data Book D.4.1**.

4.4 Estimation of Area of Various Surfaces in Each Year Based on Land Use Data

According to some existing documents[2)9)], area of land use type in the Study Area can be summarised as in **Tables D.4.3 and D.4.4**. Regarding the Langat River Basin, annual data of various land use type from 1995 to 1998 could be estimated by interpolation method based on GIS data in 1995 and in 1998. Similarly, annual data of various land use types in the Klang River Basin could be estimated based on the data in 1985 and in 2005 (assumption based on 1985). Although the land use data in the Klang River Basin were estimated values, those data were used for estimation of potential evapotranspiration corresponding to land use in 1995, 1996, 1997and 1998.

4.5 Estimation of Evapotranspiration Reflected on Land Use Change in the Study Area

Monthly potential evapotranpiration for different surfaces from 1995 to 1998 were computed as shown in **Table D.4.5**. The pan evaporation can be assumed empirically as "0.8 × (potential evapotranspiration by Penman Method)." According to the existing document[10)], the actual evaporation can be assumed empirically as "0.8 × pan evaporation." Hence, actual evaporation can be estimated as "0.8× 0.8 × potential evapotranspiration." Consequently, the actual evaporation considering land use change of the Study Area including the Klang River Basin are as given also in **Tables D.4.6 and D.4.7**.

As tabulated in **Table D.4.2**, pan evaporation is calculated at nearly 0.8 of potential evapotranspiration. Therefore, the value of pan evaporation using coefficient 0.8 can be applied for estimation when it is difficult to estimate potential evapotranspiration.

Table D.4.2 Relation between Pan Evaporation and Potential Evapotransipiration in the Study Area

Year	Pan Evaporation	Potential Evapotranspiration in the upper + Semenyih + middle Langat River Basin		Potential Evapotranspiration in the upper + middle Klang River Basin	
	A: mm/year	B: mm/year	A/B	C: mm/year	A/C
1995	1,528	1,850	0.83	1,841	0.83
1996	1,349	1,873	0.72	1,864	0.72
1997	1,259	1,797	0.70	1,799	0.70
1998	1,361	1,836	0.74	1,827	0.74
Average			0.75		0.75

Table D.4.3 Estimation of Land Use Change by Interpolation Method during 1995-1998 in the Langat River Basin

Name of River	Basin Area (km^2)	Name of Sub-Basin	Sub-Basin Area*4) (km^2)	Classification of land use		Area of Land use (km^2) 1995*5)	1996	1997	1998*5)	Varous Surface for Albedo Value	Area of Various Surface (km^2) 1995	1996	1997	1998
Langat	2750 .1 *1) (2500 *2))	Upper Langat	382.5	1	Builtup Area	37.7	44.2	50.8	57.3	Towns	40.9	47.5	54.0	60.6
				2	Mining	3.2	3.2	3.3	3.3					
				3	Rubber	85.5	81.7	77.9	74.1	(Oil Palm)	86.0	82.0	78.1	74.1
				4	Oil Palm	0.5	0.3	0.2	0.0					
				5	Plantation	22.8	21.1	19.5	17.8	Crops	22.8	21.1	19.5	17.8
				6	Grassland	4.2	2.8	1.4	0.0	Grass	4.2	2.8	1.4	0.0
				7	Forest	223.4	223.8	224.1	224.5	Tropical Forest	225.0	225.3	225.7	226.0
				8	Swamps	1.6	1.6	1.5	1.5					
				9	Water Bodies	3.6	3.7	3.9	4.0	Open Water	3.6	3.7	3.9	4.0
				Total		382.5	382.5	382.5	382.5	-	382.5	382.5	382.5	382.5
		Semenyih	254.2	1	Builtup Area	10.3	12.8	15.4	17.9	Towns	18.2	22.3	26.3	30.4
				2	Mining	7.9	9.4	11.0	12.5					
				3	Rubber	63.2	60.1	57.0	53.9	(Oil Palm)	79.6	78.6	77.7	76.7
				4	Oil Palm	16.4	18.5	20.7	22.8					
				5	Plantation	8.6	7.9	7.1	6.4	Crops	8.6	7.9	7.1	6.4
				6	Grassland	3.2	2.3	1.4	0.5	Grass	3.2	2.3	1.4	0.5
				7	Forest	140.1	138.5	136.9	135.3	Tropical Forest	140.4	138.8	137.2	135.6
				8	Swamps	0.3	0.3	0.3	0.3					
				9	Water Bodies	4.2	4.3	4.5	4.6	Open Water	4.2	4.3	4.5	4.6
				Total		254.2	254.2	254.2	254.2	-	254.2	254.2	254.2	254.2
		Middle Langat	644.3	1	Builtup Area	72.1	108.6	145.1	181.6	Towns	85.4	124.0	162.7	201.3
				2	Mining	13.3	15.4	17.6	19.7					
				3	Rubber	230.7	215.2	199.6	184.1	(Oil Palm)	345.4	319.7	293.9	268.2
				4	Oil Palm	114.7	104.5	94.3	84.1					
				5	Plantation	43.3	41.2	39.2	37.1	Crops	43.3	41.2	39.2	37.1
				6	Grassland	35.3	29.1	22.9	16.7	Grass	35.3	29.1	22.9	16.7
				7	Forest	114.4	112.0	109.6	107.2	Tropical Forest	127.0	122.1	117.1	112.2
				8	Swamps	12.6	10.1	7.5	5.0					
				9	Water Bodies	7.9	8.2	8.5	8.8	Open Water	7.9	8.2	8.5	8.8
				Total		644.3	644.3	644.3	644.3	-	644.3	644.3	644.3	644.3
		Lower Langat	1469.1	1	Builtup Area	70.4	110.0	149.6	189.2	Towns	88.4	129.4	170.5	211.5
				2	Mining	18.0	19.4	20.9	22.3					
				3	Rubber	105.2	102.5	99.7	97.0	(Oil Palm)	903.4	874.7	846.1	817.4
				4	Oil Palm	798.2	772.3	746.3	720.4					
				5	Plantation	135.9	150.9	165.9	180.9	Crops	135.9	150.9	165.9	180.9
				6	Grassland	27.1	23.4	19.7	16.0	Grass	27.1	23.4	19.7	16.0
				7	Forest	29.2	31.9	34.5	37.2	Tropical Forest	289.8	264.1	238.5	212.8
				8	Swamps	260.6	232.3	203.9	175.6					
				9	Water Bodies	24.5	26.5	28.5	30.5	Open Water	24.5	26.5	28.5	30.5
				Total		1469.1	1469.1	1469.1	1469.1	-	1469.1	1469.1	1469.1	1469.1

Note:
*1): Estimated by JICA Study Team, namely "Study Area"
*2): DID. The Multimedia Super Corridor (MSC) Macro Drainage Master Plan, Chapter 3-5. July. 1999
*3): JICA. The Study on The Flood Mitigation of the Klan River Basin, Supporting Report Volume 1. 1989
*4): Estimated by JICA Study Team
*5): Land use for Langat River was estimated by JICA Study Team based on land use map in 1995 and 1998 by DOA

Table D.4.4 Estimation of Land Use Change by Interpolation Method during 1995-1998 in the Klang River Basin

Name of River	Basin Area (km^2)	Name of Sub-Basin	Sub-basint Area[*4)] (km^2)	Classification of land use		Area of Land use (km^2)						Varous Surface for Albedo Value	Area of Various Surface (km^2)					
						1985[*5)]	1995	1996	1997	1998	2005[*5)]		1985	1995	1996	1997	1998	2005
Klang	1288.4[*3)]	Upper Klang	458.2	1	Residential	113.5	131.2	133.0	134.7	136.5	148.9	Towns	132.3	158.7	161.3	163.9	166.6	185.0
				2	Commercial	5.9	8.6	8.8	9.1	9.3	11.2							
				3	Industrial	2.6	4.8	5.0	5.2	5.4	6.9							
				4	Institutional	1.5	4.2	4.4	4.7	4.9	6.8							
				5	Recreational	4.6	7.1	7.3	7.5	7.8	9.5							
				6	Mining	4.2	3.0	2.8	2.7	2.6	1.7							
				7	Agriculture	104.1	74.1	71.1	68.1	65.1	44.1	Crops	104.1	74.1	71.1	68.1	65.1	44.1
				8	Forest	221.8	225.5	225.8	226.2	226.5	229.1	Tropical Forest	221.8	225.5	225.8	226.2	226.5	229.1
				Total		458.2	458.2	458.2	458.2	458.2	458.2	-	458.2	458.2	458.2	458.2	458.2	458.2
		Middle Klang	253.8	1	Residential	123.8	139.0	140.5	142.0	143.5	154.1	Towns	165.3	186.7	188.8	191.0	193.1	208.1
				2	Commercial	0.8	3.6	3.9	4.2	4.4	6.4							
				3	Industrial	6.1	9.7	10.0	10.4	10.7	13.2							
				4	Institutional	15.7	14.1	13.9	13.7	13.6	12.4							
				5	Recreational	7.5	12.5	13.0	13.5	14.0	17.5							
				6	Mining	11.4	8.0	7.6	7.3	6.9	4.5							
				7	Agriculture	73.1	49.0	46.6	44.2	41.8	24.9	Crops	73.1	49.0	46.6	44.2	41.8	24.9
				8	Forest	15.4	18.1	18.4	18.6	18.9	20.8	Tropical Forest	15.4	18.1	18.4	18.6	18.9	20.8
				Total		253.8	253.8	253.8	253.8	253.8	253.8	-	253.8	253.8	253.8	253.8	253.8	253.8
		Lower Klang	576.4	1	Residential	41.6	75.6	78.9	82.3	85.7	109.5	Towns	98.8	150.4	155.6	160.7	165.9	202.0
				2	Commercial	1.4	2.6	2.7	2.8	3.0	3.8							
				3	Industrial	9.7	14.0	14.4	14.9	15.3	18.3							
				4	Institutional	15.7	17.4	17.6	17.7	17.9	19.1							
				5	Recreational	3.9	15.7	16.9	18.1	19.2	27.5							
				6	Mining	26.5	25.2	25.0	24.9	24.7	23.8							
				7	Agriculture	361.9	275.9	267.3	258.7	250.1	189.9	Crops	361.9	275.9	267.3	258.7	250.1	189.9
				8	Forest	115.7	150.1	153.5	157.0	160.4	184.5	Tropical Forest	115.7	150.1	153.5	157.0	160.4	184.5
				Total		576.4	576.4	576.4	576.4	576.4	576.4	-	576.4	576.4	576.4	576.4	576.4	576.4

Note:
*1) : Estimated by JICA Study Team, namely "Study Area"
*2) : DID. The Multimedia Super Corridor (MSC) Macro Drainage Master Plan, Chapter 3-5. July. 1999
*3) : According to "JICA. The Study on The Flood Mitigation of the Klan River Basin, Supporting Report Volume 1. 1989", the whole Klang River Basin is divided into the following three aub-catchment areas:
(1) Upper Basin is the upper catchment area covering from the Sulaiman Bridge
(2) Middle Basin is the middle catchment covering from Puchong Drop to Sulaiman Bridge; and
(3) Lower Basin is the lower catchment area from Puchong Drop.
*4): Estimated by JICA Study Team
*5): Land use for Klang River was estimated by JICA Study Team based on the above*3)

Table D.4.5 Monthly Potential Evapotranspiration at Petaling Jaya (Station No. 48648) in 1995-1998

Month/Year	Towns	Oil Palm	Crops	Grass	Tropical Forest	Open Water
Jan-95	149.76	148.26	140.73	143.74	157.29	164.82
Feb-95	141.29	139.87	132.79	135.63	148.37	155.45
Mar-95	173.02	171.27	162.55	166.04	181.74	190.46
Apr-95	155.88	154.30	146.38	149.55	163.80	171.72
May-95	159.07	157.48	149.51	152.70	167.04	175.01
Jun-95	148.70	147.23	139.86	142.81	156.06	163.43
Jul-95	166.87	165.26	157.20	160.43	174.94	183.00
Aug-95	145.96	144.48	137.13	140.07	153.31	160.67
Sep-95	147.60	146.13	138.79	141.73	154.94	162.27
Oct-95	179.22	177.47	168.70	172.20	187.99	196.76
Nov-95	133.63	132.30	125.67	128.32	140.27	146.90
Dec-95	127.62	126.33	119.86	122.45	134.08	140.55
Total	1,828.62	1,810.38	1,719.17	1,755.65	1,919.83	2,011.04
Jan-96	140.92	139.51	132.43	135.26	148.00	155.08
Feb-96	161.45	159.87	151.98	155.14	169.35	177.24
Mar-96	174.25	172.48	163.61	167.16	183.13	192.00
Apr-96	151.06	149.53	141.92	144.96	158.67	166.29
May-96	172.33	170.65	162.26	165.62	180.71	189.10
Jun-96	151.66	150.18	142.79	145.75	159.05	166.44
Jul-96	154.78	153.25	145.64	148.68	162.39	170.00
Aug-96	155.28	153.74	146.02	149.11	163.00	170.72
Sep-96	168.42	166.79	158.62	161.89	176.60	184.77
Oct-96	154.10	152.56	144.87	147.95	161.79	169.48
Nov-96	141.91	140.49	133.40	136.23	149.00	156.09
Dec-96	124.51	123.25	116.98	119.49	130.78	137.05
Total	1,850.67	1,832.31	1,740.51	1,777.23	1,942.46	2,034.26
Jan-97	144.67	149.16	165.60	150.65	158.13	141.68
Feb-97	134.80	139.05	154.62	140.47	147.54	131.97
Mar-97	168.65	173.97	193.46	175.74	184.60	165.11
Apr-97	152.99	157.87	175.76	159.49	167.63	149.73
May-97	169.87	175.17	194.59	176.94	185.76	166.34
Jun-97	145.35	149.92	166.64	151.44	159.04	142.31
Jul-97	137.25	141.64	157.72	143.10	150.41	134.33
Aug-97	143.84	148.46	165.39	150.00	157.70	140.76
Sep-97	105.47	108.95	121.74	110.11	115.93	103.14
Oct-97	130.94	135.33	151.44	136.80	144.12	128.01
Nov-97	136.37	140.90	157.54	142.42	149.98	133.34
Dec-97	132.56	136.95	153.05	138.41	145.73	129.64
Total	1,702.77	1,757.37	1,957.55	1,775.57	1,866.56	1,666.37
Jan-98	164.09	162.38	153.85	157.26	172.62	181.16
Feb-98	161.13	159.45	151.05	154.41	169.53	177.94
Mar-98	178.23	176.40	167.21	170.88	187.42	196.61
Apr-98	175.30	173.52	164.61	168.17	184.21	193.12
May-98	166.76	165.05	156.49	159.91	175.32	183.88
Jun-98	134.74	133.34	126.33	129.13	141.75	148.76
Jul-98	143.62	142.12	134.60	137.61	151.13	158.65
Aug-98	138.86	137.38	129.99	132.95	146.25	153.65
Sep-98	144.40	142.87	135.24	138.29	152.03	159.66
Oct-98	154.97	153.37	145.34	148.55	163.00	171.02
Nov-98	135.02	133.61	126.56	129.38	142.07	149.11
Dec-98	114.20	112.99	106.97	109.38	120.22	126.24
Total	1,811.32	1,792.48	1,698.24	1,735.94	1,905.56	1,999.79

Table D.4.6 Estimation of Potential Evapotranspiration and Actual Evaporation in the Study Area including Klang River Basin in 1995-1996

Basin Area	Sub-Basin Area	Name of Area of Various Surface	1995				1996			
			Area of Various Surface	Potential Evapotranspiratoin by Penman Method	Assumed Evapotranspiration by using the coefficent value K *1)		Area of Various Surface	Potential Evapotranspiratoin by Penman Method	Assumed Evapotranspiration by using the coefficent value K *1)	
			(km^2)	(mm/year)	(mm/year)	($\times 10^3 m^3$)	(km^2)	(mm/year)	(mm/year)	($\times 10^3 m^3$)
			A	B	C (=B×K) K=0.64	D (=A×C)	A	B	C (=B×K) K=0.64	D (=A×C)
Langat (2750.1km^2)	Upper Langat (382.5km^2)	Towns	40.9	1,829	1,170	47,866	47.5	1,851	1,184	56,221
		(Oil Palm)	86.0	1,810	1,159	99,643	82.0	1,832	1,173	96,199
		Crops	22.8	1,719	1,100	25,086	21.1	1,741	1,114	23,541
		Grass	4.2	1,756	1,124	4,719	2.8	1,777	1,137	3,185
		Tropical Forest	225.0	1,920	1,229	276,456	225.3	1,942	1,243	280,129
		Open Water	3.6	2,011	1,287	4,633	3.7	2,034	1,302	4,861
		Total	382.5	1,873	1,198	458,403	382.5	1,896	1,213	464,136
	Semenyih (254.2km^2)	Towns	18.2	1,829	1,170	21,300	22.3	1,851	1,184	26,373
		(Oil Palm)	79.6	1,810	1,159	92,228	78.6	1,832	1,173	92,212
		Crops	8.6	1,719	1,100	9,462	7.9	1,741	1,114	8,763
		Grass	3.2	1,756	1,124	3,596	2.3	1,777	1,137	2,616
		Tropical Forest	140.4	1,920	1,229	172,508	138.8	1,942	1,243	172,553
		Open Water	4.2	2,011	1,287	5,406	4.3	2,034	1,302	5,642
		Total	254.2	1,872	1,198	304,500	254.2	1,894	1,212	308,159
	Middle Langat (644.3km^2)	Towns	85.4	1,829	1,170	99,945	124.0	1,851	1,184	146,908
		(Oil Palm)	345.4	1,810	1,159	400,195	319.7	1,832	1,173	374,866
		Crops	43.3	1,719	1,100	47,642	41.2	1,741	1,114	45,931
		Grass	35.3	1,756	1,124	39,664	29.1	1,777	1,137	33,099
		Tropical Forest	127.0	1,920	1,229	156,044	122.1	1,942	1,243	151,750
		Open Water	7.9	2,011	1,287	10,168	8.2	2,034	1,302	10,676
		Total	644.3	1,828	1,170	753,658	644.3	1,851	1,185	763,230
	Upper+Semenyih +Middle Langat (1,281km^2)	Total	1,281	1,850	1,184	1,516,561	1281	1,873	1,199	1,535,525
	Lower Langat (1469.1km^2)	Towns	88.4	1,829	1,170	103,456	129.4	1,851	1,184	153,304
		(Oil Palm)	903.4	1,810	1,159	1,046,718	874.7	1,832	1,173	1,025,780
		Crops	135.9	1,719	1,100	149,527	150.9	1,741	1,114	168,092
		Grass	27.1	1,756	1,124	30,450	23.4	1,777	1,137	26,616
		Tropical Forest	289.8	1,920	1,229	356,075	264.1	1,942	1,243	328,364
		Open Water	24.5	2,011	1,287	31,533	26.5	2,034	1,302	34,501
		Total	1,469.1	1,827	1,169	1,717,759	1,469.1	1,847	1,182	1,736,657
Klang (1288.4km^2)	Upper Klang (458.2km^2)	Towns	158.7	1,829	1,171	185,709	161.3	1,851	1,185	191,065
		Crops	74.1	1,719	1,100	81,522	71.1	1,741	1,114	79,222
		Tropical Forest	225.5	1,920	1,229	277,033	225.8	1,942	1,243	280,661
		Total	458.2	1,856	1,188	544,264	458.2	1,879	1,202	550,948
	Middle Klang (253.8km^2)	Towns	186.7	1,829	1,171	218,544	188.8	1,851	1,185	223,707
		Crops	49.0	1,719	1,100	53,908	46.6	1,741	1,114	51,912
		Tropical Forest	18.1	1,920	1,229	22,241	18.4	1,942	1,243	22,832
		Total	253.8	1,814	1,161	294,693	253.8	1,837	1,176	298,451
	Upper+Middle Klang (712.0km^2)	Total	712	1,841	1,178	838,957	712	1,864	1,193	849,399
	Lower Klang (576.4km^2)	Towns	150.4	1,829	1,171	176,052	155.6	1,851	1,185	184,283
		Crops	275.9	1,719	1,100	303,534	267.3	1,741	1,114	297,836
		Tropical Forest	150.1	1,920	1,229	184,443	153.5	1,942	1,243	190,832
		Total	576.4	1,800	1,152	664,029	576.4	1,824	1,168	672,951

Note: *1) Pan Evaporation can be assumed empirically as "0.8× Potential Evapotranspiration by Penman Method". According to the existing document, namely "DID, Evaporation in Penisular Malaysia, Water Resource Publication No.5, 1994", Actual Evaporation can be assumed empirically as "0.8× Pan Evaporation" in Malaysia. Hence, Actual Evaporation (Estimated Evapotranspiration) can be estimated as 0.64 × Potential Evaporation.

Table D.4.7 Estimation of Potential Evapotranspiration and Actual Evaporation in the Study Area including Klang River Basin in 1997-1998

Basin Area	Sub-Basin Area	Name of Area of Various Surface	1997				1998			
			Area of Various Surface	Potential Evapotranspiratoin by Penman Method	Assumed Evapotranspiration by using the coefficent value K *1)		Area of Various Surface	Potential Evapotranspiratoin by Penman Method	Assumed Evapotranspiration by using the coefficent value K *1)	
			(km^2)	(mm/year)	(mm/year)	(×10^3 m^3)	(km^2)	(mm/year)	(mm/year)	(×10^3 m^3)
			A	B	C (=B×K) K=0.64	D (=A×C)	A	B	C (=B×K) K=0.64	D (=A×C)
Langat (2,750.1km^2)	Upper Langat (382.5km^2)	Towns	54.0	1,703	1,090	58,884	60.6	1,811	1,159	70,250
		(Oil Palm)	78.1	1,757	1,125	87,803	74.1	1,792	1,147	85,006
		Crops	19.5	1,958	1,253	24,389	17.8	1,698	1,087	19,346
		Grass	1.4	1,776	1,136	1,591	0	1,736	1,111	0
		Tropical Forest	225.7	1,867	1,195	269,581	226	1,906	1,220	275,620
		Open Water	3.9	1,666	1,066	4,124	4	2,000	1,280	5,119
		Total	382.5	1,823	1,167	446,372	382.5	1,860	1,190	455,341
	Semenyih (254.2km^2)	Towns	26.3	1,703	1,090	28,697	30.4	1,811	1,159	35,241
		(Oil Palm)	77.7	1,757	1,125	87,353	76.7	1,792	1,147	87,989
		Crops	7.1	1,958	1,253	8,937	6.4	1,698	1,087	6,956
		Grass	1.4	1,776	1,136	1,591	0.5	1,736	1,111	555
		Tropical Forest	137.2	1,867	1,195	163,899	135.6	1,906	1,220	165,372
		Open Water	4.5	1,666	1,066	4,764	4.6	2,000	1,280	5,887
		Total	254.2	1,815	1,161	295,241	254.2	1,856	1,188	302,000
	Middle Langat (644.3km^2)	Towns	162.7	1,703	1,090	177,270	201.3	1,811	1,159	233,356
		(Oil Palm)	293.9	1,757	1,125	330,591	268.2	1,792	1,147	307,675
		Crops	39.2	1,958	1,253	49,069	37.1	1,698	1,087	40,323
		Grass	22.9	1,776	1,136	26,023	16.7	1,736	1,111	18,554
		Tropical Forest	117.1	1,867	1,195	139,927	112.2	1,906	1,220	136,834
		Open Water	8.5	1,666	1,066	9,065	8.8	2,000	1,280	11,263
		Total	644.3	1,775	1,136	731,945	644.3	1,814	1,161	748,005
	Upper+Semenyih +Middle Langat (1,281km^2)	Total	1,281	1,797	1,150	1,473,558	1281	1,836	1,175	1,505,346
	Lower Langat (1469.1km^2)	Towns	170.5	1,703	1,090	185,770	211.5	1,811	1,159	245,181
		(Oil Palm)	846.1	1,757	1,125	951,583	817.4	1,792	1,147	937,708
		Crops	165.9	1,958	1,253	207,845	180.9	1,698	1,087	196,616
		Grass	19.7	1,776	1,136	22,386	16	1,736	1,111	17,776
		Tropical Forest	238.5	1,867	1,195	284,872	212.8	1,906	1,220	259,521
		Open Water	28.5	1,666	1,066	30,395	30.5	2,000	1,280	39,036
		Total	1,469.1	1,790	1,145	1,682,851	1469.1	1,804	1,154	1,695,838
Klang (1288.4km^2)	Upper Klang (458.2km^2)	Towns	163.9	1,703	1,090	178,635	166.6	1,811	1,159	193,044
		Crops	68.1	1,958	1,253	85,318	65.1	1,698	1,087	70,745
		Tropical Forest	226.2	1,867	1,195	270,194	226.5	1,906	1,220	276,349
		Total	458.2	1,821	1,166	534,147	458.2	1,842	1,179	540,138
	Middle Klang (253.8km^2)	Towns	191.0	1,703	1,090	208,125	193.1	1,811	1,159	223,834
		Crops	44.2	1,958	1,253	55,350	41.8	1,698	1,087	45,392
		Tropical Forest	18.6	1,867	1,195	22,267	18.9	1,906	1,220	23,067
		Total	253.8	1,759	1,126	285,742	253.8	1,799	1,152	292,293
	Upper+Middle Klang (712.0km^2)	Total	712	1,799	1,152	819,889	712	1,827	1,169	832,431
	Lower Klang (576.4km^2)	Towns	160.7	1,703	1,090	175,148	165.9	1,811	1,159	192,262
		Crops	258.7	1,958	1,253	324,108	250.1	1,698	1,087	271,789
		Tropical Forest	157.0	1,867	1,195	187,528	160.4	1,906	1,220	195,687
		Total	576.4	1,862	1,192	686,784	576.4	1,788	1,145	659,738

Note: *1) Pan Evaporation can be assumed empirically as "0.8× Potential Evapotranspiration by Penman Method". According to the existing document, namely "DID, Evaporation in Penisular Malaysia, Water Resource Publication No.5, 1994", Actual Evaporation can be assumed empirically as "0.8× Pan Evaporation" in Malaysia. Hence, Actual Evaporation (Estimated Evapotranspiration) can be estimated as 0.64 × Potential Evaporation.

5. ANNUAL WATER BALANCE STUDY

5.1 Objective

Water balance analysis is made to identify hydrological conditions including groundwater recharge in the Study Area. For this purpose, additional collection of hydrological data and its examination, estimation of evapotranspiration using Penman's equation, review of existing report on hydrology of the Klang River Basin and examination of water balance using tank model were carried out.

5.2 Methodology

The workflow of water balance analysis can be as presented in **Figure D.5.1** below.

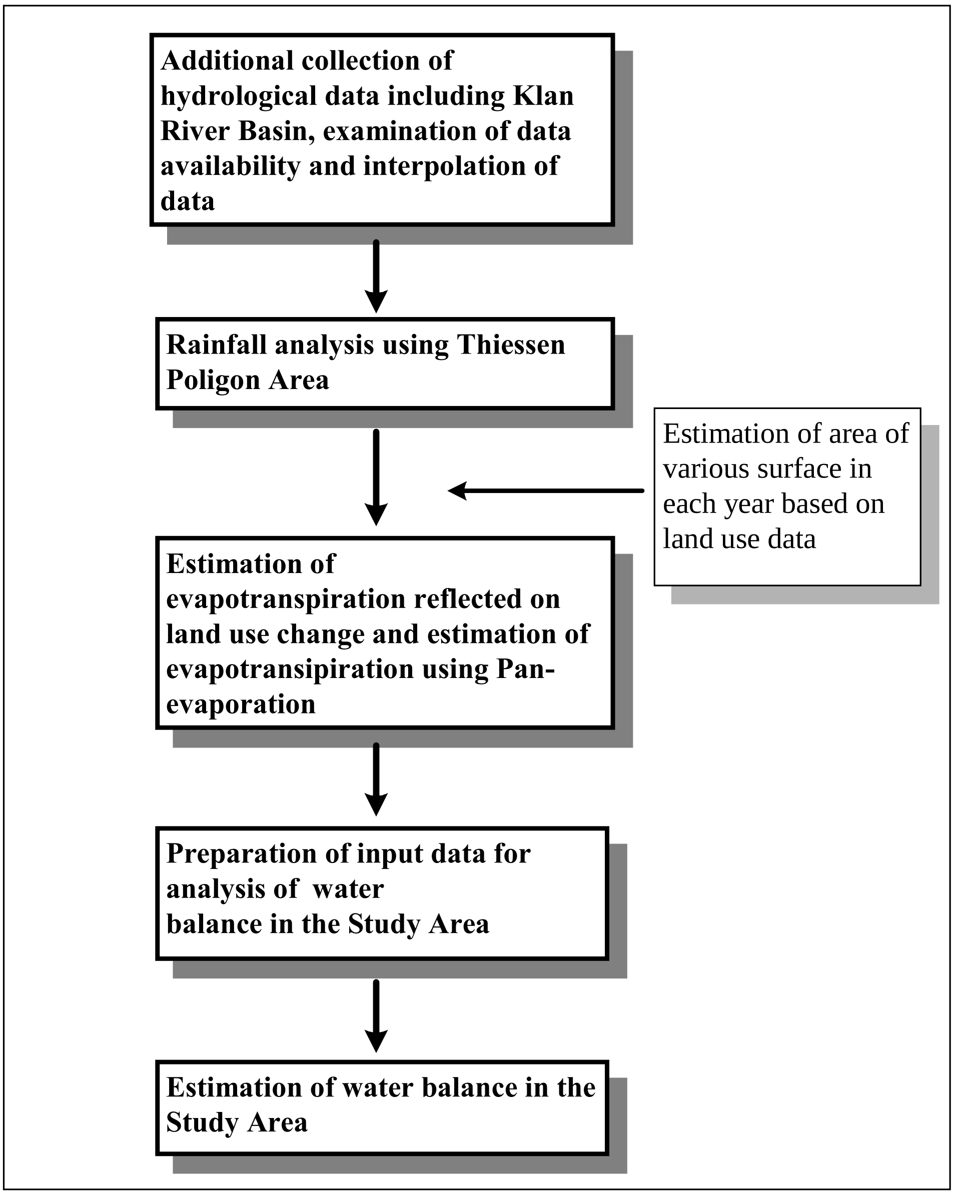


Figure D.5.1 Workflow of Water Balance Analysis

5.3 Annual Water Balance

Based on the previous rainfall analysis, interpolation of discharge, and examination of evapotranspiration as described in **Chapter 4**, the annual water balance from 1980 to 1999 at two sub-basins included in the Study Area was estimated. These two sub-basins, namely "the upper-middle Langat River Basin" and "the upper-middle Klang River Basin," can be looked upon as an area of source of groundwater supply (groundwater recharge) to an abstraction area at the lower Langat River Basin.

As presented in **Tables D.5.1 to D.5.3** and **Figures D.5.2 to D.5.5**, the annual water balance in the Study Area is as summarised below.

- Annual average groundwater recharge converted into mm in the upper + Semenyih + middle **Langat** River Basin is estimated at 108 mm/year. This is equivalent to139 $\times 10^6$ m^3/year and 4.8% of rainfall in the area.
- Annual average groundwater recharge converted into mm in the upper + middle **Klang** River Basin is estimated at 188 mm/year. This is equivalent to 131 $\times 10^6$ m^3/year and 7.5% of rainfall in the area.
- The time series of annual groundwater recharge changes irregularly in both the upper + Semenyih + middle **Langat** River Basin and the upper + middle **Klang** River Basin. The annual groundwater recharge in 1988-1990, 1992 and 1997 fell below zero in both sub-basins. Groundwater recharge seems to draw down after drought years of one or two-year period. This may suggest that the effect of surface water to the groundwater appears at approximately two years later.
- The runoff coefficient for the upper + Semenyih + middle **Langat** River (upper reach from Dengkil Town) is roughly estimated at 37.8%.
- The runoff coefficient for the upper + middle **Klang** River (upper reach from Puchon drop) is roughly estimated at 40.5%.

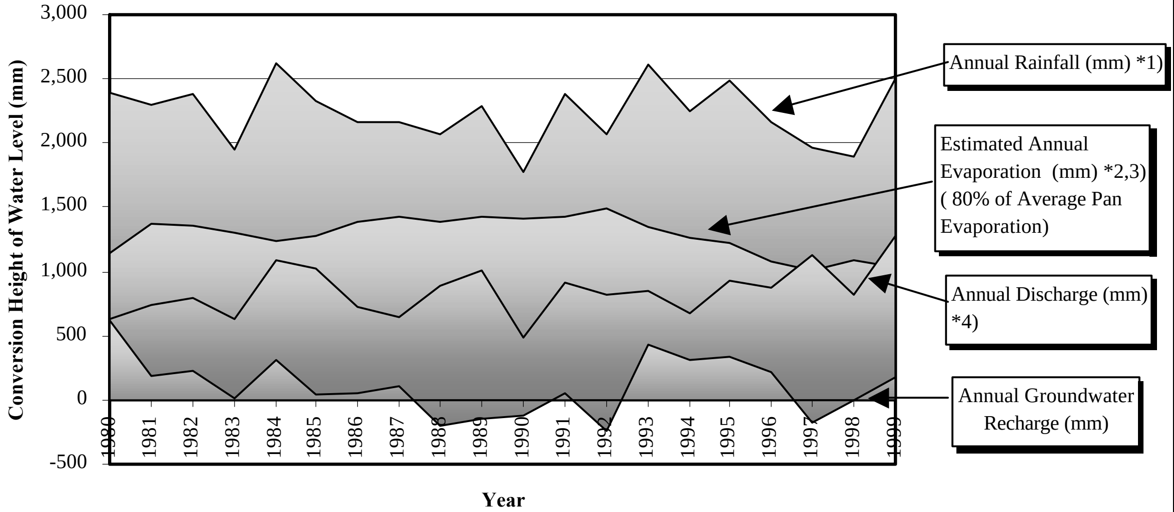
According to existing documents on hydrology including water balance, the above result seems to be adequate in the Study Area. However, further review to determine whether or not the assumption used in the calculation is appropriate and verification using analysis of the groundwater model such as Mudflow is necessary.

Table D.5.1 Annual Water Balance in the Upper＋Semenyih＋Middle Langat River Basin in 1980-1999

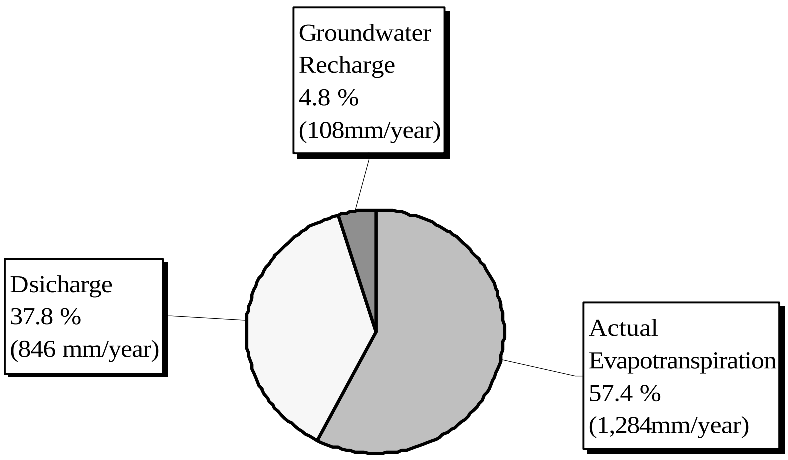
Year	Annual Rainfall (mm) *1)	Annual Pan-Evaporation (mm) *2)	Estimated Annual Evaporation (mm) *3) (80% of Average Pan Evaporation)	Annual Discharge (mm) *4)	Annual Groundwater Recharge (mm)	Annual Groundwater Recharge (× 10^6 m^3) Area: 1281.1 km^2
	A	B	C (= B×0.8)	D	E (= A-C-D)	F (=E × Area)
1980	2,391	1,429	1,143	626	623	798
1981	2,297	1,715	1,372	736	188	241
1982	2,385	1,702	1,362	797	226	289
1983	1,949	1,632	1,306	628	16	20
1984	2,624	1,539	1,231	1,086	307	393
1985	2,323	1,591	1,273	1,018	32	41
1986	2,169	1,729	1,383	728	58	74
1987	2,163	1,776	1,421	641	101	130
1988	2,072	1,725	1,380	892	-201	-257
1989	2,288	1,786	1,429	1,006	-147	-188
1990	1,772	1,771	1,417	478	-123	-158
1991	2,382	1,779	1,423	907	52	67
1992	2,068	1,865	1,492	820	-244	-313
1993	2,616	1,673	1,338	848	430	551
1994	2,248	1,583	1,266	677	305	391
1995	2,489	1,528	1,223	933	334	428
1996	2,162	1,349	1,079	870	213	273
1997	1,958	1,259	1,007	1,133	-182	-233
1998	1,901	1,361	1,088	813	0	0
1999	2,500	1,301	1,041	1,282	177	227
Average	2,238	1,605	1,284	846	108	139
%	100	-	57.4	37.8	4.8	-

Note:
*1) Estimated annual rainfall using "Thiessen Method" in the area, including the upper Langat basin, the Semenyih basin and the middle Langat basin.
*2) Estimated average annual pan-evaporation recorded by DID monitoring station.
*3) According to the existing document, namely "DID, Evaporation in Penisular Malaysia, Water Resource Publication No. 5, 1994," "Actual Evaporation by Lysimeter" can be assumed empirically as "0.8 × Pan Evaporation" in Malaysia.
*4) Converted value based on recorded flow rate (Q) at Dengkil Town.

Water Balance in the Upper+Semenyih+Middle Langat River Basin
in 1980-1999



Average Water Balance in the Upper+Semenyih+Middle Langat Basin
in 1980-1999



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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 D.5.2

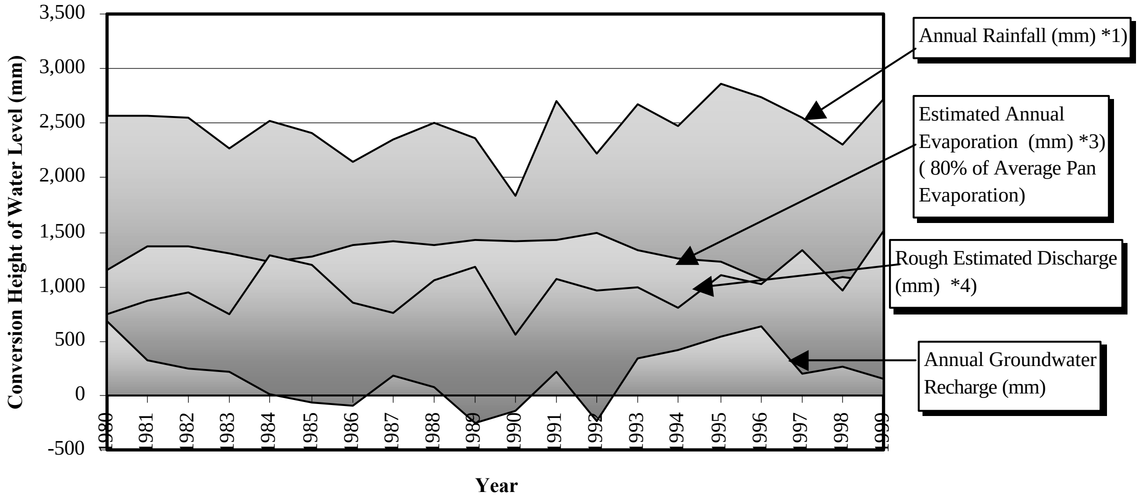
Annual Average Water Balance in the Upper + Semenyih + Middle Langat River Basin in 1980 - 1999

Table D.5.2 Annual Water Balance in the Upper+Middle Klang River Basin in 1980-1999

Year	Annual Rainfall (mm) *1)	Annual Pan-Evaporation (mm) *2)	Estimated Annual Evaporation (mm) *3) (80% of Average Pan Evaporation)	Rough Estimated Discharge (mm) *4)	Annual Groundwater Recharge (mm)	Annual Groundwater Recharge (× 10^6 m^3) Area: 712 km^2
	A	B	C (= B×0.8)	D	E (= A-C-D)	F (=E × Area)
1980	2,570	1,429	1,143	739	688	490
1981	2,569	1,715	1,372	870	328	233
1982	2,545	1,702	1,362	942	241	172
1983	2,264	1,632	1,306	741	217	155
1984	2,526	1,539	1,231	1,282	13	9
1985	2,417	1,591	1,273	1,203	-58	-42
1986	2,145	1,729	1,383	860	-98	-69
1987	2,356	1,776	1,421	757	178	127
1988	2,504	1,725	1,380	1,054	70	50
1989	2,363	1,786	1,429	1,188	-254	-181
1990	1,839	1,771	1,417	565	-142	-101
1991	2,708	1,779	1,423	1,071	214	152
1992	2,219	1,865	1,492	968	-241	-172
1993	2,676	1,673	1,338	1,001	337	240
1994	2,478	1,583	1,266	800	413	294
1995	2,865	1,528	1,223	1,102	541	385
1996	2,735	1,349	1,079	1,027	628	447
1997	2,544	1,259	1,007	1,338	200	142
1998	2,307	1,361	1,088	960	259	184
1999	2,715	1,301	1,041	1,514	161	114
Average	2,467	1,605	1,284	999	185	131
%	100	-	52.0	40.5	7.5	-

Note:
*1) Estimated annual rainfall using “Thiessen Method” in the area, including upper Klang basin and middle Klang basin.
*2) Estimated average annual pan-evaporation recorded by DID monitoring station.
*3) According to the existing document, namely “DID, Evaporation in Penisular Malaysia, Water Resource Publication No. 5, 1994,” “Actual Evaporation by Lysimeter” can be assumed empirically as “0.8 × Pan Evaporation” in Malaysia.
*4) Extremely rough assumed value based on existing documents, namely “DID, Average Annual and Monthly Surface Water Resources of Peninsular Malaysia, Water Resources Publication No. 12, 1982.” Where observed mean annual runoff is noted at Puchong station (Klang river, Q=1,103mm) and at Dengkil station (Langat River, Q=934mm).

Water Balance in the Upper+Middle Klang River Basin in 1980-1999



Average Water Balance in the Upper+Middle Klang Basin in 1980-1999

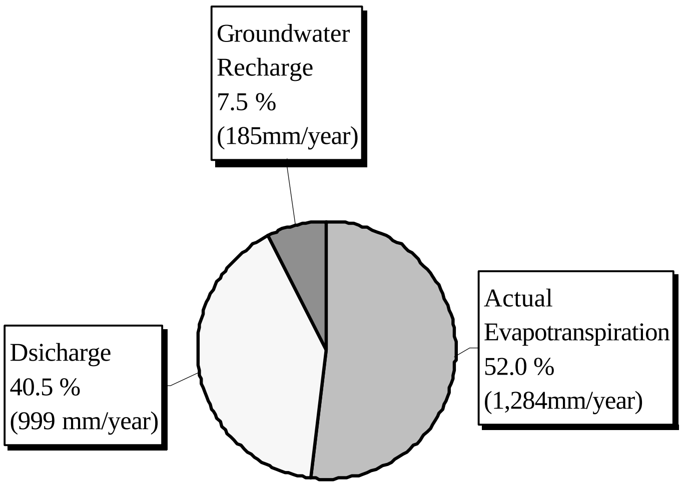


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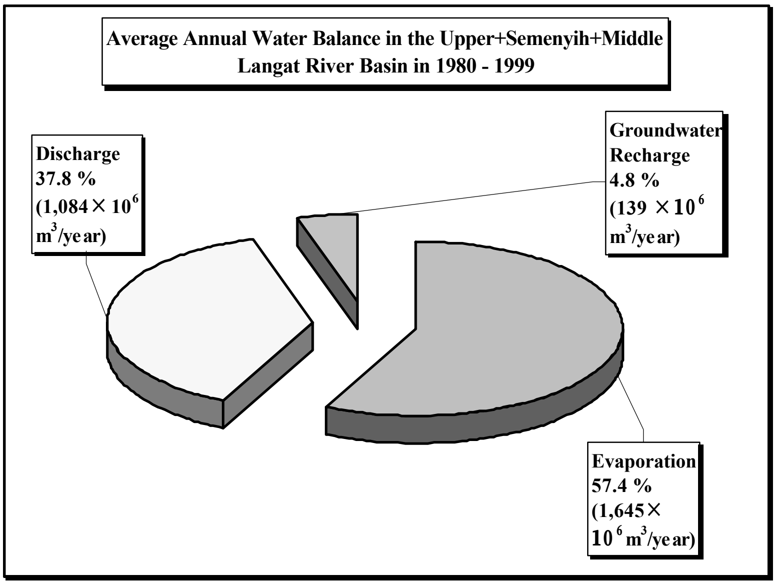
Figure D.5.3

Annual Average Water Balance in the Upper + Middle Klang River Basin in 1980 - 1999

Table D.5.3 Annual Average Water Balance in the Study Area in 1980-1999

Sub-Basin	Area (km^2)		Annual Rainfall	Annual Evaporation	Annual Discharge	Groundwater Recharge
Upper+Semenyih+Middle Langat River Basin	1,281.1	mm	2,238	1,284	846	108
		$\times 10^6 m^3$	2,867	1,645	1,084	139
		%	100.0	57.4	37.8	4.8
Upper+Middle Klang River Basin	712.0	mm	2,467	1,284	999	185
		$\times 10^6 m^3$	1,757	914	711	131
		%	100.0	52.0	40.5	7.5



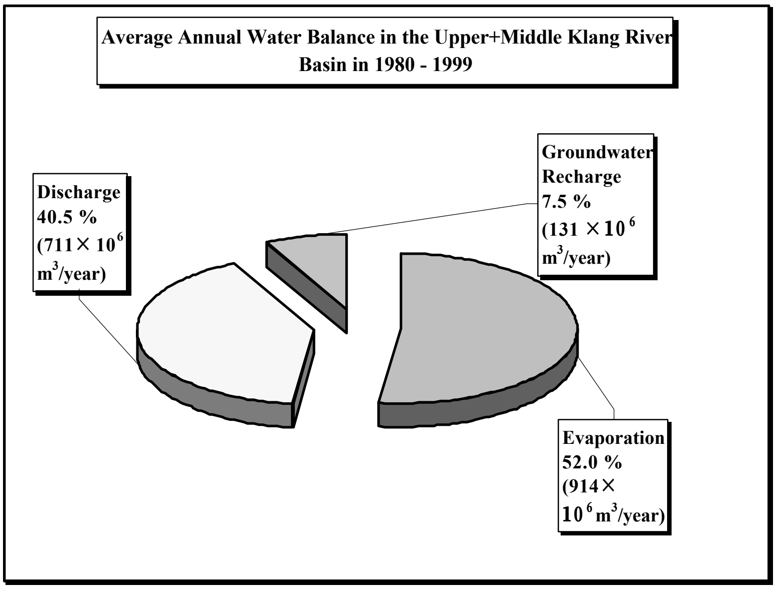


Figure D.5.4 Averaged Annual Water Balance in the Study Area in 1980-1999

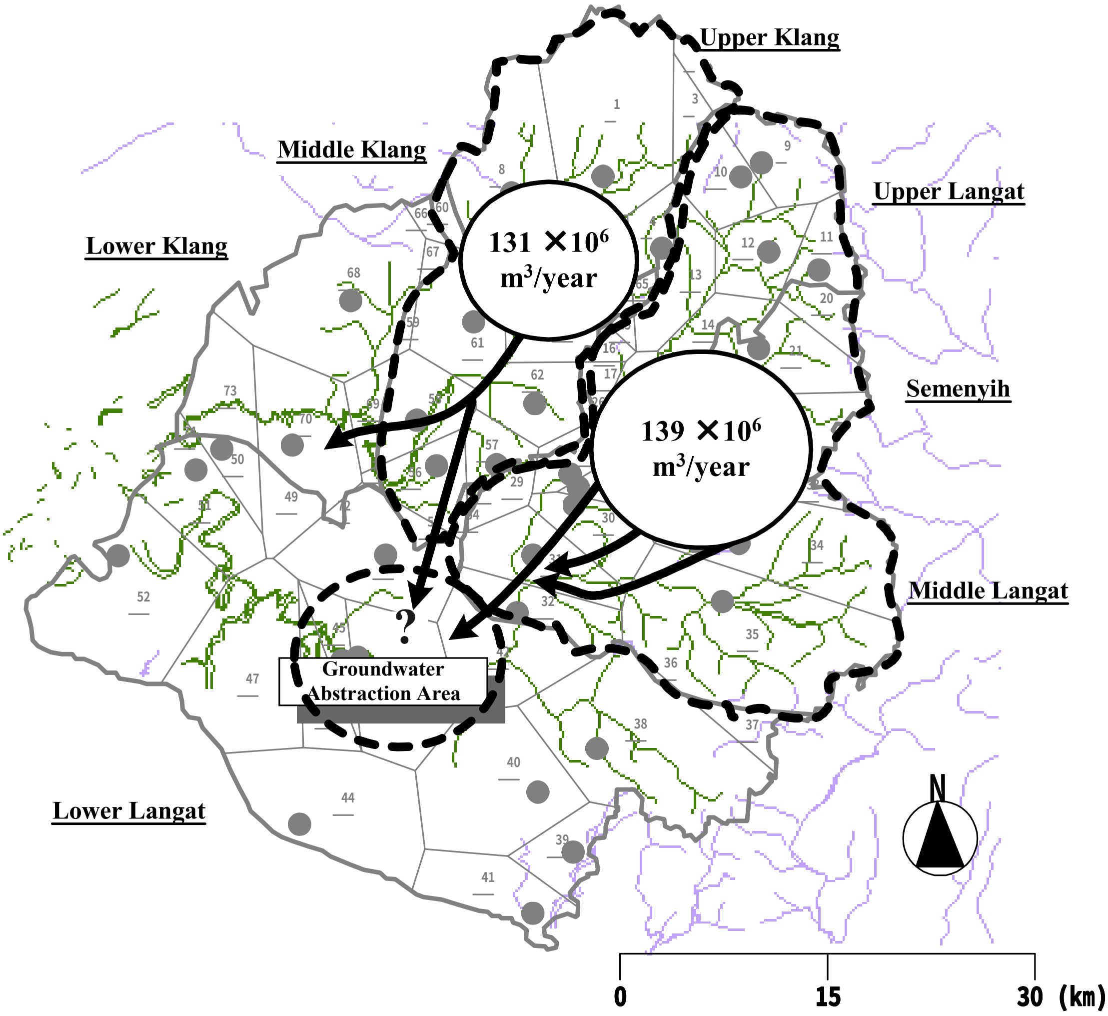


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Figure D.5.5

Groundwater Recharge in the Study Area

5.4 Estimation of Groundwater Recharge using Tank Model

5.4.1 Simulation Model

To estimate recharge of precipitation to groundwater aquifer and clarify the hydrological cycle in a basin, runoff analyses is carried out by the most effective simulation model, namely, the Tank Model.

The Tank Model is composed of a number of containers, which represent the catchment basin (hereinafter the container is called "tank"). The tanks have several holes on their sides and bottoms. Rainwater enters the top tank first, and then passes into the lower tank through holes on the bottom of the upper tank. Water also passes through holes on the sides of the respective tanks. Water moving through the bottom holes indicates infiltration while runoff moving through the side holes of all the tanks indicates river discharge.

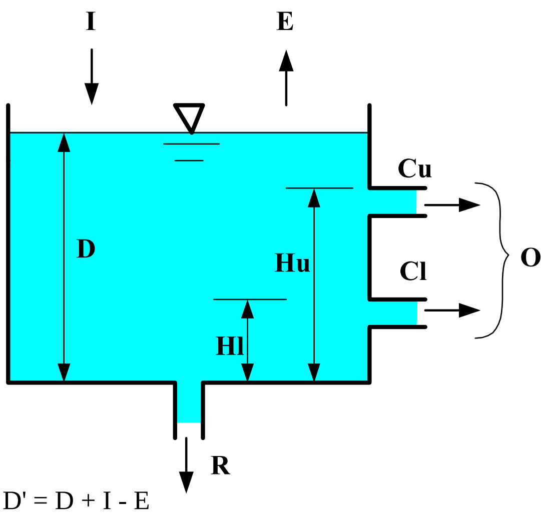
Normally, low flow can be analysed by the serial tank model using three or four tanks. Each tank represents the runoff mechanism on the ground surface or layer, and is a component of the runoff hydrograph such as surface runoff, intermediate runoff and groundwater runoff. At some time interval, runoff and infiltration of tank are calculated using diagram and equations, as shown in **Figure D.5.6**.

Calculations are made for all tanks from the upper to the lower tanks. The sum of runoff from the side holes of all the tanks indicates river runoff. The remaining depth of each tank constitutes the initial depth for the next step, and the calculations are repeated using the same process.

The tank model can express the following complicated runoff phenomena:

- Initial loss depending on previous rainfall
- Non-linear relationship between rainfall and runoff
- Runoff rate depending on the runoff magnitude
- Components of runoff, such as surface runoff, intermediate runoff, and groundwater
- Lag time

The tank model is convenient in that runoff can be estimated using simple arithmetical calculations. However, the disadvantage of the tank model is that the constants, such as coefficients and the height of the tank holes, have to be determined by trial and error. It may take a lot of time for the calculations before the constants are fixed.



(1) D' = D + I - E

(2) O = (D' - Hu) x Cu + (D' - Hl) x Cl (D' > Hu)

O = (D' - Hl) x Cl (Hl < D' < Hu)

O = 0 (D' < Hu)

(3) R = D' x Cb

(4) D" = D' - O - R

Where, I : Rainfall or infiltration from the upper tank
O : Runoff
R : Infiltration to the lower tank
E : Evapotranspiration
Cu : Coefficient of the upper hole on the side
Cl : Coefficient of the lower hole on the side
Cb : Coefficient of the bottom hole
Hu : Height of the upper hole from the bottom
Hl : Height of the lower hole from the bottom
D : Depth of water (Storage of tank)
D' : Depth of water after calculation process (1) above
D": Depth of water after calculation process (4) above

Figure D.5.6 Concept of Tank Model

5.4.2 Preparation of Data

The tank models were prepared for the middle to upper part of the Langat River Basin including Semenyih River Basin at Dengkil gauging station. The inputs for the preparation of tank models are as given below:

- Catchment area of the objective basin:

  1281km^2, upper to middle part of the Langat River Basin including Semenyih River Basin

- Runoff records observed at the stream gauge:

  Daily average runoff records from 1/1/1980 to 31/12/1999 at Dengkil gauging station

- Mean rainfall of the upstream basins for the period corresponding to that of the observed runoff records:

  Mean rainfall records from 1/1/1980 to 31/12/1999 based on Thiessen rainfall analysis in upper to middle part of the Langat River Basin including Semenyih River Basin

- Evapotranspiration estimated using the evaporation records:

  Evapotranspiration used daily pan evaporation records at Peataling Jaya station (MMS Station No. 48648)

- Constant of the tank model:

  The constants were analysed by comparing the computed runoff with the observed runoff using the runoff hydrograph. Model calibration was carried out by trial and error for setting the constants until the computed hydrograph fit the observed one as presented in **Figure D.5.7**.

The long-term runoff was simulated on daily basis for upper to middle part of the Langat River Basin including Semenyih River Basin. The runoff was simulated for twenty (20) years from 1980 to1999 using the basin mean rainfall (by Thiessen Polygon Method) for the corresponding period. Computation was carried out with 24 hours interval using a Japanese software, namely, "Tank Model Professional Version 2.20 by Wacos Japan".

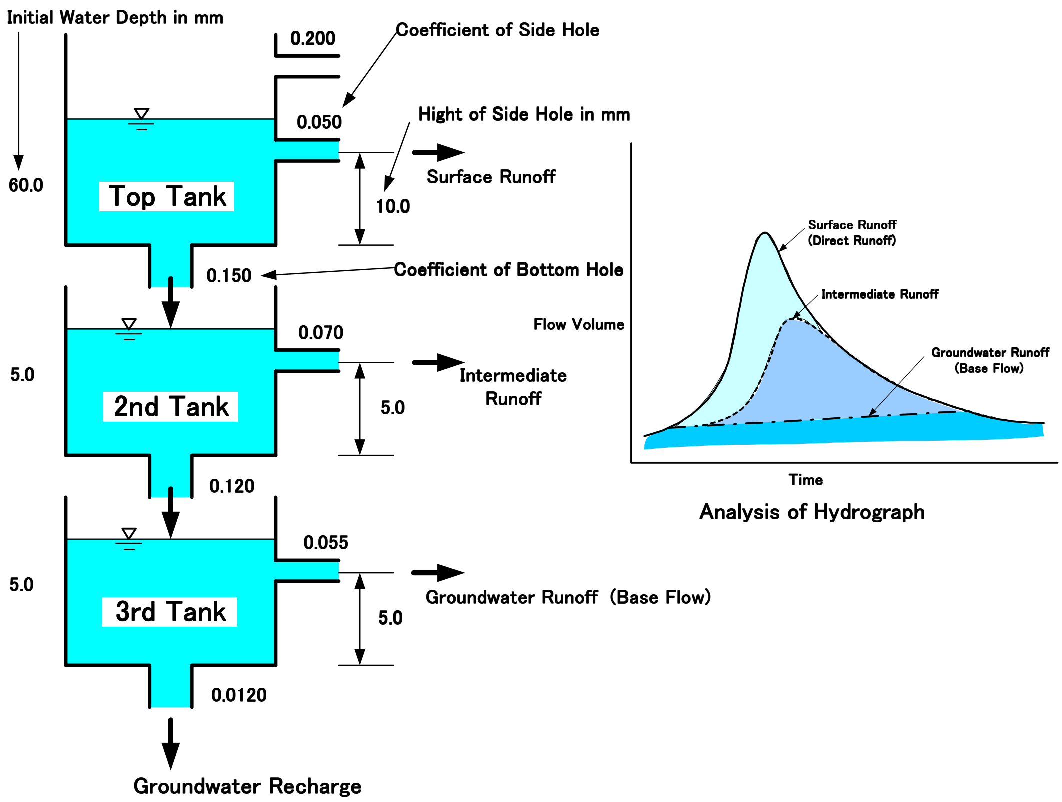


Figure D.5.7 Constants of Tank Model

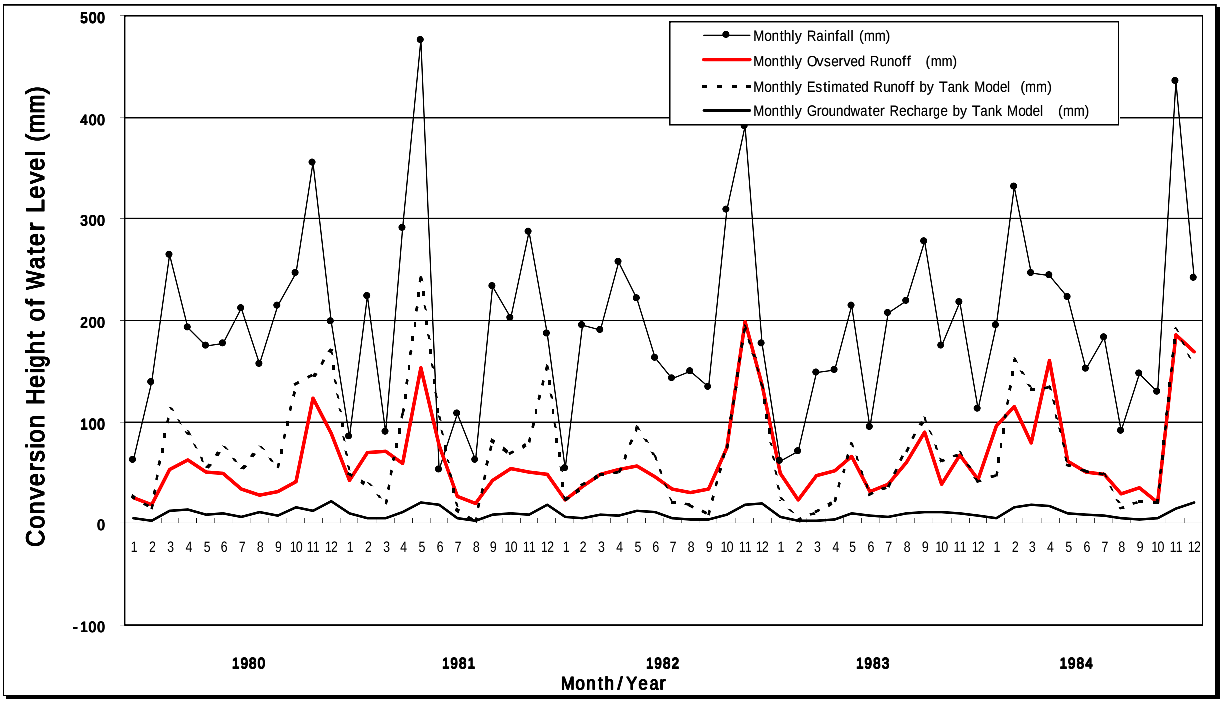
5.4.3 Verification of Simulated Runoff

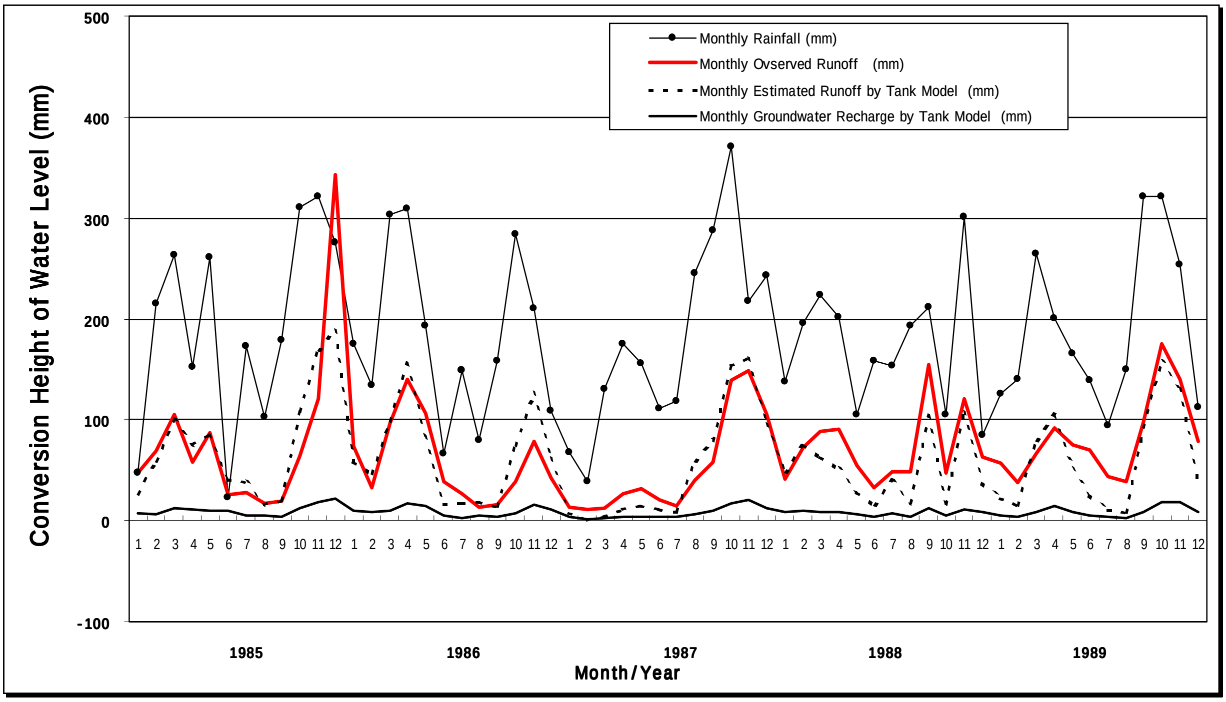
Since the tank model aims mainly for evaluating river runoff, it can also assess the condition of infiltration and storage in the ground layer, as well as surface water. As presented in **Figure D.5.7**, outflow from the side holes in the top, second and third tanks can be considered to be surface runoff, intermediate runoff and groundwater runoff (base flow) respectively. Therefore, the verification using hydrograph was carried out as to total runoff from three side holes, which correspond to observed runoff. Groundwater recharge from a bottom hole of the third tank also could be computed simultaneously on the basis of verification of total runoff.

The simulated daily runoff was verified by comparing with the observed runoffs for twenty (20) years from 1980 to 1999. **Data Book D.5.1** shows comparison with the observed runoff, estimated runoff and estimated groundwater recharges on the daily basis. The verification data in the figure on the hydrographs is occasionally far apart from the simulation curves (not matching well), however, as shown in **Table D.5.4**, **Figures D.5.8 and D.5.9,** the monthly and annual runoff give fairly good agreement with the observed runoff (**see Data Book 5.2**).

Table D.5.4 Comparison between Simulated Annual Runoff and Observed Annual Runoff

Year	Annual Rainfall (mm)	Annual Evaporation (mm)	Annual Actual Evaporation (mm)	Annual Ovserved Runoff (mm)	Annual Estimated Runoff by Tank Model (mm)	Annual Groundwater Recharge by Tank Model (mm)	Estimated Groundwater Recharge by Annual Water Balance Study (mm/year)
1980	2391.3	1282.0	1351.9	1008.5	605.5	128.6	622.5
1981	2296.7	1211.2	1246.1	966.7	712.7	122.3	188.3
1982	2385.1	1503.2	1122.1	771.6	771.9	110.2	225.8
1983	1949.2	1314.9	877.0	546.2	607.4	89.4	15.9
1984	2623.5	1450.7	1388.7	1036.2	1051.1	131.9	306.6
1985	2322.7	1270.0	1261.7	924.5	985.8	121.8	31.8
1986	2169.1	1325.2	1083.5	770.1	704.5	109.5	57.9
1987	2163.1	1401.9	913.8	605.4	620.2	88.4	101.2
1988	2071.6	1439.8	931.8	601.5	863.9	95.5	-200.7
1989	2288	1440.1	1071.6	733.2	973.5	104.9	-146.9
1990	1771.9	1264.7	735.8	440.2	462.7	74.5	-123.3
1991	2382.2	1374.3	1076.8	757.1	919.6	103.1	51.9
1992	2067.5	1440.3	927.4	619.1	792.5	92.5	-244.4
1993	2615.9	1513.4	1333.3	975.8	838.0	127.8	429.9
1994	2248.3	1335.4	1197.0	847.8	640.0	120.8	305.2
1995	2489.4	1369.7	1251.8	924.0	878.0	119.1	334.0
1996	2162.2	1054.1	1313.4	992.6	807.9	127.4	212.9
1997	1958.3	1094.7	1126.0	768.0	1096.8	112.9	-181.6
1998	1901.2	1119.1	1015.2	669.3	794.8	100.8	0.1
1999	2499.8	1144.4	1541.1	1233.9	1338.5	148.5	177.4
Average	2237.9	1317.4	1138.3	809.6	823.3	111.5	108.2
% of rainfall	100.0	58.9	50.9	36.2	36.8	5.0	4.8





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

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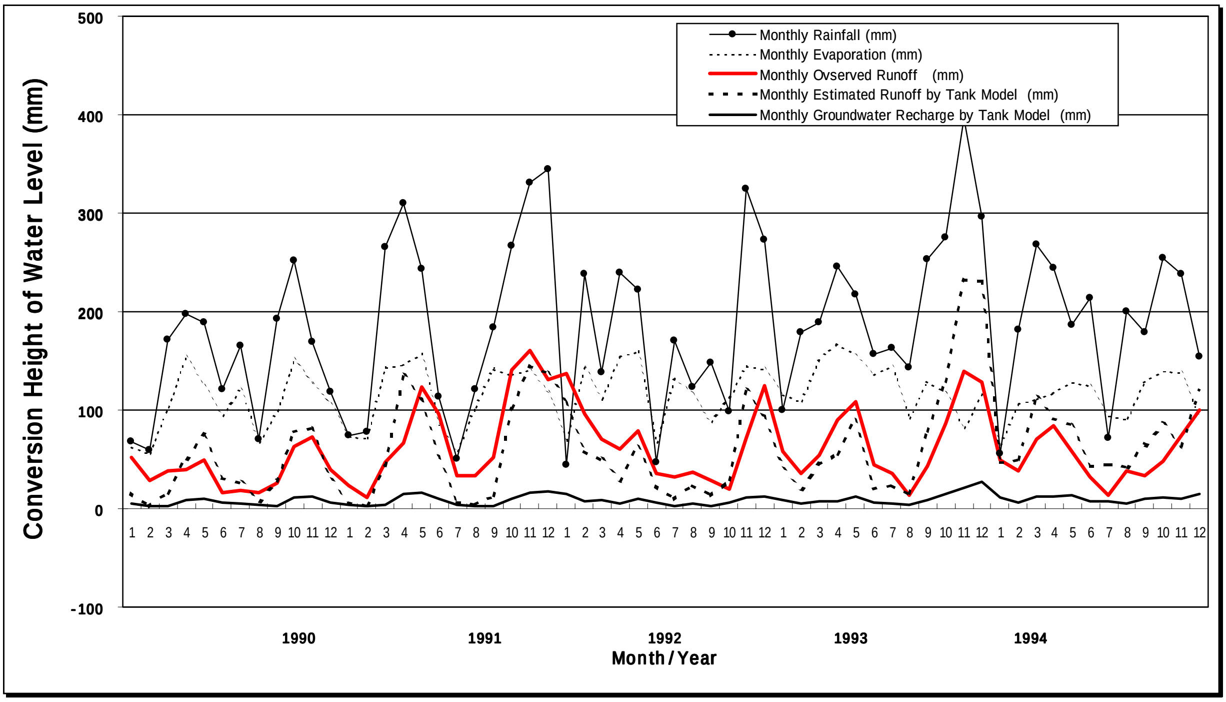
Figure D.5.8

Simulated Monthly Runoff and Groundwater Recharge in 1980 to 1989



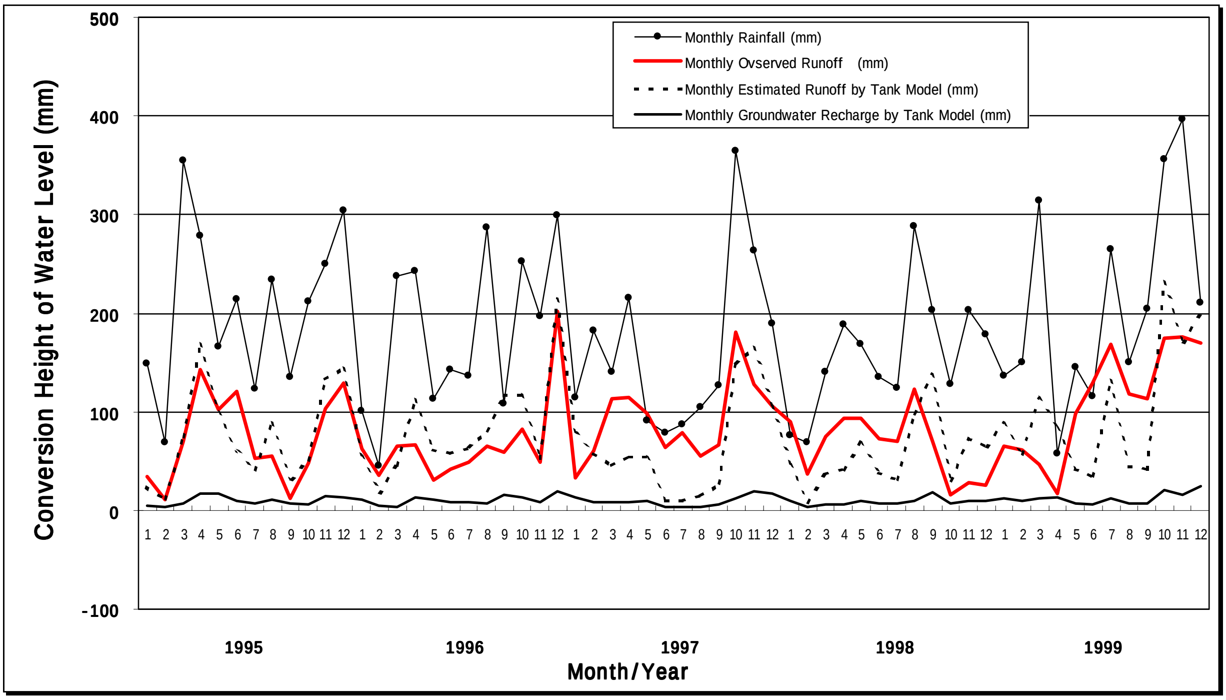


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Figure D.5.9

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

Simulated Monthly Runoff and Groundwater Recharge in 1990 to 1999

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5.4.4 Groundwater Recharge

As shown in **Table D.5.4**, annual average groundwater recharge computed by verification of simulated runoff can be estimated. Annual average groundwater recharge converted into mm in "the upper + Semenyih + middle Langat River Basin" was estimated at 111.5 mm/year. This is equivalent to 142.8 $m^3 \times 10^6 m^3$/year and 5.0% of rainfall in the area.

According to comparison between the previous estimation of annual water balance and groundwater recharge using the tank model, groundwater recharge was estimated at 5.0% of rainfall, which is similar to the result of previous estimation of annual water balance. Furthermore, as shown in **Figure D.5.10**, the time series of annual groundwater recharge using the tank model does not change sensitively in response to a given rainfall in comparison with previous estimation of annual water balance. The difference between these two can explain that the tank model has a storage mechanism that affects groundwater recharge.

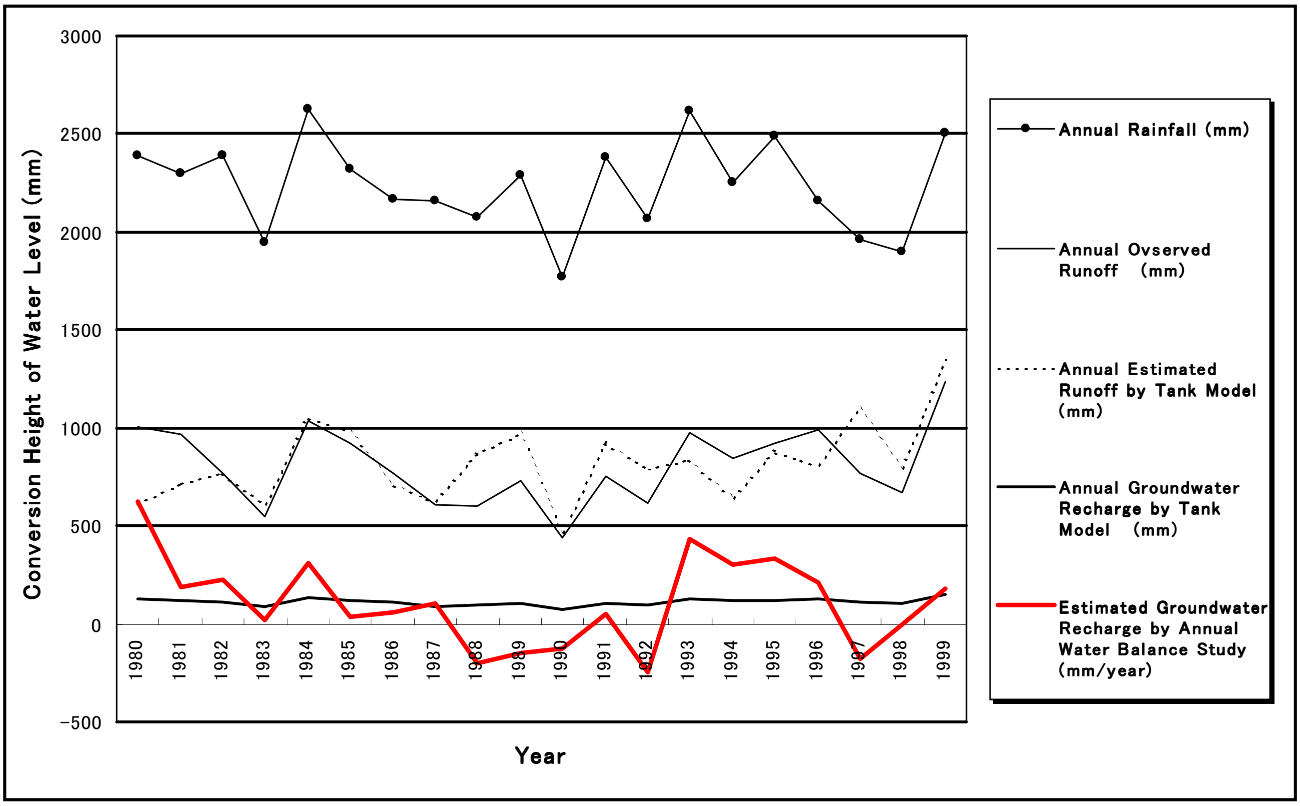


Figure D.5.10 Estimated Groundwater Recharge in 1980 – 1999

6. PAYA INDAH WETLAND SANCTUARY

6.1 Introduction

6.1.1 Objectives of Hydrological Study in the Paya Indah Wetland

The main objectives of the hydrological study in the Paya Indah Wetland are as follows:

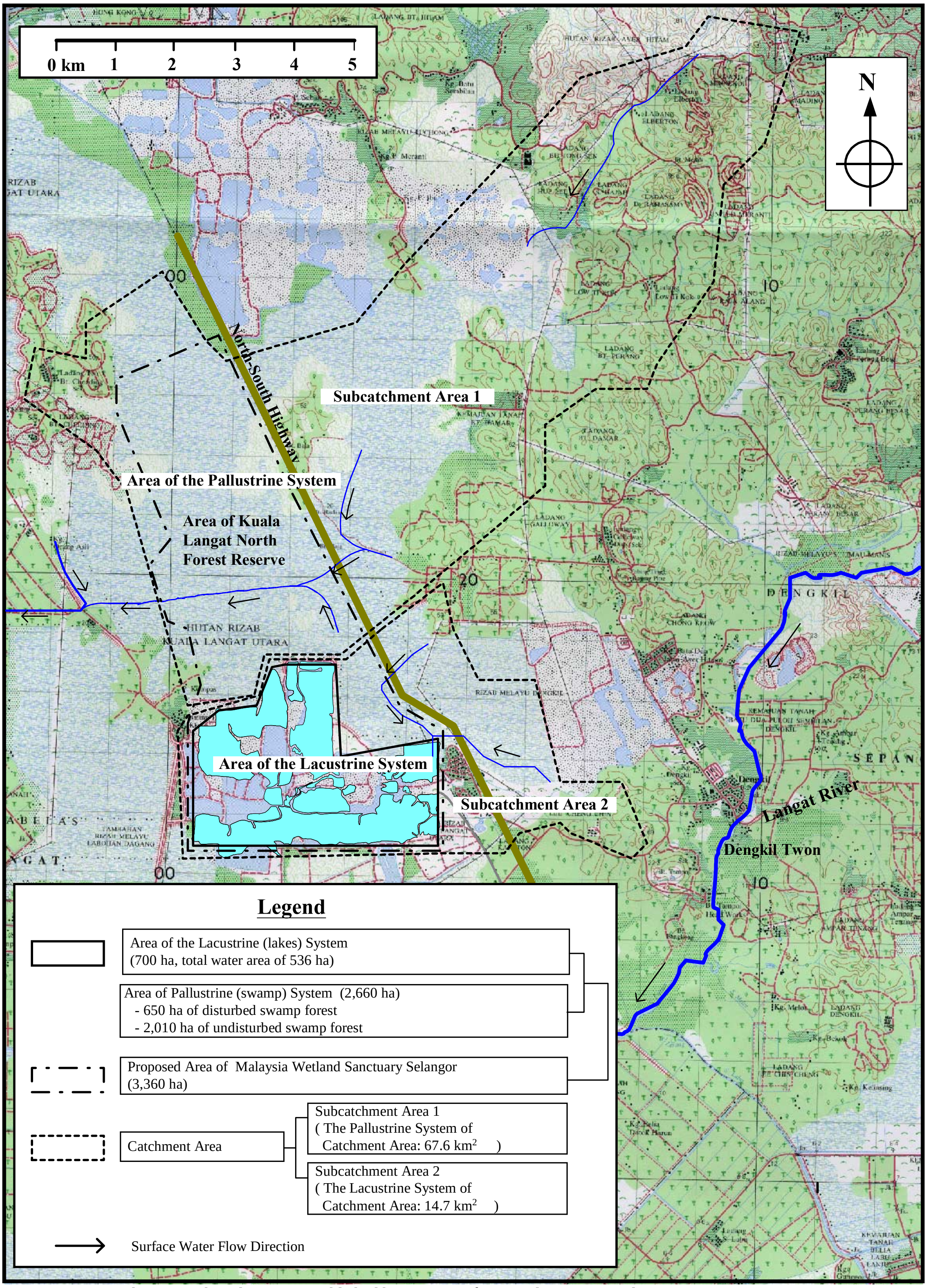
- To study the hydrology of the Paya Indah Wetland and its vicinity focussing on identification of catchment area, all inflowing and out-flowing streams and drains, water movement in each lake and water level based on the existing data and field reconnaissance;
- To plan the monitoring system of inflow and outflow;
- To install the surface water monitoring system, and carry out the monitoring of surface water level including flow rate, i.e., inflow and outflow from the Paya Indah Wetland; and
- To identify the water balance in relation with groundwater recharge into aquifer of the Paya Indah Wetland.

6.1.2 Location of the Study Area

The Paya Indah Wetland is located at approximately 30 km south of Kuala Lumpur, 12 km west of Putrajaya and 15 km north of the Kuala Lumpur International Airport (KLIA). The so-named Paya Indah, The Malaysian Wetland Sanctuary Selangor (MWSS), covers a gross area of 3,360 ha.

As shown in **Figure D.6.1**, the Study Area, including the catchment area of the proposed MWSS, can be divided into two distinct areas based on the previous study results, namely:

- Area of Lacustrine (Lakes) System:
    - Total area: 700 ha (total water area: 536 ha)
    - Catchment area: 14.7 km^2
- Area of Pallustrine (Swamp) System:
    - Total area: 2,660 ha
    - Area of disturbed swamp forest: 650 ha
    - Area of undisturbed swamp forest: 2,010 ha
    - Catchment area: 67.6 km^2



Note : This map is based on a map published by Director of National Mapping Malaysia 1991.

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Figure D.6.1

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

Location of the Study Area for Hydrology in the Paya Indah Wetland

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6.2 Paya Indah Wetland Sanctuary Project

An overview of the Paya Indah Wetland Sanctuary Project based on the information from Malaysian Wetlands Foundation (MWF) is given as the following sections.

6.2.1 Background of the Project

Peat swamp forest is one of the most important natural resources in the sense of environmental preservation of the bio-diversity for animals and plants in Malaysia. The peat swamp forest including the Paya Indah Wetland Sanctuary still keeps particularly the largest scale in the western part of the Malaysian Peninsula, where a part of the peat swamp area and its vicinity is designated as a forest reserve under the national law of urban planning in Malaysia. Since Malaysia was the 84th among the member of nations of the Lamsar International Convention in 1975, it was bound to preserve the habitat of migratory birds. Hence, the Paya Indah Wetland also has a plan to be registered as Lamsar Wetland in future. Environmental disruption is still in progress in the Paya Indah Wetland due to illegal tree felling, hunting and mining of sand. The peat swamp forest and ponds formed by mine tailing takes an important role regionally in the flood mitigation and groundwater conservation. The Paya Indah Wetland Sanctuary Project shall be the model case in the sense of combination with environmental preservation and specific development such as Cyberjaya and the Multimedia Super Corridor (MSC).

6.2.2 Objective of the Project

The project objectives are as follows:

(1) To preserve the wetland environment;

(2) To establish the environmental education centre and the wetland research centre;

(3) To establish self-supporting management by eco-tourism and recreational activity; and

(4) To promote close cooperation with the surrounding urban development and international relationship through the above environmental management activity.

6.2.3 Organisation to Carry Out the Project

The project started based on approval by the Prime Minister when the MWF (Malaysia Wetlands Foundation) was established as a responsible body to carry out the planning, promotion and management of the project. It is a unique project in the sense of difference from ordinary circumstances with the common application of environmental and municipal administration. Therefore, the project is promoted by close coordination with relevant administrative organisations under instruction of EPU. MWF supported by the Prime Minister has a committee, which is presently chaired by Mr. Razari, a former UN ambassador. Mr. Menon who belonged to the Wetland International acts as

GEO in charged of actual operations. MWF consists of three units; namely, natural resources, education and marketing.

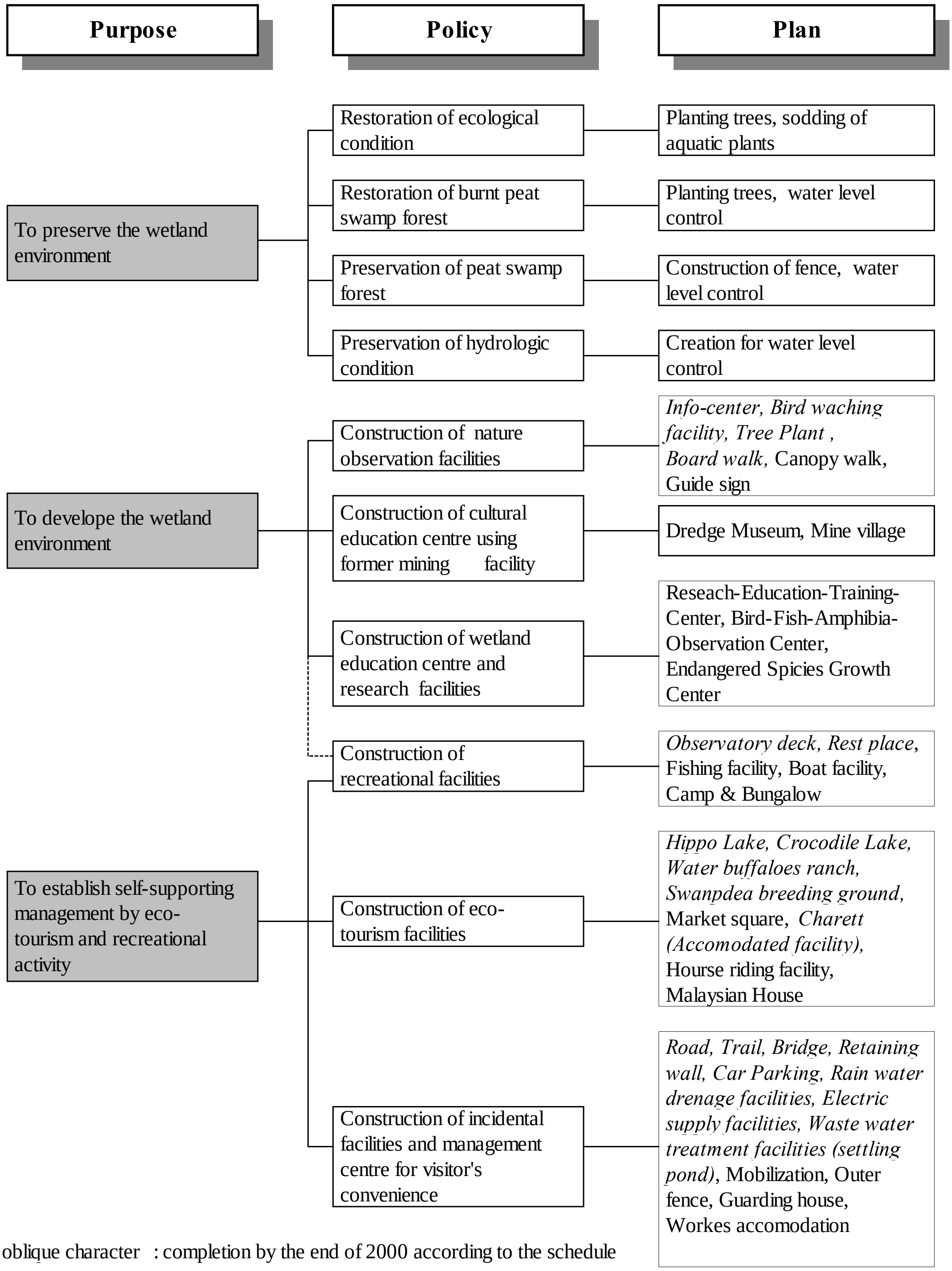
6.2.4 Characteristics of the Project

The project is located in the area where the pressure of development is the highest in Malaysia. Since the project area owned by the state government is located in the disused tin-mining area, according to the change of land use based on the National Land Code, the project was formulated when MWF obtained authorisation of land use as a sanctuary. Therefore, the project is much influenced by the intention of the state government that has the power to decide on land use. To ensure a self-supporting management by MWF after completion of the project, eco-tourism is a subject for future study.

6.2.5 Overview of the Project

An overview of the project is shown in **Figure D.6.2**. Existing facilities by this project are shown in **Figure D.6.3**. The project comprises 3 different contents. As shown in **Figure D.6.14**, construction of various facilities, some of them completed, will be accomplished within the year 2001.

- To preserve the wetland environment:
    - Restoration of burnt peat swamp forest and its ecological condition in ex-mining area
    - Preservation of peat swamp forest and its hydrological condition
- To establish the environmental education centre and the wetland research centre:
    - Construction of nature observation facilities for visitors
    - Construction of wetland education centre and research facilities
    - Construction of cultural education centre using former mining facility
- To establish self-supporting management by eco-tourism and recreational activity:
    - Construction of nature trail for visitors
    - Construction of incidental facilities and management centre for visitors' convenience
    - Construction of attraction facilities such as zoological garden



oblique character : completion by the end of 2000 according to the schedule

Source : Information from Malaysian Wetlands Foundation

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

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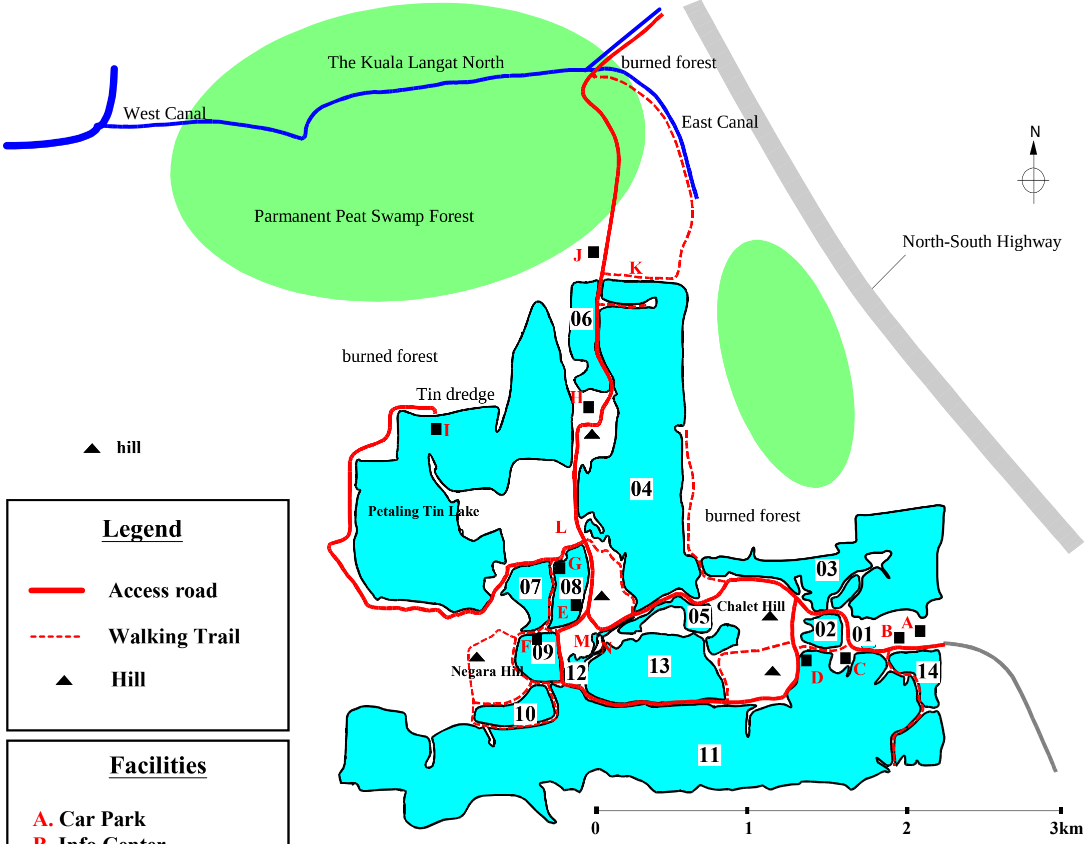
Figure D.6.2

Overview of the Paya Indah Wetland Sanctuary Project



Facilities

A. Car Park
B. Info Center
C. Promenade
D. Nursery
E. Boardwalk
F. Bird Cage
G. Bird Hide
H. Viewing Deck
I. Dredge
J. Macaranga Trail
K. Horse Trail
L. Buffalow Ranch
M.Gazebo
N. Remo Island

Surrounding Area

Ex-mining area 1,050 ha
Burned forest 825 ha
Reserve forest 2,800 ha

Name of Lakes

Code	Name
01	Hippo Lake
02	Crocodile Lake
03	Visitor Lake
04	Main Lake
05	Gunung Lake
06	Driftwood Lake
07	Perch Lake
08	Marsh Lake
09	Padi Lake
10	Swamphen Lake
11	Lotus Lake
12	Palm Lake
13	Chalet Lake
14	Typha Lake

Photo1: Marsh Lake

Photo2: Main Lake and Visitor Lake

(Photographing on May 10, 2000)

Source : Information from Malaysia Wetland Foundation

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Figure D.6.3

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

Existing Facilities of the Paya Indah Wetland Sanctuary Project

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6.3 Present Condition

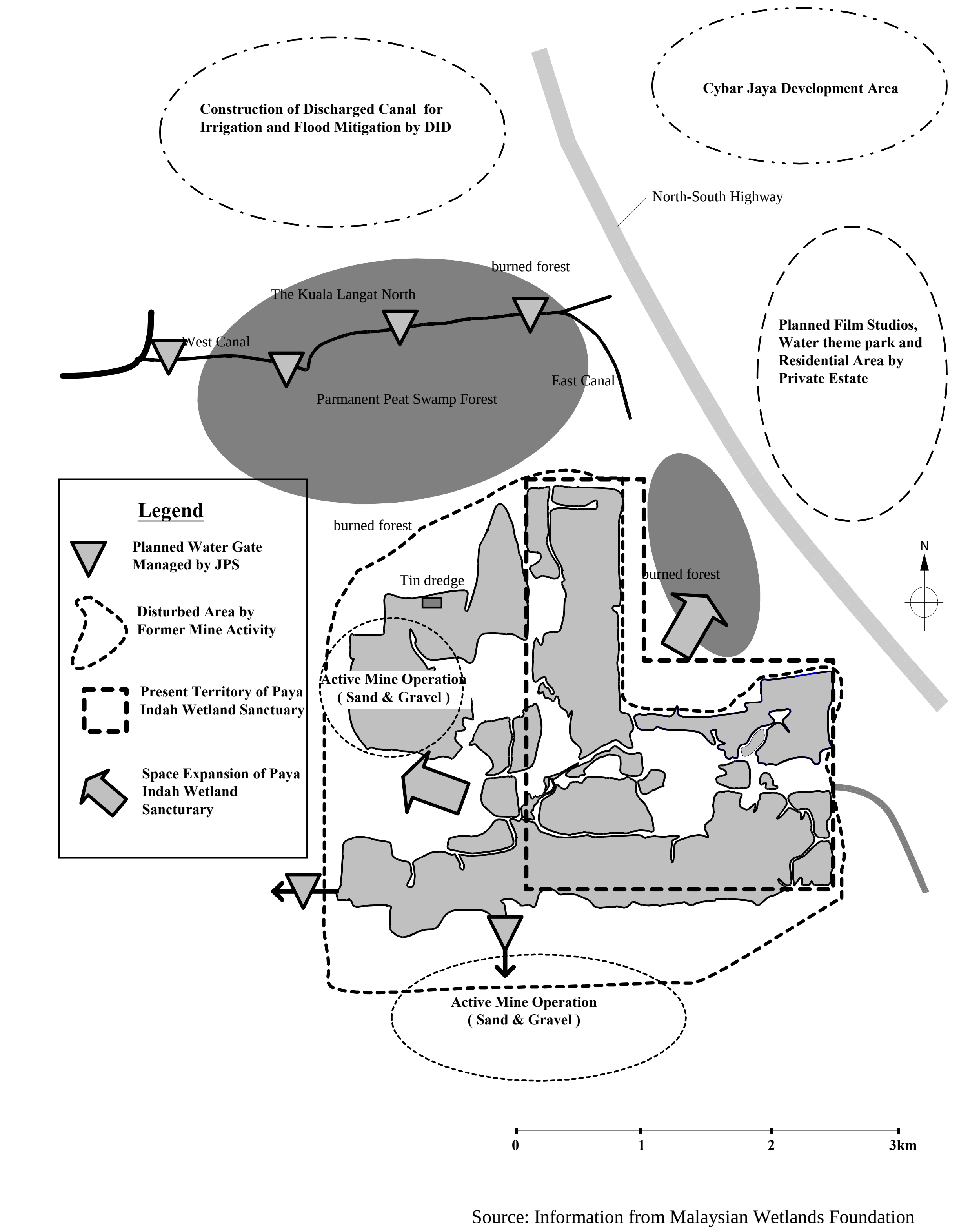
6.3.1 Boundary of Wetlands

The official boundary of the Paya Indah Wetland is shown in **Figure D.6.4**. However, as already described, the proposed area of the Malaysia Wetland Sanctuary Selangor (see **Figure D.6.1**) is larger than the territory drawn by the official boundary line. According to the latest information, since MWF has a plan of space expansion to the west of the Lotus Lake, it might be difficult to draw a definite boundary line as the Paya Indah Wetland. The National Land Code and the State Government as landowner regulate land use of the Paya Indah Wetland. MWF obtained authorisation of land use as a sanctuary from the State Government. As shown in **Figure D.6.4**, there are many plans and activities, which may seriously influence the Paya Indah Wetland, as listed below:

- Active mine operation (to the west and south of Paya Indah)
- Cyber-Jaya development (to the north-east of Paya Indah)
- Film studios, water theme park (to the north-east of Paya Indah)
- Construction of discharge canal (to the north of Paya Indah)
- Construction of water control gate (west canal, out flow from the Lotus Lake)

6.3.2 Inflow Streams and their Catchment Basins, and Discharge Streams

According to the previous study, the Paya Indah Wetland has two separate catchment areas (the Pallustrine system and the Lacustrine system) based on the topographical map with a scale of 1:50,000 and direction of inflow streams to the Paya Indah Wetland. However, since the map was published and printed in 1992, an aerial photo of about ten years old, the JICA Study Team carried out carefully to identify the catchment area through field reconnaissance. **Figure D.6.5** shows inflow streams and their catchment basins, and discharge streams based on the field reconnaissance during study period. There are three inflow streams crossing the North-South Highway. Drainage water from “sub-catchment area 2” flows across the North-South Highway at 27.35 and 29.5 km points towards the Lacustrine system. As for the Pallustrine system, drainage water from “sub-catchment area 1” flows across the 24.9 km point towards the Pallustrine system. The discharge streams from the Paya Indah Wetland are located in the west and the south side of the Lotus Lake. Since there are no significant topographic changes in the major part of the catchment area, it might be difficult to draw a definite boundary line without a detailed survey. However, from the hydrological point of view, as far as the contribution of recharging water of the wetland is concerned, “catchment area 2” might have its main source of surface water supply for Paya Indah Wetland.



Source: Information from Malaysian Wetlands Foundation

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Figure D.6.4

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

Present State of the Paya Indah Wetland and its Vicinity

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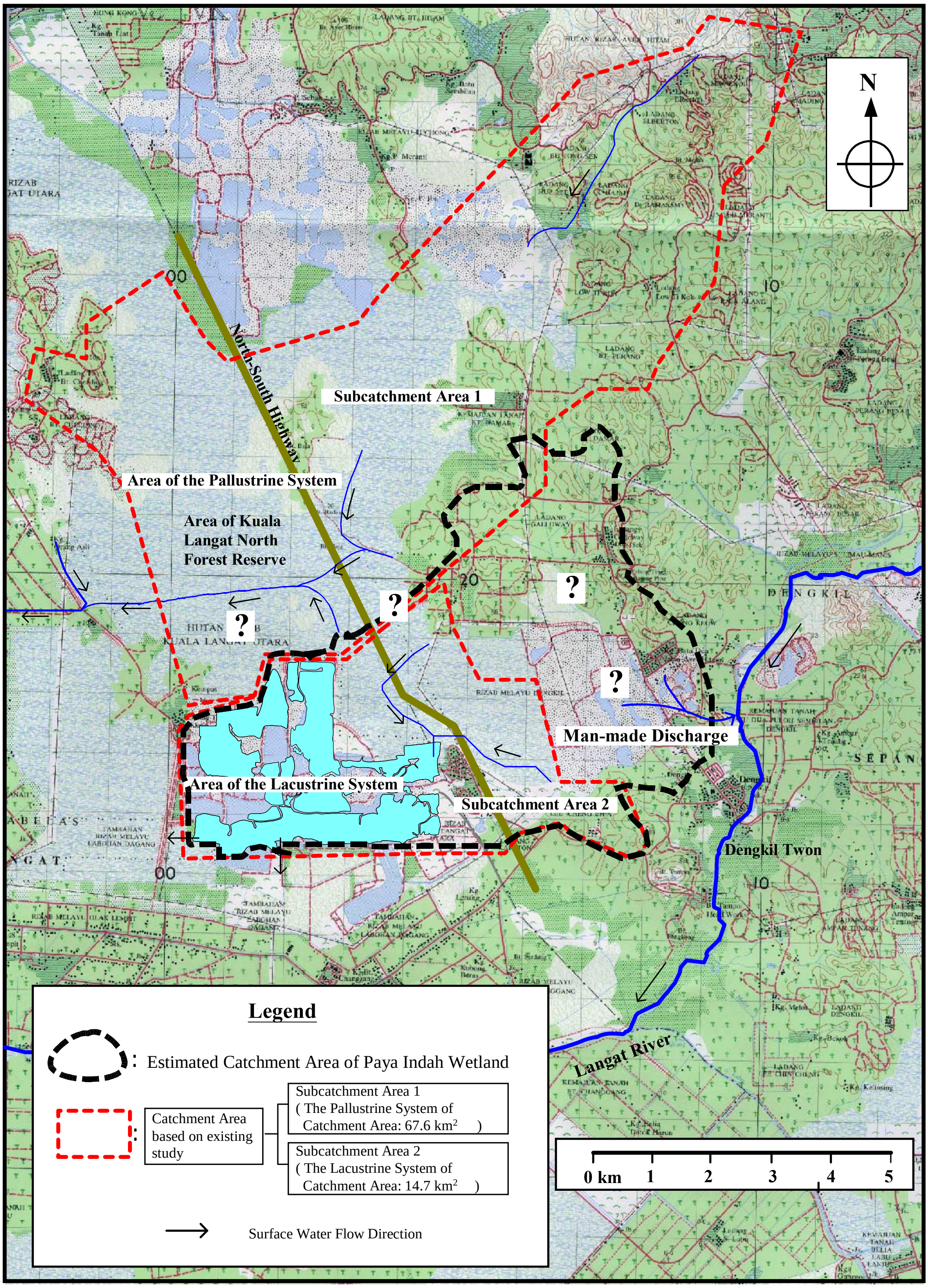

Note : This map is based on a map published by Director of National Mapping Malaysia 1991.

Source : Information from Malaysian Wetlands Foundation and field reconnaissance by JICA Study Team

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Figure D.6.5

Catchment Area of the Paya Indah Wetland

6.3.3 Water Quality

The previous information available on water quality can be quoted from the following two documents:

- WETLANDS INTERNATIONAL ASIA PACIFIC "Preliminary Hydrological and Water Quality Assessment For The Malaysian Wetland Sanctuary, Selangor" Final Report, December 1996, Centre for Environmental Technologies
- Water Quality Parameters for Selected Dates between 17 February 1998 and 8 May 1998, MWF

The results of water quality analysis including the in-situ measurements from the above are compiled and collated in **Figure D.6.6** and **Data Book D.6.1**. The water quality in the Paya Indah Wetland and its vicinity can be characterised as acidic. The source of acidic water can be explained as follows:

- Inflow streams through the peat swamp contain tannins and organic acids
- Sulphuric acid originated by exposure of pyrite-rich sediments (averaging as high as 24%) of the former mine activity is common. (During mining operation, the water in the mining pond was reported to have become more acidic. It has been recorded that the pH went down to about 2.9 - 3.0.)

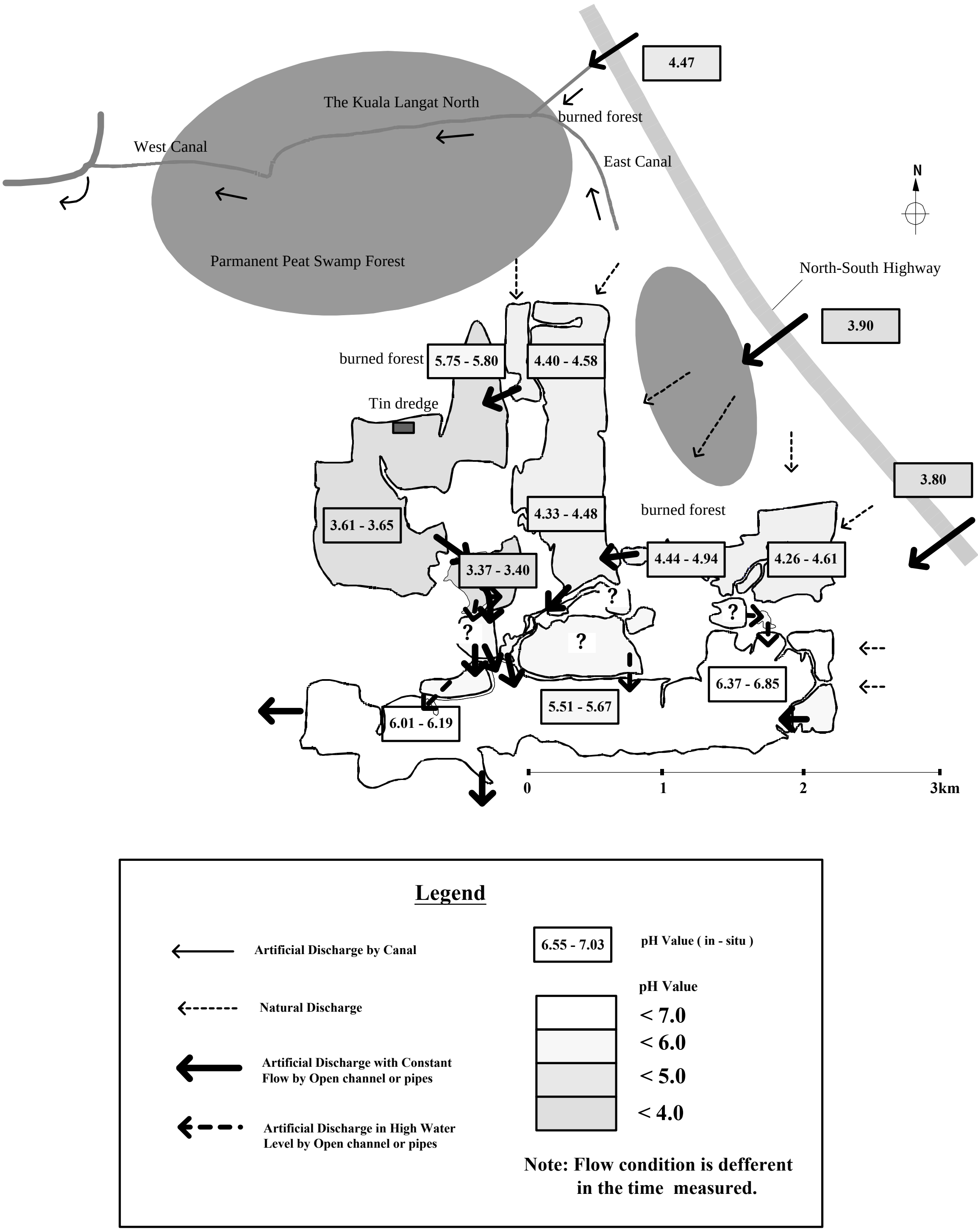
As shown in **Figure D.6.6**, the peat swamp water is likely to be the most dominant cause of acidic water, because neutralisation technique such as adding of calcium carbonate sludge and lime to water has been used in the former mine excavations. Comparing 1996 with 1998, no significant change of pH value can be seen. Except the low pH value caused by the acidic water, there is no significant high value of water quality parameters.

6.3.4 Flora and Fauna

According to the information from MWF on flora and fauna in the Paya Indah Wetland, 142 species of birds, 40 species of fish, 35 species of wildlife, and 220 species of aquatic and terrestrial plants were found in 1998.

6.3.5 Observation Items and Location

Previous observation items and location are shown in **Figure D.6.7**. There are fifteen (15) staff gauges to record the daily data of water level in each lake. Regarding rainfall data, there is a rain gauge in the west side of the Main Lake. Data has been recorded manually (not self-recording) and input in the database by MWF from October 1999. The weather station with measuring unit for rainfall, temperature and wind has been operating since the beginning of July in 2000.



Source: WETLANDS INTERNATIONAL ASIA PACIFIC *" Preliminary Hydrological and Water Quality Assessmen For The Malaysian Wetlands Sanctuary, Selangor "* Final Report , December 1996, Centre for Environmental Technologies

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Figure D.6.6

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

Overview of Water Quality (pH value) in the Paya Indah Wetland

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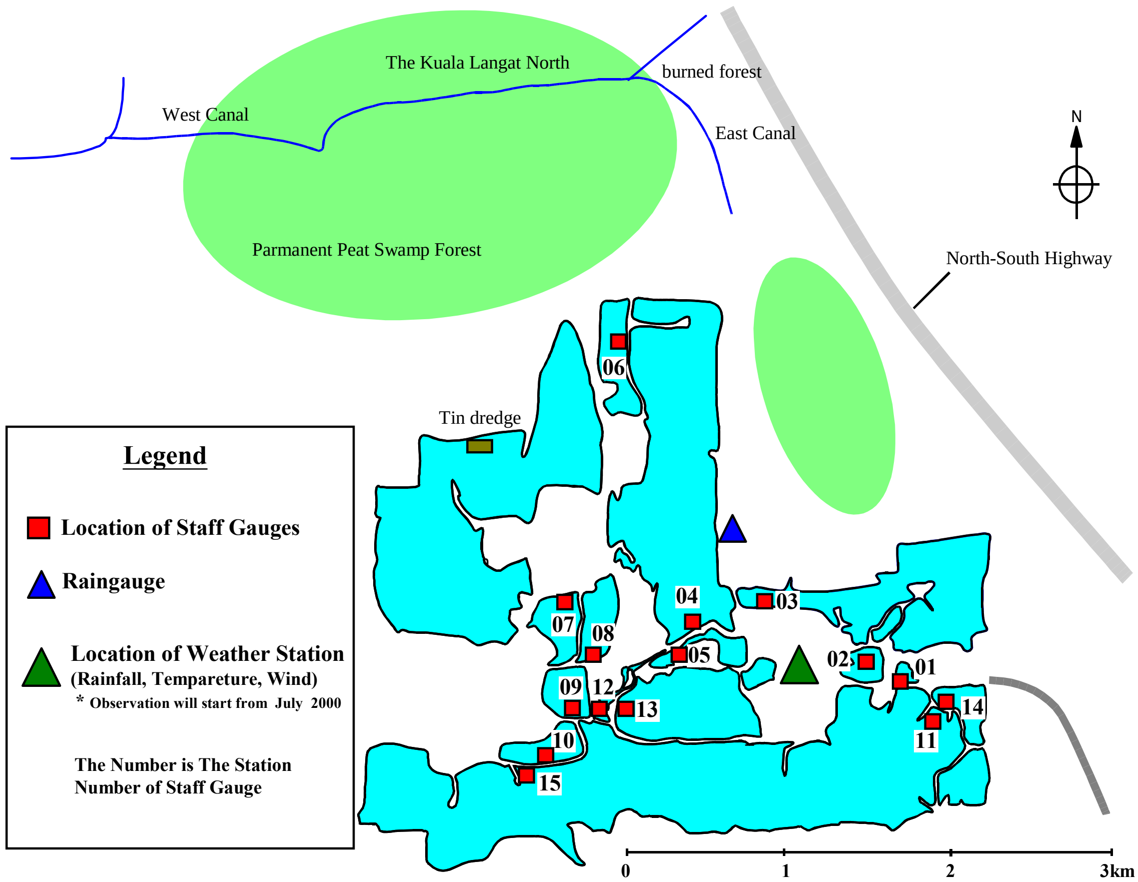

09 Padi Lake

12 Palm Lake

(Photographing on May 5, 2000)

Existing Staff Gauge

St.No	Location of Staff Gauge	Monitoring Period
01	Hippo Lake	12.10.99 - 29.2.00
02	Crocodile Lake	12.10.99 - 29.2.00
03	Visitor Lake	11.10.99 - 29.2.00
04	Main Lake	11.10.99 - 29.2.00
05	Gunung Lake	12.10.99 - 29.2.00
06	Driftwood Lake	12.10.99 - 29.2.00
07	Perch Lake	12.10.99 - 29.2.00
08	Marsh Lake	11.10.99 - 29.2.00
09	Padi Lake	11.10.99 - 29.2.00
10	Swamphen Lake	12.10.99 - 29.2.00
11	Lotus Lake (Lotus St.)	11.10.99 - 29.2.00
12	Palm Lake	11.10.99 - 29.2.00
13	Chalet Lake	12.10.99 - 29.2.00
14	Typha Lake	12.10.99 - 29.2.00
15	Lotus Lake (Typha St.)	12.10.99 - 29.2.00

Source: Information from Malaysian Wetlands Foundation

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Figure D.6.7

Location of Existing Monitoring Equipment in the Paya Indah Wetland

6.4 Hydrological Condition

6.4.1 Water Level and Precipitation

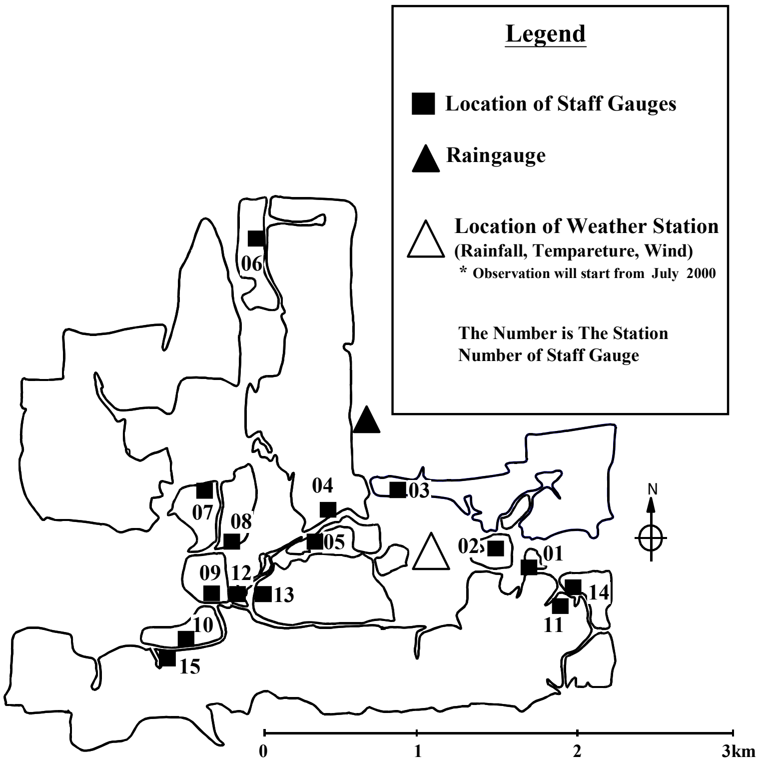
As shown in **Figure D.6.8**, MWF has conducted monitoring of water level in each lake at fifteen (15) stations. Daily water level has been measured by the staff gauge since October 1999, as shown in **Figure D.6.8** and **Data Book D.6.2**. At the same time, rainfall data near the Main Lake has been measured. **Figures D.6.9 to D.6.14** show the time-series records of daily water level and daily rainfall from November 1999 until December 2000. Hydrologic characteristics of the Paya Indah Lakes are explained as follows:

- Except the Main Lake and the Visitor Lake that are located in the upper part of the Paya Indah Wetland, at present, water level in almost all of the other lakes are artificially controlled by gate and pump facilities. Hence, monitoring data give some unnatural behaviour in comparison with rainfall, especially in dry season and rainy season (see **Figures D.6.8 to D.6.14**).
- It may be said that the yearly fluctuation of water level is not clearly cyclic in making a comparison of the water levels in November and December between 1999 and 2000 due to difference of precipitation (see **Figure D.6.9**).
- As presented in **Figure D.1.7**, there are two dry seasons in the Study Area: January-February and June-July. However, the year 2000 had an abnormal weather condition as far as rainfall data observed in this area is concerned. That may show an unclear curve of both rainfall and water level (see **Figures D.6.10 to Figure D.6.14**).
- Water levels of the Visitor Lake and the Main Lake are sensitive to rainfall, and their changes may suggest adequate correlation between rainfall and water level (see **Figure D.6.13**).
- According to the field reconnaissance and previous examination in Phase I, inflow may affect the Visitor Lake and the Main Lake, and outflow sources from the Lotus Lake. These three lakes occupy large areas of the Paya Indah Wetland and have good correlation with rainfall (see **Figure D.6.15**).

As shown in **Figure D.6.16**, the rise of water level for a certain period after heavy rainfall in the upper lakes such as the Visitor Lake and the Main Lake are more rapid in comparison with the rise in lower lakes such as the Chalet Lake and the Lotus Lake. This tends to suggest that the water of the lower lakes is regulated by the upper lakes. **Figure D.6.17** shows the shape of the wave of water level after heavy rainfall, indicating that the wave is symmetrical in both upper lakes and lower lakes. This property may explain that the recharging water to the Paya Indah lakes originated by inflow of groundwater (or inflow from a large catchment area) is relatively small.

Existing Staff Gauge

St.No	Location of Staff Gauge
01	Hippo Lake
02	Crocodile Lake
03	Visitor Lake
04	Main Lake
05	Gunung Lake
06	Driftwood Lake
07	Perch Lake
08	Marsh Lake
09	Padi Lake
10	Swamphen Lake
11	Lotus Lake (Lotus St.)
12	Palm Lake
13	Chalet Lake
14	Typha Lake
15	Lotus Lake (Typha St.)



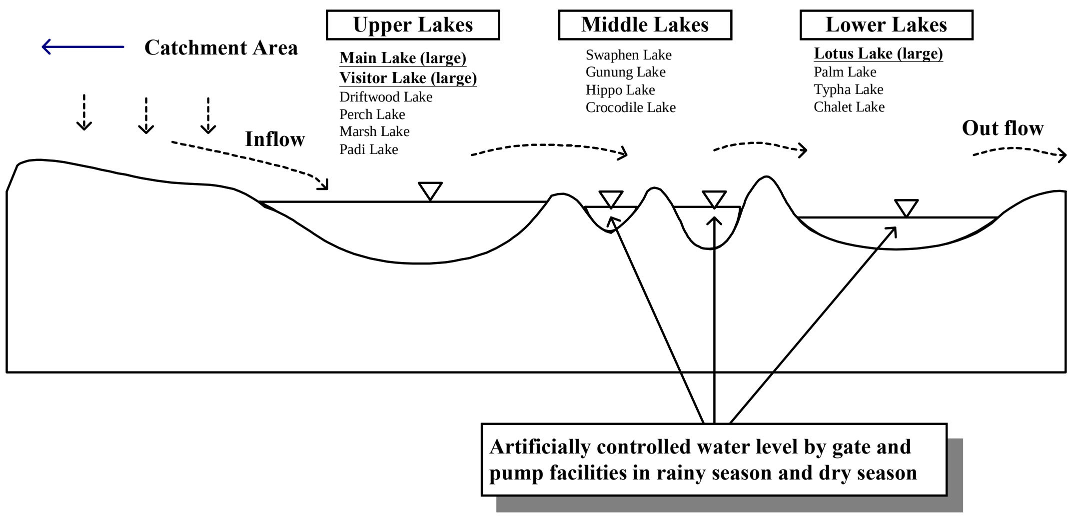


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Figure D.6.8

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

Location of Monitoring Station and Schematic Profile of the Paya Indah Lakes

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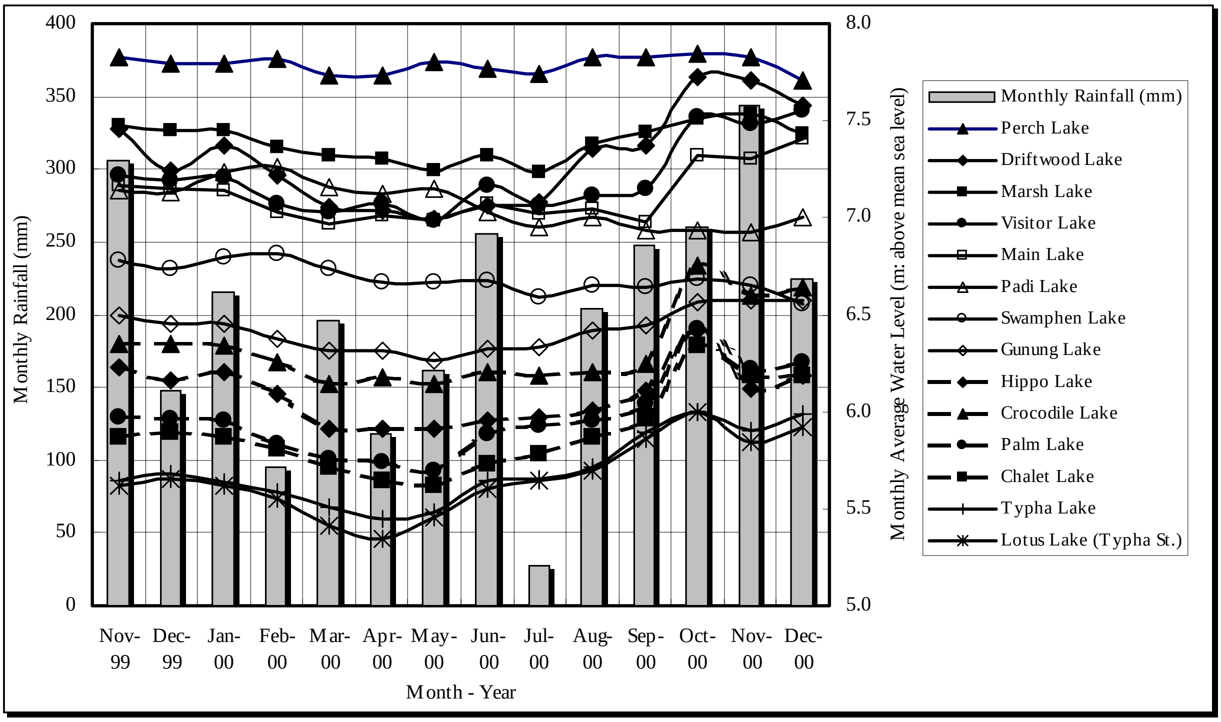
Monthly Average Water Level in the Paya Indah Lakes

Month - Year	Monthly Rainfall (mm)	Perch Lake	Driftwood Lake	Marsh Lake	Visitor Lake	Main Lake	Padi Lake	Swamphen Lake	Gunung Lake	Hippo Lake	Crocodile Lake	Palm Lake	Chalet Lake	Typha Lake	Lotus Lake (Typha St.)	Lotus Lake (Lotus St.)
Nov-99	305.7	7.8	7.46	7.48	7.22	7.17	7.14	6.78	6.49	6.23	6.35	5.98	5.87	5.65	5.62	5.62
Dec-99	147.85	7.8	7.25	7.45	7.19	7.15	7.13	6.73	6.45	6.16	6.35	5.97	5.89	5.68	5.66	5.65
Jan-00	215.8	7.8	7.37	7.45	7.21	7.14	7.24	6.79	6.45	6.21	6.34	5.95	5.87	5.64	5.62	5.62
Feb-00	95	7.8	7.21	7.36	7.08	7.03	7.26	6.81	6.38	6.09	6.26	5.83	5.80	5.59	5.55	5.54
Mar-00	196.5	7.7	7.05	7.32	7.03	6.97	7.16	6.73	6.31	5.91	6.15	5.75	5.71	5.51	5.41	
Apr-00	118	7.7	7.03	7.30	7.07	7.02	7.12	6.67	6.32	5.91	6.18	5.74	5.65	5.45	5.35	
May-00	162	7.8	7.00	7.25	6.99	6.98	7.15	6.67	6.26	5.91	6.14	5.70	5.62	5.48	5.46	
Jun-00	256	7.8	7.07	7.32	7.17	7.07	7.03	6.68	6.32	5.95	6.21	5.88	5.73	5.64	5.61	
Jul-00	27	7.7	7.08	7.23	7.06	7.02	6.95	6.59	6.33	5.97	6.19	5.93	5.78	5.65	5.65	
Aug-00	204	7.8	7.35	7.38	7.12	7.04	7.00	6.65	6.42	6.01	6.20	5.95	5.87	5.72	5.69	
Sep-00	247	7.8	7.37	7.44	7.15	6.97	6.93	6.65	6.45	6.11	6.25	6.04	5.97	5.89	5.86	
Oct-00	260	7.8	7.72	7.51	7.52	7.32	6.93	6.69	6.56	6.42	6.75	6.43	6.34	6.00	6.00	
Nov-00	344	7.8	7.71	7.53	7.48	7.30	6.93	6.65	6.57	6.12	6.60	6.22	6.18	5.90	5.85	
Dec-00	224.5	7.7	7.58	7.43	7.56	7.40	7.00	6.56	6.58	6.19	6.64	6.26	6.19	5.99	5.92	

(mm)



Source : Monitored data provided by Malaysian Wetlands Foundation

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Figure D.6.9

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

Monthly Average Water Level and Monthly Rainfall in the Paya Indah Lakes

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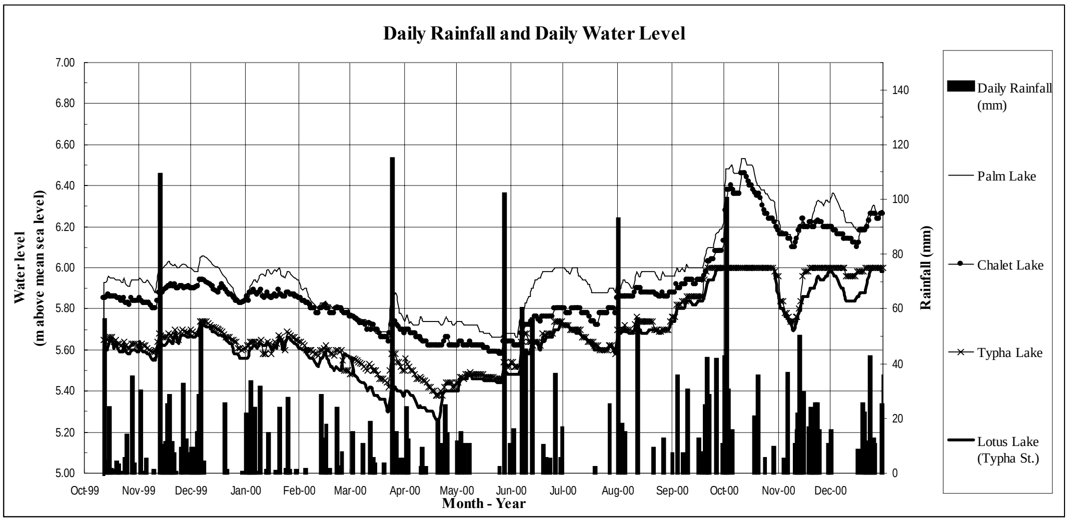

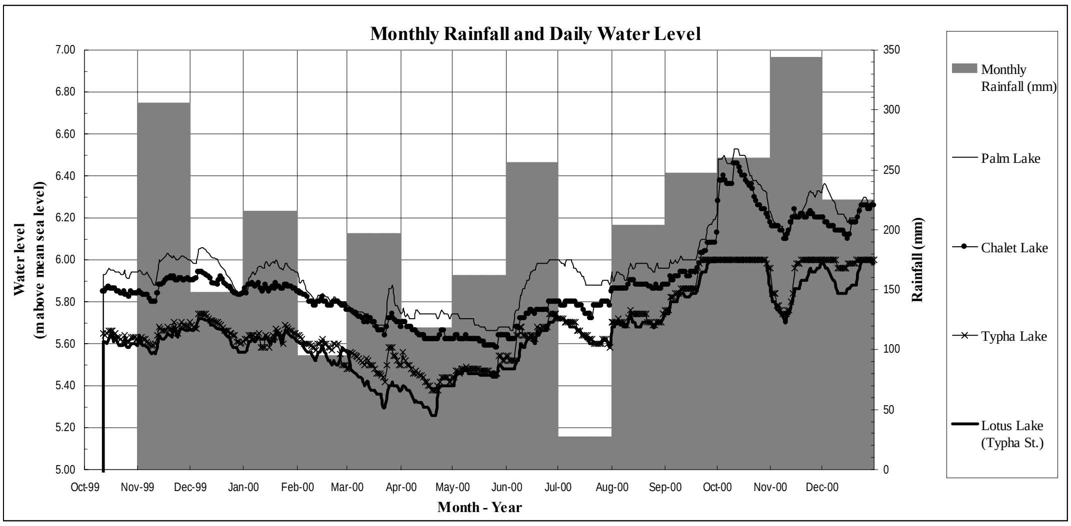

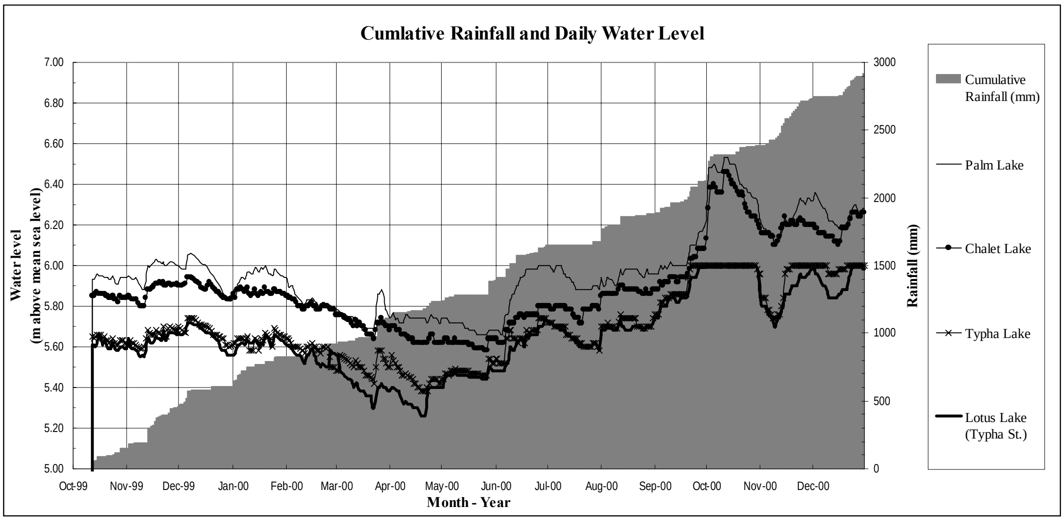

Source : Monitored data provided by Malaysian Wetlands Foundation

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Figure D.6.10

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

Rainfall and Water Level in the Paya Indah Lakes (Lower Lakes)

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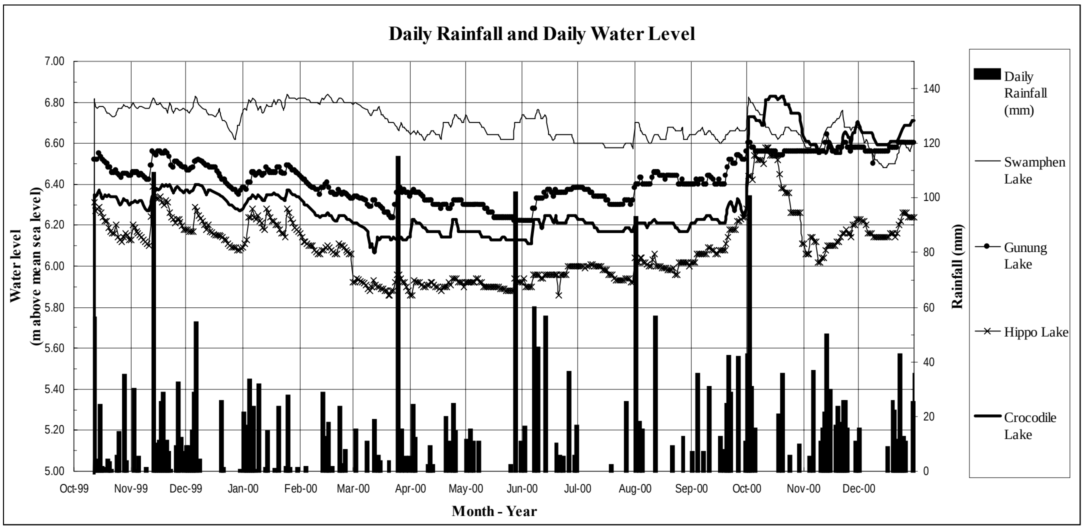

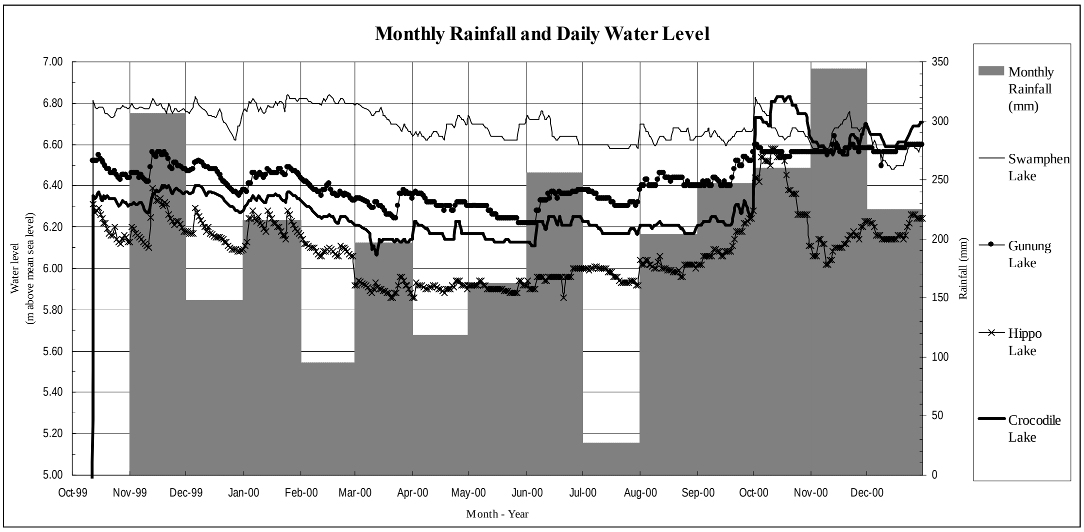

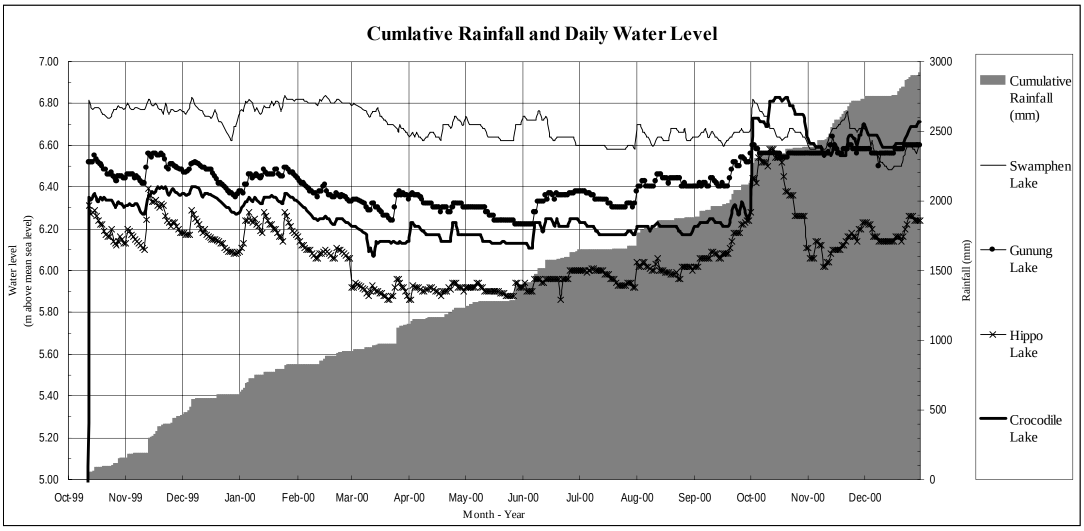

Source : Monitored data provided by Malaysian Wetlands Foundation

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

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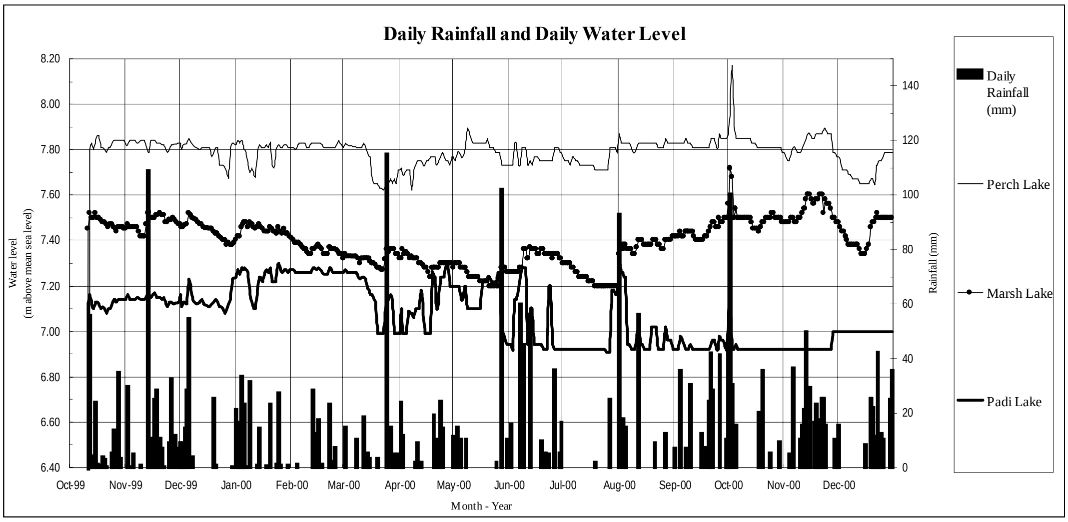
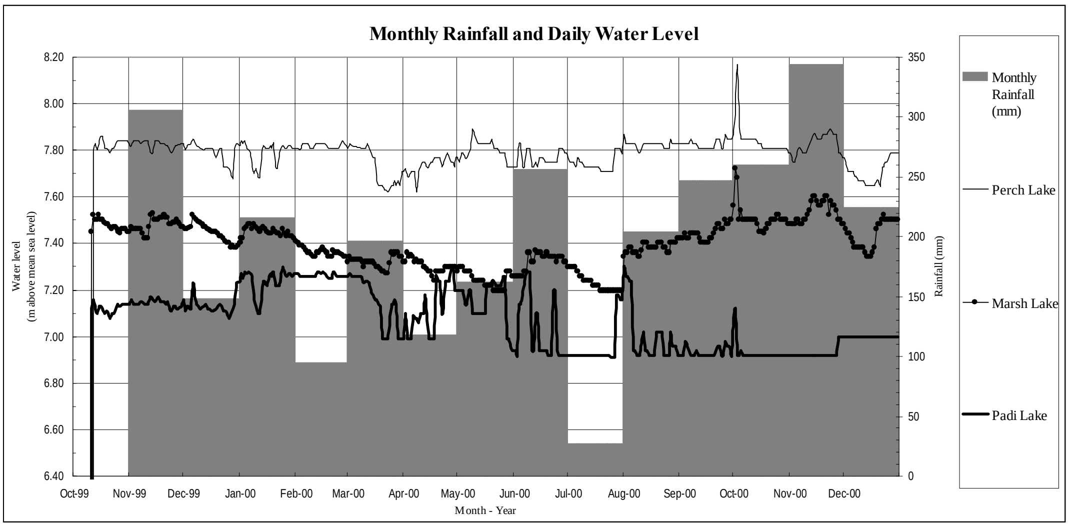
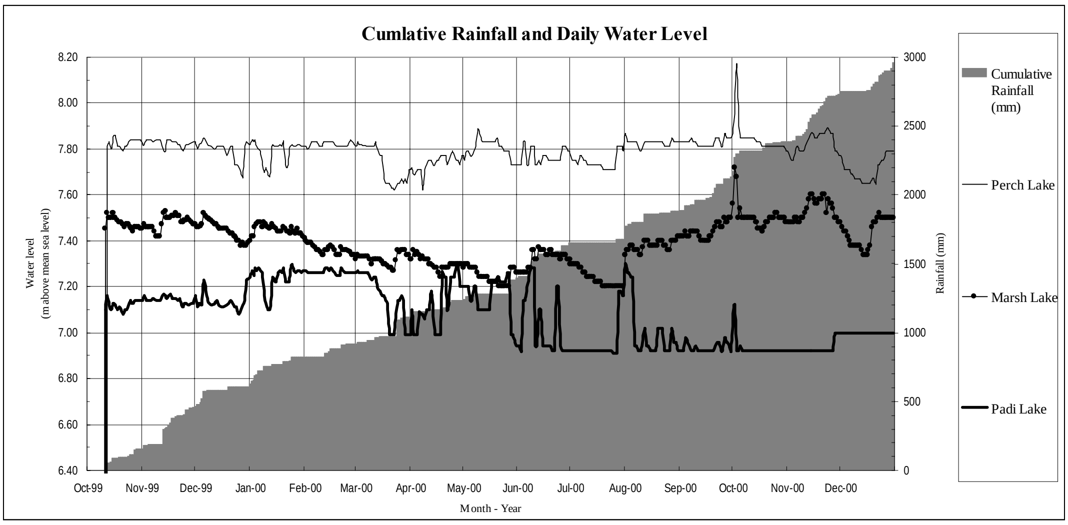
Figure D.6.11

Rainfall and Daily Water Level in the Paya Indah Lakes (Middle Lakes)







Source : Monitored data provided by Malaysian Wetlands Foundation

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Figure D.6.12

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

Rainfall and Daily Water Level in the Paya Indah Lakes (Upper Lakes (1))

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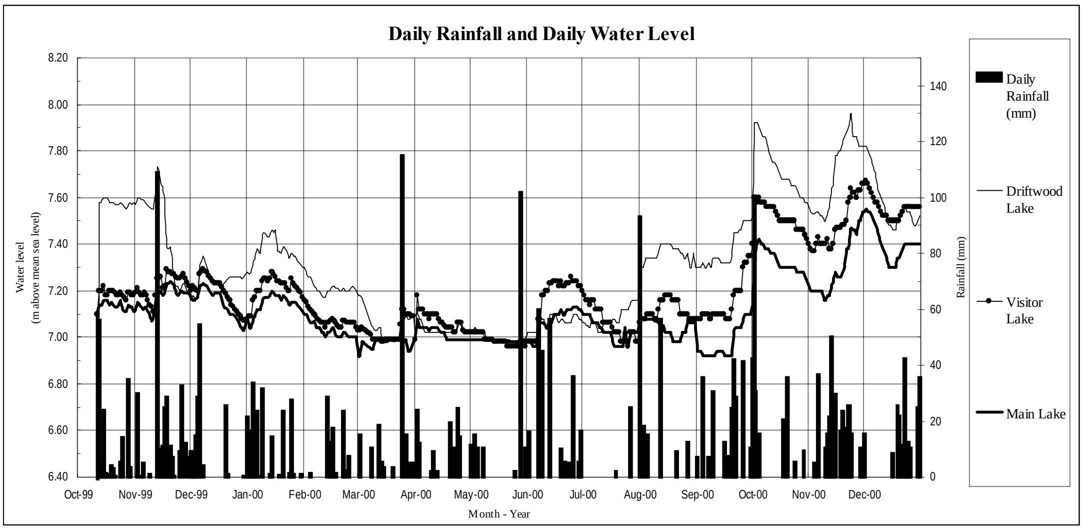

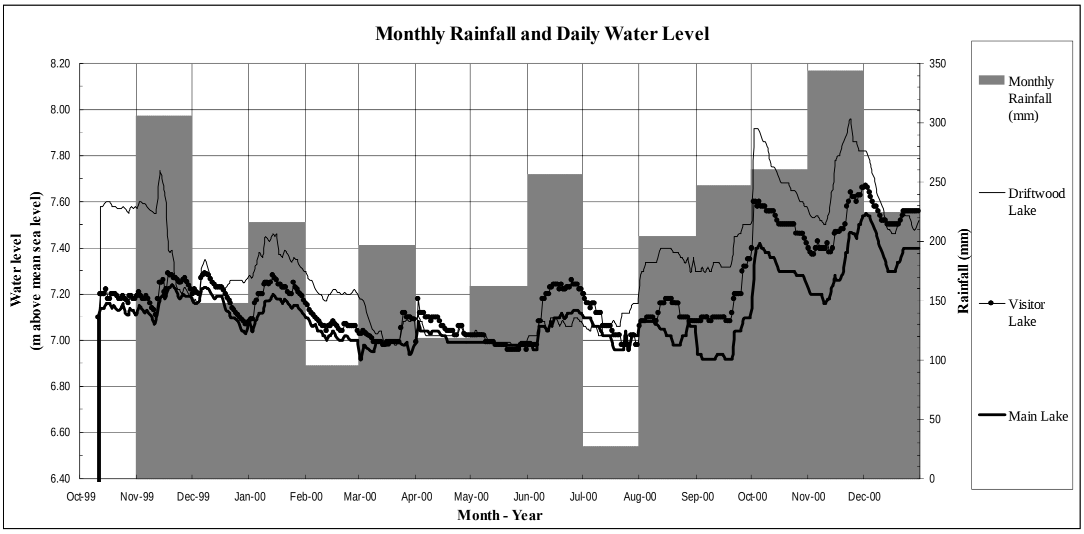

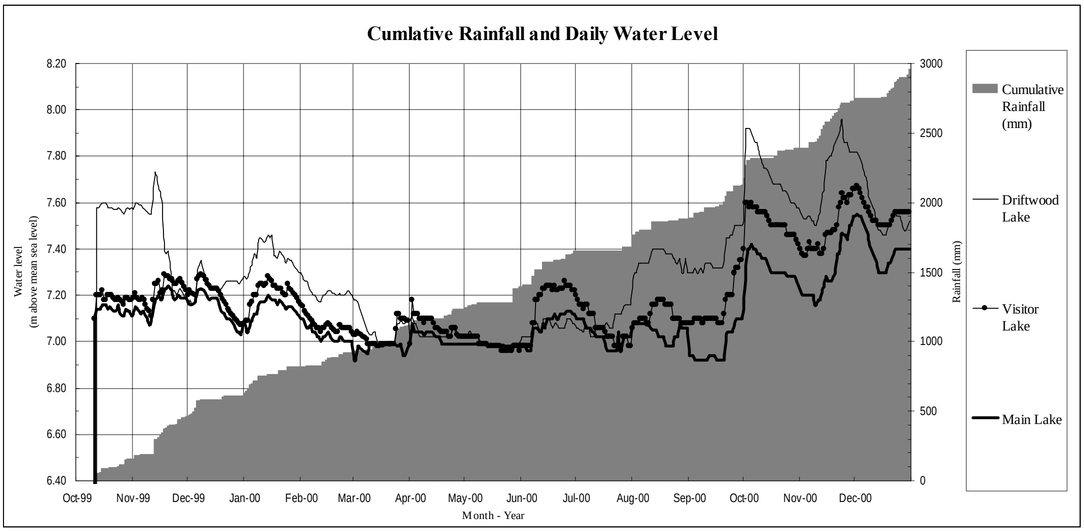

Source : Monitored data provided by Malaysian Wetlands Foundation

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Figure D.6.13

Rainfall and Daily Water Level in the Paya Indah Lakes (Upper Lakes (2))

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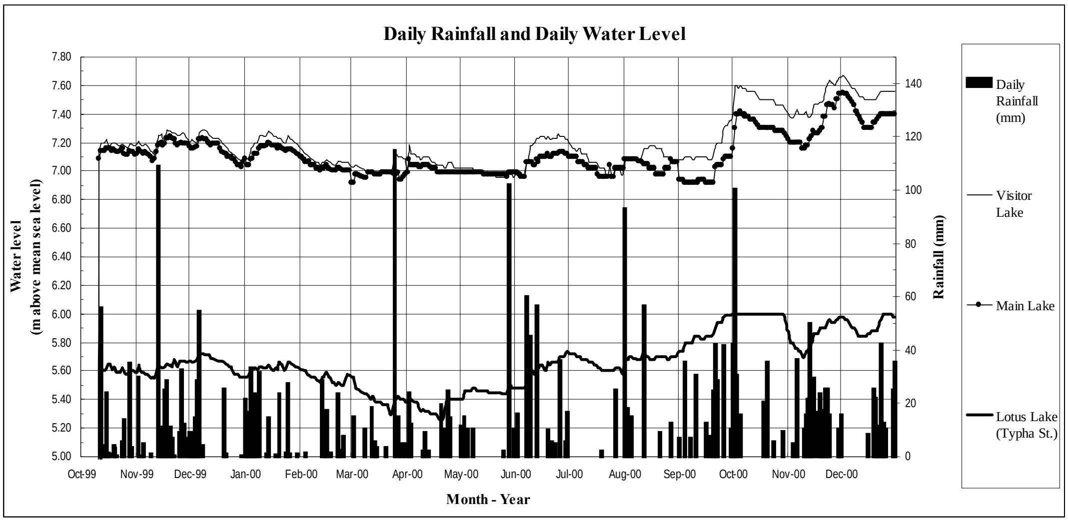

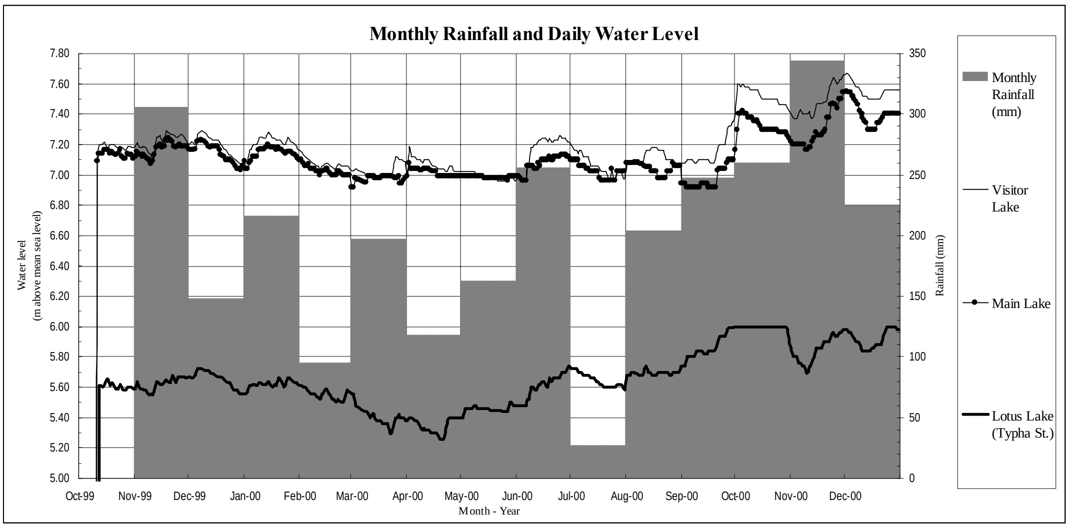

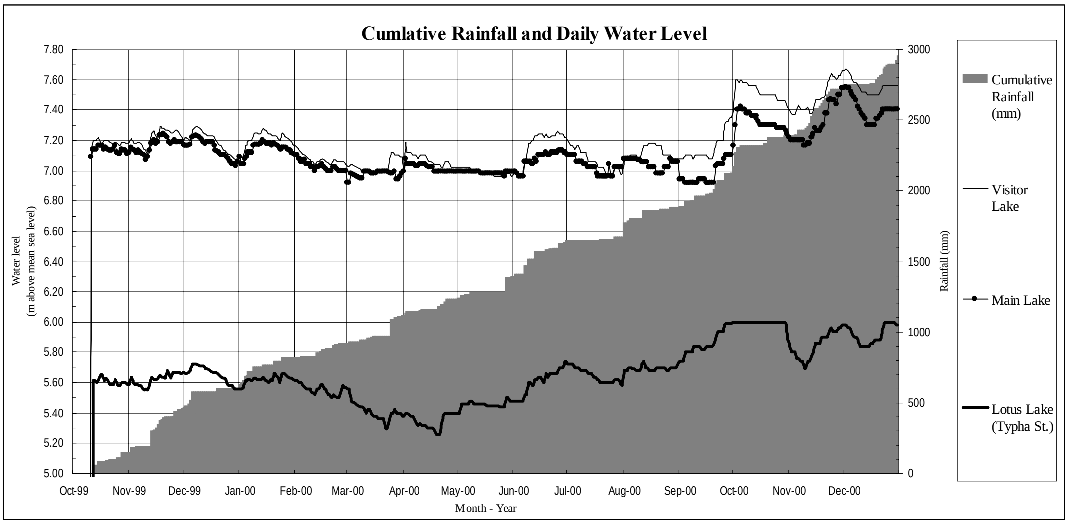

Source : Monitored data provided by Malaysian Wetlands Foundation

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Figure D.6.14

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

Rainfall and Daily Water Level in the Paya Indah Lakes (Large Lakes)

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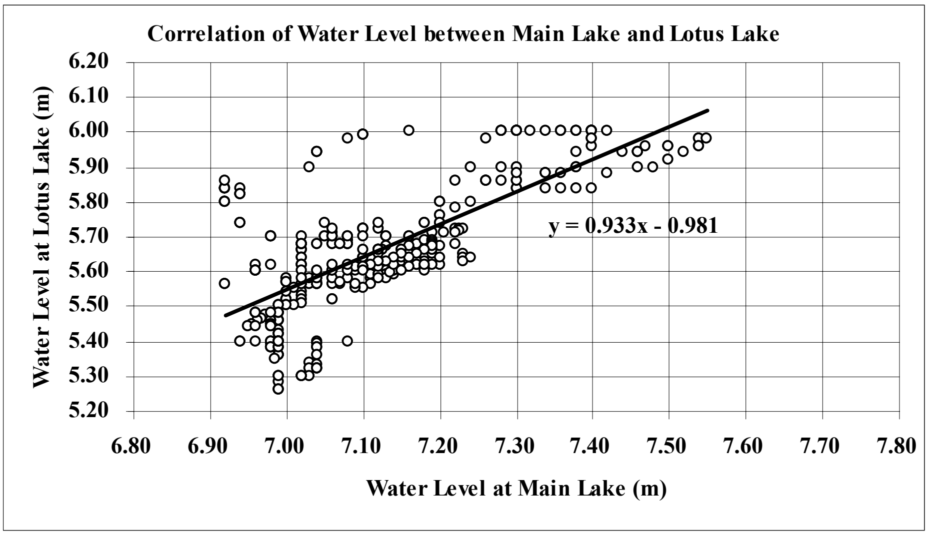

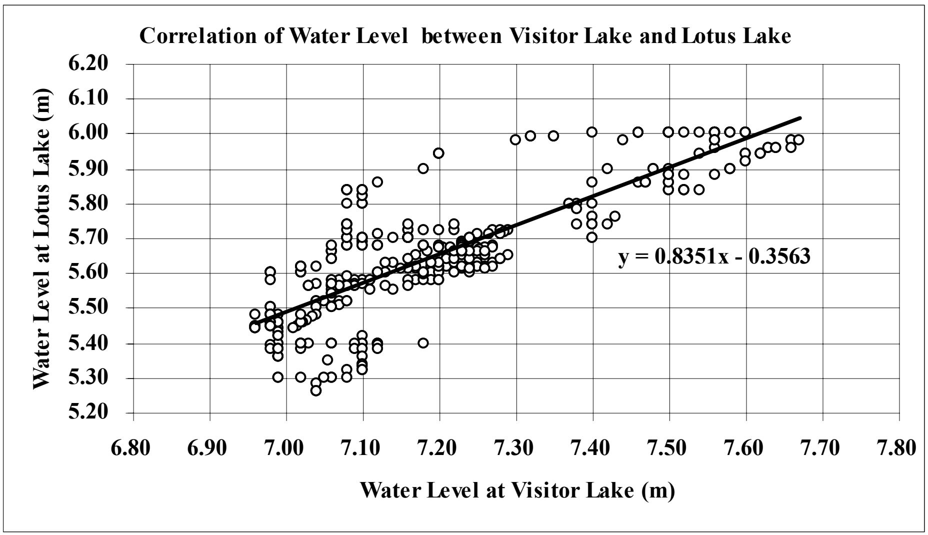

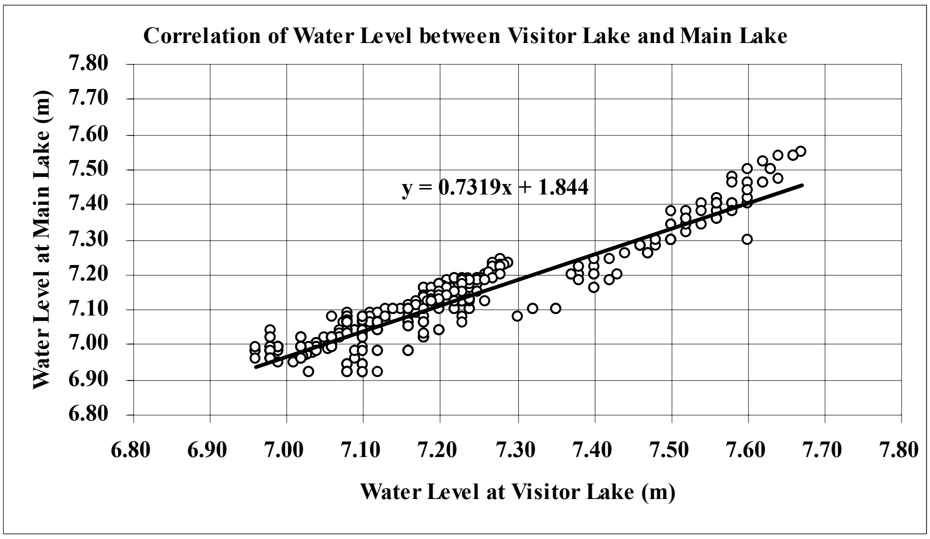

Source : Monitored data provided by Malaysian Wetlands Foundation

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

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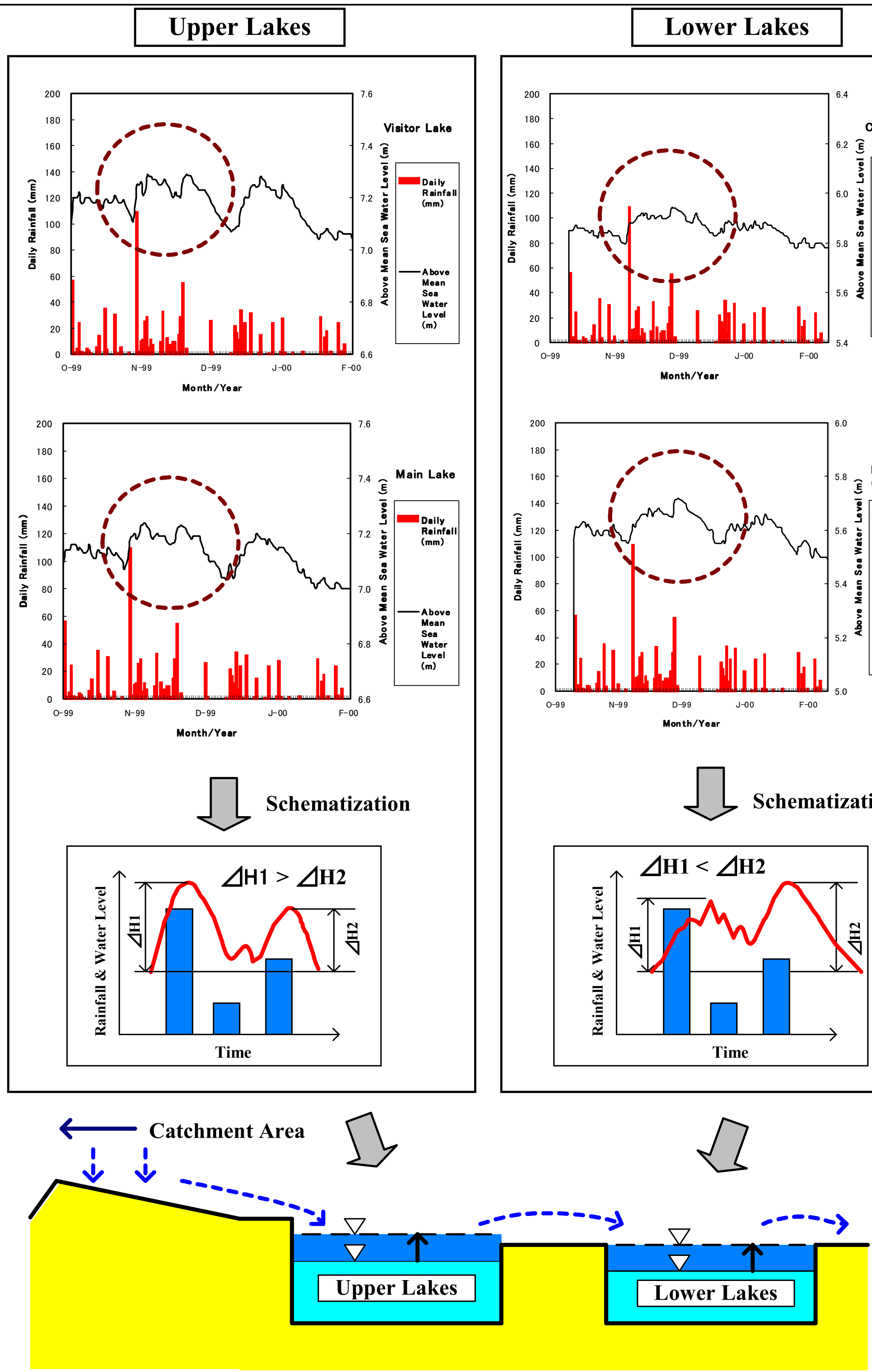
Figure D.6.15

Correlation of Water Level between Large Lakes in the Paya Indah Lakes



Source: Monitored data provided by Malaysian Wetlands Foundation

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Figure D.6.16

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

Hydrologic Property of the Paya Indah Lakes (1)

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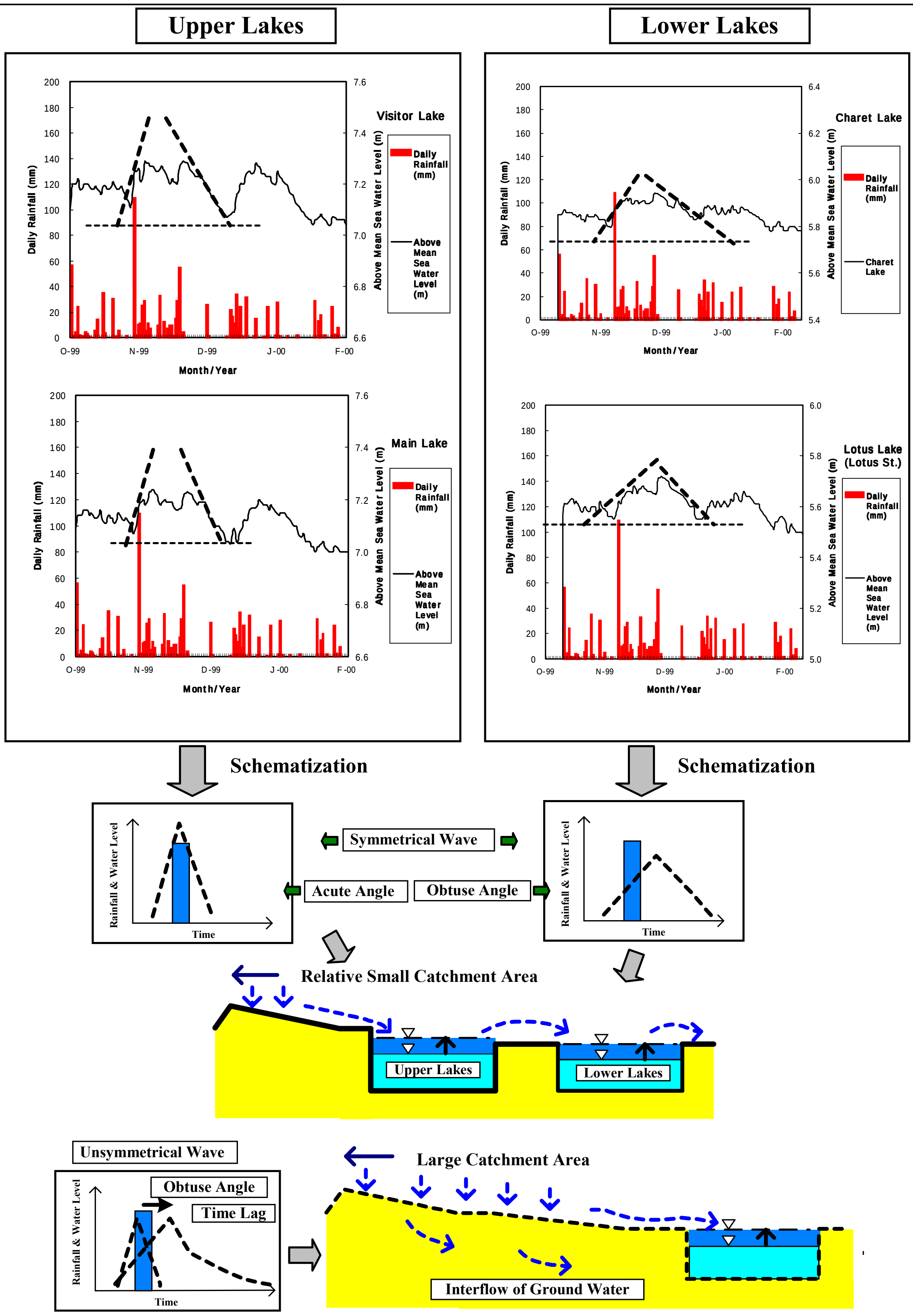

Source : Monitored data provided by Malaysian Wetlands Foundation

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Figure D.6.17

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

Hydrologic Property of the Paya Indah Lakes (2)

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6.4.2 Inflow and Outflow

Figure D.6.18 shows the system of Inflow and Outflow in the Paya Indah lakes. The lakes are linked with each other by pipe, box culvert and small creek that are situated at the appropriate height to prevent water loss. Although baseline data on the Paya Indah Wetland lakes is tabulated in **Data Book D.6.2**, no flow rate data was accurate for the examination of inflow and outflow in the Paya Indah Wetland. Therefore, from the viewpoints of hydrology based on field reconnaissance, the following five (5) stations were selected and set up as monitoring stations for inflow and outflow as described in **Chapter 2**.

- **Inflow a** (monitoring station: **SWL-1**): Box culvert, at 24.9 km point across the North-South Highway
- **Inflow b1** (monitoring station: **SWL-2**): Box culvert, at 27.45 km point across the North-South Highway
- **Inflow b2** (monitoring station: **SWL-3**): Box culvert, at 30.3 km point across the North-South Highway
- **Outflow e** (monitoring station: **SWL-4**): Small channel, flow from south edge of the Lotus Lake
- **Outflow f** (monitoring station: **SWL-5**): Flow from west edge of the Lotus Lake

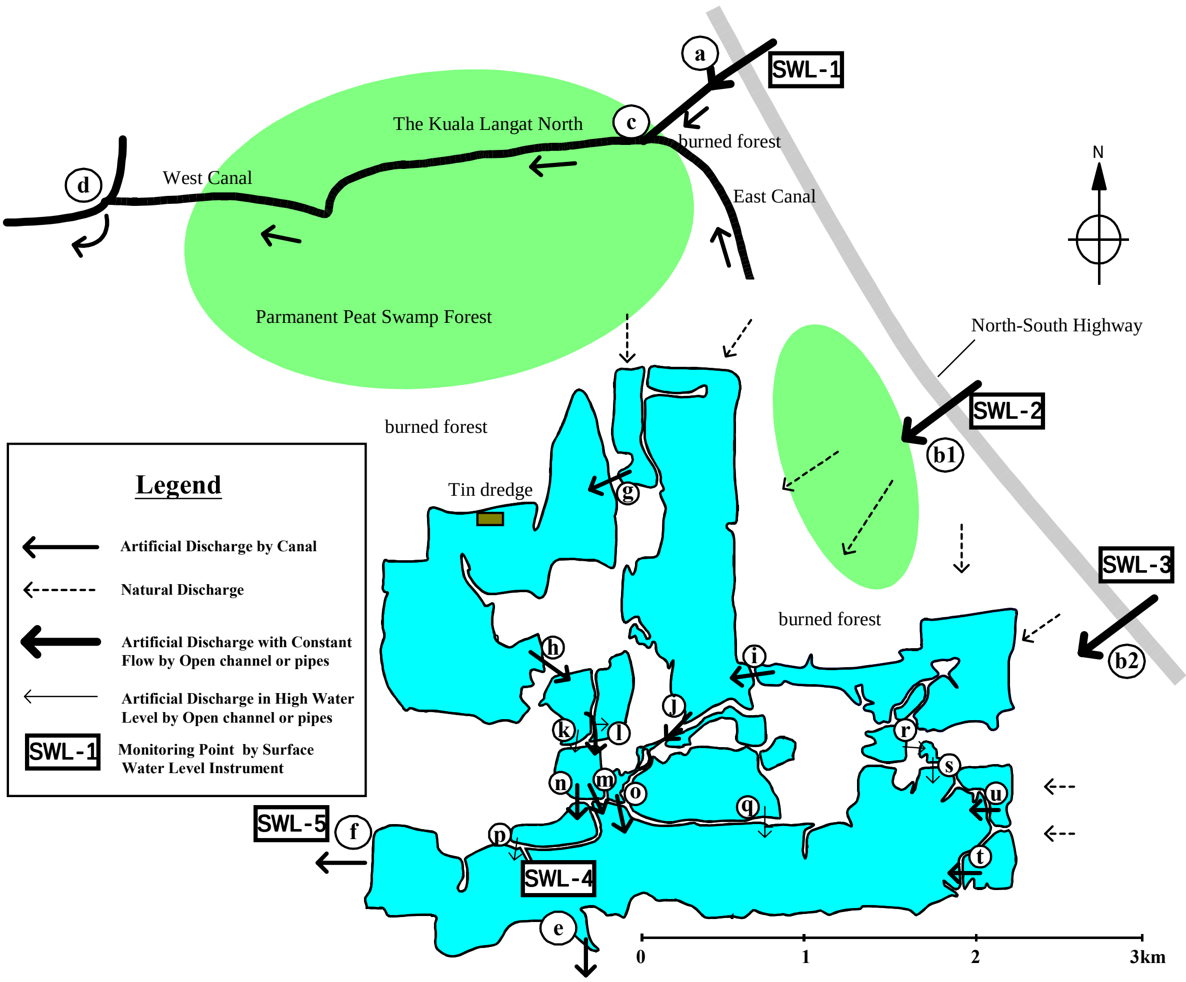
As **Outflow e** has been blocked since September 2000 due to construction of embankment, the location of monitoring station was changed to Lotus Lake.

Automatically measured water level with 30 minutes interval at the above five (5) stations from November 23, 2000 until June 7, 2001 is shown in **Figure D.6.19**. The flow rate converted by water level based on a conversion formula that can be estimated by field measurement as indicated in **Data Book D.2.8** is summarised as in **Table D.6.1**.

Table D.6.1 Summary of Flow Rate During Monitoring Period

Number of Measurement	Items	SWL-1	SWL-2	SWL-3	SWL-5
1	Date	12/12/2000	12/12/2000	-	12/12/2000
	Time	16:00	15:00	-	11:30
	Q (m^3/sec)	0.337	0.484	-	0.469
	A (m^2)	2.194	1.259	-	1.992
	V (m/sec)	0.154	0.385	-	0.236
	H: Water depth from the sensor (cm)	79.60	80.90	-	95.60
2	Date	12/3/2001	12/3/2001	12/3/2001	12/3/2001
	Time	11:00	14:00	12:00	13:00
	Q (m^3/sec)	0.819	0.271	0.023	0.17
	A (m^2)	5.11	2.096	0.291	0.87
	V (m/sec)	0.16	0.129	0.08	0.196
	H: Water depth from the sensor (cm)	90.60	69.90	94.60	83.40
Average water depth during monitoring period from 1/12/2000 until 31/5/2001 (m)		90.24	77.42	111.44	89.86
Estimated average flow rate during monitoring period from 1/12/2000 until 31/5/2001 (m^3/sec)		0.80	0.42	0.03	0.32

Source: Measured Data by JPS, JMG and JICA Study Team



Inflow and Outflow in Paya Indah Wetland and its Vicinity

Code	Name of the measuring point	Measuring date	Flow rate (m^3)	Flow condition
a	Inflow from upper part of catchment area	10/5/00	0.5 m^3/s	box culvert, constant flow
b1	Inflow from upper part of catchment area	10/5/00	0.3 m^3/s	box culvert, constant flow
b2	Inflow from upper part of catchment area	7/6/00	0.3 m^3/s	box culvert, constant flow
c	Ourflow by eest canal	10/5/00	0.1 m^3/s	constant flow
d	Outflow to west canal	2/5/00	0.5 m^3/s	box culvert, constant flow
e	Ourflow from southern part of the Lotus Lake (11)	10/5/00	0.0 m^3/s	filled with sand and gravel
f	Outflow from western part of the Lotus Lake (11)	10/5/00	0.3 m^3/s	box culvert, constant flow
g	Flow from the Driftwood Lake (06) to the Tin Lake	2/5/00	0.1 m^3/s	ϕ = 0.3 m pipe, constant flow
h	Flow from the Tin Lake to the Perch Lake (07)	2/5/00	unknown	drainage by pump, constant flow
i	Flow from the Visitor Lake (03) to the Main Lake (04)	2/5/00	0.3 m^3/s	open channel, constant flow
j	Flow from the Main Lake (04) to the Palm Lake (12)	2/5/00	0.4 m^3/s	
k	Flow from the Perch Lake (07) to the Pedi Lake (09)	2/5/00	0.0 m^3/s	no flow
l	Flow from the Perch Lake (07) to the Pedi Lake (09)	2/5/00	0.9 m^3/s	ϕ = 0.3 m double pipes, constant flow
m	Flow from the Pedi Lake (09) to the Lotus Lake (11)	2/5/00	0.9 m^3/s	ϕ = 0.5 m pipe, constant flow
n	Flow from the Pedi Lake (09) to the Swaphen Lake (10)	2/5/00	0.1m^3/s	ϕ = 0.3 m ? pipe, constant flow
o	Flow from the Palm Lake (12) to the Lotus Lake (11)	2/5/00	0.8 m^3/s	open channel, constant flow
p	Flow from the Swamphen Lake (10) to the Lotus Lake (11)	2/5/00	0.0 m^3/s	open channel, no flow
q	Flow from the Chalet Lake (13) to the Lotus Lake (11)	2/5/00	0.0 m^3/s	pipe and carbart ?, no flow
r	Flow from the Crocodile Lake (02) to the Hippo Lake (01)	2/5/00	0.0 m^3/s	open channel, no flow
s	Flow from the Hippo Lake (01) to the Lotus Lake (11)	2/5/00	0.0 m^3/s	box culvert, no flow
t	Flow to the Lotus Lake (11)	2/5/00	0.0 m3/s	open channel, flow direction is not clear
u	Flow from the Typha Lake (14) to the Lotus Lake (11)	7/6/00	0.1 m^3/s	ϕ = 0.3 m ? pipe, constant flow

g : Flow from Driftwood Lake to Tin Lake

j : Flow from Main Lake to Palm Lake

Source : Field reconnaissance by JICA Study Team

(Photographing on May 10, 2000)

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

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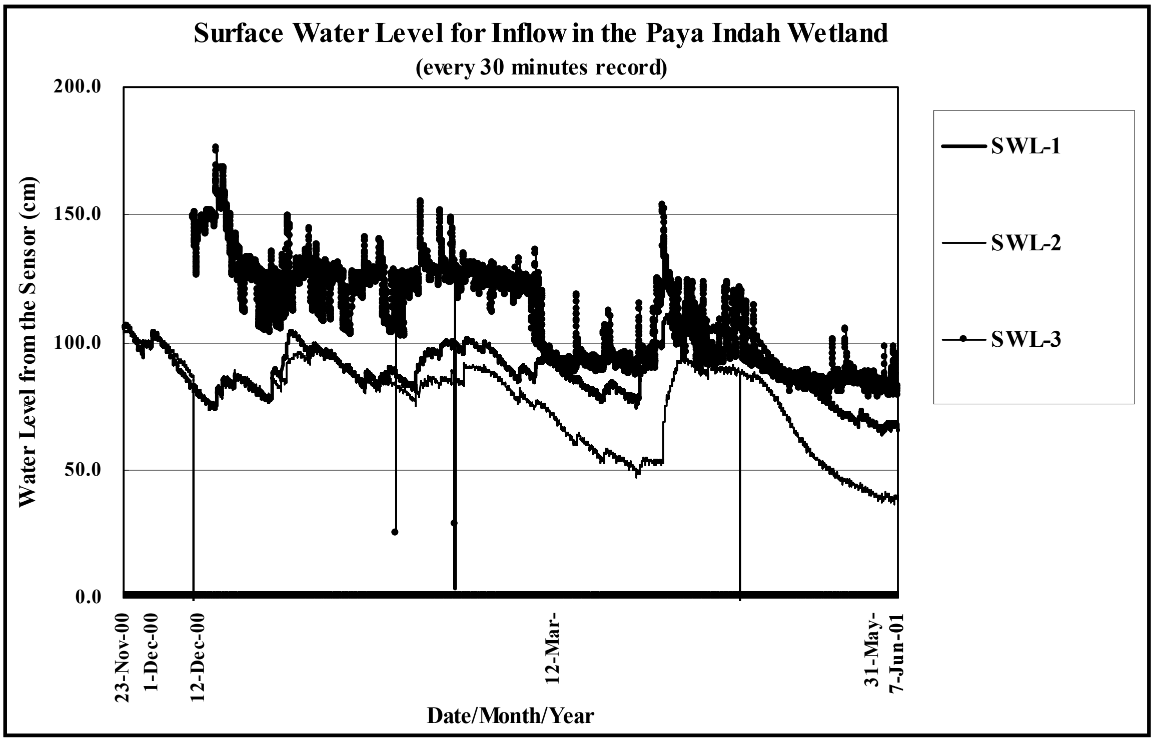
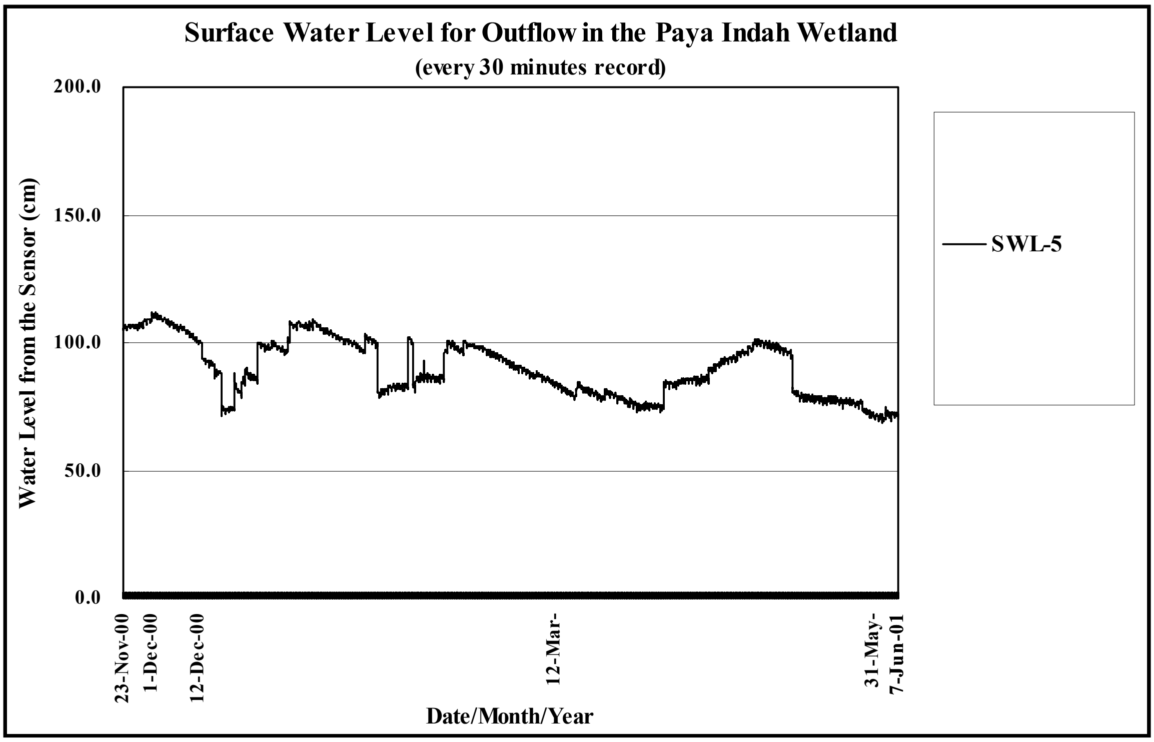
Figure D.6.18

Monthly Records on Rainfall and Evaporation near the Paya Indah Wetland





Source : Monitored Data by JMG and JICA Study Team

Japan International Cooperation Agency / Minerals and Geoscience Department Malaysia	**Figure D.6.19**
THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA	**Water Level for Inflow and Outflow in the Paya Indah Wetland**
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6.4.3 Rainfall and Evaporation

The monitoring data regarding rainfall and evaporation covered the catchment of the Paya Indah Wetland as described in **Chapter 1**, and can be referred at the following stations:

- Rainfall: Log. Galloway (Station No.2816112) managed by DID
  Prang Besar (Station No. 2916001) managed by DID
- Evaporation: Prang Besar (Station No. 2916301) managed by DID.

Daily data is available from 1980 until 1999 at the above stations. In addition, MWF has been monitoring daily rainfall in the Paya Indah Wetland since October 1999. Monthly records on rainfall and evaporation at the above stations are summarised in **Figure D.6.20**.

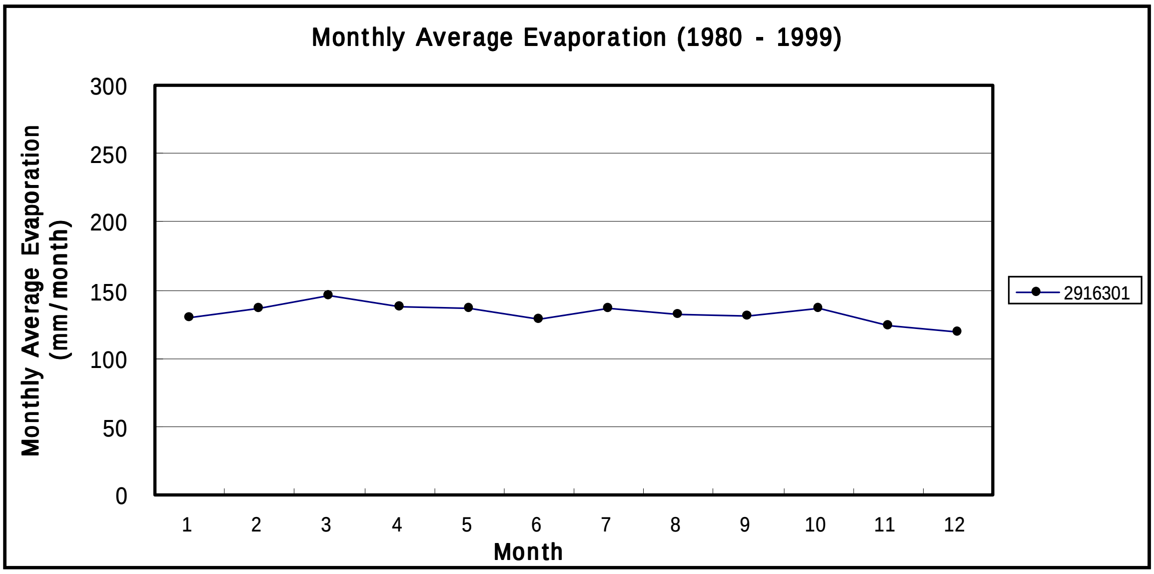
6.4.4 Infiltration to the Ground

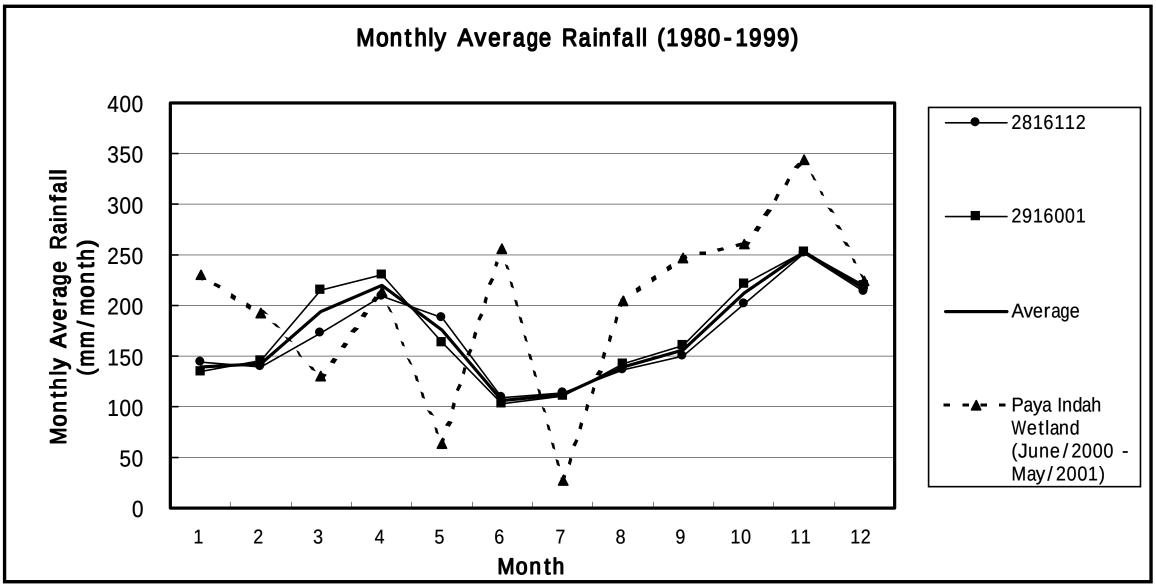
Figure D.6.21 shows the geological profile in the Paya Indah Wetland based on the field reconnaissance. Most parts of the Paya Indah lakes are covered with sand and silt as the secondary deposit by former mining activities. From the observation data of bottom sediment of the drought lake, which is almost in the same condition as the Paya Indah lakes, the bottom of lake may be sealed with impermeable layer such as silt and clay. This can be assumed from the difference of water level in each lake.

6.4.5 Continuity of Wetlands and Groundwater Aquifer

As described above, hydrological data indicates the possibility of discontinuity of wetlands and ground aquifer. However, to identify this issue clearly, a reliable method such as bottom survey and sampling of bottom layers at several points in each lake should be carried out. Furthermore, it is necessary to compare the data of the water level between the observation well and the lake.

Item	Station No.	Period/Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Pan-evaporation	2916301	1980-1999	129.3	136.6	145.8	137.9	136.3	128.3	136.8	132.5	130.5	136.7	124.3	119.6	1594.5
Rainfall	2816112	1980-1999	144.4	140.1	173.5	209.2	187.5	109.4	114.0	136.1	149.8	201.1	251.8	213.7	2030.5
	2916001	1980-1999	135.0	146.1	215.5	230.6	163.9	102.6	111.3	143.1	161.1	221.7	253.7	219.4	2104.0
	Average	1980-1999	139.7	143.1	194.5	219.9	175.7	106.0	112.7	139.6	155.4	211.4	252.8	216.6	2067.3
	Paya Indah Wetland		Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	Total
	(June/2000 - May/2001)		230.7	191.7	130.5	213.0	64.0	256.0	27.0	204.0	247.0	260.0	344.0	224.5	2392.4





Source: Data provided by JPS Ampang

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Figure D.6.20

Monthly Records on Rainfall and Evaporation near the Paya Indah Wetland

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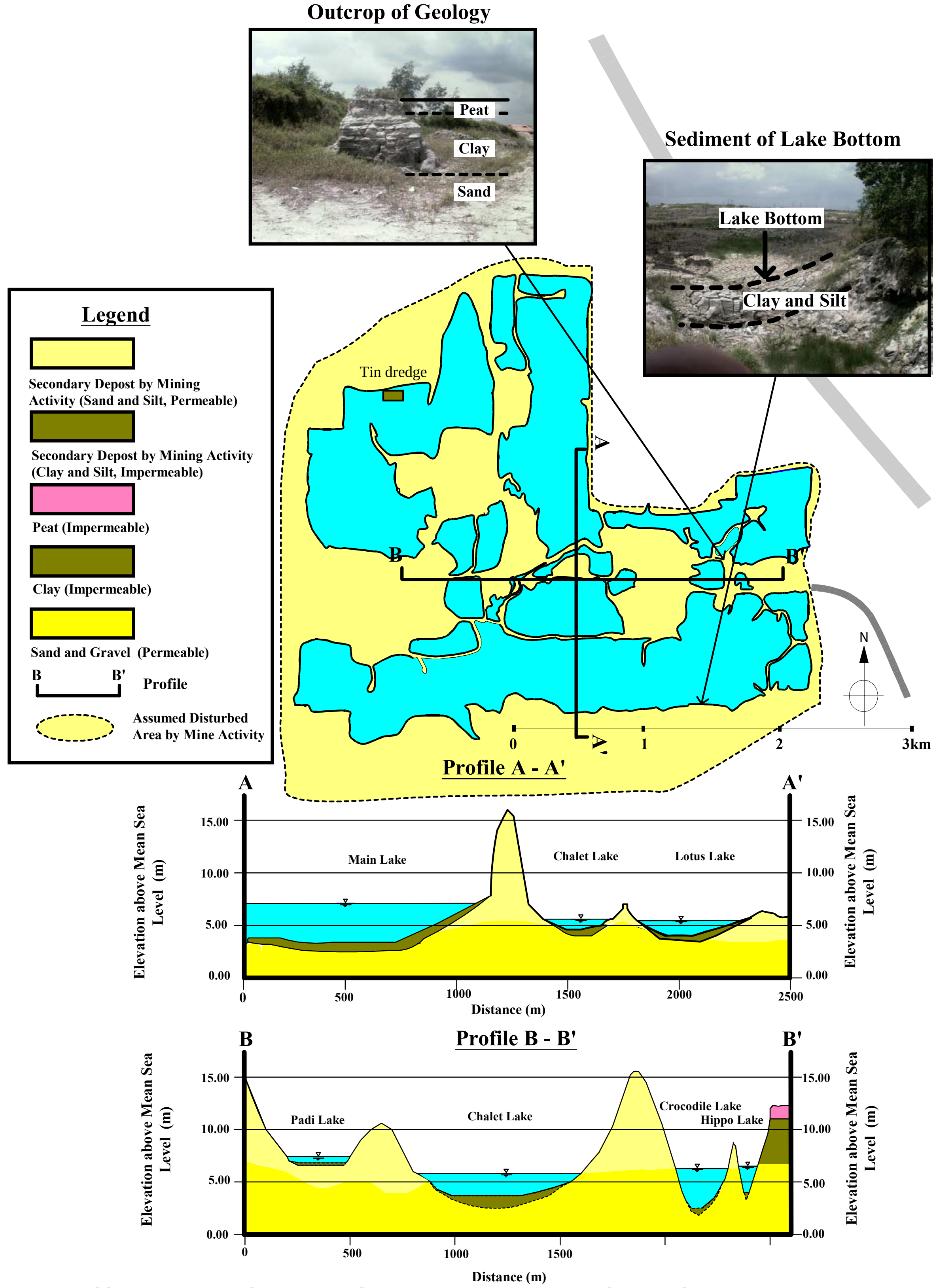

Source : Field reconnaissance by JICA Study Team (Photographing on May 10, 2000)

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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 D.6.21

Schematic Geological Profiles in Paya Indah Wetland

6.5 Water Balance Structure

6.5.1 Existing Study

Regarding the water balance of the Paya Indah Wetland, model analysis using the MODFLOW and hydrological studies have already been carried out in the following studies:

- Malaysian Wetland Sanctuary Kuala Langat Hydrological Analysis, Environment Technology System, February 1998
- Environmental Impact Assessment Report For Proposed Groundwater Abstraction on Lots 1632, 2319, 2320, 2321 & 2323, Kawasan Perindustrian Olak Lempit, Mukim of Tanjung Dua Belas, Kuala Langat District, Selangor Darul Ehsan, September 1998.

The results of the former study indicate that surface recharge of the lakes in the wetlands is significant and seepage loss is estimated to be up to 40 mm/day (0.52 m^3/s). However, this value seems to be unlikely in comparison with meteorological data such as rainfall and evaporation.

The results of the latter study indicate that there will be negligible draw down (caused by abstraction by new well) in the wetlands if the old dredge lakes do in fact contain low-permeability backfill. Furthermore, if there is no backfill, or if it has high permeability, the calculated draw down at the wetlands might be more significant (without taking into consideration water recharge of the wetlands by surface runoff).

However, there is no evidence such as hydrological data and hydro-geological data in the Paya Indah Wetland to identify that the above result is true. Therefore, to make a simulation model, the nature of the surface water hydrology of the Paya Indah Wetland needs to be monitored over a period of necessary time, and identify hydro-geological conditions to confirm the above result.

6.5.2 Conditions Necessary for Simulation

In order to simulate the water balance in the Paya Indah Wetland, the following items should be prepared:

- Following observed daily data at least for a period of one year
  - Water level in each lake
  - Inflow to the Paya Indah Wetland at three (3) points
  - Outflow from the Paya Indah Wetland at two (2) points
- In-situ daily data of precipitation at least for a period of one year
- In-situ daily data of evapotranspiration at least for a period of one year

- Geometric data of each lake based on accurate bottom survey for estimate of water volume
- Hydro-geological data based on the field reconnaissance in Phase II
    - Water level in observation well near the Main Lake
    - Geological profile in the Paya Indah Wetland

Although available information covering the above items has not been completely prepared during this study period, a rough examination of water balance structure shall be carried out using the estimated values.

6.5.3 Water Balance in the Paya Indah Wetland

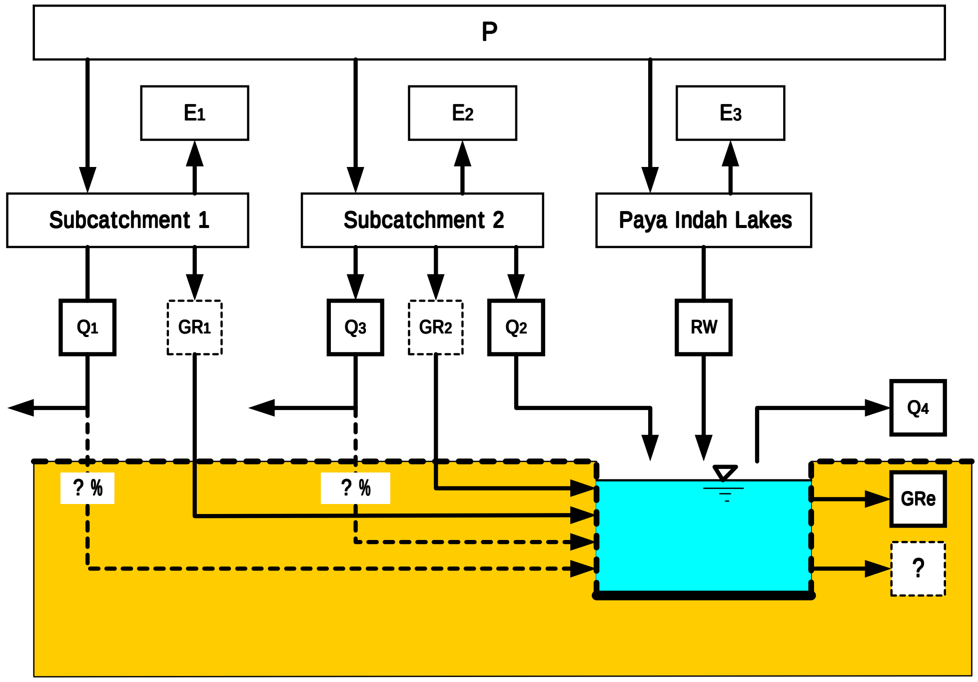
Necessary data for hydrological examination of water balance in relation with groundwater recharge into aquifer in the Paya Indah Wetland is a quantitative data such as inflow and outflow. For this purpose, monitoring of the flow rate using installed surface water level instruments has been started to record since November 2000, recorded data is still limited at present. It will take for one half a year to get available data including dry season and rainy season. Therefore, this subsection only limits to present an examination of water balance based on extremely rough assumption with limited data.

Assumed hydrological model and necessary data for estimation of water balance in the Paya Indah Wetland is summarised in **Figure D.6.22**. The water balance model can be schematised as three (3) divided areas, namely, Subcatchment 1, Subcatchment 2 and Paya Indah Lakes as described in **Section D.6.1**. According to an examination using the hydrological data from December 2000 until May 2001, groundwater recharge (or recharge to the ground) from catchment area of the Paya Indah Wetland is to be estimated –2.3 to 21.2 % of rainfall in this period (see **Table D.6.2**).

The difference of percentage between two subcatchments may be due to the differences of the boundary conditions of the peat layer (or the upper aquifer) that is distributed near the ground surface. Boundary of the peat layer in Subcatchment 1 is open to the surrounding area and the recharge from rainfall trapped in the peat layer may have a chance to flow to the surrounding area such as Kuala Langat North forest Reserve. The measured surface discharge at SWL-1 may be a part of discharge from the peat layer. On the other hand, Subcatchment 2 is small and is surrounded by hills, old mines at Dengkil and the embankment of the Highway. Recharge from rain is trapped in the peaty layer, and then most of recharged water flows out through two channels where the surface discharges were measured.

As tabulated in **Table D.6.3**, inflow from Lakes can be estimated totally at 1642.2 mm, and it indicates considerably large quantity in comparison with outflow from Lakes at 938.8 mm in this period. After all, the balance of groundwater recharge in Paya Indah Lakes (surface water) can be estimated at 703.4 mm gains. Most of the recharged groundwater may flow out though the peat layer (or the upper aquifer) to the surrounding area. Recharge to the main or lower aquifer (sandy/gravely soil layer) is considered minimal according to the results of the pumping test described in **Sector G**.

Above result does not contradict with previous description in **Section D.6**, however, in order to identify accurate annual water balance in the Paya Indah Wetland, further examination with more sufficient data is necessary.



P: Precipitation,
- Average rainfall from November until April in 1980 -1999 at Sation No. 2816112 and Station No. 2916001

E1: Evapotraspiration in Subcatchment 1
- 80 % of average Pan-Evaporation from November until April in 1980 - 1999 at Station No.2916301

E2: Evapotraspiration in Subcatchment 2
- 80 % of average Pan-Evaporation from November until April in 1980 - 1999 at Station No.2916301

E3: Evapotraspiration in Paya Indah Lakes (Surface Water)
- Average Pan-Evaporation from November until April in 1980 - 1999 at Station No.2916301

Subcatchment 1: Area of the Pallustrine (Swamp) System
- 67.6 km^2, including an area of Kuala Langat North Forest Reserve

Subcatchment 2: A Part of the Lacustrine (Lakes) System
- 16.3 km^2, an assumed area located at North-East Side of North-South highway

Paya Indah Lakes: Total water surface of the Paya Indah Lakes
- 5.36 km^2

Q1,Q2,Q3: Inflow to the Paya Indah Wetland and its vicinity measured by automatic surfacewater instruments
- Average flow rate from 23/11/2000 until 27/4/2001 with 30minutes intervals

Q4: Outflow from the Paya Indah Wetland measured by automatic surfacewater instruments
- Average flow rate from 23/11/2000 until 27/4/2001 with 30minutes intervals

RW: Estimated rain water based on P and E3

GR1,GR2: Estimated groundwater recharge from Subcatchment 1 and Subcatchment 2 respectively

GRe: Estimated groundwater recharde from the Paya Indah Lakes (mainly the water's edge)

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Figure D.6.22

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Water Balance Model for the Paya Indah Wetland

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Table D.6.2 Estimated Water Balance for Catchment Area in the Paya Indah Wetland from November 2000 to April 2001

Area	Km²	Precipiation*1)			Evaporanspiration*2)			Surface Discharge					stimated Groundwater Recharge*		
		symbol	mm	Reference Record	symbol	mm	Reference Record	symbol	m³/sec		mm	Reference Record	symbol	mm	% of rainfall
Catchment Area 1	67.6	P	1054.4	Daily Records from 1/12/2000 until 31/5/200 measured by the Paya Indah Wetland Foundation	E1	644.4	Monthly Average Records from December until Mayl in 1980 - 1999	Q1 (SWL-1)	0.80		186.1	Daily Average Records from 1/12/2000 until 31/5/2001	GR1	223.9	21.2
Catchment Area 2	16.3				E2			Q2 (SWL-2)	0.42	0.45	434.1		GR2	-24.1	-2.3
								Q3 (SWL-3)	0.03						

*1): Total average rainfall from December until May in 1980 - 1999 is estimated at 1089.5mm
*2): 80% of Pan-Evaporation
*3): GR1 = P - E1 -Q1,   GR2 = P - E2 - (Q2+Q3)

Table D.6.3 Estimated Water Balance for Paya Indah Lakes from November 2000 to April 2001

Area	Km²	Precipitaion*1)			Evapotranspiration*2)			Inflow to the Lakes				Outflow from the Lakes				Balance of Groundwater Recharge*3)	
		symbol	mm	Reference Record	symbol	mm	Reference Record	symbol	m³/sec	mm	Reference Record	symbol	m³/sec	mm	Reference Record	symbol	mm
Paya Indah Lakes	5.36	P	1054.4	Daily Records from 1/12/2000 until 31/5/200 measured by the Paya Indah Wetland Foundation	E3	644.4	Monthly Average Records from December until Mayl in 1980 - 1999	RW	-	410.0	P - E3	Q4 (SWL-4)	0.32	938.8	Daily Average Records from 1/12/2000 until 31/5/2001	GRe	703.4
								Q2 (SWL-2)	0.42	1232.2	Daily Average Records from 1/12/2000 until 31/5/2001						

*1): Total average rainfall from December until May in 1980 - 1999 is estimated at 1089.5mm
*2): 80% of Pan-Evaporation
*3): Gre = (RW+Q2) - Q4

SECTOR E

GROUNDWATER QUALITY

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

FINAL REPORT

SECTOR E

GROUNDWATER QUALITY

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SECTOR E

GROUNDWATER QUALITY

1. INTRODUCTION

Groundwater quality has become a big issue in accordance with the water demand increase in the Langat Basin. The recent water shortage in Selangor had this accelerated. Especially in Kuala Langat, Sepang and Hulu Langat, main districts of the Langat Basin, rapid changes are continuously taking place because new mega-infrastructures such as Kuala Lumpur International Airport (KLIA), Putrajaya and Cyberjaya have been developed in these areas. These developments are anticipated to result in population growth, urbanisation, agricultural, mining and logging activities, and industrialisation and finally bring deterioration of surface and ground water quality due to inadequate water treatment.

This report gives an overview of the groundwater quality in the Langat Basin based on the existing monitoring data (**Chapter 2**) and a result of *in-situ* water quality measurement of the selected wells carried out in the Hydro Census and simultaneous observation of groundwater level and quality (**Chapter 3**). In addition, potential pollution sources in the basin that may cause aggravation of the water environment are depicted in **Chapter 4**.

2. EXISTING INFORMATION ON GROUNDWATER QUALITY IN THE LANGAT BASIN

2.1 General

The groundwater quality in Peninsular Malaysia has been monitored by several organisations concerned such as the Minerals and Geoscience Department Malaysia (JMG), Department of Environment (DOE) and Drainage and Irrigation Department (DID). In terms of the Langat Basin, JMG has solely executed the groundwater quality monitoring although DOE has its own monitoring plan.1) Based on the existing data and analysis compiled in JMG, this chapter presents the groundwater quality of the existing wells to realise an overview of the groundwater quality in the Basin, and to identify the monitoring plan, including simultaneous groundwater level and quality survey that had been carried out in this Study, as background information.

2.2 JMG Monitoring Wells

Some 72 out of 121 wells registered in JMG have the groundwater quality data that was measured from 1978 to 1998. The JMG Ipoh Office had carried out the groundwater quality analysis in its laboratory. The groundwater quality representing various parameters of each well is given in **Data Book E.2.1**. Major findings of the previous quality measurement are as described below.

2.2.1 Date of Sampling

Date of sampling varies from well to well, and 31 samples, i.e., 65% of the total number, were measured in 1998. The oldest data was recorded on 6 February 1978 while the latest one was on 19 November 1998. There are no records kept in the JMG well database in the last two years. Twenty-five (25) samples, i.e., 34% of the total number, do not have a record of the sampling date. The yearly distribution of JMG records is shown in **Figure E.2.1** below.

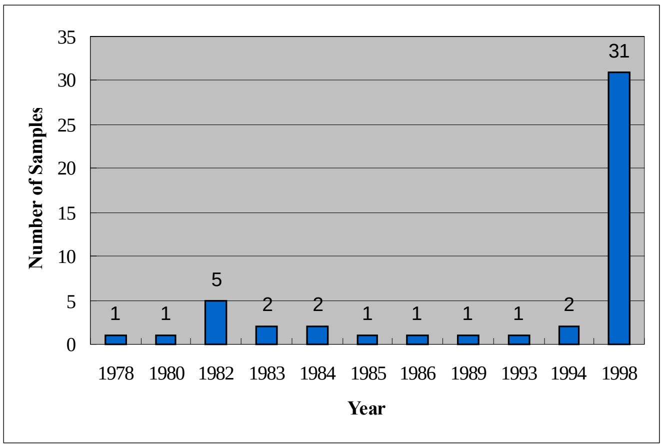

Figure E.2.1 Yearly Distribution of JMG Groundwater Quality Records
Source: JMG

2.2.2 Depth of Well

The depth of wells is schematically shown in **Figure E.2.2** below. About 18% of the wells are classified into shallow wells whose depth is below 30m that is thought to be the thickness of a surface layer. On the other hand, almost half of the wells have more than 80m in depth and there are 14 wells whose depths are over 150m. The averaged depth is calculated at 80m.

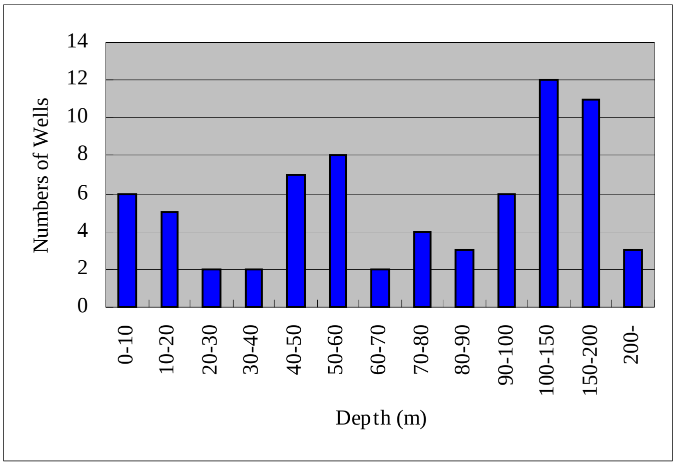

Figure E.2.2 Depth of the Wells Registered in JMG

Source: JMG

2.2.3 Values of Major Parameters

Values of major parameters such as pH, chloride and heavy metals are discussed below.

(1) pH Values

Low pH values are observed in Klang, Shah Alam, Kajang and Telok Datok. According to the pH values graphically shown in **Figure E.2.3**, highly acidic conditions where pH value is below 5 can be seen around Kajang and Olak Lempit. Although other parameters such as total iron (Fe-T) and aluminium (Al) were not measured in these areas, the occurrences of acidic conditions may be associated with mining activities nearby.

As an example, it has been reported that the pH value of the lakewater in Paya Indah, a former tin mining site, was relatively low, ranging from 3 to 5.[2)] The water bearing layer is thought to be exposed at the bottom of these lakes, and the lake water quality may therefore influence the groundwater quality, more or less. Detailed analysis by water sampling from the existing ex- and active mining areas will be required to interpret the high acidic conditions of the groundwater.

(2) Chloride Values

Seawater intrusion contributes to the high chloride values of groundwater in general.[3)] As shown in **Figure E.2.5**, values exceeding the Drinking Water Quality Standards in Malaysia, i.e., 250 mg/l, were observed at the wells located within approximately 10 km from the coastline. Although other factors such as the result of electric resistivity prospecting are necessary to be monitored in areas affected by seawater intrusion, it is said that seawater flows into the freshwater aquifer near the coastal areas.

(3) Total Iron Values

A total of 19 out of 22 wells, i.e., 86%, in the Study Area exceed the standard iron value, namely 0.3 mg/l. Among these, two (2) wells indicate more than 100 times as large as the standards; one is 5 km south of Telok Datok, and the other is southeast of the Kuala Langat South Forest Reserve. It has also been reported that the iron content of the groundwater is naturally high in Selangor.[9)] Approximately 55% of the tested wells in Selangor show the total iron value of over 1 mg/l.[9)] Values of total iron in existing wells are given in **Figure E.2.6**.

High concentration of sodium ion (Na^+) in the intruding seawater also can be predicted since seawater is predominantly an NaCl solution.[3)] **Figure E.2.4** below shows a correlation between chloride and sodium ions of the wells registered in JMG. According to this figure, these two factors are mutually related with each other.

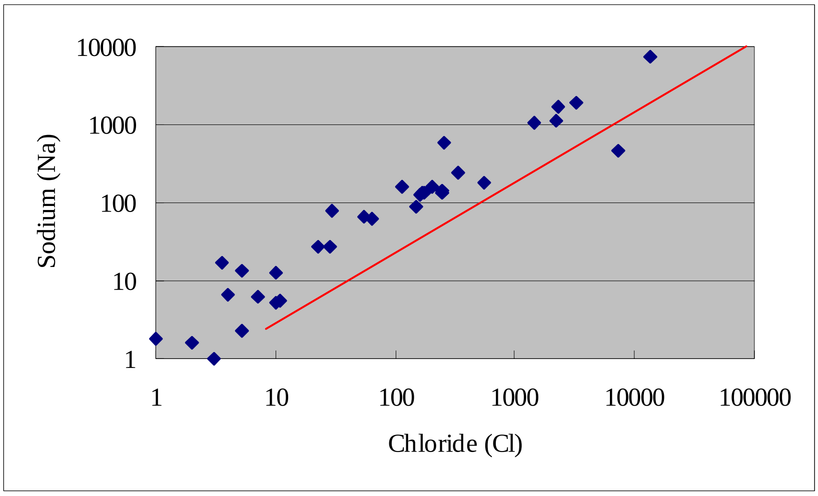

Figure E.2.4 Correlation between Chloride and Sodium Ions of Groundwater in JMG Registered Wells

Source: JMG

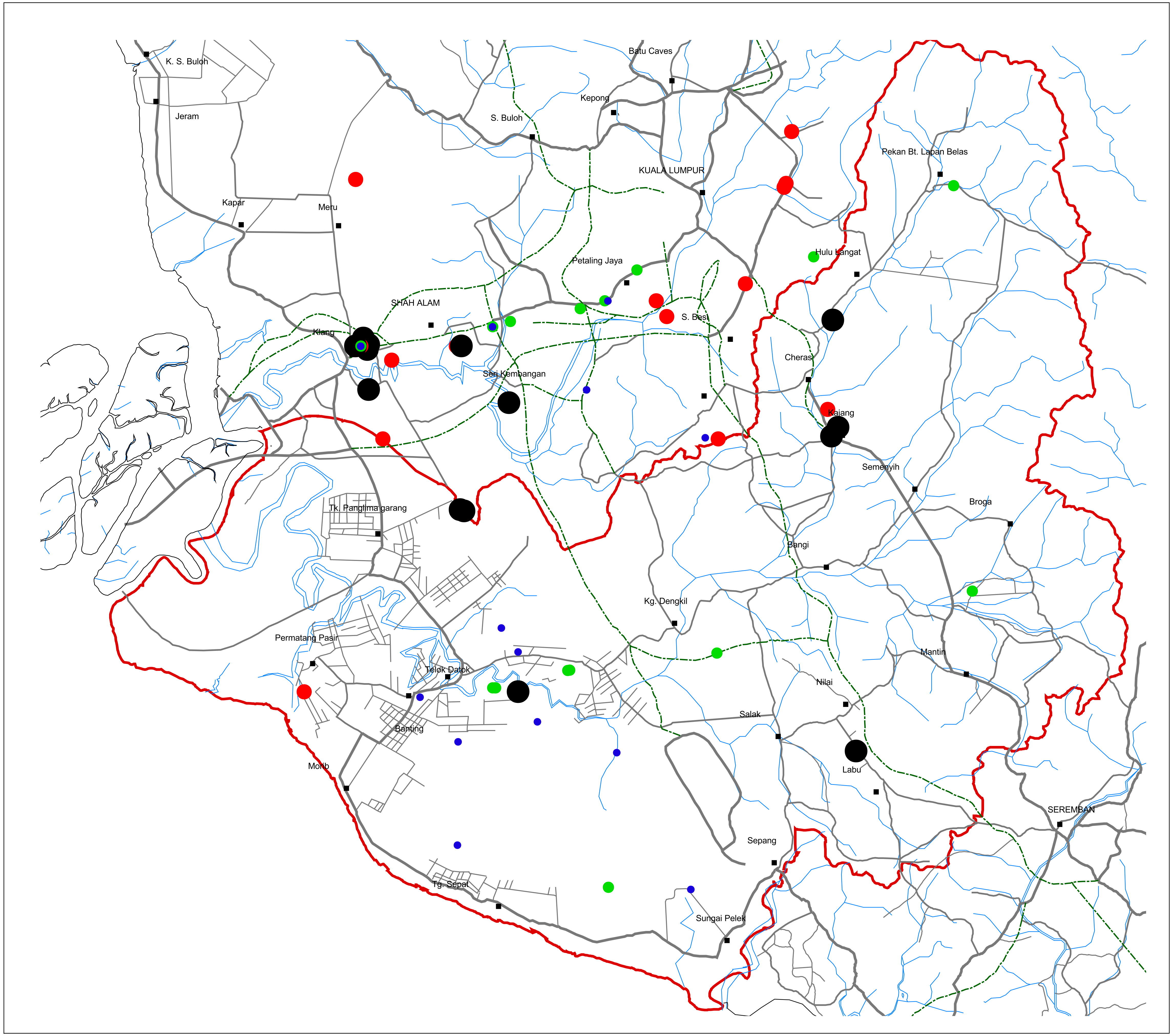

Figure E.2.3

pH Values of the Existing Wells

LEGEND

pH value
- <5
- 5 - 6.5
- 6.5 - 7
- 7.1 - 8.5

- 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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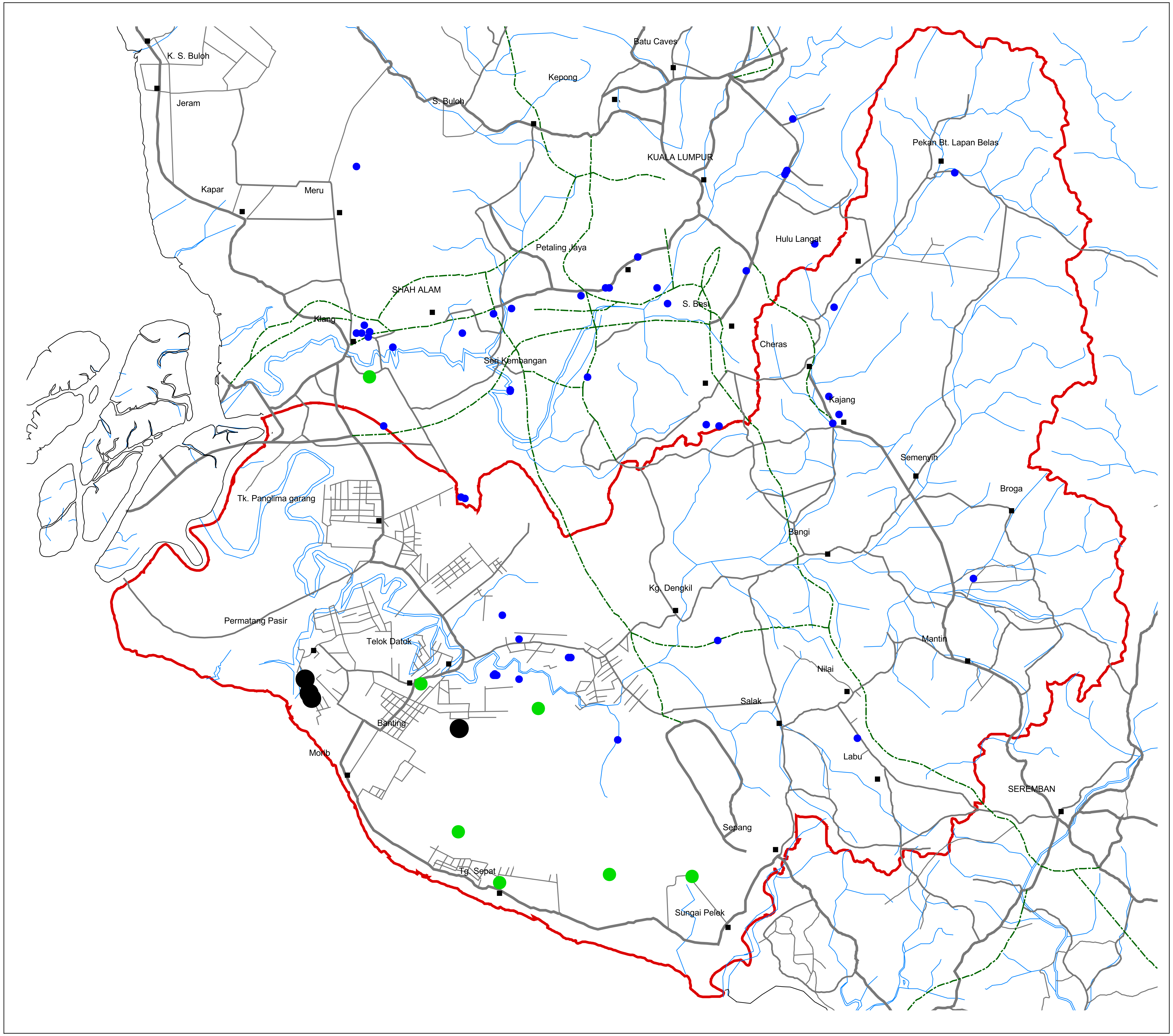

Figure E.2.5

Chloride Values of the Existing Wells

LEGEND

Chloride value
- Exceeds 10-100 times
- Exceeds standards but less than 10 times
- Below standards

- 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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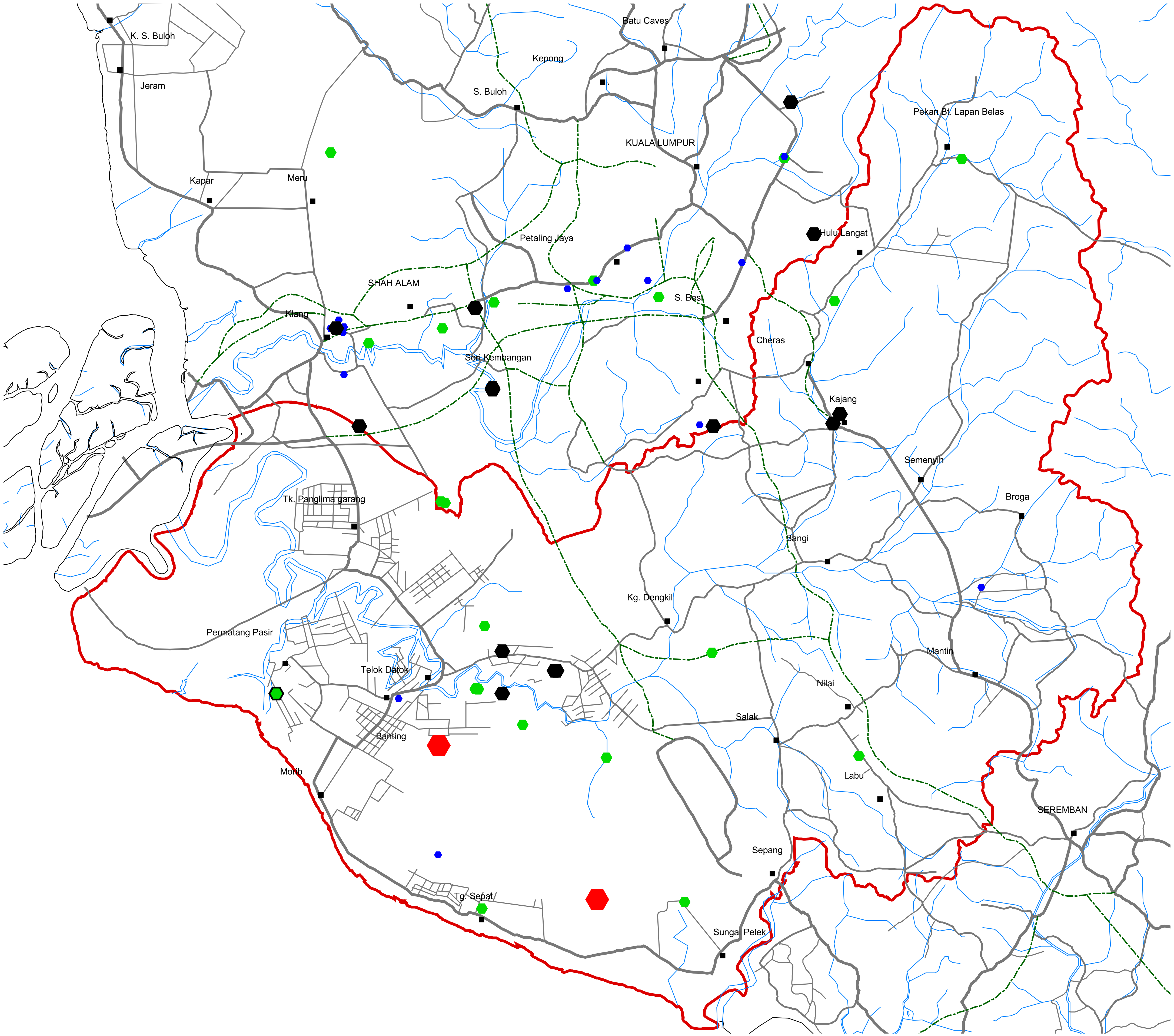
Figure E.2.6

Total Iron Values of the Existing Wells



LEGEND

Total Iron value
- Exceeds more than 100 times
- Exceeds 10 - 100 times
- Exceeds standards but less than 10 times
- Below standards

- 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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(4) Heavy Metals

Figure E.2.8 illustrates values of major heavy metals in the water of wells. The major heavy metals in this case include mercury (Hg), cadmium (Cd), arsenic (As), lead (Pb) and chromium (Cr). About 20% of the wells exceed the limit specified in the Drinking Water Quality Standards for any of these metals. This percentage may be inaccurate, because the detection limit of cadmium in the JMG Ipoh laboratory is more than the standard limit.

(5) Other Parameters

There are six (6) wells permitted as source of potable water as provided under the Drinking Water Quality Standards; however, some of the parameters were not analysed at these wells. An extremely low rate of only 8% of the total number of wells satisfies the standards.

The percentage of wells exceeding the standards was examined to determine the water quality parameters of the existing wells as shown in **Figure E.2.7**. Such parameters as turbidity, total-iron (Fe-T), calcium (Ca), mercury (Hg) and cadmium (Cd) exceed the standard in more than 50% of all the wells, while the other heavy metals, namely selenium (Se), cyanide (CN), chromium (Cr), silver (Ag) and copper (Cu), are not over the limits in all of them.

Nitrate nitrogen (NO_3-N) is known as one of the indicators showing the level of groundwater contamination. Agricultural activities and livestock farming sometimes result in a high value of this parameter due to excessive use of fertilizer and effluent from the farms. Only three (3) of the wells gave values exceeding the limit; therefore, it cannot be said that contamination by these activities makes a significant progress in the Study Area.

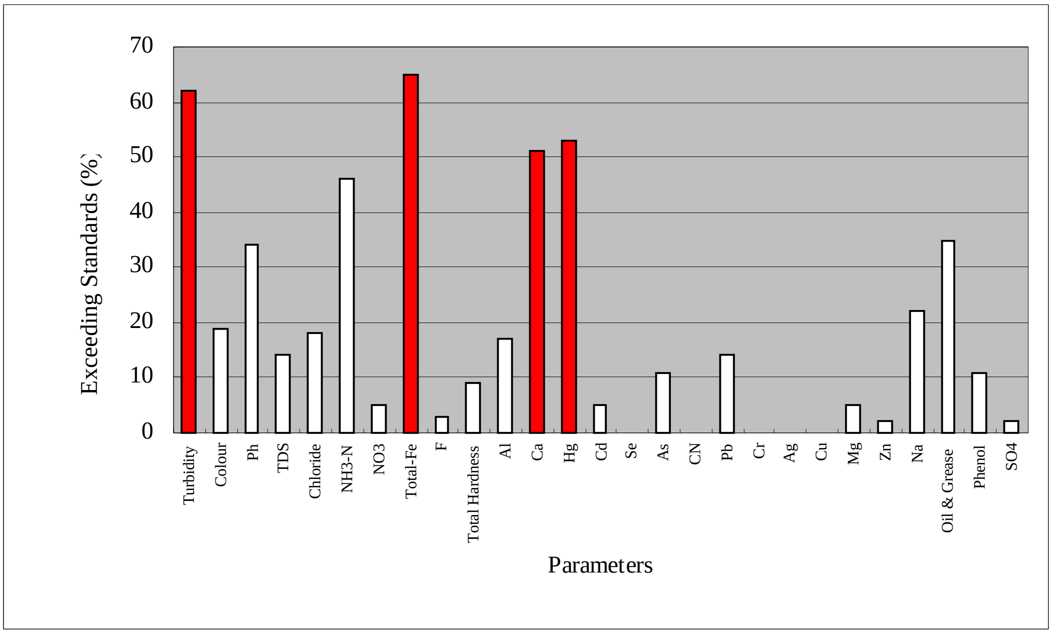


Figure E.2.7 Percentages of Exceeding the Standards for Water Quality Parameters of the Existing Wells

Source: JMG

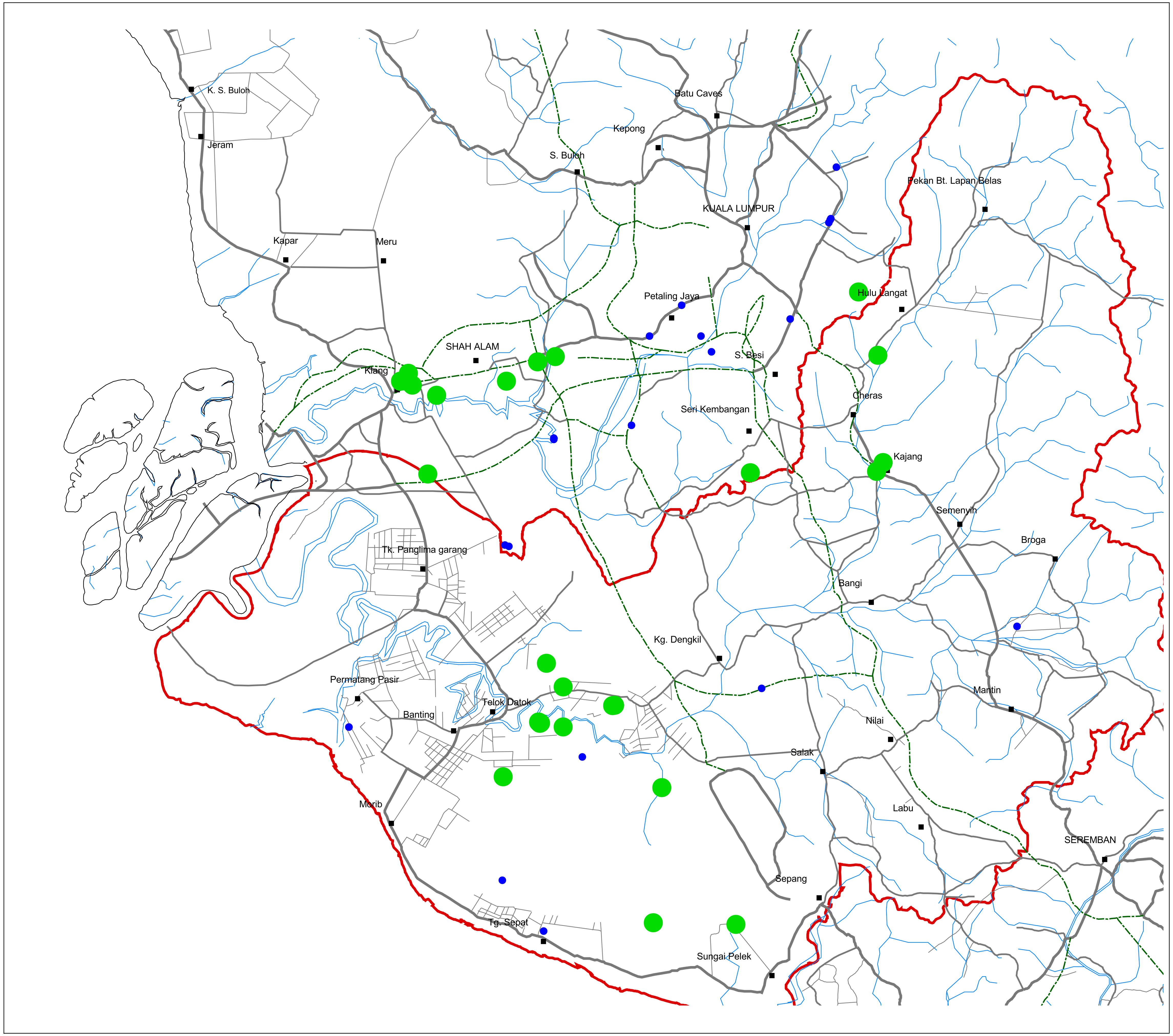
2.2.4 Recommendation for Groundwater Quality Monitoring

The existing groundwater monitoring system firstly established in JMG seems to be not functioning effectively although the groundwater level has been measured periodically. Groundwater quality measurement will be an integral part of the system for development and conservation of groundwater in the Langat Basin. As described above, JMG has already monitored the groundwater quality; however, the following actions are recommended to improve the system:

- Date of sampling should be recorded; about 34% of the existing data have no records of the data. Sampling time also should be put in a data sheet.
- Water depth of sampling should be clearly identified; the sample taken from a well sometimes mixed with waters seeping from different depths of layers. The identification of sampling depth is of great importance to estimate influences and diffusion of pollutants.
- Parameters to be measured should be consistent; the existing parameters vary from sample to sample. To observe seasonal or annual fluctuation of quality, the parameters should be fixed and measurement should be carried out regularly.

Figure E.2.8

Major Heavy Metals Values of the Existing Wells



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2.3 DOE Monitoring Wells

DOE has been monitoring groundwater quality under the Groundwater Monitoring and Reporting Network Project for Peninsular Malaysia since 1996. The objective of this project is to evaluate the status and extent of groundwater contamination throughout the country. From a total of 126 sites identified throughout the country, 42 sites consisting of 69 wells were selected for detailed monitoring of water quality.[1)]

In Selangor, five (5) sites are used for the monitoring. They were selected from different land use such as urban/suburban, industrial, solid waste landfill and golf course. The groundwater quality data of these wells measured in 1999 is presented in **Data Book E.2.2**. It is hard to assess these data because of the small number of samples; however, the same tendency as the data of JMG can be seen in terms of iron content. The iron value is high, i.e., approximately 16 mg/l on average for the five samples.

To establish a comprehensive monitoring system, “open door” policy is strongly recommended; that is, exchange of data and information between DOE and JMG should be conducted on the basis of mutual understanding of both organisations.

3. GROUNDWATER QUALITY OBSERVED IN THE PRESENT STUDY

3.1 General

Groundwater quality of the Langat Basin was observed in each study phase of the Study, i.e., from the First to the Third Phase. To grasp the background of groundwater quality in the Basin, in-situ measurement for selected wells was carried out in Phase I. In addition to the existing groundwater quality data described in the preceding **Chapter 2** and the result of this in-situ measurement, simultaneous groundwater level and quality observation was planned in Phase I and conducted in Phases II and III after completion of monitoring of wells that were used mainly for pumping tests and monitoring. The monitoring work, on a regular basis in particular, will be of great importance in the concept of groundwater management, although the observation was made only three times during this Study. **Sector H** describes the monitoring for groundwater management and this chapter covers the results of groundwater quality measurements in this Study.

3.2 In-Situ Groundwater Quality Measurement of Selected Wells in Phase I

3.2.1 Introduction

Under the Hydro Census, *in-situ* groundwater quality measurement was carried out at 23 wells, comprising 12 open wells and 11 JMG tube wells. The open wells were visited and measured on two different days: 16th of July and 7th of August 2000. The same *in--situ* measurements made for open wells were also carried out on the 9th and 15th of August 2000. The water quality parameters measured were temperature (°C), dissolved oxygen (mg/l), water depth (meter from surface), conductivity (mS/cm), pH, redox potential (mV), oxygen saturation (%), and salinity ($^{o}/_{oo}$). Readings were recorded using the Hydrolab Surveyor 3, a portable multi-sensor probe, at three depth levels for deepwater columns and only two or one for shallower ones. Major findings of these surveys are described below.

3.2.2 Measurement for Selected Open Wells

(1) General

The first measurement was conducted on Sunday, 16 July 2000, between 10:15 to 16:30hrs. The weather was hot, fine and clear throughout the day of visit, and it was during the dry season when most wells indicated markings of water level decrease. The 12 open wells selected were visited and measured again for the second time on Monday, 7 August 2000, between 11:25 and 16:15hrs. The week prior to the second round of sampling experienced a few days of rain, and thus a noticeable increase in depth of water column was observed in a majority of these open wells. Typical open wells in the Langat Basin are shown in **Photographs E.3.1 and E.3.2**, and results of measurements are given in **Data Book E.3.1**.

Photographs E.3.1

Domestic Open Well with Motorised Pump

Source: A. Fariz, LESTARI, 2000.

Photographs E.3.2

Domestic Open Well without Motorised Pump

Source: A. Fariz, LESTARI, 2000.

(2) Water Temperature

On 16 July 2000, the averaged water temperature ranged from 25.10 to 29.32°C, as measured within the 10:00 to 16:30 hour period. On 7 August 2000, the temperature ranged from 26.17 to 28.98°C. The measurement results are illustrated in **Figure E.3.1**. The temperatures of water at bottom, middle and surface were observed to be about constant. Since the columns measured were generally shallow, the maximum depth of column was 2.2 m on the 16^{th} of July at UKM Well No. 3 (ID-121), and 3.1 m on the 7^{th} of August at Kg. Jenderam Hulu (ID-113). The range of temperatures observed seems normal for tropical well waters and does not indicate the presence of warm water discharged into the ground.

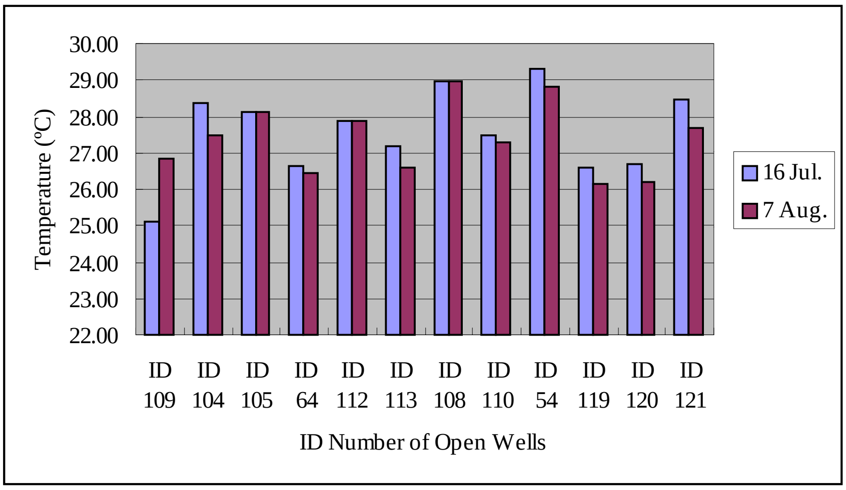


Figure E.3.1 Averaged Water Temperature of the Open Wells

(3) Depth of Measured Water

The depths of water columns of the 12 open wells on 16 July 2000 ranged from 0.3 m at Kg. Sungai Jai (ID-104) to 2.2 m at UKM Well No. 3 (ID-121). On 7 August 2000 the depth of water columns of these same wells ranged from 0.8 m at Kg. Abu Bakar Baginda (ID-54) to 3.1 m at Kg. Jenderam Hulu (ID-113).

(4) Dissolved Oxygen (DO)

Concentrations of dissolved oxygen (DO) on 16 July 2000 ranged from 0.45 mg/l at the surface well water of Kg. Jenderam Hilir (ID-110), to 7.40 mg/l at the surface well water of UKM Well No. 3 (ID-121). Some wells had similar DO values in the whole water column (e.g., Kg. Tanjung Beranang: ID-64), some data demonstrated a decreasing value from bottom to top (e.g., Kg. Salak Tinggi: ID-112). The rest of the wells showed an increasing DO trend from bottom to surface of water columns (e.g., Kg. Abu Bakar Baginda: ID-54). However, the readings at Kg. Abu Bakar Baginda (ID-54) were recorded when consumers were pumping out the water for car washing purposes. Turbulence of water had occurred at the surface and near surface region of the well water column. On 7 August, the DO range was 0.66 mg/l at surface of water column at Kg. Jenderam Hulu (ID-113) to 7.17 mg/l at 1.3 m depth bottom of UKM Well No. 1 (ID-119). Majority of the wells showed a decreasing DO value from bottom to surface layer of water column, with a number of them showing a decreasing followed by increasing trend. **Figure E.3.2** shows the measurement results of DO.

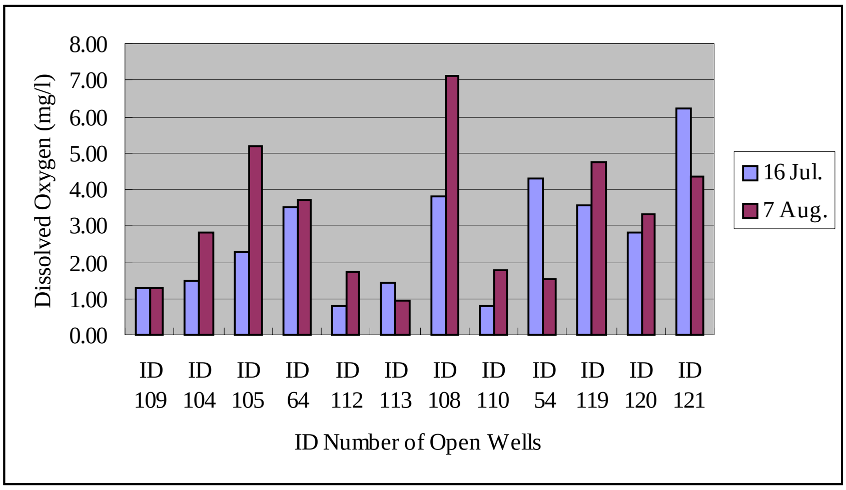


Figure E.3.2 Averaged Dissolved Oxygen of the Open Wells

(5) Conductivity

Conductivity values observed ranged from 0.200 mS/cm at the surface of UKM Well No. 2 (ID-120) to 0.528 mS/cm at 1.2 m (bottom) of Kg. Jenderam Hulu (ID-113). Conductivity values for Class I waters of the Interim National Water Quality Standards for Malaysia (INWQS) is 250 umhos/cm, and 500 umhos/cm for Class II. Some wells showed decreasing conductivity readings from bottom to top (e.g., Kg. Sesapan Batu Minangkabau: ID-109), and others showed a fairly constant value (e.g., Pekan Beranang: ID-105). On 7 August conductivity values ranged from 0.186 mS/cm at the surface of well at UKM Well No. 2 (ID-120) to 0.534 mS/cm at 0.8 m depth level of well at Kg. Salak Tinggi (ID-112). A majority of the wells demonstrated a fairly constant value of conductivity (within ±5 mS/cm) throughout the water column, and only a few showed a decreasing trend towards the surface. The measurement results are illustrated in **Figure E.3.3**.

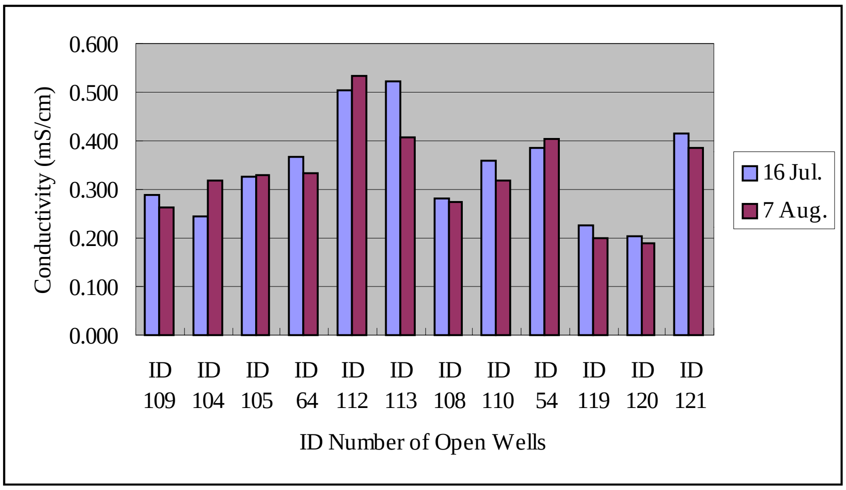


Figure E.3.3 Averaged Conductivity of the Open Wells

(6) pH Value

The pH values ranged from 6.66 (at surface of Pekan Beranang: ID-105) to 10.18 (at surface of UKM Well No. 3: ID-121) on the 16th of July. A majority of the wells showed a decreasing pH value from bottom to surface waters (e.g., Pekan Beranang: ID-105), and the rest showed the opposite (e.g., Salak Tinggi: ID-112). The pH range for August 7 was 6.75 at the surface water of the well at Pekan Beranang to 8.92 at the surface water of UKM Well No. 3. Six out of twelve wells on August 7 showed decreasing pH values from bottom towards the surface (e.g,. Kampung Sesapan Batu Minangkabau: ID-109); four out of twelve wells demonstrated an increasing pH value from bottom to surface water of the well (e.g., UKM Well No. 3); and, the other wells showed a decrease followed by increase of pH value from bottom to top (e.g., Kg. Sungai Jai: ID-104). No excessively low pH value was observed. The INWQS pH values for Classes I, II, III, and IV waters are 6.5-8.5, 6-9, 5-9, and 5-9, respectively. **Figure E.3.4** shows the pH values measured at the sites.

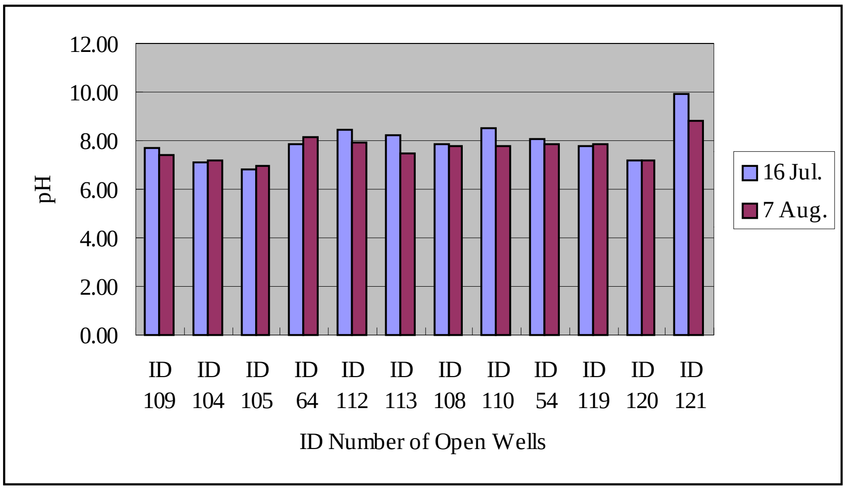


Figure E.3.4 Averaged pH Value of the Open Wells

(7) Redox Potential

Redox potential values on 16 July ranged from 217 mV at the surface of Kg. Jenderam Hilir (ID-110) to 506 mV at the bottom of 2.2 m at UKM Well No. 3 (ID-121). On 7 August the redox range was 232 mV at 0.8 m (bottom) of the well of Kg. Abu Bakar Baginda (ID-54), to 428 mV at 1.9 m (bottom) of the well at Kg. Tanjung Beranang (ID-64). This range indicates oxidizing water on all the wells. Some wells showed redox values decreasing from bottom to surface (e.g., UKM Well No. 3 on 16 July, and at Kg. Tanjung Beranang on 7 August). **Figure E.3.5** presents the redox values measured.

The others showed an increasing trend of redox values from bottom to top (e.g., UKM Well No. 2 on 16 July, and at Pekan Beranang on 7 August). The remainder showed an up and down trend as the water column from bottom to top was transcended (e.g., Salak Tinggi: ID-112), or down and up trend (e.g., UKM Well No. 3 on 7 August). There are no redox values included in the INWQS.

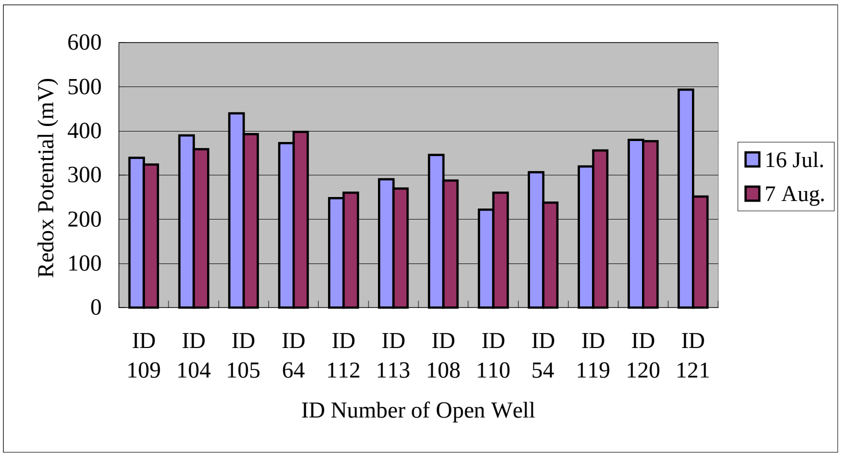


Figure E.3.5 Averaged Redox Potential of the Open Wells

(8) Oxygen Saturation

Oxygen saturation values ranged from 5.3% at the surface layer of the well at Kg. Jenderam Hilir (ID-110), to 92.3% at the surface of the well water at UKM Well No. 3 (ID-121) on 16 July. The range on 7 August was 7.6% at the surface of the well water at Kg. Salak Tinggi (ID-112), to 65.8% at the bottom of the well (2.3 m) at Pekan Beranang (ID-105). The measurement results are shown in **Figure E.3.6**. Some wells showed a decreasing trend of redox values from bottom to surface layer (e.g., Kg. Sesapan Batu Minangkabau on 16 July), and at Kampumg Sungai Jai on 7 August, some other wells showed an increasing trend (e.g. Kg Tanjung Beranang on 16 July, and UKM Well No. 1 on 7 August) and an up and down trend (e.g., UKM Well No. 1 on 16 July, and at Kampung Jenderam Hulu on 7 August). No value of oxygen saturation is included in the INWQS.

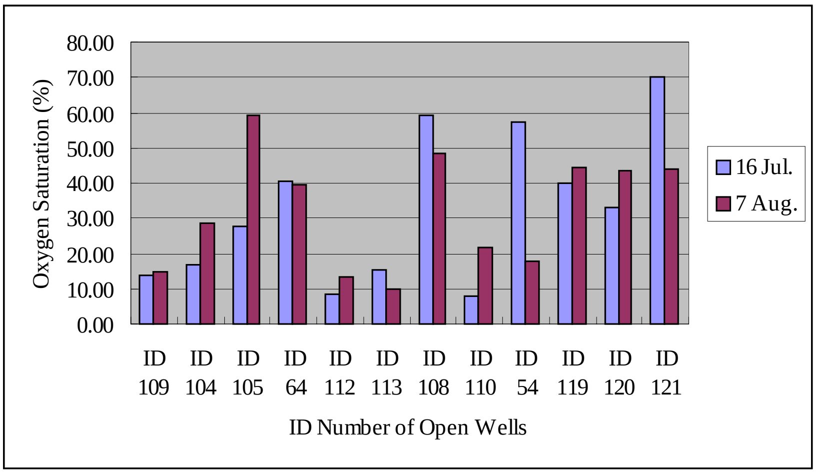


Figure E.3.6 Averaged Oxygen Saturation of the Open Wells

(9) Salinity

Salinity values ranged from 0.1$^{o}/_{oo}$ (e.g. at all depth levels at Kg. Sesapan Batu Minangkabau on 16 July, and at all depth levels at UKM Well No. 1 on 7 August) to 0.3$^{o}/_{oo}$ (e.g. at all depth levels of well at Salak Tinggi on 16 July, and at all depth levels at well of Kampung Salak Tinggi). At all the wells, the values of salinity were very low and representative of freshwaters without seawater intrusion. The salinity values were all constant (within 0.1$^{o}/_{oo}$) throughout the whole water column at all locations. **Figure E.3.7** shows the salinity values measured.

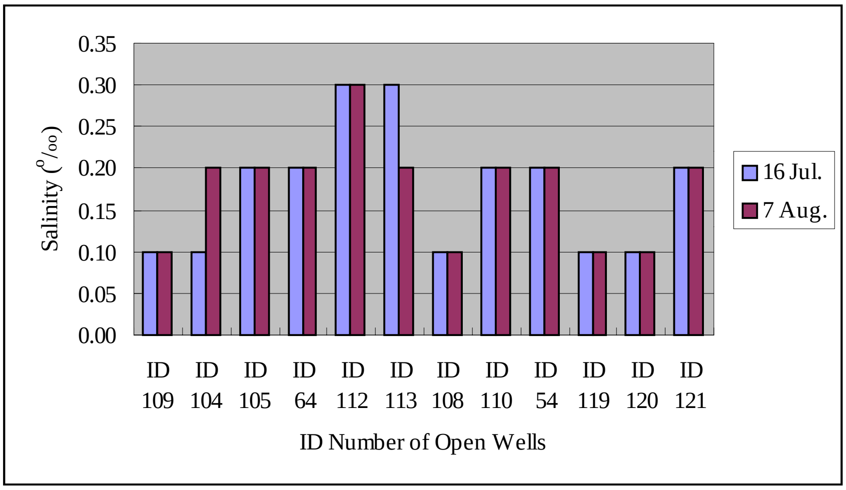


Figure E.3.7 Averaged Salinity of the Open Wells

(10) Comparison between the Two Different Measurement Days

When the average values of parameters over all depth levels at all the wells on both dates are compared, the following could be observed:

(a) Water temperature seems to be about similar on both dates, within the 25.10 to 29.32 degree Celsius range;

(b) On the whole, the DO values are apparently higher on 7 August 2000 than 16 July 2000 at most wells, probably due to fresher input of rainwater within the week prior to the second date of measurement;

(c) Conductivity values seem to be about the same at all wells for the two dates of measurement, within the 0.189 to 0.414 mS/cm window, and the maximum was observed at Kampung Salak Tinggi;

(d) Average values of pH are also about the same for both dates at all wells, ranging from 6.81 to 9.94, the maximum pH observable at UKM Well No. 3 on both dates;

(e) Redox values are also very similar on both dates at almost all the wells, ranging from 222 to 494 mV, indicating oxidising waters;

(f) Oxygen saturation values are higher on 7 August than on 16 July at most wells, and the profiles for oxygen saturation and DO are similar; and

(g) Salinity values are very similar on both dates at all wells, and all values are within the very small range of 0.1 to $0.30^{o}/_{oo.}$

3.2.3 Measurement for Selected JMG Tube Wells

(1) General

The same *in-situ* water quality parameter measurements as the ones in open wells were carried out on samples of tube wells of JMG in the Langat Basin. The eleven locations of the tube wells selected are as follows:

(a) [ID-78] Brooklands Estate Well 1

(b) [ID-79] Brooklands Estate Well 2

(c) [ID-97] JBA Olak Lempit

(d) [ID-75] JBA Brooklands Estate

(e) [ID-103] Sungai Maggis near Store of JBA, Kuala Langat

(f) [ID-16] Water Gate of JBA Banting, Kg. Sugai Lang Tengah

(g) [ID-1] Oil palam estate, Sg. Lang

(h) [ID-77] Brooklands Estate Well 3

(i) [ID-17] Ulu Sg. Kelambu

(j) [ID-7] Elite Highway Well 1

(k) [ID-10] Elite Highway Well 2

These wells belong to the JMG of Malaysia, and consist of tubes that are buried into the ground, with diameters smaller than the diameter of the Hydrolab Multiprobe. Thus the samples of well waters had to be pumped up into a pail for water quality measurements. The rate of pumping into pail was about 110 litres per minute, and at all wells the first ten minutes of water pumped was discarded. The water was then collected for over 10, 15 and 20 minutes (up to 25 for some) into a pail for measurements using the Hydrolab Surveyor. Hence, no profile of water quality parameter values over the different depth levels was done for these tube wells.

Two sets of measurements were carried out on these tube wells: the first on 9 August and the second on 15 August 2000. The results of the measurements are shown in **Data Book E.3.2**.

(2) Water Temperature

Regarding water temperature, the second set of measurements on 15 August for tube wells showed readings that are very similar to the first set on 9 August except at ID-78, as shown in **Figure E.3.8**. On 9 August the temperature ranged from 27.39°C at ID-79 to 29.48°C at ID-16, while the records on 15 August range from 27.39°C at ID-78 to 29.56°C at ID-1. As a whole it can be seen that the average for tube wells seems to be higher than that for open wells. This may be explained by either (i) the fact that tube wells are deeper and could be in contact with soil and/or stones which are slightly hotter, or (ii) the process of pumping/flowing up and out for the water from deep tube wells could have caused flowing friction hence heating up of the water when it was collected in the pail on the ground surface. The first day of tube well measurements on 9 August was hot, humid and dry; and the second day of measurements of 15 August were cool and humid in the morning till about 15:00hrs., and drizzled and rained from about 15:00 to 16:30hrs. It has to be noted that the averages for the two days were very similar at almost all the tube wells, even though the ambient air temperature and conditions were different. It has also to be noted that the maximum value of averages for the tube wells and the open wells seem to be about the same.

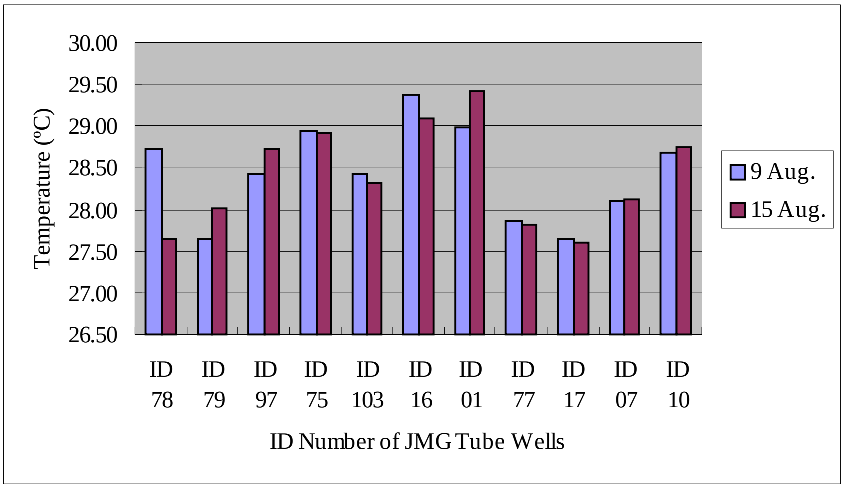


Figure E.3.8 Averaged Water Temperature of the JMG Tube Wells

(3) Depth of Measured Water

The shallowest depth taken for water samples was at ID-78 with a depth of 0.0 m, and the deepest was at ID-77 with a depth of 56.8 m. In comparison with the open wells, the depth of the tube wells is much deeper.

(4) Dissolved Oxygen (DO)

Diisolved oxygen was a minimum at 0.28 mg/l at ID-79 and maximum at ID-103 with 8.91 mg/l measured on the 9^{th} of August. The measurement on 15 August, on the other hand, indicates a minimum at 0.42 mg/l at ID-78 and a maximum of 2.92 mg/l at ID-97. The results of measurements executed on the two dates are illustrated in **Figure E.3.9**.

The average DO values for the open wells and tube wells seem to be in a similar range. The DO for the 9^{th} of August readings of the tube wells are higher than that of the August 15 readings at tube wells ID-78, 97, 75, 103, 16, 77 and 17. DO averages were about the same for the two dates at ID-1, 7 and 10. DO for 15 August was higher than that for 9 August at ID-79. The shape of profile for oxygen saturation values was very similar to that for the DO.

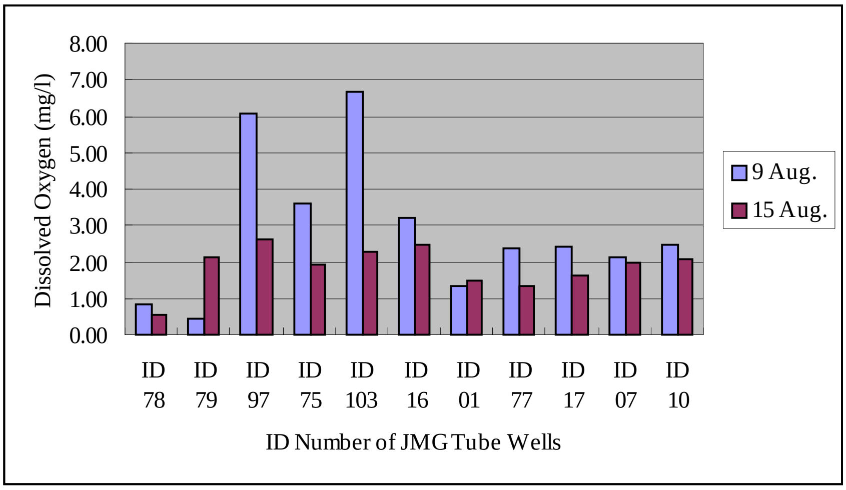


Figure E.3.9 Averaged Dissolved Oxygen of the JMG Tube Wells

(5) Conductivity

On 9 August, conductivity ranged from 0.273 mS/cm at ID-10 to 15.0 mS/cm at ID-1, with ten of the wells having conductivity values of less than 4.0 mS/cm. Exactly the same tendency can be seen regarding the records on 15 August; that is, the lowest value was 0.271 mS/cm at ID-10 and the highest one was recorded at ID-1 with 14.83 mS/cm. Only one well at ID-1 in an oil palm estate at Sg. Lang showed a higher reading for conductivity, which is 14.92 to 15.00 mS/cm, and this may have some relation to the state of the environment in that locality, i.e., the presence of an oil palm plantation. The measurement results are given in **Figure E.3.10** below.

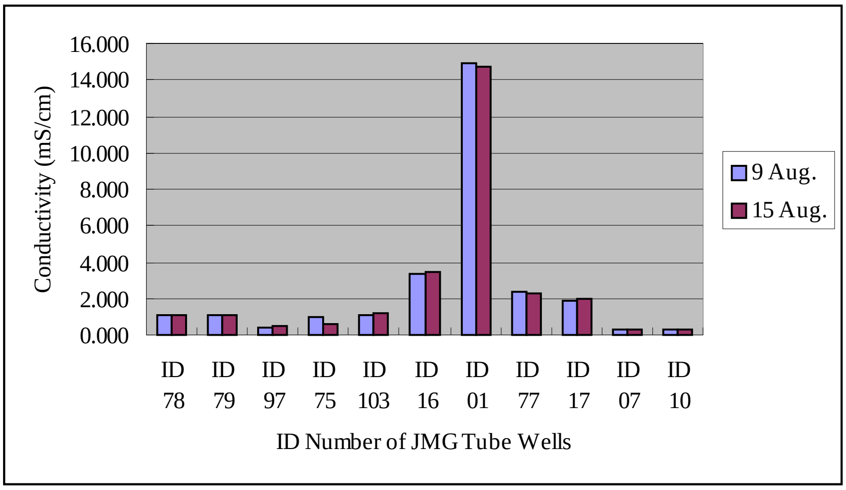


Figure E.3.10 Averaged Conductivity of the JMG Tube Wells

The average conductivity values for the tube wells seem to be about one magnitude higher than the average for open wells, due to the presence of more ions in deeper wells. Similar profile was observed for average values for salinity as described later. One significant feature of the salinity and conductivity profiles is the relatively very high value for location ID-1 in Sg. Lang Tengah. On both days of measurements, the quantity of water that could be pumped up from this tube well ID-1 was little and limited. Tube well at ID-16 also showed apparent higher salinity and conductivity values even though not as high as the ID-1. This could be explained perhaps by the phenomenon of very slight seawater intrusion because ID-16 near the water gate of Sg. Lang is situated at about 7 km from the mouth of the river.

The conspicuous level of salinity and conductivity at ID-1 well is suspected to result from insufficient quantity of water. Therefore, more concentrated salts and ions were present and hence higher salinity and conductivity were measured. Another factor that should be investigated in future is the characteristics of the subsurface soil.

(6) pH Value

The average pH values for tube wells on 9th and 15th of August were very similar at a majority of well locations, as shown in **Figure E.3.11**. Values for pH ranged from 5.61 at ID-16 to 9.76 at ID-103 on 9 August and from 5.86 at ID-16 to 8.79 at ID-78 on 15 August. Average pH values for open and tube wells also seem to be within the same range of about 6-9.

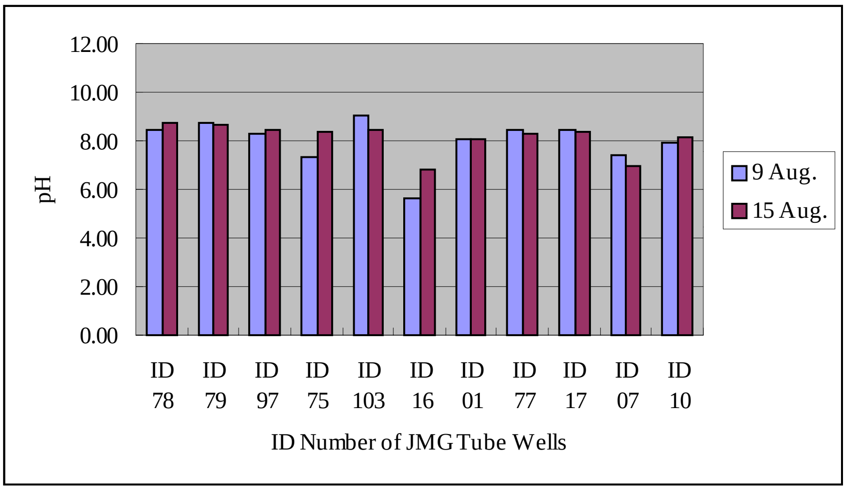


Figure E.3.11 Averaged pH Value of the JMG Tube Wells

(7) Redox Potential

Redox potentials for the well waters ranged from –65 mV at ID-103 to 306 mV at ID-75 on the record of August 9, while measurement values ranged from 4 mV at ID-78 to 243 mV at ID-16. The results of measurement are shown in **Figure E.3.12**. Redox potential average values for tube wells were found to be significantly lower than those for open wells. The deeper tube wells contained water that were very low in DO and had the strong pungent smell of sulphides, indicative of conditions that are low in oxygen and dominantly anaerobic in nature. In addition, with the measured redox potential for groundwater, it is possible to calculate the total dissolved iron concentration. Thus, it may be said that the water of the open wells contains much more ferrous and ferric forms than that of the tube wells.

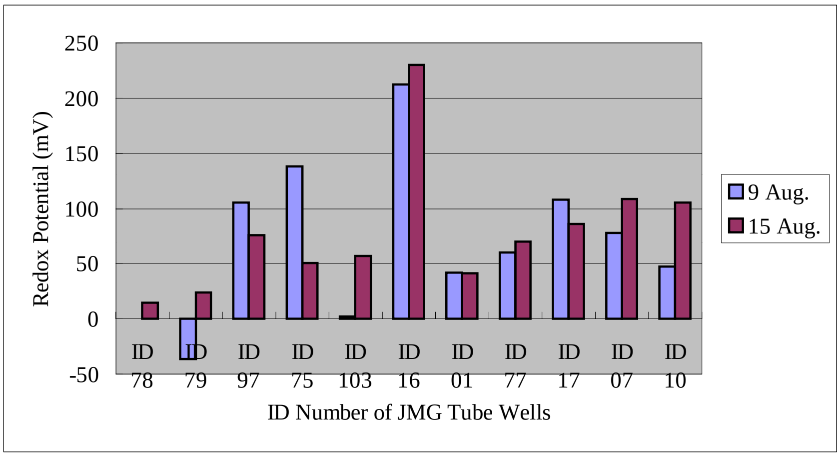


Figure E.3.12 Averaged Redox Potential Value of the JMG Tube Wells

(8) Oxygen Saturation

Oxygen saturation was a minimum of 3.2% at ID-79 and maximum of 63.3% at ID-103 on the record of August 9, and a minimum of 5.7% at ID-78 and maximum of 36.4% at ID-97 on the record of August 15. This seems to be in line with the observations on DO values. Compared with the values of open wells, the records of tube well are relatively lower. **Figure E.3.13** shows the averaged oxygen saturation on the two dates.

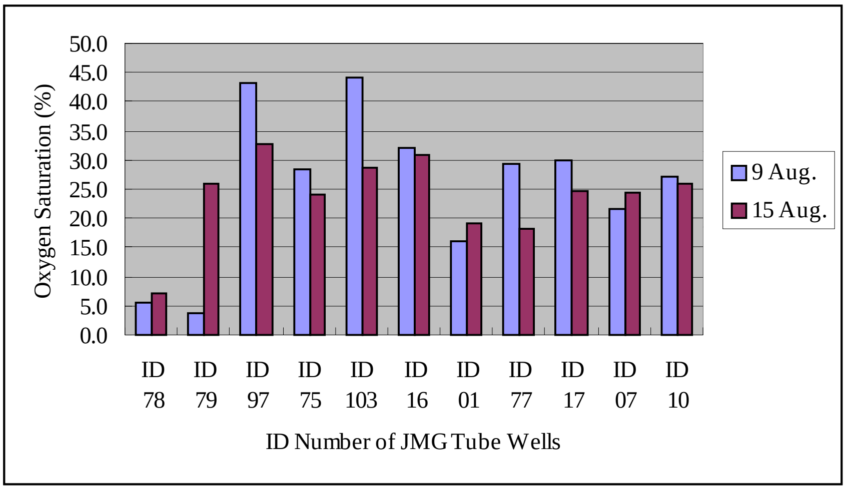


Figure E.3.13 Averaged Oxygen Saturation of the JMG Tube Wells

(9) Salinity

Salinity values ranged from $0.1^{o}/_{oo}$ at ID-7 and 10 and $8.7^{o}/_{oo}$ at ID-1 on 9 August. Exactly the same tendency was recorded from $0.1^{o}/_{oo}$ at ID-7 and 10 and $8.6^{o}/_{oo}$ at ID-1 on 15 August. The values of salinity are shown in **Figure E.3.14**. It seems that the values for salinity and conductivity are very much related due to the possibility of seawater intrusion. Generally, the values of all the parameters for tube wells were about similar to the values for open wells, with few exceptions. The tube wells were definitely deeper and narrower than the open wells. The range of values of the types of wells did overlap with one another; hence, the preliminary conclusion that the water characteristics of well waters in the Langat Basin, be it open or tube, are still indicative of fairly good quality without overwhelming pollution from human activities.

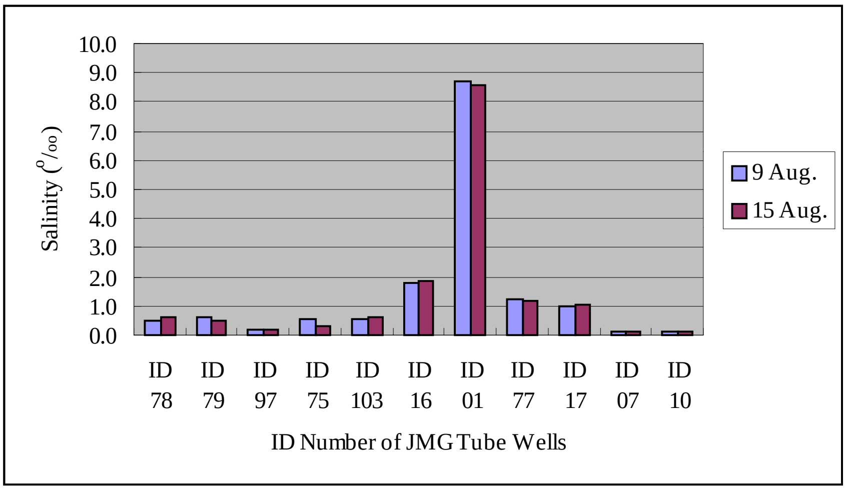


Figure E.3.14 Averaged Salinity of the JMG Tube Wells

3.3 Groundwater Level and Quality Observation in Phase II and Phase III

3.3.1 Introduction

This subsection presents results of groundwater level and quality observation as well as surface water quality, which were obtained after completion of the Second and Third Field Work in Malaysia. The total number of monitoring work was three (3) during the study period; the first observation was made between February and March 2001, the second one was in May 2001, and the last was in August and September 2001.

3.3.2 Location of Observation Points

There were a total of 34 wells for the groundwater level measurement. Out of these 34 wells, 30 were selected for the groundwater quality and 10 for the surface water quality measurements. Lists of these monitoring wells comprising existing and new ones, and surface water sampling points are shown in **Tables H.2.1, H.2.2 and H.3.1 in Sector H**, respectively. Locations of the observation points are also given in **Figure H.3.1 in Sector H**.

3.3.3 Result of the Observation

(1) Groundwater Level

The result of the groundwater level observation is presented in **Tables E.3.1 and E.3.2**. Changes of the level vary from location to location. Evaluation of the result will be made in **Section 2.4 of Sector G**.

Table E.3.1 Result of the Groundwater Level Measurement for the Existing Monitoring Wells

Well Name	No.	Date	Time	Water Level (m)	Collar (m)	Elevation (m)
MWD1	1	22-Feb-01	11:07	4.55	0.49	-1.691
	2	28-May-01	13:15	3.05	0.33	-0.351
	3	22-Aug-01	11:50	5.34	0.33	-2.641
MWD2	1	21-Feb-01	11:10	4.40	0.35	0.357
	2	23-May-01	14:52	4.65	0.38	0.137
	3	23-Aug-01	12:00	4.93	0.38	-0.143
MWD4	1	2-Mar-01	-	1.16	0.35	2.650
	2	29-May-01	11:08	3.22	0.36	0.600
	3	30-Aug-01	10:05	1.77	0.36	2.050
MWD5	1	21-Feb-01	13:10	1.46	0.35	0.781
	2	23-May-01	13:10	1.793	0.39	0.488
	3	23-Aug-01	15:23	1.95	0.39	0.331
MWD6	1	21-Feb-01	13:35	2.52	0.31	1.084
	2	28-May-01	11:00	3.32	0.31	0.284
	3	22-Aug-01	15:25	2.90	0.31	0.694
MWD7	1	21-Feb-01	10:36	4.44	0.36	-1.333
	2	23-May-01	16:10	4.815	0.355	-1.713
	3	23-Aug-01	10:25	5.12	0.355	-2.018
MWD8	1	9-Feb-01	-	3.90	0.38	1.182
	2	23-May-01	12:30	3.963	0.395	1.134
	3	23-Aug-01	14:00	4.00	0.395	1.097
MWD9	1	2-Mar-01	-	1.29	0.36	4.256
	2	21-May-01	16:19	1.375	0.37	4.181
	3	29-Aug-01	10:50	1.63	0.37	3.926
MWD10	1	26-Feb-01	10:50	3.21	0.52	0.034
	2	22-May-01	10:50	3.364	0.33	-0.310
	3	22-Aug-01	13:30	3.64	0.33	-0.546
LED2	1	22-Feb-01	16:55	2.76	0.40	7.140
	2	24-May-01	16:00	2.88	0.42	7.040
	3	28-Aug-01	14:40	2.80	0.42	7.120
LED3*[1]	1	22-Feb-01	10:30	1.73	0.43	8.200
	2	-	-	-	-	-
	3	-	-	-	-	-
Megasteel MW1*[2]	1	8-Mar-01	16:22	12.37	0.145	-7.972
	2	17-May-01	16:11	13.72	0.21	-9.257
	3	-	-	-	-	-
EXPL2*[1]	1	8-Mar-01	12:14	2.21	0.90	?
	2	-	-	-	-	-
	3	-	-	-	-	-

Note: *[1] Water level observation from these wells was carried out in the first measurement only.
*[2] The third sampling at Megasteel MW1 could not be carried out due to unfunctioning of water level gauge.

Table E.3.2 Result of the Groundwater Level Measurement for the New Monitoring Wells

Well Name	No.	Date	Time	Water Level (m)	Collar (m)	Elevation (m)
J1-1-1	1	28-Mar-01	12:00	1.35	0.31	7.557
	2	24-May-01	12:00	1.203	0.31	7.704
	3	28-Aug-01	11:30	1.18	0.31	7.727
J1-1-2	1	28-Mar-01	11:10	1.03	0.34	7.907
	2	24-May-01	13:40	0.95	0.355	8.002
	3	28-Aug-01	12:15	1.28	0.355	7.642
J2-1-2	1	23-Mar-01	10:52	1.22	0.320	6.902
	2	21-May-01	12:49	0.715	0.23	7.317
	3	18-Aug-01	13:30	0.99	0.23	7.042
J2-1-3	1	23-Mar-01	11:37	1.23	0.320	6.892
	2	21-May-01	12:50	0.705	0.225	7.322
	3	4-Sep-01	9:55	1.00	0.225	7.027
J3-1	1	1-Mar-01	-	1.20	0.355	6.639
	2	22-May-01	12:20	0.992	0.16	6.652
	3	27-Aug-01	10:50	1.27	0.16	6.374
J3-2	1	1-Mar-01	15:58	1.18	0.23	6.467
	2	22-May-01	12:20	1.20	0.28	6.497
	3	27-Aug-01	11:40	1.055	0.28	6.642
J4-1	1	9-Mar-01	11:16	1.14	0.305	4.922
	2	22-May-01	15:46	5.25	0.305	0.812
	3	27-Aug-01	14:30	4.28	0.305	1.782
J4-2	1	9-Mar-01	11:21	2.87	0.385	3.29
	2	22-May-01	15:42	2.745	0.3	3.33
	3	3-Sep-01	14:53	3.00	0.3	3.075
J5-2-2	1	20-Feb-01	12:15	8.58	0.71	-2.188
	2	17-May-01	12:15	9.27	0.6	-2.988
	3	20-Aug-01	9:40	8.80	0.6	-2.518
J5-2-3	1	20-Feb-01	12:17?	8.38	0.71	-1.988
	2	17-May-01	13:20	9.03	0.6	-2.748
	3	20-Aug-01	10:00	9.20	0.6	2.918
J6-1	1	8-Mar-01	11:45	0.65	0.35	2.181
	2	25-May-01	17:30	0.785	0.35	2.046
	3	27-Aug-01	16:25	1.09	0.35	1.741
J7-1-1	1	13-Mar-01	-	1.05	0.11	3.873
	2	18-May-01	10:30	1.00	0.111	3.924
	3	21-Aug-01	10:20	0.95	0.111	3.974
J7-1-2	1	13-Mar-01	15:36	1.11	0.10	3.803
	2	18-May-01	10:37	1.04	0.098	3.871
	3	21-Aug-01	10:30	1.01	0.098	3.901
J7-1-3	1	13-Mar-01	14:50	4.26	0.21	0.763
	2	18-May-01	10:32	4.31	0.215	0.718
	3	21-Aug-01	10:50	4.35	0.215	0.678

Table E.3.2 Result of the Groundwater Level Measurement for the New Monitoring Wells (cont'd)

Well Name	No.	Date	Time	Water Level (m)	Collar (m)	Elevation (m)
J7-1-4	1	13-Mar-01	14:20	5.03	0.22	0.003
	2	18-May-01	10:30	5.04	0.24	0.013
	3	21-Aug-01	11:00	5.10	0.24	-0.047
J7-2	1	13-Mar-01	12:50	5.29	0.405	0.098
	2	18-May-01	10:42	5.22	0.405	0.168
	3	21-Aug-01	11:00	5.33	0.405	0.058
J7-5	1	31-Jan-01	-	0.92	0.35	4.227
	2	18-May-01	15:17	0.90	0.35	4.247
	3	21-Aug-01	15:16	1.04	0.35	4.107
J8-1	1	27-Feb-01	13:00?	2.78	0.33	-0.159
	2	25-May-01	15:26	2.17	0.34	0.461
	3	24-Aug-01	13:07	2.53	0.34	0.001
J8-2	1	27-Feb-01	12:10?	2.93	0.31	-0.332
	2	25-May-01	15:27	2.62	0.32	-0.012
	3	24-Aug-01	13:08	2.65	0.32	-0.042
J9-1	1	1-Mar-01	11:50?	2.47	0.24	0.099
	2	25-May-01	11:16	1.998	0.15	0.481
	3	24-Aug-01	9:55	2.00	0.15	0.479
J9-2	1	27-Feb-01	15:40?	2.49	0.44	0.305
	2	25-May-01	11:17	2.311	0.42	0.464
	3	24-Aug-01	10:00	1.60	0.42	1.175
J10-1-1	1	23-Mar-01	17:00	1.14	0.33	8.056
	2	24-May-01	11:50	1.305	0.32	7.881
	3	28-Aug-01	9:30	2.42	0.32	6.766
J10-1-2	1	13-Mar-01	16:20	2.28	0.33	6.916
	2	24-May-01	11:10	2.13	0.32	7.056
	3	28-Aug-01	9:30	4.375	0.32	4.811

(2) Groundwater Quality

Water quality analysis had been carried out in-situ by using a handy analyser, simple chemical testing at the site, and laboratory testing both in JMG Ipoh and a private company. Results of the analysis are compiled in **Annex Tables E.3.1, E.3.2 and E.3.3**, and major findings are described as follows:

(a) pH Values

The first measurement of pH was conducted from around the end of February to the beginning of March 2001 while the second was between the middle and end of May 2001. Finally, the last measurement was carried out in late August through early September 2001 although some of the wells were subjected to a fourth observation due to the requirement for additional analysis for E-coli. Measured pH values on the three or four observations are shown in **Table E.3.3** below. There is no large difference among the first, second, third and fourth observation values in the lapse of three months.

The pH value of distilled water that is in equilibrium under one atmospheric pressure is about 5.6 in general.[10), 16)] Therefore, water whose pH is less than 5 is said to be uncommon.[14)] The pH values below 5 can be observed mainly in surface water near the Paya Indah area, as shown in **Figure E.3.15**. Three (3) 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 values ranging from 3.9 to 4.7. In terms of groundwater in this area, it is assumed that the highly acidic surface water affects pH values like 4.5 – 4.7 of the area.

Table E.3.3 pH Values Measured in Groundwater and Surface Water

Point Name	Location	pH Value			
		First	Second	Third	Fourth
MWD1	Jambatan Batu, Jln. ke Sg. Kelambu	6.7	6.6	6.1	6.5
MWD2	Jln. Dahilia, Sg. Kelambu	6.7	6.7	6.3	6.5
MWD4	Mutiara Telekom, Jln ke Salak Tinggi-KLIA	6.5	6.6	6.4	-
MWD5	Pintu Air, Sg. Lang, detak pekan Banting	-	5.3	5.9	-
MWD6	Kg. Sg. Manggis, Telok Datok	6.7	6.8	6.2	-
MWD7	Kg. Sg. Kelambu	-	6.7	6.2	-
MWD8	Jl. Idaman, Sg. Lang Tengah	-	6.8	6.1	-
MWD9	FELCRA, Bt. Changgang	6.4	6.3	6.4	6.3
MWD10	Kajibumi WF1	6.8	6.8	6.3	-
MW14*	FELCRA, Bt. Changgang	6.7	-	-	-
LED2	Express Highway KLIA-Subang-Nilai	5.5	5.6	5.0	-
LED3*	-ditto-	6.1	-	-	-
EXPL2*	**Pintu Air, Sg. Lang, detak pekan Banting**	**4.4**	-	-	-
MW1	Magasteel	6.8	6.6	6.2	-
J1-1-1	South of Bt. Baja	5.9	6.0	5.6	-
J1-1-2	-ditto-	6.2	6.4	5.9	-
J2-1-2	Paya Indah	5.9	6.3	5.6	-
J2-1-3	**-ditto-**	**4.7**	**4.5**	**4.7**	**5.1**
J3-1	Northwest of Paya Indah	6.5	6.4	6.3	-
J3-2	-ditto-	6.7	6.7	6.2	-
J4-2	Kg. Jenjarom	7.0	6.9	6.6	6.7
J5-2-2	Kajibumi WF2	6.8	6.7	6.0	-
J5-2-3	Kajibumi WF2	6.6	6.5	6.0	-

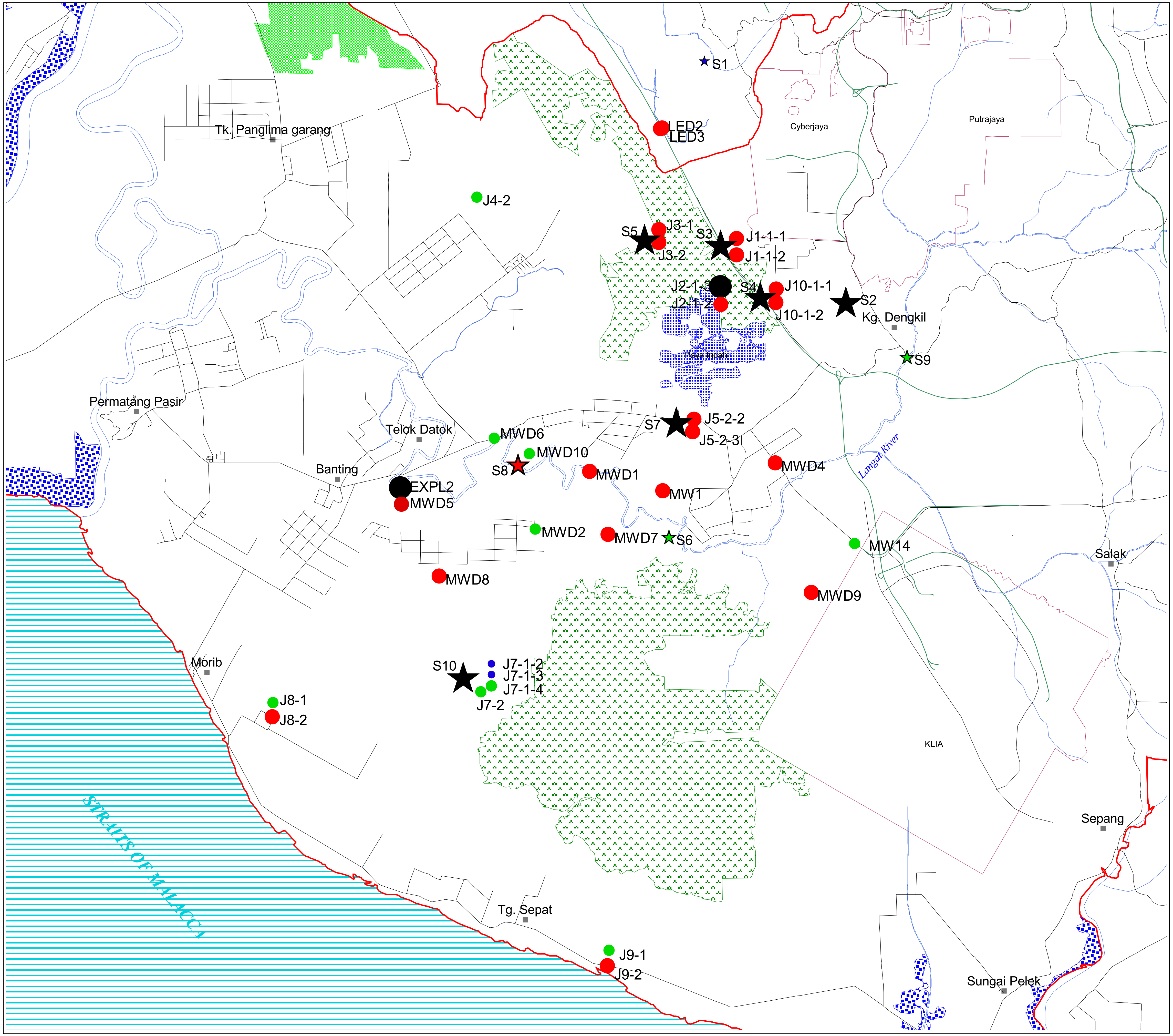
Table E.3.3 pH Values Measured in Groundwater and Surface Water (cont 'd)

Point Name	Location	pH Value			
		First	Second	Third	Fourth
J7-1-2	Kanchong Darat	7.5	7.4	7.0	7.2
J7-1-3	-ditto-	7.4	7.3	6.9	7.1
J7-1-4	-ditto-	7.1	7.0	6.7	-
J7-2	-ditto-	7.0	6.9	6.6	-
J8-1	Kg. Endah	6.9	6.8	6.6	6.6
J8-2	-ditto-	6.2	6.3	5.6	6.2
J9-1	Ladang Tumbuk	6.9	6.9	6.6	-
J9-2	-ditto-	6.2	6.3	6.0	-
J10-1-1	East of Paya Indah	6.2	6.3	5.7	-
J10-1-2	-ditto-	6.4	6.4	5.8	-
S1	Puchong Mine	7.3	7.3	7.1	-
S2	**Dengkil Mine**	**4.1**	**4.2**	**4.1**	-
S3	**Paya Indah Inflow (SW1)**	**4.3**	**4.7**	**4.6**	-
S4	**Paya Indah Inflow (SW2)**	**3.9**	**4.6**	**4.3**	-
S5	**Bt. Cheeding**	**4.1**	**4.6**	**4.8**	-
S6	Sand Mine	6.5	7.2	6.8	-
S7	**Kajibumi WF2**	**4.3**	**5.2**	**4.9**	-
S8	Langat River (Kajibumi WF1)	5.7	6.5	6.8	-
S9	Langat River (Dengkil)	6.6	7.0	7.1	-
S10	**Kanchong Darat**	**4.0**	**3.7**	**3.8**	-

Note: * These wells were observed in the first measurement only because these ones would not be used for long term monitoring.

Figure E.3.15

Averaged pH Values in the Water Quality Measurement



pH value

Groundwater	Surface water
<5	<5
5 - 6.5	5 - 6.5
6.6 - 7	6.6 - 7
7.1 - 8.5	7.1 - 8.5

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

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

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

CTI Engineering International Co., Ltd.

OYO CORPORATION

(b) Electric Conductivity

Ion solutions have electric conductivity that depends on type and concentration of ion. Electric conductivity of a dilute solution indicates the sum of conductivities of each ion. Hence, it is possible to assume the volume of ions dissolved in the solution by measuring the conductivity. The electric conductivity measured in the first, second and third (some are fourth) sampling is presented in **Table E.3.4**, and the averaged values of the measurements are shown in **Figure E.3.16**. This index also indicates a small difference among them except S7.

The low pH area in the north of Paya Indah, such as S2, S3, S4, S5 and wells LED2 and J2-1-3, shows low conductivity that is specifically less than 100 μS/cm. This tendency is contrary to the general one; that is, high acidic conditions such as pH less than 5 usually bring high conductivity ranging from over several hundred to thousands μS/cm.[15)] Therefore, it is assumed that these waters have some strong acidic substances while a small quantity of ions is dissolved in those sampling waters.

In the south and along the of Langat River, high conductivity of more than 500 μS/cm was observed. Marine sediments in the area such as Gula Formation and Kempadang Formation may cause this high conductivity. Saltwater coming from the river and shoreline may also contribute to conductible condition of the groundwater. Especially, wells in the coastal area, i.e., J8-1, J8-2, J9-1 and J9-2, showing more than 10,000 μS/cm, are actually located in the interface between fresh and saline waters. The electric conductivity of seawater is said to be about 45,000μS/cm.[14)] As a result of this conductivity measurement, it is estimated that seawater intrudes at least 2km from the shoreline.

Table E.3.4 Electric Conductivity Measured in Groundwater and Surface Water

Point Name	Location	Electric Conductivity (μS/cm)			
		First	Second	Third	Fourth
MWD1	Jambatan Batu, Jln. ke Sg. Kelambu	574	581	572	440
MWD2	Jln. Dahilia, Sg. Kelambu	2020	2100	1917	1672
MWD4	Mutiara Telekom, Jln ke Salak Tinggi-KLIA	478	516	398	-
MWD5	Pintu Air, Sg. Lang, detak pekan Banting	-	4370	3729	-
MWD6	Kg. Sg. Manggis, Telok Datok	933	929	857	-
MWD7	Kg. Sg. Kelambu	-	1940	1730	-
MWD8	**Jl. Idaman, Sg. Lang Tengah**	**-**	**15840**	**13913**	**-**
MWD9	FELCRA, Bt. Changgang	814	883	714	726
MWD10	Kajibumi WF1	875	887	795	-
MW14*	FELCRA, Bt. Changgang	330	-	-	-

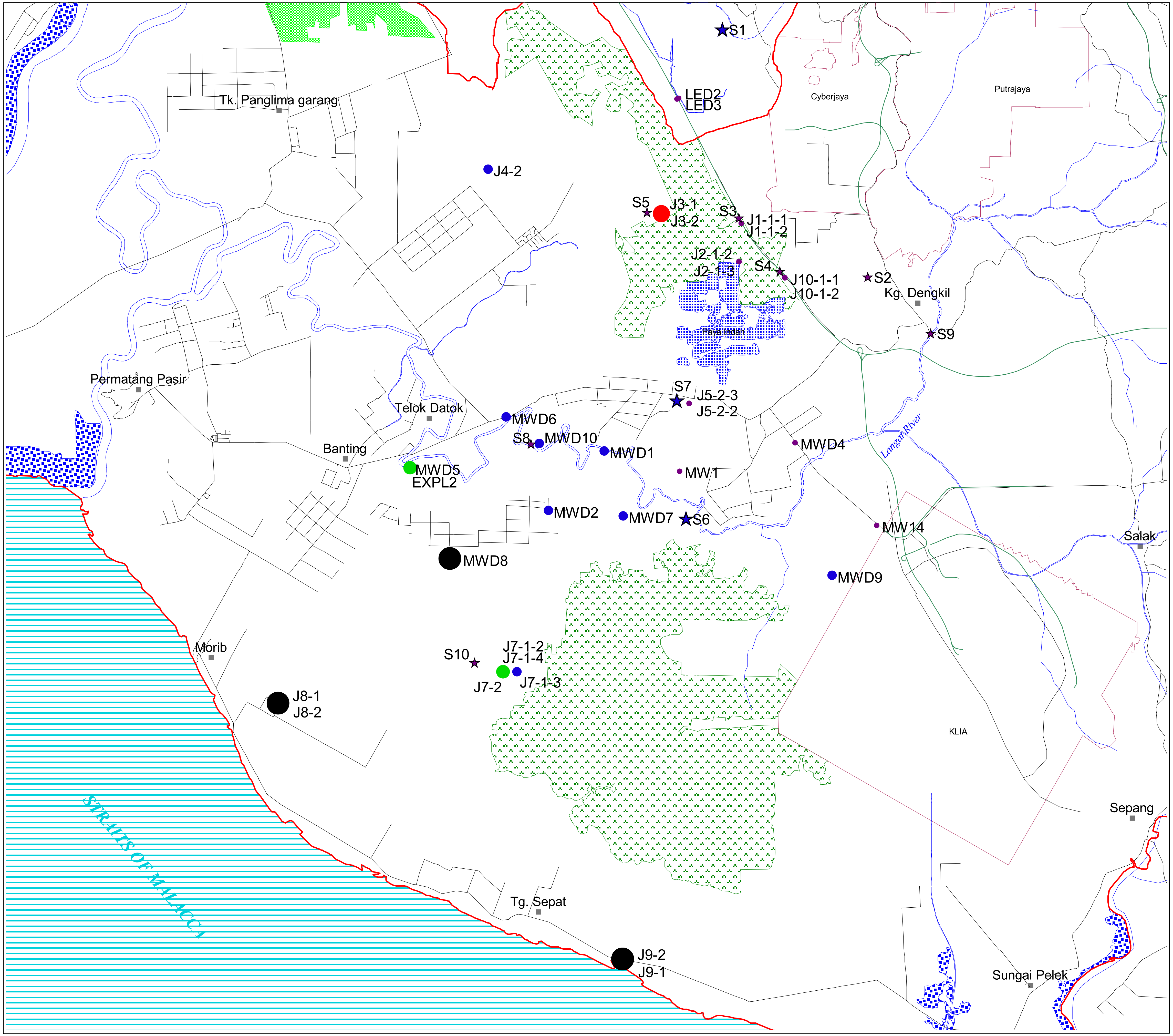
Table E.3.4 Electric Conductivity Measured in Groundwater and Surface Water (cont'd)

Point Name	Location	Electric Conductivity (μS/cm)			
		First	Second	Third	Fourth
LED2	Express Highway KLIA-Subang-Nilai	55	53	49	-
LED3*	-ditto-	95	-	-	-
EXPL2*	Pintu Air, Sg. Lang, detak pekan Banting	3670	-	-	-
MW1	Magasteel	301	311	286	-
J1-1-1	South of Bt. Baja	251	246	248	-
J1-1-2	-ditto-	164	172	154	-
J2-1-2	Paya Indah	84	108	-	-
J2-1-3	-ditto-	25	29	-	26
J3-1	Northwest of Paya Indah	7130	7560	4646	-
J3-2	-ditto-	4980	5040	6620	-
J4-2	Kg. Jenjarom	2070	2100	1931	1621
J5-2-2	Kajibumi WF2	311	337	251	-
J5-2-3	-ditto-	400	402	390	-
J7-1-2	Kanchong Darat	2130	2660	2456	2196
J7-1-3	-ditto-	1199	1369	975	845
J7-1-4	Kanchong Darat	2400	2020	1811	-
J7-2	-ditto-	4190	4460	3778	-
J8-1	**Kg. Endah**	**29800**	**25800**	**20937**	**19429**
J8-2	**-ditto-**	**17990**	**16750**	**13845**	**13617**
J9-1	**Ladang Tumbuk**	**10960**	**10670**	**9395**	**-**
J9-2	**-ditto-**	**11830**	**11800**	**10221**	**-**
J10-1-1	East of Paya Indah	250	270	182	-
J10-1-2	-ditto-	224	218	198	-
S1	Puchong Mine	981	941	616	-
S2	Dengkil Mine	97	92	72	-
S3	Paya Indah Inflow (SW1)	27	36	34	-
S4	Paya Indah Inflow (SW2)	37	42	47	-
S5	Bt. Cheeding	103	96	67	-
S6	Sand Mine	-	1484	2041	-
S7	Kajibumi WF2	118	165	1514	-
S8	Langat River (Kajibumi WF1)	118	179	120	-
S9	Langat River (Dengkil)	73	111	148	-
S10	Kanchong Darat	227	241	150	-

Note: * These wells were observed in the first measurement only because these ones would not be used for long term monitoring.

Figure E.3.16

Averaged Electric Conductivity in the Water Quality Measurement



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

CTI Engineering International Co., Ltd.

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(c) Major Ion Ratios

Major chemical components of groundwater are listed as follows:

- Cation: Na^+, K^+, Ca^{2+}, Mg^{2+}
- Anion: Cl^-, SO_4^{2-}, HCO_3^-
- Indissociation component: H_4SiO_4
- Gas component: CO_2

The potential presence of any other element in groundwater is limited only by contact of the solution with a solid or gas containing the element; however, most other elements and compounds are found dissolved in groundwater at levels less than 1 mg/l (milligram per litre). On the other hand, the major ions listed above are present at concentrations greater than 1 mg/l under natural conditions. Investigation of the major components is important to identify the origin of groundwater and classify the type of groundwater. The water classification will be discussed later, and ratios of sodium (Na^+), calcium (Ca^{2+}) and sulfate (SO_4^{2-}) to chloride (Cl^-) in milliequivalents per litre (meq/l) are calculated as shown in **Table E.3.5**. Since chloride ion is hardly affected by oxidation-reduction processes and does not produce insoluble matters under natural conditions, it is relatively easy to trace what has been done. Averaged chloride values in the three measurement are given in **Figure E.3.17**.

The ratio of sodium (Na^+) to chloride (Cl^-) in seawater is about 0.85.[11)] If the ratio of water is less than 0.85, the water will have some special reasons. Wells located near the seacoast such as J8-1 and J8-2 indicated values lower than 0.85. Although samples from surface water, namely S1, S3, S4, S5 and S10, are categorised into the special water, the reason why the ratio of these waters is so low has not been clarified.

Samples from active mines such as S1 and S6 indicate a high concentration of both ions. Mining waste or tailing piles may result in enhancing production of these ions. In comparison, the ratio of groundwater is more than twice as large as that of surface water on average. It may be a well-grounded argument that the surface water has not been influenced by seawater seriously, while seawater intrusion makes sodium concentration of some wells like J8-1&2 and J9-1&2 higher than usual.

Major sources of calcium ion (Ca^{2+}) in groundwater and surface water are the solid materials contacted by the water. The ratio of calcium to chloride in seawater is about 0.038.[12)] Only 21 samples out of 84 for the groundwater have the ratio less than this figure while no sample for the surface water is in excess of 0.038. Average values for the ratio of the groundwater are one-third that of surface water.

Mineral springs or mining wastes are among the major sources of sulfate ion (SO_4^{2-}) in the groundwater. Industrial and domestic wastewater also sometimes causes detection of this ion. Although well EXPL2 has an extremely high value, this is only one sample. Other high concentration can be seen at MWD5 for the groundwater, and S1, S6, S7 and S8 for the surface water. Average ratio of the groundwater is one sixth that of surface water. The ratio of sulfate to chloride in groundwater is lower than that of surface water in general because sulfate is easily absorbed by precipitates.13) The result of measurement can support this. The ratio of sulfate to chloride in seawater is about 0.101.12) Almost half of the wells show the values lower than this ratio while all surface water samples indicate a higher ratio.

Table E.3.5 Major Ion Ratios in Groundwater and Surface Water

Point Name	No. *1	Na^+ (mg/l)	Na^+ (meq/l)	Ca^{2+} (mg/l)	Ca^{2+} (meq/l)	SO_4^{2-} (mg/l)	SO_4^{2-} (meq/l)	Cl^- (mg/l)	Cl^- (meq/l)	Na/Cl*2	Ca/Cl*2	SO_4/Cl*2
MWD1	1	79.0	3.435	3.5	0.175	3.0	0.062	96.0	2.708	1.268	0.064	**0.023**
	2	76.0	3.304	4.6	0.230	3.0	0.062	99.0	2.793	1.183	0.082	**0.022**
	3	83.0	3.609	4.1	0.205	3.0	0.062	114.0	3.216	1.122	0.064	**0.019**
MWD2	1	322.0	14.000	7.8	0.389	3.0	0.062	482.0	13.597	1.030	**0.029**	**0.005**
	2	320.0	13.913	8.3	0.414	3.0	0.062	445.0	12.553	1.108	0.033	**0.005**
	3	315.0	13.696	7.1	0.354	3.0	0.062	493.0	13.907	0.985	**0.025**	**0.004**
MWD4	1	64.0	2.783	4.3	0.215	3.0	0.062	57.0	1.608	1.731	0.133	**0.039**
	2	57.0	2.478	6.5	0.324	3.0	0.062	49.0	1.382	1.793	0.235	**0.045**
	3	68.0	2.957	4.1	0.205	3.0	0.062	59.0	1.664	1.776	0.123	**0.038**
MWD5	1	-	-	-	-	-	-	-	-	-	-	-
	2	475.0	20.652	22.0	1.098	365.0	7.599	816.0	23.018	0.897	0.048	0.330
	3	440.0	19.130	33.0	1.647	643.0	13.387	749.0	21.128	0.905	0.078	0.634
MWD6	1	146.0	6.348	3.5	0.175	3.0	0.062	158.0	4.457	1.424	0.039	**0.014**
	2	113.0	4.913	3.7	0.185	3.0	0.062	125.0	3.526	1.393	0.052	**0.018**
	3	138.0	6.000	3.3	0.165	3.0	0.062	168.0	4.739	1.266	**0.035**	**0.013**
MWD7	1	-	-	-	-	-	-	-	-	-	-	-
	2	253.0	11.000	13.0	0.649	12.0	0.250	370.0	10.437	1.054	0.062	**0.024**
	3	292.0	12.696	7.7	0.384	3.0	0.062	443.0	12.496	1.016	**0.031**	**0.005**
MWD8	1	-	-	-	-	-	-	-	-	-	-	-
	2	2310.0	100.435	144.0	7.186	3.0	0.062	3590.0	101.269	0.992	0.071	**0.001**
	3	2540.0	110.435	112.0	5.589	3.0	0.062	4236.0	119.492	0.924	0.047	**0.001**
MWD9	1	117.0	5.087	3.5	0.175	19.0	0.396	164.0	4.626	1.100	0.038	**0.086**
	2	104.0	4.522	3.7	0.185	16.0	0.333	136.0	3.836	1.179	0.048	**0.087**
	3	148.0	6.435	4.5	0.225	16.0	0.333	194.0	5.472	1.176	0.041	**0.061**
MWD10	1	141.0	6.130	3.5	0.175	3.0	0.062	128.0	3.611	1.698	0.048	**0.017**
	2	104.0	4.522	2.7	0.135	3.0	0.062	89.0	2.511	1.801	0.054	**0.025**
	2	146.0	6.348	2.3	0.115	3.0	0.062	133.0	3.752	1.692	**0.031**	**0.017**

Table E.3.5 Major Ion Ratios in Groundwater and Surface Water (cont'd)

Point Name	No. *1	Na^+ (mg/l)	Na^+ (meq/l)	Ca^{2+} (mg/l)	Ca^{2+} (meq/l)	SO_4^{2-} (mg/l)	SO_4^{2-} (meq/l)	Cl^- (mg/l)	Cl^- (meq/l)	Na/Cl*2	Ca/Cl*2	SO_4/Cl*2
MW14	1	61.0	2.652	0.9	0.045	18.0	0.375	2.0	0.056	47.010	0.796	6.643
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
LED2	1	-	-	-	-	-	-	-	-	-	-	-
	2	-	-	-	-	-	-	-	-	-	-	-
	3	7.0	0.304	0.5	0.025	3.0	0.062	1.0	0.028	10.789	0.884	2.214
EXPL2	1	92.0	4.000	87.0	4.341	1477.0	30.752	167.0	4.711	**0.849**	0.922	6.528
	2	-	-	-	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-	-
MW-1	1	39.0	1.696	3.5	0.175	3.0	0.062	21.0	0.592	2.862	0.295	**0.105**
	2	40.0	1.739	4.2	0.210	3.0	0.062	23.0	0.649	2.681	0.323	**0.096**
	3	42.0	1.826	3.6	0.180	3.0	0.062	24.0	0.677	2.697	0.265	**0.092**
J1-1-1	1	17.0	0.739	9.5	0.474	3.0	0.062	4.0	0.113	6.551	4.201	0.554
	2	-	-	-	-	-	-	-	-	-	-	-
	3	13.0	0.565	4.3	0.215	3.0	0.062	12.0	0.339	1.670	0.634	0.185
J1-1-2	1	12.0	0.522	5.6	0.279	3.0	0.062	10.0	0.282	1.850	0.991	0.221
	2	11.0	0.478	4.3	0.215	3.0	0.062	10.0	0.282	1.695	0.761	0.221
	3	9.5	0.413	4.5	0.225	3.0	0.062	12.0	0.339	1.220	0.663	0.185
J2-1-2	1	3.6	0.157	3.4	0.170	3.0	0.062	2.0	0.056	2.774	3.007	1.107
	2	1.3	0.057	4.3	0.215	3.0	0.062	1.0	0.028	2.004	7.607	2.214
	3	1.8	0.078	3.6	0.180	3.0	0.062	2.0	0.056	1.387	3.184	1.107
J2-1-3	1	1.8	0.078	1.7	0.085	3.0	0.062	3.0	0.085	0.925	1.002	0.738
	2	1.5	0.065	1.1	0.055	3.0	0.062	2.0	0.056	1.156	0.973	1.107
	3	3.2	0.139	1.1	0.055	3.0	0.062	2.0	0.056	2.466	0.973	1.107
J3-1	1	1085.0	47.174	123.0	6.138	6.0	0.125	1992.0	56.192	**0.840**	0.109	**0.002**
	2	1025.0	44.565	114.0	5.689	3.0	0.062	1851.0	52.214	0.854	0.109	**0.001**
	3	800.0	34.783	26.0	1.297	3.0	0.062	1231.0	34.725	1.002	**0.037**	**0.002**
J3-2	1	860.0	37.391	28.0	1.397	3.0	0.062	1170.0	33.004	1.133	0.042	**0.002**
	2	680.0	29.565	29.0	1.447	3.0	0.062	1005.0	28.350	1.043	0.051	**0.002**
	3	1060.0	46.087	98.0	4.890	3.0	0.062	2019.0	56.953	**0.809**	0.086	**0.001**
J4-2	1	362.0	15.739	7.8	0.389	3.0	0.062	325.0	9.168	1.717	0.042	**0.007**
	2	305.0	13.261	8.2	0.409	3.0	0.062	283.0	7.983	1.661	0.051	**0.008**
	3	335.0	14.565	7.0	0.349	3.0	0.062	331.0	9.337	1.560	**0.037**	**0.007**
J5-2-2	1	39.0	1.696	6.9	0.344	3.0	0.062	7.0	0.197	8.587	1.744	0.316
	2	43.0	1.870	7.8	0.389	7.0	0.146	8.0	0.226	8.285	1.725	0.646
	3	47	2.043	3.8	0.190	3	0.062	61.0	1.721	1.188	0.110	**0.036**
J5-2-3	1	50.0	2.174	7.8	0.389	3.0	0.062	64.0	1.805	1.204	0.216	**0.035**
	2	49.0	2.130	8.5	0.424	3.0	0.062	59.0	1.664	1.280	0.255	**0.038**
	3	39	1.696	3.8	0.190	9	0.187	8.0	0.226	7.514	0.840	0.830

Table E.3.5 Major Ion Ratios in Groundwater and Surface Water (cont'd)

Point Name	No. *1	Na^+		Ca^{2+}		SO_4^{2-}		Cl^-		Na/Cl*2	Ca/Cl*2	SO_4/Cl*2
		(mg/l)	(meq/l)	(mg/l)	(meq/l)	(mg/l)	(meq/l)	(mg/l)	(meq/l)			
J7-1-2	1	388.0	16.870	38.0	1.896	3.0	0.062	119.0	3.357	5.025	0.565	**0.019**
	2	445.0	19.348	17.0	0.848	3.0	0.062	109.0	3.075	6.292	0.276	**0.020**
	3	450.0	19.565	40.0	1.996	3.0	0.062	118.0	3.329	5.878	0.600	**0.019**
J7-1-3	1	146.0	6.348	21.0	1.048	3.0	0.062	59.0	1.664	3.814	0.630	**0.038**
	2	118.0	5.130	31.0	1.547	3.0	0.062	68.0	1.918	2.675	0.806	**0.033**
	3	122.0	5.304	28.0	1.397	3.0	0.062	57.0	1.608	3.299	0.869	**0.039**
J7-1-4	1	355.0	15.435	17.0	0.848	3.0	0.062	382.0	10.776	1.432	0.079	**0.006**
	2	267.0	11.609	19.0	0.948	3.0	0.062	279.0	7.870	1.475	0.120	**0.008**
	3	260.0	11.304	18.0	0.898	3.0	0.062	301.0	8.491	1.331	0.106	**0.007**
J7-2	1	690.0	30.000	12.0	0.599	3.0	0.062	820.0	23.131	1.297	**0.026**	**0.003**
	2	695.0	30.217	26.0	1.297	3.0	0.062	871.0	24.570	1.230	0.053	**0.003**
	3	650.0	28.261	22.0	1.098	3.0	0.062	887.0	25.021	1.129	0.044	**0.002**
J8-1	1	4760.0	206.957	173.0	8.633	4.0	0.083	7868.0	221.946	0.932	0.039	**0.000**
	2	3600.0	156.522	156.0	7.784	3.0	0.062	5871.0	165.614	0.945	0.047	**0.000**
	3	3650.0	158.696	135.0	6.737	3.0	0.062	6649.0	187.560	**0.846**	**0.036**	**0.000**
J8-2	1	2490.0	108.261	175.0	8.733	3.0	0.062	4819.0	135.938	**0.796**	0.064	**0.000**
	2	1970.0	85.652	186.0	9.281	3.0	0.062	4055.0	114.386	**0.749**	0.081	**0.001**
	3	2180.0	94.783	166.0	8.283	3.0	0.062	4630.0	130.606	**0.726**	0.063	**0.000**
J9-1	1	1920.0	83.478	42.0	2.096	3.0	0.062	2655.0	74.894	1.115	**0.028**	**0.001**
	2	1680.0	73.043	40.0	1.996	3.0	0.062	2338.0	65.952	1.108	**0.030**	**0.001**
	3	1760.0	76.522	36.0	1.796	3.0	0.062	2857.0	80.592	0.949	**0.022**	**0.001**
J9-2	1	1810.0	78.696	83.0	4.142	3.0	0.062	3246.0	91.566	0.859	0.045	**0.001**
	2	1430.0	62.174	94.0	4.691	3.0	0.062	2687.0	75.797	**0.820**	0.062	**0.001**
	3	2210.0	96.087	82.0	4.092	3.0	0.062	3029.0	85.444	1.125	0.048	**0.001**
J10-1-1	1	3.5	0.152	5.2	0.259	3.0	0.062	3.0	0.085	1.798	3.066	0.738
	2	1.8	0.078	2.7	0.135	3.0	0.062	2.0	0.056	1.387	2.388	1.107
	3	3.0	0.130	1.4	0.070	3.0	0.062	4.0	0.113	1.156	0.619	0.554
J10-1-2	1	22.0	0.957	3.4	0.170	3.0	0.062	20.0	0.564	1.695	0.301	0.111
	2	17.0	0.739	3.6	0.180	3.0	0.062	16.0	0.451	1.638	0.398	0.138
	3	24.0	1.043	3.1	0.155	3.0	0.062	22.0	0.621	1.681	0.249	**0.101**
Average										2.559	0.550	0.367
S1	1	14.0	0.609	100.0	4.990	215.0	4.476	33.0	0.931	**0.654**	5.360	4.809
	2	17.0	0.739	82.0	4.092	212.0	4.414	28.0	0.790	0.936	5.181	5.588
	3	11.0	0.478	81.0	4.042	233.0	4.851	25.0	0.705	**0.678**	5.731	6.879
S2	1	1.8	0.078	1.7	0.085	16.0	0.333	2.0	0.056	1.387	1.504	5.905
	2	4.5	0.196	1.5	0.075	10.0	0.208	3.0	0.085	2.312	0.884	2.460
	3	1.7	0.074	2.3	0.115	17.0	0.354	3.0	0.085	0.873	1.356	4.182
S3	1	1.3	0.057	2.3	0.115	3.0	0.062	1.0	0.028	2.004	4.069	2.214
	2	1.3	0.057	13.0	0.649	3.0	0.062	6.0	0.169	**0.334**	3.833	0.369
	3	2.4	0.104	2.6	0.130	3.0	0.062	10.0	0.282	**0.370**	0.460	0.221

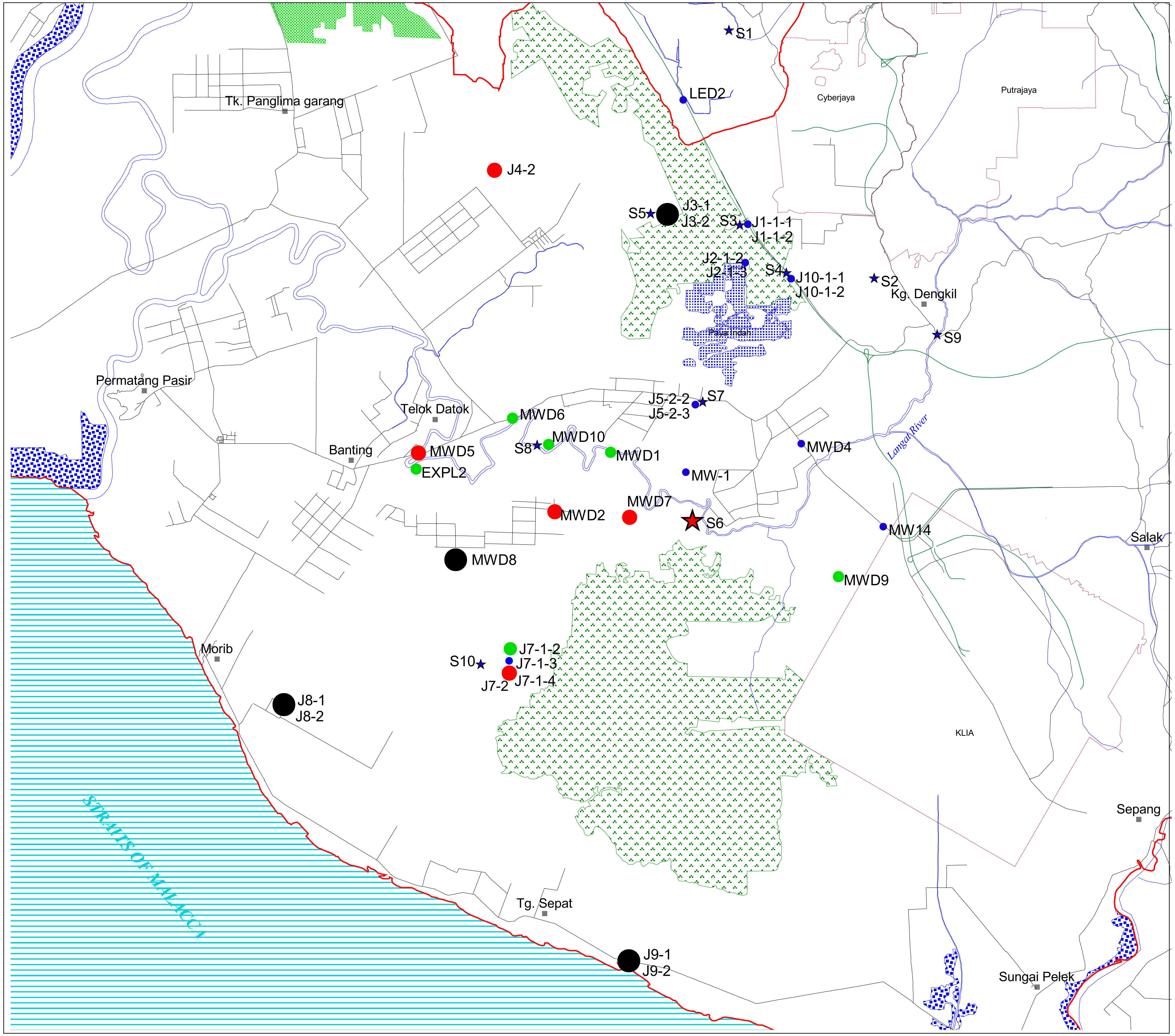
Table E.3.5 Major Ion Ratios in Groundwater and Surface Water (cont'd)

Point Name	No. *1	Na^+		Ca^{2+}		SO_4^{2-}		Cl^-		Na/Cl*2	Ca/Cl*2	SO_4/Cl*2
		(mg/l)	(meq/l)	(mg/l)	(meq/l)	(mg/l)	(meq/l)	(mg/l)	(meq/l)			
S4	1	1.2	0.052	2.6	0.130	3.0	0.062	4.0	0.113	**0.462**	1.150	0.554
	2	1.1	0.048	4.3	0.215	3.0	0.062	20.0	0.564	**0.085**	0.380	0.111
	3	1.5	0.065	1.9	0.095	3.0	0.062	7.0	0.197	**0.330**	0.480	0.316
S5	1	3.3	0.143	2.6	0.130	3.0	0.062	12.0	0.339	**0.424**	0.383	0.185
	2	14.0	0.609	96.0	4.790	244.0	5.080	34.0	0.959	**0.635**	4.995	5.297
	3	5.2	0.226	1.3	0.065	3.0	0.062	13.0	0.367	**0.617**	0.177	0.170
S6	1	157.0	6.826	16.0	0.798	163.0	3.394	163.0	4.598	1.485	0.174	0.738
	2	132.0	5.739	14.0	0.699	43.0	0.895	168.0	4.739	1.211	0.147	0.189
	3	285.0	12.391	23.0	1.148	98.0	2.040	508.0	14.330	0.865	0.080	0.142
S7	1	3.0	0.130	3.4	0.170	33.0	0.687	6.0	0.169	**0.771**	1.002	4.059
	2	13.0	0.565	4.8	0.240	48.0	0.999	6.0	0.169	3.339	1.415	5.905
	3	6.2	0.270	4.1	0.205	48.0	0.999	6.0	0.169	1.593	1.209	5.905
S8	1	3.3	0.143	6.9	0.344	22.0	0.458	8.0	0.226	**0.636**	1.526	2.030
	2	14.0	0.609	9.9	0.494	22.0	0.458	20.0	0.564	1.079	0.876	0.812
	3	9.5	0.413	8.1	0.404	19.0	0.396	12.0	0.339	1.220	1.194	1.169
S9	1	3.3	0.143	6.1	0.304	8.0	0.167	4.0	0.113	1.272	2.698	1.476
	2	5.2	0.226	5.6	0.279	8.0	0.167	5.0	0.141	1.603	1.981	1.181
	3	11.0	0.478	13.0	0.649	14.0	0.291	15.0	0.423	1.130	1.533	0.689
S10	1	7.9	0.343	6.9	0.344	3.0	0.062	12.0	0.339	1.015	1.017	0.185
	2	8.5	0.370	6.5	0.324	4.0	0.083	24.0	0.677	**0.546**	0.479	0.123
	3	7.8	0.339	1.3	0.065	3.0	0.062	18.0	0.508	**0.668**	0.128	0.123
Average										1.018	1.713	2.133

Note: *1"No." means time of measurement.
*2These ratios are calculated in milliequivaients per litre (meq/l).

Figure E.3.17

Averaged Chloride Values in the Water Quality Measurement



Chloride Values (mg/l)

Groundwater	Surface water
>1,000	>1,000
250 - 1,000	250 - 1,000
100 - 250	100 - 250
<100	<100

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

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

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

CTI Engineering International Co., Ltd.

OYO CORPORATION

(d) Total Iron (Fe-T)

All total iron values except for nine (9) samples out of 109 exceed the standard iron value, i.e., 0.3 mg/l. Iron is a common constituent of many primary minerals, such as biotite, pyroxenes and amphiboles.[4)] It is assumed that the 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.[21)] A total of 25 points out of 30, 83% of the total, show that the total iron values in the second measurement indicate larger levels than that of the first one. While observed values are fluctuated among the three measurements, S1 and S6 that are situated in active mines have relatively low concentration of iron.

Table E.3.6 Total Iron Measured in Groundwater and Surface Water

Point Name	Location	Total Iron (mg/l)		
		First	Second	Third
MWD1	Jambatan Batu, Jln. Ke Sg. Kelambu	5.71	6.23	0.97
MWD2	Jln. Dahilia, Sg. Kelambu	-	1.83	1.52
MWD4	Mutiara Telekom, Jln ke Salak Tinggi-KLIA	0.97	9.45	1.47
MWD5	Pintu Air, Sg. Lang, detak pekan Banting	-	1.35	8.30
MWD6	Kg. Sg. Manggis, Telok Datok	1.42	2.23	1.23
MWD7	Kg. Sg. Kelambu	-	2.17	1.24
MWD8	Jl. Idaman, Sg. Lang Tengah	-	1.73	2.13
MWD9	FELCRA, Bt. Changgang	1.02	1.87	-
MWD10	Kajibumi WF1	-	3.17	0.87
LED2	Express Highway KLIA-Subang-Nilai	-	8.75	8.95
MW1	Magasteel	-	3.30	12.15
J1-1-1	South of Bt. Baja	0.72	13.65	12.25
J1-1-2	-ditto-	1.02	10.30	10.85
J2-1-2	Paya Indah	-	2.91	2.43
J2-1-3	-ditto-	-	2.91	1.60
J3-1	Northwest of Paya Indah	0.67	1.39	0.92
J3-2	-ditto-	0.91	1.35	**0.06**
J4-2	Kg. Jenjarom	-	1.85	**0.00**
J5-2-2	Kajibumi WF2	2.94	2.81	3.85
J5-2-3	-ditto-	3.01	1.73	2.22
J7-1-2	Kanchong Darat	0.69	8.65	7.70
J7-1-3	-ditto-	0.82	7.30	10.10
J7-1-4	-ditto-	1.02	7.86	10.15
J7-2	-ditto-	1.89	13.90	7.90
J8-1	Kg. Endah	1.98	0.90	0.67
J8-2	-ditto-	2.64	6.15	1.39

Table E.3.6 Total Iron Measured in Groundwater and Surface Water (cont'd)

Point Name	Location	Total Iron (mg/l)		
		First	Second	Third
J9-1	Ladang Tumbuk	1.61	7.25	2.28
J9-2	-ditto-	1.68	6.75	1.62
J10-1-1	East of Paya Indah	0.82	1.28	9.10
J10-1-2	-ditto-	1.46	11.30	8.75
S1	**Puchong Mine**	0.62	**0.19**	**0.09**
S2	Dengkil Mine	1.62	2.01	**0.12**
S3	Paya Indah Inflow (SW1)	1.52	2.11	2.68
S4	Paya Indah Inflow (SW2)	1.78	2.34	1.83
S5	Bt. Cheeding	0.81	3.27	1.57
S6	**Sand Mine**	**0.04**	**0.03**	0.49
S7	Kajibumi WF2	1.30	1.65	**0.25**
S8	Langat River (Kajibumi WF1)	1.17	2.35	4.75
S9	Langat River (Dengkil)	1.21	1.72	**0.13**
S10	Kanchong Darat	2.36	7.80	0.72

(e) Major 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 (hereinafter referred to as "the Standards") 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 (see **Tables E.3.7 and E.3.8**, and **Figure E.3.20**).

Well MWD10, one of the JMG monitoring wells, 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. Sources of lead contamination to the environment include fairly localised impacts, such as disposal of lead-acid batteries, lead-based paint wastes in landfills and tailings from the processing of Pb minerals. More widespread occurrences of lead contamination have been associated with aerosols from leaded gasoline and smelters and use of insecticide.[5)] The results show that lead contamination has not yet prevailed in the Langat Basin.

Regarding mercury, concentrations of 12 wells (38% of a total of 32 wells) exceed the Standards of 0.001 mg/l. The mercury values were generally high in the Basin. It is reported that slime in ponds at abandoned mines in the Kinta Valley, Perak, indicates higher concentrations of heavy metals such as mercury and cadmium.[22)] It was also discussed that high arsenic content in the soil could result from the breakdown of pyrites and arsenopyrites in soil.[23] It is another possibility that detection of mercury, lead and zinc, on the other hand, may be related to fertiliser inputs.[24]

There are seven (7) 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 east of Paya Indah. These areas where arsenic was detected over the standards were used for agricultural purpose 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.[6] Arsenic was widely detected in the study area while some were under the limit for drinking water.

Figure E.3.18 shows that shallower wells indicate higher arsenic concentrations than that of deeper ones at the same location in six (6) wells out of eight (8). Correlation between screen depth and arsenic concentrations is shown in **Figure E.3.19**. Although it is not clearly figured out, the screen depth of well is deeper and the higher concentrations could come out. 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.

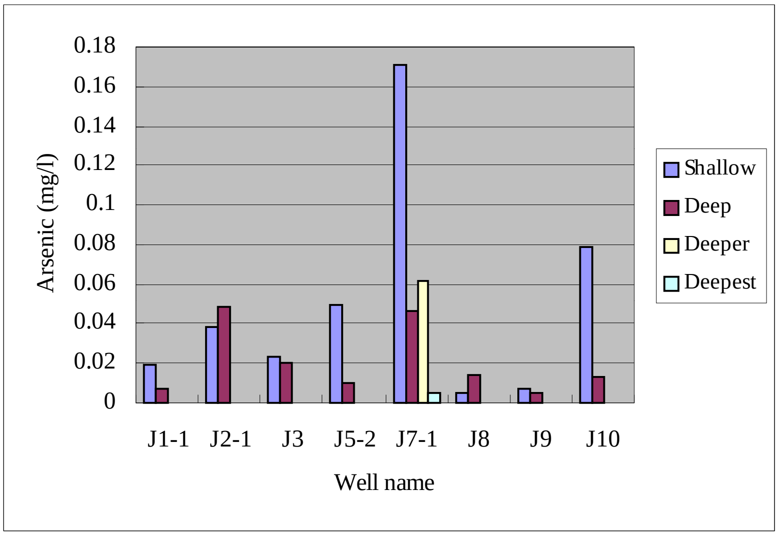


Figure E.3.18 Arsenic Concentrations by Well Depth

Samples from seven (7) wells contain excess of chromium concentration. It could be assumed that industrial activities including their waste disposal affects this condition while the chromium content is likely to be related to the Oxisols and Ultisols, which are the dominant soil in Peninsular Malaysia.[24], [25]

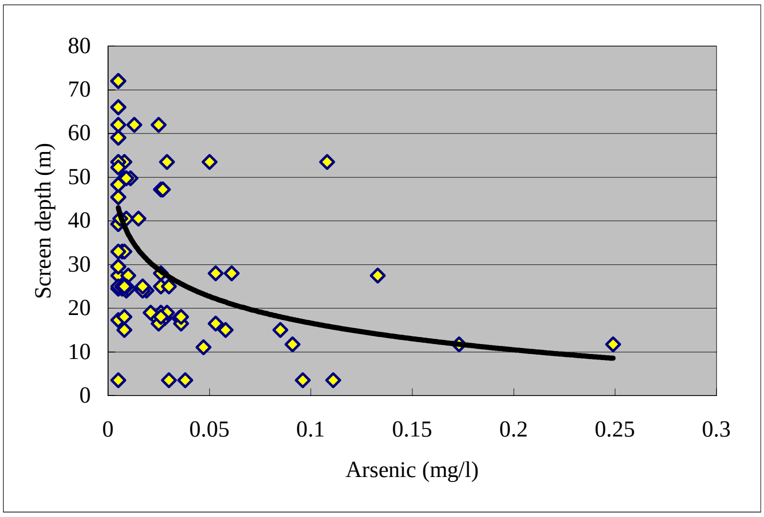


Figure E.3.19 Correlation between Screen Depth and Arsenic Concentrations in the Monitoring Wells

Table E.3.7 Major Heavy Metals Measured in Groundwater and Surface Water (1)

Point Name	Mercury (Hg)			Arsenic (As)			Lead (Pb)		
	First	Second	Third	First	Second	Third	First	Second	Third
MWD1	-	**0.0023**	0.0007	0.026	0.027	0.027	<0.01	0.01	<0.01
MWD2	-	0.0009	0.0005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01
MWD4	-	0.0009	0.0005	0.019	0.009	0.017	<0.01	<0.01	<0.01
MWD5	-	**0.0017**	**0.0020**	-	<0.005	<0.005	-	<0.01	<0.01
MWD6	-	0.0003	0.0004	0.008	0.011	0.009	<0.01	<0.01	<0.01
MWD7	-	0.0007	0.0005	-	<0.005	<0.005	-	<0.01	<0.01
MWD8	-	**0.0016**	0.0005	-	<0.005	<0.005	-	<0.01	<0.01
MWD9	-	0.0010	0.0006	0.028	0.024	0.035	<0.01	<0.01	<0.01
MWD10	-	0.0010	0.0005	0.008	<0.005	<0.005	**0.08**	0.03	0.02
MW14	-	-	-	0.047	-	-	<0.01	-	-
LED2	-	-	0.0005	-	-	<0.005	-	-	<0.01
EXPL2	-	-	-	<0.005	-	-	<0.01	-	-
MW1	-	0.0005	0.0005	0.026	0.021	0.029	<0.01	<0.01	<0.01
J1-1-1	**0.0022**	-	0.0006	0.038	-	<0.005	<0.01	-	<0.01
J1-1-2	0.0002	0.0008	0.0005	0.007	<0.005	0.010	<0.01	<0.01	<0.01
J2-1-2	-	<0.0002	0.0006	0.025	0.036	**0.053**	<0.01	<0.01	<0.01
J2-1-3	-	0.0005	0.0008	<0.005	0.01	**0.133**	<0.01	<0.01	<0.01
J3-1	-	**0.0028**	-	0.026	0.036	0.008	<0.01	<0.01	<0.01
J3-2	-	**0.0015**	-	0.005	0.026	0.030	<0.01	<0.01	<0.01
J4-2	-	0.0006	0.0005	0.007	0.009	0.009	<0.01	<0.01	<0.01
J5-2-2	-	0.0004	-	**0.058**	0.008	**0.085**	<0.01	<0.01	<0.01
J5-2-3	-	**0.0012**	-	0.009	0.006	0.015	<0.01	<0.01	<0.01

Table E.3.7 Major Heavy Metals Measured in Groundwater and Surface Water (1) (cont'd)

Point Name	Mercury (Hg)			Arsenic (As)			Lead (Pb)		
	First	Second	Third	First	Second	Third	First	Second	Third
J7-1-2	<0.0002	0.0004	0.0005	**0.091**	**0.249**	**0.173**	<0.01	<0.01	<0.01
J7-1-3	-	**0.0013**	0.0005	0.026	**0.053**	**0.061**	<0.01	<0.01	<0.01
J7-1-4	-	**0.0023**	0.0007	0.029	0.050	**0.108**	<0.01	<0.01	<0.01
J7-2	-	**0.0016**	0.0007	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01
J8-1	-	<0.0002	0.0007	0.005	<0.005	<0.005	<0.01	<0.01	<0.01
J8-2	-	0.0002	0.0008	<0.005	0.013	0.025	<0.01	<0.01	<0.01
J9-1	-	<0.0002	0.0004	0.007	0.008	<0.005	<0.01	<0.01	<0.01
J9-2	-	**0.0012**	0.0005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01
J10-1-1	0.0009	**0.0013**	0.0009	0.030	**0.111**	**0.096**	<0.01	<0.01	<0.01
J10-1-2	-	<0.0002	0.0007	0.017	0.008	-	<0.01	<0.01	<0.01
S1	-	0.0004	**0.0017**	0.018	0.018	<0.005	<0.01	<0.01	<0.01
S2	-	0.0002	0.0008	<0.005	<0.005	<0.005	<0.01	<0.01	0.02
S3	-	**0.0015**	**0.0012**	<0.005	<0.005	<0.005	<0.01	<0.01	0.02
S4	0.0008	0.0009	0.0007	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01
S5	0.0004	0.0004	0.0006	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01
S6	-	**0.0022**	0.0005	<0.005	0.010	<0.005	0.01	<0.01	<0.01
S7	0.0004	<0.0002	0.0005	<0.005	<0.005	<0.005	<0.01	<0.01	<0.01
S8	**0.0011**	**0.0016**	0.0005	0.008	0.010	0.009	0.01	<0.01	0.02
S9	-	0.0007	0.0005	0.007	0.014	0.020	0.01	<0.01	<0.01
S10	-	0.0002	0.0005	0.006	<0.005	<0.005	0.02	<0.01	<0.01

Note: Concentration of each metal is written in milligram per litre (mg/l).

Table E.3.8 Major Heavy Metals Measured in Groundwater and Surface Water (2)

Point Name	Chromium (Cr)			Copper (Cu)			Zinc (Zn)		
	First	Second	Third	First	Second	Third	First	Second	Third
MWD1	-	<0.01	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MWD2	-	<0.01	<0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MWD4	-	0.02	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MWD5	-	**0.07**	0.02	-	<0.1	<0.1	-	<0.1	<0.1
MWD6	-	0.01	0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MWD7	-	0.02	0.02	-	<0.1	<0.1	-	<0.1	<0.1
MWD8	-	0.01	0.03	-	<0.1	<0.1	-	<0.1	<0.1
MWD9	-	0.01	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MWD10	-	0.02	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
MW14	-	-	-	<0.1	<0.1	-	0.1	-	-
LED2	-	-	0.11	-	-	<0.1	-	-	0.1
EXPL2	-	-	-	<0.1	-	-	0.2	-	-
MW1	-	<0.01	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

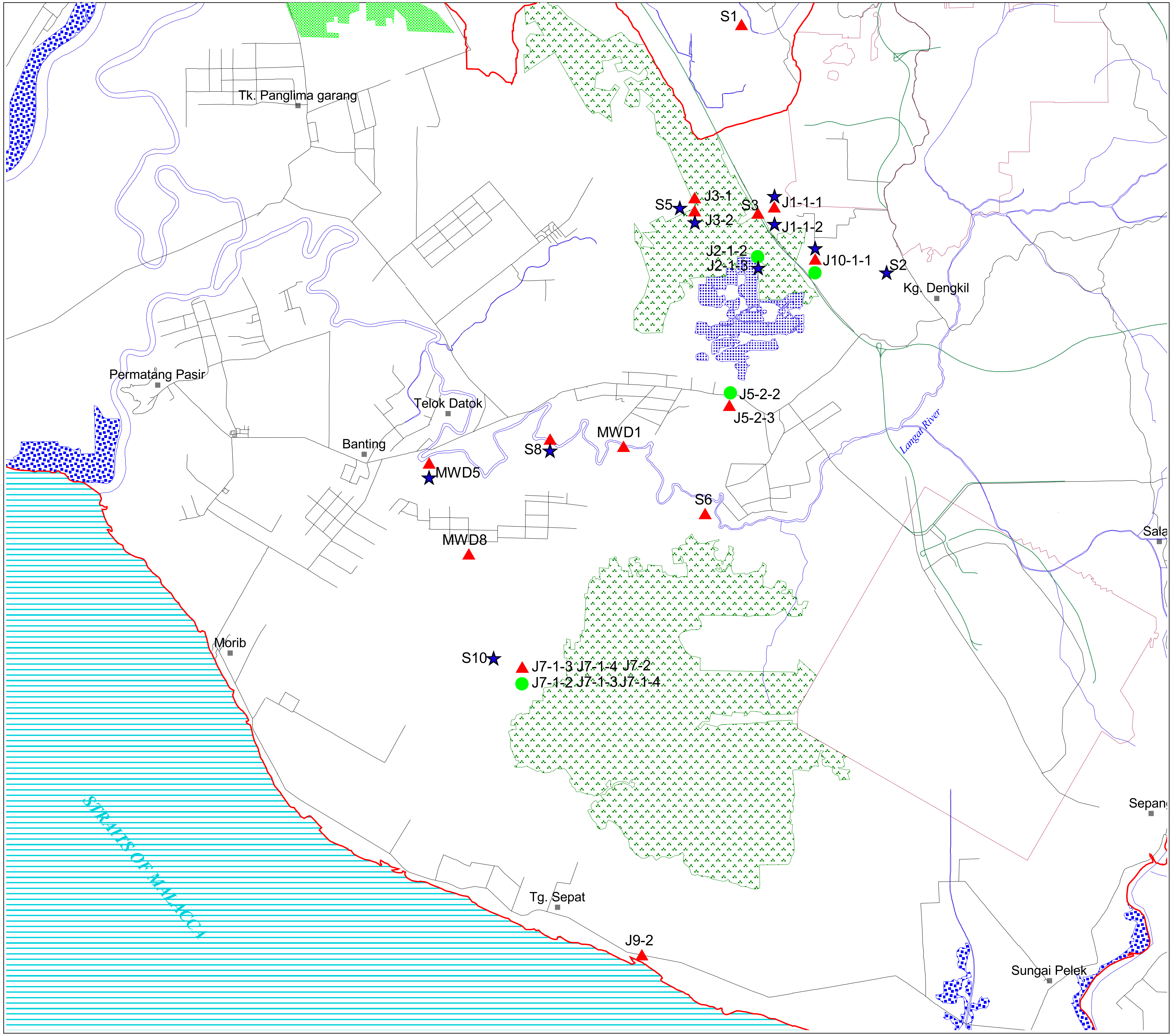
Table E.3.8 Major Heavy Metals Measured in Groundwater and Surface Water (2) (cont'd)

Point Name	Chromium (Cr)			Copper (Cu)			Zinc (Zn)		
	First	Second	Third	First	Second	Third	First	Second	Third
J1-1-1	-	-	**0.07**	<0.1	-	<0.1	0.4	-	<0.1
J1-1-2	-	**0.06**	**0.06**	<0.1	<0.1	<0.1	0.4	<0.1	<0.1
J2-1-2	-	**0.09**	**0.08**	<0.1	<0.1	<0.1	0.1	<0.1	<0.1
J2-1-3	-	0.05	**0.17**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J3-1	-	0.03	0.04	<0.1	<0.1	<0.1	0.4	0.2	<0.1
J3-2	-	0.03	**0.15**	<0.1	<0.1	<0.1	<0.1	<0.1	0.2
J4-2	-	0.01	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J5-2-2	-	<0.01	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J5-2-3	-	<0.01	0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J7-1-2	-	0.04	0.04	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J7-1-3	-	0.01	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J7-1-4	-	<0.01	0.01	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J7-2	-	0.02	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J8-1	-	0.02	0.03	<0.1	<0.1	<0.1	0.2	<0.1	<0.1
J8-2	-	0.02	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J9-1	-	0.02	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J9-2	-	0.02	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
J10-1-1	-	**0.10**	**0.10**	<0.1	<0.1	<0.1	0.1	0.1	<0.1
J10-1-2	-	0.02	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S1	-	0.02	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S2	-	0.04	**0.06**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S3	-	<0.01	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S4	-	0.01	0.02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S5	-	<0.01	**0.08**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S6	-	0.01	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S7	-	0.02	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S8	-	**0.06**	**0.06**	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S9	-	0.03	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
S10	-	**0.06**	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

Note: Concentration of each metal is written in milligram per litre (mg/l).

Figure E.3.20

Observed Major Heavy Metals Exceeding the Drinking Water Quality Standards in the Water Quality Measurement



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(f) Organic Compounds

Detected organic compounds are listed in **Table E.3.9**. Only four (4) wells, namely J7-1-2, J7-1-3, J8-2 and J9-1, gave five kinds of compounds. Because of their toxicity, carcinogenicity and the effects of reactions 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.[17] Trimethylbenzene is mainly applied for solvents.[19] Napthalene and methylnapthalene are also used for insecticides.[18), 20] More additional observation, at any rate, is necessary since these compounds were detected only once except that a sample from J9-1 contained 2-methylnapthalene in the second and third measurement.

No detection of chlorinated solvents that primarily consist of the aliphatic compounds tetrachloroethene, trichloroethene and 1,1,1-trichloroethene was made in both measurement. Continuous periodical observation of these compounds will be indispensable because a relatively small amount of a chlorinated solvent can impact very large quantities of groundwater and affect a wide area of an aquifer.[7]

Table E.3.9 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.

(g) Coliform Group Bacteria

Total coliform bacteria (coliform group bacteria) are composed of escherichia coli (e-coli) and other bacteria that have quite similar properties to e-coli. In ordinary water quality analysis, total coliform bacteria are subject for a biological parameter since it is very difficult to identify and detect each bacterium in water. Total coliform bacteria always live in the intestines of humans or animals in general. A quite small amount of the bacteria can be detected sensitively if water is contaminated by human waste. Only three (3) wells do not have any total coliform bacteria in the first and second measurement. These are J2-1-2, J2-1-3 and J10-1-1. **Table E.3.10** gives a result of measured coliform group bacteria.

There is much difference in numbers among the three or four measurements. The order of 200000 for coliform group bacteria normally indicates highly contaminated water, and it is rare for groundwater to show such a large amount. In this sense, the fourth sampling was additionally conducted in a different day to compare the result with the third ones; however, the readings in the fourth still had a large difference from the third ones. While high counts of bacteria contaminants often indicate existence of sources of sewage or animal waste pollution in the area of study, no indication of these sources in the area has been reported. It is thus still greatly doubtful whether the test results and biological testing methods are reliable.

Table E.3.10 Coliform Group Bacteria Measured in Groundwater and Surface Water

Point Name	Coliform Group Bacteria (cfu/100ml)			
	First	Second	Third	Fourth
MWD1	0	50	26000	50
MWD2	>200000	26	4300	10
MWD4	86000	>200000	0	-
MWD5	-	0	2200	-
MWD6	900	4600	>200000	-
MWD7	-	0	1100	-
MWD8	-	24	1000	-
MWD9	>200000	0	0	0
MWD10	5100	0	>200000	-
MW14*	>200000	-	-	-
LED2	74000	0	180000	-
LED3*	0	-	-	-
EXPL2*	0	-	-	-
MW1	>200000	1	110000	1

Table E.3.10 Coliform Group Bacteria Measured in Groundwater and Surface Water (cont 'd)

Point Name	Coliform Group Bacteria (cfu/100ml)			
	First	Second	Third	Fourth
J1-1-1	>200000	0	4000	-
J1-1-2	0	0	5700	-
J2-1-2	**0**	**0**	**0**	-
J2-1-3	**0**	**0**	**0**	**0**
J3-1	9900	0	190000	-
J3-2	4100	0	2500	-
J4-2	>200000	0	>200000	0
J5-2-2	>200000	0	1800	0
J5-2-3	>200000	10	1900	10
J7-1-2	>200000	34	20000	0
J7-1-3	>200000	2	62000	0
J7-1-4	>200000	32	57000	-
J7-2	>200000	2	54000	-
J8-1	>200000	0	2000	0
J8-2	36	0	0	0
J9-1	3200	0	2800	-
J9-2	1800	0	0	-
J10-1-1	**0**	**0**	**0**	-
J10-1-2	0	0	4700	-
S1	0	40	0	-
S2	4	0	370	-
S3	38000	45	180000	-
S4	200	120	0	-
S5	1700	600	43000	-
S6	2300	0	700	-
S7	2300	260	0	-
S8	2400	1600	8000	-
S9	9800	6000	50000	-
S10	1100	460	1000	-

Note: * These wells were observed in the first measurement only because these ones would not be used for long term monitoring.

(h) Water Classification

The major ion composition of groundwater is used to classify groundwater into various types based on the dominant cations and anions.[8)] For example, if calcium and biocarbonate are the dominant cation and anion, then the groundwater would be a $Ca(HCO_3)_2$ type. In this sense, there are five (5) types of water to be classified by the dominant ions, as follows:

- I : $Ca(HCO_3)_2$ type
- II : $NaHCO_3$ type
- II : $CaSO_4$ or $CaCl_2$ type
- IV : Na_2SO_4 or NaCl type
- V : Intermediate type

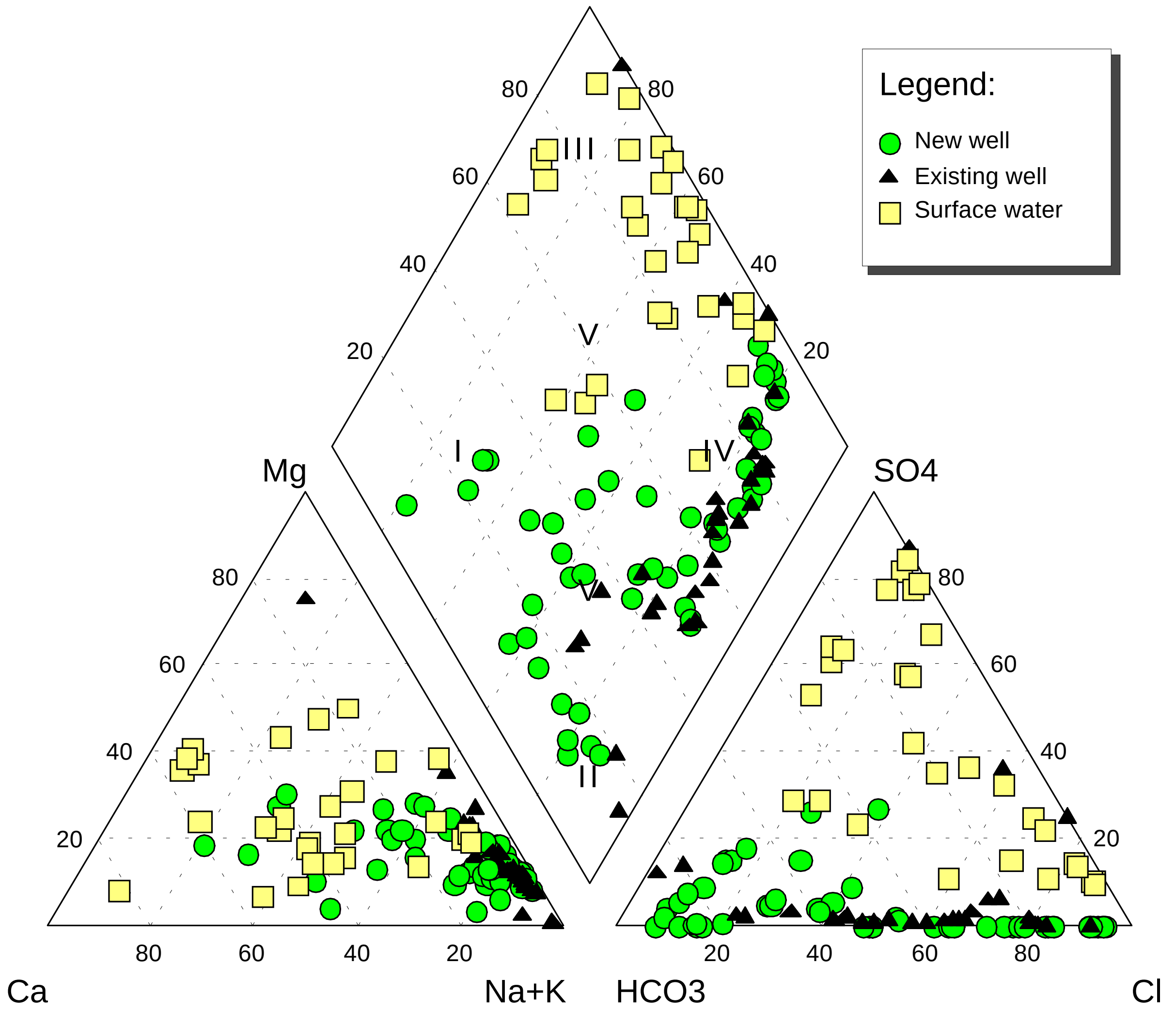
The composition of the dominant ions can be displayed graphically by several methods. **Figure E.3.21** shows a Piper diagram that is one of the more useful summary presentations. On this diagram the relative concentrations of the major ions in percent meq/l (milliequivaients per litre) are plotted on cation and anion triangles, and then the locations are projected to a point on a quadrilateral representing both cation and anions.

Based on the diagram, samples from groundwater and surface water in the study are classified into the types shown in **Table E.3.11**.

Table E.3.11 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	-

Water type based on the above classification is plotted on a study area map as presented in **Figure E.3.22**, and the Stiff diagrams, belonging to the group of pattern diagrams, of all the samples for each water type are illustrated in **Figures E.3.23 to E.3.35**. The Stiff diagrams show that the shape of each diagram in the same classification is just like the others. Thus, it is easier to evaluate the change in water quality at a single location over a period of time by the eyes.



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 E.3.21

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

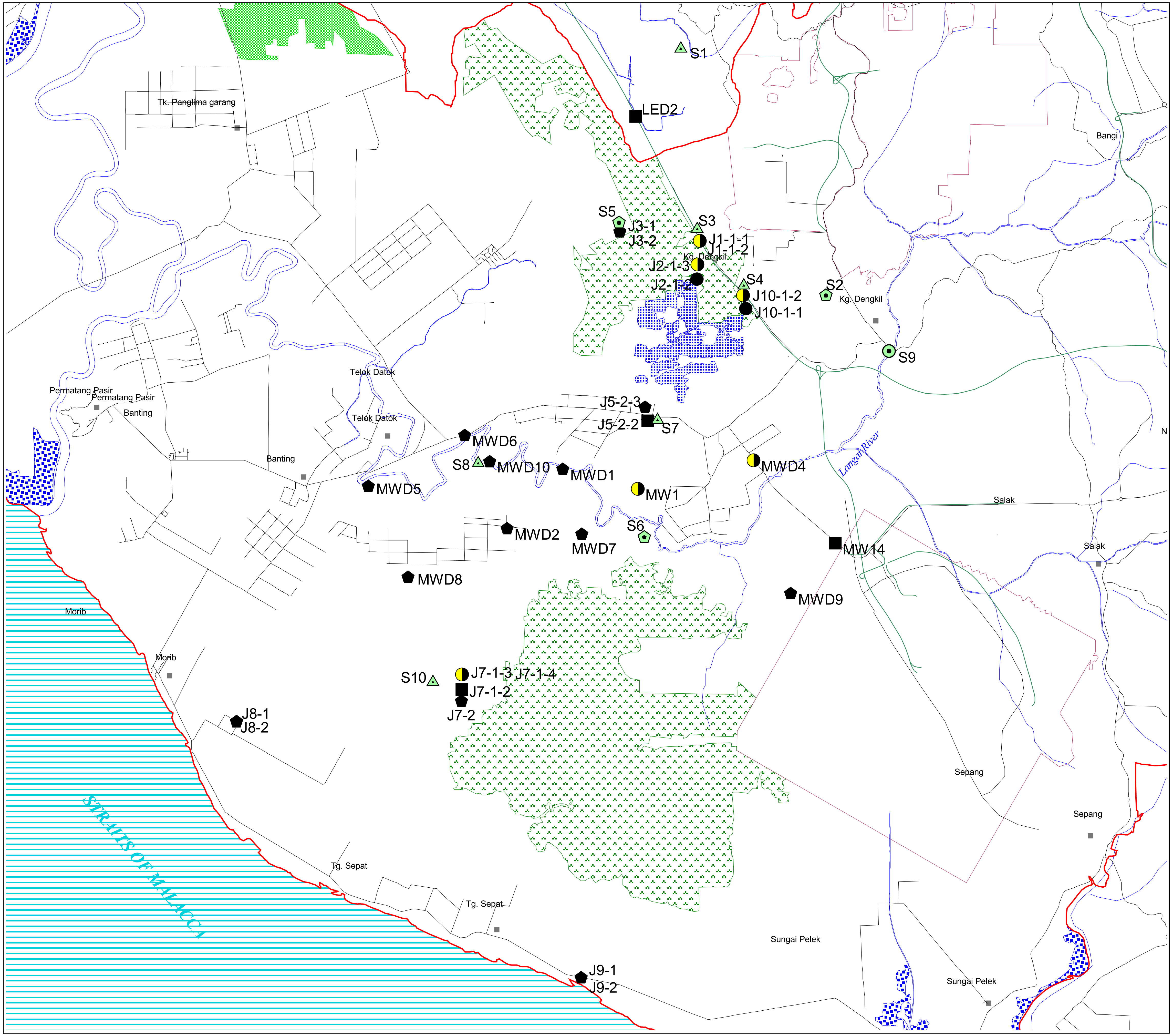

Figure E.3.22

Water Classification by Major Ions in Measured Groundwater and Surface Water

Water Classification (Type)

Groundwater	Surface water
$Ca(HCO_3)_2$	$Ca(HCO_3)_2$
$NaHCO_3$	$NaHCO_3$
$CaSO_4$ or $CaCL_2$	$CaSO_4$ or $CaCL_2$
Na_2SO_4 or NaCL	Na_2SO_4 or NaCL
Intermediate	Intermediate

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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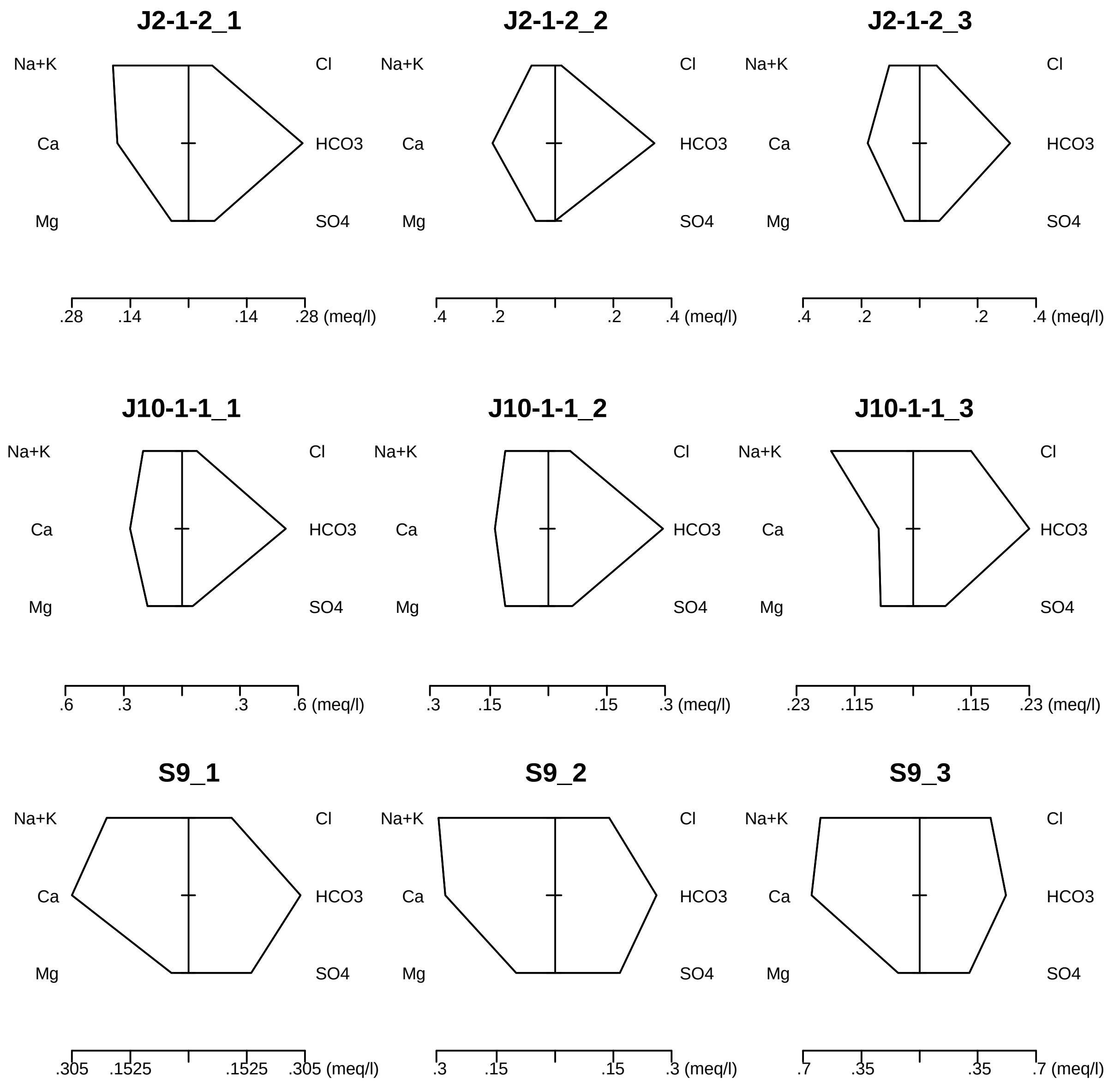

Type I: $Ca(HCO_3)_2$ – 2 wells & 1 surface water

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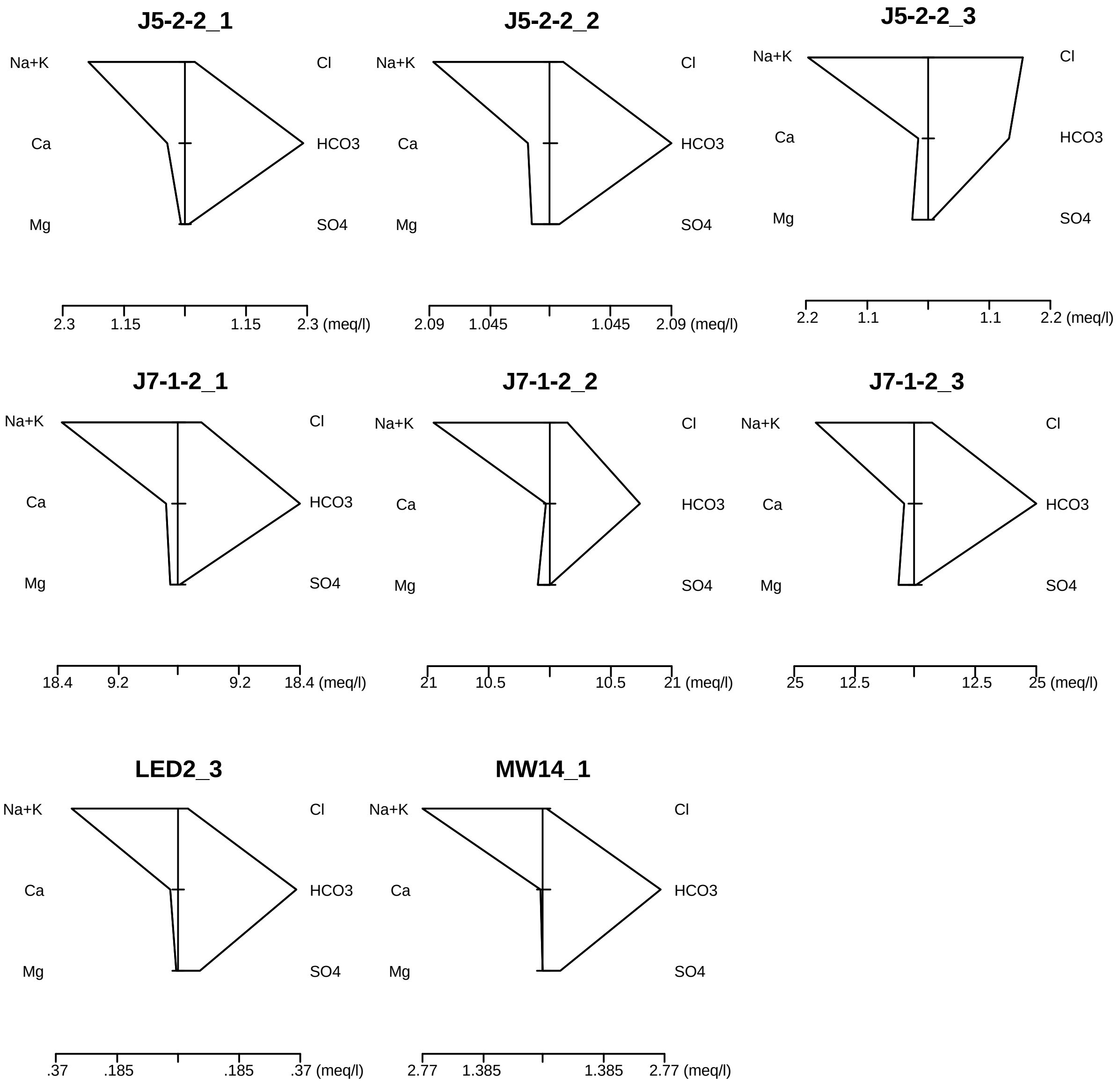
Figure E.3.23

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type I)



Type II: $NaHCO_3$ – 4 wells

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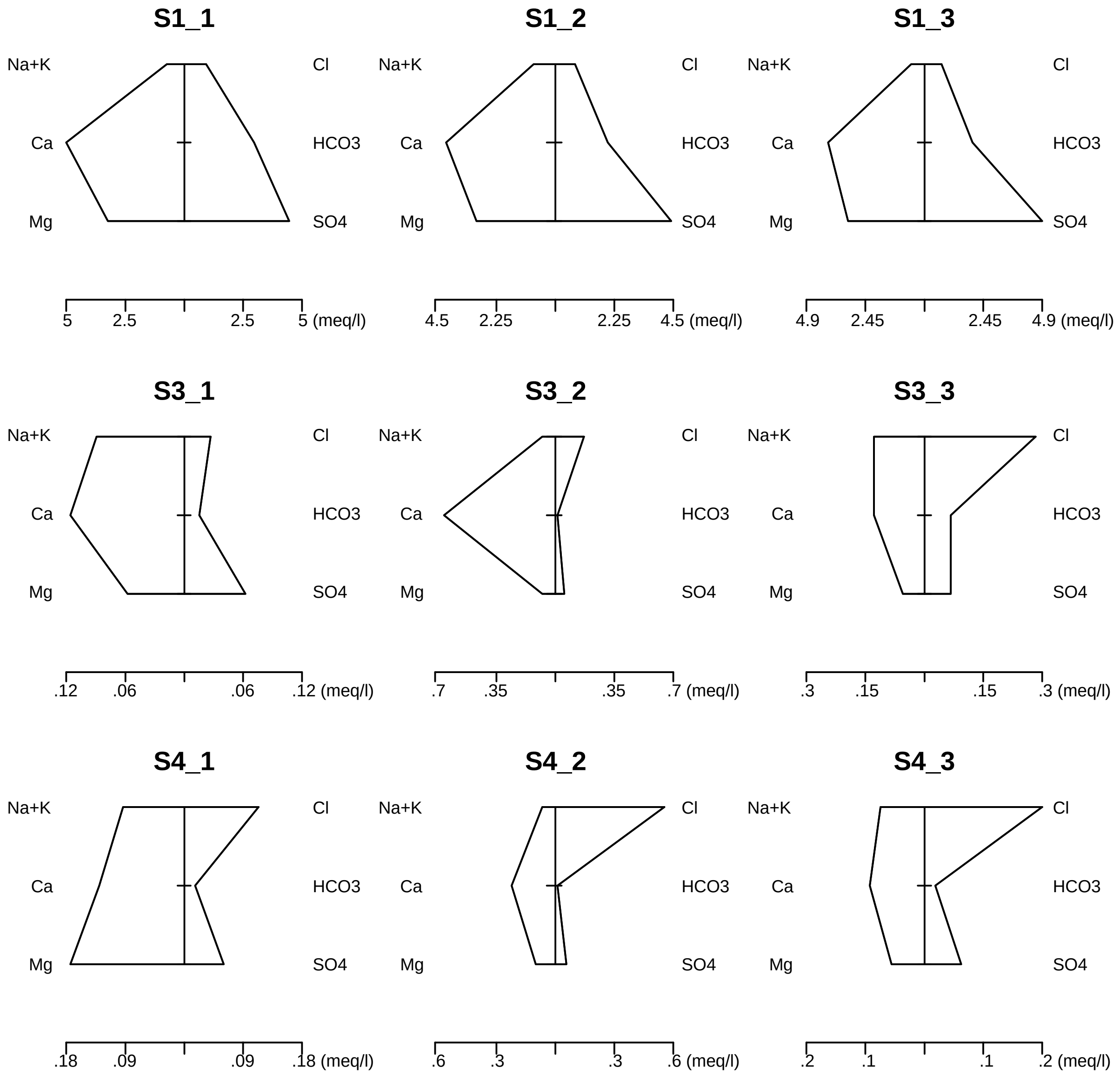
Figure E.3.24

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type II)



Type III: $CaSO_4$ or $CaCl_2$ – 6 surface waters

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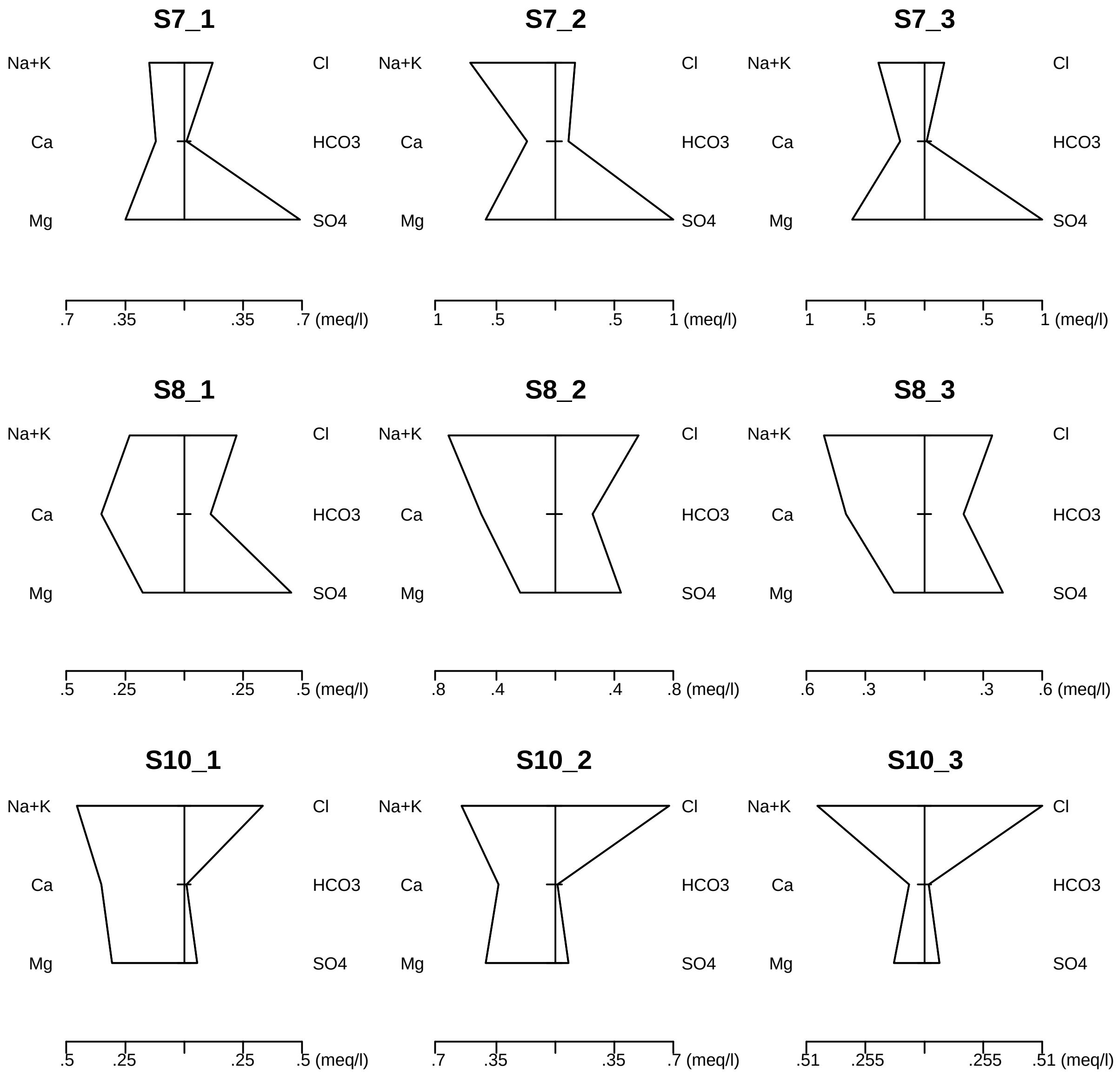
Figure E.3.25

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type III) (1/2)



Type III: $CaSO_4$ or $CaCl_2$ – 6 surface waters

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Figure E.3.26

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Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type III) (2/2)

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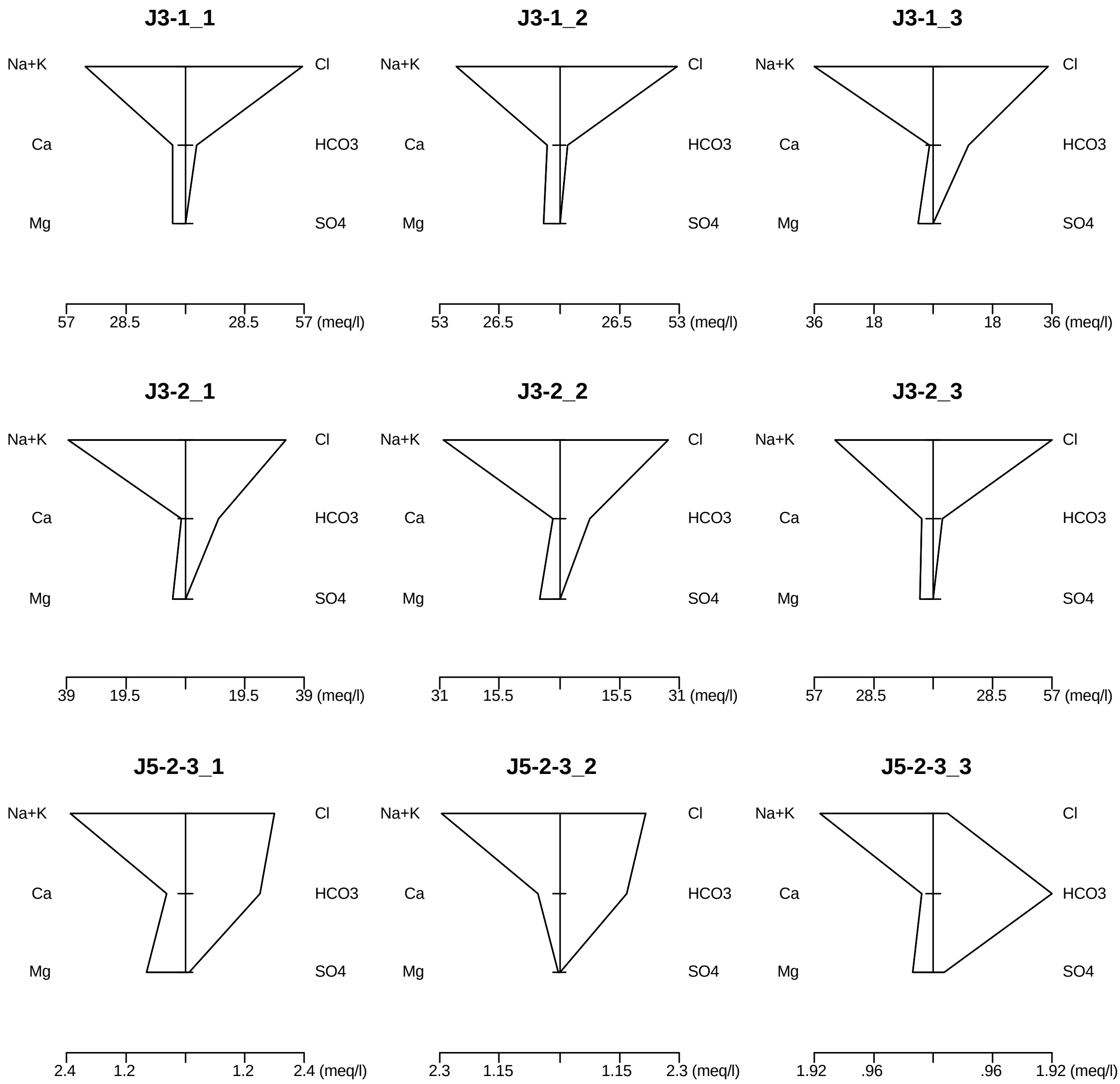

Type IV: Na_2SO_4 or NaCl – 16 wells & 3 surface waters

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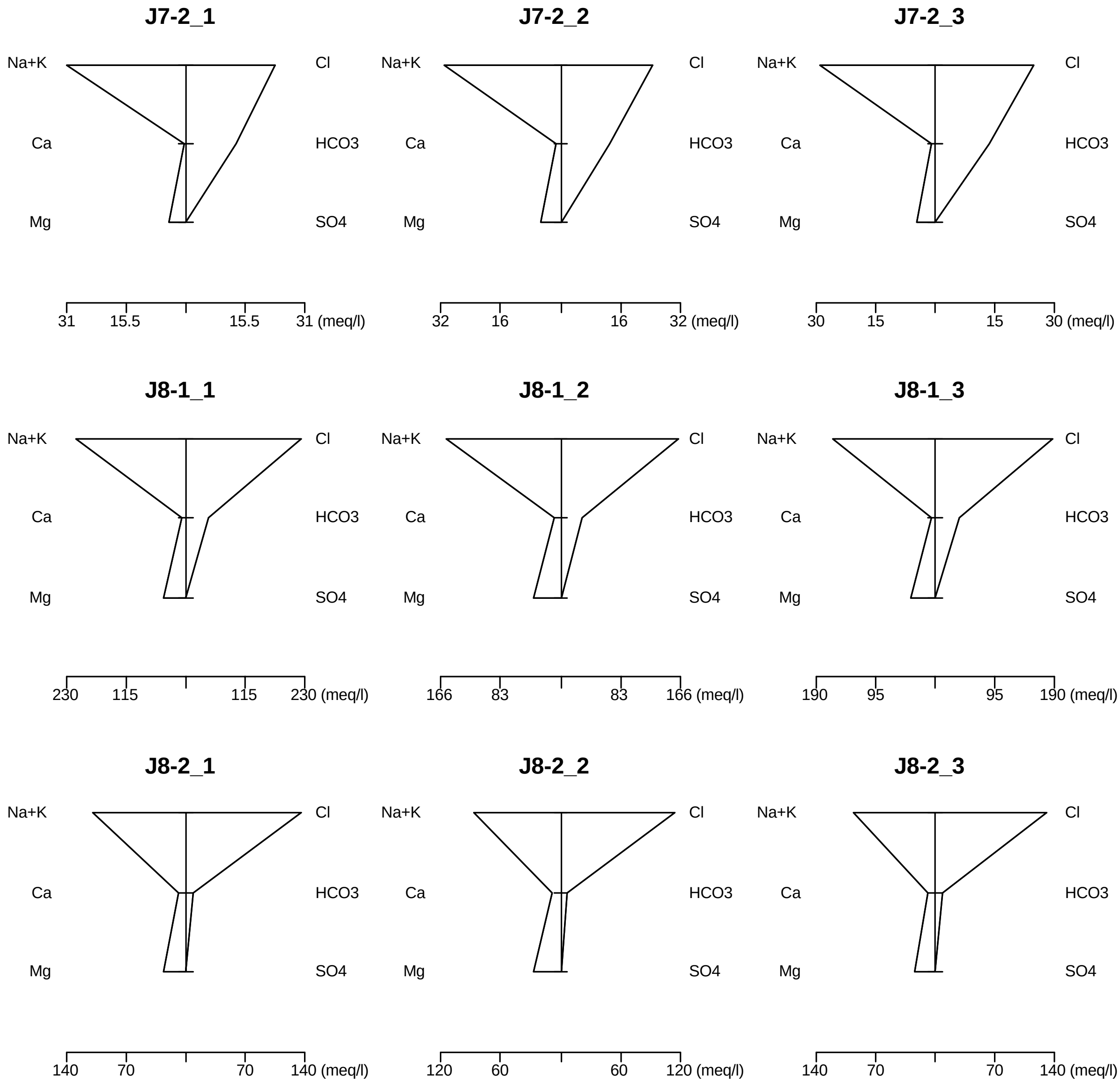
Figure E.3.27

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type IV) (1/6)



Type IV: Na_2SO_4 or NaCl – 16 wells & 3 surface waters

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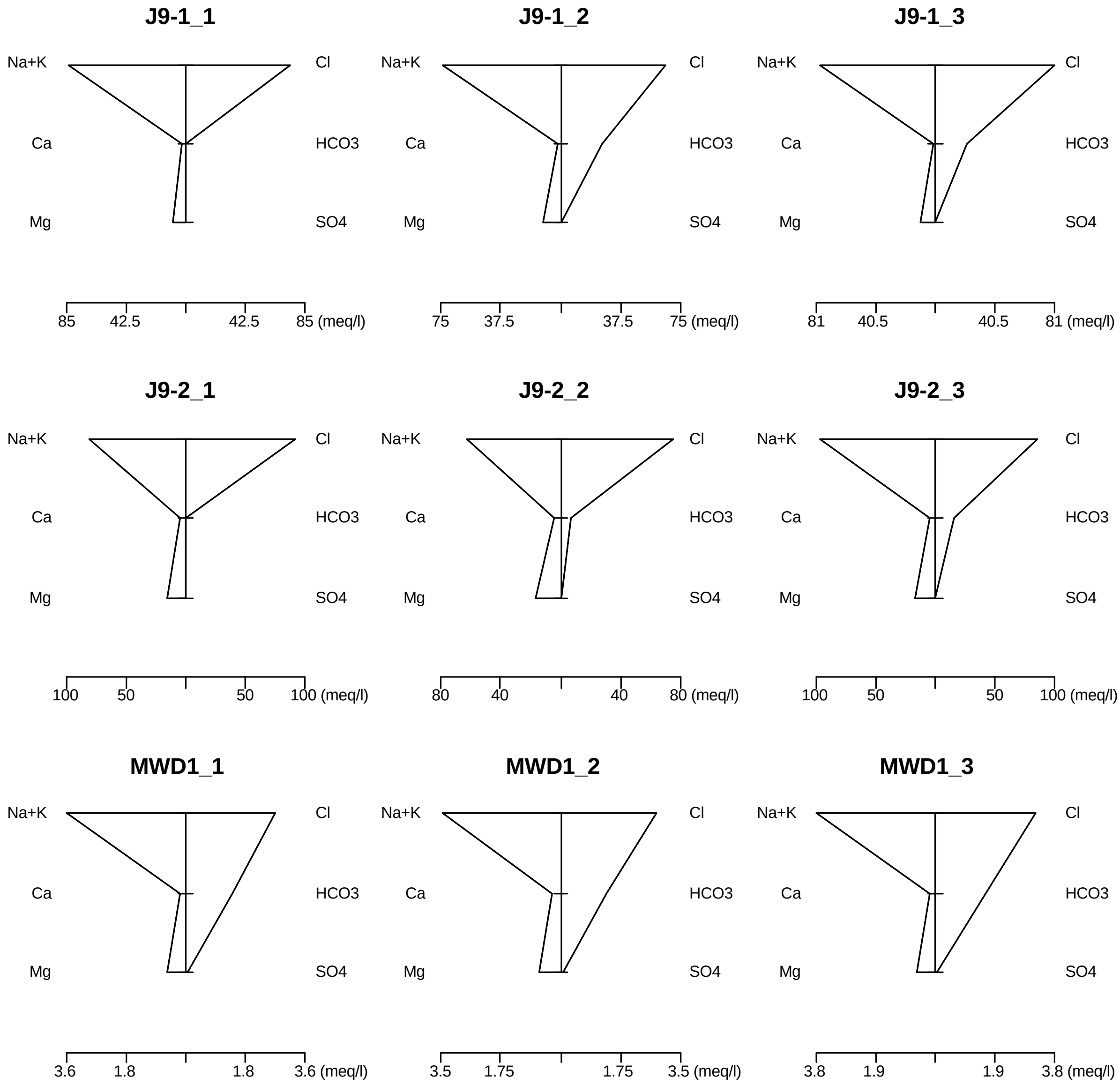
Figure E.3.28

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type IV) (2/6)



Type IV: Na_2SO_4 or NaCl – 16 wells & 3 surface waters

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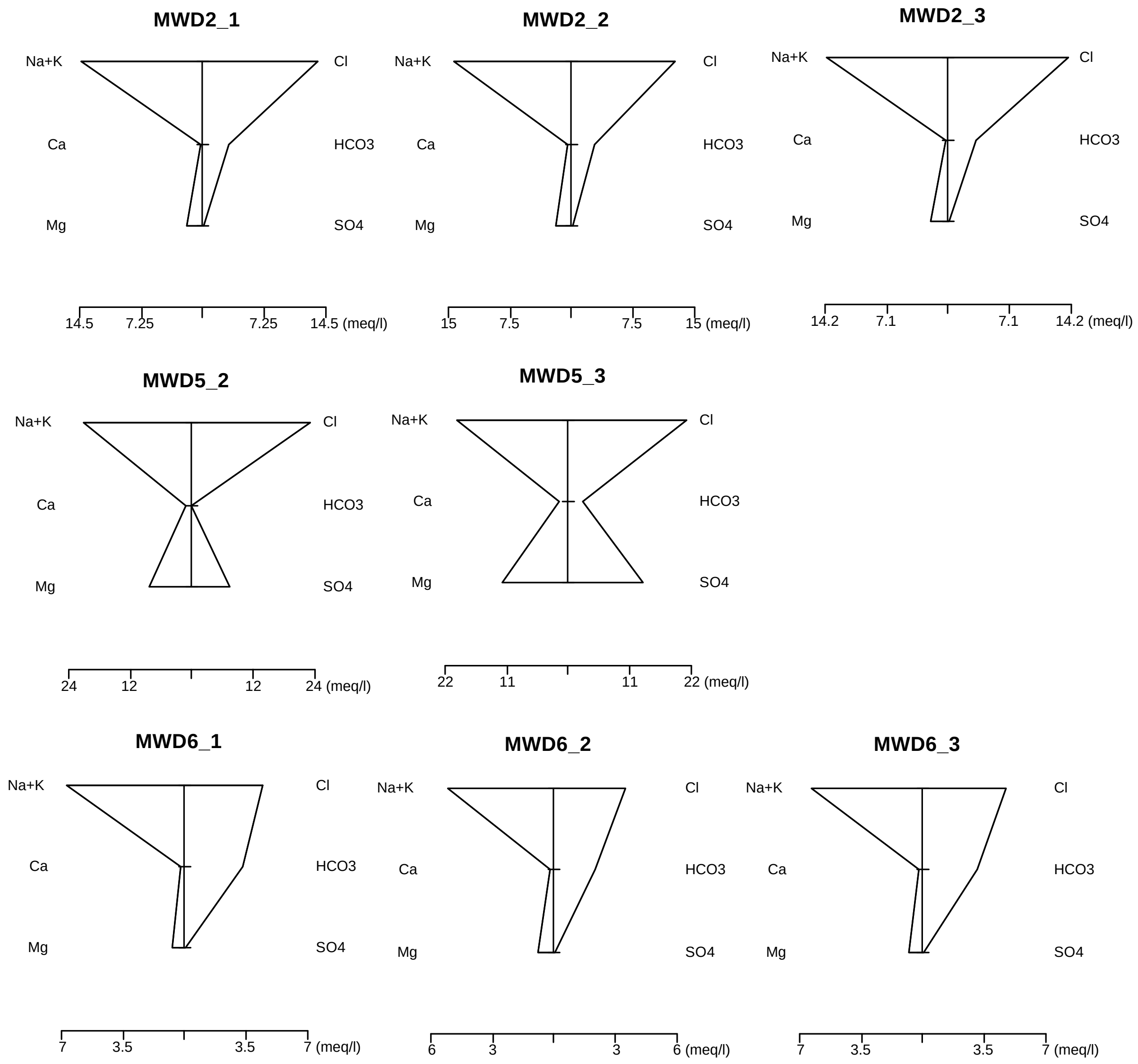
Figure E.3.29

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type IV) (3/6)



Type IV: Na_2SO_4 or NaCl – 16 wells & 3 surface waters

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Figure E.3.30

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Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type IV) (4/6)

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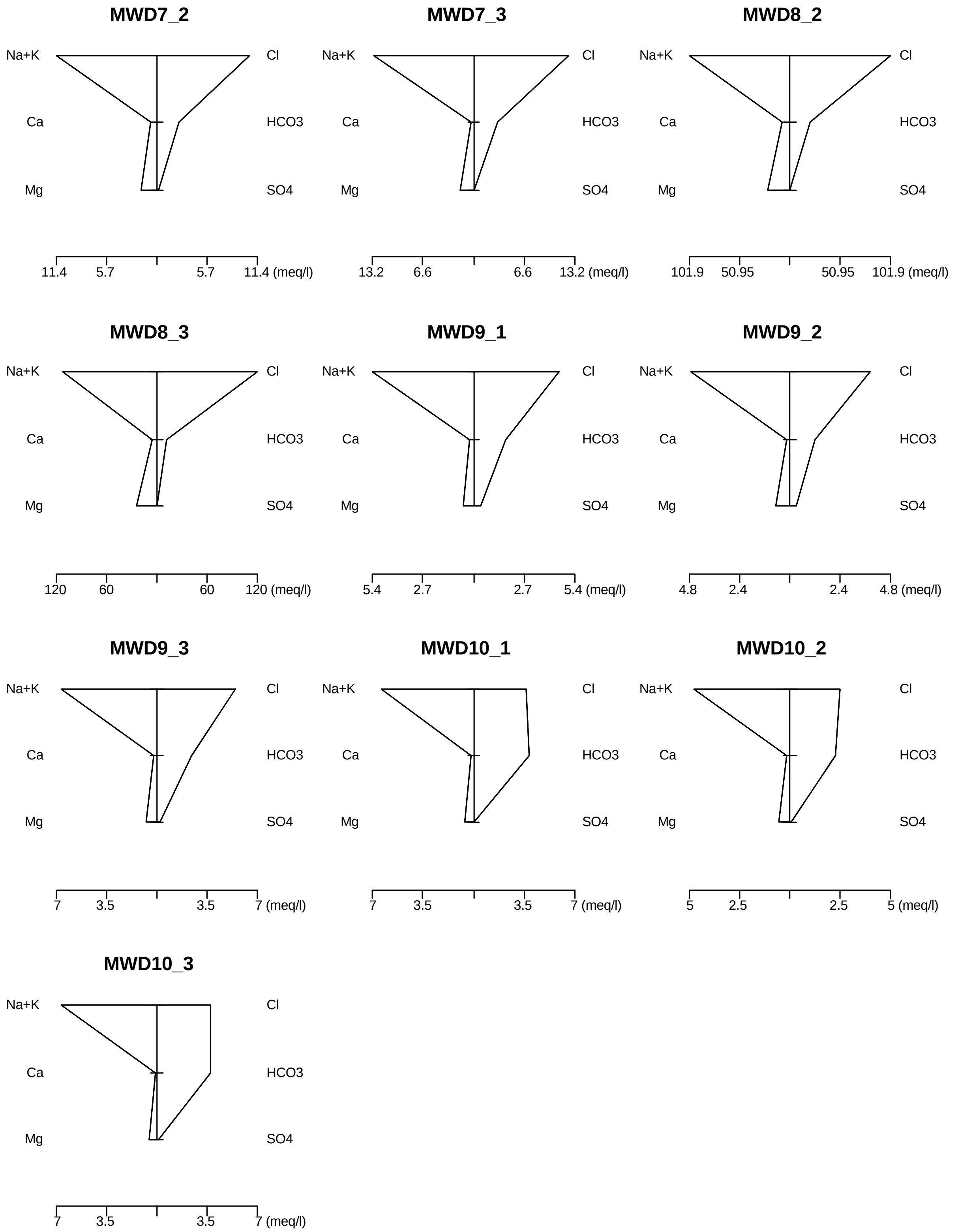

Type IV: Na_2SO_4 or NaCl – 16 wells & 3 surface waters

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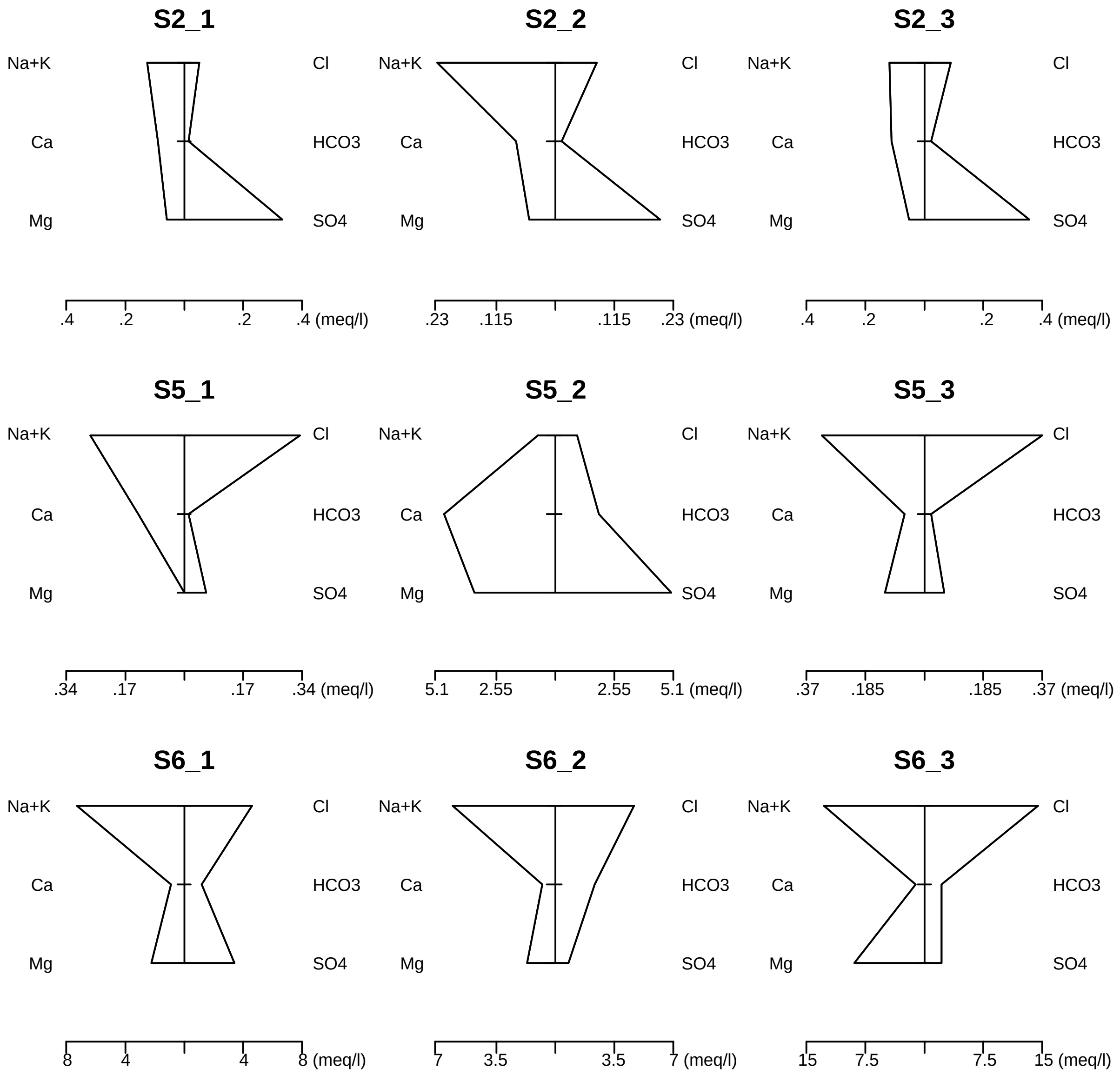
Figure E.3.31

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type IV) (5/6)



Type IV: Na_2SO_4 or NaCl – 16 wells & 3 surface waters

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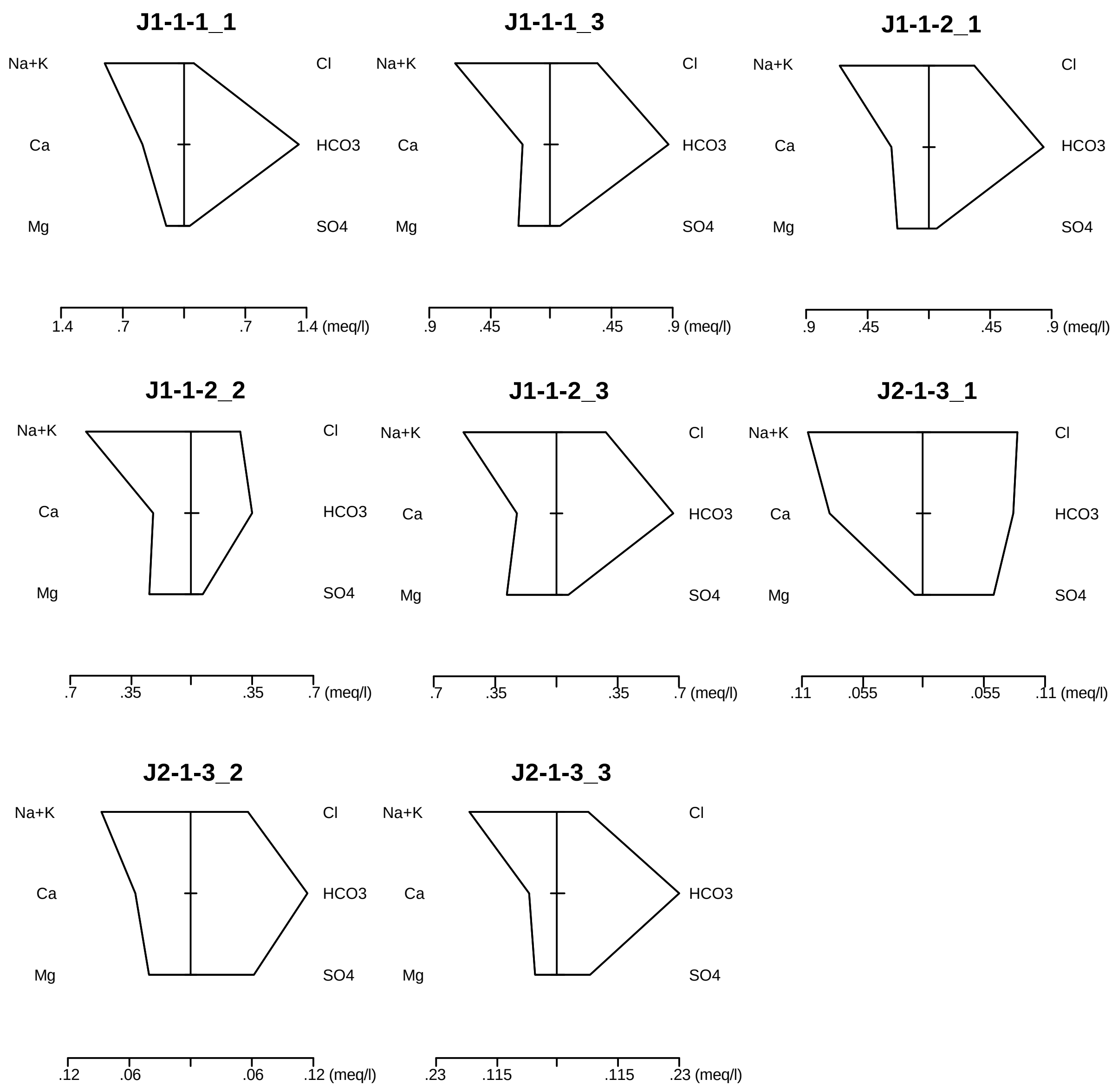
Figure E.3.32

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type IV) (6/6)



Type V: Intermediate – 8 wells

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Figure E.3.33

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

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type V) (1/3)

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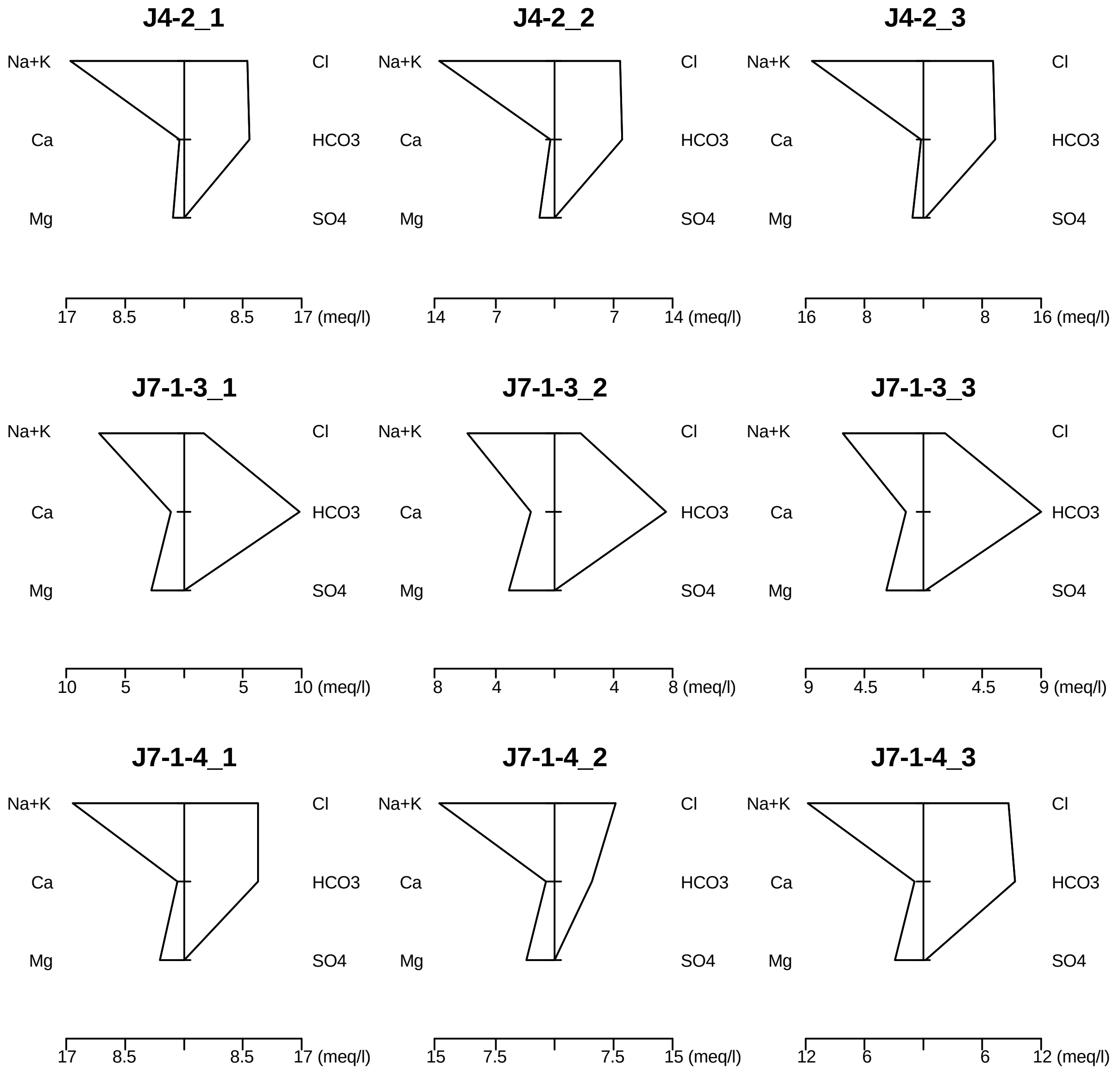

Type V: Intermediate – 8 wells

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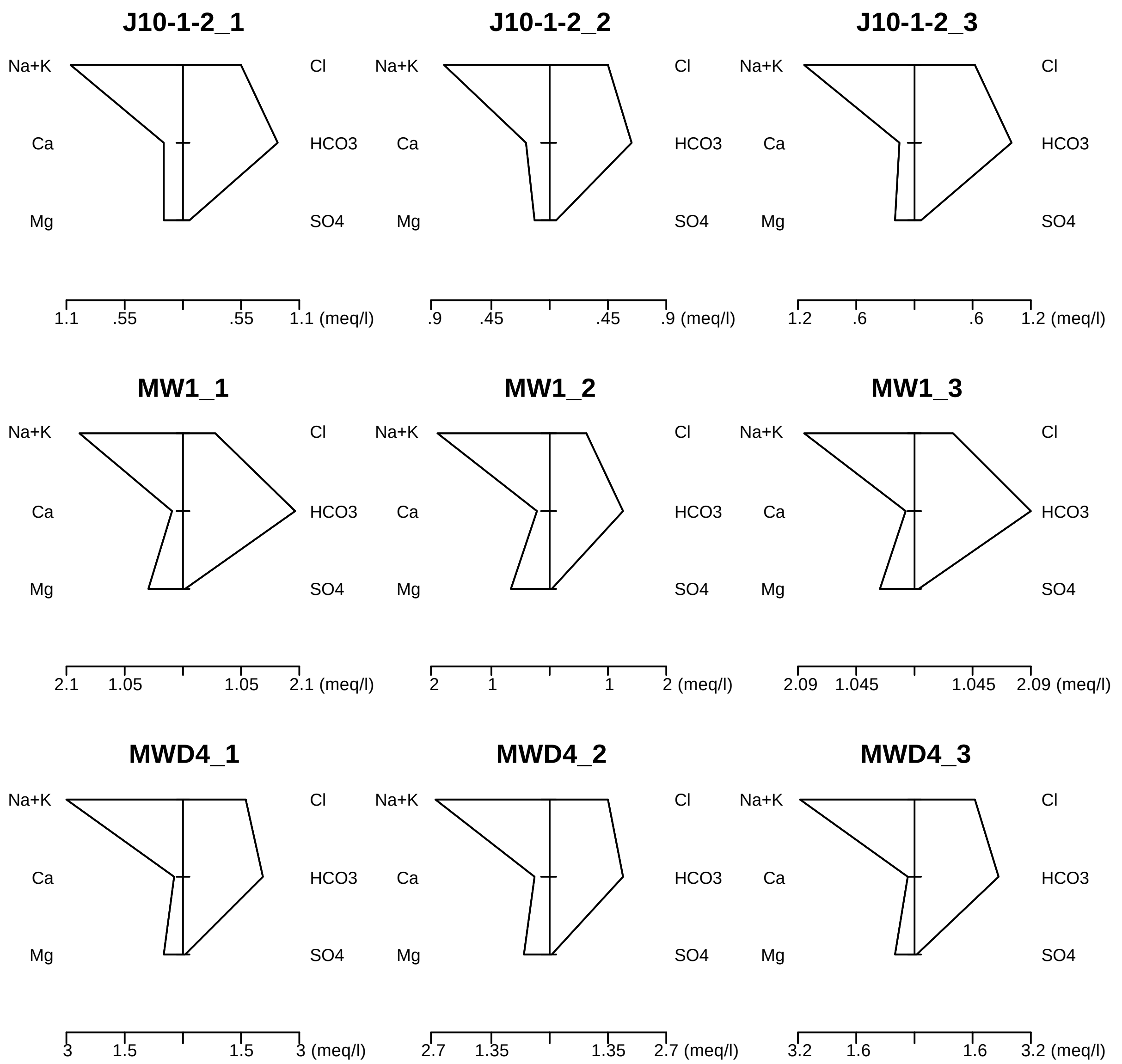
Figure E.3.34

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type V) (2/3)



Type V: Intermediate – 8 wells

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Figure E.3.35

Stiff Diagram of Major Ions in Groundwater and Surface Water in the Study Area (Water Type V) (3/3)

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 (6) locations out of nine (10) 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, namely, J5-2-2, MW14, J7-1-2 and LED2, in this type. On the contrary to this tendency, these wells were built in shallow depths; that is, water from these wells come from sand layers in depth of 10 to 18 metres. More additional investigation will be needed if it can be evaluated for reasons of the contradiction.

4. POTENTIAL POLLUTION SOURCES

4.1 General

The rapid population growth and continuous increase of industrial and agricultural development can pose a threat to the groundwater quality. Since these vivid human activities can always generate a wide variety of waste and effluent, it is quite important to recognise what kinds of activities are potentially causing pollution to the groundwater. This chapter describes the potential pollution sources based on the results of "Hydro Census" and other data collection and field surveys conducted in the First Field Work in Malaysia.

4.2 Hydro Census for Establishment of an Inventory of Potential Pollution Sources

4.2.1 Methodology of the Census

The Institute for Environment and Development (LESTARI), Universiti Kebangsaan Malaysia (UKM) carried out the Hydro Census on a subcontract basis under the supervision of the JICA Study Team. Focusing on industrial and agricultural activities in the Langat Basin, the Census covered the following:

- Data compilation by reviewing literatures, existing data and information; and
- Field reconnaissance and interview survey to reinforce the compiled data above.

Other potential pollution sources, such as mining, waste disposal sites, sewage treatment plants and oil storage tanks, which are not covered by this census, are discussed later. The methodology of the census is summarised as follows:

(1) Data Compilation

The compiled data regarding industrial and agricultural sectors include the following items in principle:

(a) Industries

- Owner of the industry (name, address, contact person, telephone number);
- Location of the industry (geographical coordination);
- Type of the industry;
- Year of establishment;
- Number of employees;
- Type of products;

- Output of production and total sales;
- Process of production; and
- Effluent (type, quantity and treatment).

(b) Agriculture

- Owner of the agricultural land (name, address, contact person, telephone number);
- Location of the agricultural land (geographical coordination);
- Area of the agricultural land;
- Year of establishment;
- Type of products;
- Output of production and total sales; and
- Usage of agricultural chemicals (type, name, quantity and frequency).

(2) Field Reconnaissance and Interview Survey

(a) Industries

The total number of industries to be surveyed was planned to be at least 300. Among them, some industries were selected by each industrial classification and by total sales of each category. The total number of the selected industries was 100. LESTARI tried to visit these industries and interview them.

In addition, LESTARI made a questionnaire to confirm the items listed in Item (i) above for all the listed industries. The set of questionnaire for industries is attached as **Data Book E.4.1**.

(b) Agriculture

The total number of agriculture to be surveyed shall be at least 100. LESTARI also tried to visit these agricultural lands and interview them to confirm the items listed in Item (i) above. The questionnaire survey was carried out in addition to the site visits and interviews. The questionnaire form is presented in **Data Book E.4.2**.

4.2.2 Limitations of the Census

Although contents of the questionnaire were carefully prepared and a request letter issued by JMG was attached to the questionnaire, it was extremely difficult to get a reply from every industry and agriculture. Most industries and agricultural-land owners were reluctant to give a few information to the Study Team because of the negative impact to the public should they be recognised as potential sources of pollutants. Such a closed policy of most industries and agriculture significantly restricted the collection of data and information through the questionnaire and interview.

4.2.3 Results of the Census

(1) Industrial Pollution Sources

(a) Number of Industries in the Langat Basin

There are 30 industrial estates and 337 factories located in the Langat Basin.[26)] The number of industrial estates in each district in the Basin is shown in **Figure E.4.1**. **Table E.4.1** shows a list of the industrial estates in the Langat Basin and **Figure E.4.2** shows their location. Most of the industries are located in the middle section of the Basin and within reach of major towns and roads. **Photograph E.4.1** shows the industrial estates in the vicinity of Balakong Town in Hulu Langat.

The private sector developed a total of 20 industrial estates in the Basin while the State Government developed the remaining 10 estates. Factories in the Basin engage in 22 categories of industrial production, ranging from the manufacture of agricultural end products to high-tech products such as consumer electronics.

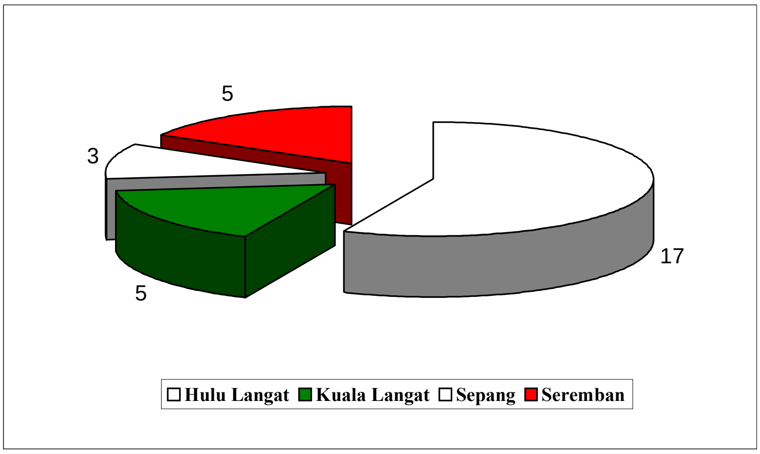


Figure E.4.1 Number of Industrial Estates in Each District of Langat Basin (Study Area)

Source: MIDA 1997.

Photograph E.4.1 Industrial Estates in Balakong, Hulu Langat

Source: M. Nordin, LESTARI, 1998.

Figure E.4.3 shows the number of industries by product category 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. **Data Book E.4.3** shows the number of factories in each industrial estate by product category. The categorisation here uses the classification of industry that is generally applied in Malaysia on the basis of MIDA classification. A photograph showing an example of a factory in Langat Basin is given in **Photograph E.4.2**.

Photograph E.4.2 Factory in Telok Panglima Garang Industrial Estates, Kuala Langat

Source: A. Fariz, LESTARI, 1998.

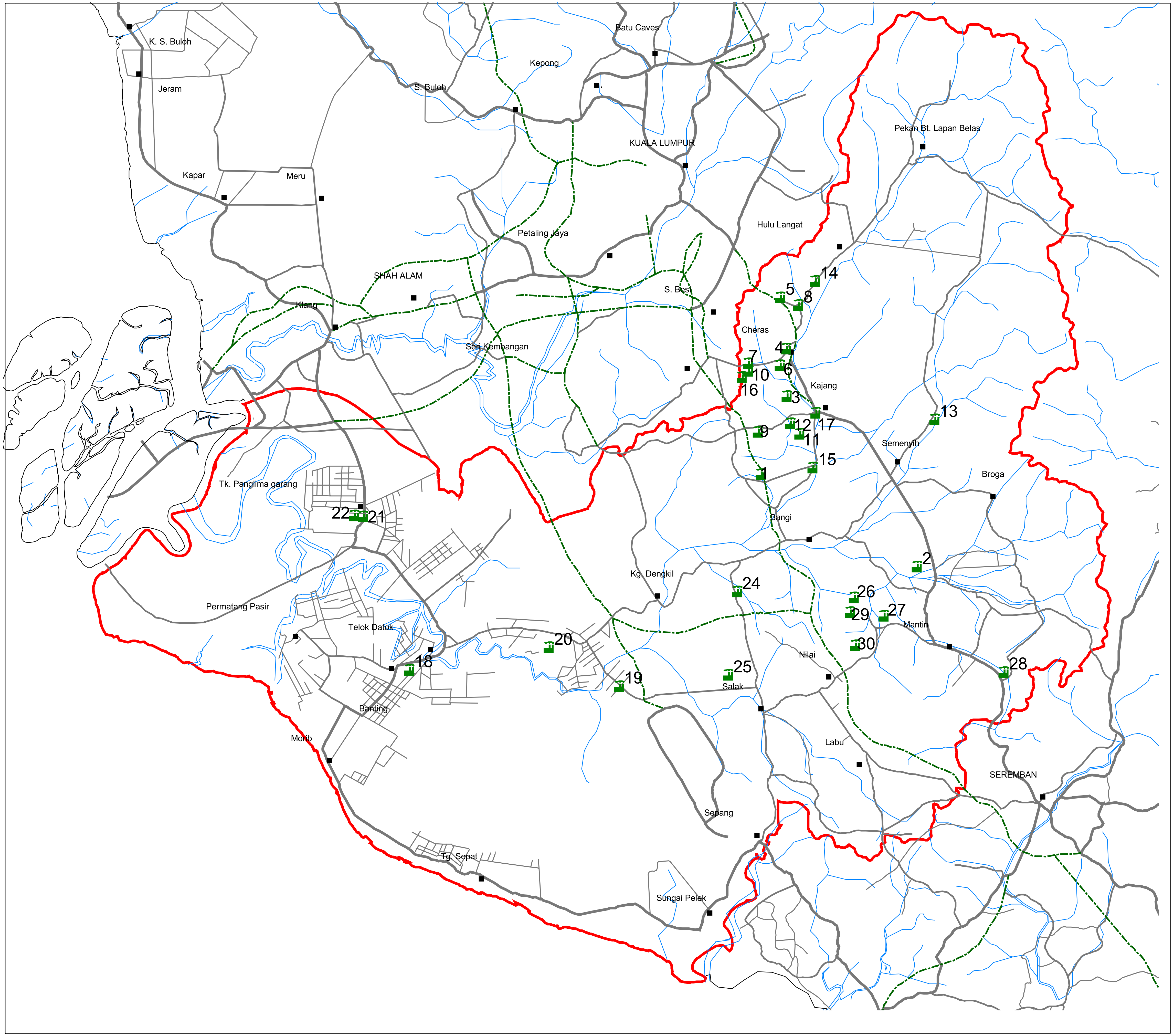
Table E.4.1 List of Industrial Estates in the Langat Basin

No.	Industrial Area or Park	Sub District (Mukim)	District	East (Longitude)	North (Latitude)
1	Bangi Phase I&II	Kajang	Hulu Langat	101^{O} 45.04	2^{O} 56.95
2	Beranang Industrial Park	Beranang	Hulu Langat	101^{O} 51.58	2^{O} 53.07
3	Bukit Angkat	Kajang	Hulu Langat	101^{O} 46.11	3^{O} 00.24
4	Cheras Bt. 11	Cheras	Hulu Langat	101^{O} 46.08	3^{O} 02.24
5	Cheras Bt. 9	Cheras	Hulu Langat	101^{O} 45.83	3^{O} 04.39
6	Cheras Jaya	Cheras	Hulu Langat	101^{O} 45.82	3^{O} 01.53
7	Kg. Baru Balakong	Cheras	Hulu Langat	101^{O} 44.49	3^{O} 01.61
8	Mas Jaya Industrial Park	Ulu Langat	Hulu Langat	101^{O} 46.59	3^{O} 04.07
9	Selaman Industrial Park	Kajang	Hulu Langat	101^{O} 44.91	2^{O} 58.73
10	Selesa Jaya Industrial Park	Cheras	Hulu Langat	101^{O} 44.51	3^{O} 01.29
11	Sg. Chuau	Kajang	Hulu Langat	101^{O} 46.65	2^{O} 58.65
12	Sg. Chuau Industrial Park	Kajang	Hulu Langat	101^{O} 46.27	2^{O} 59.09
13	Sg. Lalang	Semenyih	Hulu Langat	101^{O} 52.03	2^{O} 59.27
14	Sg. Serai	Ulu Langat	Hulu Langat	101^{O} 47.28	3^{O} 05.07
15	Sg. Tangkas	Kajang	Hulu Langat	101^{O} 47.21	2^{O} 57.23
16	Tanming Jaya Industrial Park	Cheras	Hulu Langat	101^{O} 44.23	3^{O} 01.03
17	West Country	Kajang	Hulu Langat	101^{O} 47.33	2^{O} 59.53
18	Banting Industrial Park	Banting	Kuala Langat	101^{O} 30.35	2^{O} 48.69
19	Bukit Changgang	Tanjung 12	Kuala Langat	101^{O} 39.13	2^{O} 48.02
20	Olak Lempit Industrial Park	Olak Lempit	Kuala Langat	101^{O} 36.19	2^{O} 49.65
21	Telok Panglima Garang	Telok Panglima Garang	Kuala Langat	101^{O} 28.39	2^{O} 55.13
22	Telok Panglima Garang FTZ	Telok Panglima Garang	Kuala Langat	101^{O} 28.03	2^{O} 55.17
23	Bukit Tampoi	Dengkil	Sepang	101^{O} 30.35	2^{O} 48.69
24	Jenderam Hilir	Jenderam	Sepang	101^{O} 44.06	2^{O} 52.01
25	Salak Tinggi Industrial Park	Salak Tinggi	Sepang	101^{O} 43.69	2^{O} 48.51
26	Arab Malaysian Industrial Park	Setul	Seremban	101^{O} 48.94	2^{O} 51.77
27	Country Height Industrial Park	Setul	Seremban	101^{O} 50.19	2^{O} 51.01
28	Mantin	Setul	Seremban	101^{O} 55.22	2^{O} 48.65
29	Nilai 3 Industrial Park	Setul	Seremban	101^{O} 48.79	2^{O} 51.16
30	Nilai Industrial Park	Setul	Seremban	101^{O} 49.01	2^{O} 49.76

Source: MIDA 1997.

Figure E.4.2

Location of Industrial Estates in the Langat Basin



LEGEND

Industrial estates

No. Numbers indicated in this figure are the same as those of Table 3.1.3 in the text.

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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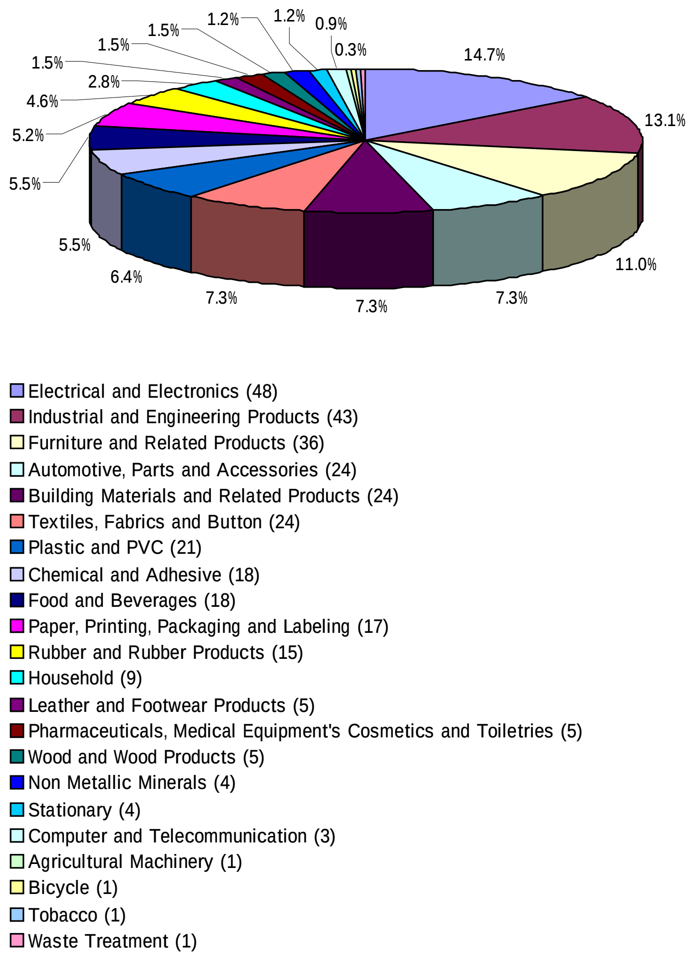

Figure E.4.3 Proportion of Industries by Product Category in the Langat Basin

(b) Selected Industries Surveyed

Three hundred (300) factories were selected for the survey. Criteria chosen for the survey were based on the number of factories to represent each district and types of industry according to products. **Table E.4.2** shows the number of factories chosen for the survey that cover the whole range of industry from each industrial estate. A list of factories to which questionnaires were sent are given in **Data Book E.4.4**. This questionnaire survey was conducted for one month starting from 29th May to 28th June 2000. The number of response from factories was not encouraging although the survey was prolonged until 1st July 2000; until that date only 28 respondents had registered. Responses to the questionnaire survey received were keyed in a database and attached hereto as **Data Book E.4.5**.

Table E.4.2 Number of Factories Chosen for the Questionnaire Survey

Districts	Number of Factories	Percentage of the Total
Hulu Langat	189	63%
Kuala Langat	37	12%
Sepang	8	3%
Seremban	66	22%
Total	**300**	**100%**

From the above factories listed up, interviews and factory visits were arranged with one hundred (100) factories that were selected using similar criteria used for the questionnaire survey. The factories chosen from the list in **Data Book E.4.4** covered all types of industry in each district (see **Table E.4.3**). All the factories were sent letters by fax and follow-up calls were made to set interview dates. The interview survey activity was conducted for three weeks starting from 30th May until 20th June 2000. The interview was conducted based on questions in the survey. Environmental management and usage of water and energy were the main focus of the interview. Out of the 100 factories selected, however, only three (3) of them agreed for interview. However, the respondents gave valuable information for the study.

Table E.4.3 Number of Factories Chosen for the Interview Survey

Districts	Number of Factories	Percentage of the Total
Hulu Langat	40	40%
Kuala Langat	25	25%
Sepang	5	5%
Seremban	30	30%
Total	**100**	**100%**

(c) Industrial Activities

Data received from respondents surveyed were analysed. From 28 respondents, information essential to the purpose of the survey was analised to better understand industrial activity. The total number of factory employees was 17,237 with an average of 615 employees per factory. The smallest number was 34 and the highest was recorded at 2,800 workers. About 64% of the factories operate 24 hours a day on three 8-hour shifts. Details of operation hours of factories are shown in **Figure E.4.4** below.

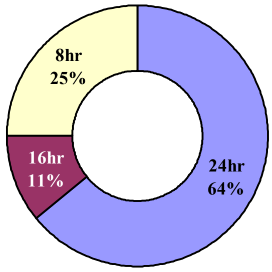

Figure E.4.4 Operation Hours of the Factories

(d) Chemical Usage

Almost 80 percent of the factories, i.e., 23 factories, use chemicals in their daily operation. There are 62 kinds of chemicals being used. A list of chemicals used in the factories is given in **Data Book E.4.6**. No data was received regarding consumption of these chemicals.

(e) Water Usage

All the respondents use public water supply. The total amount of RM429,104.00 per month is billed for water usage at an average of RM15,325.00 during the survey. The minimum costs were RM200 and the maximum reported at RM280,000.00 per month.

(f) Wastewater Treatment

Ten (10) factories drain their wastewater straight to the drainage system while others treat it before discharge to the drainage system. All factories that do not treat their wastewater plan to install a water treatment plant in the future. One of the main reasons given is the expensive cost of installation and maintenance. Out of the 18 factories with treated water, only three (3) of them recycle the water.

(2) Agricultural Pollution Sources

(a) Overview of Agricultural Activities in the Langat Basin

In 1995, agricultural activities in the Langat Basin utilised an area of 1,735.83 km^2, which is 60% of the total land area of the Basin.[27)] The main activity of agriculture is dominated by palm oil plantation, followed by rubber, piggery, poultry, aquaculture, cattle and orchards. **Photograph E.4.3** shows an example of agricultural area in the Basin.

Photograph E.4.3 Agriculture Activities in Carey Island and Jugra, Kuala Langat

Source: M. Nordin, LESTARI, 1998.

According to the Palm Oil Registration and Licensing Authority (PORLA), there are 94 palm oil estates and 8,543 small holders in the Basin.[28)] Distribution of plantations in each district in the Basin is as shown in **Table E.4.4**.

Rubber plantations were found to have diminished in size and number with 15 plantations that included small holders reported in the Basin. Ten (10) plantations are located in Kuala Langat and 5 in Hulu Langat.[29)] The size of the palm oil and rubber plantations are classified as confidential.[28), 29)] However, a rough estimation was made from the map produced by the Directorate of National Mapping with scale of 1:50,000. The roughly estimated size of palm oil and rubber plantations is as shown in **Table E.4.5** below.

Table E.4.4 Distribution of Palm Oil Plantations in the Langat Basin

Type of Plantation	District				Total
	Kuala Langat	Hulu Langat	Sepang	Seremban	
Estate	43	17	16	18	94
Small Holders	6090	281	2137	35	8543
Total	**6133**	**298**	**2153**	**53**	**8637**

Source: PORLA, 2000.

Table E.4.5 Area of Agricultural Activities in the Langat Basin

Agriculture Activity	Area (Hectares)
Palm Oil	10,392.16
Rubber	3,367.5
Orchards	885.27
Piggeries	659.62
Poultry	595.65
Aquaculture	833.20
Cattle	624.90
Total	**17,358.30**

Source: Directorate of National Mapping Malaysia, Topographic Maps, Scale 1: 50000, 1992.

Livestock activity is one of the main agricultural activities in the Basin. Pig farms dominated when compared to poultry and cattle. There are 252 pig farms, 3 poultry farms and 4 cattle farms in the Basin. The locations of these farms are given in **Figure E.4.5** while **Data Book E.4.7** shows the location of these farms according to latitude and longitude as described in the Rectified Skew Orthomorphic (RSO).

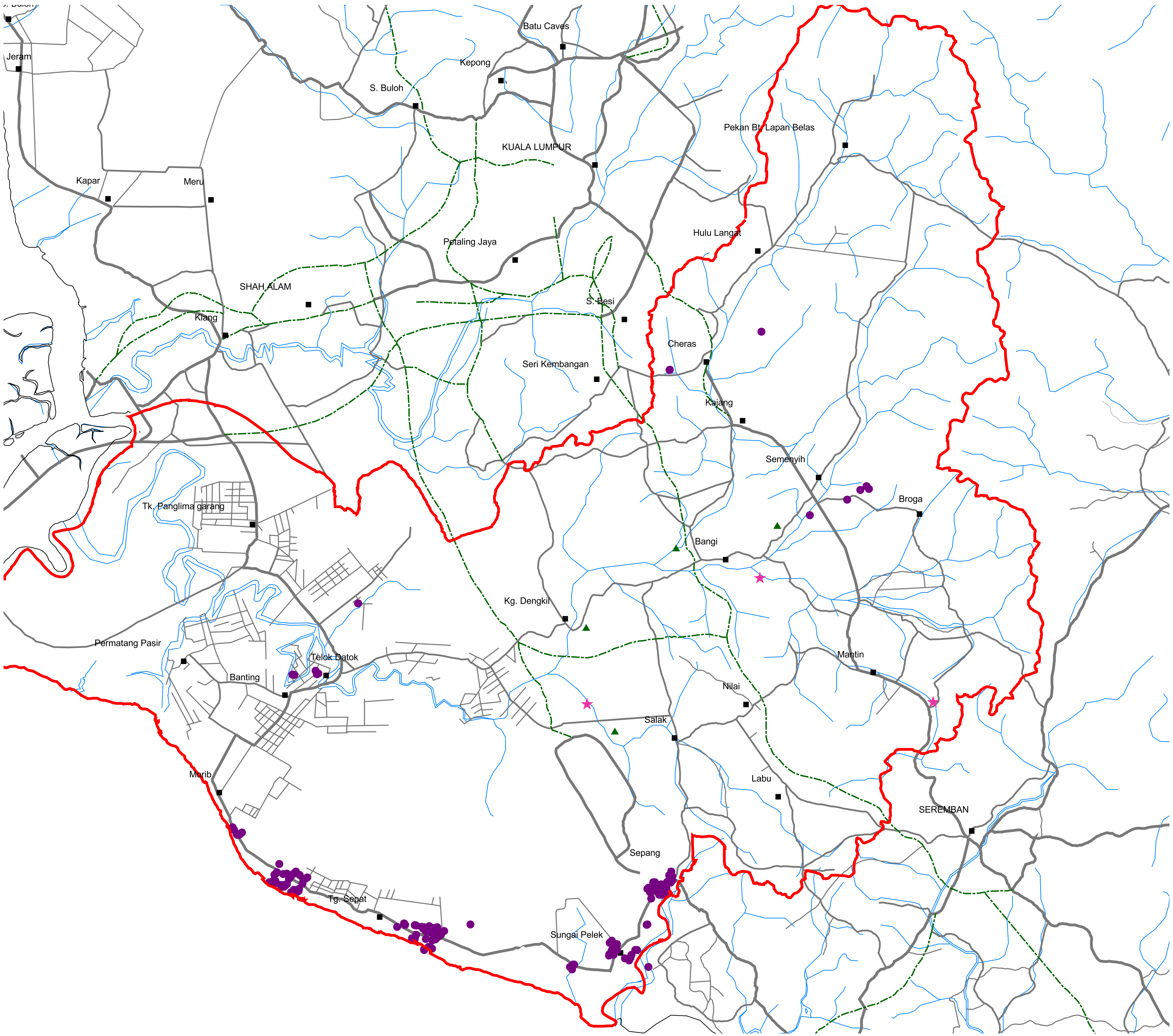

Figure E.4.5

Location of Pig Farms, Poultry Farms and Cattle Farms in the Langat Basin

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(b) Number of Agricultural Activities Surveyed

Survey for agricultural activities in the Basin was conducted through questionnaire and interview. The questionnaire was designed with the assistance of JMG, as attached in **Data Book E.4.2**. The questionnaires were posted to respondents such as plantation managers and farmers by mail. A total number of 156 questionnaires were sent. The criterion was that each agricultural activity should represent each district according to the proportion available. The representative agricultural activities that were sent with questionnaires are given in **Table E.4.6**.

Table E.4.6 List of Agricultural Activities Surveyed

Agricultural Activity	Number of Questionnaire Sent				
	Hulu Langat	Kuala Langat	Sepang	Seremban	Total
Palm Oil					
Estates	7	16	12	12	47
Small Holders	10	20	15	5	50
Rubber	4	3	2	3	12
Pig Farm	10	5	15	10	40
Poultry Farm	-	1	1	1	3
Cattle Farm	-	4	-	-	4
Total	**31**	**49**	**45**	**31**	**156**

(c) Chemical Usage

Due to the poor response, analysis of these activities could not be done for all parameters. The questionnaire respondents for agriculture are summarised in **Data Book E.4.8**. According to this result, agricultural activities use various types of chemicals such as pesticides and fertilisers. There are many types of pesticides being used mainly to control weeds, insects, rats and other pests. Data received from the small number of response give some indication of types of chemicals used for pesticides. According to the assistant manager of the palm oil plantation in Dengkil, Sepang, a few plantations mix pesticides with other chemicals to reduce rain-wash. For example, they mixed Roundup with Lisaphole, a type of detergent, and Tenac-sticker that is a kind of oil. The mixture is then sprayed in the plantation at the rate of 3.3 litres of pesticide per hectare.

Table E.4.7 gives the list of pesticides used in palm oil, rubber and orchards in the Basin, while **Data Book E.4.9** shows the rate of each pesticide used for the three agricultural activities. According this table, "Roundup" and "Spark" that are composed of Glyphosate isopropylamine are the major biocides used for agriculture.

Table E.4.7 List of Pesticide Used in Palm Oil, Rubber and Orchards in the Langat Basin

Commercial Name	Active Ingredient	Inert Ingredients
Spark	Glyphosate isopropylamine 13.6% w/w	Aluminum sulphate 27.0 % w/w Others 59.4%
Roundup	Glyphosate isopropylamine 41% w/w	
Touch Up	Glyphosate isopropylamine 41% w/w	
Gramoxone PP910	Paraquate dichloride 25% w/w	
Ato Cuprofix	Boreaux mixture 80% w/w Metalic copper 20% w/w	
Cypermethrhin	Cypermethrhin	
Midafos	Midafos	
Basta	Glufosinate ammonium 13.5% w/w	

Fertilisers used in the palm oil industry are reported as Guthrie Natural Fertiliser, borate, nitrite acid, rock phosphate (C.I.R.P), ground made limestone (G.M.L), morate of potash (M.O.P), Nitric Acid, supergro, biorgano and kieserite, as presented in **Data Book E.4.10**. Each fertiliser has a different rate of usage per year. Palm oil use eight types of fertilisers with different rates of usage, depending on age of plants and location.[30)] Some ingredients are mixed and the average rate of fertiliser used is 0.1 to 9 Kg/ha/year. On the average fertiliser is sprayed twice a year for adult trees. GML and CIRP are used once at the early stages of planting.

4.3 Other Potential Pollution Sources

4.3.1 Mines

Mining activities are thought to be major pollution sources in the Langat Basin. Many excavated areas comprising active and ex-mining sites exist in the Basin to mine for tin, one of main minerals of the country. The location of these mining activities is shown in

Figure E.4.6, and the list of these activities is given in **Data Book E.4.11**. However, not all the activities listed in the geological department have traced their locations on topographic maps. **Photographs E.4.4 and E.4.5** below show the conditions of one of the largest active tin mines in the Basin near the Megasteel, Dengkil.

Photograph E.4.4 Active Mine near Megasteel, Dengkil (1)

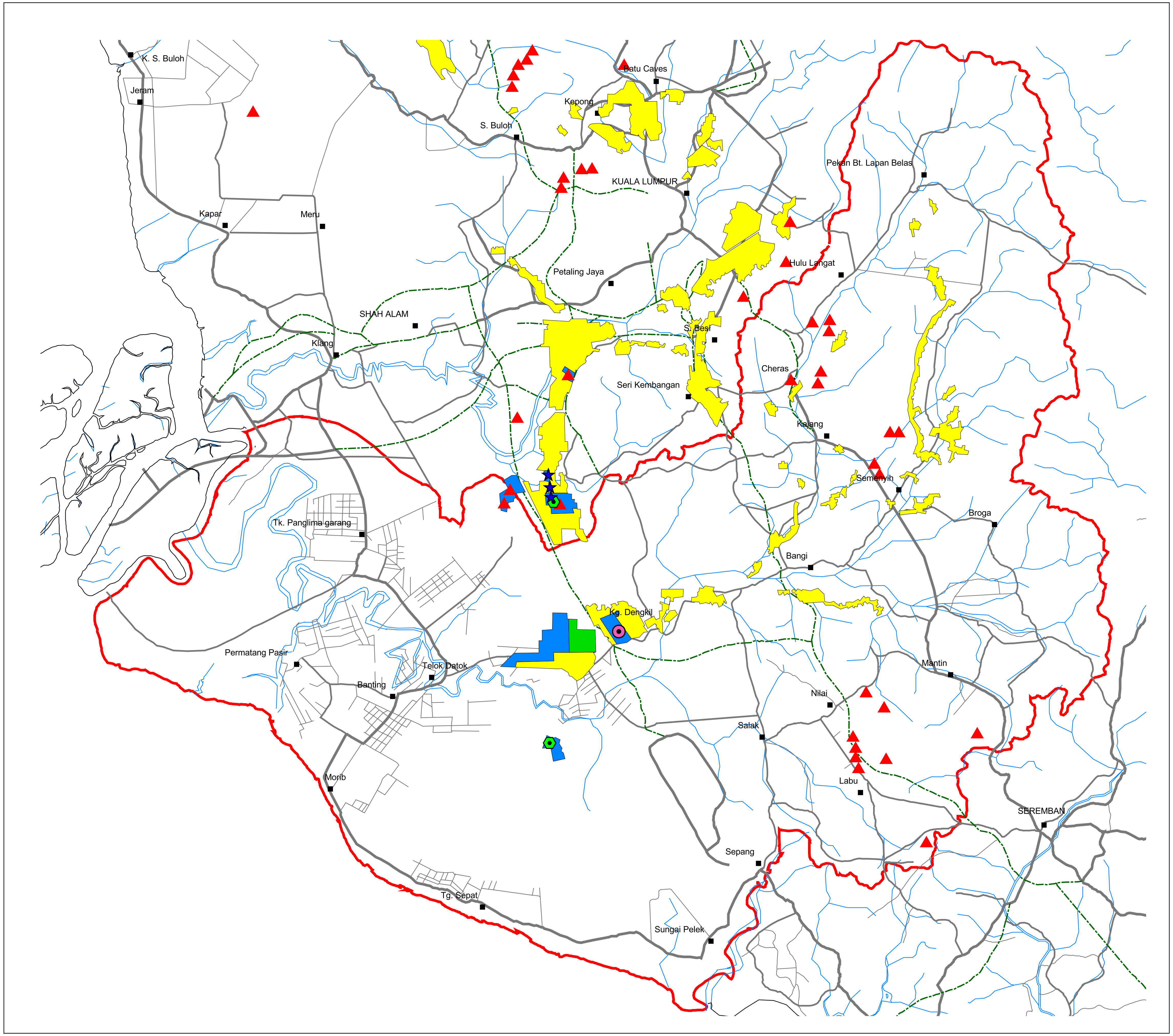
Source: JICA Study Team, taken in 10 July 2000.

Photograph E.4.5 Active Mine near Megasteel, Dengkil (2)

Source: JICA Study Team, taken in 10 July 2000.

Figure E.4.6

Location of Mining Activities



LEGEND

- ▲ Quarry Location
- Sand Mining
- Tin Mine (Dredge)
- ★ Tin Mining (Open Cast)
- Ex-Mining Land
- Mining Land
- Wetland
- ▪ Town
- Coastal line
- Major Sealed Federal Road
- Other Sealed Federal Road
- Major Sealed State Road
- Other Sealed State Road
- Toll Expressway
- River
- Langat Basin

Source : Present of Mining Land for Selangor (as of 15 April 2000), JMG

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Tin is included in the Simpang Formation of sand and gravel layer that is also regarded as an aquifer of the Basin. The excavated land exposed in this formation may thus contribute to the infiltration of pollutants from the surface.

4.3.2 Solid Waste Landfill Sites

Solid waste landfill sites may produce potential pollutants by leachate containing toxic organic compounds as well as high oxygen demand substances. There are three (3) landfill sites officially operating for disposal of solid waste generated in the Langat Basin: Sungai Sedu, Ampar Tenang and Sungai Kembong, as shown in **Figure E.4.7**. Condition of the waste disposal sites is shown in **Photographs E.4.6 and E.4.7**.

Photograph E.4.6 Sungai Sedu Solid Waste Disposal Site in Kuala Langat

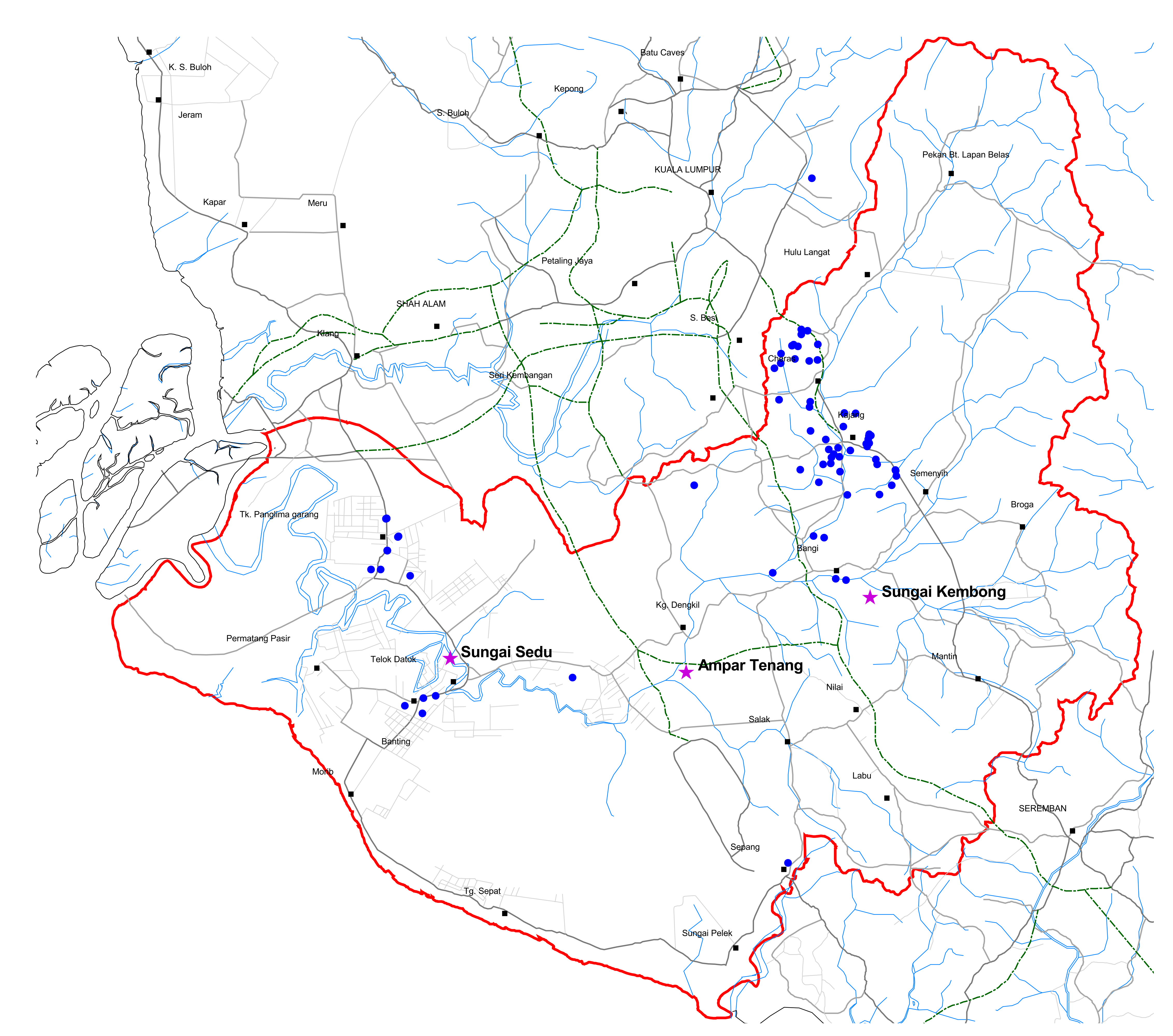
Source: JICA Study Team, taken in 10 July 2000.

Photograph E.4.7 Ampar Tenang Solid Waste Disposal Site in Kuala Langat

Source: JICA Study Team, taken in 10 July 2000.

Figure E.4.7

Location of Solid Waste Landfill Sites and Wastewater Treatment Plants in the Langat Basin



LEGEND

- Wastewater Treatment Plant
- Solid Wastes Landfill Site
- 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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Alam Flora Sdn. Bhd., a private solid waste management company, has operated and managed the sites at Sungai Sedu of Kuala Langat District and Ampar Tenang of Sepan District by concession from the local authorities. The site at Sungai Kembong is being operated and managed by the Hulu Langat District Office. A summary of these landfill sites is presented in **Table E.4.8**.[31)]

Table E.4.8 Summary of Official Solid Waste Landfill Sites in the Langat Basin

Site Name	**Sungai Sedu**	**Ampar Tenang**	**Sungai Kembong**
Area	6.07 ha	4.05 ha	Exact boundary is unknown; existing footprint is scattered within approximately 34 ha. of state land.
Geographical Setting	• Low-lying land • Negative relief was formed due to excavation of clay for a brick-making factory and created a pond of 6m deep. • Western area of the site is located at the edge of Sg. Langat, which flows north-northwest direction.	• Low-lying land • Southern area of the site is located at the edge of Sg. Labu.	• Located at Kg. Sg. Kembong Hulu along Sg. Beranang • Ex-mining area that consists of three ponds
Geology	• Underlain with clay and silt, low permeability of 10^{-6} cm/s. • Locally very clayey of silty sand of Holocene Age marine deposits of the Gula Formation. • Western area of the site is located at the edge of Sg. Langat, which flows north-northwest direction.	• Underlain mainly with peat • Probably lying over Quaternary alluvium	• Site soil is sandy in nature
Groundwater	• Groundwater level likely to be shallow. • Flow is expected to be towards Sg. Langat.	No data on groundwater condition.	No data on groundwater condition.
Facilities Available	• Access road • Perimeter fence • Leachate containment (natural clay liner) • Site office	• Access road • Perimeter fence • Leachate containment (natural clay liner) • Site office	• Access road • Perimeter fence • Frontal gate • Site office
Operations	• Started from 1993 • Plan to finish in 2004 • Receiving 2471 ton/month • One track dozer • 4 people working (1 supervisor, 1 operator and 2 workers)	• Started from 1995 or 96 • Operated by Alam Flora from 1998 • Receiving 4000 ton/month • One track dozer and 2 excavators • 4 people working (1 supervisor and 3 workers)	No data on site operations

Source: Alam Flora, Landfill Information for Sungai Langat Basin, July 2000.

Proper treatment of the leachate can avoid polluting the groundwater. The existing facilities of these sites, however, are insufficient for the leachate collection and treatment; that is, neither surface water drainage, leachate collection pipes nor leachate retention ponds are operating due to lack of budget. It is said that untreated leachate has a strength of 5 to 20 times that of domestic wastewater[32)], although there is no detailed information on the characteristics of the leachate produced in these landfill sites.

In addition, there are some waste dumping sites illegally operating in the Basin, but the location of these sites has not yet been identified in this study. Needless to say, these sites are not equipped with any leachate collection and treatment facilities as a sanitary landfill site, so that potential of groundwater contamination caused by these sites may be expected to some extent. Moreover, ex-dumping sites may also have possibility of potential pollution sources. More detailed survey regarding solid waste disposal sites including illegal and former sites will be required.

4.3.3 Wastewater Treatment Plants

The Indah Water Konsortium (IWK) operate the wastewater treatment plants in the Langat Basin. Location of 103 IWK treatment plants is identified by coordinates, as shown in **Figure E.4.7** while it is reported that 112 plants are operating in the Basin.[33)] A list of the identified plants is attached in **Data Book E.4.12**. Biochemical oxygen demand (BOD) and ammoniacal nitrogen (NH_3-N) loads discharged by all the wastewater treatment plants in the Basin are estimated at 5,579 kg/day and 2,095 kg/day, respectively.[34)] According to this analysis, about 75% of the BOD load and 99% of the NH_3-N load in the Langat River are caused by the wastewater treatment plants. This implies that the wastewater treatment plants are among the potential pollution sources if the water quality of Langat River contributes to the groundwater quality.

4.3.4 Petroleum Storage Tanks

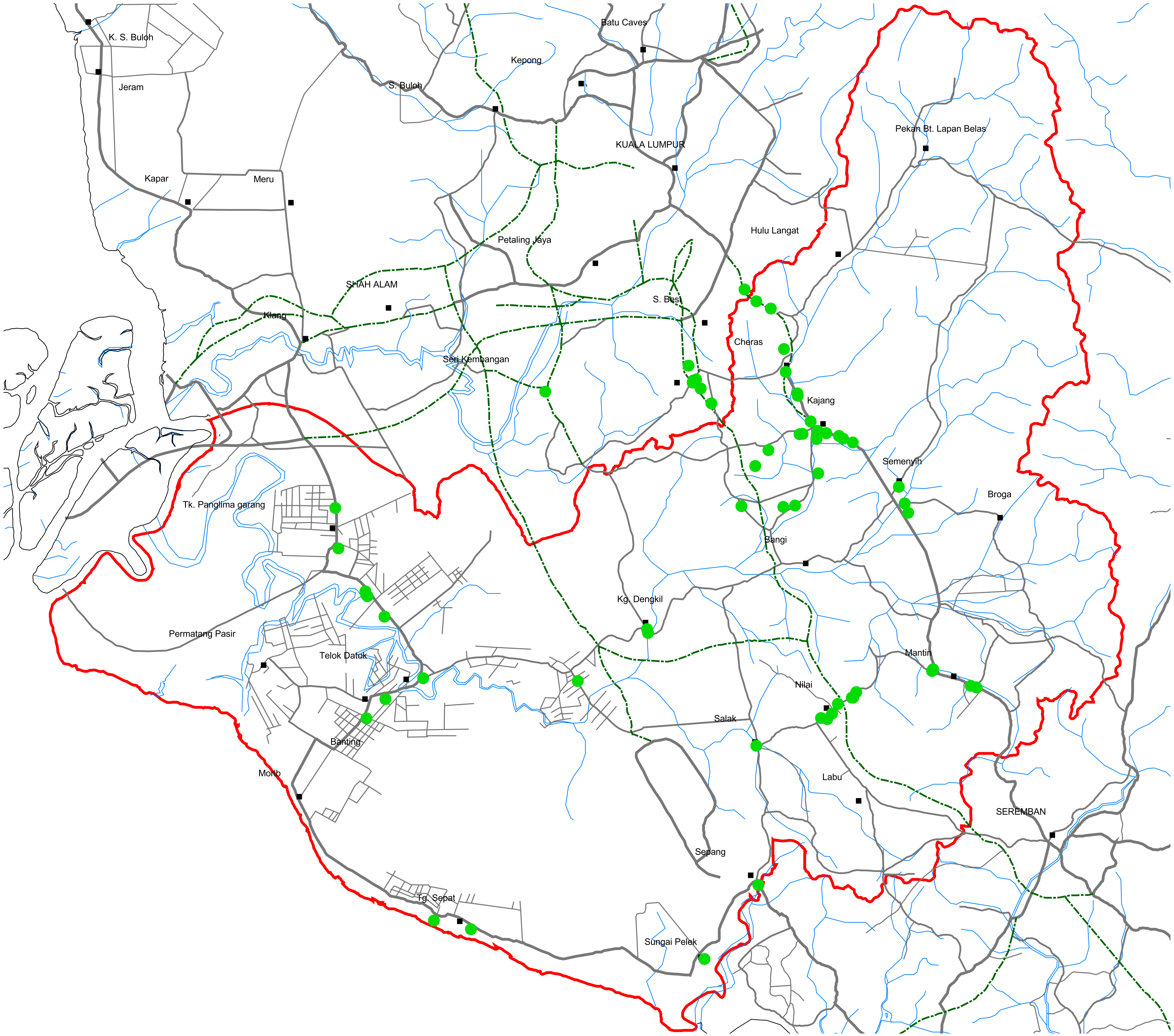
Frequent oil spill incidents have been reported in the Langat River Basin and other regions in the recent couple of years. The causes of spillage vary from incident to incident. Some of the incidents clearly show that spillage made its way into the drainage and waterway system, and consequently, might result in contamination of not only the surface water but also the groundwater. In terms of the Langat Basin, DOE conducted a survey for compiling information on the amounts of diesel and fuel oil stored by industries in aboveground storage tanks or drums for a three-month period in 1998. As a result of the survey, the total amount of diesel and fuel oil stored by industries in the Basin was estimated at 975,000 litres, comprising 63% for diesel and 37% for fuel oil.[35)]

Although the list of registered diesel and fuel oil storage made by DOE does not show location or coordinates of each storage facility, JMG surveyed the number of petrol stations and their location during the Phase I of the Study. According to the survey results, there were 91 petrol stations in the Langat Basin as of August 2000. **Figure**

E.4.8 shows the location of petrol stations, and a list of the stations is given in **Data Book E.4.13**.

Figure E.4.8

Location of Petrol Stations in the Langat Basin



LEGEND

- Petrol Station
- 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

N E S W

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

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

CTI Engineering International Co., Ltd.

OYO CORPORATION

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ANNEX E.3.1

RESULTS OF GROUNDWATER AND SURFACE WATER QUALITY DURING THE STUDY PHASES

Annex Table E.3.1 (1) Groundwater Quality of the Existing Monitoring Wells

Bil.	Reference No.	Date of sampling	Time	Physical						Inorganic																				
				Temper -ature	Electric Conductivity (Cond.)	Turbidity (TUR)	Colour (COL)	pH	pH (Lab)	Oxygen Contents (O_2)	Oxygen Saturation (O_2)	Biochemical Oxigen Demand (BOD)	Chemical Oxigen Demand (COD)	Manganese (Mn)	Iron Ferrous / Soluble Iron (Fe^{2+})	Total iron (Fe-T)	Nitrate (NO_3^-)	Nitrite (NO_2^-)	Total Dissolved Solids (TDS)	Total Solids (TS)	Chloride (Cl)	Anionic Detergent (MBAS)	Ammoniacal Nitrogen (NH_3^+-N)	Fluoride (F)	Carbonate (CO_3^{2-})	Hydrogen Carbonate (HCO_3^-)	Total Hardness ($CaCO_3$)	Sodium (Na)	Calcium (Ca)	Potassium (K)
Drinking Water Quality Standards (1983)				-	-	5	15	6.5-8.5	-	-	-	-	-	0.1	-	0.3	10	-	1000	-	250	-	0.5	1.5	-	-	500	200	-	-
Measurement Unit				°C	us	NTU				mg/l	%DO	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	MWD1	26-Feb-01	13:08	27.6	574	1.0	5	6.7	7.8	0.3	2.6		29	0.100	3.11	5.71	0.61	2.200	0.60		96.0			<0.5	6.0	86.0		79.0	3.5	5.7
2		28-May-01	13:15	27.9	581	2.0		6.6	8.0	8.9		2	31	0.012	5.15	6.23	0.29	0.160	0.36	262.0	99.0	<0.25	<0.50	<0.5	5.0	81.0	42	76.0	4.6	5.7
3		22-Aug-01	12:45	27.5	572	0.6		6.1	6.4	0.6		2	5	0.300	0.04	0.97	1.20	0.004		282.0	114.0	<0.25	0.50	<0.5	<1	98.0		83.0	4.1	6.1
4		29-Aug-01	13:20	27.6	440	0.8		6.5		0.3	4.1																			
5	MWD2	21-Feb-01	11:40	27.9	2020	13.9	5	6.7	8.0	0.1	0.9		0						0.89		482.0			<0.5	10.0	192.0		322.0	7.8	16.0
6		23-May-01	15:47	27.9	2100	9.0		6.7	7.7	18.9	232.7	1	0	0.009	0.96	1.83	2.70	0.047	0.91	900.0	445.0	<0.25	<0.50	<0.5	5.0	170.0	120	320.0	8.3	15.0
7		23-Aug-01	12:50	27.8	1917	1.5		6.3	6.9	1.6		-33	0	0.500	0.40	1.52	4.50	0.009		1028.0	493.0	<0.25	<0.50	<0.5	<1	194.0		315.0	7.1	16.0
8		4-Sep-01	14:19	27.9	1672	1.8		6.5		0.4	4.8																			
9	MWD4	2-Mar-01	?	27.8	478	21.0	5	6.5	6.6	5.7	61.8		31	0.100	0.69	0.97	1.00	2.600	0.32		57.0			<0.5	<1	125.0		64.0	4.3	7.0
10		29-May-01	11:50	28.2	516	16.1		6.6	7.0	26.2	336.3	3	26	0.077	11.70	9.45	3.50	0.033	0.23	210.0	49.0	<0.25	<0.50	<0.5	<1	104.0	44	57.0	6.5	5.9
11		30-Aug-01	10:50	28.0	398	0.4		6.4	6.5	1.3	16.1	8	97	1.800	0.01	1.47	0.50	0.018		238.0	59.0	<0.25	2.60	<0.5	<1	139.0		68.0	4.1	6.9
12	MWD5																													
13		23-May-01	12:00	30.2	4370	10.6		5.3	7.4	17.8	236.6	2	40	0.120	1.02	1.35		0.025	1.81	2100.0	816.0	<0.25	4.50	<0.5	<1	<1	463	475.0	22.0	16.0
14		23-Aug-01	16:15	29.7	3729	2.8		5.9	6.6	0.8		7	29	8.000	15.05	8.30	4.50	0.013		2588.0	749.0	<0.25	6.60	<0.5	<1	158.0		440.0	33.0	26.0
15	MWD6	26-Feb-01	16:05	28.6	933	1.4	5	6.7	6.8	0.2	2.1		0	0.000	0.84	1.42	0.27	2.700	0.49		158.0			<0.5	<1	202.0		146.0	3.5	13.0
16		28-May-01	12:07	28.6	929	3.3		6.8	8.0	0.9	9.6	6	35	0.015	2.18	2.23	4.70	0.039	0.41	338.0	125.0	<0.25	<0.50	<0.5	9.0	122.0	50	113.0	3.7	9.7
17		22-Aug-01	16:15	28.4	857	0.7		6.2	7.5	0.4		1	165	0.400	0.59	1.23	1.20	0.002		478.0	168.0	<0.25	<0.50	<0.5	<1	189.0		138.0	3.3	12.0
18	MWD7																													
19		23-May-01	17:04	27.6	1940	2.0		6.7	7.4	11.1	154.3	1	0	0.000	1.86	2.17	3.60	0.041	0.18	844.0	370.0	<0.25	0.70	<0.5	<1	154.0	119	253.0	13.0	14.0
20		23-Aug-01	11:20	27.6	1730	2.2		6.2	6.80	1.4		-1	0	0.200	0.53	1.24	0.30	0.002		928.0	443.0	<0.25	<0.50	<0.5	<1	191.0		292.0	7.7	16.0
21	MWD8																													
22		23-May-01	13:15	28.4	15840	5.3		6.8	8.1	9.0	117.1	6	0	0.001	0.98	1.73	2.40	0.039	0.21	7360.0	3590.0	<0.25	18.80	<0.5	88.0	1243.0	1467	2310.0	144.0	54.0
23		23-Aug-01	14:55	28.3	13913	0.6		6.1	8	1.3		4	0	0.800	0.22	2.13	1.90	0.017		8488.0	4236.0	<0.25	12.10	<0.5	<1	648.0		2540.0	112.0	56.0
24	MWD9	2-Mar-01	?	27.8	814	54.0	5	6.4	6.4	3.6	60.9		0	0.100	0.81	1.02	0.11	2.200	0.39		164.0			<0.5	<1	103.0		117.0	3.5	12.0
25		21-May-01	17:13	27.9	883	2.0		6.3	8.1	66.3	844.4		0	0.001	0.98	1.87	6.00	0.062	0.44	324.0	136.0	<0.25	<0.50	<0.5	5.0	74.0	41	104.0	3.7	8.4
26		29-Aug-01	11:45	28.1	714	4.3		6.4	6.7	0.3	3.6									478.0	194.0	<0.25	0.90	<0.5	<1	146.0		148.0	4.5	11.0
27		4-Sep-01	12:00	28.1	726	1.4		6.3		0.1	1.6																			
28	MWD10	26-Feb-01	11:51	28.3	875	916.2	60	6.8	7.0	0.6	4.6		143						0.35		128.0			<0.5	<1	239.0		141.0	3.5	11.0
29		22-May-01	11:09	28.1	887	290.8		6.8	8.0	65.5	838.2	8	129	0.259	3.01	3.17	1.27	0.006	0.40	478.0	89.0	<0.25	<0.50	<0.5	9.0	136.0	35	104.0	2.7	7.6
30		22-Aug-01	15:00	28.2	795	199.0		6.3	6.9	0.6		0	0	1.800	0.42	0.87	31.90	0.003		536.0	133.0	<0.25	<0.50	<0.5	<1	227.0		146.0	2.3	11.0
31	MW14	8-Mar-01	15:38	28.9	330	375.8	5	6.7	6.6	6.3	81.3		21						0.17		2.0			<0.5	<1	163.0		61.0	0.9	4.2
32																														
33																														
34	LED2	28-Mar-01	15:30	28.5	55	1098.4		5.5		1.6	19.7		123						0.04											
35		24-May-01	16:30	27.8	53	1098.5		5.6		7.1	90.2	19	139	0.810	8.02	8.75	0.39	11.150	0.04											
36		28-Aug-01	15:50	27.9	49	>1000		5.0	6.3	0.6		-3	0	57.000	3.08	8.95	54.50	1.395		438.0	<1	0.40	<0.50	<0.5	<1	22.0		7.0	0.5	0.7
37	LED3	29-Mar-01	14:00	29.5	95	1098.4		6.1		0.3	3.5		121						0.04											
38																														
39																														
40	EXPL2	8-Mar-01	13:36	30.3	3670	2.7	5	4.4	3.0	1.2	13.9		34						0.33		167.0			<0.5	<1	<1		92.0	87.0	17.0
41																														
42																														
43	Megasteel	8-Mar-01	17:20	28.4	301	1.6	5	6.8	6.8	0.6	6.5		4						0.21		21.0			<0.5	<1	124.0		39.0	3.5	6.8
44	(MW-1)	17-May-01	16:54	28.1	311	2.1		6.6	7.5	10.9	139.2		4	0.001	1.65	3.30	0.01	0.002	0.15	172.0	23.0	<0.25	<0.50	<0.5	<1	79.0	43	40.0	4.2	6.8
45		22-Aug-01	10:50	28.7	286	1.0		6.2	6.8	0.5		7	48	1.300	3.60	12.15	4.70	0.031		172.0	24.0	<0.25	1.70	0.6	<1	127.0		42.0	3.6	6.7

Annex Table E.3.1 (2) Groundwater Quality of the Existing Monitoring Wells

Bil.	Reference No.	Date of sampling	Time	Inorganic	Heavy Metals, etc.																	Pesticide etc.						Organic	
				Aluminium (Al)	Magnesium (Mg)	Mercury (Hg)	Cadmium (Cd)	Selenium (Se)	Arsenic (As)	Cyanide (CN)	Lead (Pb)	Chromium (Cr)	Silver (Ag)	Copper (Cu)	Zinc (Zn)	Sulfate (SO_4)	Phosphorous (P)	Silica (SiO_2)	Oil & Grease	Phenol	Chloroform	Organochlorine Pesticides	Organophorus Pesticides	BTEX	Volatile Organic Compounds (VOC)	Semivolatile Organic Compounds (SVOC)	Total Petroleum Hydrocarbon (TPH)	Total Coliform Bacteria	Escherichia Coli (E-Coli)
Drinking Water Quality Standards (1983)				0.2	150	0.001	0.005	0.1	0.05	0.1	0.05	0.05	0.05	1	5	400	-	-	0.3	0.002	-	-	-	-	-	-	-	-	-
Measurement Unit				mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	cfu/100ml	cfu/100ml
1	MWD1	26-Feb-01	13:08		6.8			<0.005	0.026		<0.01			<0.1	<0.1	<3		9.2	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
2		28-May-01	13:15	<0.1	7.5	0.0023	<0.01	<0.005	0.027	<0.05	0.01	<0.01	<0.05	<0.1	<0.1	<3	<0.02	13.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	50	20
3		22-Aug-01	12:45	<0.1	7.2	0.0007	<0.01	<0.005	0.027	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	<0.02	12.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	26000	6000
4		29-Aug-01	13:20																										0
5	MWD2	21-Feb-01	11:40		22.0			<0.005	<0.005		<0.01			<0.1	<0.1	<3		8.9	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	>200000
6		23-May-01	15:47	<0.1	24.0	0.0009	<0.01	<0.005	<0.005	<0.05	<0.01	<0.01	<0.05	<0.1	<0.1	<3	<0.02	13.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	26	6
7		23-Aug-01	12:50	<0.1	24.0	0.0005	<0.01	<0.005	<0.005	<0.05	<0.01	<0.01	<0.05	<0.1	<0.1	<3	0.05	12.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	4300	1800
8		4-Sep-01	14:19																									10	0
9	MWD4	2-Mar-01	?		5.8			<0.005	0.019		<0.01			<0.1	<0.1	<3		10.4	1	ND	ND	ND	ND	ND	ND	ND	ND	86000	0
10		29-May-01	11:50	<0.1	6.8	0.0009	<0.01	<0.005	0.009	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	<0.02	14.0	1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	>200000
11		30-Aug-01	10:50	<0.1	6.4	0.0005	<0.01	<0.005	0.017	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.03	13.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
12	MWD5																												
13		23-May-01	12:00	7.6	99.0	0.0017	<0.01	<0.005	<0.005	<0.05	<0.01	0.07	<0.05	<0.1	<0.1	365.0	<0.02	29.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
14		23-Aug-01	16:15	0.3	143.0	0.0020	<0.01	<0.005	<0.005	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	643.0	<0.02	42.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	2200	800
15	MWD6	26-Feb-01	16:05		8.4			<0.005	0.008		<0.01			<0.1	<0.1	<3		8.9	1	ND	ND	ND	ND	ND	ND	ND	ND	900	0
16		28-May-01	12:07	<0.1	9.8	0.0003	<0.01	<0.005	0.011	<0.05	<0.01	0.01	<0.05	<0.1	<0.1	<3	<0.02	13.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	4600	2800
17		22-Aug-01	16:15	<0.1	9.4	0.0004	<0.01	<0.005	0.009	<0.05	<0.01	0.01	<0.05	<0.1	<0.1	<3	0.05	12.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	95000
18	MWD7																												
19		23-May-01	17:04	0.2	21.0	0.0007	<0.01	<0.005	<0.005	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	12.0	<0.02	14.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
20		23-Aug-01	11:20	<0.1	21.0	0.0005	<0.01	<0.005	<0.005	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.03	12.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	1100	500
21	MWD8																												
22		23-May-01	13:15	<0.1	269.0	0.0016	<0.01	<0.005	<0.005	<0.05	<0.01	0.01	<0.05	<0.1	<0.1	<3	0.10	34.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	24	16
23		23-Aug-01	14:55	<0.1	285.0	0.0005	<0.01	<0.005	<0.005	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	<3	0.16	34.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	1000	200
24	MWD9	2-Mar-01	?		6.8			<0.005	0.028		<0.01			<0.1	<0.1	19.0		8.6	1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	0
25		21-May-01	17:13	<0.1	7.8	0.0010	<0.01	<0.005	0.024	<0.05	<0.01	0.01	<0.05	<0.1	<0.1	16.0	<0.02	13.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
26		29-Aug-01	11:45	0.2	8.7	0.0006	<0.01	<0.005	0.035	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	16.0	<0.02	12.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
27		4-Sep-01	12:00																									0 (0)	0 (0)
28	MWD10	26-Feb-01	11:51		6.8			<0.005	0.008		0.08			<0.1	<0.1	<3		15.0	1	ND	ND	ND	ND	ND	ND	ND	ND	5100	0
29		22-May-01	11:09	0.9	6.9	0.0010	<0.01	<0.005	<0.005	<0.05	0.03	0.02	<0.05	<0.1	<0.1	<3	0.20	27.0	1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
30		22-Aug-01	15:00	1.7	6.8	0.0005	<0.01	<0.005	<0.005	<0.05	0.02	0.02	<0.05	<0.1	<0.1	<3	0.38	26.0	<1	ND	ND	ND	ND	ND	ND	ND	*C	>200000	20000
31	MW14	8-Mar-01	15:38		0.3			<0.005	0.047		<0.01			<0.1	0.1	18.0		7.9	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	110
32														<0.1															
33																													
34	LED2	28-Mar-01	15:30																2	ND	ND	ND	ND	ND	ND	ND	ND	74000	1000
35		24-May-01	16:30							<0.05									<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
36		28-Aug-01	15:50	0.9	<0.1	0.0005	<0.01	<0.005	<0.005	<0.05	<0.01	0.11	<0.05	<0.1	0.1	<3	0.06	4.3	<1	ND	ND	ND	ND	ND	ND	ND	ND	180000	80000
37	LED3	29-Mar-01	14:00																<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
38																													
39																													
40	EXPL2	8-Mar-01	13:36		318.0			<0.005	<0.005		<0.01			<0.1	0.2	1477.0		57.0	3	ND	ND	ND	ND	ND	ND	ND	ND	0	0
41																													
42																													
43	Megasteel	8-Mar-01	17:20		7.4			<0.005	0.026		<0.01			<0.1	<0.1	<3		9.2	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	11000
44	(MW-1)	17-May-01	16:54	<0.1	8.0	0.0005	<0.01	<0.005	0.021	<0.05	<0.01	<0.01	<0.05	<0.1	<0.1	<3	0.10	15.0	1	ND	ND	ND	ND	ND	ND	ND	ND	1	0
45		22-Aug-01	10:50	<0.1	7.9	0.0005	<0.01	<0.005	0.029	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	<3	0.06	13.0	<1	ND	ND	ND	ND	ND	ND	ND	*C	110000	30000

Annex Table E.3.2 (1) Groundwater Quality of New Monitoring Wells

Bil.	Reference No.	Date of sampling	Time	Physical						Inorganic																				
				Temper -ature	Electric Conductivity (Cond.)	Turbidity (TUR)	Colour (COL)	pH	pH (Lab)	Oxygen Contents (O_2)	Oxygen Saturation (O_2)	Biochemical Oxigen Demand (BOD)	Chemical Oxigen Demand (COD)	Manganese (Mn)	Iron Ferrous / Soluble Iron (Fe^{2+})	Total iron (Fe-T)	Nitrate (NO_3^-)	Nitrite (NO_2^-)	Total Dissolved Solids (TDS)	Total Solids (TS)	Chloride (Cl)	Anionic Detergent (MBAS)	Ammoniacal Nitrogen (NH_3^+-N)	Fluoride (F)	Carbonate (CO_3^{2-})	Hydrogen Carbonate (HCO_3^-)	Total Hardness ($CaCO_3$)	Sodium (Na)	Calcium (Ca)	Potassium (K)
Drinking Water Quality Standards (1983)				-	-	5	15	6.5-8.5	-	-	-	-	-	0.1	-	0.3	10	-	1000	-	250	-	0.5	1.5	-	-	500	200	-	-
Measurement Unit				°C	us	NTU				mg/l	%DO	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	J1-1-1	28-Mar-01	13:15	30.8	251	436.8	60	5.9	6.0	0.6	8.3		5	0.100	0.61	0.72	6.311	42.000	0.11		4.0			<0.5	<1	80.0		17.0	9.5	6.5
2		24-May-01	13:27	29.0	246	936.4		6.0		9.9	127.6	4	0	0.000	13.10	13.65	0.15	0.258	0.12											
3		28-Aug-01	12:20	30.2	248	212.0		5.6	6.3	1.0		-10	6	9.900	17.70	12.25	27.00	0.109		88.0	12.0	<0.25	<0.50	<0.5	<1	53.0		13.0	4.3	5.6
4	J1-1-2	28-Mar-01	12:13	26.9	164	3.0	5	6.2	6.4	0.2	2.3		145	0.100	0.82	1.02	3.612	21.000	0.19		12.0			<0.5	<1	51.0		12.0	5.6	5.6
5		24-May-01	14:04	26.9	172	3.2		6.4	6.8	11.9	147.2	1	165	0.001	9.82	10.30	0.08	0.176	0.11	74.0	10.0	<0.25	<0.50	<0.5	11.0	21.0	23	11.0	4.3	5.1
6		28-Aug-01	13:10	26.8	154	1.4		5.9	6.4			-2	0	0.400	5.75	10.85	0.40	0.001		68.0	10.0	<0.25	<0.50	<0.5	<1	41.0		9.5	4.5	4.9
7	J2-1-2	23-Mar-01	11:35	27.2	84	1.5	5	5.9	5.8	0.1	1.4										2.0			<0.5	<1	17.0		3.6	3.4	1.0
8		21-May-01	13:45	26.5	108	0.5		6.3	7.4	14.8	182.6		33	0.001	1.84	2.91	5.70	0.038	1.00	32.0	<1	<0.25	0.50	<0.5	<1	21.0	14	1.3	4.3	0.7
9		16-Aug-01	14:25	26.9		0.8		5.6	5.6	0.6		6	164	1.800	0.23	2.43	2.60	0.026		58.0	2.0	<0.25	0.60	<0.5	<1	19.0		1.8	3.6	1.0
10	J2-1-3	23-Mar-01	12:28	27.2	25	1.1	5	4.7	5.4	2.2	27.0										3.0			<0.5	<1	5.0		1.8	1.7	1.0
11		21-May-01	14:36	26.5	29	0.4		4.5	7.1	19.5	242.1		20	0.011	1.85	2.91	5.90	0.030	0.02	20.0	2.0	<0.25	<0.50	<0.5	<1	7.0	5	1.5	1.1	0.9
12		16-Aug-01	15:20	26.8		0.5		4.7	5.6	1.5		4	165	2.900	0.15	1.60	2.40	0.027		30.0	2.0	<0.25	<0.50	<0.5	<1	14.0		3.2	1.1	1.0
13		4-Sep-01	10:35	26.9	26	0.6		5.1		1.8	21.9																			
14	J3-1	1-Mar-01	16:44	28.2	7130	19.0	150	6.5	6.3	1.1	13.8		29	0.100	0.42	0.67	0.103	1.400	2.73		1992.0			<0.5	<1	317.0		1085.0	123.0	39.0
15		22-May-01	13:05	30.1	7560	6.6		6.4	7.5	59.0	782.1	4	50	0.002	0.94	1.39	4.90	0.038	3.13	3632.0	1851.0	<0.25	<0.50	<0.5	<1	228.0	643	1025.0	114.0	37.0
16		27-Aug-01	12:00	27.5	4646	0.7		6.3		0.7		-8	26	0.000	0.37	0.92	0.60	0.013		2580.0	1231.0	<0.25	4.00	<0.5	<1	648.0		800.0	26.0	39.0
17	J3-2	1-Mar-01	16:36	27.8	4980	18.7	80	6.7	7.1	0.1	0.2		12	0.000	0.79	0.91	0.134	1.400	1.47		1170.0			<0.5	<1	669.0		860.0	28.0	39.0
18		22-May-01	12:14	27.8	5040	2.8		6.7	7.8	8.9	116.1	14	0	0.120	1.02	1.35	4.30	0.057	2.16	2180.0	1005.0	<0.25	<0.50	<0.5	<1	493.0	319	680.0	29.0	33.0
19		27-Aug-01	12:20	28.3	6620	7.0		6.2		1.0		-5	97	1.100	0.04	0.06	1.80	0.007		4096.0	2019.0	<0.25	3.90	<0.5	<1	289.0		1060.0	98.0	41.0
20	J4-2	9-Mar-01	12:35	28.2	2070	105.4	75	7.0	7.0	0.3	4.0		0						0.98		325.0			<0.5	<1	589.0		362.0	7.8	21.0
21		22-May-01	16:37	27.9	2100	92.0		6.9	8.4	66.2	844.2	10	0	0.010	1.02	1.85	0.002	0.009	0.94	900.0	283.0	<0.25	4.80	<0.5	<1	493.0	107	305.0	8.2	17.0
22		27-Aug-01	15:15	27.8	1931	6.6		6.6	7.0	0.5		-5	19	1.300	0.14	0.00	7.80	0.000		1120.0	331.0	<0.25	4.80	0.6	<1	584.0		335.0	7.0	21.0
23		3-Sep-01	15:40	28.0	1621	21.6		6.7		0.5	6.3																			
24	J5-2-2	20-Feb-01	12:23	28.2	311	3.9	5	6.8	6.9	7.3	23.3		0	0.010	1.63	2.94	4.981	0.052	144.00		7.0			<0.5	<1	136.0		39.0	6.9	5.3
25		17-May-01	14:40	28.6	337	1.4		6.7	8.3	8.4	108.7		2	0.037	1.85	2.81	5.52	0.044	0.18	178.0	8.0	<0.25	<0.50	<0.5	7.0	127.0	36	43.0	7.8	5.4
26		20-Aug-01	11:10	28.6	251	0.7		6.0	6.5	0.6		2	9	1.300	0.32	3.85	0.00	0.340		200.0	61.0	<0.25	<0.50	<0.5	<1	89.0		47.0	3.8	5.7
27	J5-2-3	20-Feb-01	12:45	28.7	400	4.3	5	6.6	6.7	0.2	2.3		167	0.000	1.54	3.01	0.002	4.90	145.20		64.0			<0.5	<1	91.0		50.0	7.8	5.2
28		17-May-01	13:59	28.5	402	1.8		6.5	8.0	9.4	121.0		4	0.000	2.82	1.73	0.004	5.500	0.19	184.0	59.0	<0.25	<0.50	<0.5	5.0	79.0	57	49.0	8.5	5.3
29		20-Aug-01	12:11	28.7	390	1.4		6.0	6.7	0.6		2	24	0.900	0.16	2.22	1.70	0.014		138.0	8.0	<0.25	0.90	<0.5	<1	117.0		39.0	3.8	5.6
30	J7-1-2	13-Mar-01	16:00	28.3	2130	16.4	500	7.5	7.5	0.0	0.4		8	0.100	0.51	0.69	1.417	3.800	1.03		119.0			0.7	<1	1122.0		388.0	38.0	31.0
31		18-May-01	16:35	28.5	2660	4.8		7.4	8.1	13.2	171.1		3	0.000	7.65	8.65	0.00	0.018	1.00	1488.0	109.0	<0.25	1.70	<0.5	139.0	950.0	150	445.0	17.0	33.0
32		21-Aug-01	12:00	28.1	2456	32.6		7.0	7.6	0.9		7	137	1.800	0.35	7.70	4.60	0.032		1688.0	118.0	<0.25	9.20	0.8	<1	1519.0		450.0	40.0	35.0
33		3-Sep-01	12:50	28.9	2196	3.9		7.2		0.8	10.1																			
34	J7-1-3	13-Mar-01	15:25	27.4	1199	2.9	150	7.4	7.6	0.3	2.7		32	0.100	0.76	0.82	2.162	4.800	1.89		59.0			0.7	<1	598.0		146.0	21.0	32.0
35		18-May-01	12:23	27.0	1369	25.3		7.3	7.6	16.0	201.1		51	0.000	7.69	7.30	2.20	0.000	1.00	632.0	68.0	<0.25	1.00	<0.5	<1	462.0	226	118.0	31.0	30.0
36		21-Aug-01	12:40	27.1	975	2.2		6.9	7.4	0.3		4	0	0.700	0.10	10.10	13.80	0.009		688.0	57.0	<0.25	0.80	0.6	<1	545.0		122.0	28.0	34.0
37		3-Sep-01	12:25	27.5	845	1.1		7.1		0.4	9.9																			
38	J7-1-4	13-Mar-01	14:44	27.9	2400	1.4	150	7.1	7.2	0.3	3.2		28	0.010	0.98	1.02	1.762	3.200	0.59		382.0			0.6	<1	667.0		355.0	17.0	25.0
39		18-May-01	11:22	27.4	2020	0.6		7.0	7.9	6.0	76.6		51	0.000	6.55	7.86	0.90	0.000	1.00	1000.0	279.0	<0.25	0.60	<0.5	89.0	300.0	216	267.0	19.0	121.0
40		21-Aug-01	13:40	27.6	1811	2.0		6.7	7.1	0.4		4	21	0.500	0.06	10.15	12.20	0.000		1076.0	301.0	<0.25	4.10	0.6	<1	562.0		260.0	18.0	22.0
41	J7-2	13-Mar-01	13:46	28.1	4190	2.4	150	7.0	7.2	0.3	4.3	1	0	0.100	1.22	1.89	0.962	2.400	0.83		820.0			0.4	<1	789.0		690.0	12.0	33.0
42		18-May-01	17:17	27.8	4460	1.0		6.9	7.2	9.8	124.3		5	0.000	9.00	13.90	0.00	0.000	1.00	2144.0	871.0	<0.25	6.90	<0.5	<1	800.0	333	695.0	26.0	31.0
43		21-Aug-01	15:00	27.9	3778	4.7		6.6	7.1	2.6		3	61	6.100	0.17	7.90	11.70	0.000		2244.0	887.0	<0.25	2.60	<0.5	<1	818.0		650.0	22.0	33.0
44	J8-1	27-Feb-01	13:45	32.0	29800	4.5	75	6.9	6.8	2.0	29.3		135	0.100	1.64	1.98	0.412	2.300	7.90		7868.0			<0.5	<1	2670.0		4760.0	173.0	160.0
45		25-May-01	16:09	31.5	25800	2.0		6.8	7.7	8.0	106.5	19	165	0.085	1.51	0.90	0.17	0.011	8.74	11464.0	5871.0	0.27	47.20	<0.5	91.0	1826.0	2321	3600.0	156.0	119.0
46		24-Aug-01	14:10	31.8	20937	0.9		6.6	7.1	0.6		10	165	0.800	0.00	0.67	0.30	0.021		13216.0	6649.0	<0.25	44.20	<0.5	<1	2359.0		3650.0	135.0	151.0
47		30-Aug-01	13:00	31.9	19429	1.8		6.6		0.2	3.5																			
48	J8-2	27-Feb-01	13:00	34.3	17990	27.1	5	6.2	6.5	0.3	4.1		129	0.100	2.23	2.64	0.112	1.100	12.90		4819.0			<0.5	<1	481.0		2490.0	175.0	70.0
49		25-May-01	17:04	33.7	16750	1.6		6.3	8.2	8.7	122.7	10	165	0.105	10.85	6.15	0.41	0.208	6.02	8032.0	4055.0	<0.25	13.00	<0.5	<1	444.0	1832	1970.0	186.0	61.0
50		24-Aug-01	15:15	33.7	13845	3.0		5.6	6.4	0.5		-4	9	2.700	0.41	1.39	0.30	0.037		13208.0	4630.0	<0.25	17.10	<0.5	<1	500.0		2180.0	166.0	67.0
51		30-Aug-01	12:45	33.6	13617	0.5		6.2		2.1	31.0																			
52	J9-1	27-Feb-01	16:17	29.5	10960	97.8	100	6.9	7.0	0.1	0.7		141	0.100	1.03	1.61	0.017	0.080	4.69		2655.0			<0.5	<1			1920.0	42.0	24.0
53		25-May-01	12:24	29.5	10670	1.9		6.9	8.2	14.3	187.9	10	165	0.009	5.60	7.25	0.04	0.070	4.18	4944.0	2338.0	<0.25	22.00	<0.5	114.0	1588.0	648	1680.0	40.0	52.0
54		24-Aug-01	11:00	29.3	9395	6.3		6.6	7.1	0.7		4	31	0.000	0.00	2.28	2.40	0.028		9256.0	2857.0	<0.25	20.20	0.9	<1	1313.0		1760.0	36.0	58.0
55	J9-2	1-Mar-01	12:56	29.6	11830	0.5	5	6.2	6.7	0.1	0.1		141	0.100	1.32	1.68	0.712	1.800	5.83		3246.0			<0.5	<1			1810.0	83.0	72.0
56		25-May-01	13:04	29.9	11800	3.7		6.3	7.5	14.7	194.0	16	165	0.041	10.25	6.75	0.04	0.050	4.59	5272.0	2687.0	<0.25	11.10	<0.5	14.0	418.0	1050	1430.0	94.0	42.0
57		24-Aug-01	11:50	29.6	10221	0.7		6.0	7.5	0.3		-1	0	1.100	0.05	1.62	3.90	0.000		6392.0	3029.0	<0.25	12.00	<0.5	<1	966.0		2210.0	82.0	49.0
58	J10-1-1	23-Mar-01	17:03	31.0	250	9.3	5	6.2	5.8	0.5	6.6		0	0.100	0.49	0.82	4.129	2.900	0.20		3.0			<0.5	<1	33.0		3.5	5.2	1.6
59		24-May-01	12:20	31.6	270	21.2		6.3	6.5	6.3	72.2	4	78	0.000	1.84	1.28	4.40	0.001	0.12	86.0	2.0	<0.25	1.00	<0.5	<1	18.0	12	1.8	2.7	1.2
60		28-Aug-01	11:00	31.0	182	9.6		5.7	5.5	1.2		8	132	0.700	2.41	9.10	4.30	0.013		72.0	4.0	<0.25	1.20	<0.5	<1	14.0		3.0	1.4	1.3
61	J10-1-2	23-Mar-01	16:18	27.3	224	0.9	5	6.4	6.3	0.0	0.3		69	0.100	1.22	1.46	3.469	1.700	0.21		20.0			<0.5	<1	55.0		22.0	3.4	3.5
62		24-May-01	11:41	27.1	218	1.7		6.4	7.5	7.5	94.1	1	0	0.080	10.30	11.30	0.08	0.000	0.13	86.0	16.0	<0.25	<0.50	<0.5	1.0	39.0	14	17.0	3.6	2.6
61		28-Aug-01	10:25	27.1	198	0.3		5.8	6.4	0.6		-8	47	2.000	4.00	8.75	3.40	0.025		98.0	22.0	<0.25	0.60	<0.5	<1	60.0		24.0	3.1	3.4

Note: *A *B *C for details are presented in Table E.3.12 of the main texts.

Annex Table E.3.2 (2) Groundwater Quality of New Monitoring Wells

Bil.	Reference No.	Date of sampling	Time	Inorganic	Heavy Metals, etc.																	Pesticide etc.						Organic	
				Aluminium (Al)	Magnesium (Mg)	Mercury (Hg)	Cadmium (Cd)	Selenium (Se)	Arsenic (As)	Cyanide (CN)	Lead (Pb)	Chromium (Cr)	Silver (Ag)	Copper (Cu)	Zinc (Zn)	Sulfate (SO_4)	Phosphorous (P)	Silica (SiO_2)	Oil & Grease	Phenol	Chloroform	Organochlorine Pesticides	Organophorus Pesticides	BTEX	Volatile Organic Compounds (VOC)	Semivolatile Organic Compounds (SVOC)	Total Petroleum Hydrocarbon (TPH)	Total Coliform Bacteria	Escherichia Coli (E-Coli)
Drinking Water Quality Standards (1983)				0.2	150	0.001	0.005	0.1	0.05	0.1	0.05	0.05	0.05	1	5	400	-	-	0.3	0.002	-	-	-	-	-	-	-	-	-
Measurement Unit				mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
1	J1-1-1	28-Mar-01	13:15		2.6	0.0022		<0.005	0.038		<0.01			<0.1	0.4	<3		26.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	>200000
2		24-May-01	13:27							<0.05									<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
3		28-Aug-01	12:20	<0.1	2.9	0.0006	<0.01	<0.005	<0.005	<0.05	<0.01	0.07	<0.05	<0.1	<0.1	<3	0.05	12.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	4000	2800
4	J1-1-2	28-Mar-01	12:13		2.9	0.0002		<0.005	0.007		<0.01			<0.1	0.4	<3		12.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
5		24-May-01	14:04	<0.1	2.9	0.0008	<0.01	<0.005	<0.005	<0.05	<0.01	0.06	<0.05	<0.1	<0.1	<3	<0.02	16.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
6		28-Aug-01	13:10	<0.1	3.5	0.0005	<0.01	<0.005	0.010	<0.05	<0.01	0.06	<0.05	<0.1	<0.1	<3	0.05	15.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	5700	3000
7	J2-1-2	23-Mar-01	11:35		0.5			<0.005	0.025		<0.01			<0.1	0.1	<3		12.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
8		21-May-01	13:45	<0.1	0.8	<0.0002	<0.01	<0.005	0.036	<0.05	<0.01	0.09	<0.05	<0.1	<0.1	<3	<0.02	15.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
9		16-Aug-01	14:25	<0.1	0.7	0.0006	<0.01	<0.005	0.053	<0.05	<0.01	0.08	<0.05	<0.1	<0.1	<3	0.03	14.0	2	ND	ND	ND	ND	ND	ND	ND	ND	0	0
10	J2-1-3	23-Mar-01	12:28		<0.1			<0.005	<0.005		<0.01			<0.1	<0.1	<3		11.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
11		21-May-01	14:36	<0.1	0.5	0.0005	<0.01	<0.005	0.01	<0.05	<0.01	0.05	<0.05	<0.1	<0.1	<3	<0.02	14.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
12		16-Aug-01	15:20	0.6	0.5	0.0008	<0.01	<0.005	0.133	<0.05	<0.01	0.17	<0.05	<0.1	<0.1	<3	<0.02	10.0	2	ND	ND	ND	ND	ND	ND	ND	ND	0	0
13		4-Sep-01	10:35				<0.01	<0.005																				0	0
14	J3-1	1-Mar-01	16:44		71.0			<0.005	0.026		<0.01			<0.1	0.4	6.0		7.9	<1	ND	ND	ND	ND	ND	ND	ND	ND	9900	0
15		22-May-01	13:05	<0.1	87.0	0.0028	<0.01	<0.005	0.036	<0.05	<0.01	0.03	<0.05	<0.1	0.2	<3	<0.02	15.0	1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
16		27-Aug-01	12:00	<0.1	57.0	0.0006	<0.01	<0.005	0.008	<0.05	<0.01	0.04	<0.05	<0.1	<0.1	<3	0.19	27.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	190000	7300
17	J3-2	1-Mar-01	16:36		53.0			<0.005	0.005		<0.01			<0.1	<0.1	<3		17.8	<1	ND	ND	ND	ND	ND	ND	ND	ND	4100	0
18		22-May-01	12:14	<0.1	60.0	0.0015	<0.01	<0.005	0.026	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	<3	0.10	30.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
19		27-Aug-01	12:20	<0.1	80.0	0.0003	<0.01	<0.005	0.030	<0.05	<0.01	0.15	<0.05	<0.1	0.2	<3	0.03	14.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	2500	1100
20	J4-2	9-Mar-01	12:35		18.0			<0.005	0.007		<0.01			<0.1	<0.1	<3		17.3	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	>200000
21		22-May-01	16:37	0.1	21.0	0.0006	<0.01	<0.005	0.009	<0.05	<0.01	0.01	<0.05	<0.1	<0.1	<3	0.60	29.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
22		27-Aug-01	15:15	0.2	18.0	0.0005	<0.01	<0.005	0.009	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.28	25.0	<1	ND	ND	ND	ND	ND	ND	ND	*C	>200000	3700
23		3-Sep-01	15:40																									0 (30)	0 (0)
24	J5-2-2	20-Feb-01	12:23		1.1			<0.005	0.058		<0.01			<0.1	<0.1	<3		8.9	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	0
25		17-May-01	14:40	0.2	4.0	0.0004	<0.01	<0.005	0.008	<0.05	<0.01	<0.01	<0.05	<0.1	<0.1	7.0	<0.02	14.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
26		20-Aug-01	11:10	0.1	3.5	0.0005	<0.01	<0.005	0.085	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.03	14.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	1800	0
27	J5-2-3	20-Feb-01	12:45		9.5			<0.005	0.009		<0.01			<0.1	<0.1	<3		8.6	<1	0.0124	ND	ND	ND	ND	ND	ND	ND	>200000	0
28		17-May-01	13:59	<0.1	8.7	0.0012	<0.01	<0.005	0.006	<0.05	<0.01	<0.01	<0.05	<0.1	<0.1	<3	<0.02	14.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	10	2
29		20-Aug-01	12:11	<0.1	3.9	0.0006	<0.01	<0.005	0.015	<0.05	<0.01	0.01	<0.05	<0.1	<0.1	9.0	0.03	13.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	1900	810
30	J7-1-2	13-Mar-01	16:00		17.0	<0.0002		<0.005	0.091		0.01			<0.1	<0.1	<3		23.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	20
31		18-May-01	16:35	<0.1	26.0	0.0004	<0.01	<0.005	0.249	<0.05	<0.01	0.04	<0.05	<0.1	<0.1	<3	0.30	31.0	<1	ND	ND	ND	ND	ND	*A	*B	*C	34	24
32		21-Aug-01	12:00	<0.1	43.0	0.0005	<0.01	<0.005	0.173	<0.05	<0.01	0.04	<0.05	<0.1	<0.1	<3	0.19	32.0	<1	ND	ND	ND	ND	ND	ND	ND	*C	20000	17000
33		3-Sep-01	12:50																									0 (0)	0 (0)
34	J7-1-3	13-Mar-01	15:25		34.0			<0.005	0.026		<0.01			<0.1	<0.1	<3		54.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	110
35		18-May-01	12:23	<0.1	36.0	0.0013	<0.01	<0.005	0.053	<0.05	<0.01	0.01	<0.05	<0.1	<0.1	<3	0.20	59.0	<1	ND	ND	ND	ND	ND	*A	*B	*C	2	2
36		21-Aug-01	12:40	<0.1	35.0	0.0005	<0.01	<0.005	0.061	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.33	63.0	<1	ND	ND	ND	ND	ND	ND	ND	*C	62000	16000
37		3-Sep-01	12:25																									0 (0)	0 (0)
38	J7-1-4	13-Mar-01	14:44		40.0			<0.005	0.029		<0.01			<0.1	<0.1	<3		33.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	20
39		18-May-01	11:22	<0.1	41.0	0.0023	<0.01	<0.005	0.050	<0.05	<0.01	<0.01	<0.05	<0.1	<0.1	<3	0.20	44.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	32	16
40		21-Aug-01	13:40	<0.1	36.0	0.0007	<0.01	<0.005	0.108	<0.05	<0.01	0.01	<0.05	<0.1	<0.1	<3	0.17	42.0	<1	ND	ND	ND	ND	ND	ND	ND	*C	57000	18000
41	J7-2	13-Mar-01	13:46		56.0			<0.005	<0.005		<0.01			<0.1	<0.1	<3		19.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	>200000	80
42		18-May-01	17:17	<0.1	65.0	0.0016	<0.01	<0.005	<0.005	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.10	22.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	2	2
43		21-Aug-01	15:00	<0.1	56.0	0.0007	<0.01	<0.005	<0.005	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	<3	0.16	21.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	54000	31000
44	J8-1	27-Feb-01	13:45		539.0			<0.005	0.005		<0.01			<0.1	0.2	4.0		18.1	2	ND	ND	ND	ND	ND	ND	ND	ND	>200000	>200000
45		25-May-01	16:09	<0.1	469.0	<0.0002	<0.01	<0.005	<0.005	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.20	29.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
46		24-Aug-01	14:10	<0.1	478.0	0.0007	<0.01	<0.005	<0.005	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	<3	0.13	29.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	2000	600
47		30-Aug-01	13:00																									0	0
48	J8-2	27-Feb-01	13:00		314.0			<0.005	<0.005		<0.01			<0.1	<0.1	<3		13.5	2	ND	ND	ND	ND	ND	ND	ND	ND	36	8
49		25-May-01	17:04	<0.1	332.0	0.0002	<0.01	<0.005	0.013	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	<0.02	25.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
50		24-Aug-01	15:15	<0.1	301.0	0.0008	<0.01	<0.005	0.025	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	<3	0.06	22.0	<1	ND	ND	ND	ND	ND	ND	*B	*C	0	0
51		30-Aug-01	12:45																									0 (0)	0 (0)
52	J9-1	27-Feb-01	16:17		121.0			<0.005	0.007		<0.01			<0.1	<0.1	<3		22.6	2	ND	ND	ND	ND	ND	ND	ND	ND	3200	0
53		25-May-01	12:24	<0.1	133.0	<0.0002	<0.01	<0.005	0.008	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.40	32.0	<1	ND	ND	ND	ND	ND	ND	*B	*C	0	0
54		24-Aug-01	11:00	0.4	119.0	0.0004	<0.01	<0.005	<0.005	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.27	29.0	<1	ND	ND	ND	ND	ND	ND	*B	*C	2800	1100
55	J9-2	1-Mar-01	12:56		189.0			<0.005	<0.005		<0.01			<0.1	<0.1	<3		10.2	<1	ND	ND	ND	ND	ND	ND	ND	ND	1800	2
56		25-May-01	13:04	<0.1	198.0	0.0012	<0.01	<0.005	<0.005	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	<3	0.03	16.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
57		24-Aug-01	11:50	<0.1	211.0	0.0005	<0.01	<0.005	<0.005	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.05	15.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
58	J10-1-1	23-Mar-01	17:03		2.1	0.0009		<0.005	0.030		<0.01			<0.1	0.1	<3		8.5	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
59		24-May-01	12:20	0.2	1.3	0.0013	<0.01	<0.005	0.111	<0.05	<0.01	0.10	<0.05	<0.1	0.1	<3	<0.02	12.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
60		28-Aug-01	11:00	<0.1	0.8	0.0009	<0.01	<0.005	0.096	<0.05	<0.01	0.10	<0.05	<0.1	<0.1	<3	0.03	9.9	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
61	J10-1-2	23-Mar-01	16:18		2.1			<0.005	0.017		<0.01			<0.1	<0.1	<3		8.5	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
62		24-May-01	11:41	<0.1	1.3	<0.0002	<0.01	<0.005	0.008	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	<0.02	14.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
61		28-Aug-01	10:25	<0.1	2.6	0.0007	<0.01	<0.005		<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.05	12.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	4700	3600

Note: *A *B *C for details are presented in Table E.3.12 of the main texts.

Annex Table E.3.3 (1) Surface Water Quality

Bil.	Reference No.	Date of sampling	Time	Physical						Inorganic																				
				Temper -ature	Electric Conductivity (Cond.)	Turbidity (TUR)	Colour (COL)	pH	pH (Lab)	Oxygen Contents (O_2)	Oxygen Saturation (O_2)	Biochemical Oxigen Demand (BOD)	Chemical Oxigen Demand (COD)	Manganese (Mn)	Iron Ferrous / Soluble Iron (Fe^{2+})	Total iron (Fe-T)	Nitrate (NO_3^-)	Nitrite (NO_2^-)	Total Dissolved Solids (TDS)	Total Solids (TS)	Chloride (Cl)	Anionic Detergent (MBAS)	Ammoniacal Nitrogen (NH_3^+-N)	Fluoride (F)	Carbonate (CO_3^{2-})	Hydrogen Carbonate (HCO_3^-)	Total Hardness ($CaCO_3$)	Sodium (Na)	Calcium (Ca)	Potassium (K)
Drinking Water Quality Standards (1983)				-	-	5	15	6.5-8.5	-	-	-	-	-	0.1	-	0.3	10	-	1000	-	250	-	0.5	1.5	-	-	500	200	-	-
Measurement Unit				°C	us	NTU				mg/l	%DO	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1	S1	15-Feb-01	15:30	33.2	981	636.3	5	7.3	7.9	8.5	121.3		14	0.000	0.18	0.62	0.021	0.200	30.10		33.0			<0.5	5.0	184.0		14.0	100.0	4.0
2		28-May-01	16:50	30.0	941	17.2		7.3	8.3	7.7	104.7	<1	18	0.077	0.42	0.19	37.00	0.181	0.42	596.0	28.0	<0.25	<0.50	1.0	7.0	122.0	353	17.0	82.0	2.8
3		29-Aug-01	15:30	30.1	616	472.0		7.1	7.4	3.3	44.0	-5	27	0.100	0.06	0.09	1.70	0.005		576.0	25.0	<0.25	<0.50	1.0	<1	120.0		11.0	81.0	3.5
4	S2	14-Feb-01	15:45	30.3	97	12.5	5	4.1	4.1	31.7	444.9		0	0.010	0.41	1.62	0.09	1.012	33.90		2.0			<0.5	<1	<1		1.8	1.7	1.8
5		21-May-01	11:35	31.6	92	0.6		4.2	4.4	55.1	749.5		0	0.002	1.78	2.01	0.40	0.003	1.00	42.0	3.0	<0.25	<0.50	<0.5	<1	<1	6	4.5	1.5	1.3
6		20-Aug-01	13:41	31.6	72	2.1		4.1	3.7	3.5	48.1	1	31	0.200	0.00	0.12	1.30	0.004		40.0	3.0	<0.25	<0.50	<0.5	<1	<1		1.7	2.3	1.8
7	S3	15-Feb-01	13:00	28.1	27	11.3	250	4.3	5.0	9.8			0	0.100	0.58	1.52	0.16	1.536	8.30		<1			<0.5	<1	<1		1.3	2.3	1.2
8		24-May-01	14:30	28.6	36	2.3		4.7	5.1	5.3	68.4	3	0	0.030	1.84	2.11	0.30	0.017	0.03	84.0	6.0	<0.25	0.90	<0.5	<1	<1	36	1.3	13.0	0.7
9		28-Aug-01	13:20	28.6	34	1.5		4.6	4.7	0.9	11.4	-16	32	0.300	0.70	2.68	3.80	0.025		108.0	10.0	<0.25	0.80	<0.5	<1	4.0		2.4	2.6	1.0
10	S4	15-Feb-01	12:30	28.1	37	1.8	500	3.9	4.6	58.2			112	0.200	0.66	1.78	0.14	1.622	12.60		4.0			<0.5	<1	<1		1.2	2.6	1.5
11		24-May-01	12:40	26.4	42	1.6		4.6	4.8	22.2	280.1	2	103	0.720	1.67	2.34	0.30	0.024	0.03	92.0	20.0	<0.25	0.60	<0.5	<1	<1	15	1.1	4.3	0.6
12		28-Aug-01	11:17	26.2	47	1.7		4.3	4.0	1.1	13.6	-7	35	0.800	1.07	1.83	3.80	0.023		154.0	7.0	0.52	2.80	<0.5	<1	<1		1.5	1.9	0.4
13	S5	14-Feb-01	13:09	29.9	103	4.7	600	4.1	4.3	30.3	400.6		69	0.100	0.26	0.81	0.22	2.617	32.70		12.0			<0.5	<1	<1		3.3	2.6	4.8
14		22-May-01	13:56	38.2	96	9.5		4.6	8.4	40.0	606.7	4	80	0.119	2.95	3.27	0.87	0.002	0.14	720.0	34.0	<0.25	<0.50	1.2	23.0	117.0	413	14.0	96.0	2.5
15		27-Aug-01	12:40	31.3	67	25.9		4.8	4.4	13.6	184.3	-3	165	0.700	0.27	1.57	0.00	0.000		218.0	13.0	0.38	2.70	<0.5	<1	<1		5.2	1.3	3.8
16	S6	15-Feb-01	11:20	30.8		1085.0	20	6.5	7.3	135.7			3	0.200	0.21	0.04	0.07	0.192	397.00		163.0			<0.5	<1	74.0		157.0	16.0	14.0
17		17-May-01	17:30	30.7	1484	1098.0		7.2	7.8	10.3	132.7		3	0.205	1.12	0.03	36.00	0.269	58.20	792.0	168.0	<0.25	<0.50	<0.5	<1	150.0	117	132.0	14.0	12.0
18		20-Aug-01	15:30	30.3	2041	57.4		6.8	6.7	3.5	47.5	3	14	1.800	0.07	0.49	0.80	0.350		1236.0	508.0	<0.25	<0.50	<0.5	<1	124.0		285.0	23.0	19.0
19	S7	14-Feb-01	11:11	28.6	118	46.7	40	4.3	4.4	32.2	418.1		1	0.001	0.53	1.30	1.90	0.050	7.90		6.0			<0.5	<1	<1		3.0	3.4	3.0
20		17-May-01	15:00	32.5	165	5.4		5.2	6.0	10.0	137.7		1	0.001	0.65	1.65	2.20	0.048	40.50	144.0	6.0	<0.25	<0.50	<0.5	<1	7.0	41	13.0	4.8	5.5
21		20-Aug-01	16:30	31.8	1514	4.6		4.9	4.6	3.7	49.6	0	0	0.300	0.05	0.25	0.80	0.002		112.0	6.0	<0.25	<0.50	<0.5	<1	<1		6.2	4.1	5.0
22	S8	14-Feb-01	11:55	28.5	118	27.8	10	5.7	6.5	35.9	467.0		0	0.100	0.46	1.17	0.116	1.400	301.00		8.0			<0.5	<1	7.0		3.3	6.9	3.2
23		22-May-01	11:20	30.3	179	221.9		6.5	7.0	15.6	210.7	3	0	0.000	1.69	2.35	0.80	0.003	0.15	264.0	20.0	<0.25	<0.50	<0.5	<1	16.0	36	14.0	9.9	4.1
24		22-Aug-01	14:28	28.1	120	6.7		6.8	6.3	1.3	16.4	6	0	9.400	2.03	4.75	7.50	0.191		566.0	12.0	<0.25	<0.50	<0.5	<1	12.0		9.5	8.1	4.0
25	S9	15-Feb-01	10:16	26.3	73	119.2	5	6.6	7.0	9.6	35.6		2.3	0.200	0.49	1.21	0.101	1.20	33.90		4.0			<0.5	<1	18.0		3.3	6.1	2.6
26		21-May-01	11:00	28.4	111	84.9		7.0	6.8	46.9	653.8		2	0.001	1.02	1.72	2.30	0.046	0.40	74.0	5.0	<0.25	<0.50	<0.5	<1	16.0	19	5.2	5.6	2.7
27		29-Aug-01	9:35	27.8	148	169.0		7.1	6.2	50.7	4.0	-2	0	0.100	0.02	0.13	3.90	0.002		152.0	15.0	<0.25	<0.50	<0.5	<1	31.0		11.0	13.0	4.8
28	S10	14-Feb-01	14:30	32.5	227	62.6	600	4.0	4.0	31.7	432.5		18	<0.1	0.39	2.36	<0.06	1.488	73.30		12.0			<0.5	<1	<1		7.9	6.9	4.1
29		18-May-01	17:40	31.6	241	31.5		3.7	4.1	11.7	163.4		18	0.000	9.50	7.80	0.00	0.000	0.15	266.0	24.0	<0.25	2.40	<0.5	<1	<1	36	8.5	6.5	7.1
30		21-Aug-01	15:25	28.2	150	6.3		3.8	3.5	1.1	14.3	2	165	0.100	0.31	0.72	3.30	0.004		216.0	18.0	<0.25	6.20	<0.5	<1	<1		7.8	1.3	4.9

Annex Table E.3.3 (2) Surface Water Quality

Bil.	Reference No.	Date of sampling	Time	Inorganic	Heavy Metals, etc.																	Pesticides etc.						Organic	
				Aluminium (Al)	Magnesium (Mg)	Mercury (Hg)	Cadmium (Cd)	Selenium (Se)	Arsenic (As)	Cyanide (CN)	Lead (Pb)	Chromium (Cr)	Silver (Ag)	Copper (Cu)	Zinc (Zn)	Sulfate (SO_4)	Phosphorous (P)	Silica (SiO_2)	Oil & Grease	Phenol	Chloroform	Organochlorine Pesticides	Organophorus Pesticides	BTEX	Volatile Organic Compounds (VOC)	Semivolatile Organic Compounds (SVOC)	Total Petroleum Hydrocarbon (TPH)	Total Coliform Bacteria	Escherichia Coli (E-Coli)
Drinking Water Quality Standards (1983				0.2	150	0.001	0.005	0.1	0.05	0.1	0.05	0.05	0.05	1	5	400	-	-	0.3	0.002	-	-	-	-	-	-	-	-	-
Measurement Unit				mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	cfu/100ml	cfu/100ml
1	S1	15-Feb-01	15:30		39.0			<0.005	0.018		<0.01			<0.1	<0.1	215.0		7.1	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
2		28-May-01	16:50	0.4	36.0	0.0004	0.09	<0.005	0.018	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	212.0	<0.02	11.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	40	20
3		29-Aug-01	15:30	0.8	39.0	0.0017	<0.01	<0.005	<0.005	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	233.0	0.03	6.6	<1	ND	ND	ND	ND	ND	ND	ND	*C	0	0
4	S2	14-Feb-01	15:45		0.7			<0.005	<0.005		<0.01			<0.1	<0.1	16.0		3.3	<1	ND	ND	ND	ND	ND	ND	ND	ND	4	0
5		21-May-01	11:35	0.4	0.6	0.0002	<0.01	<0.005	<0.005	<0.05	<0.01	0.04	<0.05	<0.1	<0.1	10.0	0.20	7.3	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
6		20-Aug-01	13:41	0.4	0.7	0.0008	<0.01	<0.005	<0.005	<0.05	0.02	0.06	<0.05	<0.1	<0.1	17.0	<0.02	7.6	<1	ND	ND	ND	ND	ND	ND	ND	ND	370	140
7	S3	15-Feb-01	13:00		0.7			<0.005	<0.005		<0.01			<0.1	<0.1	<3		4.3	<1	ND	ND	ND	ND	ND	ND	ND	ND	38000	36000
8		24-May-01	14:30	<0.1	0.8	0.0015	<0.01	<0.005	<0.005	<0.05	<0.01	<0.01	<0.05	<0.1	<0.1	<3	<0.02	8.9	<1	ND	ND	ND	ND	ND	ND	ND	ND	45	0
9		28-Aug-01	13:20	0.6	0.7	0.0012	<0.01	<0.005	<0.005	<0.05	0.02	0.02	<0.05	<0.1	<0.1	<3	0.05	7.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	180000	80000
10	S4	15-Feb-01	12:30		2.1	0.0008		<0.005	<0.005		<0.01			<0.1	<0.1	<3		7.6	<1	ND	ND	ND	ND	ND	ND	ND	ND	200	0
11		24-May-01	12:40	0.3	1.1	0.0009	<0.01	<0.005	<0.005	<0.05	<0.01	0.01	<0.05	<0.1	<0.1	<3	0.00	7.3	<1	ND	ND	ND	ND	ND	ND	ND	ND	120	0
12		28-Aug-01	11:17	0.4	0.7	0.0007	<0.01	<0.005	<0.005	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	<3	0.03	3.7	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
13	S5	14-Feb-01	13:09			0.0004		<0.005	<0.005		<0.01			<0.1	<0.1	<3		3.1	<1	ND	ND	ND	ND	ND	ND	ND	ND	1700	250
14		22-May-01	13:56	0.5	42.0	0.0004	<0.01	<0.005	<0.005	<0.05	<0.01	<0.01	<0.05	<0.1	<0.1	244.0	<0.02	8.8	<1	ND	ND	ND	ND	ND	ND	ND	ND	600	400
15		27-Aug-01	12:40	0.8	1.5	0.0006	<0.01	<0.005	<0.005	<0.05	<0.01	0.08	<0.05	<0.1	<0.1	<3	0.06	7.4	<1	ND	ND	ND	ND	ND	ND	ND	ND	43000	30000
16	S6	15-Feb-01	11:20		27.0			<0.005	<0.005		0.01			<0.1	<0.1	163.0		16.8	<1	ND	ND	ND	ND	ND	ND	ND	ND	2300	200
17		17-May-01	17:30	2.1	20.0	0.0022	<0.01	<0.005	0.010	<0.05	<0.01	0.01	<0.05	<0.1	<0.1	43.0	0.00	32.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
18		20-Aug-01	15:30	0.3	108.0	0.0005	<0.01	<0.005	<0.005	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	98.0	0.05	21.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	700	220
19	S7	14-Feb-01	11:11		4.2	0.0004		<0.005	<0.005		<0.01			<0.1	<0.1	33.0		5.3	<1	ND	ND	ND	ND	ND	ND	ND	ND	2300	800
20		17-May-01	15:00	0.4	7.1	<0.0002	<0.01	<0.005	<0.005	<0.05	<0.01	0.02	<0.05	<0.1	<0.1	48.0	<0.02	8.3	<1	ND	ND	ND	ND	ND	ND	ND	ND	260	70
21		20-Aug-01	16:30	0.8	7.4	0.0005	<0.01	<0.005	<0.005	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	48.0	0.03	7.1	<1	ND	ND	ND	ND	ND	ND	ND	ND	0	0
22	S8	14-Feb-01	11:55		2.1	0.0011		<0.005	0.008		0.01			<0.1	<0.1	22.0		7.6	<1	ND	ND	ND	ND	ND	ND	ND	ND	2400	200
23		22-May-01	11:20	1.2	2.8	0.0016	<0.01	<0.005	0.010	<0.05	<0.01	0.06	<0.05	<0.1	<0.1	22.0	<0.02	17.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	1600	600
24		22-Aug-01	14:28	4.7	1.9	0.0005	<0.01	<0.005	0.009	0.10	0.02	0.06	<0.05	<0.1	<0.1	19.0	0.05	17.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	8000	2000
25	S9	15-Feb-01	10:16		0.5			<0.005	0.007		0.01			<0.1	<0.1	8.0		2.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	9800	1100
26		21-May-01	11:00	0.9	1.2	0.0007	<0.01	<0.005	0.014	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	8.0	0.03	13.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	6000	3800
27		29-Aug-01	9:35	1.6	1.6	0.0005	<0.01	<0.005	0.020	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	14.0	0.06	15.0	<1	ND	ND	ND	ND	ND	ND	ND	ND	50000	24000
28	S10	14-Feb-01	14:30		3.7			<0.005	0.006		0.02			<0.1	<0.1	3.0		2.3	<1	ND	ND	ND	ND	ND	ND	ND	ND	1100	140
29		18-May-01	17:40	0.8	4.9	0.0002	<0.01	<0.005	<0.005	<0.05	<0.01	0.06	<0.05	<0.1	<0.1	4.0	0.50	7.9	<1	ND	ND	ND	ND	ND	ND	ND	ND	460	160
30		21-Aug-01	15:25	0.5	1.6	0.0005	<0.01	<0.005	<0.005	<0.05	<0.01	0.03	<0.05	<0.1	<0.1	<3	0.95	2.2	<1	ND	ND	ND	ND	ND	ND	ND	ND	1000	700

SECTOR F

PHYSICAL CHARACTERISTICS OF GROUNDWATER BASIN

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

FINAL REPORT

SECTOR F

PHYSICAL CHARACTERISTICS OF GROUNDWATER BASIN

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SECTOR F

PHYSICAL CHARACTERISTICS OF GROUNDWATER BASIN

1. INTRODUCTION

The physical characteristics of groundwater basin in the Langat Basin were studied during Phase I and Phase II of the Study. An aquifer for the Study was identified and its configuration, including areal distribution and thickness, boundary conditions, and physical properties were studied. The groundwater monitoring system was also established.

During Phase I, topographical and hydrogeological characteristics of the Langat Basin were studied by the existing information and data, field reconnaissance and geophysical survey. Three aquifers were identified in the Langat Basin and the neighboring Klang River Basin. These are: (1) Quaternary Sediments distributing in the lowlands of the Langat Basin, (2) Riverside Alluvial Sediments found in the hill and mountain area of the Langat Basin, and (3) Limestone and Marble Formation distributing in the Klang River Basin.

The Study was concentrated on (1), the Quaternary Sediments (hereafter called the Aquifer) distributing in the lowlands of the Langat Basin (hereafter called the Groundwater Basin or the Basin). A detailed field survey was conducted in Phase II in order to obtain the physical properties of the Groundwater Basin, including areal distribution, thickness, and boundary conditions of the Aquifer, and physical properties of Quaternary sediments consisting the Aquifer System. The survey included soil investigation, pumping tests, establishment of groundwater monitoring wells and installation of extensometer.

This **Sector F** presents the results of the field survey (**Chapter 2**), and describes general characteristics of the Langat Basin (**Chapter 3**) and the physical characteristics of the Groundwater Basin (**Chapter 4**), which was used for groundwater modelling and simulations to evaluate groundwater level change, sustainable yield of groundwater, ground subsidence, seawater intrusion and pollution dispersion.

2. FIELD SURVEY

2.1 Introduction

The results of field survey in Phase I and Phase II are presented in this chapter. The field survey consisted of the following items:

Phase I

- TEM (Transient Electro-Magnetic Survey): 93 stations
- 2D (2-dimensional) resistivity exploration: 3 survey lines (152 points)

Phase II

- Soil investigation: 10 locations
- Pumping tests: 3 locations
- Establishment of groundwater monitoring wells: 10 locations
- Installation of extensometer: 1 location

The geophysical survey of Phase I, namely TEM and 2D resistivity exploration, is described briefly. The results of TEM, together with those of the existing surveys of JMG, were interpreted to obtain a general picture of the bedrock surface and to estimate the boundary between fresh and saline water. The soil investigation, consisting of boring, sampling, laboratory soil tests, electrical logging and seismic survey, is documented and their results are compiled for further usage.

The pumping tests and interpretation of results are covered in **Sector G**. Groundwater monitoring wells and their installation records are described in this sector, however, long-term monitoring records of groundwater level are presented in **Sectors E and G**. Installation of extensometer and its monitoring records are described in **Sector E**.

Conditions of the field survey at sites can be seen in **Data Book F.2.1**.

2.2 Geophysical Survey

2.2.1 General

(1) Objectives of Geophysical Survey

The objectives of TEM (Transient Electro-Magnetic Survey) and 2D (2-dimensional) resistivity exploration are as follows:

TEM

- To estimate rough boundaries between soil layers consisting the Aquifer System and the bedrock; and
- To estimate location of boundary between fresh and saline water.

2D Resistivity Exploration

- To obtain profiles of the Aquifer System at the north-east boundary of the Aquifer, where inflow of groundwater from upstream is expected; and
- To obtain profiles of the Aquifer at the vicinity of the planned pumping tests.

(2) Scope and Locations of Geophysical Survey

In the Study, TEM was carried out at 93 stations and 2D resistivity prospecting was carried out along 3 survey lines. The location of surveys was selected to fill the gaps where existing data was insufficient. **Figure F.2.1** shows the locations of TEM and 2D resistivity prospecting.

(3) Methodologies and Equipment Used

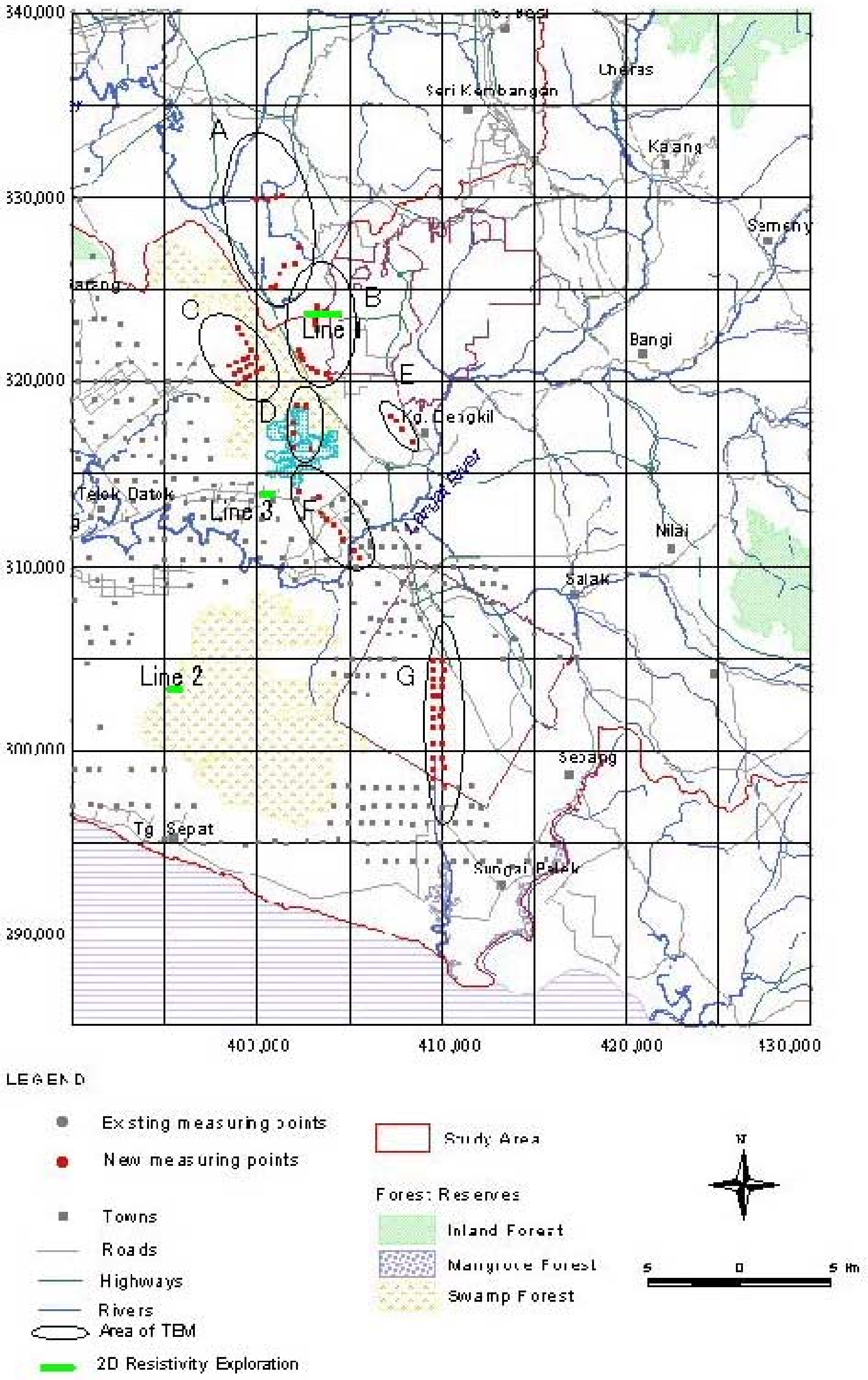
The equipment of TEM, “SIROTEM MK3”, was used for the survey with a 10, 20 or 40m coincident loop configuration. The inversion of the TEM data was carried out using TEMIXP software package to obtain the resistivity and depth profiles.

The equipment, “Sting R1”, was used for the 2-D resistivity prospecting survey with the Schlumberger configuration. The analysis software was “Geoelectrical Imaging 2D & 3D RES2DINV Ver. 3.4”, which was supplied to JMG by JICA.

The JMG geophysical survey crew carried out both geophysical surveys in June 2000.

2.2.2 Existing Surveys of JMG

JMG had carried out geophysical surveys several times in the Study area and surroundings[1), 2), 3)]. The works included TEM at 799 stations, vertical electric survey at 317 stations and gravity survey at 615 stations. Since there was some obscurity in interpreting the existing data, the results of gravity survey were not used for the interpretation of bedrock configuration. **Figure F.2.2** shows the locations of existing TEM and vertical electric survey stations.



Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

Figure F.2.1

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

Location of TEM and 2D Resistivity Exploration

CTI Engineering International Co., Ltd.

OYO CORPORATION

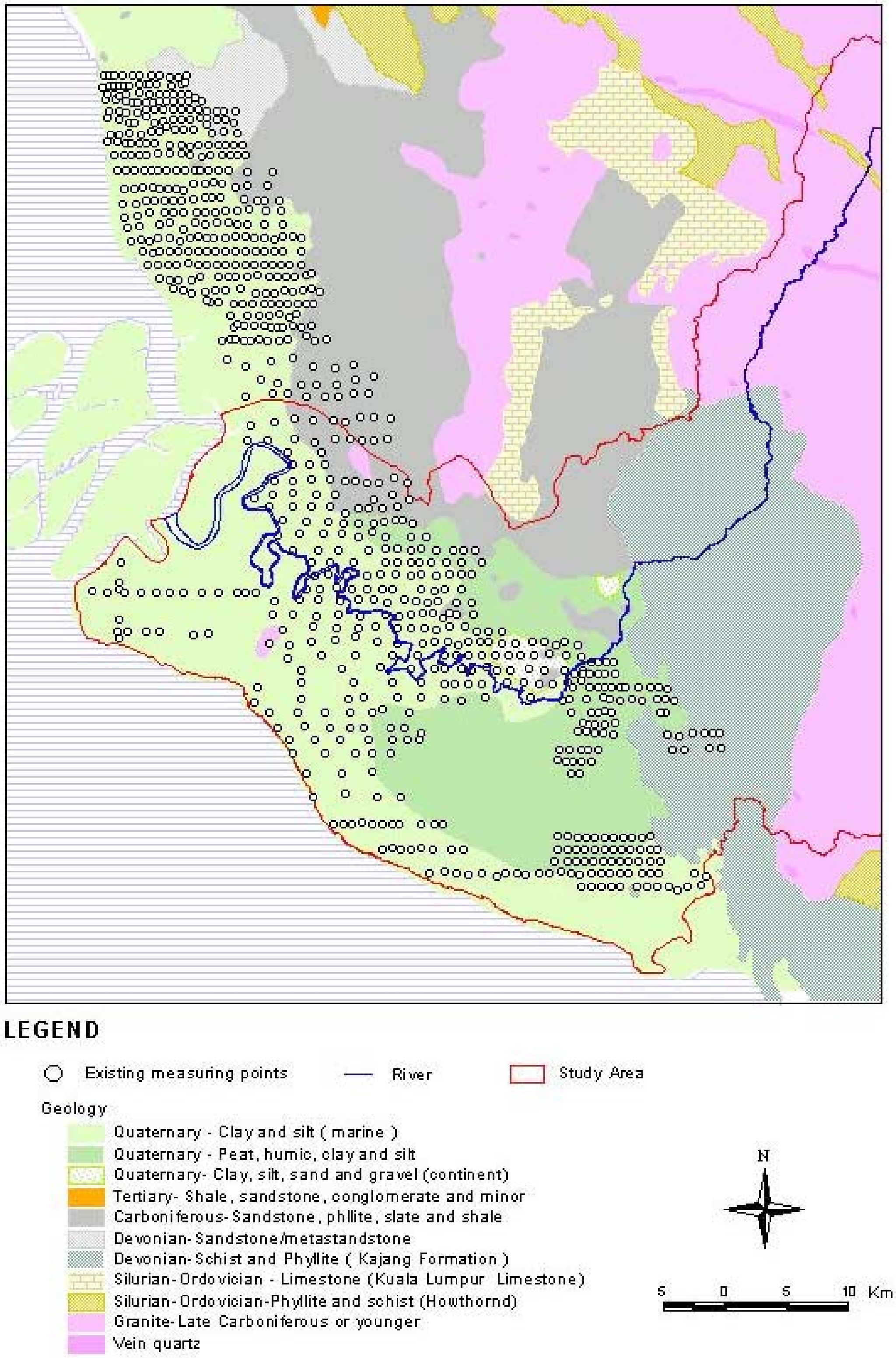


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Figure F.2.2

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

Location of Existing TEM Stations

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2.2.3 Results of Transient Electro-Magnetic Survey

The results of TEM indicate that the alluvium comprises two layers in terms of resistivity value. **Data Book F.2.2** shows TEM profiles obtained by the current survey and **Data Book F.2.2** summarise the results of inversion of TEM. **Figure F.2.3** shows a rough configuration of the upper boundary of the second layer. A buried valley was recognised running from the northeast of the Basin towards the southwest or the seacoast. The depth of the valley also increased towards the seacoast. From interpretation of the existing borehole logs, the upper boundary of the second layer could be assumed to correspond to the bedrock surface, although the depths obtained by TEM are shallower than those of the borehole logs.

The existing TEM results showed a zone of low resistivity. **Figure F.2.4** shows the boundary line between the zone of low resistivity and the zone of higher resistivity. Careful interpretation of the data is required with hydro-geological information and chemical test results in order to define the area of saline groundwater.

2.2.4 Results of Electric Prospecting

Figure F.2.5 shows the result of Survey Line 1. At both edges of the survey line zones of high resistivity, over 400ohm-m, were obtained, because the sedimentary rock appeared at a shallow depth at both edges. In the centre part of the survey line or centre part of a valley, this high resistivity zone was observed below 40 m from the ground surface. This implies that the bedrock is encountered around 40 m below the ground level. Zones of less than 50ohm-m correspond to less permeable silt or clayey soils, and zones of 50 to 100ohm-m correspond to permeable sandy or gravelly soils.

Figure F.2.6 shows the result of Survey Line 2. The results can be interpreted as follows:

Depth	Resistivity	Soil Type
0 m ~ 15 m	10 to 50 ohm-m	peaty soils
15m ~ 30 m	less than 10 ohm-m	clayey soils (marine clay)
30 m ~	10 to 50 ohm-m	aquifer

Results of Survey Line 3 (**Figure F.2.7**) are also interpreted as follows:

Depth	Resistivity	Soil Type
0 m ~ 10 m	10 to 50 ohm-m	peaty soils/clayey soils
10m ~	10 to 100 ohm-m	aquifer

In the aquifer at Survey Line 3, zones of higher permeability (100 ~ 200 ohm-m) can be found.

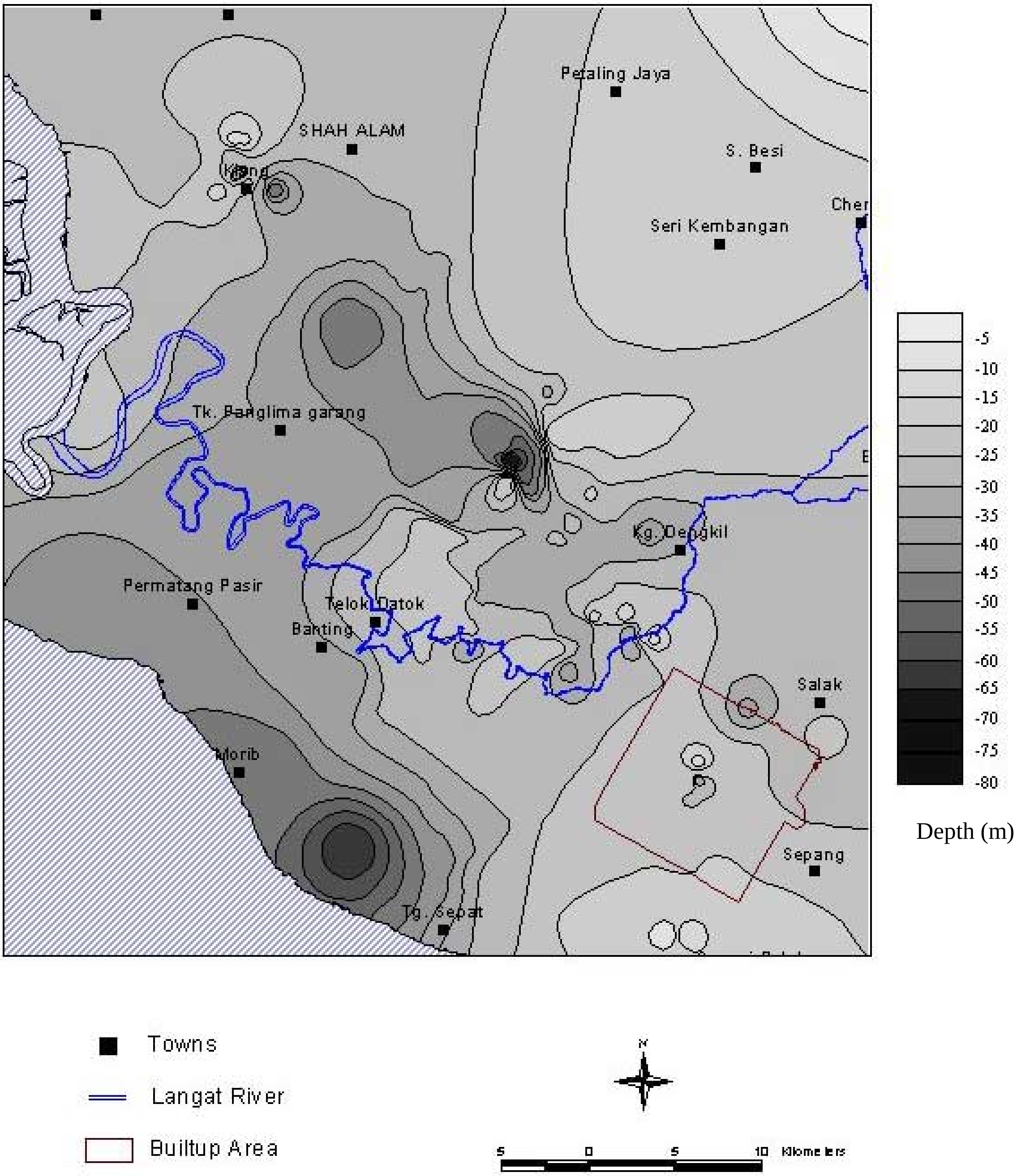

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Figure F.2.3

Counter Map of Bedrock by TEM

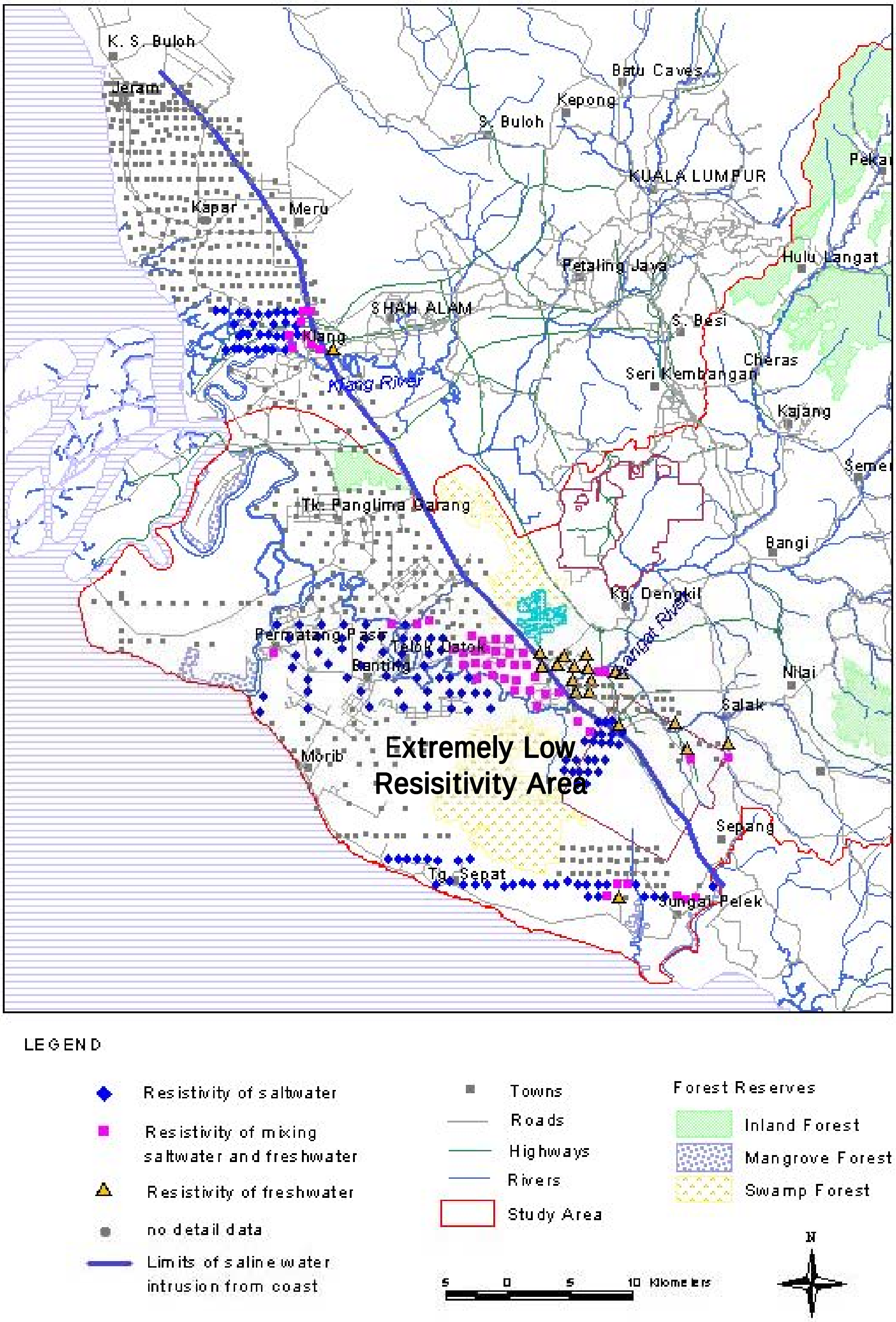

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Figure F.2.4

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Area of Extremely Low Resistivity

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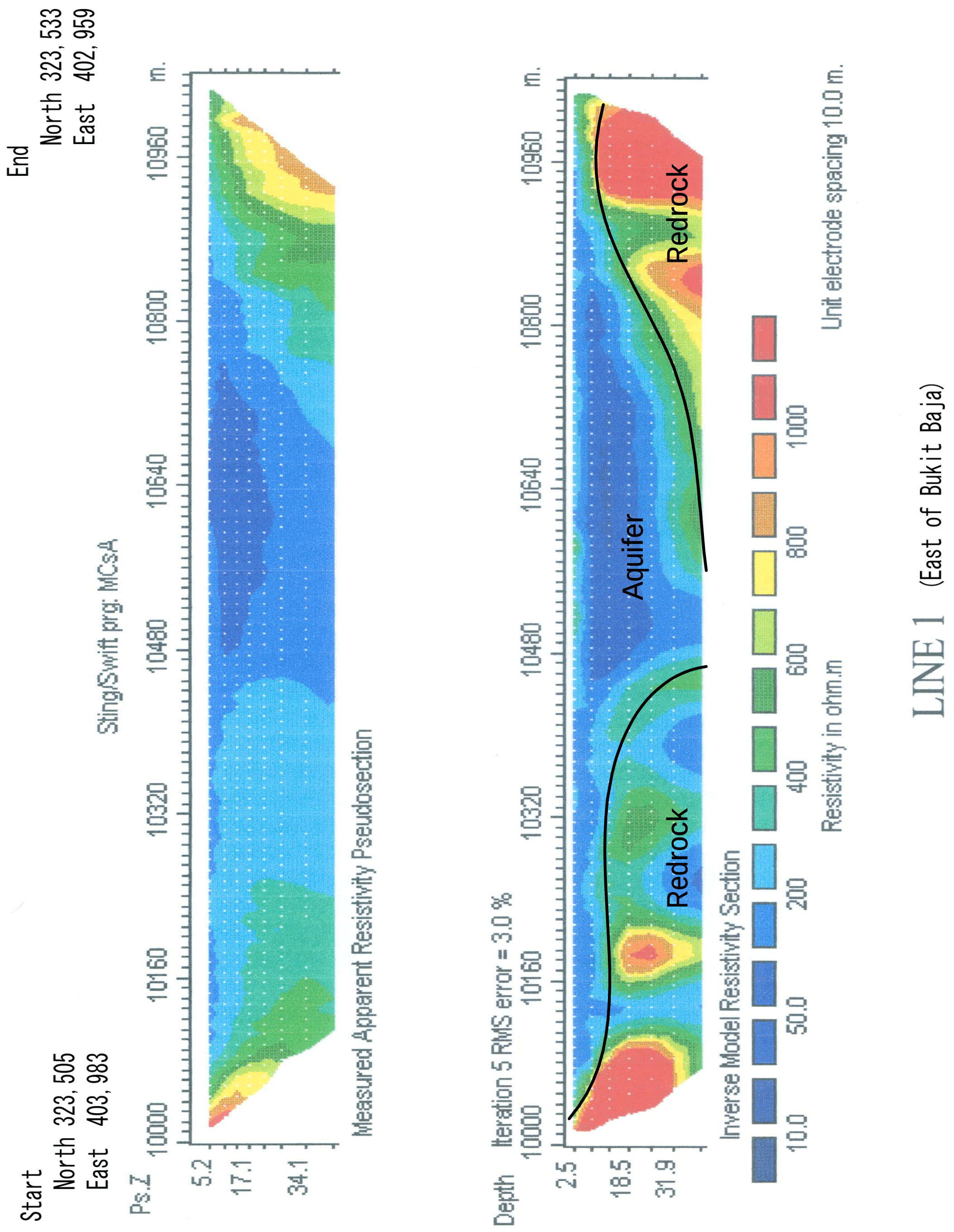

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Figure F.2.5

Resistivity Imaging of Line1(Bukit Baja)

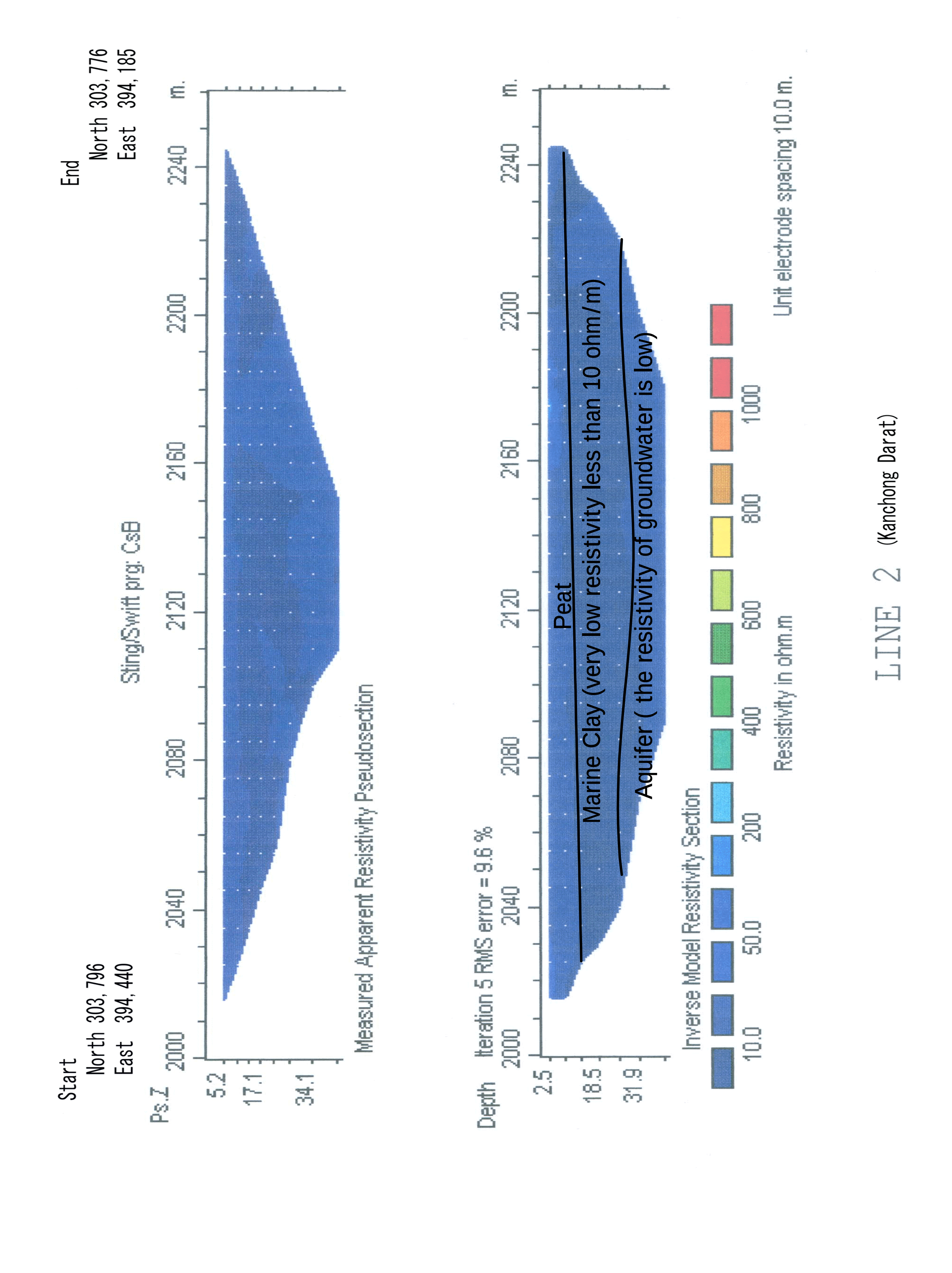

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Figure F.2.6

Resistivity Imaging of Line2 (Kanchong Darat)

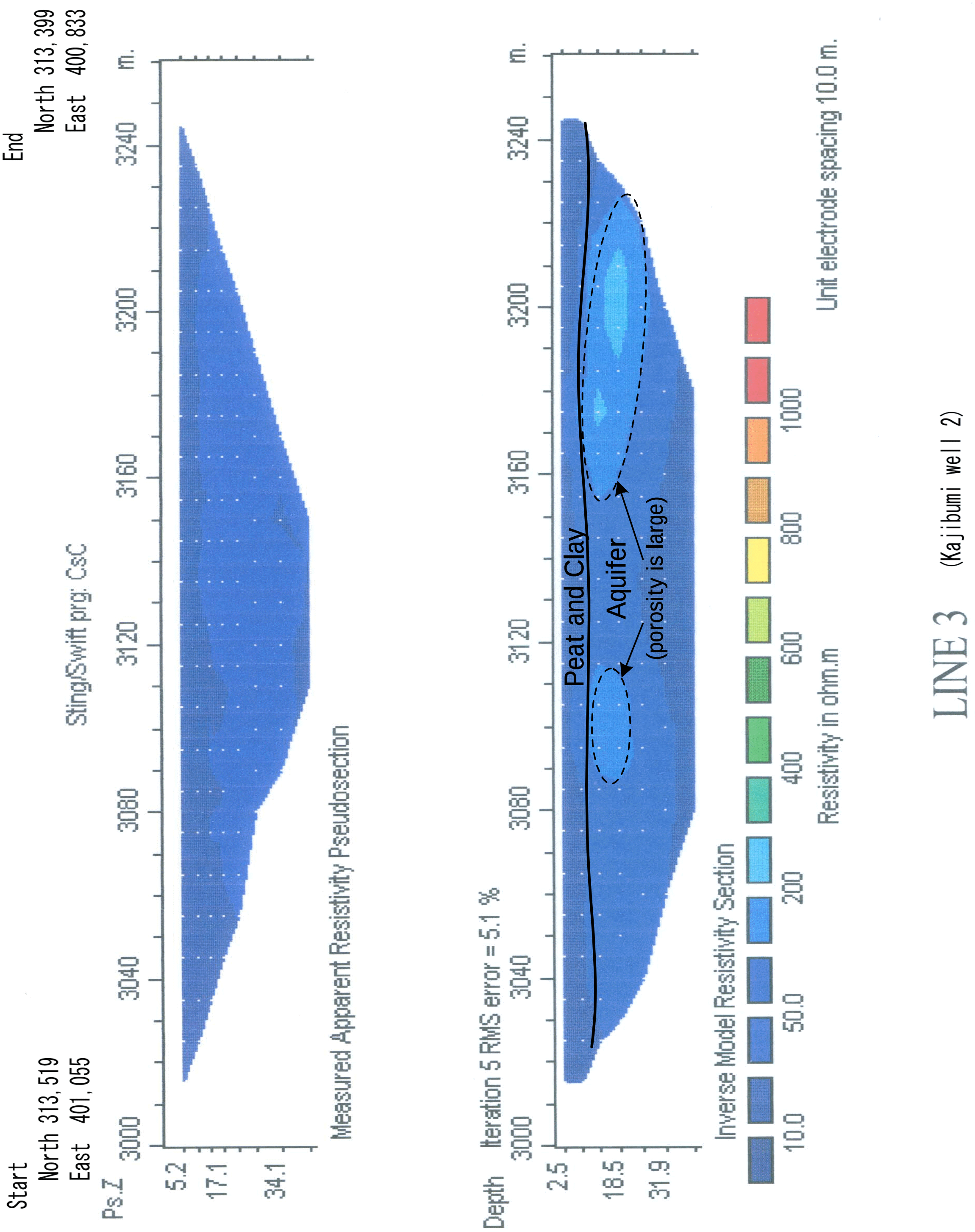

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Figure F.2.7

Resistivity Imagin of Line 3 (Kajibumi Well Field 2)

2.3 Soil Investigation

2.3.1 General

(1) Objectives of Soil Investigation

During Phase II of the Study, the soil investigation was carried out to obtain 1) geological conditions of the Groundwater Basin, 2) hydro-geological and consolidation properties of sediments of the aquifer system, and 3) basic information for designing pumping tests, long-term groundwater monitoring wells, and a settlement gauge (extensometer).

(2) Items of Soil Investigation

Items of the soil investigation and their objectives are summarised in **Table F.2.1**. Existing borehole logs [4) to 19)] were compiled and used to complement the results of the soil investigation.

Table F.2.1 Items and Objectives of Soil Investigation

Layer	Test Item	Objectives
Upper Clayey Soil	Undisturbed Soil Sampling	To obtain undisturbed samples for consolidation test.
	Consolidation Test	To obtain consolidation property to estimate subsidence of clayey soil layer.
	Classification Tests	To obtain basic soil property for classification of clayey soils.
	Standard Penetration Test	To obtain hardness of clayey soils to estimate subsidence of clayey soil layer.
Aquifer		To estimate hardness of sandy/gravelly soil and obtain disturbed samples for grain size analysis.
	Grain Size Analysis	To estimate permeability of the aquifer.
	Electrical Logging	To obtain the structure of aquifer, such as alternate sequences of clayey layer and sandy layer.

(3) Location of the Soil Investigation

In the Groundwater Basin, ten (10) locations were selected for the soil investigation. The locations were selected where1) typical geological conditions in the Groundwater Basin could be obtained, 2) groundwater flows into the Basin and flows out form the Basin, 3) the pumping tests were planned, and

4) installation of the long-term monitoring wells and the settlement gauge were planned.

Figure F.2.8 shows the locations of the soil investigation in the Groundwater Basin, and **Table F.2.2** summarises objectives of each location. In the table a symbol "Yes" is used to identify the objectives.

Table F.2.2 Objectives of Soil Investigation at Each Location

Location No.	Location	Geological Conditions	Inflow and Out Flow	Pumping Test	Long Term GW Monitoring	Settlement Gauge
1	South of Bt. Baja	Yes	Yes (Inflow)	-	Yes	-
2	Paya Indah	Yes	Yes (Inflow)	Yes	Yes	-
3	NW of Paya Indah	Yes	Yes (Inflow)	-	Yes	-
4	Kg. Jenjarom	Yes	Yes (Inflow)	-	Yes	-
5	Kajibumi Well Field 2	Yes	-	Yes	Yes	Yes
6	Ladang TK. Gong	Yes	Yes (Out flow)	-	Yes	-
7	Kanchong Darat	Yes	-	Yes	Yes	-
8	Kg. Endah	Yes	Yes (Out flow)	-	Yes	-
9	Ladang Tumbuk	Yes	Yes (Out flow)	-	Yes	-
10	East of Paya Indah	Yes	Yes (Inflow)	-	Yes	-

Location No. 1, 2, 3, and 4 were placed along the northern boundary of the Groundwater Basin in order to obtain information of inflow from the Klang River Basin. Location No. 10 was placed at the northeastern boundary to study inflow conditions from Dengkil where the ex-mines are located.

Location No. 6 was placed at the western boundary, and No. 8 and 9 were placed at the southern boundary of the Groundwater Basin where groundwater flow from the Basin.

Location No. 5 and 7 were placed along the centre of one of the major buried valleys in the Groundwater Basin.

As a supplement of the soil investigation, the existing boreholes were utilised to characterise the Basin. Locations of existing borehole are plotted in

Figure F.2.9, and enlarged portions of the figure are shown in **Annex Figures F.2.1 and F.2.2**.

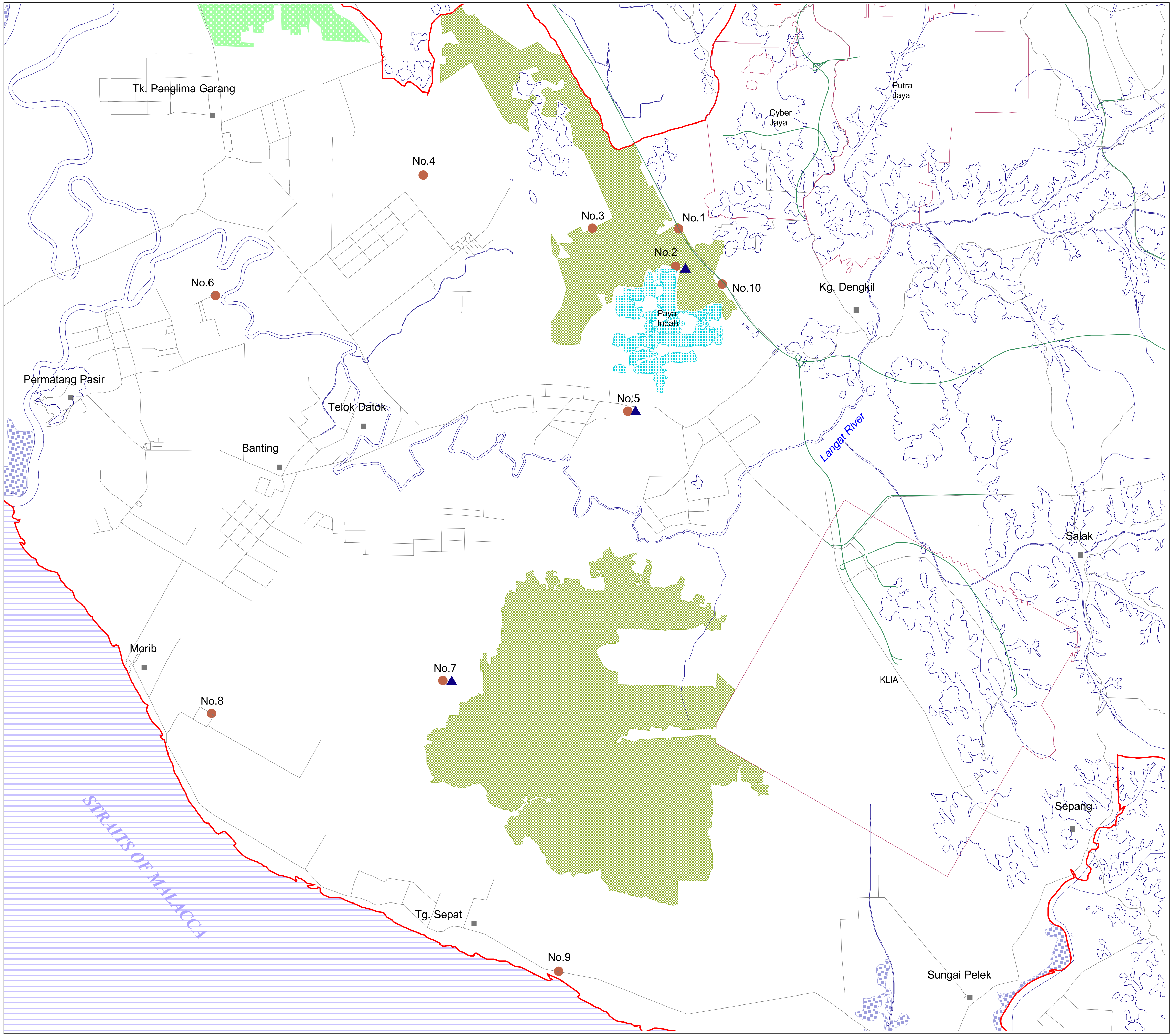
Detailed site maps of the location of soil investigation are presented in **Annex Figures F.2.3 to F.2.12**.

(4) Work Quantity of the Soil Investigation

Work quantity of the soil investigation is summarised in **Table F.2.3**.

Figure F.2.8

Location Map of Soil Investigation



LEGEND

- Location of Soil Investigation
- No.1 - No.10 Location Number
- Pumping Test
- Topographic Contourline of 20m Height
- Highway
- Roads
- Rivers
- Towns
- Builtup Area
- Paya Indah
- Forest Reserve
  - Inland Forest
  - Mangrove Forest
  - Swamp Forest
- Study Area

N W E S

Scale 1 : 200,000

2 0 2 4 Kilometers

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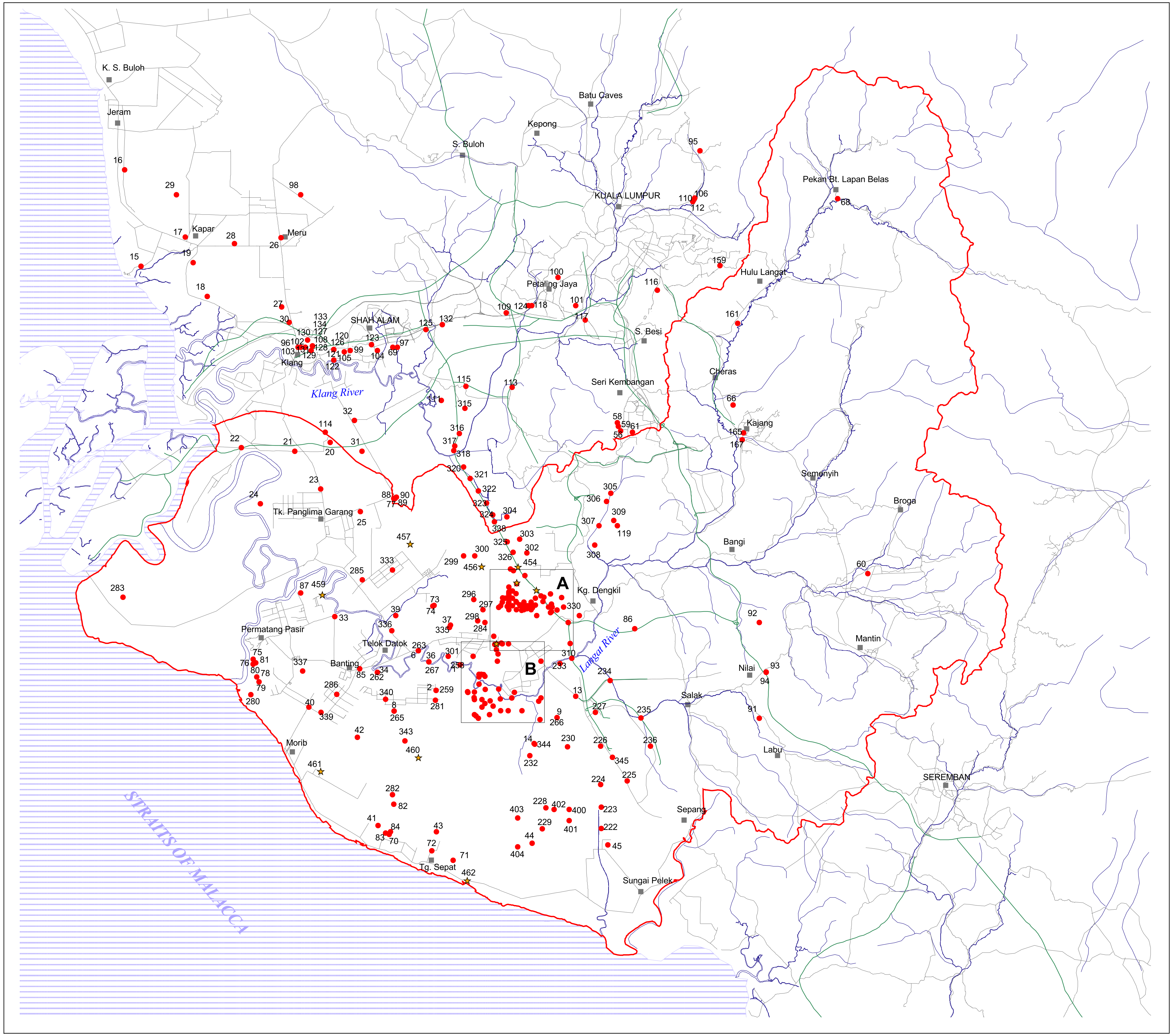

Figure F.2.9

Location Map of Existing Boreholes

LEGEND

- Existing Borehole Point
- Location of Soil Investigations of the Present Study
- Highways
- Roads
- Rivers
- Town
- Study Area

Enlarged maps of areas A and B are prepared in Annex Figures I-3.2.1 and I-3.2.2, respectively

Scale 1 : 550,000

2 0 2 4 6 Kilometers

N W E S

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Table F.2.3 Quantities of Soil Investigation and Laboratory Soil Test

Location Name	Bore Hole Name	Depth (m)	Method of Drilling	Site Investigation			Laboratory Soil Test						Coordinate(R.S.O)**		Elevation (m,s,l)***
				Standerd Penetration Test (no.)	Undisturb Sampling (no.)	EL Logging (m)	Grain Size Analysis	Specific Gravity	Atterberg Limits Test	Natural Water Content	Unit Weight	Consolidation Test	X (m)	Y (m)	Z (m)
South of Bt.Baja	BH1	33	Rottary	33	-	30	6	2	-	-	-	-	402785	319999	8.785
	J1-1	-	Percussion	-	-	-	17	-	-	-	-	-	402777	319993	8.597
Paya-Indah	BH2	36	Rottary	31	-	34	16	4	-	-	-	-	402695	318667	8.250
	MW*	-	Percussion	-	-	-	144	-	-	-	-	-	402696	318653	8.133
NW of Paya Indah	BH3	40	Rottary	40	-	38	10	3	-	-	-	-	399896	320335	7.385
Kg. Jenjarom	BH4	41	Rottary	41	-	39	11	-	9	9	-	-	393657	321925	5.787
	BH4-2 (J4-1)	11	Rottary	-	5	-	17	5	5	5	5	5	393661	321921	5.757
KAJIBUMI WF2	BH5	50	Rottary	49	5	27	27	4	4	4	-	-	400944	313486	5.700
	EX5	17	Rottary	-	-	-	5	5	5	5	5	5	400958	313521	5.727
	J5-2	-	Percussion	-	-	-	34	-	-	-	-	-	400897	313508	5.682
Ladang TK. Gong	BH6	70	Rottary	70	-	69	32	8	8	8	-	-	386416	317926	2.467
	BH6-2 (J6-1)	15	Rottary	-	5	-	5	5	5	5	5	5	386415	317920	2.481
Kanchong Darat	BH7	110	Rottary	89	-	94	57	14	9	9	-	-	394368	303871	4.923
	BH7-2 (J7-5)	8	Rottary	-	5	-	5	5	5	5	5	5	394362	303866	4.797
Kg.Endah	BH8	103	Rottary	89	-	101	46	15	12	12	-	-	386093	302698	2.181
	BH8-2 (J8-1)	20	Rottary	-	5	-	5	5	5	5	5	5	386090	302702	2.291
Ladang Tumbuk	BH9	109	Rottary	109	-	105	72	31	-	-	-	-	398492	293488	2.328
	BH9-2 (J9-1)	37	Rottary	-	5	-	5	5	5	5	5	5	398497	293485	2.329
East of Paya-Indah	BH10	32	Rottary	27	-	31	16	4	-	-	-	-	404345	318030	8.911
	J10-1	-	Percussion	-	-	-	22	-	-	-	-	-	404338	318038	8.866
Total		732	-	578	30	568	552	115	72	72	30	30	-	-	-

* M.W. ; Monitoring Well. Samples were taken at PW2,J2-1,J2-2,J2-3,J2-4,J2-6 and J2-8

** R.S.O. ;stands for Rectified Skew Orthomorphic that is a coordinate system widely used in Malaysia

***m,s,l; mean sea level

2.3.2 Boring

(1) Methodologies and Equipment Used

Rotary boring machines were used to drill 100 mm diameter boreholes. Standard penetration test (S.P.T.) was performed at 1 metre interval in all boreholes in accordance with BS (British Standard) 5930-21.2. Groundwater levels in boreholes were measured and recorded at the beginning and the end of each working day.

The boreholes were numbered as BH1 to BH10 according to the location numbers 1 to 10.

(2) Results of Boring

Ten (10) borehole logs with N values of S.P.T. are summarised in **Figure F.2.10** to overview soil conditions of the Groundwater Basin. Groundwater levels measured during drilling at ten (10) boreholes are given in **Figure F.2.11**. Detailed borehole logs of all locations are presented in **Data Book F.2.4**.

Results of boring were used to define quantitatively the aquifer system of the Groundwater Basin, namely, areal distribution of the Quaternary sediments which consist of the aquifer system, thickness and properties of the sediments, and boundary conditions of the Basin. These are presented in **Subsection 2.3.2(3)**, and interpreted in **Section 4.2**.

The existing borehole logs were compiled in digital form with the same format of the current soil investigation. An example of the existing borehole log is shown in **Figure F.2.12**.

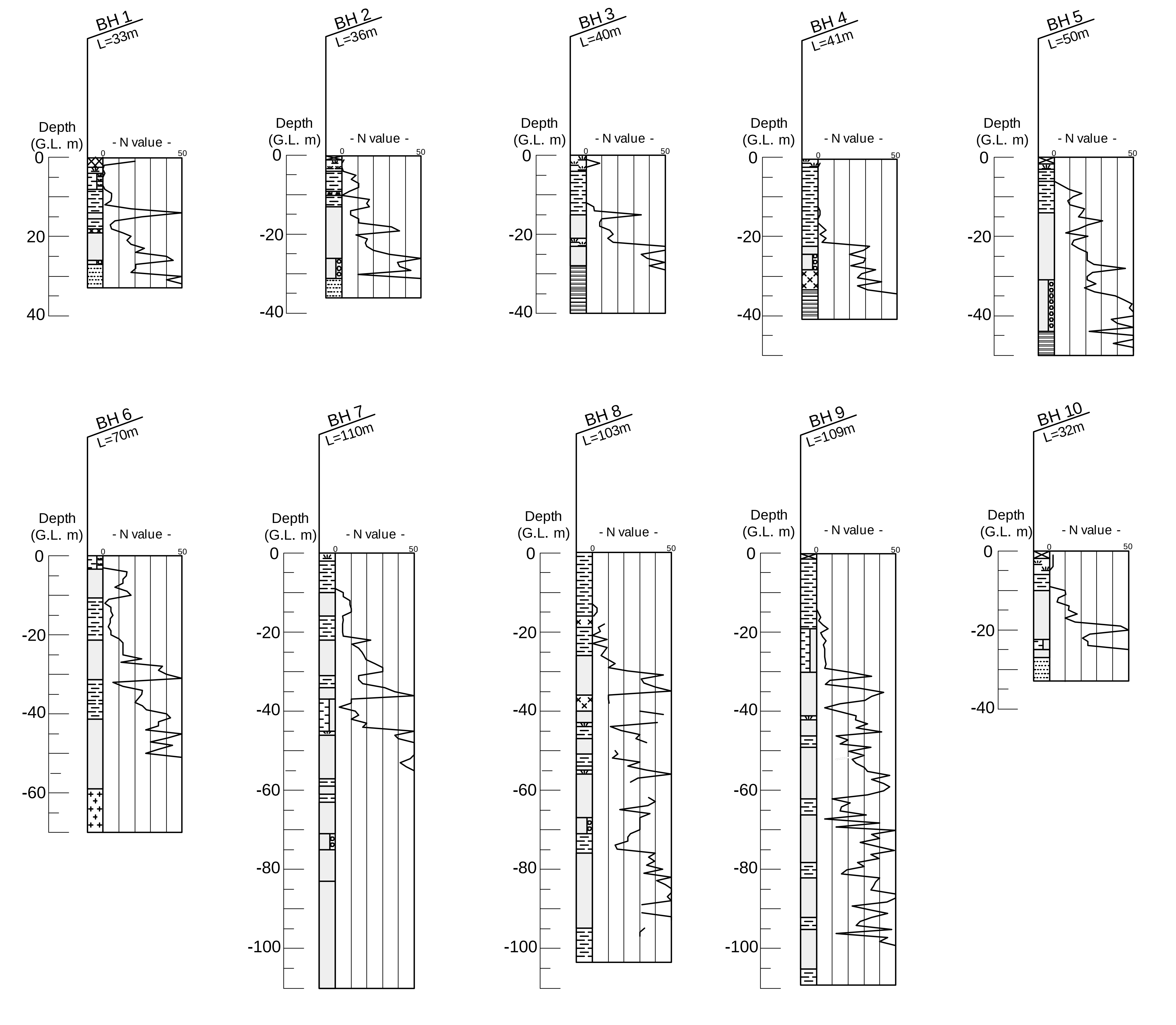

Figure F.2.10

Summary of Borehole Logs

LEGEND

Key of Borehole Log

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

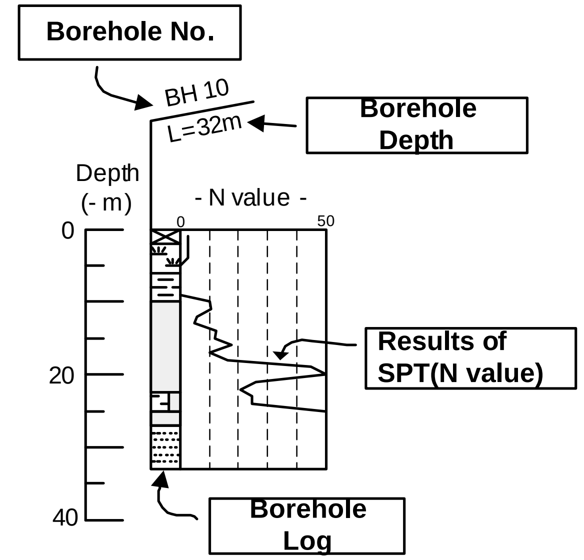

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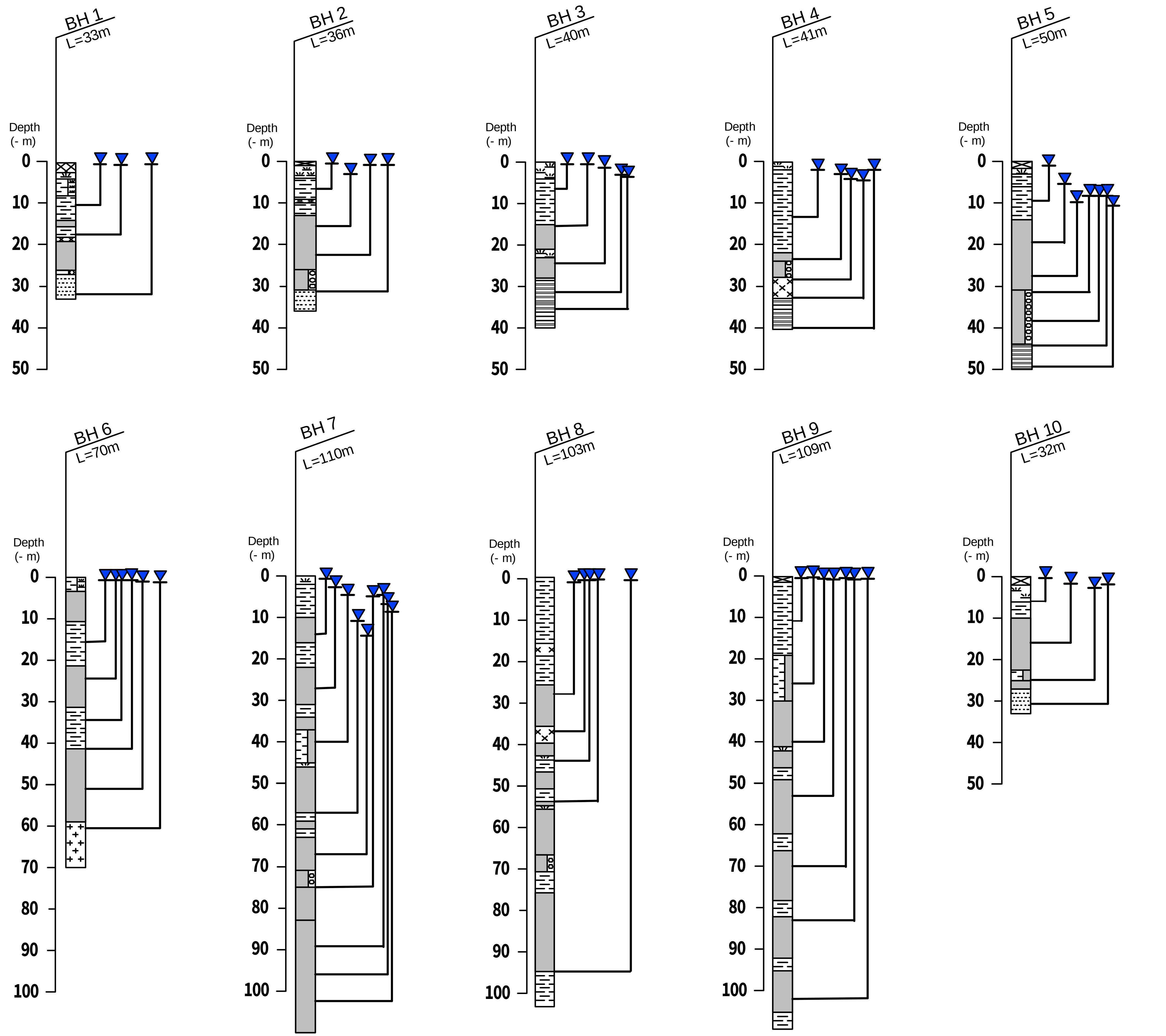
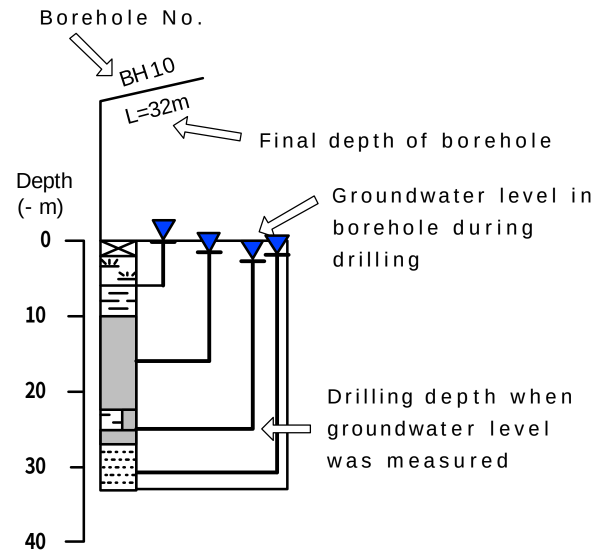
Figure F.2.11

Groundwater Level Measurement during Drilling



LEGEND

PEAT
CLAY
SILT
SAND
GRAVEL
LIMESTONE
SHALE, SLATE, PHYLLITE
SANDSTONE, QUARTZITE, SCHIST
GRANITE



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DB-ID	1	Field Name	MWD1	Other Name	PB572
Location	Jambatan Batu Ladang Brooklands			Source No.	1
X-RSO (m)	397837	Y-RSO (m)	311787	Z-RSO (m)	

Depth (m)	Test	Sampling	Graphic Log	Description of Materials	N - Value blow per 30cm (10 20 30 40 50)	Groundwater Level (G.L. - m)
0 – 3.25 m				Soft CLAY		
3.25 – 8.75 m				Sandy CLAY		
8.75 – 11.05 m				Soft CLAY		
11.05 – 13.35 m				SAND		
13.35 – 15.65 m				Sandy CLAY		
15.65 – 21.65 m				Soft CLAY		
21.65 – 27.3 m				SAND		
27.3 – 50 m			○	Medium to coarse SAND with angular to sub-rounded gravel & trace feldspar		

Symbols
- ◩ Standard Penetration Test
- ◫ Undisturbed Samples
- ☐ Disturbed Samples
- ○ Permeability Test

Remarks
- ☐ Soil Investigation
- ☒ Well
- ☐ Mineral Exploration
- ☐ Others

BOREHOLE LOG

DB-ID - 1

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Figure F.2.12

Sample of Existing Borehole Log

(3) Description of Soil Conditions

A brief description of soil conditions at boring points is given below. The location map, **Figure F.2.8**, can be referred to identify the relative location of the boring points in the Groundwater Basin and its surroundings.

(a) Location No. 1, South of Bt. Baja (Annex Figure F.2.1 and Data Book Figure F.2.15)

Borehole BH1 is located in a low flat plain between Bt. Baja in the west and a series of hills leading to Cyberjaya and Putrajaya in the east. The site is situated at the northern boundary of a remaining secondary forest that covers the north edge of Paya Indah.

Borehole BH1 shows that the soil formations consist of 5.0 m of fill, 3.0 m of peaty clay, 11.0 m of clayey soils and 8.0 m thick of sandy soils. Some gravel was found in the sandy soil. Bedrock, completely weathered mudstone and sandstone, was found at a depth of 27 m and confirmed to a depth of 33.27 m.

(b) Location No. 2, Paya Indah (Annex Figure F.2.2 and Data Book Figure F.2.16)

Borehole BH2 is located in a peat swamp at the northeast corner of the Main Lake of Paya Indah. One of the pumping tests was conducted at this location. The site is partially surrounded by the secondary forest to the east, north and west. Upstream is the low flat plain where BH1 is situated.

Soil formations found at the BH2 location consist of 3 m of fill, 1 m of peaty clay, 12 m of clayey soils, and 15.5 m of sandy and gravelly soils. Bedrock, cracky quartzite, was met at a depth of 31.51 m and confirmed to a depth of 35.95 m. Please note that the fill was imported, just before the fieldwork of the Study, to form a platform for drilling and the pumping test.

(c) Location No. 3, Northwest of Paya Indah (Annex Figure F.2.3 and Data Book Figure F.2.17)

Borehole BH3 is located in a low flat plain distributing between Bt. Cheeding and Bt. Baja. The site is within a palm plantation and facing the secondary forest in the east.

Soil formations at this locality consist of 3 m of peat, 12 m of clayey soils and 13 m of sandy soils. Bedrock, completely weathered shale, was found at a depth of 28 m and confirmed to a depth of 40.28 m.

(d) Location No. 4, Kg. Jenjarom (Annex Figure F.2.4 and Data Book Figure F.2.18)

Borehole BH4 is located in a low flat plain between Bt. Cheeding, Bt. Puloh, and a series of small hills located south of Bt. Lanchong. The site is situated in a palm plantation.

Soil formations found at BH4 consist of 1 m of fill, 1 m of peat, 20 m of clayey soils, 6 m of sandy soils and 5 m of clayey soils. The lower part of the sandy soils contains gravels. Bedrock, completely weathered shale, was met at a depth of 33 m and confirmed to a depth of 41.22 m.

(e) Location No. 5, Kajibumi Well Field 2 (Annex Figure F.2.5 and Data Book Figure F.2.19)

Borehole BH5 is in a flat land of Olak Lempit, which is located north of the current channel of Langat River. The site, situated within a reclaimed area for light industry, is surrounded by palm plantations. One of the pumping tests was carried out at this location.

At BH5, soil formations consist of 1.3 m of fill, 1.7 m of peat and peaty clay, 9.4 m of clayey soils and 31.6 m of sandy and gravelly soils. Bedrock, completely weathered shale, was found at a depth of 44 m and confirmed to a depth of 49.5 m.

(f) Location No. 6, Ladang TK. Gong (Annex Figure F.2.6 and Data Book Figure F.2.20)

Borehole BH6 is located in a flat plain along the south bank of the meandering Langat River. The site is within a palm plantation.

Soil formations consist of 0.3 m of peaty clay, 3.7 m of clayey soils, 7 m of sandy soils, 12 m of clayey soils, 9 m of sandy soils, 10 m of clayey soils and 17 m of sandy and gravelly soils. Bedrock, moderately weathered granite, was confirmed between depths of 59 m and 70 m.

(g) Location No. 7, Kanchong Darat (Annex Figure F.2.7 and Data Book Figure F.2.21)

Borehole BH7 is located at the centre of the Groundwater Basin. The site is within a palm plantation, and the forest reserve is seen to the east. The distance to the seacoast from the site is around 8.5 km. One of the pumping tests was carried out at this location.

Soil formations at the site consist of 0.5 m of fill, which was filled to form a platform for the current investigation, 1.5 m of peat, 8 m of clayey soils, 6 m of sand, 6 m of clayey soils, and over 88 m of sandy and gravelly soils.

The sandy/gravelly soils are interbedded by 3 m, 8 m, 2 m and 2 m thick of clayey soil layers from a depth of 31m, 37 m, 57 m and 61 m, respectively.

The thickness of the sandy/gravelly soils was confirmed to 105 m during drilling of a monitoring well located just next to the soil investigation hole, BH7. Bedrock depth was estimated by the seismic survey as around 130 m to 150 m below the ground level. Results of the seismic survey are presented in **Subsection 2.3.6**.

(h) Location No. 8, Kg. Endah (Annex Figure F.2.8 and Data Book Figure F.2.22)

Borehole BH 8 is located in a flat plain along the seacoast, around 2 km from the seacoast. The site is situated in a schoolyard.

Soil formations at BH8 consist of 0.3 m of fill, 25.7 m of clayey soils, and over 69 m of sandy and gravelly soils. The sandy/gravelly soils are interbedded by 4 m, 4 m, 3 m, 1 m and 5 m thick of clayey soil layers from a depth of 36m, 43 m, 51 m, 66 m and 71 m, respectively. From a depth of 95 m, a clayey soil layer of more than 8 m thick was found.

The clayey soil layer was confirmed to a depth of 103.45 m. A depth of bedrock was estimated by the seismic survey as around 130 m to 150 m below the ground level.

(i) Location No. 9, Ladang Tumbok (Annex Figure F.2.9 and Data Book Figure F.2.23)

Borehole BH9 is located in a flat plain along the seacoast. The distance to the seacoast is around 0.4 km.

Soil formations at BH8 consist of 1.45 m of topsoil, 28.55 m of clayey soils, and over 75 m of sandy and gravelly soils. The sandy/gravelly soils are interbedded by 3 m, 2 m, 4 m, 4 m and 4 m thick of clayey soil layers from a depth of 39 m, 47 m, 62 m, 78 m and 91 m, respectively. From a depth of 105 m, a clayey soil layer of more than 4 m thick was confirmed.

The clayey soil layer was confirmed to a depth of 109.45 m at this location. The depth of bedrock was estimated by the seismic survey as around 140 m to 160 m below the ground level.

(j) Location No. 10, East of Paya Indah (Annex Figure F.2.10 and Data Book Figure F.2.24)

Borehole BH10 is located in a low flat plain, downstream of the ex-mining area of Dengkil and upstream of the ex-mining area of Paya Indah.

Soil formations consist of 1.42 m of fill, 4.58 m of peat and peaty clay, 4.0 m of clayey soils and 16.85 m of sandy and gravelly soils. Bedrock, completely weathered sandstone, was found at a depth of 27.19 m and confirmed to a depth of 32.28 m.

2.3.3 Sampling

(1) Disturbed Sampling of Soils

During drilling, disturbed soil samples were collected by a split mould sampler of the standard penetration test (S.P.T). Classification tests and grain size analysis were carried out on the disturbed samples. Depths of soil sampling are shown along the simplified borehole log in **Data Book F.2.5**.

The results of the laboratory soil tests are presented in **Subsection 2.3.4** and interpreted in **Section 4.2**.

(2) Undisturbed Sampling of Clayey Soils

Undisturbed samples of soft clays, 75 mm diameter, were taken by using a thin-walled sampler with fixed piston in accordance with BS 5930-19.4. Consolidation test and classification tests were carried out on the undisturbed samples. The undisturbed samplings were performed at boreholes BH4, 5, 6, 7, 8 and 9, where thick soft clayey soils were expected. Depths of sampling and soil tests, together with a simplified borehole log, are presented in **Data Book F.2.5**.

The results of the laboratory soil test on the undisturbed samples are presented in **Section 3.3.4** and interpreted in **Section 4.2**.

2.3.4 Laboratory Soil Tests

(1) Methodologies

The standards used for the laboratory soil test are summarised in **Table F.2.4**.

Table F.2.4 Specifications for Laboratory Soil Test

Laboratory Soil Test		Standards
Classification Test	Grain size analysis	BS 1377-part 2-9
	Specific gravity	BS 1377-part 2-8
	Natural moisture content	BS 1377-part 2-3
	Atterberg limits test	BS 1377-part 2-5
	Unit weight	BS 1377-part 2-7
Consolidation Test		BS 1377-part 6-3

(2) Results of Laboratory Soil Tests on Clayey Soils

The results of the laboratory test on undisturbed samples of clayey soils are tabulated in **Annex Table F.2.1**. **Tables F.2.5 and F.2.6** summarise ranges of properties of the clayey soils.

Figures F.2.13 and F.2.14 present distributions of natural water content and Atterberg limits with depth, and distributions of compression index with depth of boreholes BH4, 5, 6, 7, 8, and 9, respectively. The figures also include borehole logs and S.P.T. N values. **Figure F.2.15** summarises distribution of physical properties of clayey soils with depth, namely bulk density, void ratio, and natural water content. Distribution of grain size characteristics with depth is plotted in **Figure F.2.16**.

Table F.2.5 Summary of Laboratory Soil Test on Undisturbed Samples (1)

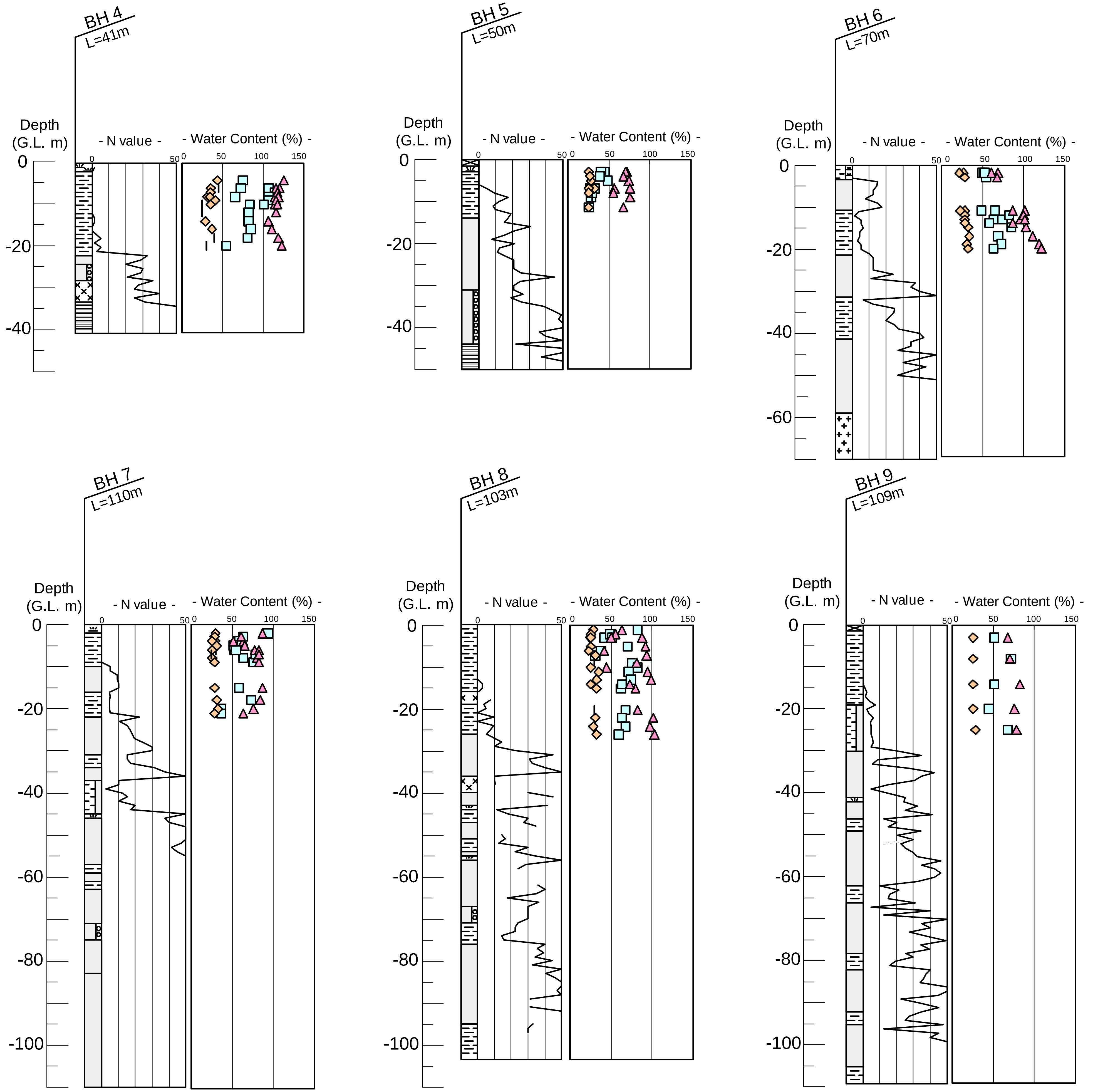
Borehole No.	SPT N value (-)	Unit Weight (mg/m^3)	Natural Water Content (%)	Atterberg Limits		Plasticity Index (-)
				Liquid Limit (%)	Plastic Limit (%)	
BH4	0~2	1.35~1.39	101 ~114	116~119	34~41	75~85
BH5	0~1	1.73~1.77	39~41	68~70	26~27	41~44
BH6	1~5	1.46~1.49	49~82	87~101	23~29	58~72
BH7	0	1.39~1.55	52~79	51~83	24~31	25~59
BH8	0~3	1.39~1.62	49~83	46~73	25~26	20~48
BH9	0~3	1.34~1.54	45~71	68~83	25~29	42~57

Table F.2.6 Summary of Laboratory Soil Test on Undisturbed Samples (2)

Borehole No.	Particle Size Distribution			Consolidation Test	
	Clay (%)	Silt (%)	Sand (%)	pc (kN/m^2)	Cc (-)
BH4	50~59	39~48	1~2	36~70	0.87~1.14
BH5	55~58	36~41	1~9	57~145	0.25~0.30
BH6	34~56	30~40	1~36	135~190	0.87~1.08
BH7	52~72	27~44	1~12	42~220	0.39~0.85
BH8	48~64	35~45	1~10	73~100	0.40~1.00
BH9	40~59	30~46	1~30	33~170	0.51~1.03

Figure F.2.13

Summary of Laboratory Soil Tests, Distribution of Natural Water Content and Atterberg Limits of Clayey Soils to Depth



LEGEND

Soil Property

- Natural Water Content
- Plastic Limit
- Liquid Limit

Key of Borehole Log

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

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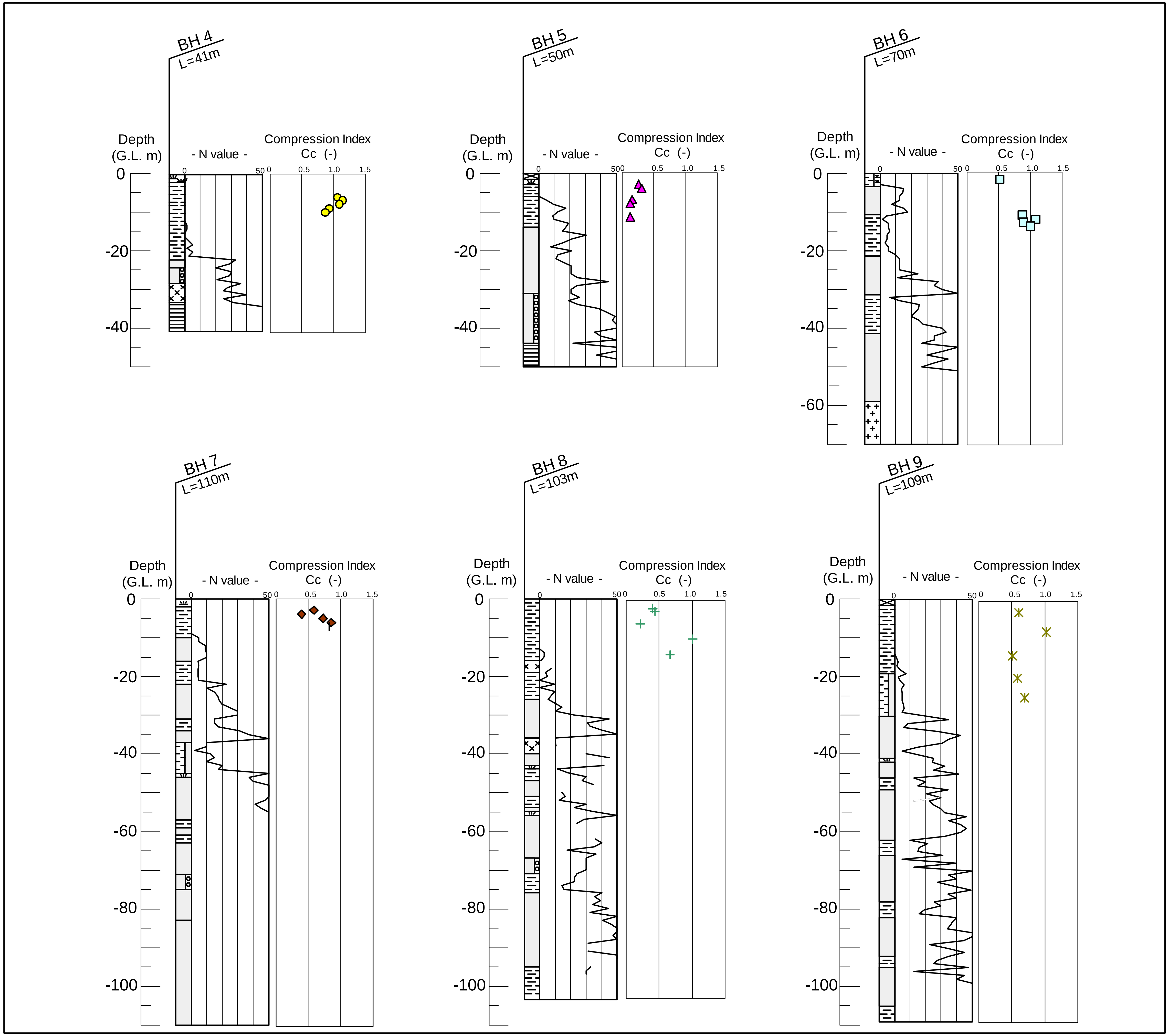
Figure F.2.14

Summary of Laboratory Soil Tests, Distribution of Compression Index of Clayey Soils to Depth



LEGEND

Soil Property

Cc : Compression Index

Key of Borehole Log

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

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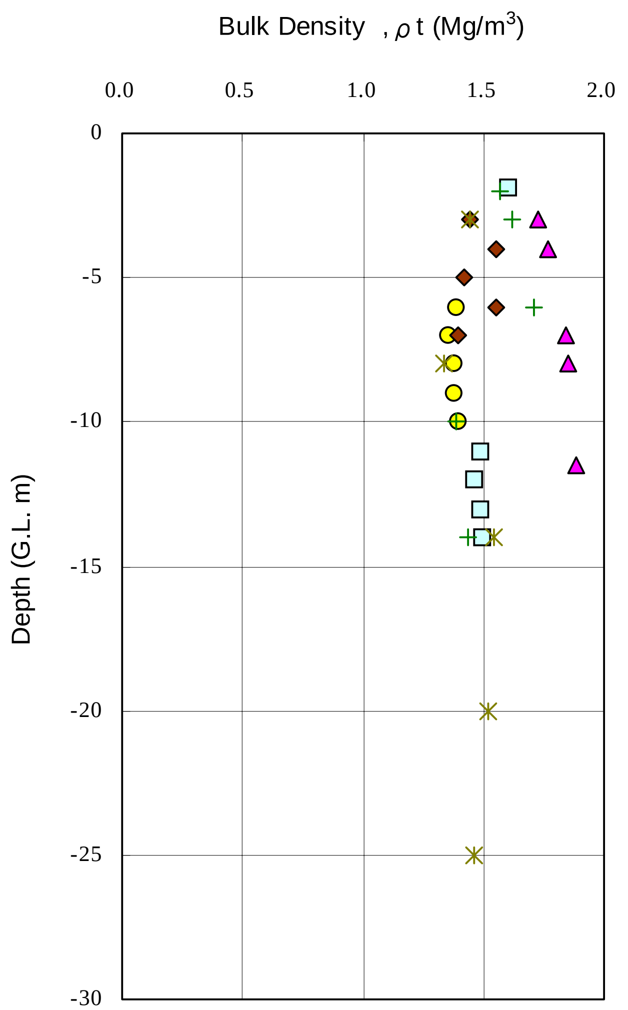
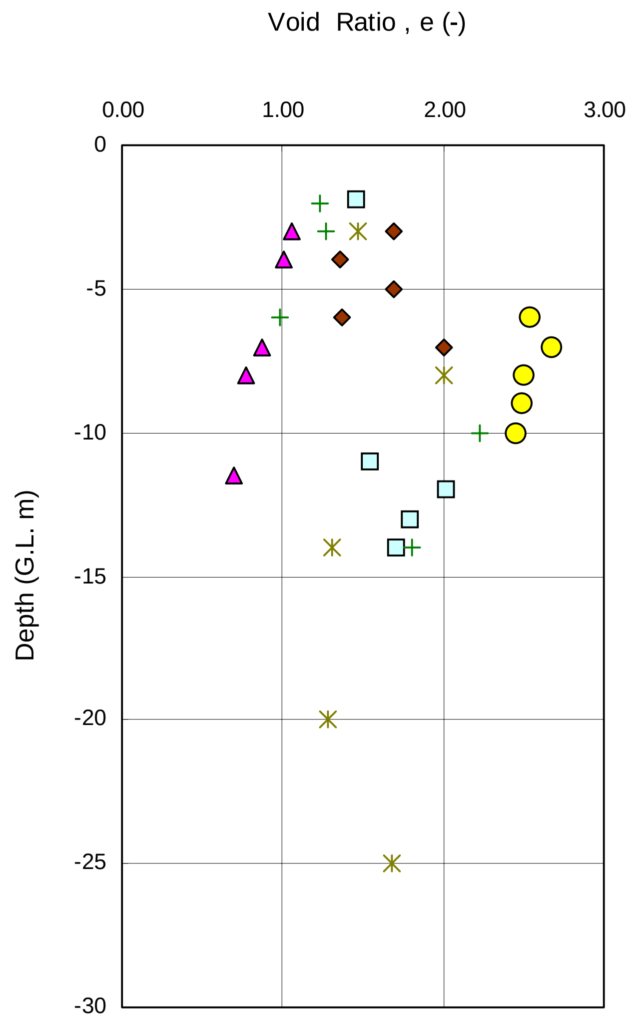
Figure F.2.15

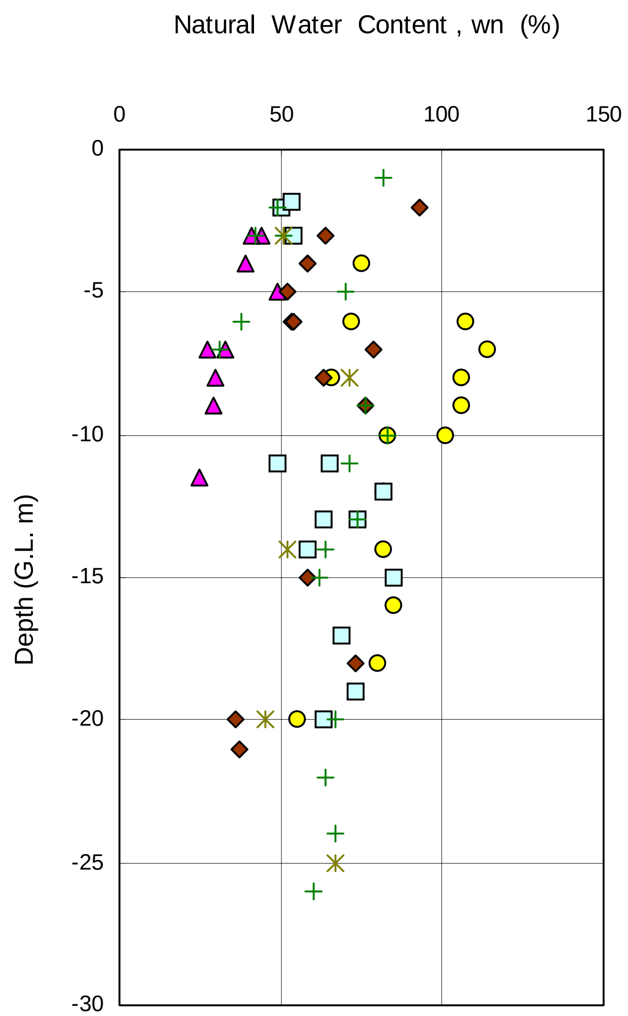
Distribution of Physical Properties of Clayey Soils



(a) Distribution of Bulk Density to Depth



(b) Distribution of Void Ratio to Depth



(c) Distribution of Natural Water Content to Depth

LEGEND

Borehole Number

- BH4
- BH5
- BH6
- BH7
- BH8
- BH9

Soil Property

ρ t : Bulk density
e : Void Ratio
wn : Natural Water Content

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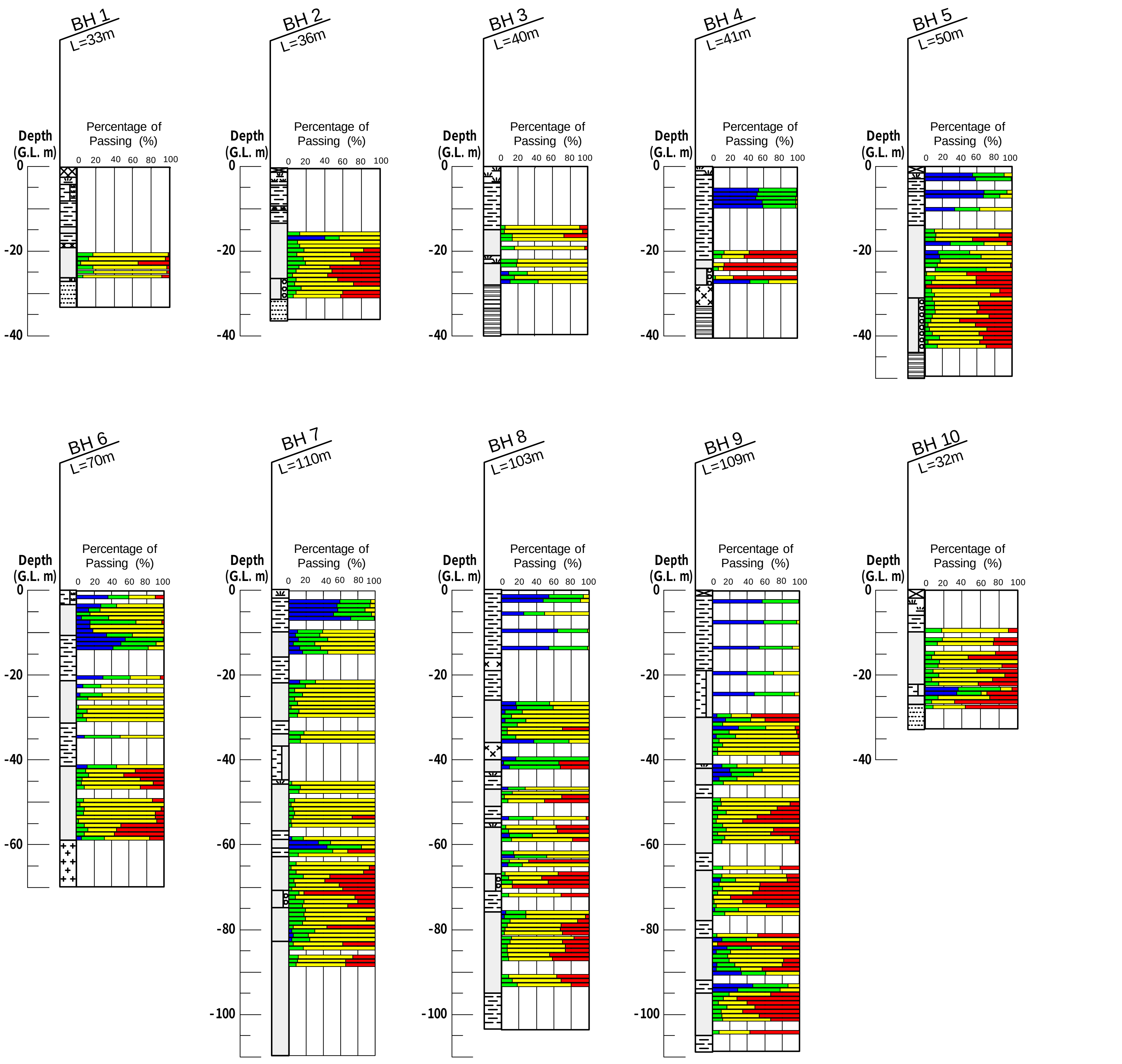

Figure F.2.16

Summary of Laboratory Soil Tests, Distribution of Grain Size Characteristics of Soils with Depth

LEGEND

Grain Size Analysis

0 %	20 %	40 %	60 %	80 %	100 %
Clay	Silt	Sand	Gravel		

Key of Borehole Log

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

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(3) Results of Laboratory Soil Test on Sandy Soils

Grain size characteristics of sandy soils of all ten (10) boreholes are summarised in **Figure F.2.16**.

2.3.5 Electric Logging

(1) Methodologies and Equipment Used

Electrical Logging was carried out by the normal pole-pole method at all boreholes, BH1 to BH10. **Figure F.2.17** shows a schematic drawing of the electrical logging equipment. As shown in the figure, the normal pole-pole method has 3 different pole distances, i.e., the first pole distance 250 mm, the second pole distance 500 mm and the third pole distance 1000 mm, was employed.

Before the electrical logging, PVC pipes of 50 mm in diameter were installed into the borehole to prevent the borehole wall from collapsing during the measurement. The PVC pipes had small holes of 10 mm in diameter at intervals of 100 mm.

(2) Results of Electrical Logging

Results of the electrical logging are summarised in **Figure F.2.18**. Measurements of each borehole are presented in **Data Book F.2.6** with a simplified borehole log and particle distribution characteristics. Since the measurement by the first pole distance of 250 mm was influenced by the presence of PVC pipes, only the measurements by the second and the third pole distances are presented.

(3) Correlation to Soil Conditions

Apparent resistivity of soils and rocks obtained by the electrical logging can be used to characterise the aquifer system. Although there is a trend that apparent resistivity of soils/rocks increases as parameters such as sand and gravel contents [**Figure F.2.19(a)**] or 20% diameter, D_{20} [**Figure F.2.19(b)**] increases, it is difficult to specify specific values of apparent resistivity to different types of soil/rock. This is because the apparent resistivity is a function not only of porosity of soil, but also of resistivity of fluid in a borehole, mixing of groundwater and drilling fluid, and of resistivity of minerals that compose soil grains.

It is common to use relative changes of apparent resistivity in a borehole in order to classify soils/rocks, such as clayey soil, sandy soil, gravelly soil and bedrock. Interbedded sandy soil layers in a clayey soil and interbedded clayey soils in a sandy/gravelly soil can be found by the electrical logging. An example of classification of soils or aquifer system at a location of borehole BH2 (Paya

Indah) is shown in **Figure F.2.20**. Based on this methodology, the description of ten (10) locations is made as follows:

(a) Location No. 1, South of Bt. Baja (Data Book Figure F.2.36)

Since the conductivity of groundwater is low at this location, relatively high resistivity values were obtained. The result shows impermeable layer, mainly consisting of clayey soils, to a depth of around 14 m. Layers between depths 20 and 26 m show high resistivity values of 200 to 300ohm-m, implying that permeability of this zone is high.

(b) Location No. 2, Paya Indah (Data Book Figure F.2.37)

The results can be read that an impermeable layer distributes to a depth of 12 m, and a permeable layer exists between depths 16 and 30 m. Especially, soils between 28 to 30 m are expected as highly permeable.

(c) Location No. 3, Northwest of Paya Indah (Data Book Figure F.2.38)

The results show that permeable layers distribute at depths around 16 m and 28 m. Relatively low resistivity values imply that the overall permeability at this location is lower.

(d) Location No. 4, Kg. Jenjarom (Data Book Figure F.2.39)

Impermeable layers distribute to a depth of around 22 m. A higher permeability zone is expected between depths of 26 and 32 m.

(e) Location No. 5, Kajibumi Well Field 2 (Data Book Figure F.2.40)

The results can be read that impermeable layers distribute to a depth of 12 m. Permeability of permeable layers increases gradually to a depth of 22 m.

(f) Location No. 6, Ladang TK. Gong (Data Book Figure F.2.41)

The conductivity of groundwater is high at this location, so that the relatively low resistivity values were obtained. The results show that impermeable layers exist at depths of around 15 and 36 m. Several layers of permeable zone are expected at this location.

(g) Location No. 7, Kanchong Darat (Data Book Figure F.2.42)

Layers to a depth of around 20 m are mainly impermeable. A high permeable zone is expected between depths of 25 and 35 m.

(h) Location No. 8, Kg. Endah (Data Book Figure F.2.43)

Impermeable layers are expected to a depth around 25 m, and permeable layers distribute between depths of 30 and 45 m. Impermeable layers can be seen in the permeable layers from a depth of 45 m.

(i) Location No. 9, Ladang Tumbok (Data Book Figure F.2.44)

Impermeable layers are expected to a depth around 33 m. Permeable layers exist below a depth around 40 m. The results also demonstrate alternating impermeable and permeable layers.

(j) Location No. 10, East of Paya Indah (Data Book Figure F.2.45)

High conductivity of groundwater gives highest resistivity values, 200 to 1,000ohm-m, among the 10 locations. Permeable layers exist between depths of 12 and 20 m, and at a depth of around 26 m.

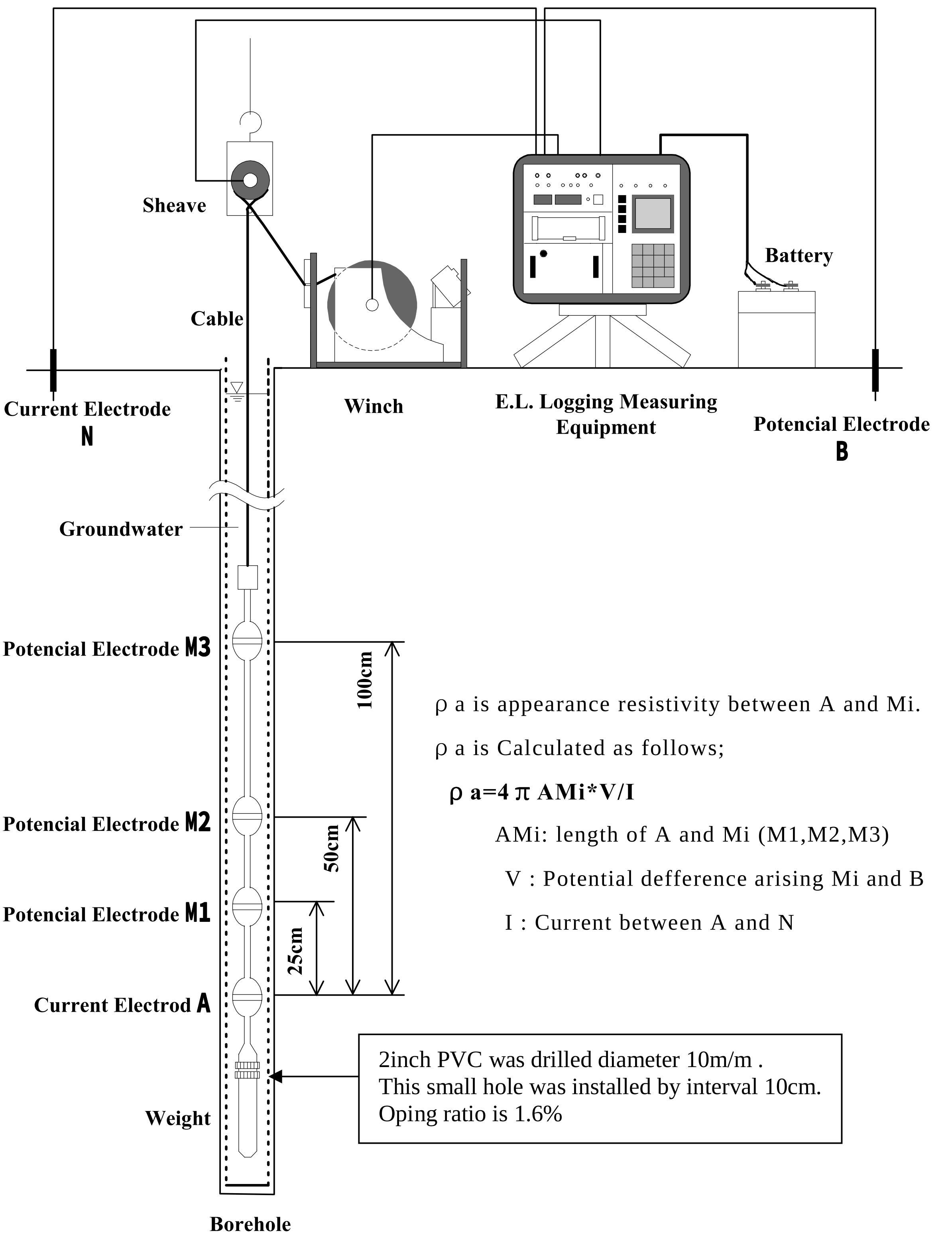

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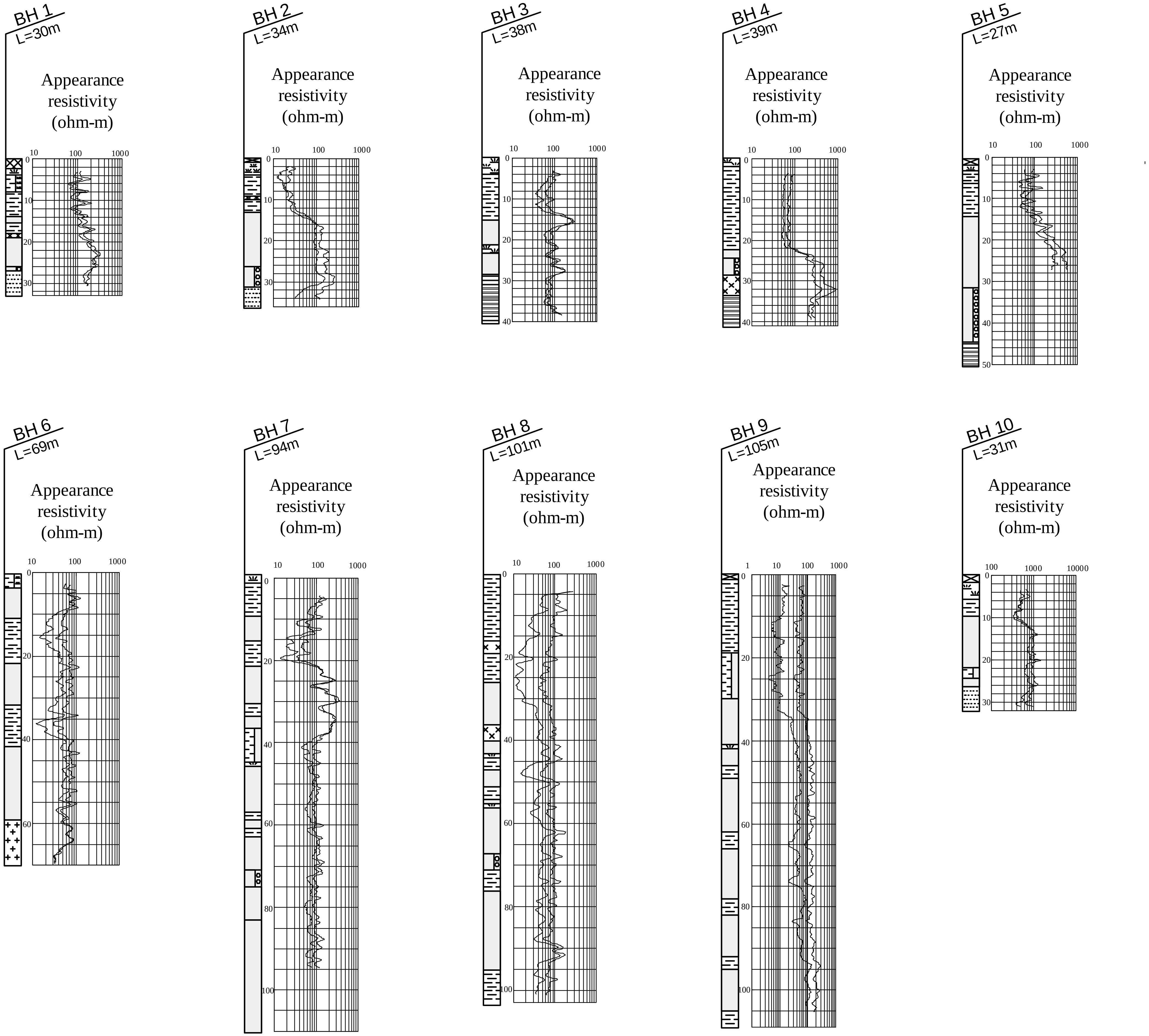
Figure F.2.17

Schematic Drawing of Electrical Logging Equipment

Figure F.2.18

Summary of Results of Electrical Logging



LEGEND

EL Logging

- Pole distance 100cm
- Pole distance 50cm

Key of Borehole Log

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

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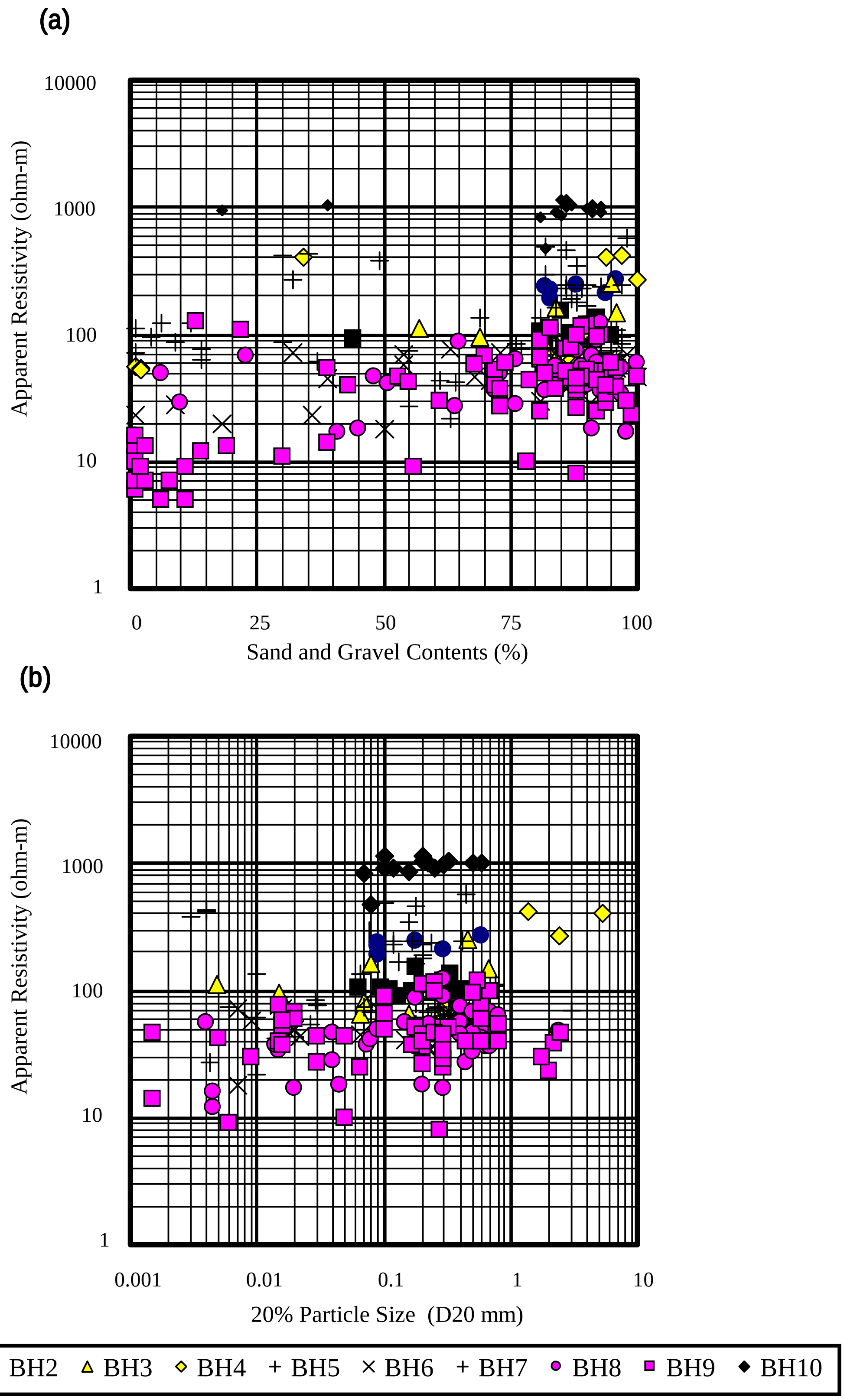

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Figure F.2.19

Relationship Between Grain Size and Apparent Resistivity

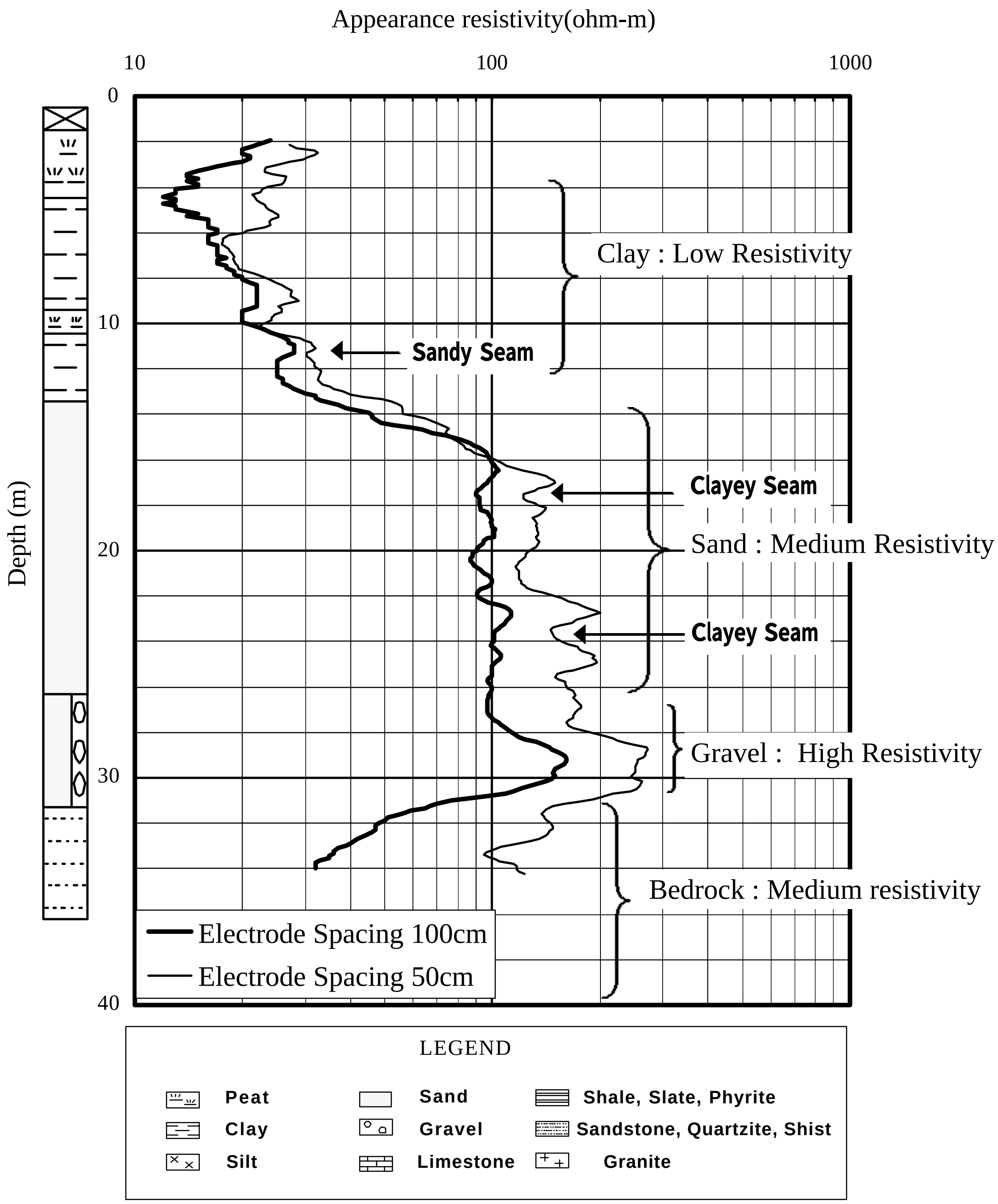

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Figure F.2.20

Interpretation of Results of Electrical Logging (Example at BH2)

2.3.6 Seismic Survey

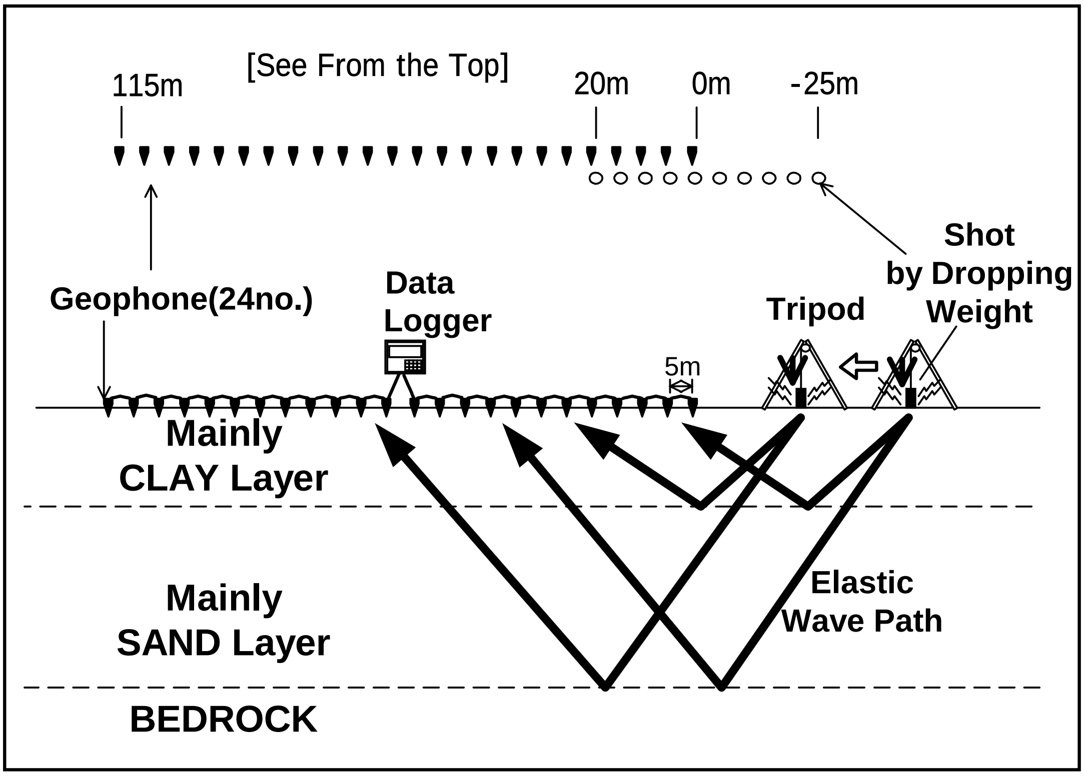
(1) Methodologies and Equipment Used

The seismic reflection survey was carried out to estimate the depth of the lower boundary of the Aquifer or the upper boundary of the bedrock at locations No. 7, No. 8 and No. 9, where the bedrock depths were not confirmed by the drilling. Survey lines are shown in **Annex Figures F.2.9**, **F.2.10 and F.2.11** for location of No. 7, No. 8 and No. 9, respectively.

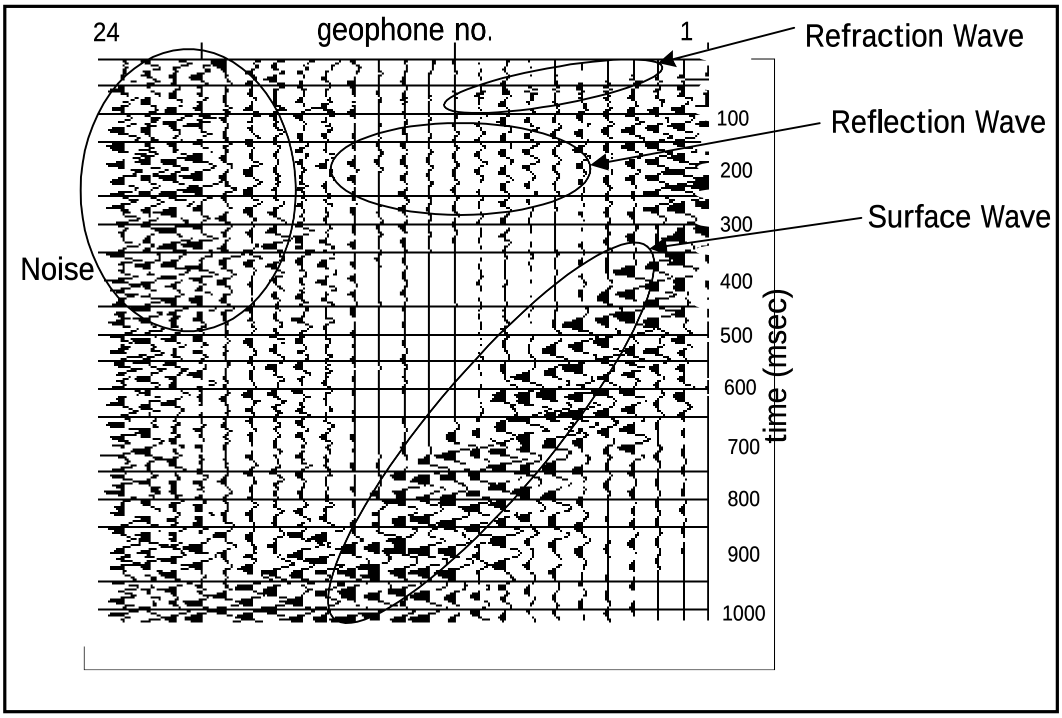
Figure F.2.21 shows a schematic drawing of the seismic reflection survey and a sample of records of the survey. A specification of the survey is summarised as follows:

- Length of survey line : 115 m
- Interval of receivers (geophones) : 5 m
- Number of receivers (geophones) : 24
- Interval of source points : 5 m
- Number of source points : 10 points
- Method of seismic source : free fall of a weight of the standard penetration test

An example of record produced by a single source is presented in **Figure F.2.21**. Reflection wave was extracted from three types of waves produced by the seismic source, i.e., reflection, refraction and surface waves. Records of several seismic sources were stacked to emphasise the depths of boundaries, where the seismic waves were reflected.



Schematic Drawing of seismic survey



Example of Seismic Survey Wave Form

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Figure F.2.21

Schematic Drawing of Seismic Reflection Survey

(2) Results of Seismic Survey

Results of the analysis are presented in **Figure F.2.22**. Since the survey gives only the boundaries of seismic wave reflection, another information such as borehole logs nearby and general geological conditions of the Groundwater Basin is required in order to correlate the survey results to the geological conditions. Estimated geological boundaries are shown in the columns attached to the stacked waves. Estimated depths of the lower boundary of the Aquifer or the upper boundary of the bedrock are summarised as follows:

- Location No. 7 (Kanchong Darat) : around 130 m to 150 m from the ground surface
- Location No. 8 (Kg. Endah) : around 130 m to 150 m from the ground surface
- Location No. 9 (Ladang Tumbuk) : around 140 m to 160 m from the ground surface

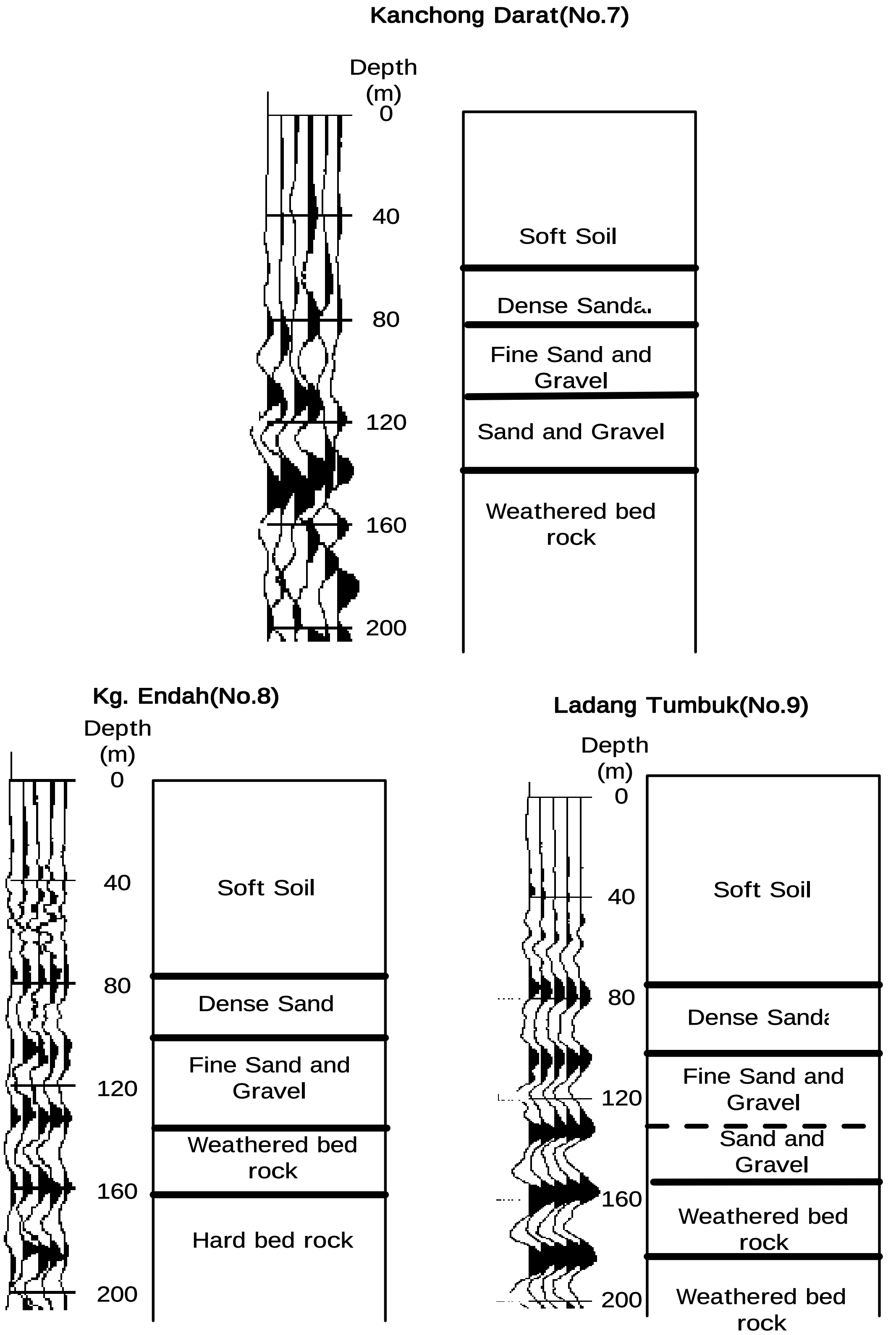

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Figure F.2.22

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Results of Seismic Reflection Survey

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3. TOPOGRAPHICAL AND GEOLOGICAL CONDITIONS OF THE LANGAT BASIN

3.1 Introduction

This chapter describes the topographical and geological conditions of the Langat Basin. Topographically, the Langat Basin can be divided into three areas; namely, the mountainous area, the hilly area and the lowlands. Each area is described briefly together with the status of the Langat River.

Three aquifers were identified in the Langat Basin and its neighbouring Klang River Basin. These are also described briefly in this chapter.

3.2 Topographical Conditions

3.2.1 Mountainous Area

The mountainous area is located in the northeastern part of the Basin. The Langat River and its major tributary, the Semenyih River, originate in the western slope of the mountain ridge penetrating the Malay Peninsula. Both rivers collect water in the mountainous area and flow generally southwestward in the mountainous terrain (**Photograph F.3.1**).

Height of mountains at their riverhead area is around 1,000 m, and most of the mountainous area is below 500 m. Ridges in the mountainous area are steeper than those in the hilly area. Transformation from mountainous to hilly is gradual, but the two areas may be divided at the elevation of around 100 m.

Photograph F.3.1

General View of Mountainous Area

The Langat River flows along a valley in the mountainous area and passes through small waterfalls. Width of the upstream river is around 10 m. The river collects water from small channels and small waterfalls running down from slopes towards the river. Springs from joints of granite were observed. River terraces are developed in some areas.

Riverbed materials are mostly boulders of granite (refer **Photograph F.3.2**). Diameter of some boulders exceeds 2 m. River water is clearer upstream compared to downstream, as shown in **Photograph F.3.2**.

Photograph F.3.2

Langat River in Mountainous Area

3.2.2 Hilly Area

The topography of the hilly area is characterised by gentle slopes spreading widely from north to east in the middle part of the Langat Basin. Height of the hills is less than 100 m. The lower part of the hilly area covers Cyberjaya, Dengkil, and KLIA. At present, most of the mega projects are concentrated in this hilly area.

Photograph F.3.3 Langat River in Hilly Area

River terraces have developed at both sides of the river. Width of the terrace ranges from several hundred metres to several kilometres. The river flows by cutting several metres into this terrace. During floods, floodplain deposits accumulate over the existing ones.

The river flows gently in the hilly area, and its colour turns into light brown from suspended sediment (**Photograph F.3.3**). Riverbed sediments change composition gradually from boulder/gravel in the mountainous area to sand and then silt in the hilly area.

3.2.3 Lowland Area

The lowland area, an alluvial plane, is located in the southwestern part of the Langat Basin. It is bounded by the hilly area in the north and east and by the sea in the southwest. Several small hills can be found at the northern and eastern boundaries of the lowlands.

The Langat River turns its direction to the west at the boundary of the hilly area and the lowland, and receives a tributary, the Semenyih River. After receiving another tributary, the Labu River, the Langat River starts meandering. The river flows so gently that (**Photograph F.3.4**) at Banting, a back flow of the river is even observed.

Photograph F.3.4 Langat River in Lowlands

Near the seacoast, the Langat River flows around a hill, Bt. Jugra, meanders in a peaty swamp (**Photograph F.3.5**), and then flows into the sea.

Riverbed sediments change from silty at the confluence of the Langat and Semenyih Rivers (**Photograph F.3.6**) to clayey at Banting (**Photograph F.3.7**).

Photograph F.3.5
Langat River near the Seacoast

Photograph F.3.6

Riverbed Sediment at Confluence of Rivers Langat and Semenyih

Photograph F.3.7

Riverbed Sediment at Banting

3.3 Geological Conditions

3.3.1 Mountainous Area

The stratigraphic table of the regional geology is summarised in **Table F.3.1**.

Table F.3.1 Stratigraphic Table of the Region

Era	Formation	Member	Litho facies
Holocene	Beruas Formation	Pengklan Member	inland freshwater deposits; clay, silt, sand
		Matang Timbul Member	fluviatile, brackish lake deposits; silt, clay
	Gula Formation	Port Weld Member	mangrove, tidal flat deposits; silt, clay
		Metang Gelugor Member	Sand ridge deposits; sand
Pleistocene	Simpang Formation	Upper Clay Member (Kempadang Formation)	shallow marine deposits; clay
		Lower Sand Member	fluviatile deposits; sand, gravel
Permian	Kenny Hill Formation	-	shale, phyllite
Devonian ?	Kajang Formation	-	phyllite, schist
Old-Silurian	KL Limestone	-	limestone
	Howthornden Formation	-	schist, quartzite

Bedrock in the mountainous area consists of schist and phyllite of Howthornden Formation in Old Silurian and granitic rock of Permian. 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.

3.3.2 Hilly Area

Bedrock in the hilly area consists of phyllite, shale and quartzite of Kajang Formation and Kenny Hill Formation

3.3.3 Lowlands

Geology of the lowlands consists of unconsolidated gravel, sand, silt and clay of Simpang Formation of Pleistocene and Gula and Beruas Formations of Holocene. These 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 studied in this Study.

Detail descriptions of each formation are given in **Section 4.2** with focus on hydrogeological and engineering aspects. Geological profiles across the lowlands are presented in **Section 4.2**.

3.4 Aquifers

From the study of existing information and field reconnaissance, three possible aquifers were identified in the Langat Basin and in the neighbouring Klang River Basin. These are the alluvial sediments in the lowlands of the Langat Basin, the riverside alluvium sediments in the hilly and mountainous areas of the Langat Basin, and the limestone and marble found in the neighbouring Klang River Basin.

3.4.1 Alluvial Sediments

Alluvial sediments, mainly consisting of sand and gravel, distribute widely in the lowlands of the Langat Basin. These are Terrestrial Pleistocene sediments (Lower Sand Member of Simpang Formation) and considered as an important aquifer in the Basin. This Simpang Formation is the thickest and oldest Quaternary sediment in the Basin and has aggraded above the eroded older hard rocks surface. The Alluvial sediments are covered by younger clayey layers and then, at some locations, by peat layer.

The thickness of the Formation varies considerably due to the undulating nature of the top of the formation and uneven bedrock surface, upon which the formation is in direct contact. The thickness is expected from several metres in the upper part of area to as much as over 100 metres at the lower part.

The Study was focused on the alluvial sediments and most of the field investigations in Phase II were targeted on this formation.

3.4.2 Riverside Alluvial Sediments

Field trips, interpretation of topographical maps, and the existence of old tin mines suggest that riverside alluvial sediments, consisting of sandy and gravel deposits, may distribute along the Langat River in the hilly and mountainous areas and also along the tributaries, such as the Semenyih and Labu Rivers. Exact locations of the riverside alluvial sediments and their properties were not identified in the Study.

It is not the scope of the Study to investigate the riverside alluvial sediments in Phase II; however, in general, there exists the possibility of obtaining groundwater of good quality from the so-called riverbank infiltration wells situated near the riverbanks in the hilly and mountainous areas.

For development of groundwater resources in the Riverside Alluvial Sediments (riverbank infiltration), it is necessary to choose an area in the riverbank of the stretch where the river is still fast flowing and the riverbed sediments are coarse to allow the recharge of groundwater from the riverbed into the aquifer during water extraction (pumping). River water should be of good quality, suited for the riverbank infiltration. The area should be without present or past mining activity that would influence the groundwater flow and quality.

3.4.3 Limestone and Marble

Limestone (and marble), which is karstic and fractured, is underlying much of the Klang River Basin including Kuala Lumpur. The Limestone is the oldest and significant permeable layer in the region. According to the short geological field reconnaissance and remarks in various literatures, there exists a possibility of obtaining good quality groundwater from the limestone areas, especially in the upper or northern part of limestone occurrence, which is not influenced by mining activities.

In general, under the limestone and marble of Silurian period, older sediments such as meta-sandstone, quartzite, phyllite and schists, and intruded granites and its differentiates exist and are creating a nearly impermeable aquifer bed. Granite and its differentiates intruded during the Mesozoic era. The limestone is overlain by Quaternary sedimentary rocks such as arenaceous schistose rocks followed by quartzite and shale.

The Limestone in the Klang River Basin was expected as a good recharge source of groundwater to the Alluvial Sediments in the Langat Basin, if both aquifers had a good contact. However, the drillings during the field survey in Phase II did not give a direct evidence of the direct contact between the aquifers. A hypothesis of the boundary between the Langat Basin and the Klang River Basin is given in **Figure 4.4.12**.

3.5 Aquifer System

3.5.1 General

This section gives a general description of the aquifer system in the lowlands of the Langat Basin (the Groundwater Basin). Based on the regional geological knowledge (**Table F.3.1**), the aquifer system of the Groundwater Basin can be divided into the following formations:

- Aquifer Bedrock;
- Aquifer, Terrestrial Pleistocene Sediments (Lower Sand Member, Simpang Formation);
- Shallow Marine Sediments (Upper Clay Member, Kempadang Formation);

- Marine Origin Sediments (Gula Formation); and
- Young Holocene Fluviatile Sediments (Beruas Formation).

Description of each formation is given below.

3.5.2 Aquifer Bedrock

Aquifer bedrock consists of granite and its differentiates, and of other pre-Quaternary old sedimentary rocks. Surface of bedrock can be very variable because of old alluvial erosion sedimentation processes.

3.5.3 Aquifer, Terrestrial Pleistocene Sediments (Simpang Formation)

The Aquifer, the thickest and oldest Quaternary sediment unit, has aggraded above the eroded older hard rocks surface and creates terrestrial Pleistocene sediments (Simpang Formation), which is equivalent to the Old Alluvium.

The terrestrial formation (predominantly alluvial fan and braided stream deposits) mainly consists of gravel and/or sand. They are permeable and widely spread, forming the main aquifer in the area. The formation is usually overlying undulating bedrock and is underlain by the less permeable or nearly impermeable layer/layers of silt, sandy clay and clay.

The formation generally comprises gravel grading layer at the lower part, and changes its sediment composition upwards to sand grading layer. The sequence shows that the formation is more permeable at the lower part and becomes less permeable upwards. The thickness of the Formation varies considerably due to the undulating nature of the top of the formation and uneven bedrock surface, upon which the formation is in direct contact.

3.5.4 Shallow Marine Sediments (Kempadang Formation)

Shallow marine sediments of Kempadang Formation (clay, silt, sand) deposited during the late Pleistocene at the coastal area. This corresponds to the age of deposition of the late Pleistocene terrestrial sediments in the terrestrial inland area. The shallow marine sediments have similar features to the marine origin sediments (Gula Formation). In driller's logs they are usually described together as a unit.

3.5.5 Marine Origin Sediments (Gula Formation)

Marine sediments of Gula Formation deposited during the first half of Holocene age, when the sea level rose some 100 m in comparison with the conditions at the end of the previous terrestrial conditions. They distribute over a large portion of the west coast of Peninsular Malaysia. Sediments are mainly of greenish to olive grey colour marine and estuarine clay, silt, eventual with subordinate beach ridges sand and sand with gravel.

Gula Formation is overlying the terrestrial Simpang Formation and Kempadang Formation, if developed. Sand detritus sequences (including sand, mica) of few mm to few metres thick are found within the Formation. Pyrite is a dominant mineral in the clay layers. The thickness of the Formation generally increases from inland toward the sea, and can reach 20 to 40 m.

Gula Formation is considered as impermeable or nearly impermeable. From the modelling point of view Gula Formation and the Kempadang Formation could be considered as a unit and could be modelled together.

3.5.6 Young Holocene Fluviatile Sediments (Beruas Formation)

Young Holocene river sediments deposited as a result of retreat of the shoreline from its maximum inland position some 5000 years ago in mid-Holocene, when it may have peaked about 5 m higher than the present sea level. They are overlying Gula Formation and are still depositing by the current river channel's activities. The Formation is up to several metres thick and consists of the following:

- River channel deposits (gravel, sand, silt), deposits of levee accumulations (up to 4 m high, sand, sandy silt, silt, clay) along the rivers;
- Deposits of flooded area behind the levees (flood fine sand, silt clay, plant remains), back swamp deposits (fresh water swamps in the water logged areas, interlaminated with humic clay and humic silt); and
- Peat layers (plant remains, clay, silt) at various depths.

Sand ridges (medium to coarse sand dikes) near the present shoreline are of new Holocene age, and of the coastline origin. They originated during the recent sea regression in the late Holocene. Morphologically they have risen to a height of up to few metres (maximal 4-5 m) above the present mean sea level.

4. PHYSICAL CHARACTERISTICS OF THE GROUNDWATER BASIN

4.1 Introduction

Based on the field survey (**Chapter 2**) and general topographical and geological conditions (**Chapter 3**), the physical characteristics of the Groundwater Basin are as defined and described in this chapter.

Boundary conditions of the Groundwater Basin, namely, topographical boundary and bedrock surface, were determined and presented in a plan. Geological conditions of the Groundwater Basin are simplified and separated into four (4) layers: peat and peaty soils (Beruas Formation), clayey soils (Gula Formation and Kempadang Formation, when exists), the Aquifer or sandy and gravelly soils (lower sand member of Simpang Formation), and the aquifer bedrock. The simplified geological conditions are presented in geological profiles and the distributions of the layers are shown in plan maps.

Typical physical properties of the layers are described. Especially, consolidation properties of the clayey soil layers are defined for the estimation of land subsidence. Although the typical characteristics of the Aquifer are described in this chapter, detailed hydro-geological properties evaluated from the pumping tests are given in **Sector G**.

4.2 Boundary of Groundwater Basin

4.2.1 General

Topographical boundary (or horizontal boundary) of the Groundwater Basin is determined by the surface topographical conditions. The bedrock surface, regarded as the lower boundary of the Basin, is defined by using the results of the soil investigation in Phase II, the existing geological logs and the general geological conditions. The topographical boundary and the contour map of the bedrock surface (elevation from the mean sea level) are presented in **Figure F.4.1**.

4.2.2 Topographical Boundary

Topographically, the Langat Basin is divided into three areas, namely, the mountainous areas, the hilly areas and the flat lowlands. The areal distribution of the Groundwater Basin is considered analogous to those of the lowlands that are located in the southwest of the Langat Basin. The boundary between the lowlands and hills was defined firstly by drawing topographical contour lines of 20 metres in height, and then adjusted by interpreting aerial photographs. The boundary of the Groundwater Basin is presented in **Figure F.4.1**.

The Groundwater Basin in the north and the east is bounded by the hills. In the north, three small but distinct hills are recognised. Three valleys between the hills connect the Groundwater Basin and the Klang Basin. In the east, valleys formed by Langat River, Labu River and a hypothetical old channel of Langat River, which run through Dengkil, connect the hilly 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.

In the south, the sea bounds the Groundwater Basin.

4.2.3 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.

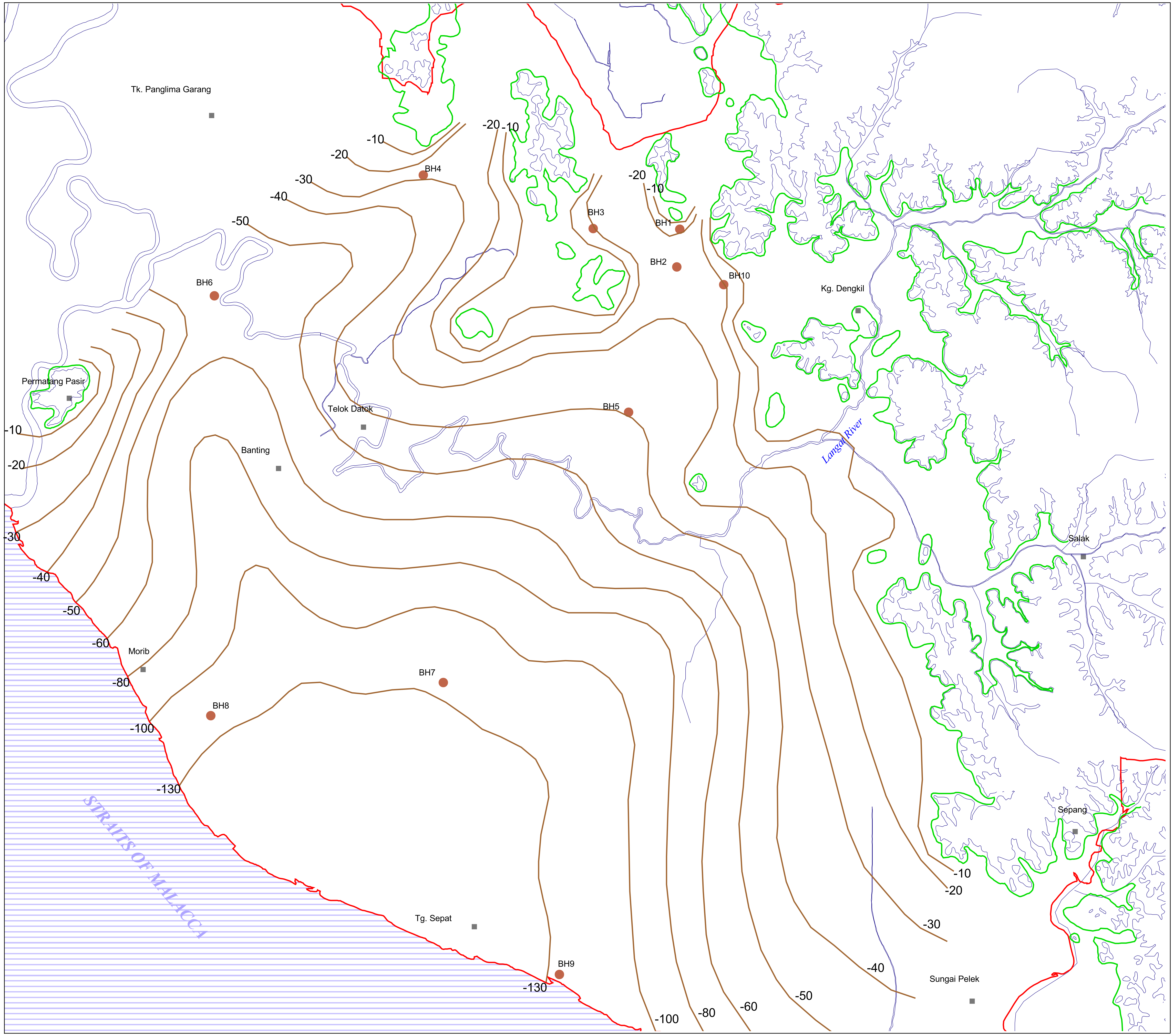
Contour lines of the bedrock surface in **Figure F.4.1** are constructed by interpolating discrete points of bedrock level determined from the borehole logs. From the contour map in the figure the following features of the buried valleys formed into the bedrock can be seen.

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 to -150m from the mean sea level at Location No. 7 and 8, and around -140m to -160m at Location No. 9. Contour lines at the centre of the valley near the seacoast were deduced by information at the above three locations.

Figure F.4.1

Topographic Boundary of Lowlands and Contour Map of Bedrock Level



LEGEND

Topographic Boundary

Topographic Contourline of 20m Height

Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation

Bedrock Level

Contourline of Bedrock Surface

Boring Point (Present Study)

Rivers

Towns

Study Area

Contourline Level is from the mean sea level

N W E S

Scale 1 : 200,000

2 0 2 4 Kilometers

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4.3 Geological Conditions of Groundwater Basin

4.3.1 General

To simplify the geological conditions of the Groundwater Basin the Quaternary sediments and the bedrocks in the Basin are separated into four (4) layers; namely,

- Layer 1: peat and peaty soils (Beruas Formation);
- Layer 2: clayey soils (Gula Formation and Kempadang Formation, when exists);
- Layer 3: the Aquifer or sandy and gravelly soils (lower sand member of Simpang Formation); and
- Layer 4: the aquifer bedrock.

The clayey soils (Layer 2) are subdivided into two layers according to their consistency, namely the soft clayey soil (Layer 2a) and the medium to stiff clayey soils (Layer 2b).

4.3.2 Geological Profiles

Eleven (11) geological profiles are prepared by integrating the results of the soil investigation, the existing borehole logs and the general geological information. A location map of the profiles is shown in **Figure F.4.2**. Locations of the profiles are selected so as to overview the geological conditions over the Groundwater Basin; some profiles pass along or across the major valleys in the Basin, and the others profiles pass along and across the boundaries of the Basin, as summarised in **Table F.4.1**.

Table F.4.1 Locations of Geological Profile

Profile Name	Location of Profile	Figure Number
A-A'	along the major valley from the north	**Figure F.4.3**
B-B’	along the major valley from the north	**Figure F.4.4**
C-C’	along the major valley from the east	**Figure F.4.5**
D-D'	along the northern boundary	**Figure F.4.6**
E-E’	profile across the Basin at the centre	**Figure F.4.7**
F-F'	along the sea coast, the southern boundary	**Figure F.4.8**
G-G'	along the western boundary	**Figure F.4.9**
H-H’	along the eastern boundary	**Figure F.4.10**
I-I’	crossing the western boundary	**Figure F.4.11**
J-J’	crossing the northern boundary	**Figure F.4.12**
K-K’	crossing the eastern boundary	**Figure F.4.13**

Geological profiles with grain size characteristics are prepared for Profiles A-A', B-B', D-D', E-E', and F-F' and presented in **Annex Figures F.4.1 to F.4.5**. Similarly, geological profiles with apparent resistivity from the electrical logging for the same profiles are presented in **Annex Figures F.4.6 to F.4.10**.

The profile B-B' (see **Figures F.4.4**, **Annex Figure F.4.2**, **Annex Figure F.4.7**) passes along one of the major buried valleys from the entrance to the outlet of the Groundwater Basin. Soil investigation sites No. 1 (South of Bt. Baja), No.2 (Paya Indha), No. 7 (Kanchong Darat) are located on the profile line. The thickness of the Quaternary sediments deposited on the bedrock varies from 27 m at the entrance of the Groundwater Basin to over 150 m (estimated) at the seacoast.

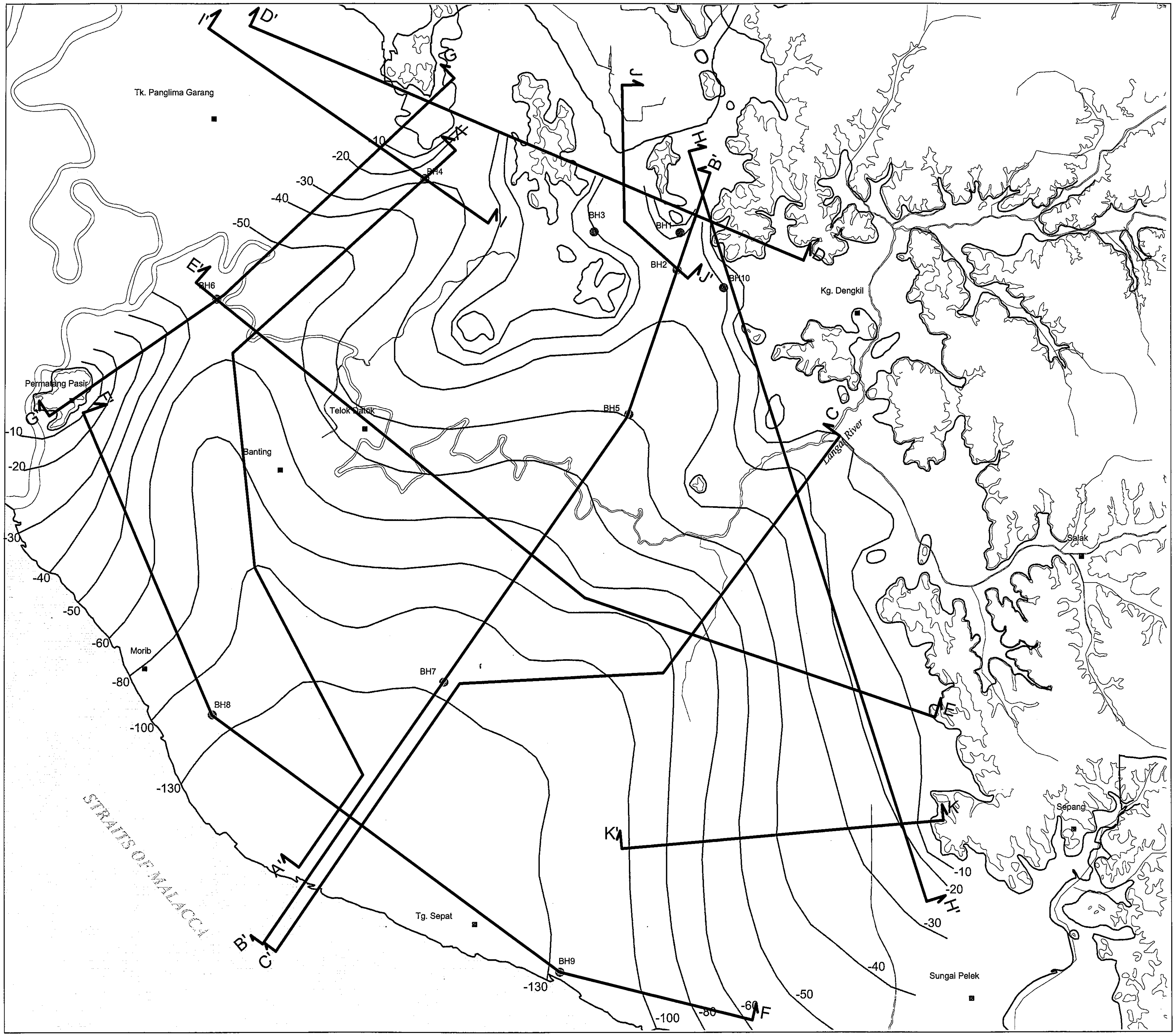
Typical geological conditions in the Groundwater Basin can be seen along the Profile B-B'. Four (4) layers as divided, namely from the ground surface the peat/peaty clay layer (Layer 1), clayey soil layer (Layers 2a and 2b), the sandy and gravelly soil layer (Layer 3) and the bedrock (Layer 4). The sandy/gravelly soil layer (Layer 3) corresponds to the Aquifer. Although the clayey soil layer (Layer 2) may be regarded as a single unit in terms of hydro-geological point of view, a subdivision is made between soft layer (layer 2a) and medium to stiff layer (layer 2b) for the purpose of evaluating land subsidence. Artificial fill of 0.3 to 2.5 m thick, which was found at Location Nos. 1, 2, 4, 5, 7, 8, 9, and 10, is not included in the layer numbering system.

Geological conditions along the northern boundary of the Basin (Profile D-D') are shown in **Figure F.4.6**, **Annex Figure F.4.3** and **Annex Figure F.4.8**. Three narrow buried channels are expected along the northern boundary. Geological profiles along the seacoast (Profile F-F') are presented in **Figure F.4.8**, **Annex Figure F.4.5** and **Annex Figure F.4.10**.

The four layers defined above are common at all localities. Description of the layers is given in the next section.

Figure F.4.2

Locations of Geological Profiles



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 S E W

Scale 1 : 200,000

2 0 2 4 Kilometers

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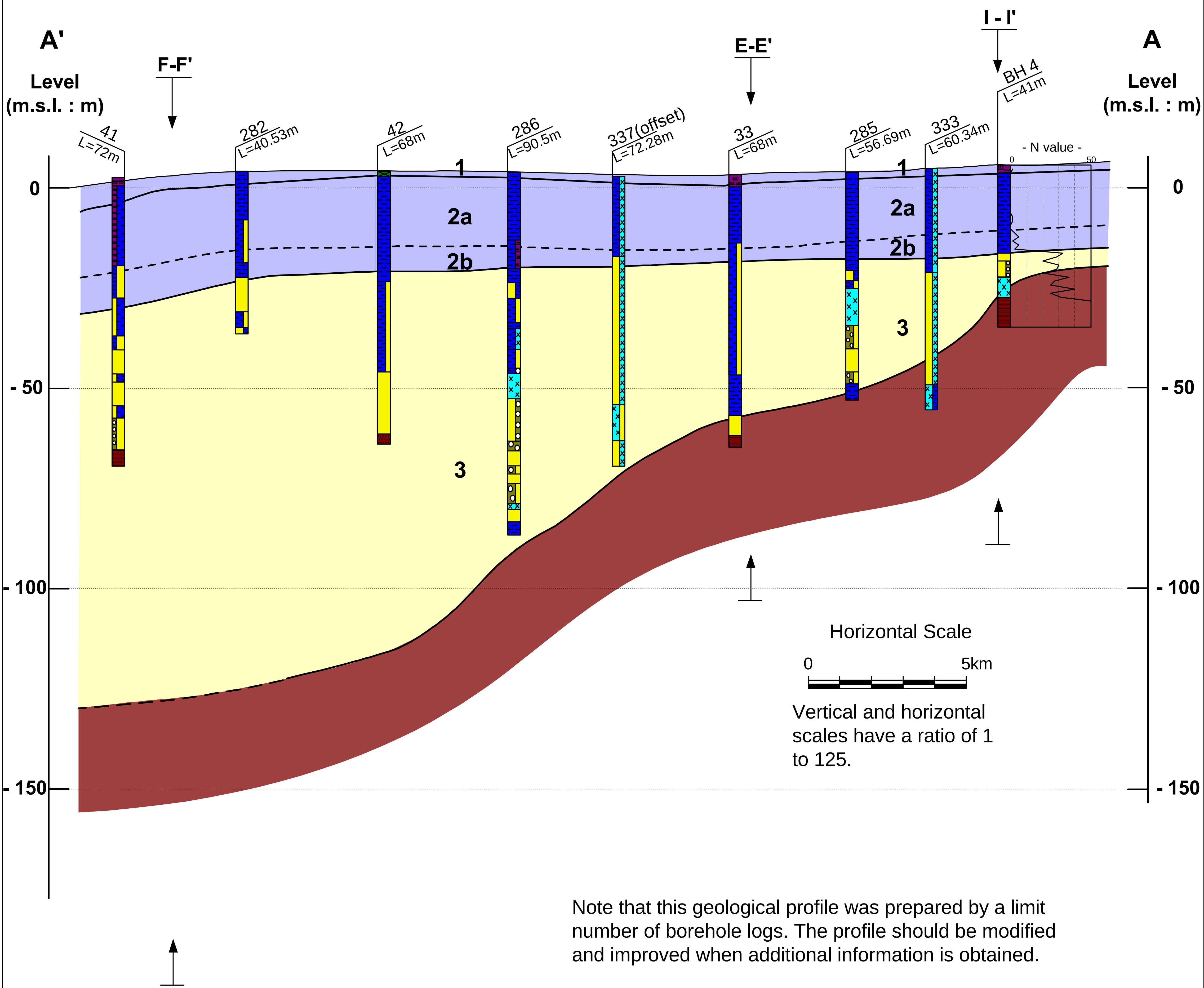

Note that this geological profile was prepared by a limit number of borehole logs. The profile should be modified and improved when additional information is obtained.

Figure F.4.3

Geological Profiles, A -A'

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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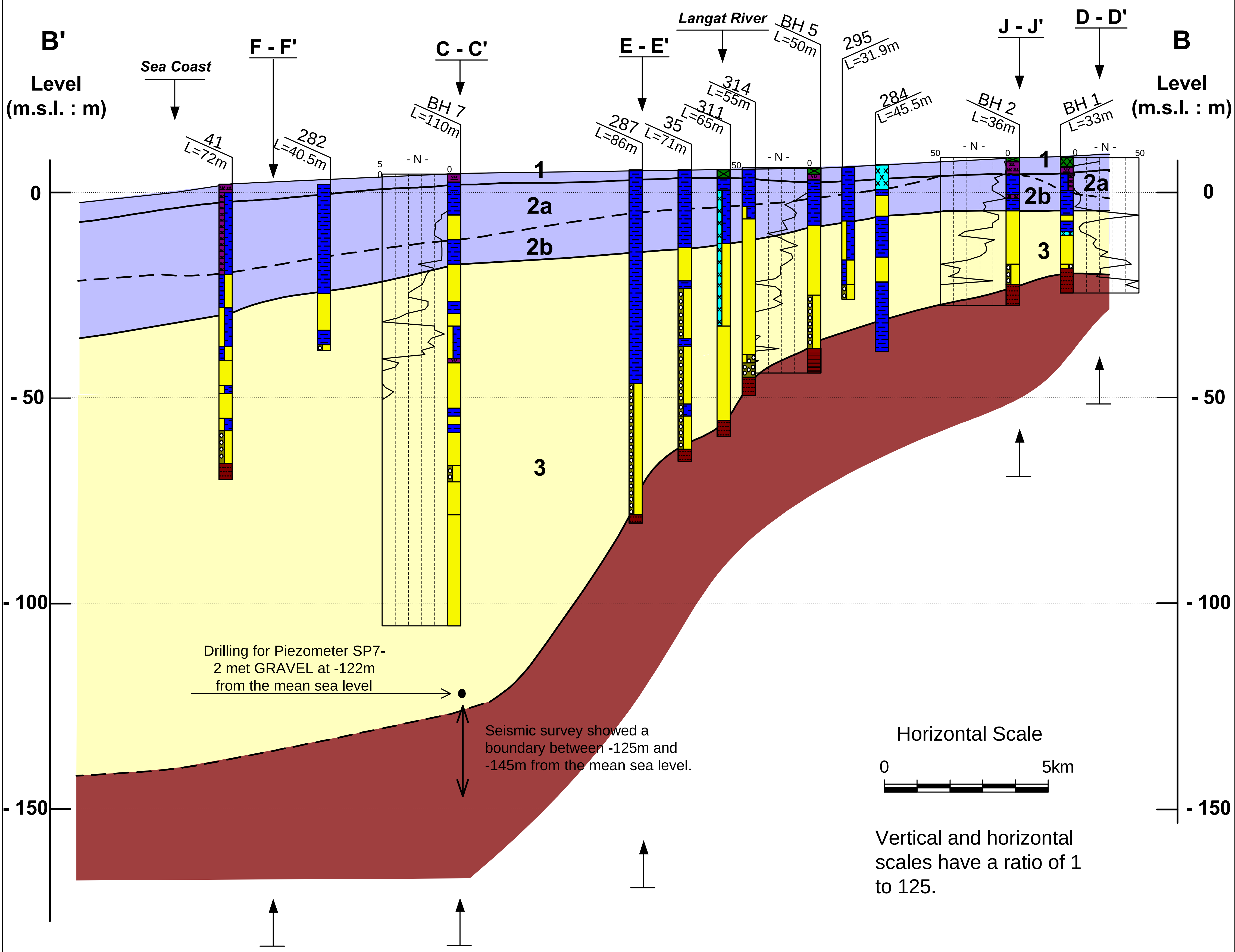
Figure F.4.4

Geological Profiles, B - B'



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.

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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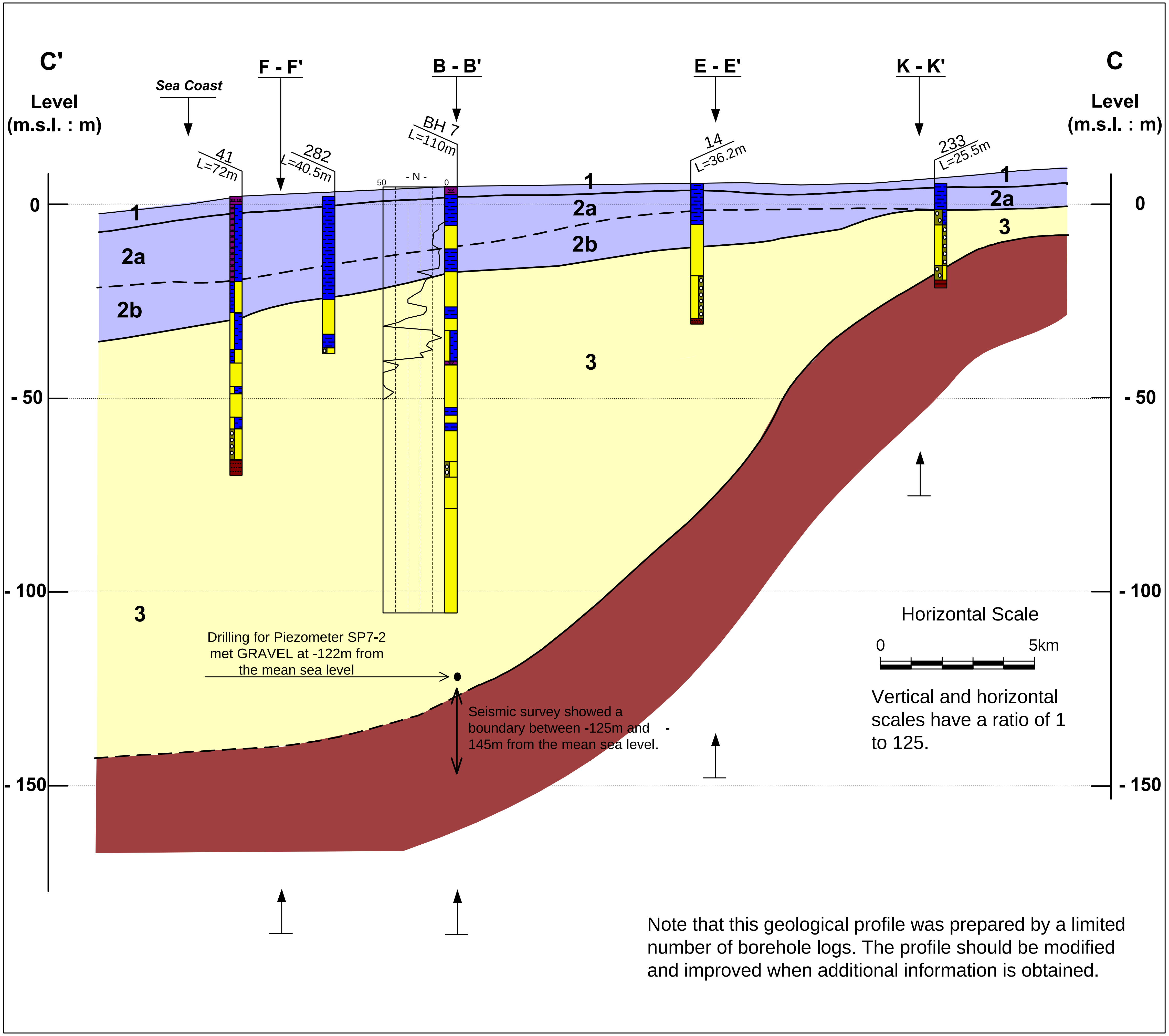
Figure F.4.5

Geological Profiles, C - C'



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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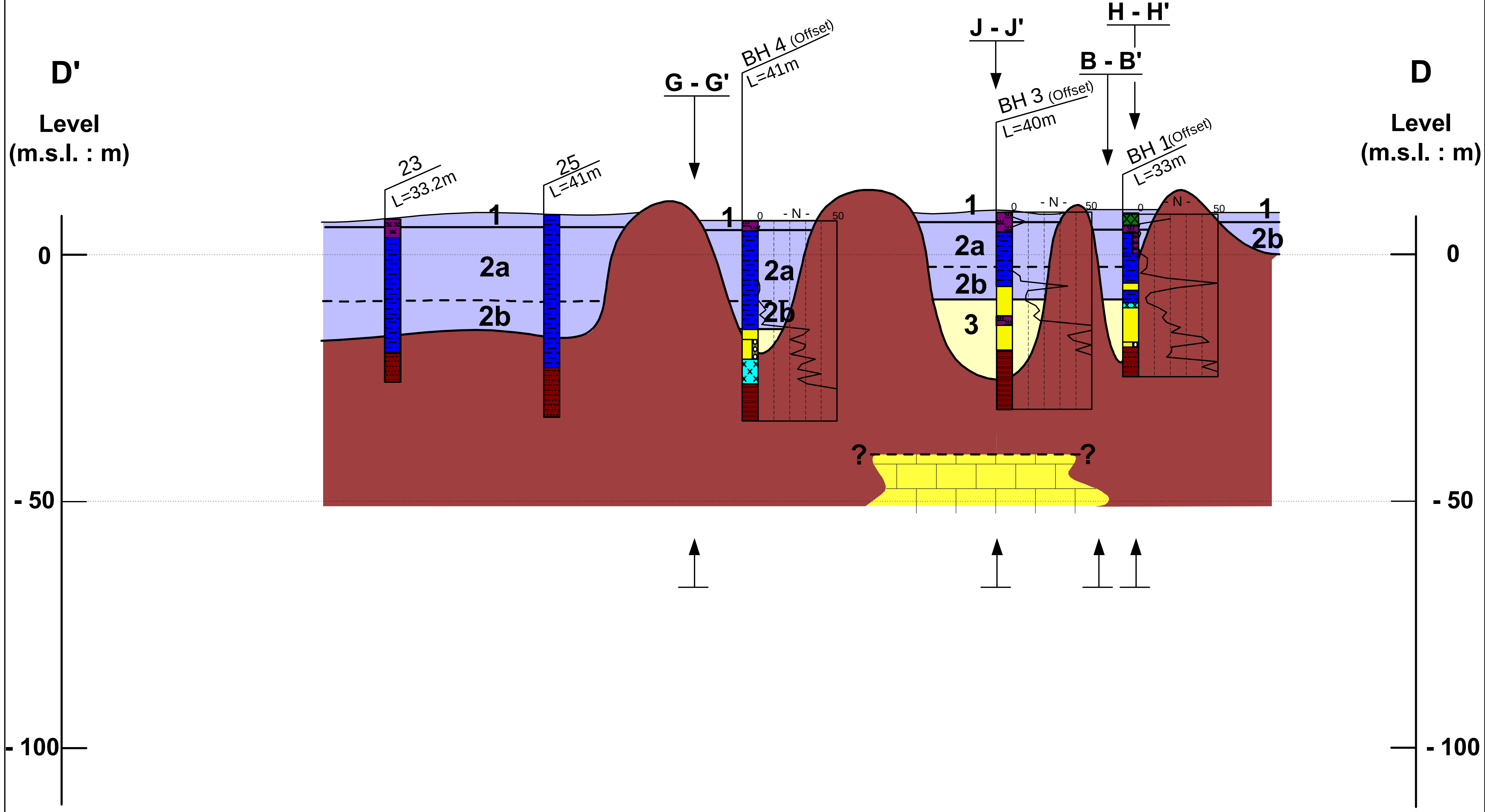
Figure F.4.6

Geological Profiles, D - D'



Horizontal Scale

0 5km

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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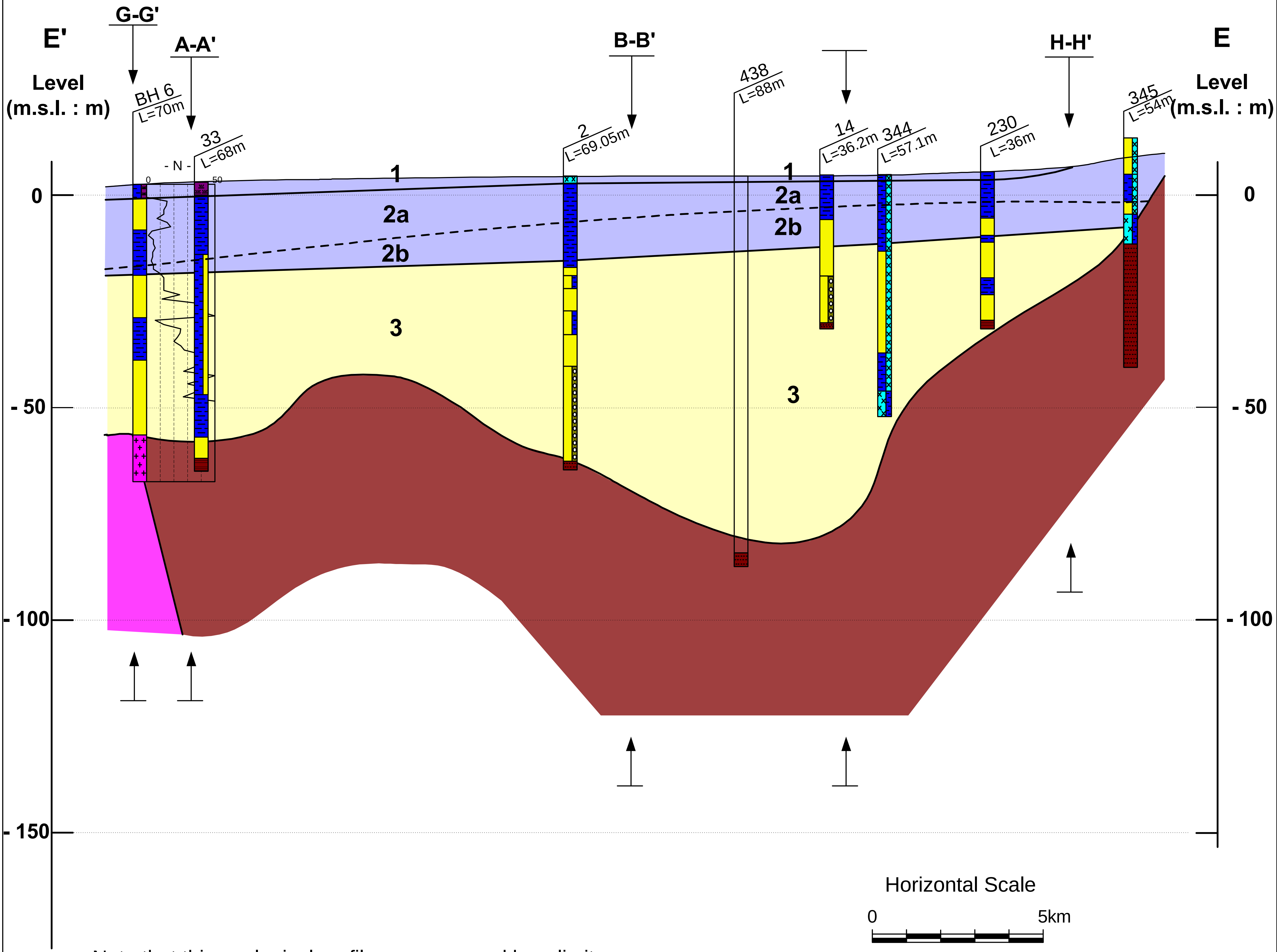
Figure F.4.7

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

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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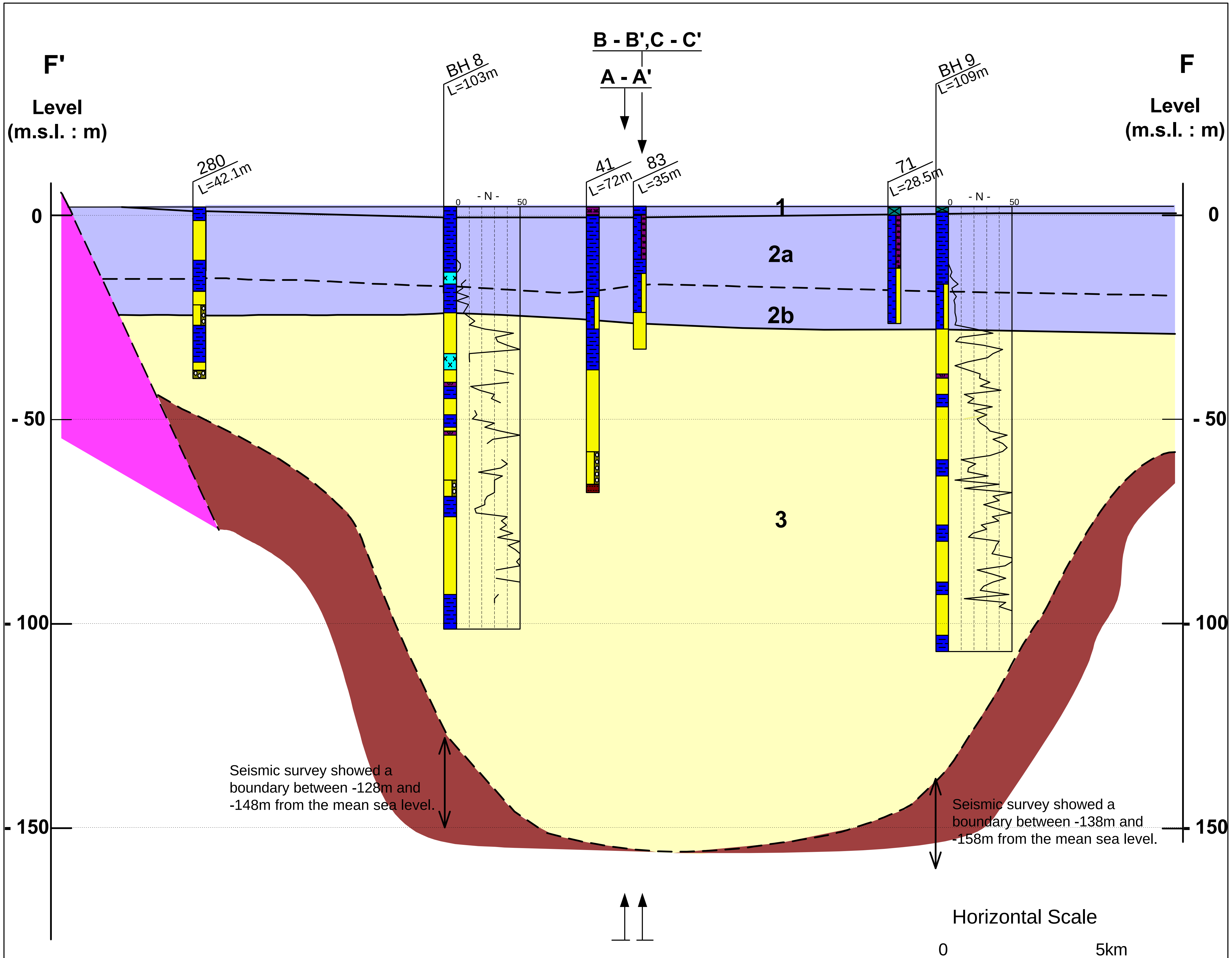
Figure F.4.8

Geological Profiles, F - F'



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

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.

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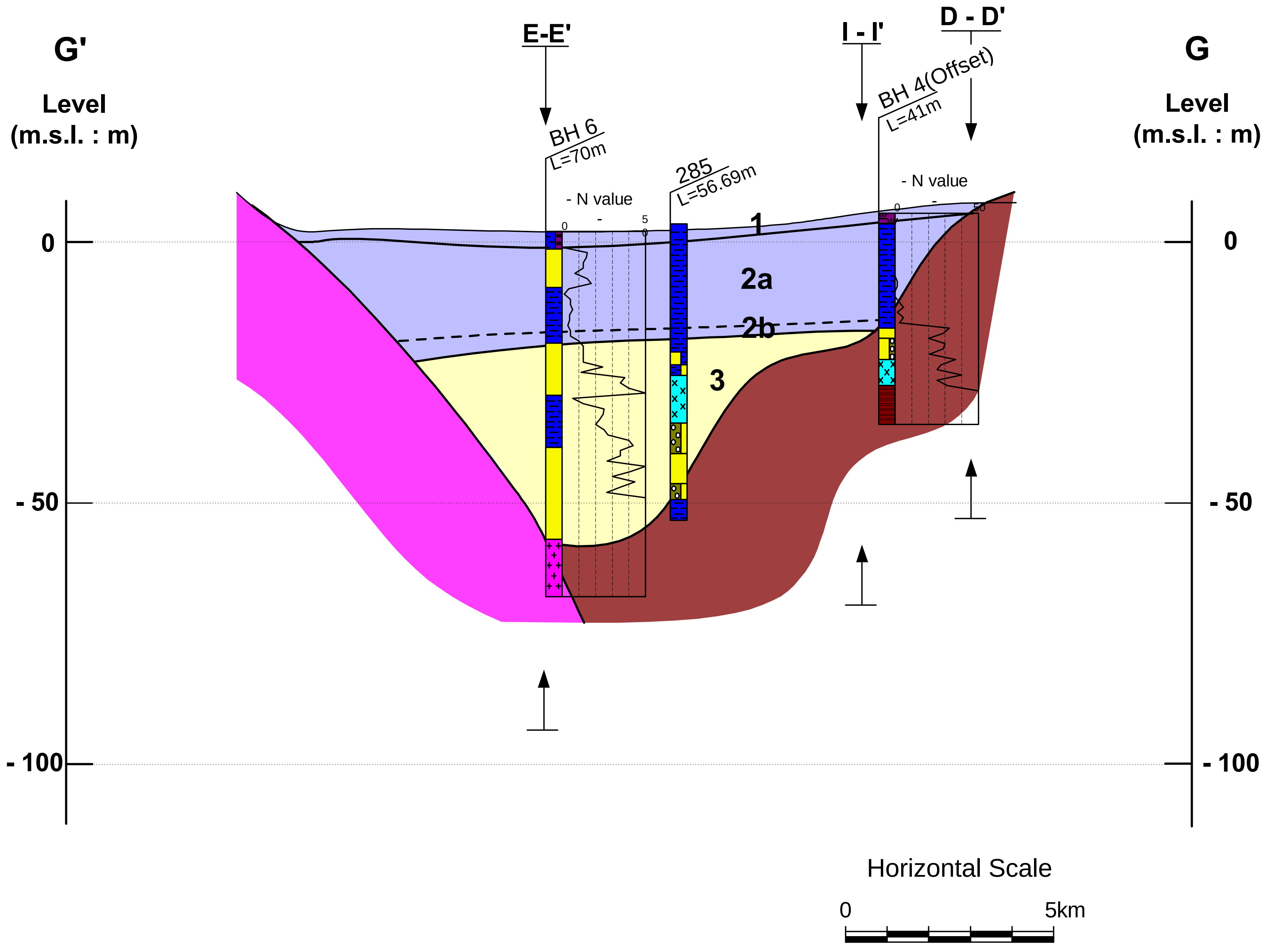
Figure F.4.9

Geological Profiles, G - G'



LEGEND

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

1 - 3 Layer Number

Boundary of Geology

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.

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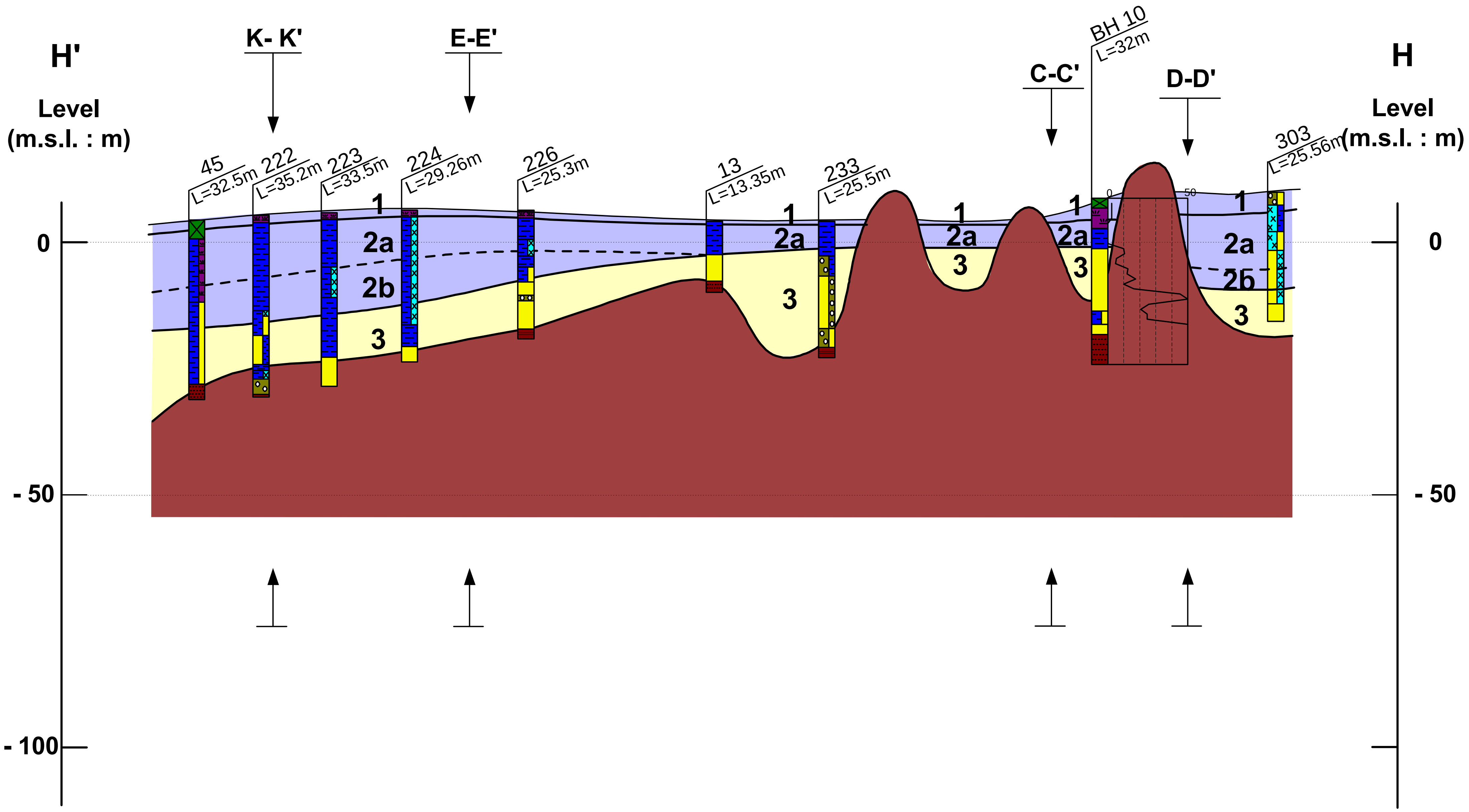
Figure F.4.10

Geological Profiles, H - H'



LEGEND

PEAT

CLAY

SILT

SAND

GRAVEL

LIMESTONE

SHALE, SLATE, PHYLLITE

SANDSTONE, QUARTZITE, SCHIST

1 - 3 Layer Number

Boundary of Geology

Horizontal Scale

0 5km

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.

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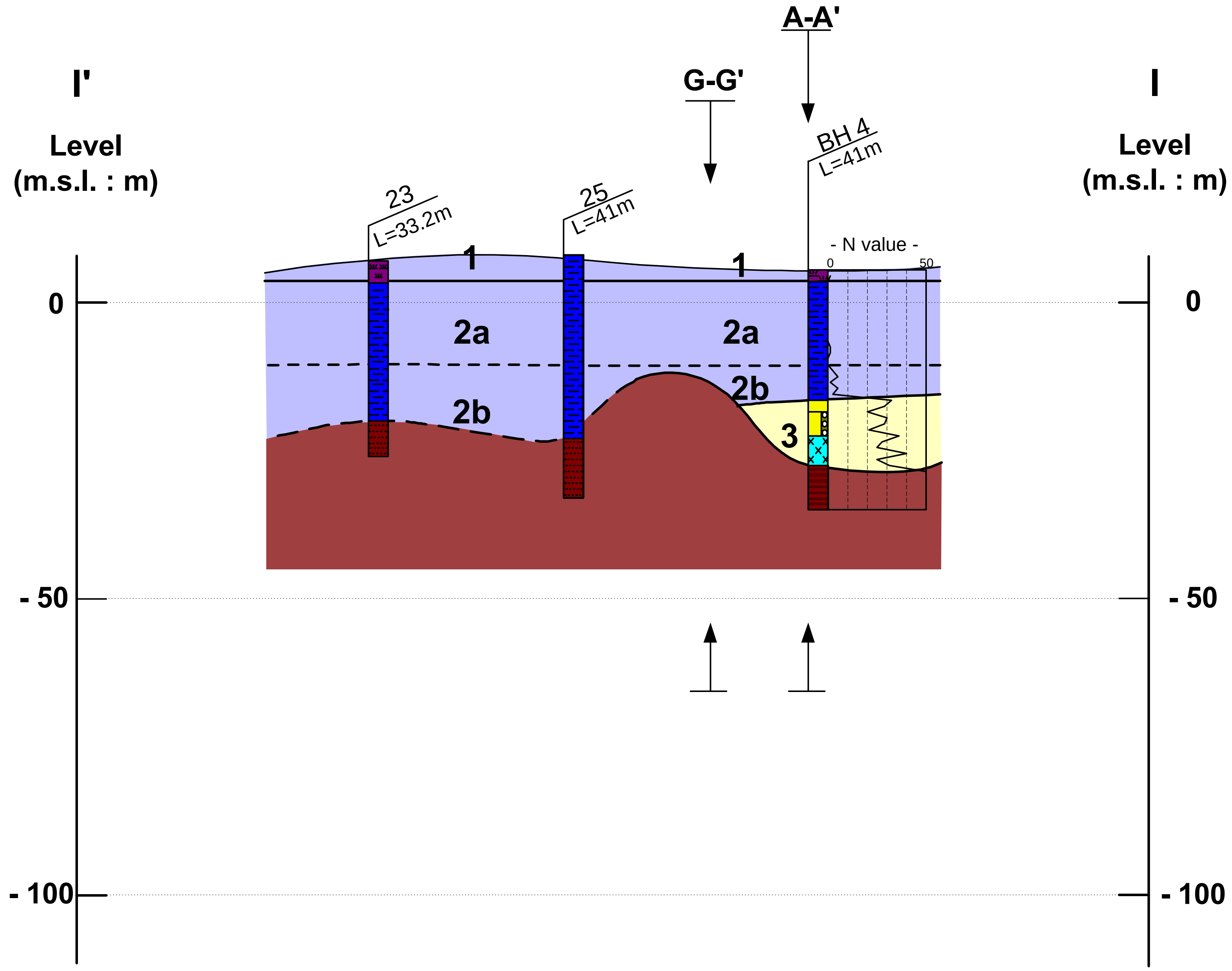
Figure F.4.11

Geological Profiles, I - I'



Horizontal Scale

0 5km

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.

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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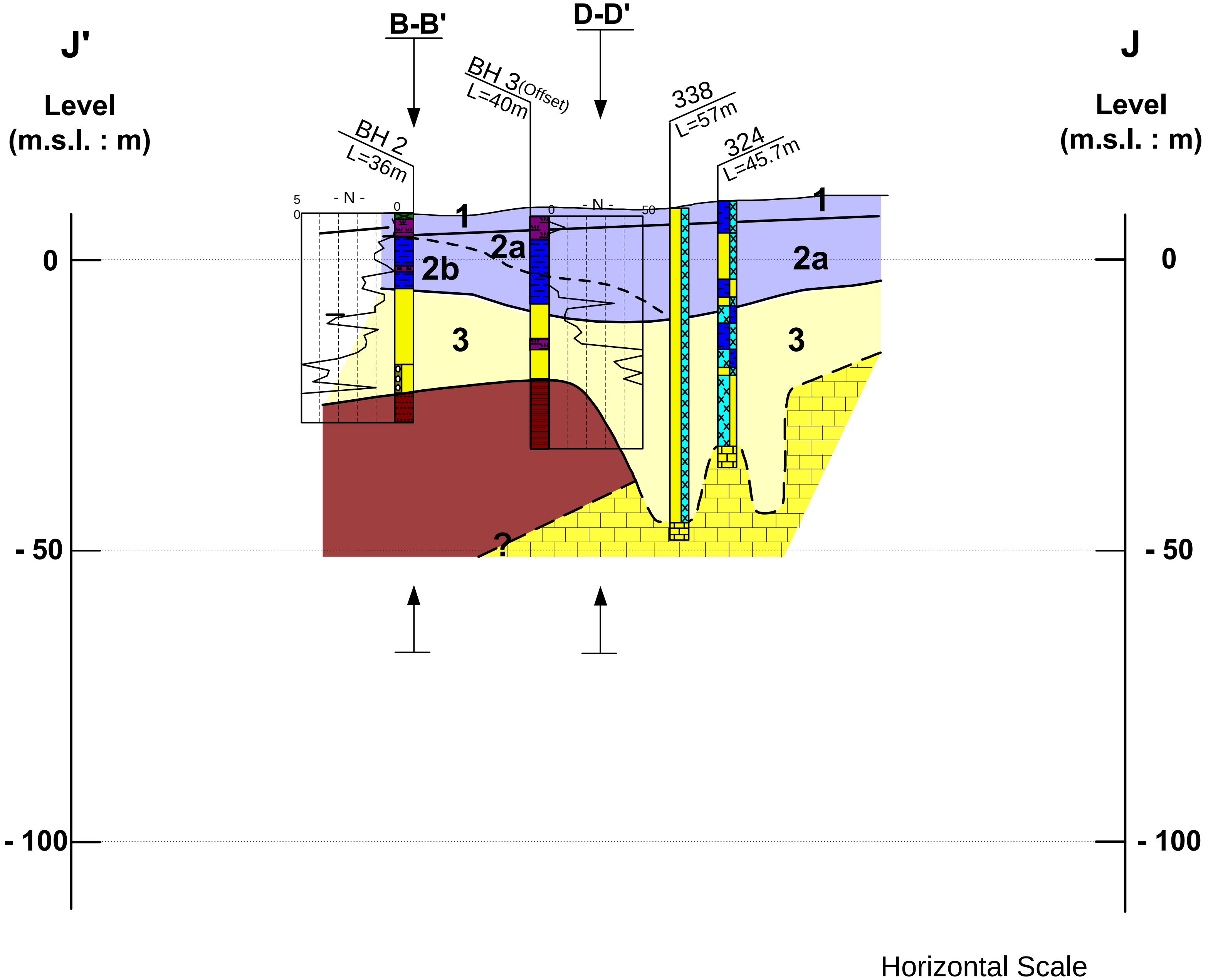
Figure F.4.12

Geological Profiles, J - J'



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.

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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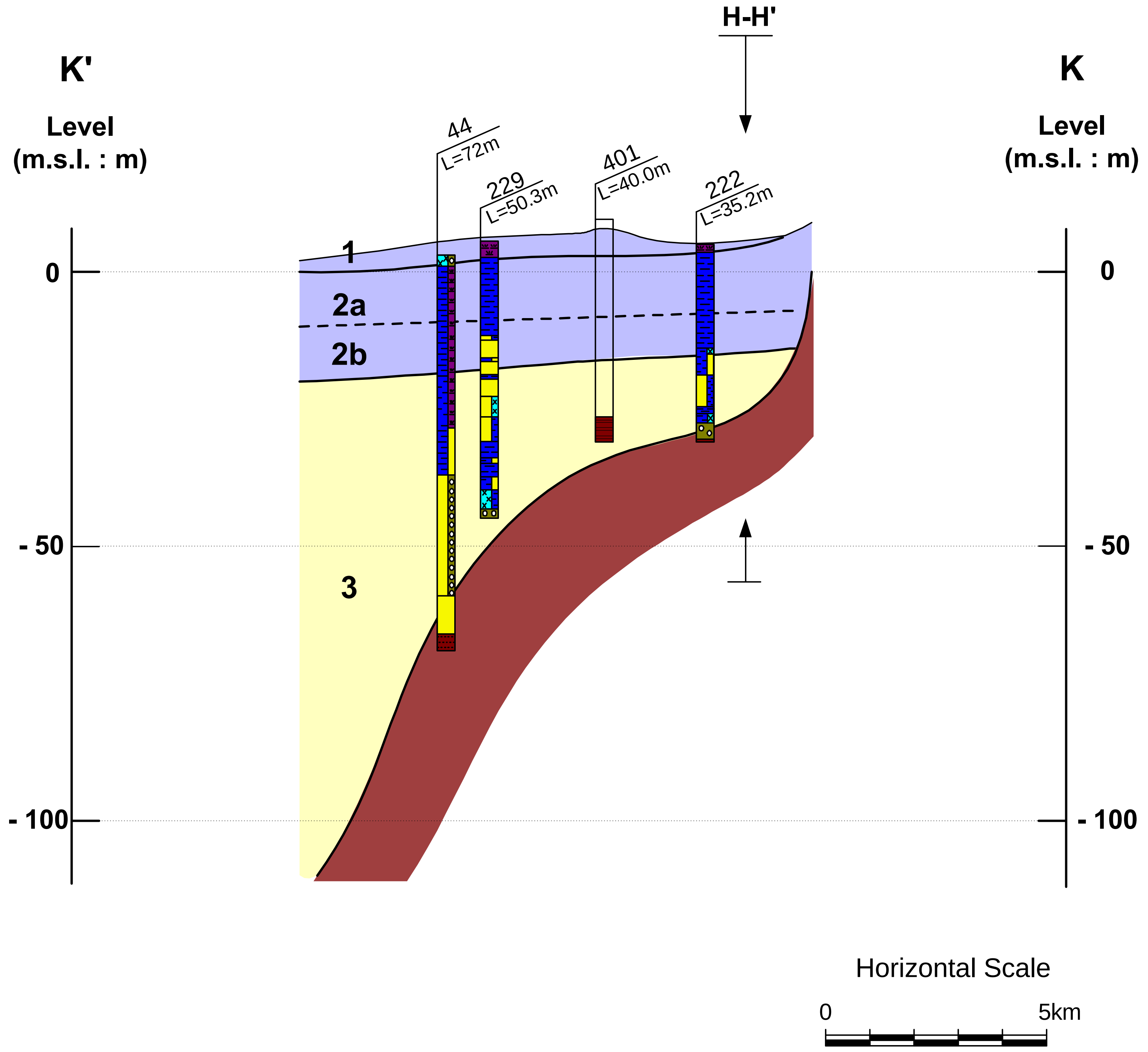

Note that this geological profile was prepared by a limited number of borehole logs. The profile should be modified and improved when additional information is obtained.

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

Figure F.4.13

Geological Profiles, K - K'

LEGEND

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

1 - 3 Layer Number

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4.3.3 Description of Soil Layers and Their Distribution in Groundwater Basin

(1) Layer 1 (Peat and Peaty Soils)

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.

(2) Layer 2a (Soft Clayey Soils)

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.

The estimated distribution area and contour lines of the upper boundary level of the Layer 2a are shown in **Figure F.4.14**. The actual boundary between Layers 1 and 2a is expected irregular, however, the contour map is simplified to view the general distribution characteristics and to allow the estimation of land subsidence rational.

(3) Layer 2b (Medium to Stiff Clayey Soils)

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 compacted and give low compressibility.

The estimated distribution area and contour lines of the upper boundary level of Layer 2b are shown in **Figure F.4.15**. Again, the contour map is simplified to view the actual irregular boundary between Layers 2a and 2b.

(4) Layer 3 (the Aquifer, Sandy and Gravelly Soils)

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 (refer to **Figure F.4.8**). The clayey soil layers in Layer 3 have a thickness of 1m to over 8 metres.

The estimated distribution area and contour lines of the upper boundary level of Layer 3 are shown in **Figure F.4.16**. The contour map is simplified to view the actual irregular boundary condition between Layers 2b and 3.

(5) Layer 4 (Aquifer Bedrock)

Including the existing borehole data, rock type of the bedrock in the Basin is plotted over the bedrock contour map of the Groundwater Basin in **Figure F.4.17**. Limestone is noted at two locations, one at the outside of the northern boundary of the Basin and the other at the western boundary of the Basin. Estimated distributions of limestone are shown in **Figure F.4.17**.

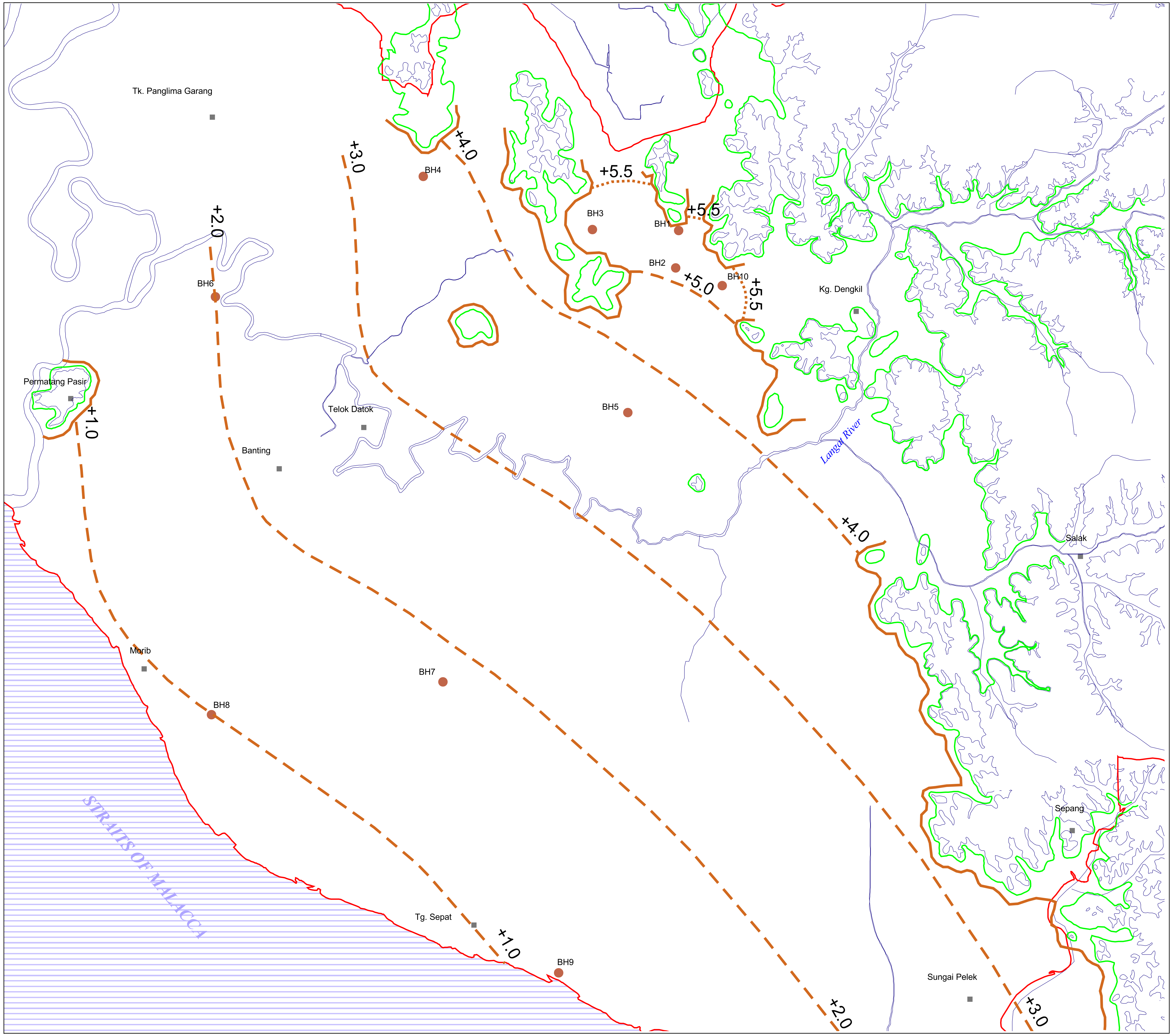
Rock type and degree of weathering of the bedrock found at the bottom of the boreholes during the soil investigation are summarised in **Table F.4.2**. Degree of weathering varies from fresh to completely weathered.

Table F.4.2 Rock Type and Weathering Condition of Bedrock

Borehole	Rock Type	Status
BH1	Mudstone and sandstone	Completely weathered
BH2	Quartzite	Fresh, cracked
BH3	Shale	Completely weathered
BH4	Slate	Completely weathered
BH5	Shale	Completely weathered
BH6	Granite	Moderately weathered
BH7	Not encountered the bedrock	
BH8	Not encountered the bedrock	
BH9	Not encountered the bedrock	
BH10	Sandstone	Completely weathered

Figure F.4.14

Distribution of Soft Clayey Soil Layers and Contour Map of Upper Boundary Level



LEGEND

- Boundary of Soft Clayey Soil Distribution
- Level of Upper Boundary of Soft Clay Layer

(Numbers are in meter and measured from the mean sea level)

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

Note that the distribution area of the soft clayey soil layers is estimated by a limited number of boreholes. The contourlines are simplified the actual irregular conditions.

Scale 1 : 200,000

2 0 2 4 Kilometers

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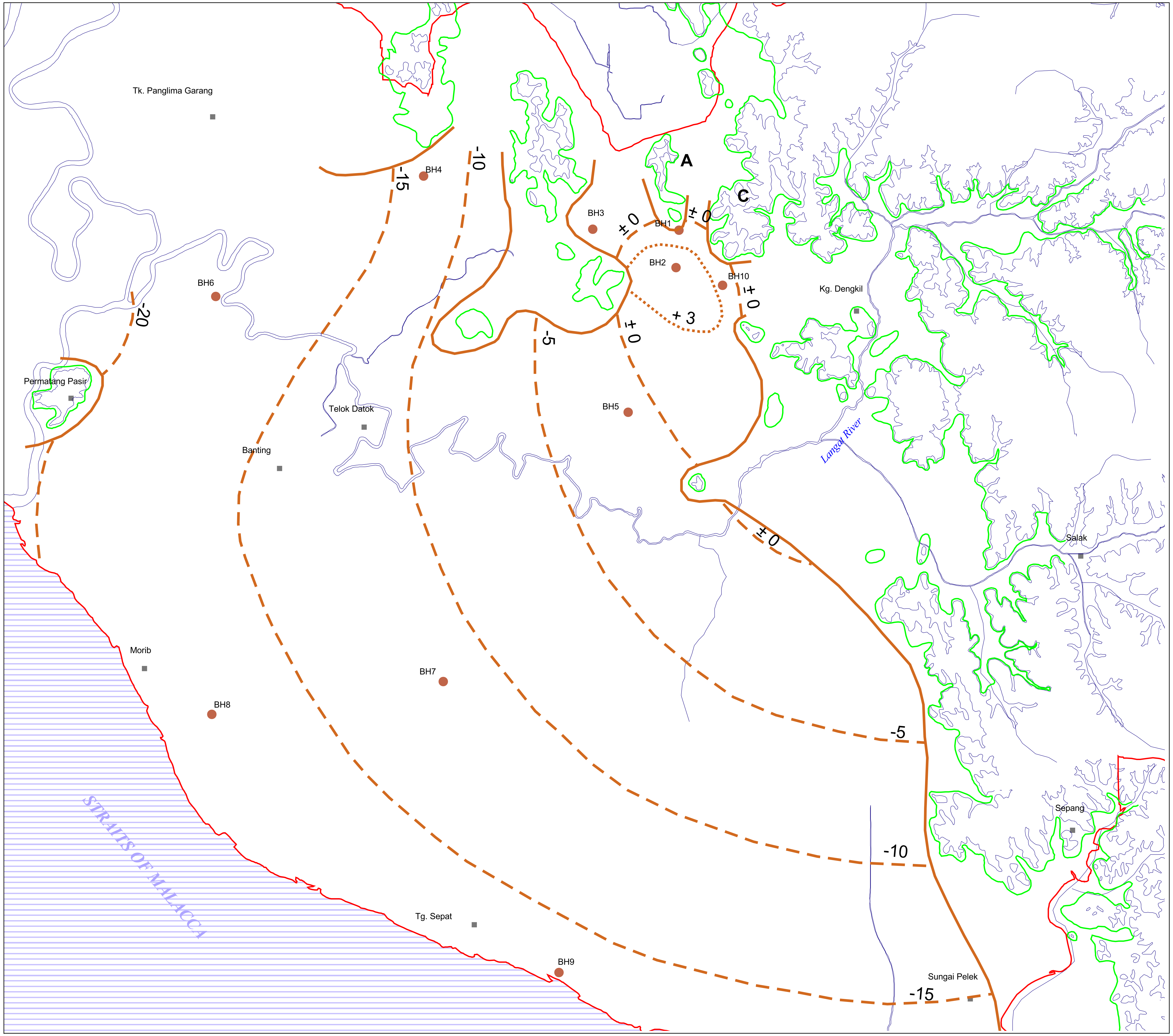

Figure F.4.15

Distribution of Medium to Stiff Clayey Soil Layers and Contour Map of Upper Boundary Level

LEGEND

- Boundary of Medium to Stiff Clayey Soil Distribution
- Level of Upper Boundary of Medium to Stiff Clayey Soil Layers

(Numbers are in meter and measured from the mean sea level.)

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

Note that the distribution area of the medium to stiff clayey soil layers is estimated by a limited number of boreholes. The contourlines are simplified theactual irregular conditions.

Scale 1 : 200,000

2 0 2 4 Kilometers

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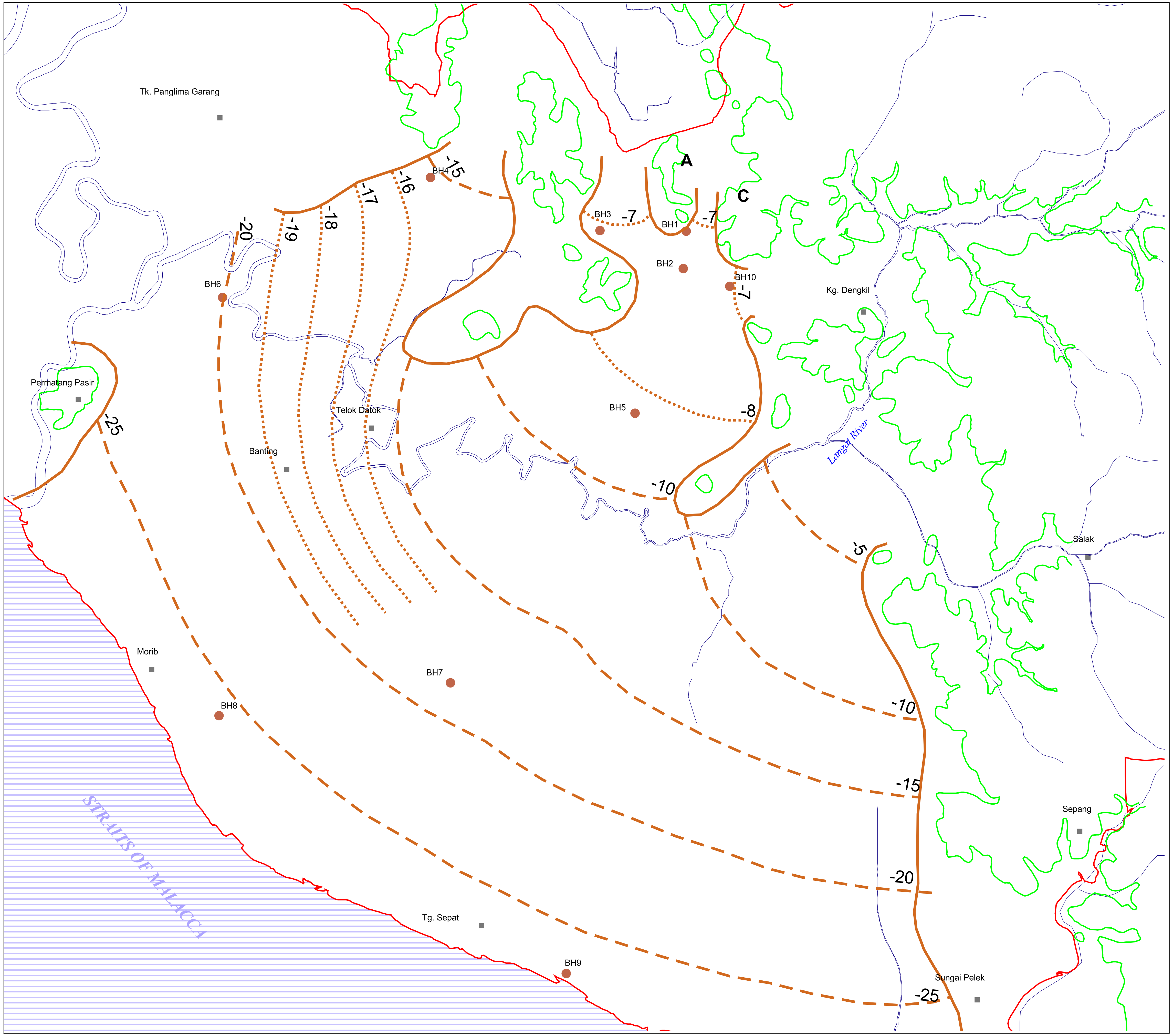

Figure F.4.16

Distribution of the Aquifer and Contour Map of Upper Boundary Level

LEGEND

- Boundary of the Aquifer Distribution
- Level of Upper Boundary of the Aquifer

(Numbers are in meter and measured from the mean sea level)

- Boring Point (Present Study)
- Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation
- Rivers
- Towns
- Study Area

Note that the distribution area of the aquifer is estimated by a limited number of boreholes. The contourlines are simplified the actual irregular conditions.

Scale 1 : 200,000

2 0 2 4 Kilometers

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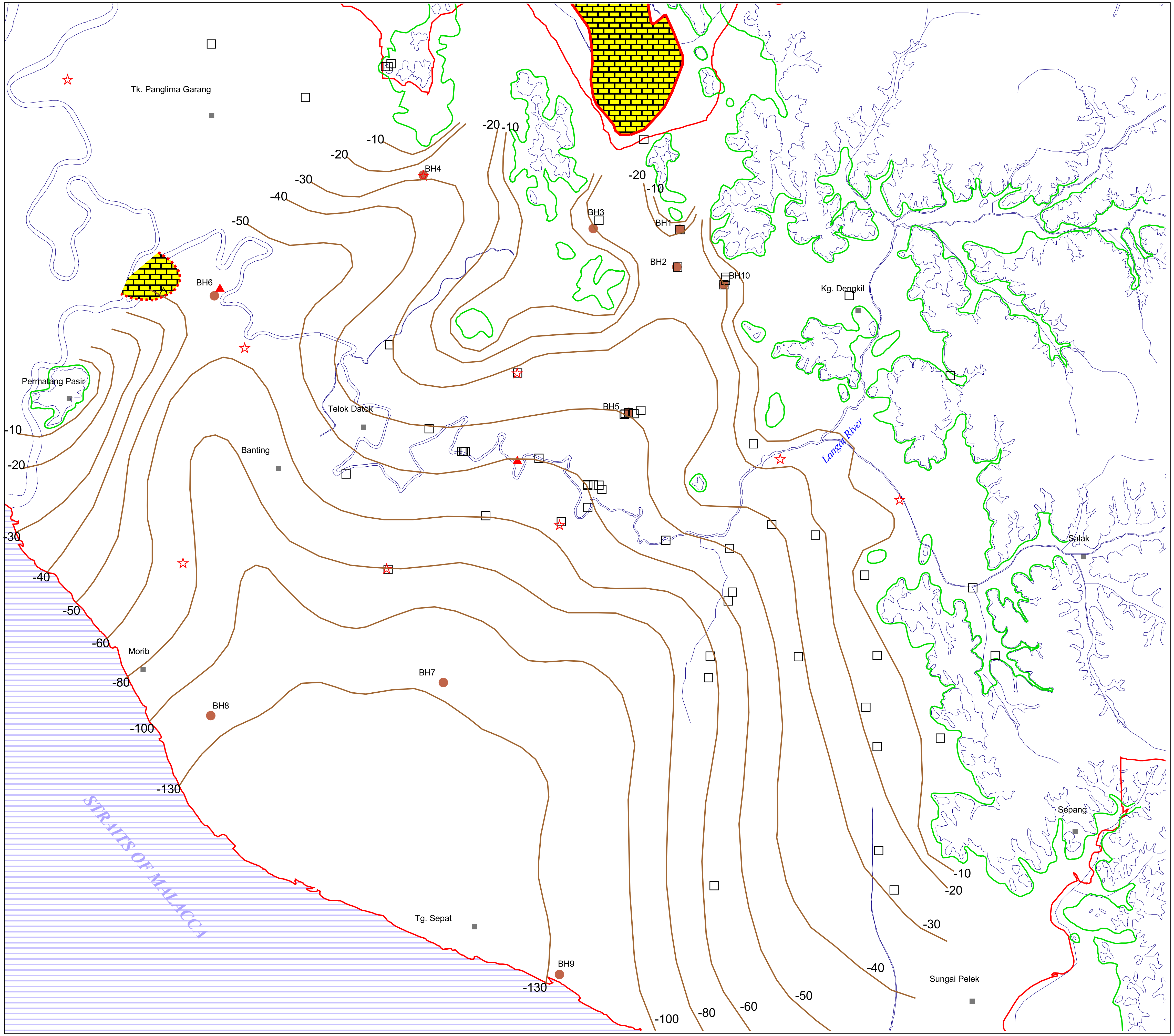

Figure F.4.17

Rock Type of Bedrock and Estimated Distribution Area of Limestone

LEGEND

Bedrock Type

- Limestone / Marble
- Sandstone, Quartzite, Shale
- Granitic Rock
- Schist, Phyllite, Slate

Distribution Area of Limestone

Contourline of Bedrock Surface

Boring Point (Present Study)

Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation

Topographic Contourline of 20m Height

Rivers

Towns

Study Area

N W E S

Scale 1 : 200,000

2 0 2 4 Kilometers

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4.4 Physical Characteristics of Soil Layers

4.4.1 General

Results of the laboratory soil test are evaluated and presented for the clayey soils, Layers 2a and 2b. The Layers, 2a and 2b are subdivided into three and two zones respectively by considering index properties of soils such as natural water content, liquid limit and plasticity index. Consolidation properties of the clayey soils are compiled for each divided zone for the estimation of land subsidence in **Sector G**.

Physical characteristics of the Aquifer in the Groundwater Basin are summarised in this section. Distribution and boundary conditions are defined, and characteristics of the selected part of the Aquifer are briefly described. Detailed hydrolo-geological properties, determined by the pumping tests and groundwater simulation, are described in **Sector G**.

4.4.2 Clayey Soil Layers

(1) Zoning of Clayey Soil Layers

As shown in **Figures F.2.13** to **F.2.16**, the nature of clayey soils, represented by bulk density, void ratio, or natural water content, varies considerably from location to location. To classify or to see the regional variation of properties of the clayey soils, plasticity chart and the relationship between natural water content and liquid limit are prepared in **Figure F.4.18**.

From the figure, a range of plasticity index and liquid limit can be summarised, as indicated in **Table F.4.3**, for three groups of boreholes located in similar areas. Borehole Nos. 4 and 6 are located in the western part, Nos. 7, 8, and 9 are in the central and southern part, and No. 5 is in the north eastern part of the Groundwater Basin.

Table F.4.3 Classification of Clayey Soils

Borehole No.	Plasticity Index	Liquid Limit	Area
4, 6	70 to 90	100 to 125	Western part of the Groundwater Basin
7, 8, 9	30 to 70	60 to 100	Central and Southern part of the Groundwater Basin
5	30 to 45	55 to 75	North Eastern Part of the Groundwater Basin

Since the type of clay mineral influences the plasticity index, and the liquid limit reflects compressibility of clayey soil, these two indexes may indicate depositional conditions (or location of deposition) of the clayey soils. **Figure F.4.1** shows Borehole Nos. 4 and 6 in the western valley, Borehole No. 5

in the central valley, and Borehole Nos. 7, 8, and 9 in the centre and the southern part of the Groundwater Basin.

Consolidation test results of Borehole No. 5 in the upper and flatter part of the central valley give a compacted and stiffer nature compared to the others. This indicates that the clayey soils at this location, except peaty clay of Layer 1 or Beruas Formation, may be different from the clayey soil of Gula Formation found in the rest of the Groundwater Basin.

Based on the discussion above, the soft clayey soil layer may be divided into three zones and the medium to stiff clay layer into two zones as indicated in **Figure F.4.19**. Please note that the zoning is based on a limited number of information.

(2) Consolidation Properties of Clayey Soil Layers

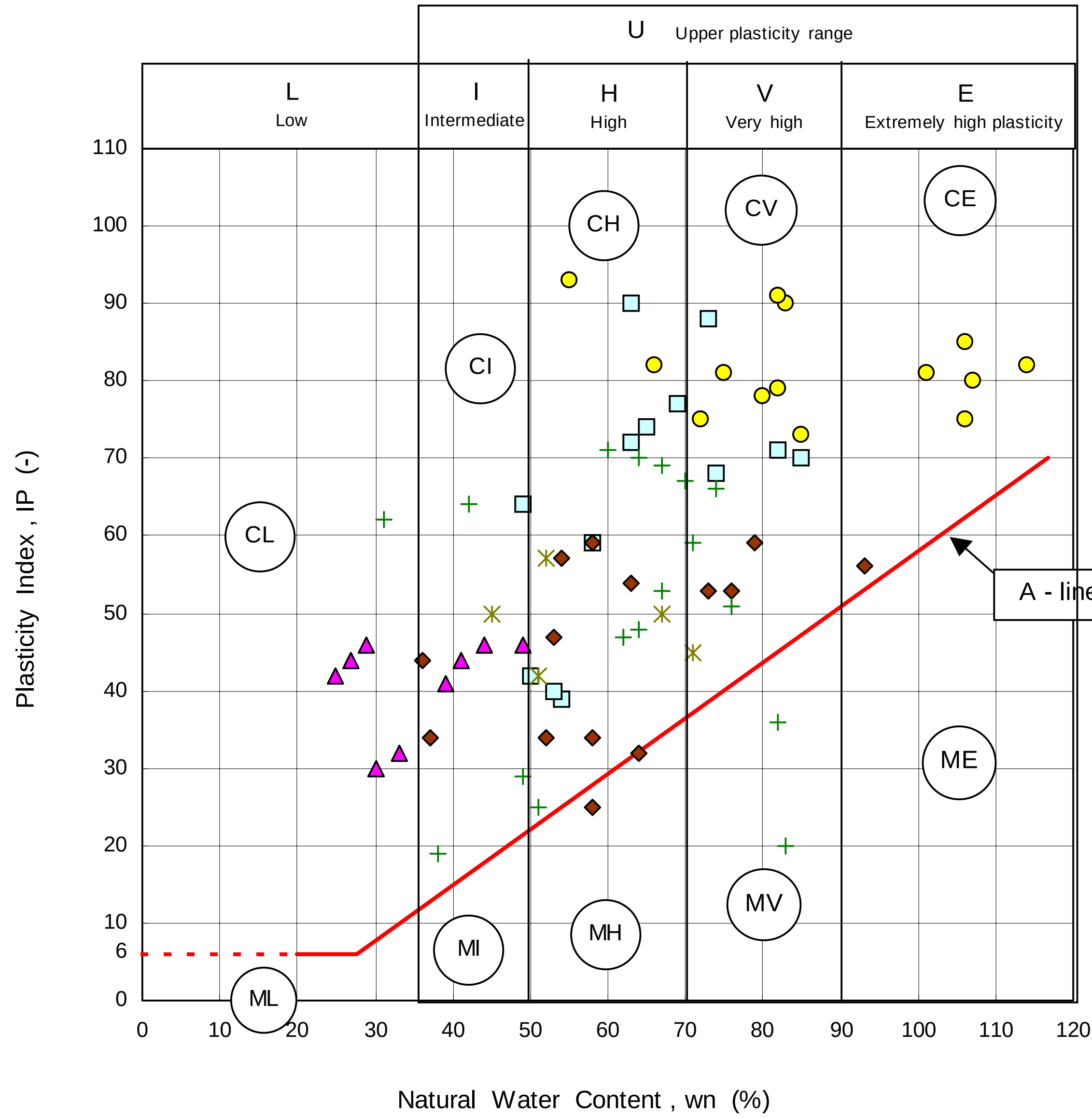
Consolidation properties of divided zones are presented separately in the following figures:

- **Figure F.4.20** Distribution of Compression Index with Depth
- **Figure F.4.21** Distribution of Consolidation Yield Stress with Depth
- **Figure F.4.22** e – log p Curves from Consolidation Tests
- **Figure F.4.23** Relationship between Coefficient of Volume Compressibility and Consolidation Pressure
- **Figure F.4.24** Relationship between Coefficient of Consolidation and Consolidation Pressure

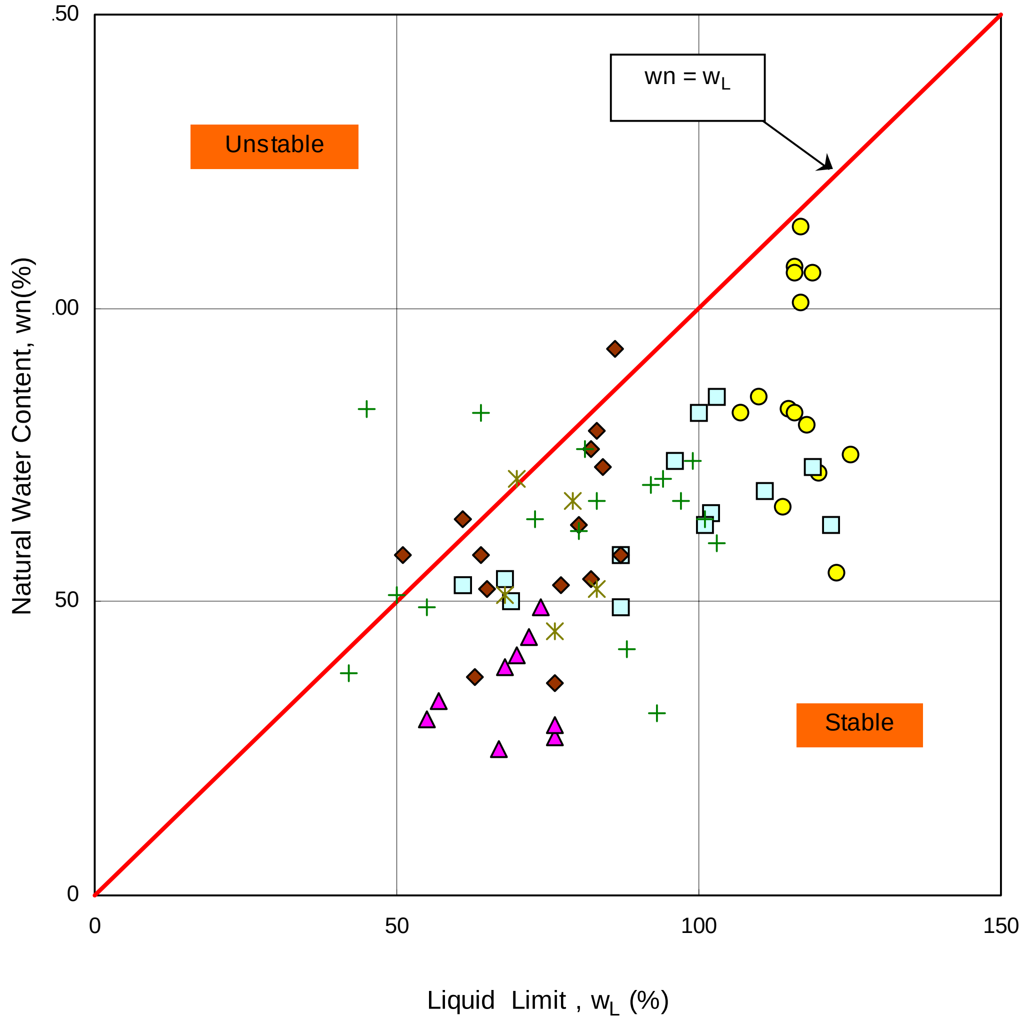
Compression index in **Figure F.4.20** and e-log p curves in **Figure F.4.22** clearly demonstrate differences of compressibility of clayey soils in different zones: the highest compressibility in the western part (Zone I in **Figure F.4.19**), the lowest compressibility in the north eastern part (Zone II), and medium compressibility in the central and southern part (Zone III) of the Groundwater Basin.

Figure F.4.18

Classification of Clayey Soils by Natural Water Content and Atterberg Limits



(a) Plasticity Chart



(b) Relationship between Natural Water Content and Liquid Limit

wn : Natural Water Content

w_P : Plastic Limit

w_L : Liquid Limit

Ip : Plasticity Index

$Ip = w_L - w_P$

LEGEND

Borehole Number

- ○ BH4
- ▲ BH5
- □ BH6
- ◆ BH7
- + BH8
- * BH9

Classification of Clayey Soils

- CE : Clay Extremely High Plasticity
- CV : Clay Very High Plasticity
- CH : Clay High Plasticity
- CI : Clay Intermediate Plasticity
- CL : Clay Low Plasticity
- ME : Silt(M-Soil) Extremely High Plasticity
- MV : Silt(M-Soil) Very High Plasticity
- MH : Silt(M-Soil) High Plasticity
- MI : Silt(M-Soil) Intermediate Plasticity
- ML : Silt(M-Soil) Low Plasticity

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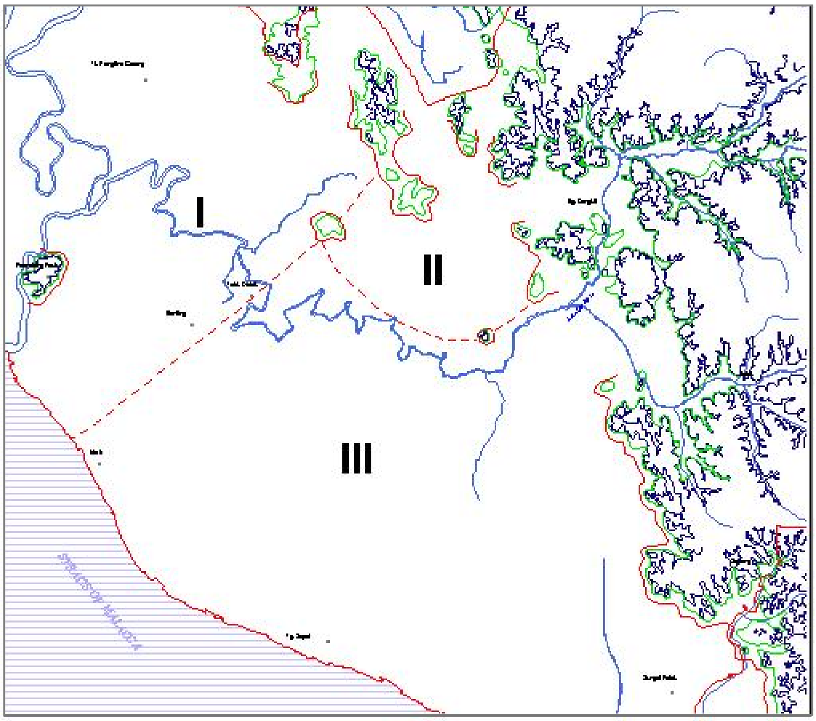
(a) Zoning of Soft Clayey Soil Layer



(b) Zoning of Medium to Stiff Clayey Soil Layer

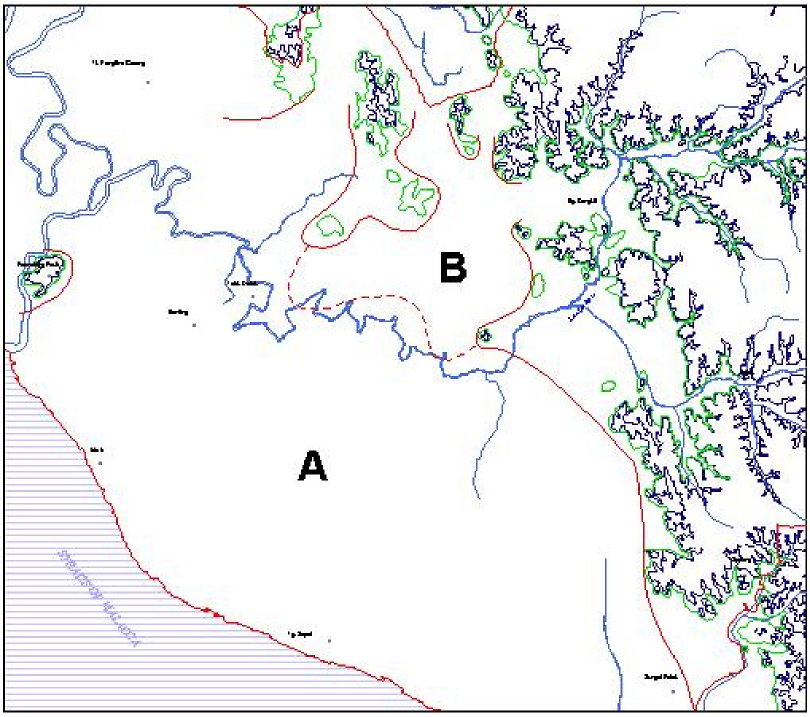


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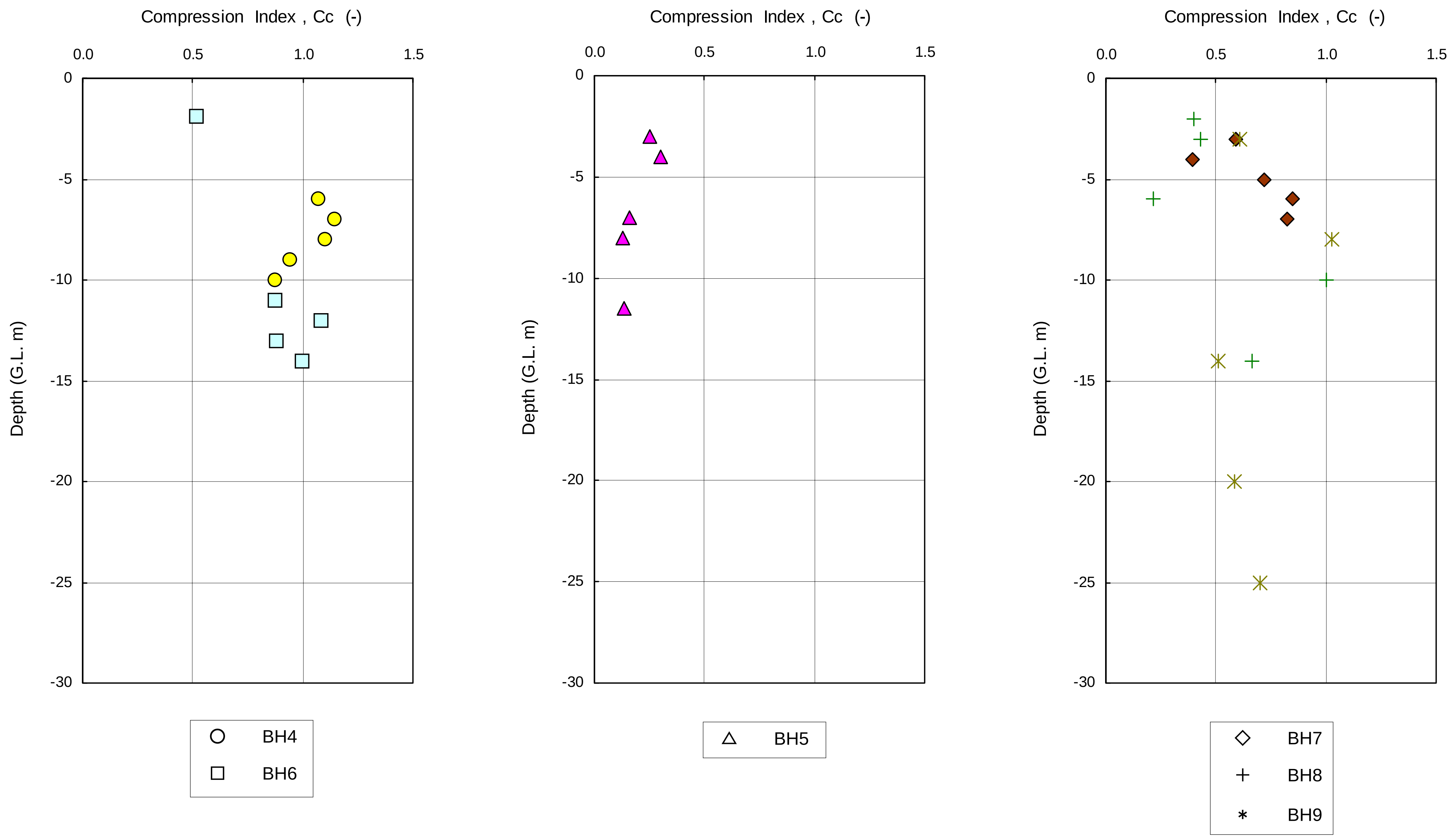
Figure F.4.19

Zoning of Clayey Soil Layers

Figure F.4.20

Distribution of Compression Index with Depth



(a) Distribution of Compression Index with Depth, (Western Part of Groundwater Basin)

(b) Distribution of Compression Index with Depth, (North Eastern Part of Groundwater Basin)

(c) Distribution of Compression Index with Depth, (Southern Part of Groundwater Basin)

LEGEND

Borehole Number

- BH4
- BH5
- BH6
- BH7
- BH8
- BH9

Soil Property

Cc : Compression Index

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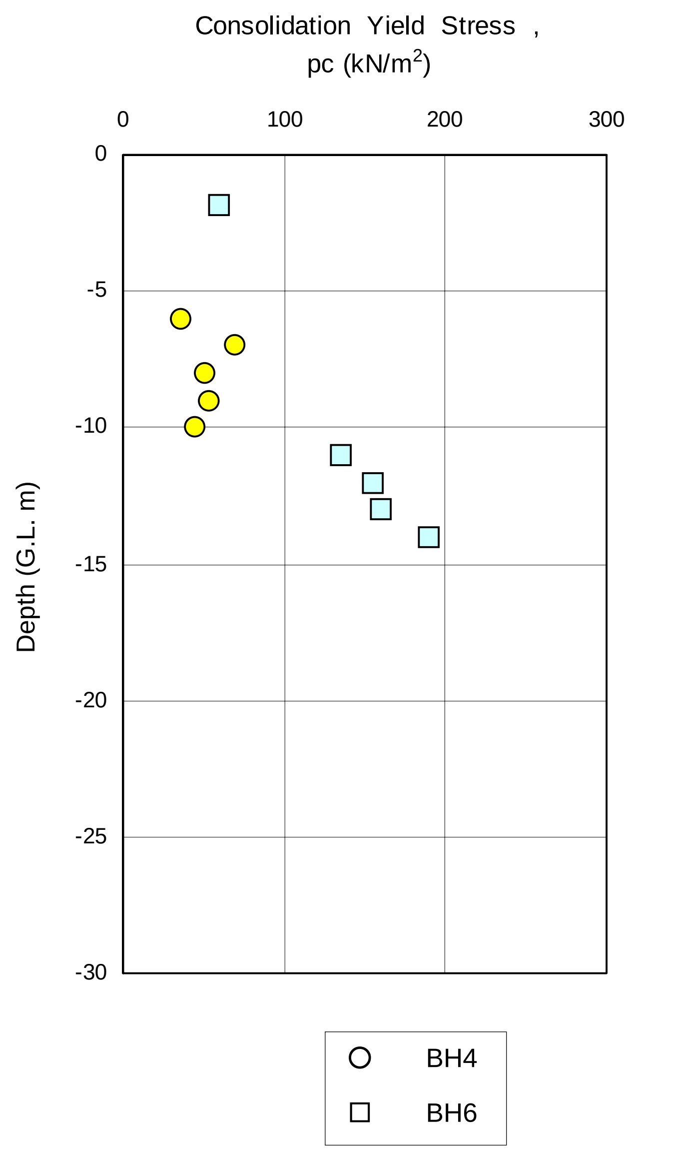
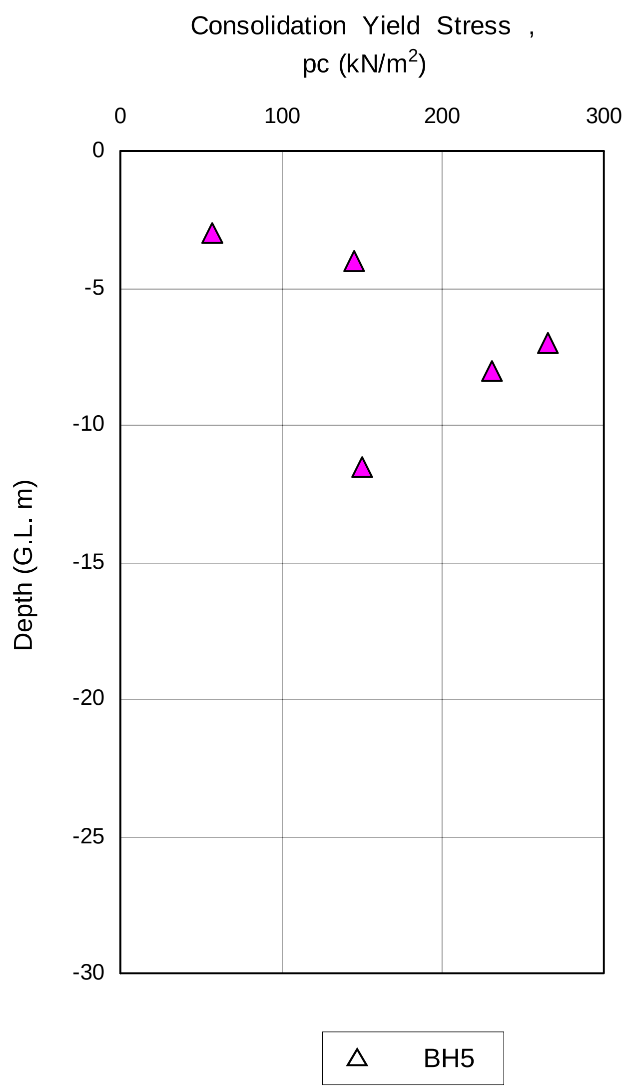
Figure F.4.21

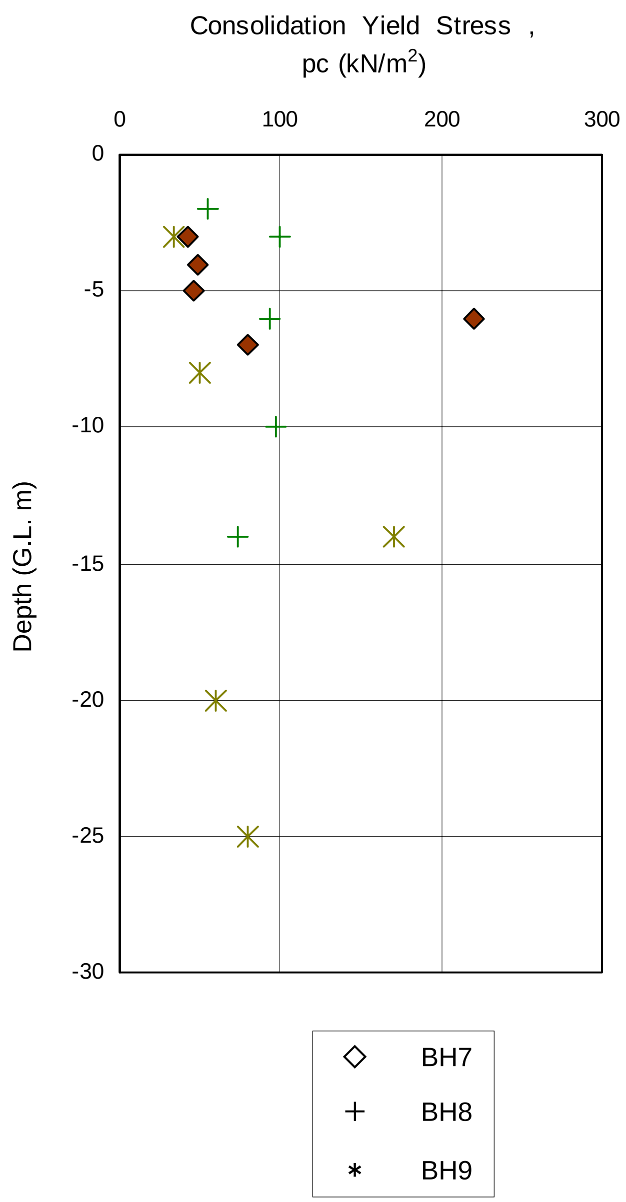
Distribution of Consolidation Yield Stress with Depth



(a) Distribution of Consolidation Yield Stress with Depth, (Western Part of Groundwater Basin)



(b) Distribution of Consolidation Yield Stress with Depth, (North Eastern Part of Groundwater Basin



(c) Distribution of Consolidation Yield Stress with Depth, (Southern Part of Groundwater Basin)

LEGEND

Borehole Number

- BH4
- BH5
- BH6
- BH7
- BH8
- BH9

Soil Property

pc : Consolidation Yield Stress

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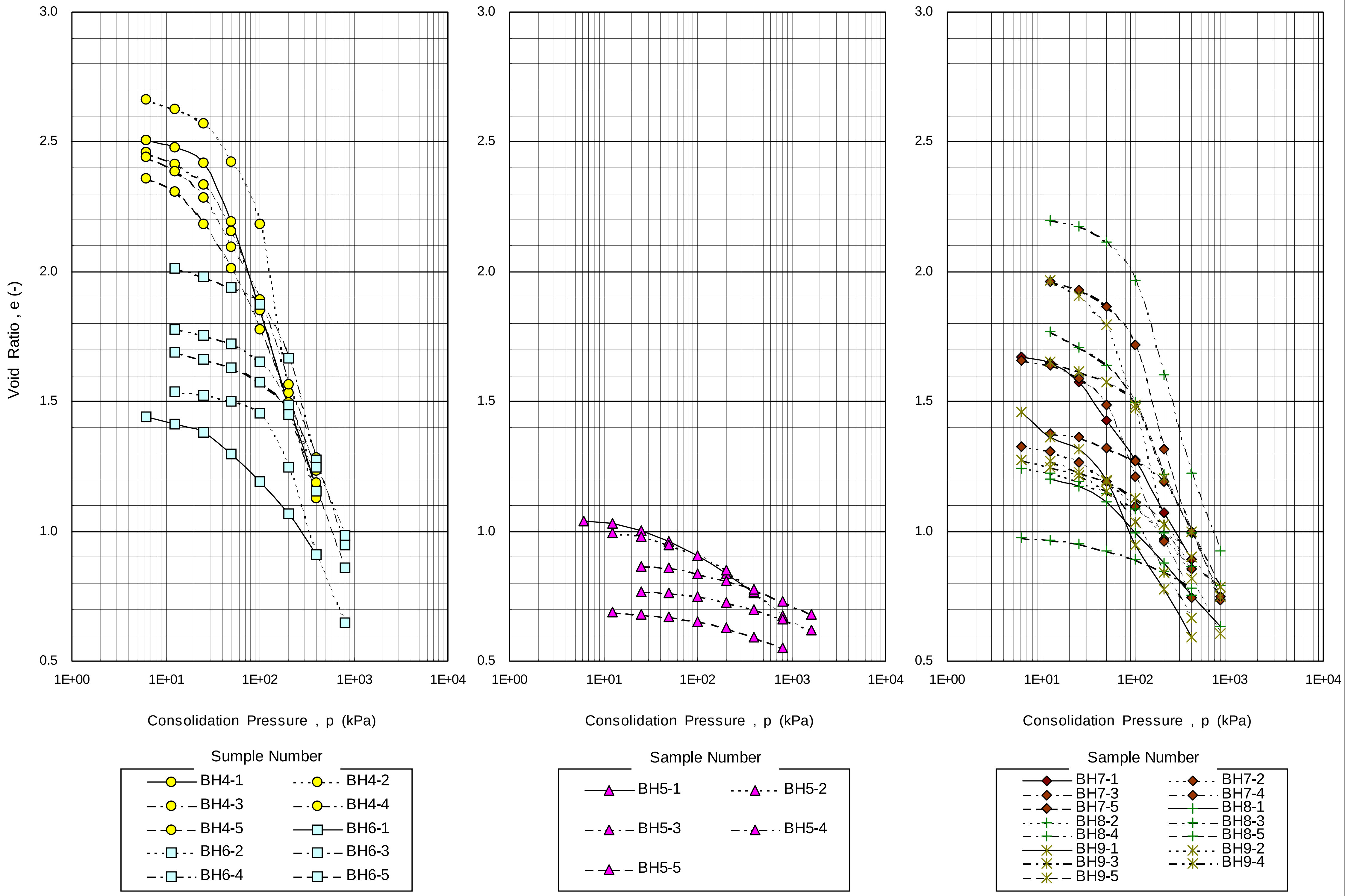
Figure F.4.22

e ～ log p Curves from Consolidation Tests



(a) e～log p Curves, (Western Part of Groundwater Basin)

(b) e～log p Curves, (North Eastern Part of Groundwater Basin)

(c) e～log p Curves, (Southern Part of Groundwater Basin)

LEGEND

Borehole Number

- BH4
- BH5
- BH6
- BH7
- BH8
- BH9

Soil Property

e : Void Ratio

p : Consolidation Pressure

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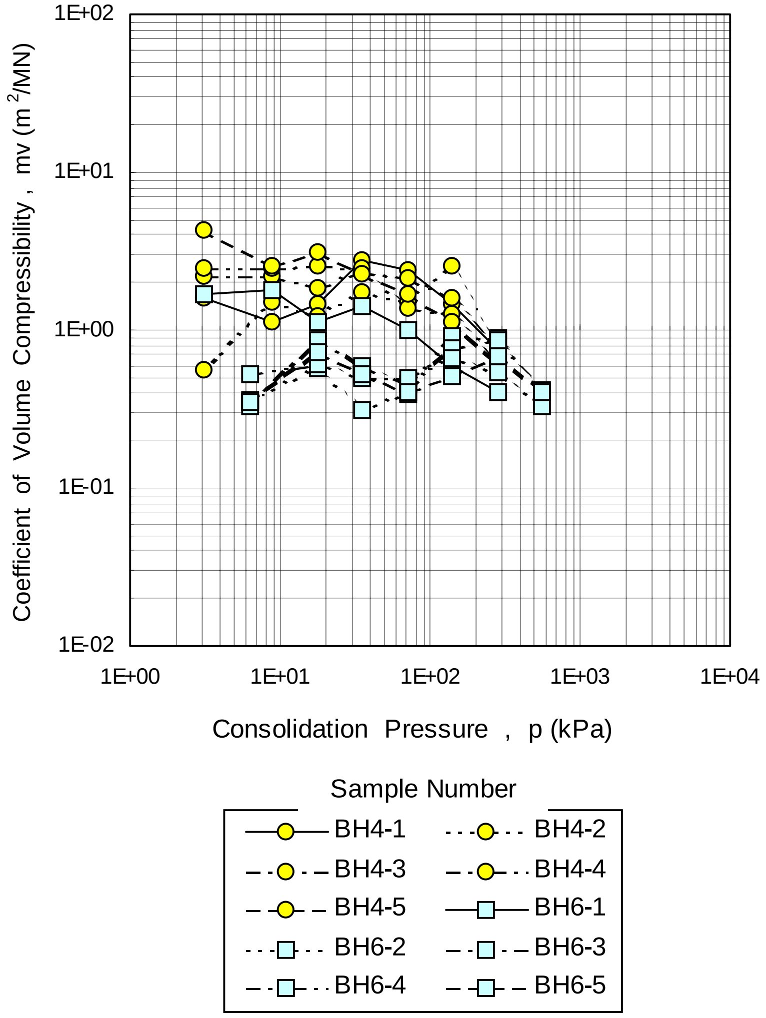
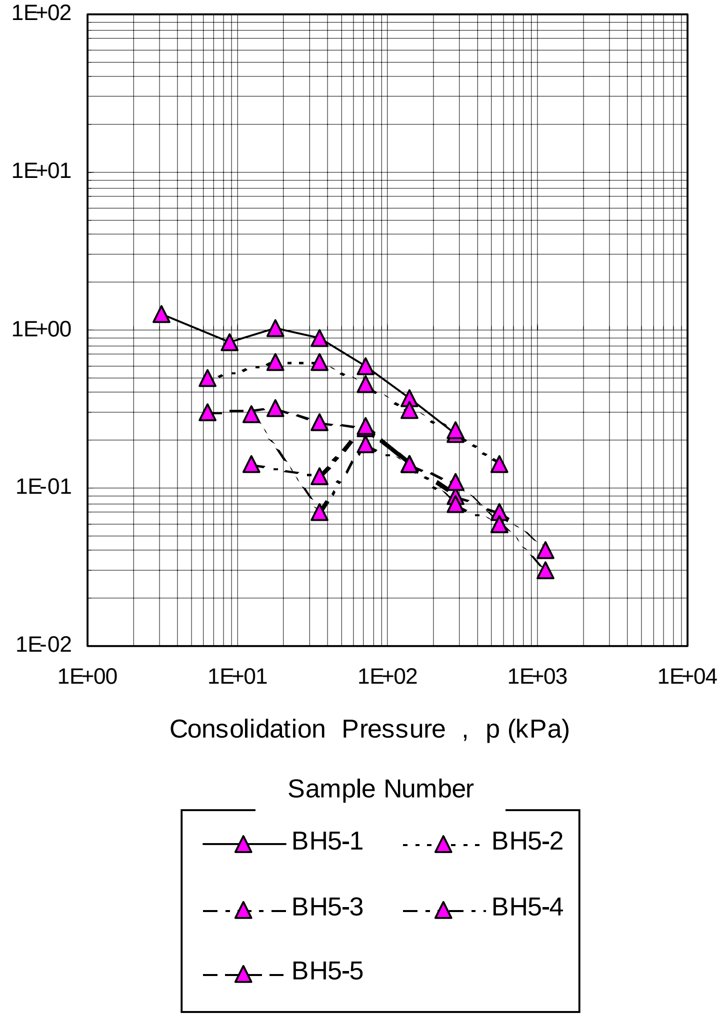
Figure F.4.23

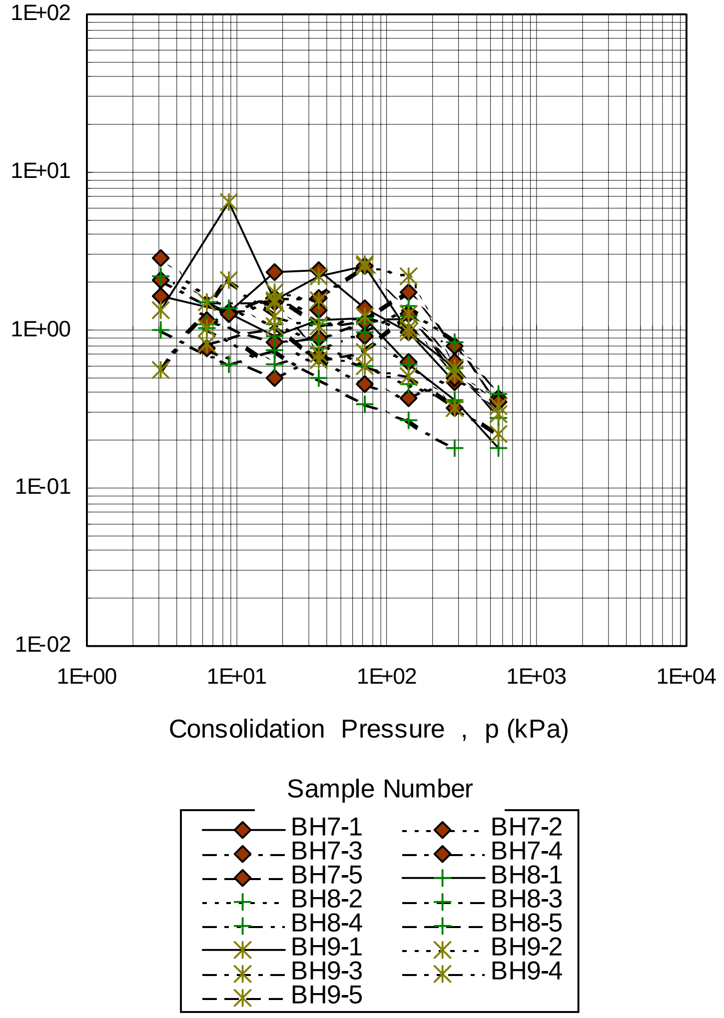
Relationship between Coefficient of Volume Compressibility and Consolidation Pressure



(a) Relationship between Coefficient of Volume Compressibility and Consolidation Pressure (Western Part of Groundwater Basin)



(b) Relationship between Coefficient of Volume Compressibility and Consolidation Pressure (North Eastern Part of Groundwater Basin)



(c) Relationship between Coefficient of Volume Compressibility and Consolidation Pressure (Southern Part of Groundwater Basin)

LEGEND

Borehole Number

- ○ BH4
- △ BH5
- □ BH6
- ◆ BH7
- + BH8
- * BH9

Soil Property

mv : Coefficient of Volume Compressibility
p : Consolidation Pressure

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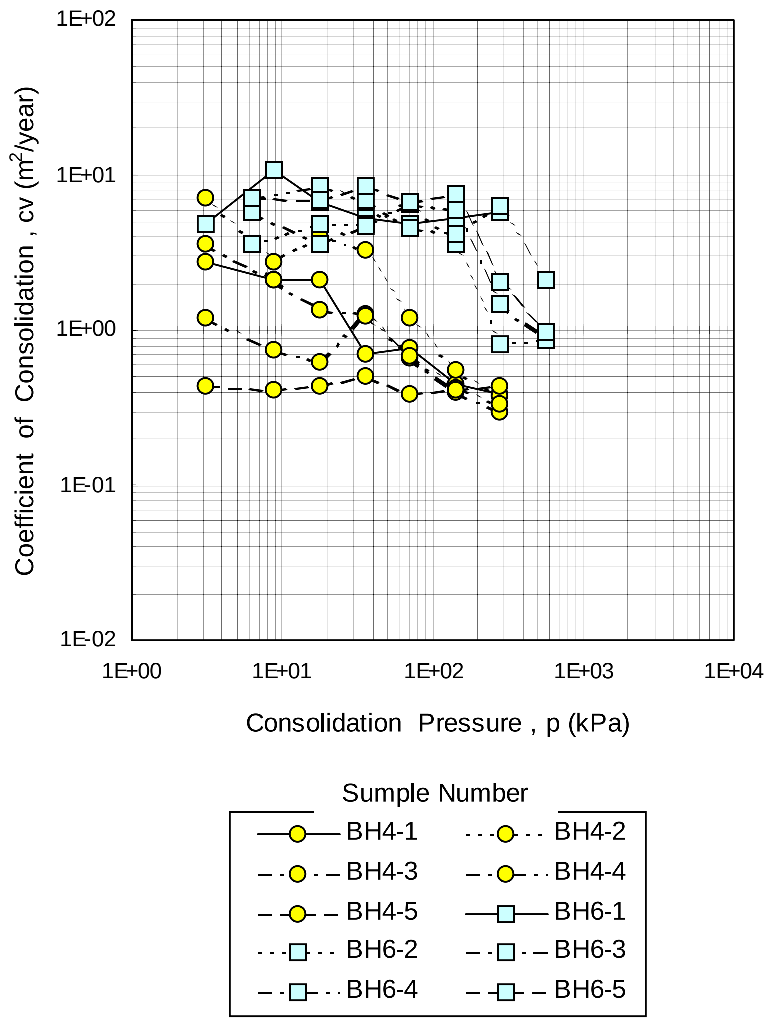
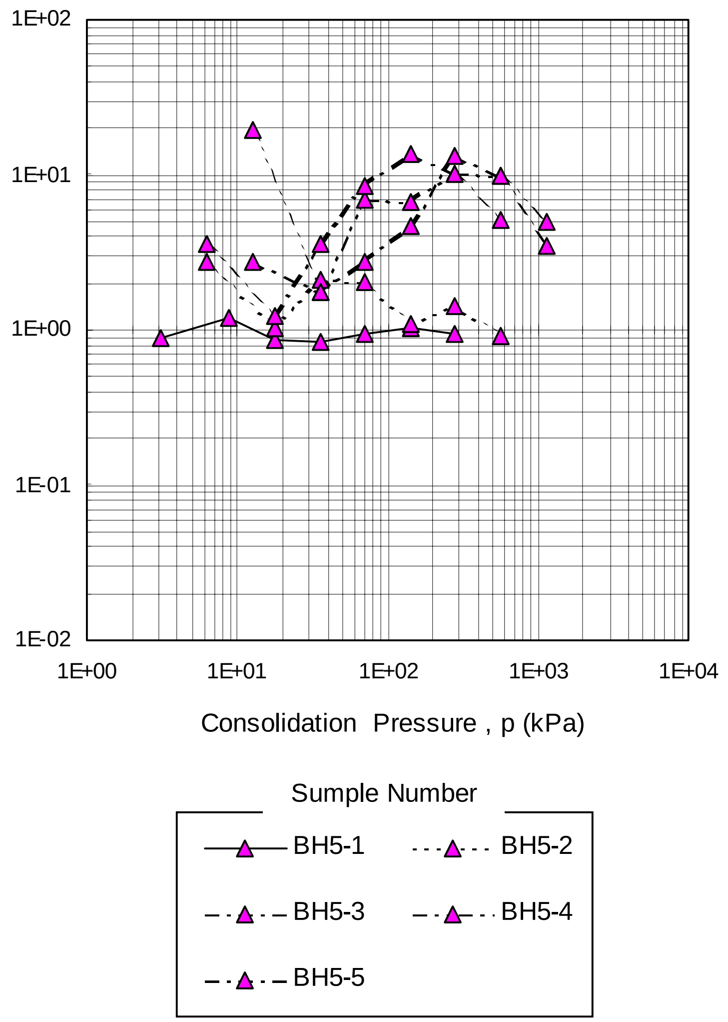
Figure F.4.24

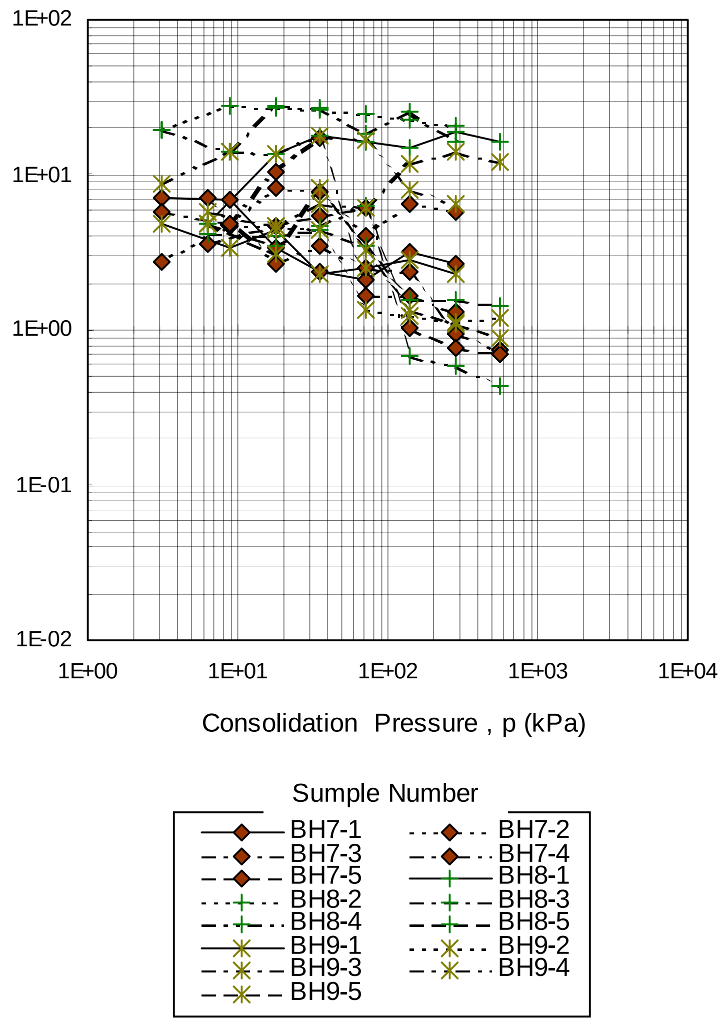
Relationship between Coefficient of Consolidation and Consolidation Pressure



(a) Relationship between Coefficient of Consolidation and Pressure (Western Part of Groundwater Basin)



(b) Relationship between Coefficient of Consolidation and Pressure (North Eastern Part of Groundwater Basin)



(c) Relationship between Coefficient of Consolidation and Pressure (Southern Part of Groundwater Basin)

LEGEND

Borehole Number

- ○ BH4
- ▲ BH5
- □ BH6
- ◆ BH7
- + BH8
- ✳ BH9

Soil Property

cv : Coefficient of Consolidation

p : Consolidation Pressure

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4.4.3 The Aquifer

(1) Distribution

As shown in **Figure F.4.25**, areal distribution of the Aquifer can be defined by the topographic boundaries, except the western boundary of the Aquifer. The northern boundary is drawn along the line passing through the small hills, and the eastern boundary corresponds to the boundary between the lowlands and the hilly area. The southern boundary can be defined as temporary along the seacoast, although the Aquifer is expected to extend towards offshore.

Geological profiles G-G' (**Figure F.4.9**) and I-I' (**Figure F.4.11**) show the hypothetical sub-ground conditions along and crossing a line between Bt. Puloh and Bt. Jugra, respectively. Since the existing borehole logs, Borehole No. 25 and 23 in **Figure F.4.11**, show layers of clayey soil and no sandy soils are indicated, a sub-ground boundary, such as a hypothetical buried hill, may exist to confine the Aquifer. This line between Bt. Puloh and Bt. Jugra can be regarded as the western boundary. As indicated **Figure F.4.9**, a buried valley opened to the west is found on the boundary.

(2) Boundary Conditions

The lower boundary of the Aquifer is defined by the bedrock surface. Their contour lines are shown in **Figure F.4.1**. Rock types of the bedrock are presented in **Figure F.4.17**. As summarised in **Table F.4.2**, their weathering conditions are mainly moderately weathered to completely weathered, except location No. 2 (Paya Indah) where the cracked fresh rock was found.

Thick clayey soil layers cover the upper boundary of the Aquifer. Although the upper surface of the Aquifer is expected irregular, the contour map of the upper boundary level is simplified as in **Figure F.4.16**.

Horizontal boundaries are shown in **Figure F.4.25**. As presented in **Figure F.4.6**, three small valleys are expected along the northern boundary of the Aquifer. These connect the Groundwater Basin and the Klang River Basin. Limestone is found in the northern part of the boundary as indicated in **Figure F.4.17**. To know whether or not the limestone has a direct contact to the Aquifer is important for evaluating the hydro-geological balance of the Aquifer. Since no limestone was found at Location No. 1, No. 2, No. 3, No. 4 and No. 10, which are located along the northern boundary, there is no direct evidence so far to show a direct contact between the limestone and the Aquifer. This condition is shown schematically in Geological Section J-J' (**Figure F.4.12**). The limestone seems to submerge under the less permeable bedrock.

Geological cross sections along and crossing the eastern boundary are presented in **Figures F.4.10 and F.4.13**. In the northern part, small valleys formed by the channels of the Langat and Labu rivers are expected. In the southern part of the boundary, the depth of the bedrock seems to be shallow.

(3) Typical Characteristics

To overview the grain size characteristics of the Aquifer, the results of the grain size analysis are plotted in the triangular soil classification chart (**Figure F.4.26**). The results on the upper stream of the Groundwater Basin are shown in **Figure F.4.27,** and those of the middle stream and downstream of the Basin are in **Figure F.4.28**. Generally, the Aquifer is gravelly upstream (refer to **Figure F.4.27**), and finer downstream [refer to **Figure F.4.28(c)**].

Figure F.4.29 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 Nos. 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. Generally speaking, the sandy soil layers distributing above -50 m from the mean sea level contain less gravel contents, especially at Location No. 7.

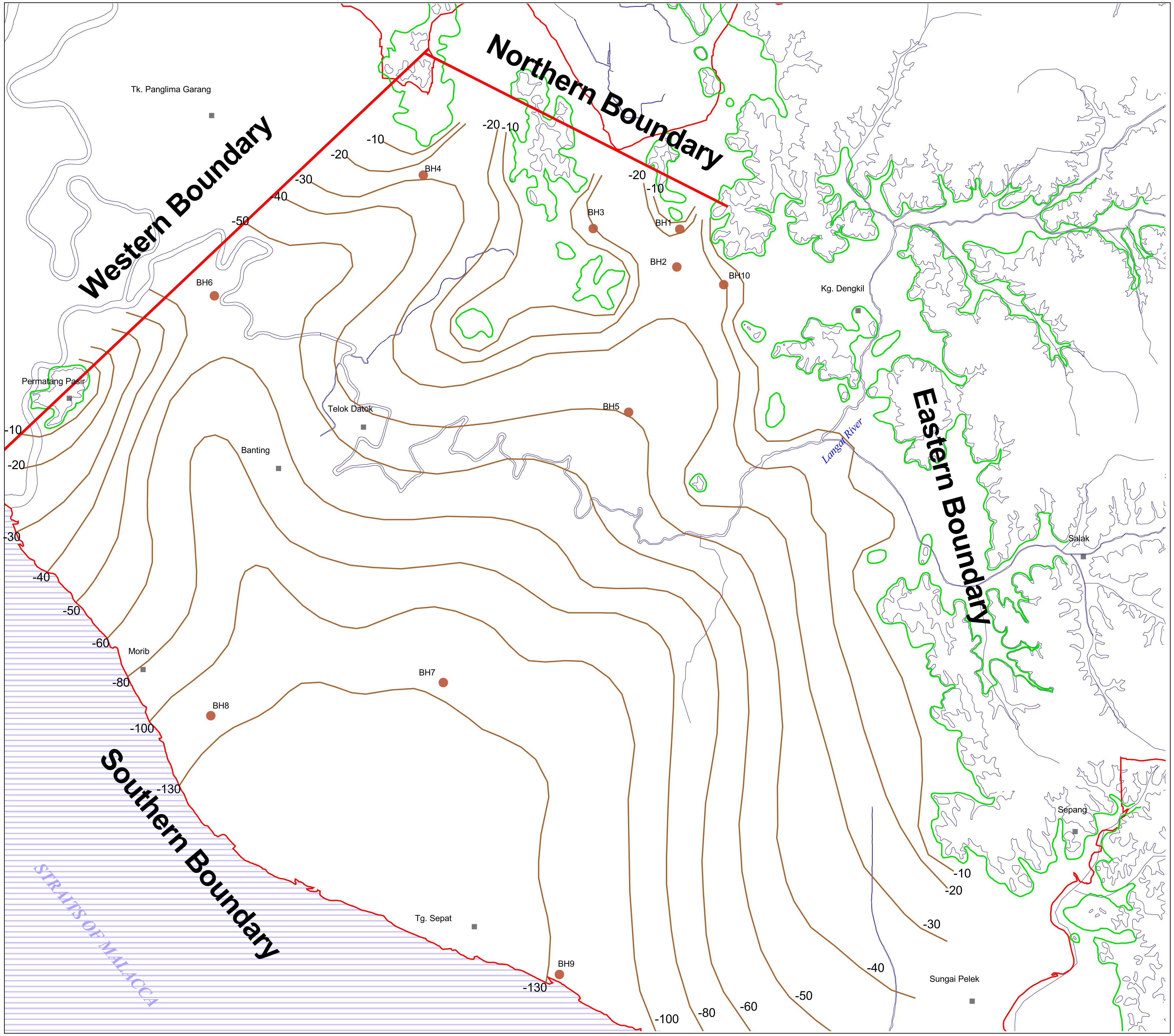

Figure F.4.25

Boundaries of the Aquifer

LEGEND

Topographic Boundary

Topographic Contourline of 20m Height

Bedrock Level

Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation

Contourline of Bedrock Surface

Boring Point (Present Study)

Rivers

Towns

Study Area

Contourline Level is from the mean sea level

Scale 1 : 200,000

2 0 2 4 Kilometers

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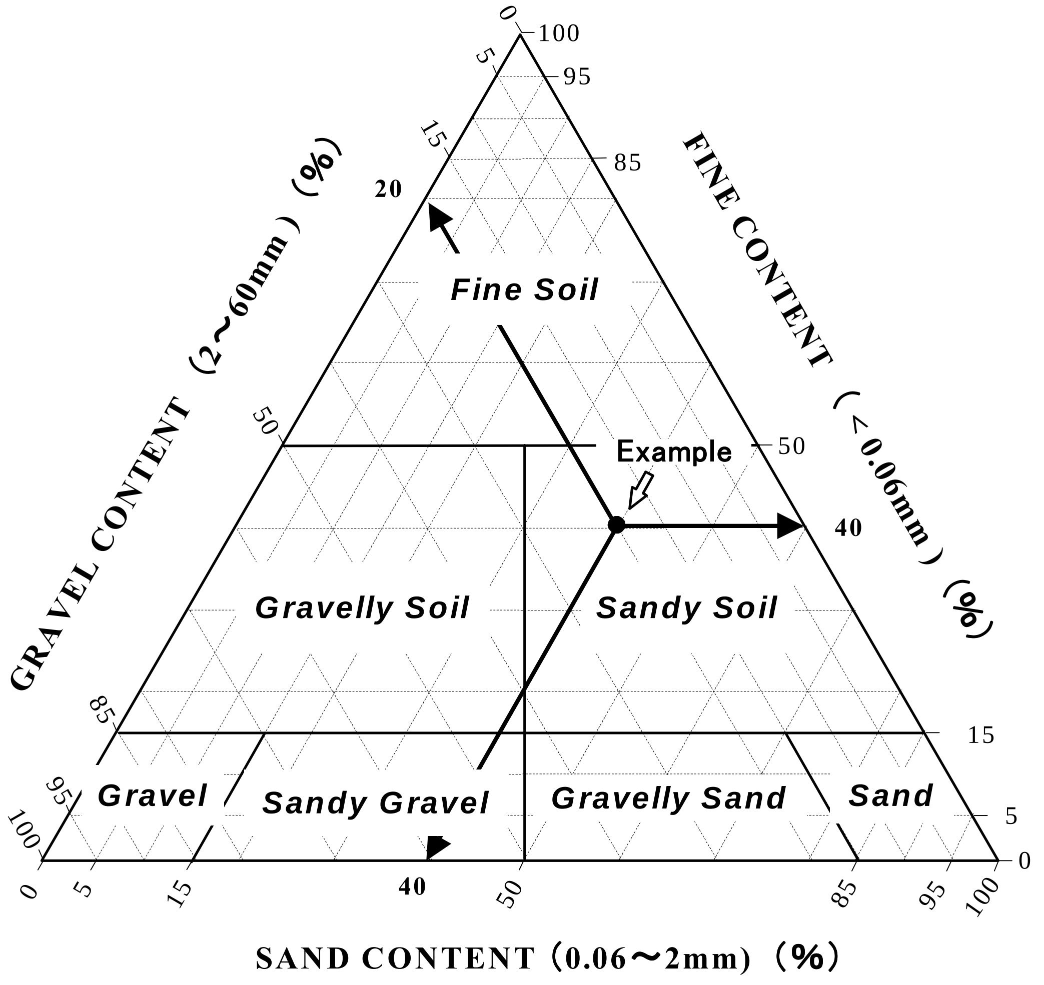

Example

Fine content (Clay, Silt)	40%		
Sand content	40%	→	Classified as Sandy Soil
Gravel content	20%		
Total	100%		

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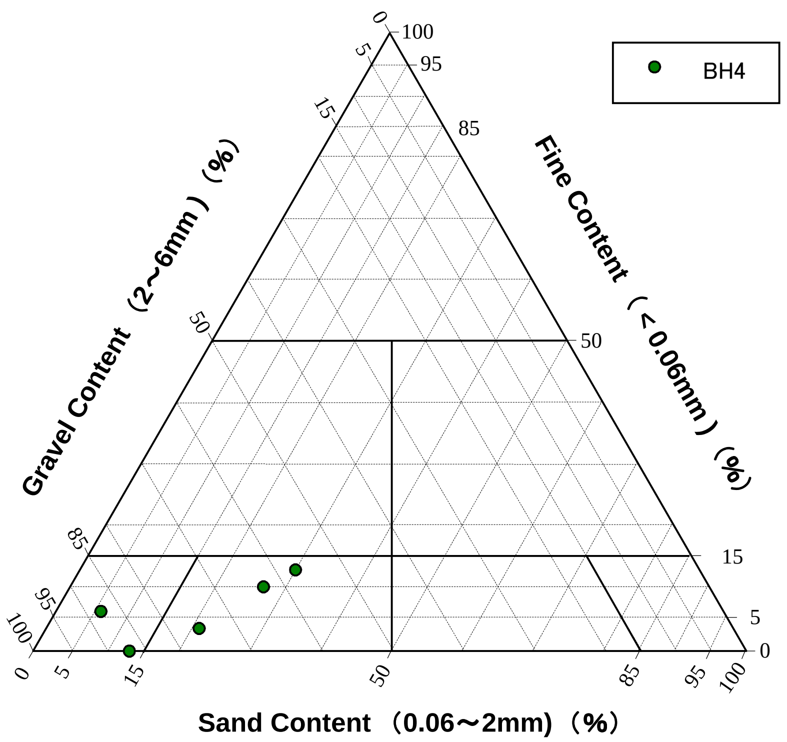
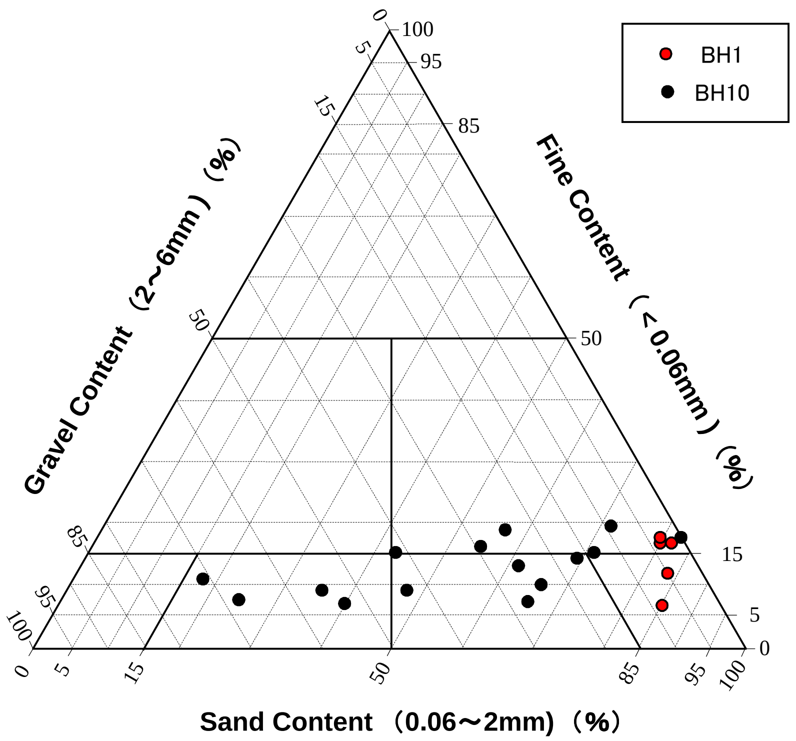
Figure F.4.26

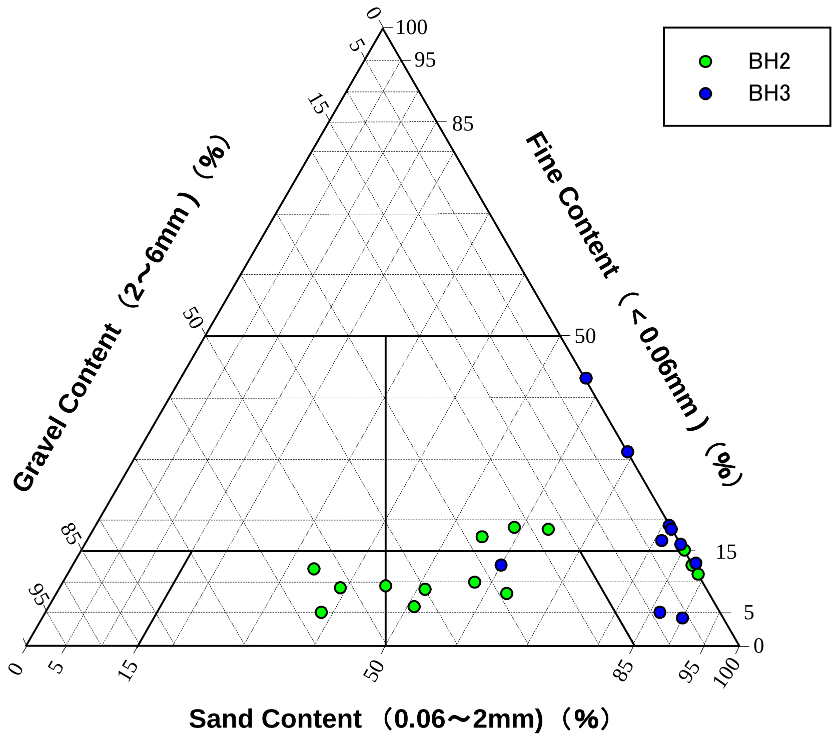
Classification System of Soils by Triangular Soil Classification Chart



Upper Stream and Midstream of Groundwater Basin



Upper Stream of Groundwater Basin

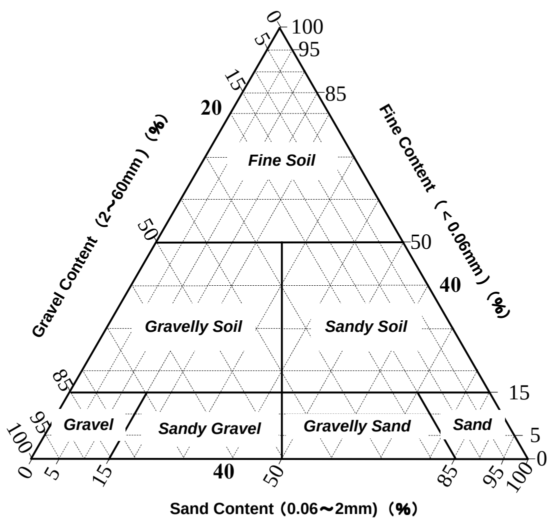


Upper Stream of Groundwater Basin

Figure F.4.27

Grain Size Characteristics of Sandy Soils, Upper Stream of Groundwater Basin

LEGEND



Classification System of Soils by Triangular Soil Classification System

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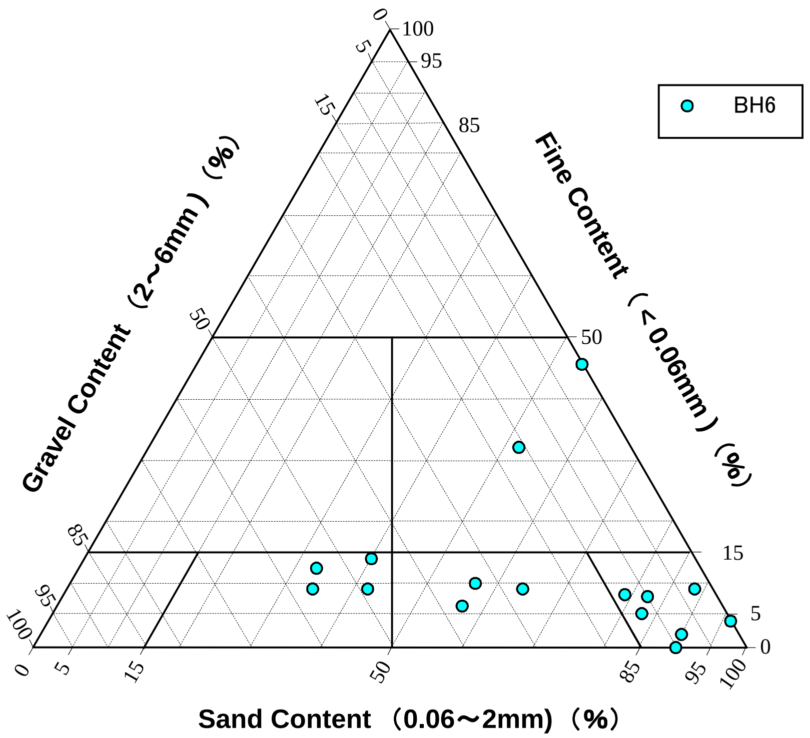
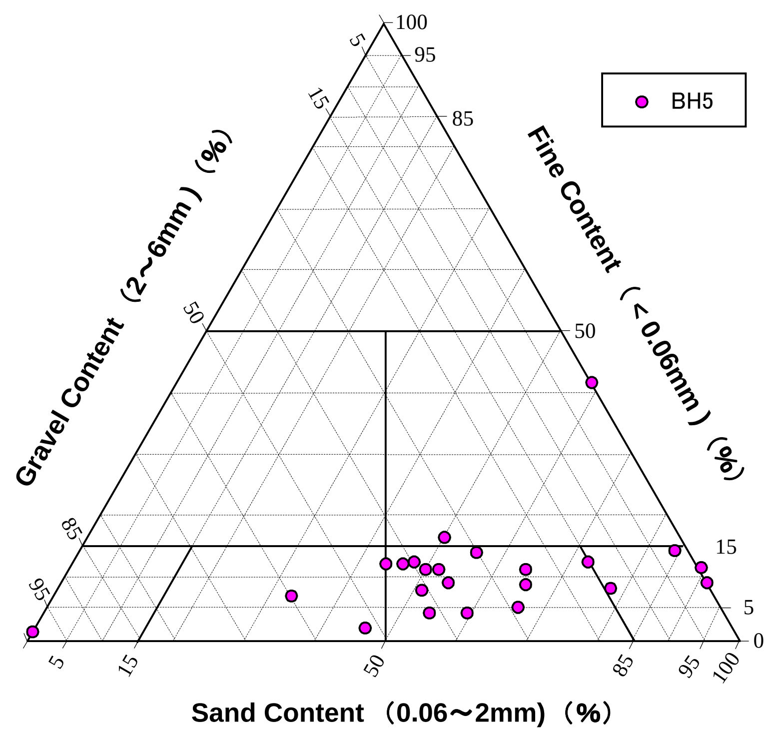
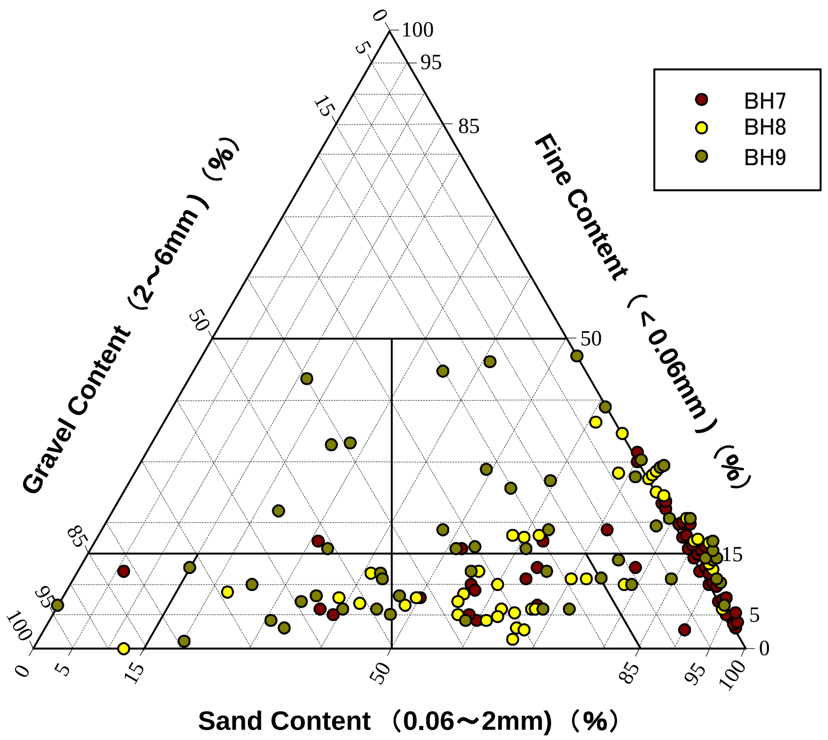


Upper Stream and Midstream of Groundwater Basin



Midstream of Groundwater Basin

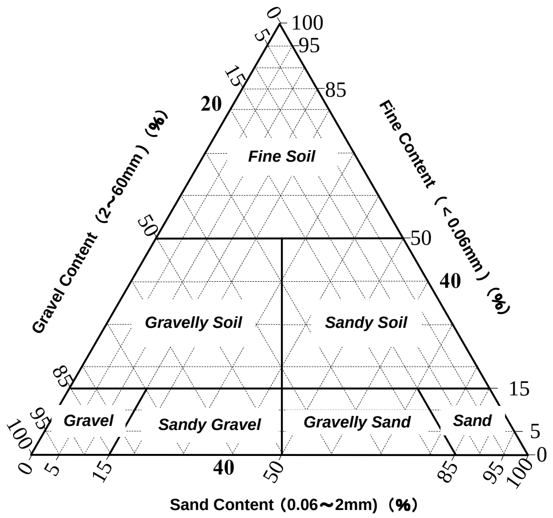


Downstream of Groundwater Basin

Figure F.4.28

Grain Size Characteristics of Sandy Soils, Midstream and Downstream of Groundwater Basin

LEGEND



Classification System of Soils by Triangular Soil Classification System

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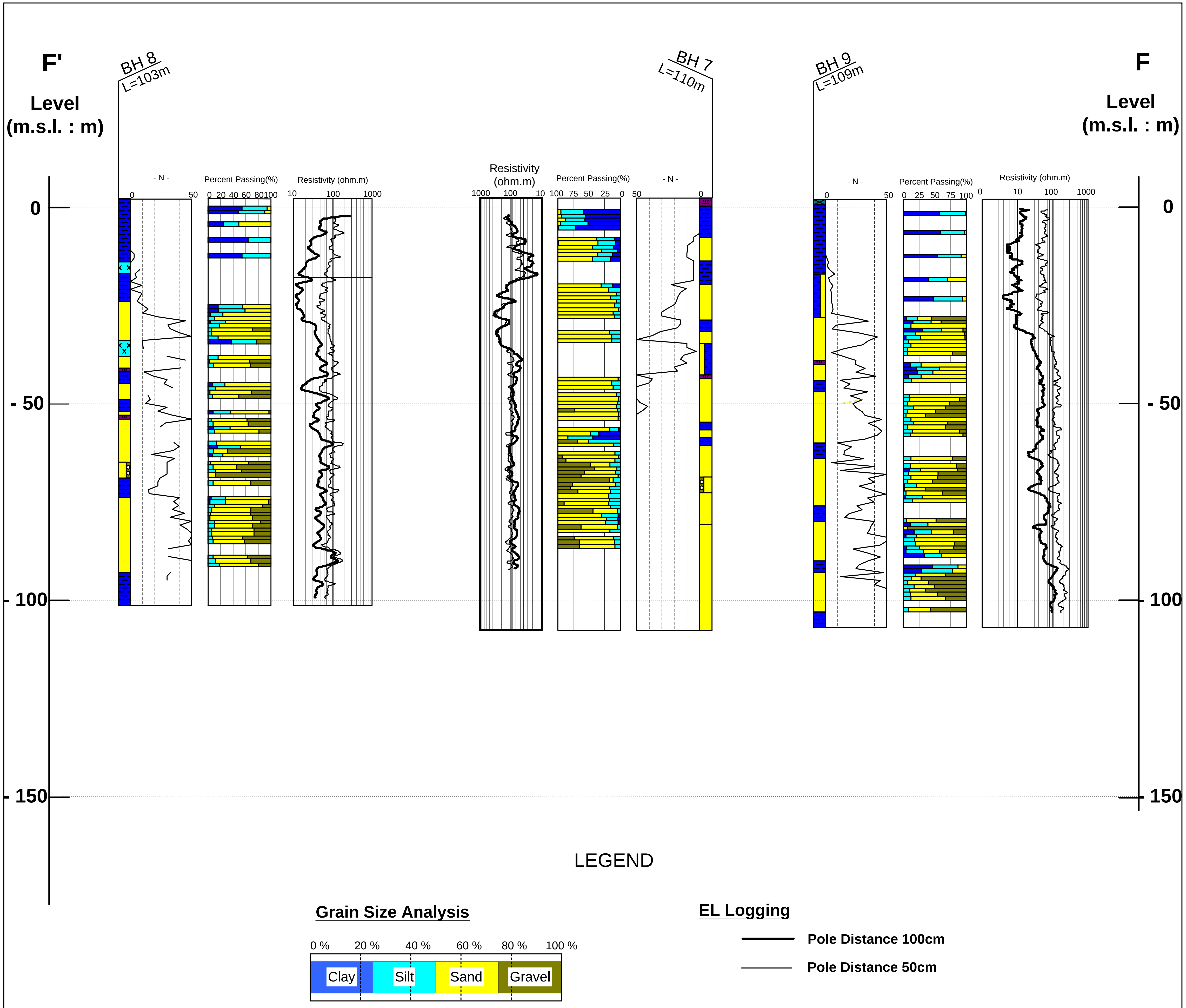
Figure F.4.29

Characteristics of the Aquifer (Centre and Southern Part of Aquifer)



LEGEND

- 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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5. SUMMARY AND CONCLUSIONS

The field survey was carried out during Phase I and Phase II of the Study. The results of the survey, the existing boreholes and geological knowledge of the region were used to characterise the Groundwater Basin.

The Groundwater Basin is distributed in the lowlands of the Langat Basin. Boundary of the Basin is defined by the hills in the north and in the east, and by the seacoast in the south. The western boundary can be determined by geological conditions along the line between Bt. Puloh and Bt. Jugra.

The aquifer system of the Groundwater Basin was simplified into four layers. Layer 1, very soft peaty soil (Beruas Formation) covers most of the Basin. Layer 2, clayey soils, distributes over the Groundwater Basin. For the estimation of land subsidence, Layer 2 was divided into two sub-layers; namely Layer 2a, soft clayey soils (Gula Formation) and Layer 2b, and medium to stiff clayey soils (mainly Gula Formation). Consolidation properties of the clayey soil layers, Layers 2a and 2b, were determined from the laboratory soil tests. Layer 3, the Aquifer, consisting of sandy/gravelly soils (Lower Member of Simpang Formation), covers Layer 4, the aquifer bedrock, over the Groundwater Bain. In some areas, the Aquifer shows alternate nature of the sandy/gravelly soil layers and the clayey soil layers.

The characteristics of the Groundwater Basin described in this chapter will be used for groundwater modelling, groundwater simulation and estimation of land subsidence.

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15) JMG's Internal Document, Tin Prospecting Report, A31-40.

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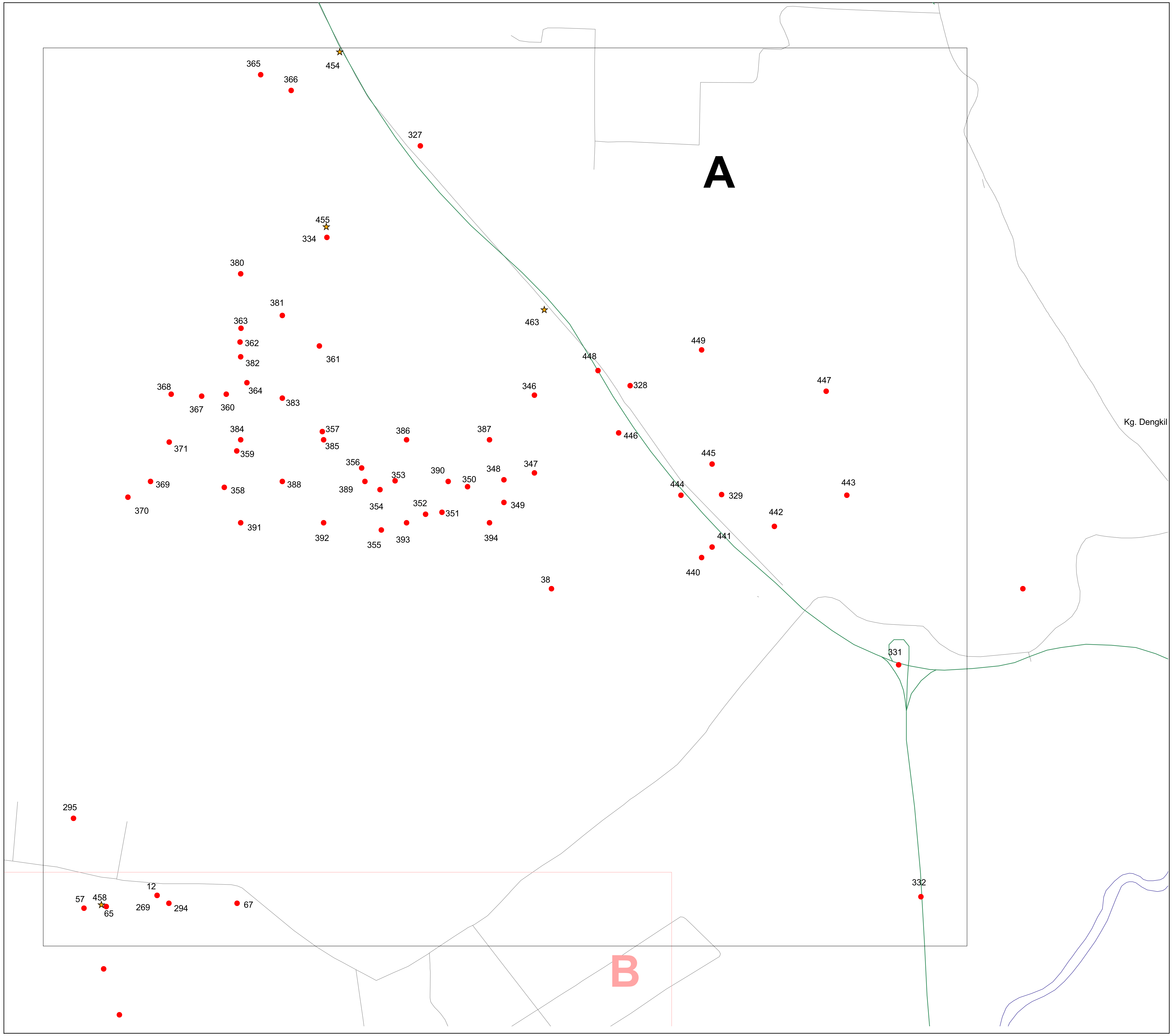
ANNEX F.2.1

LOCATION MAP OF EXISTING BOREHOLES

Annex Figure F.2.1

Location Map of Existing Boreholes (Enlarged Area A)



LEGEND

- Existing Borehole Point
- Location of Soil Investigation of the Present Study
- Highways
- Roads
- Rivers
- Town

Scale 1 : 50,000

200 0 200 400 600 800 1000 Meters

N E S W

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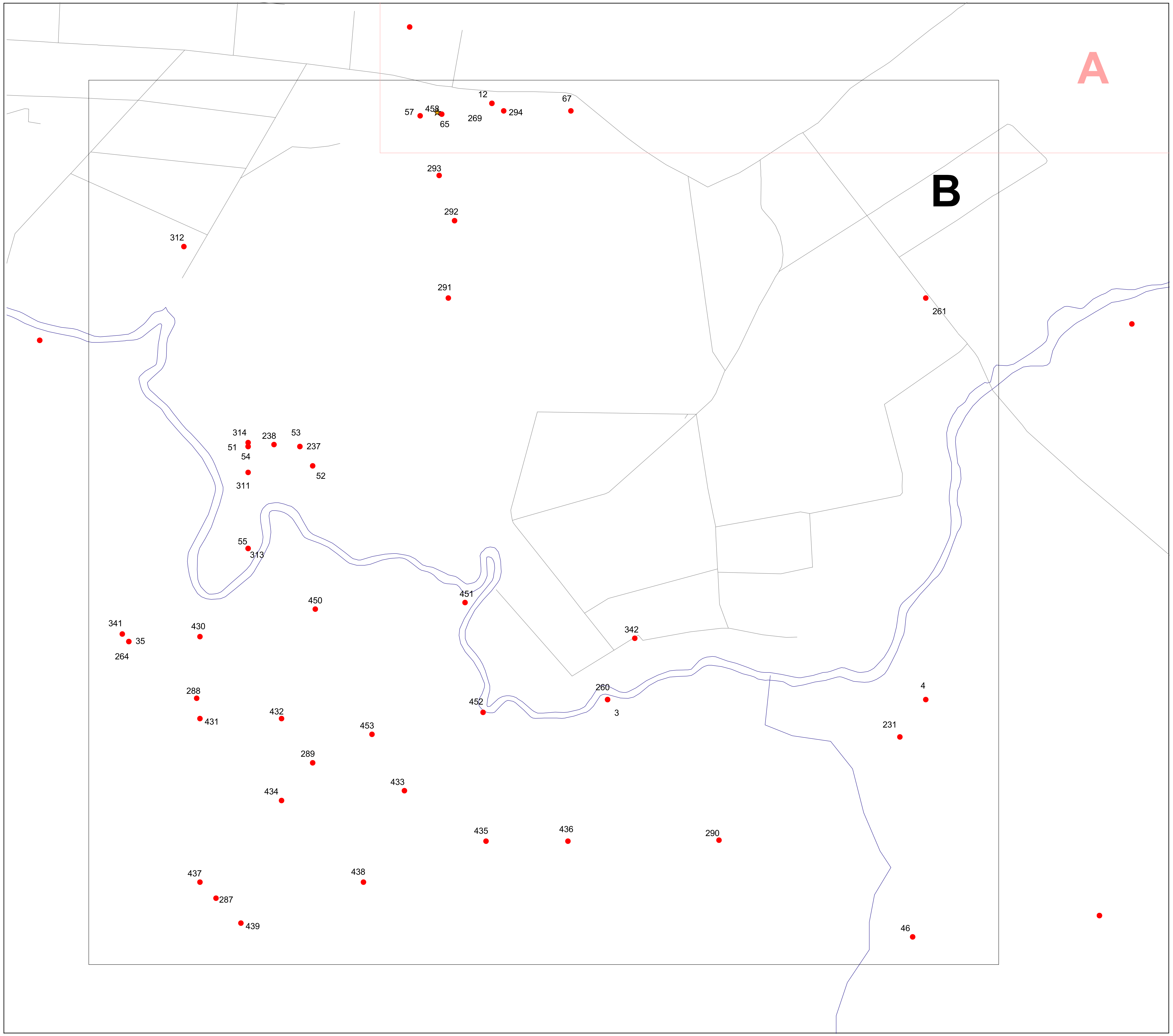

Annex Figure F.2.2

Location Map of Existing Boreholes (Enlarged Area B)

LEGEND

- Existing Borehole Point
- Location of Soil Investigation of the Present Study
- Highways
- Roads
- Rivers
- Town

Scale 1 : 50,000

200 0 200 400 600 800 1000 Meters

N W E S

JICA Japan International Cooperation Agency

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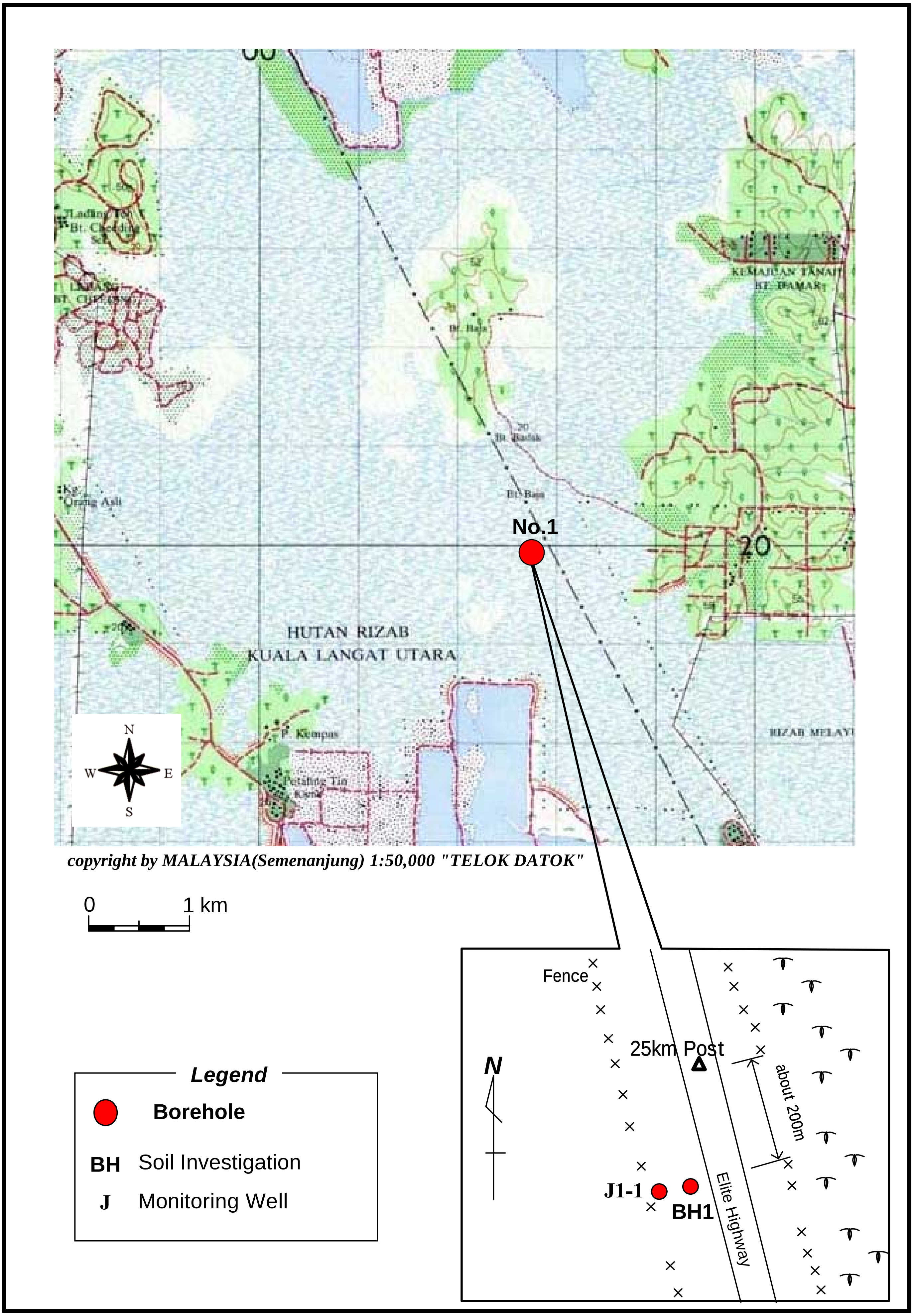
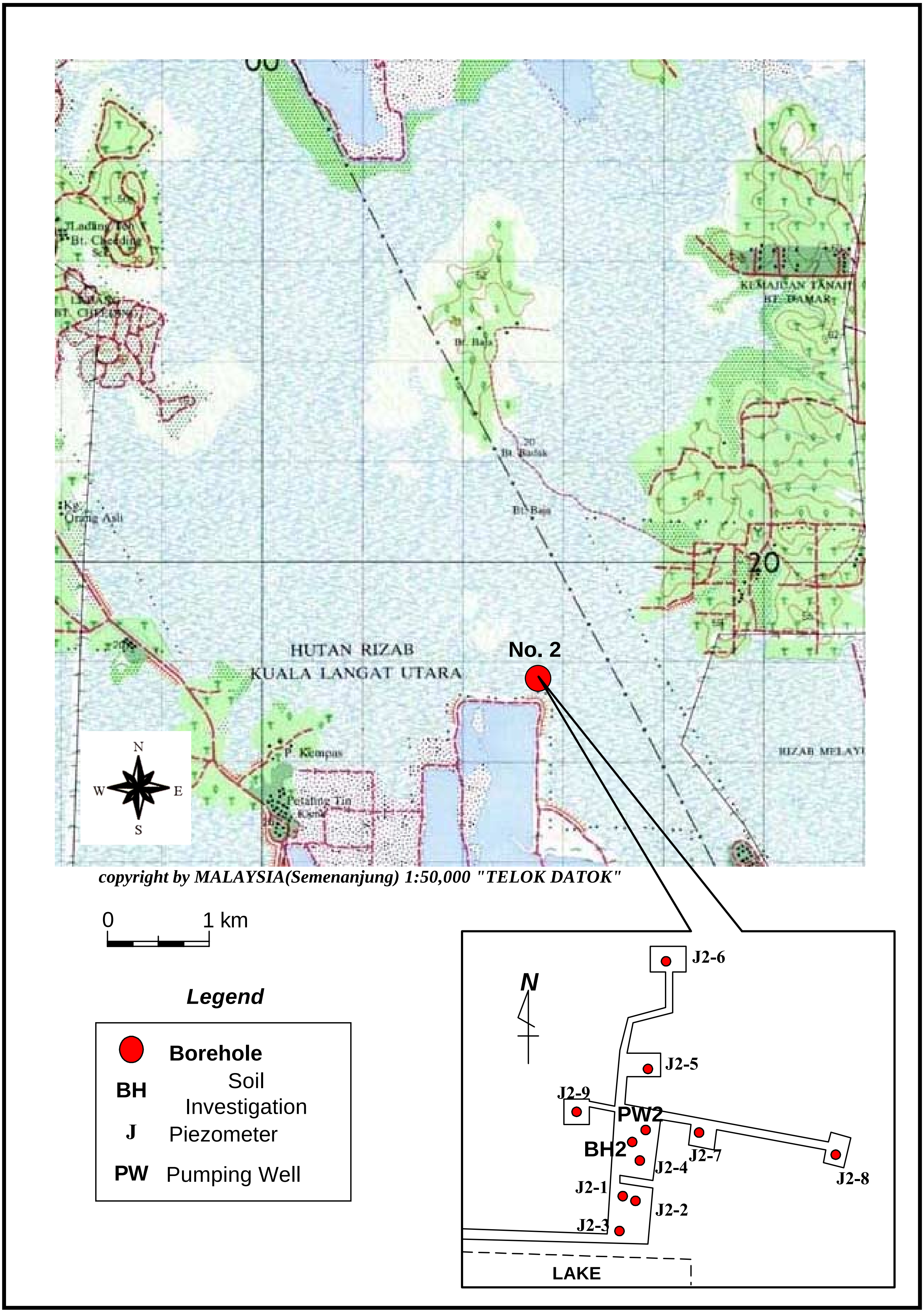
ANNEX F.2.2

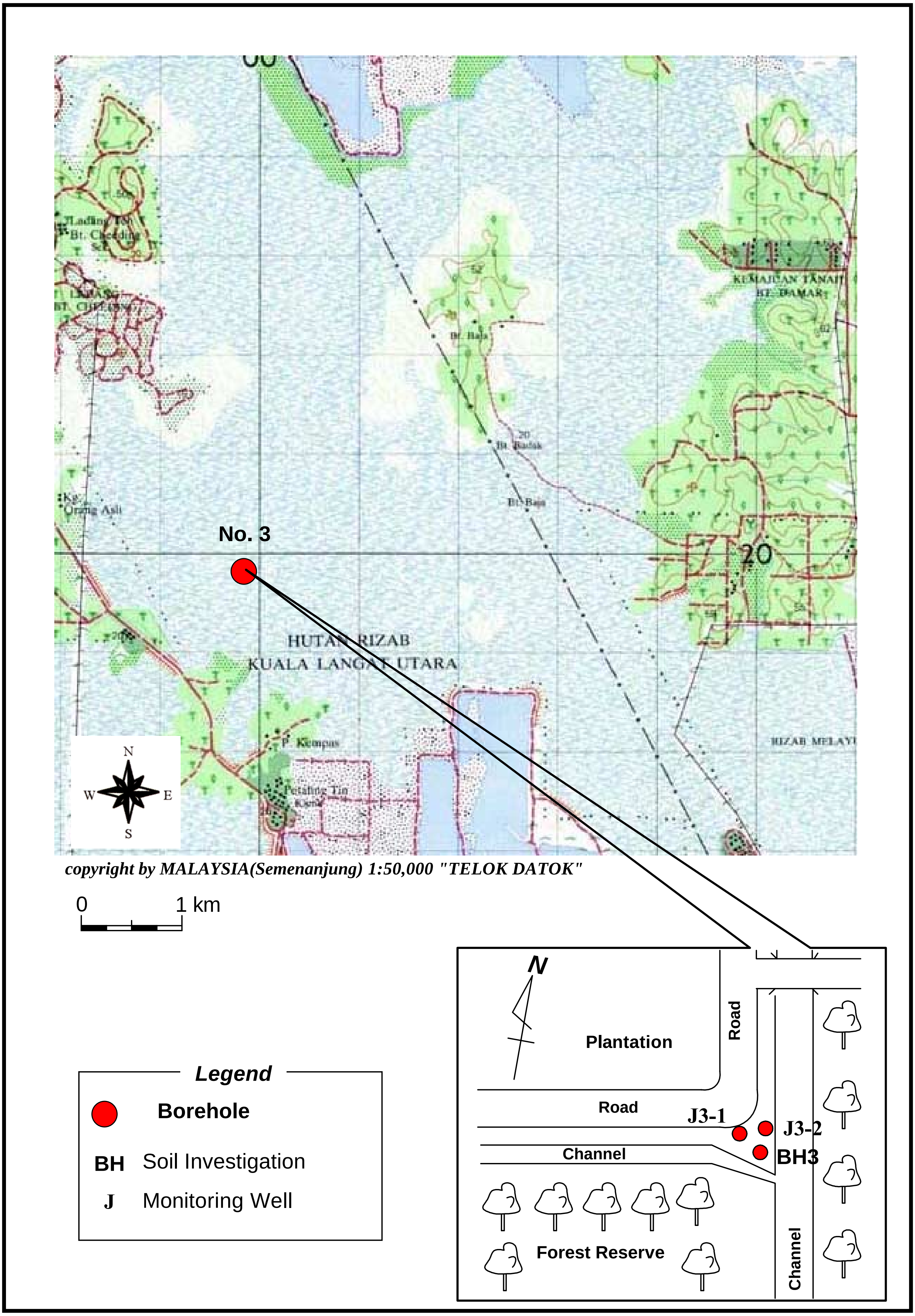
LOCATION OF SOIL INVESTIGATION



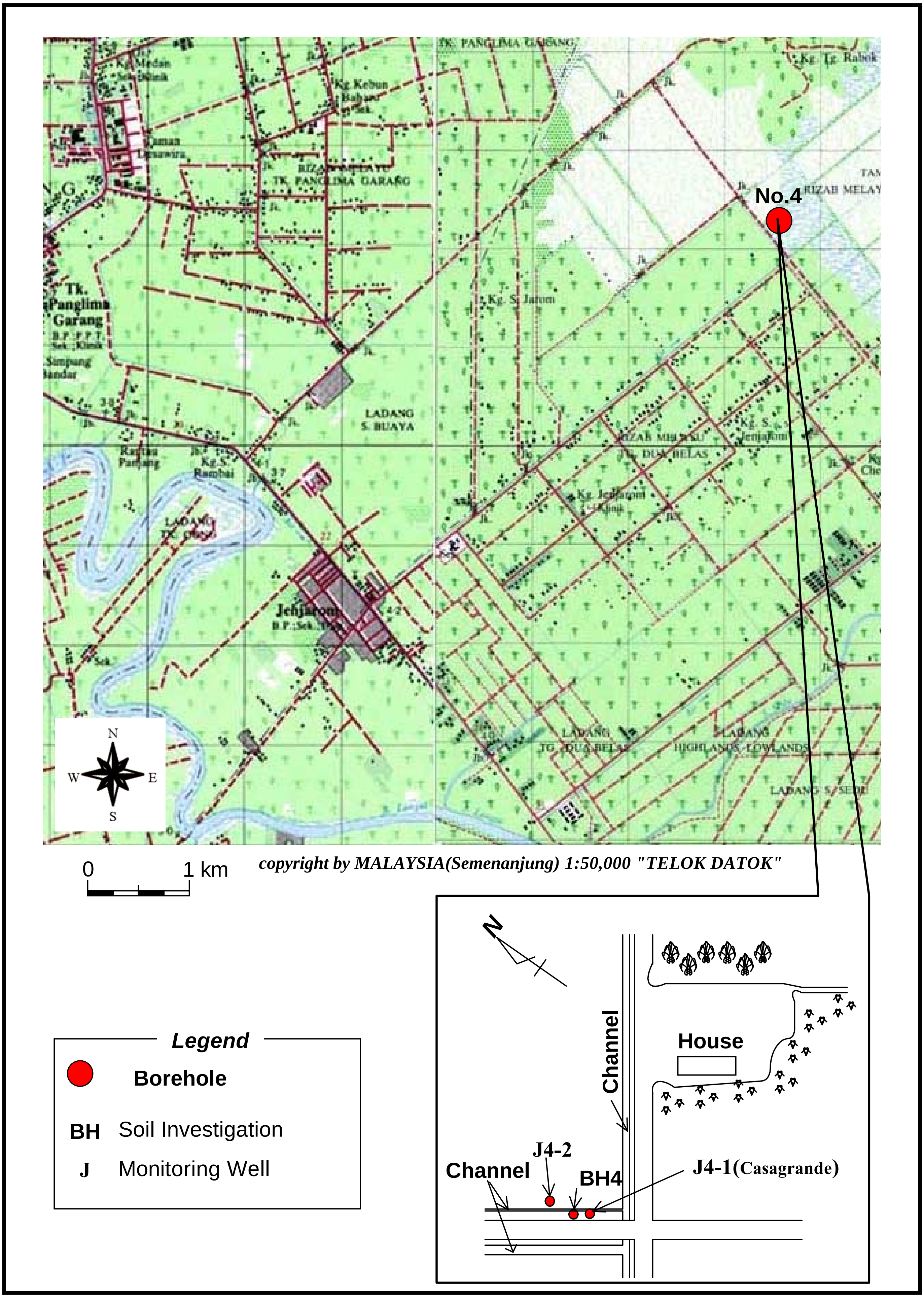
Annex Figure F.2.3 Site Map of Boring Site No.1



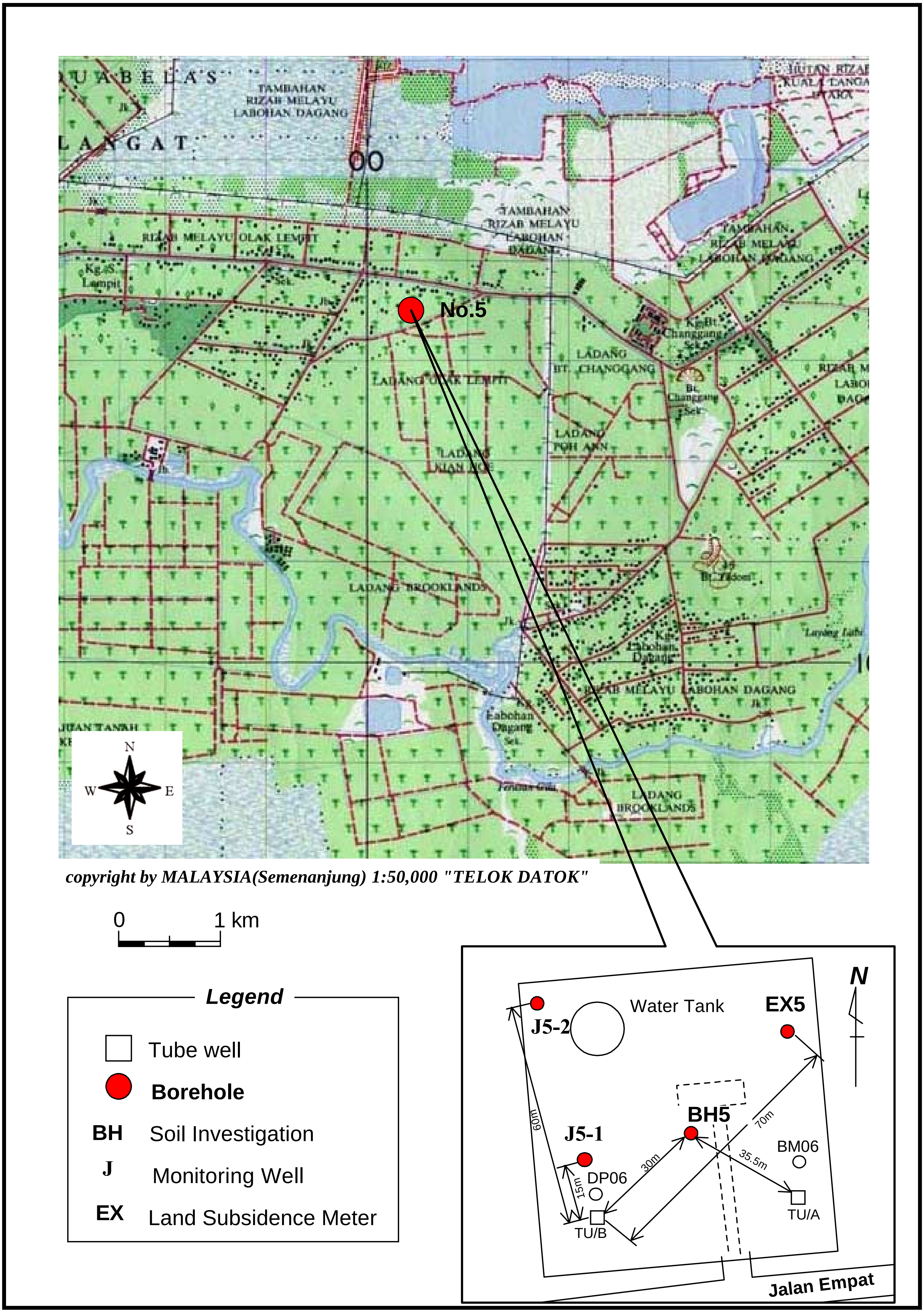
Annex Figure F.2.4 Site Map of Boring Site No.2



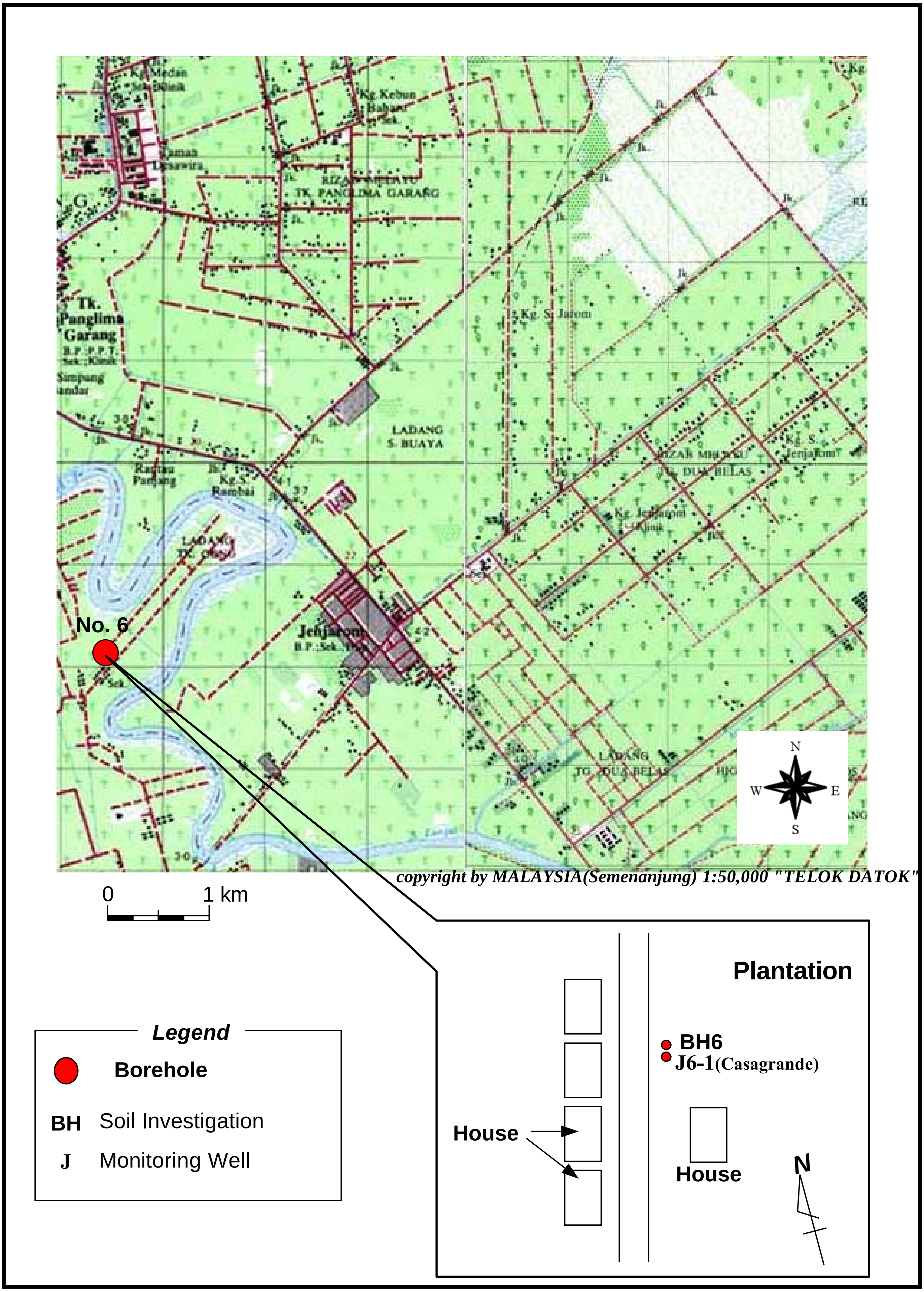
Annex Figure F.2.5 Site Map of Boring Site No.3



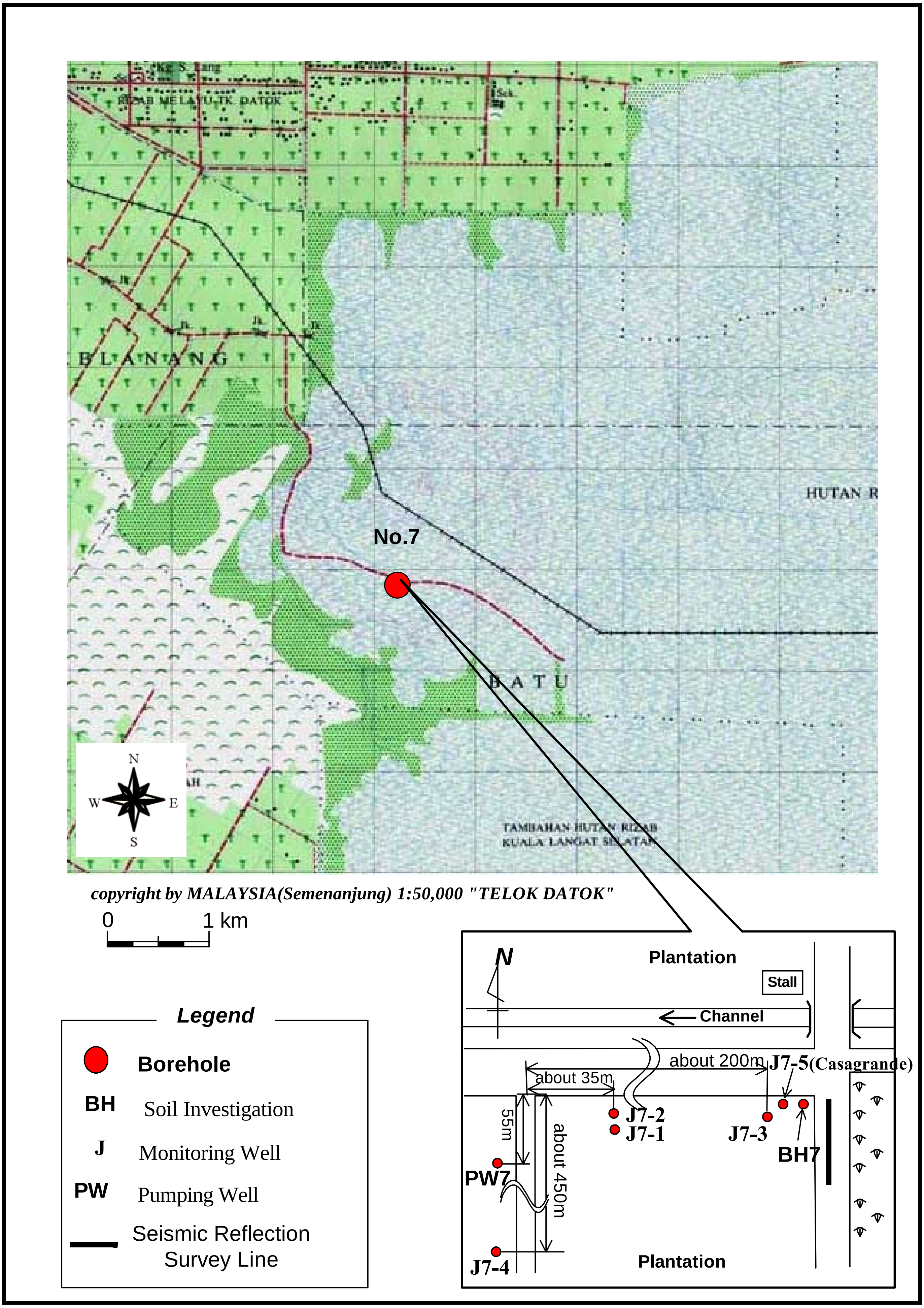
Annex Figure F.2.6 Site Map of Boring Site No.4



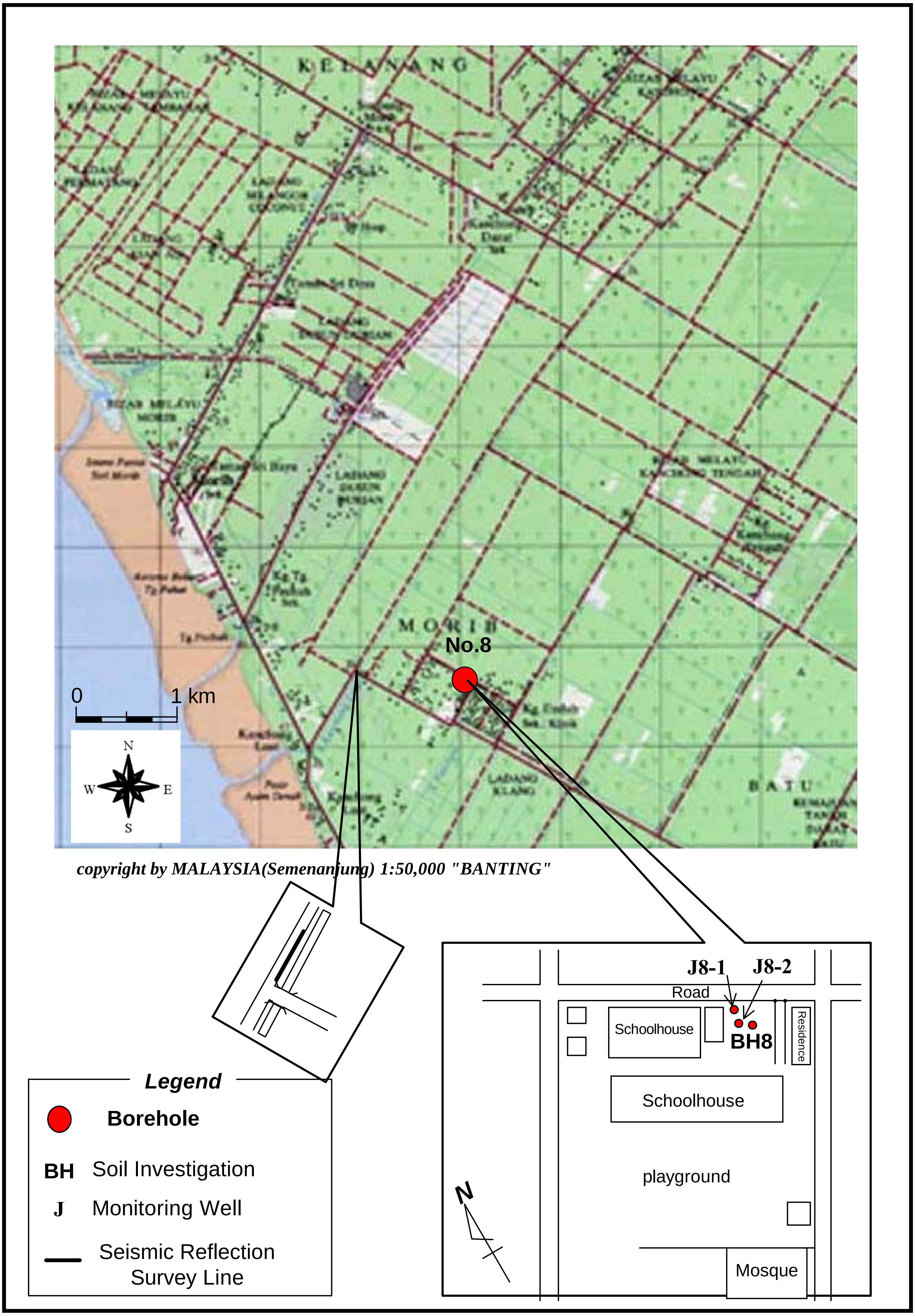
Annex Figure F.2.7 Site Map of Boring Site No.5



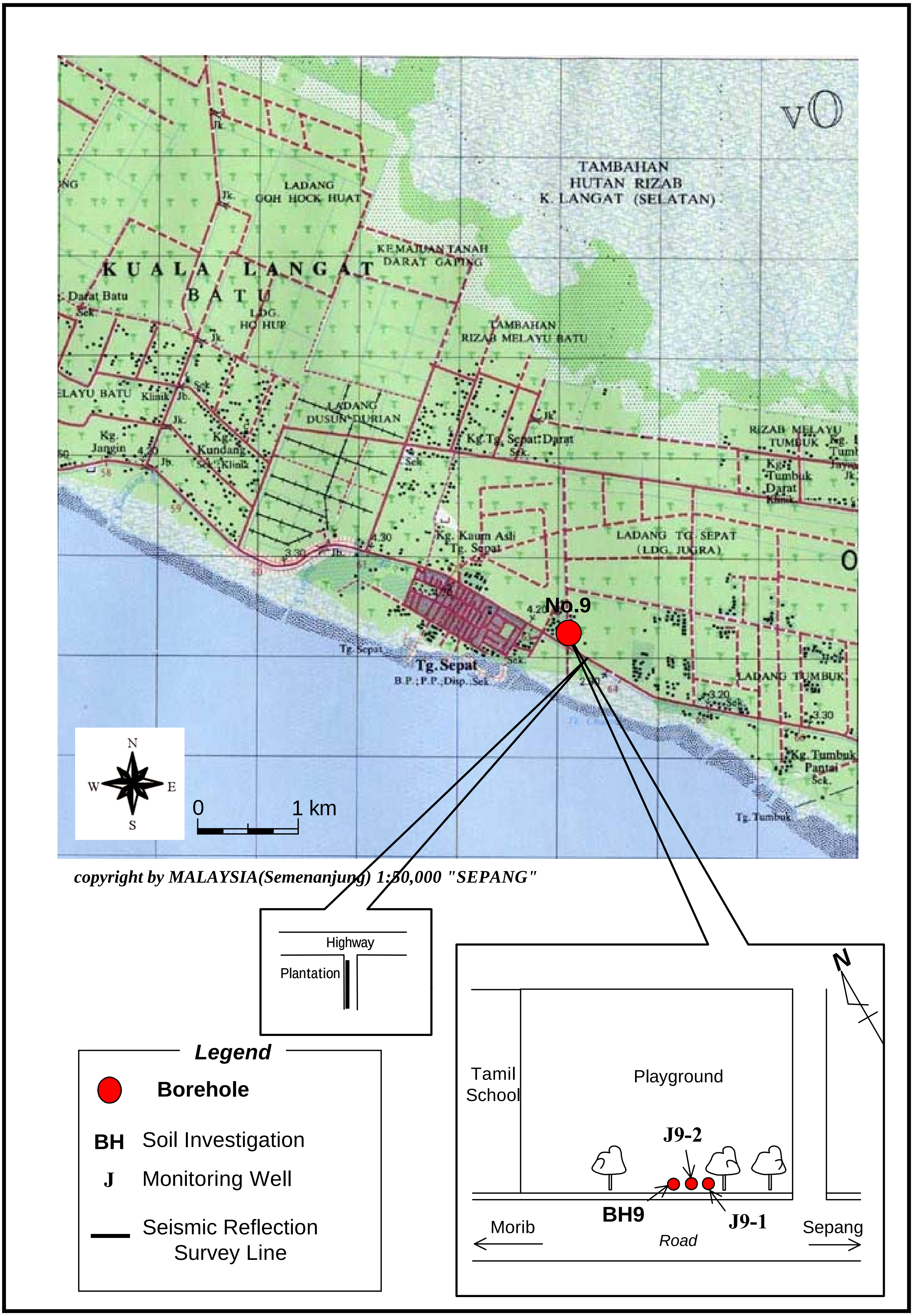
Annex Figure F.2.8 Site Map of Boring Site No.6



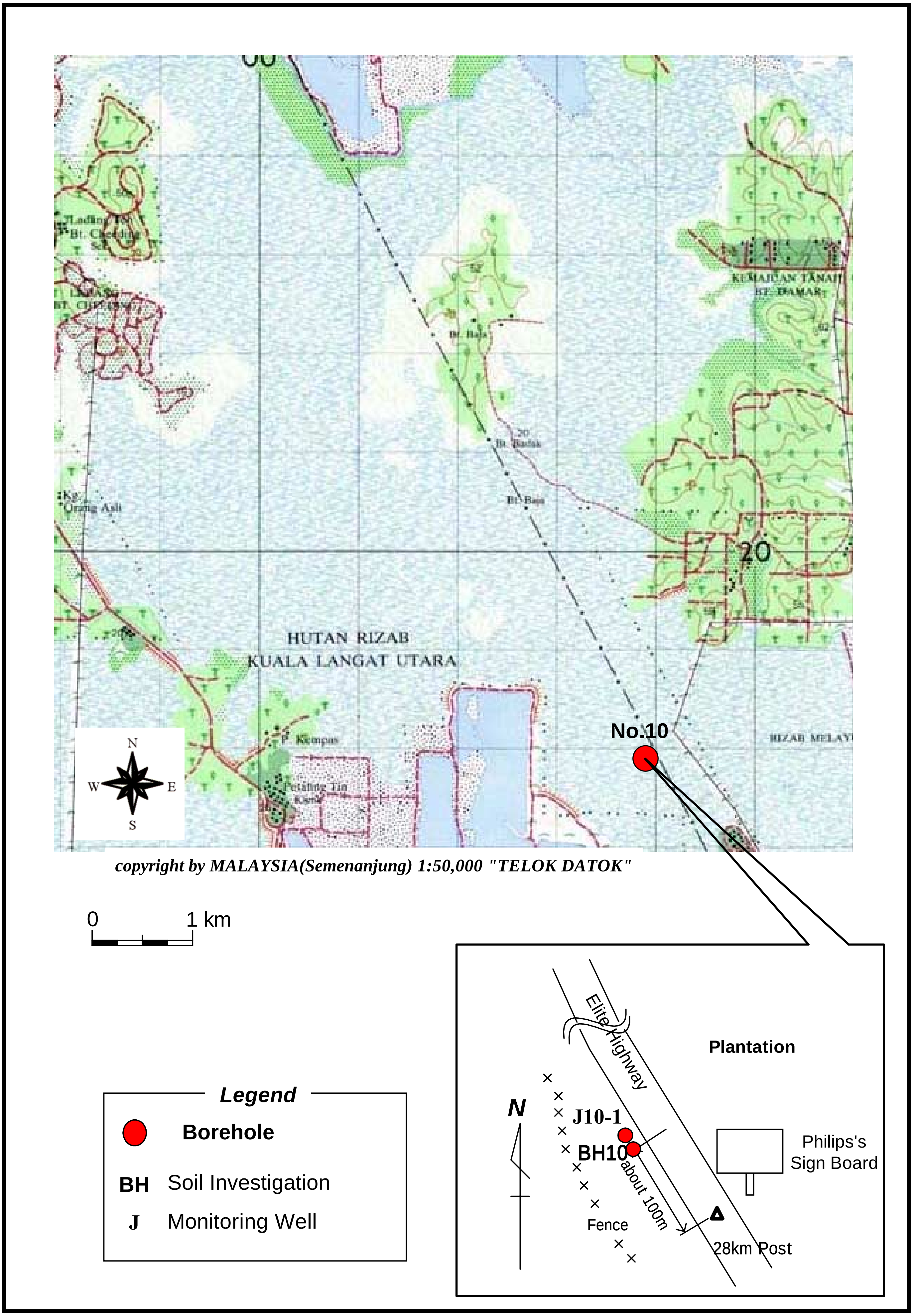
Annex Figure F.2.9 Site Map of Boring Site No.7



Annex Figure F.2.10 Site Map of Boring Site No.8



Annex Figure F.2.11 Site Map of Boring Site No.9



Annex Figure F.2.12 Site Map of Boring Site No.10

ANNEX F.2.3

SUMMARY OF LABORATORY SOIL TEST RESULTS FOR CLAYEY SOILS

Annex Table F.2.1 Summary of Laboratory Soil Test Results for Clayey Soils

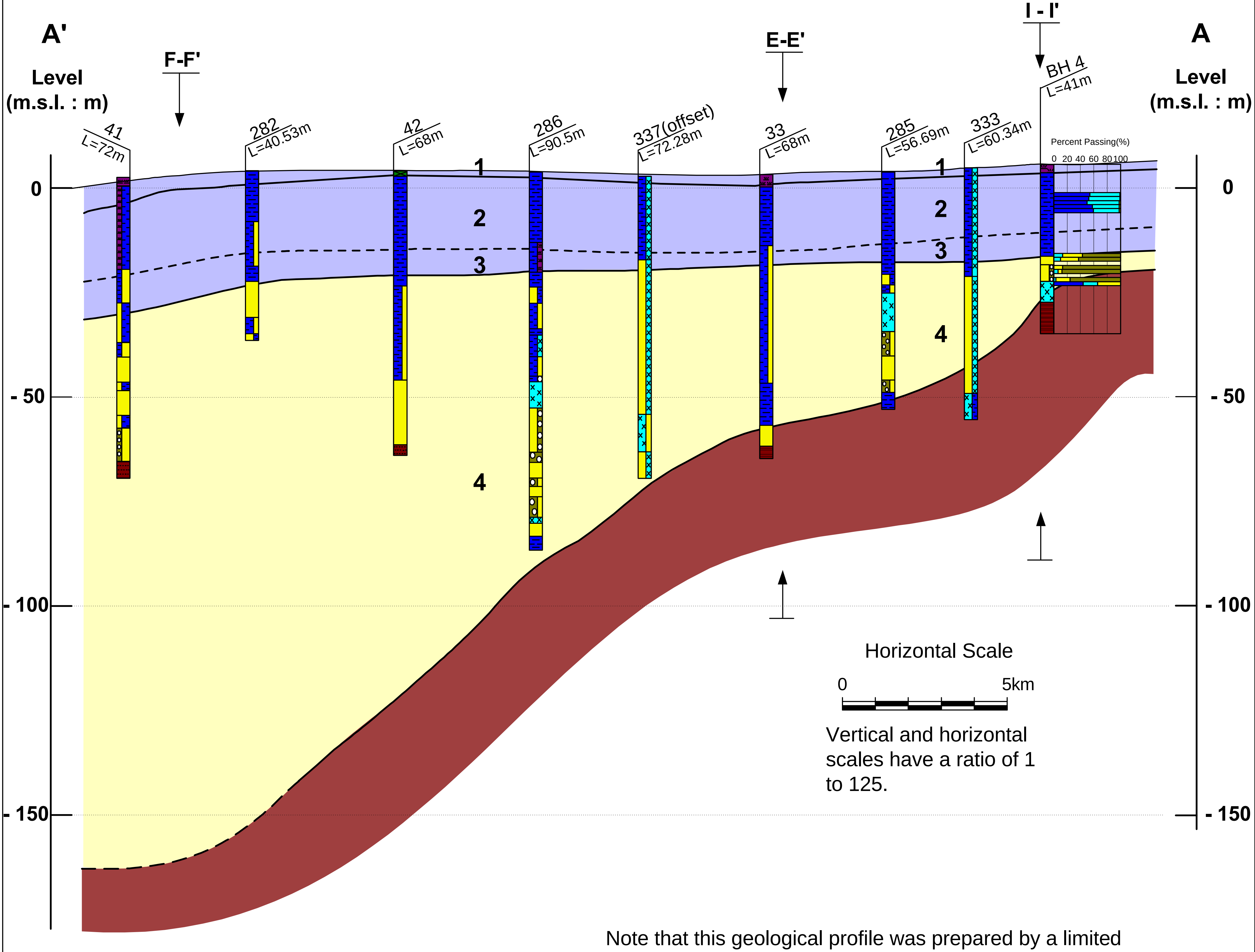
Borehole No.	Sample No.	Depth (G.L.-m)	Specific Gravity ρ	Grain Size Analysis				Bulk Density ρ t	Natural Water Content wn	Void Ratio e	Liquid Limit w_L	Plastic Limit w_P	Plasticity Index Ip	Consolidation Yield Stress pc	Compression Index Cc
				Clay	Silt	Sand	Gravel								
			(-)	(%)	(%)	(%)	(%)	(Mg/m^3)	(%)	(-)	(%)	(%)	(-)	(kN/m^2)	(-)
BH4	1	6	2.37	54	45	1	0	1.384	107	2.545	116	36	80	36	1.070
	2	7	2.32	52	47	1	0	1.350	114	2.678	117	35	82	70	1.141
	3	8	2.35	50	48	2	0	1.381	106	2.505	119	34	85	51	1.098
	4	9	2.33	58	40	2	0	1.374	106	2.493	116	41	75	53	0.941
	5	10	2.39	59	39	2	0	1.393	101	2.449	117	36	81	45	0.871
BH5	1	3	2.52	55	36	9	0	1.726	41	1.059	70	26	44	57	0.254
	2	4	2.55	58	41	1	0	1.769	39	1.004	68	27	41	145	0.303
	3	7	2.58	68	26	6	0	1.839	33	0.866	57	25	32	265	0.162
	4	8	2.53	67	19	14	0	1.851	30	0.777	55	25	30	230	0.127
	5	11.5	2.55	34	29	37	0	1.884	25	0.692	67	25	42	150	0.134
BH6	1	1.85	2.58	36	24	30	10	1.605	53	1.459	61	21	40	60	0.515
	2	11	2.54	34	30	36	0	1.487	49	1.545	87	23	64	135	0.872
	3	12	2.42	56	43	1	0	1.462	82	2.013	100	29	71	155	1.079
	4	13	2.54	51	40	9	0	1.483	63	1.792	101	29	72	160	0.880
	5	14	2.55	42	40	18	0	1.492	58	1.700	87	28	59	190	0.993
BH7	1	3	2.37	59	36	5	0	1.444	64	1.692	61	29	32	42	0.592
	2	4	2.32	56	38	6	0	1.552	58	1.362	51	26	25	48	0.392
	3	5	2.51	57	31	12	0	1.417	52	1.692	65	31	34	46	0.719
	4	6	2.39	52	44	4	0	1.553	54	1.370	82	25	57	220	0.846
	5	7	2.34	72	27	1	0	1.394	79	2.005	83	24	59	80	0.821
BH8	1	2	2.35	54	40	6	0	1.566	49	1.236	55	26	29	5	0.400
	2	3	2.43	48	42	10	0	1.618	51	1.268	50	25	25	100	0.430
	3	6	2.46	25	24	51	0	1.711	38	0.984	42	23	19	93	0.213
	4	10	2.45	64	35	1	0	1.387	83	2.233	45	25	20	97	1.003
	5	14	2.45	54	45	1	0	1.433	64	1.804	73	25	48	73	0.666
BH9	1	3	2.36	57	42	1	0	1.441	51	1.473	68	26	42	33	0.608
	2	8	2.35	59	38	3	0	1.338	71	2.003	70	25	45	50	1.026
	3	14	2.34	54	38	8	0	1.540	52	1.310	83	26	57	170	0.512
	4	20	2.39	40	30	30	0	1.518	45	1.283	76	26	50	60	0.586
	5	25	2.34	48	46	6	0	1.460	67	1.677	79	29	50	80	0.700

ANNEX F.4.1

GEOLOGICAL PROFILES WITH GRAIN SIZE CHARACTERISTICS

Annex Figure F.4.1

Geological Profile with Grain Size Characteristics, Profile A -A'



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.

LEGEND

Grain Size Analysis

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

Clay | Silt | Sand | Gravel

Key of BoreholeLog

- PEAT
- CLAY
- SILT
- SAND
- GRAVEL
- LIMESTONE
- SHALE, SLATE, PHYRITE
- SANDSTONE, QUARTZITE, SHIST
- Granitic rock

1 - 4 :Layer Number

Boundary of Geology

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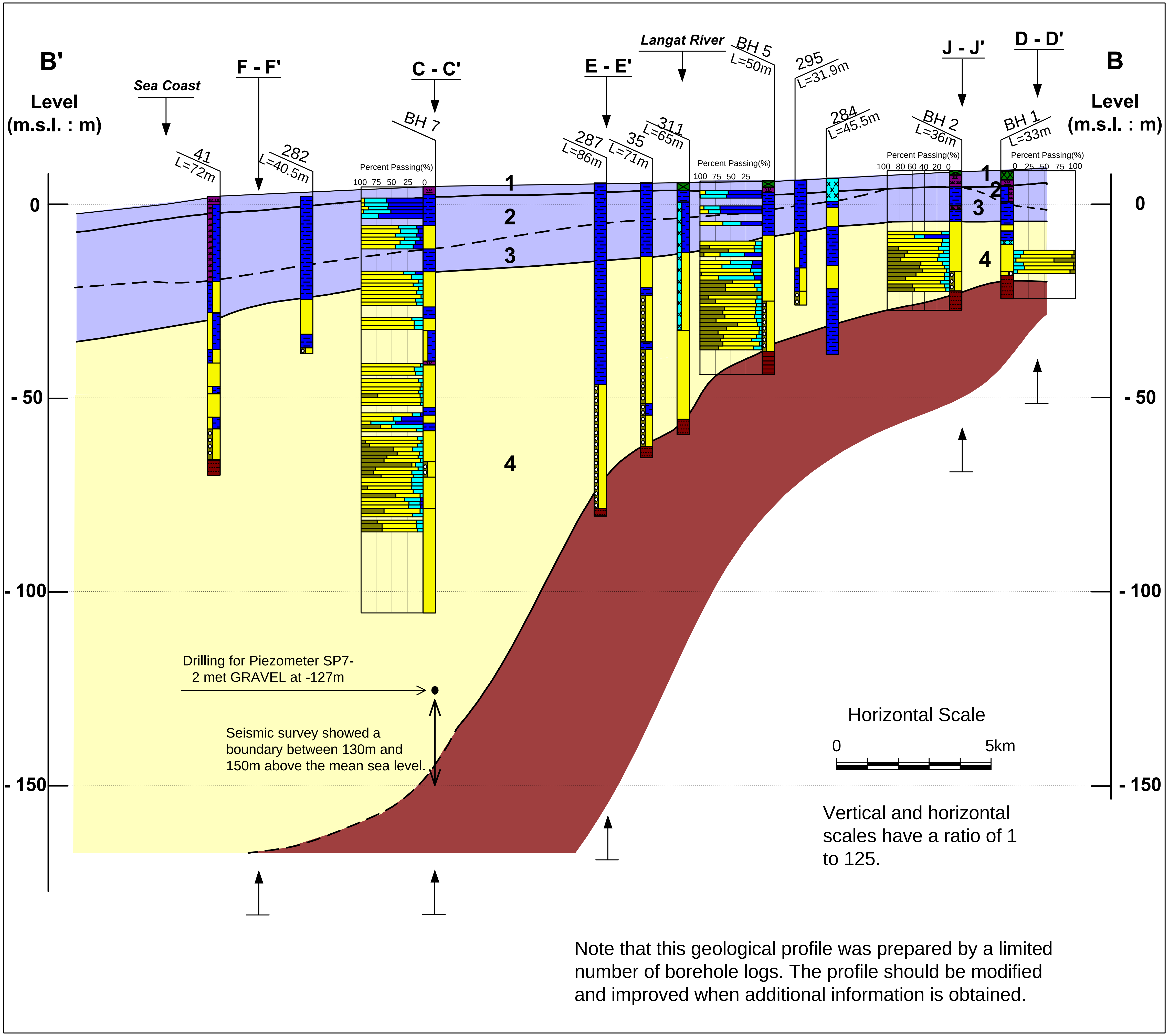
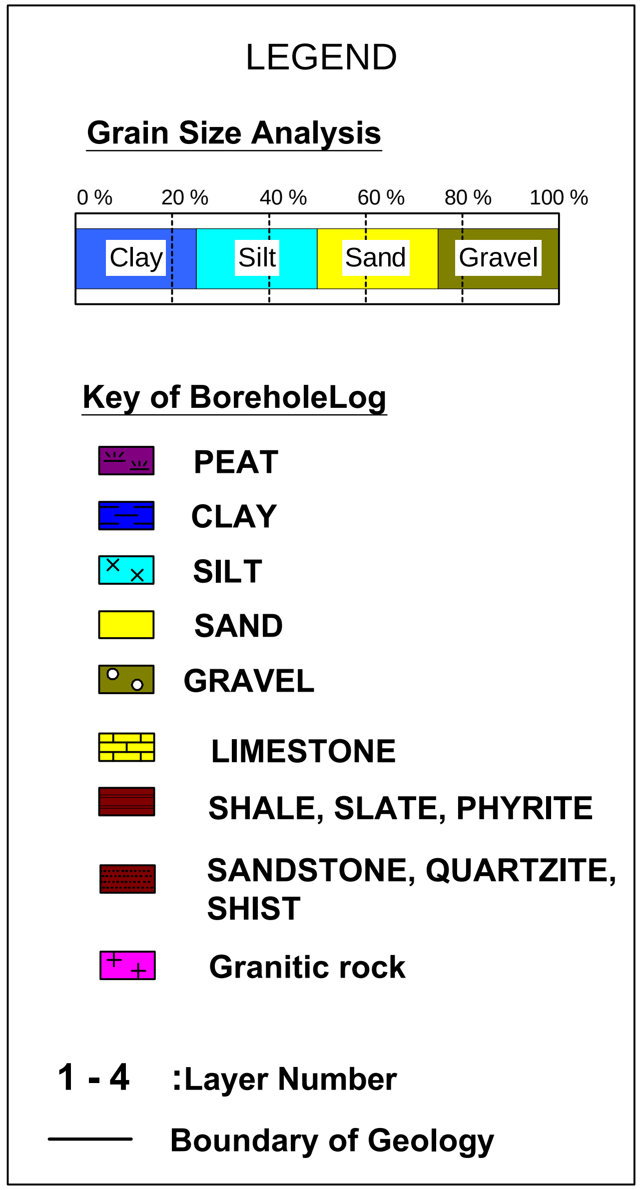
Annex Figure F.4.2

Geological Profile with Grain Size Characteristics, Profile B -B'





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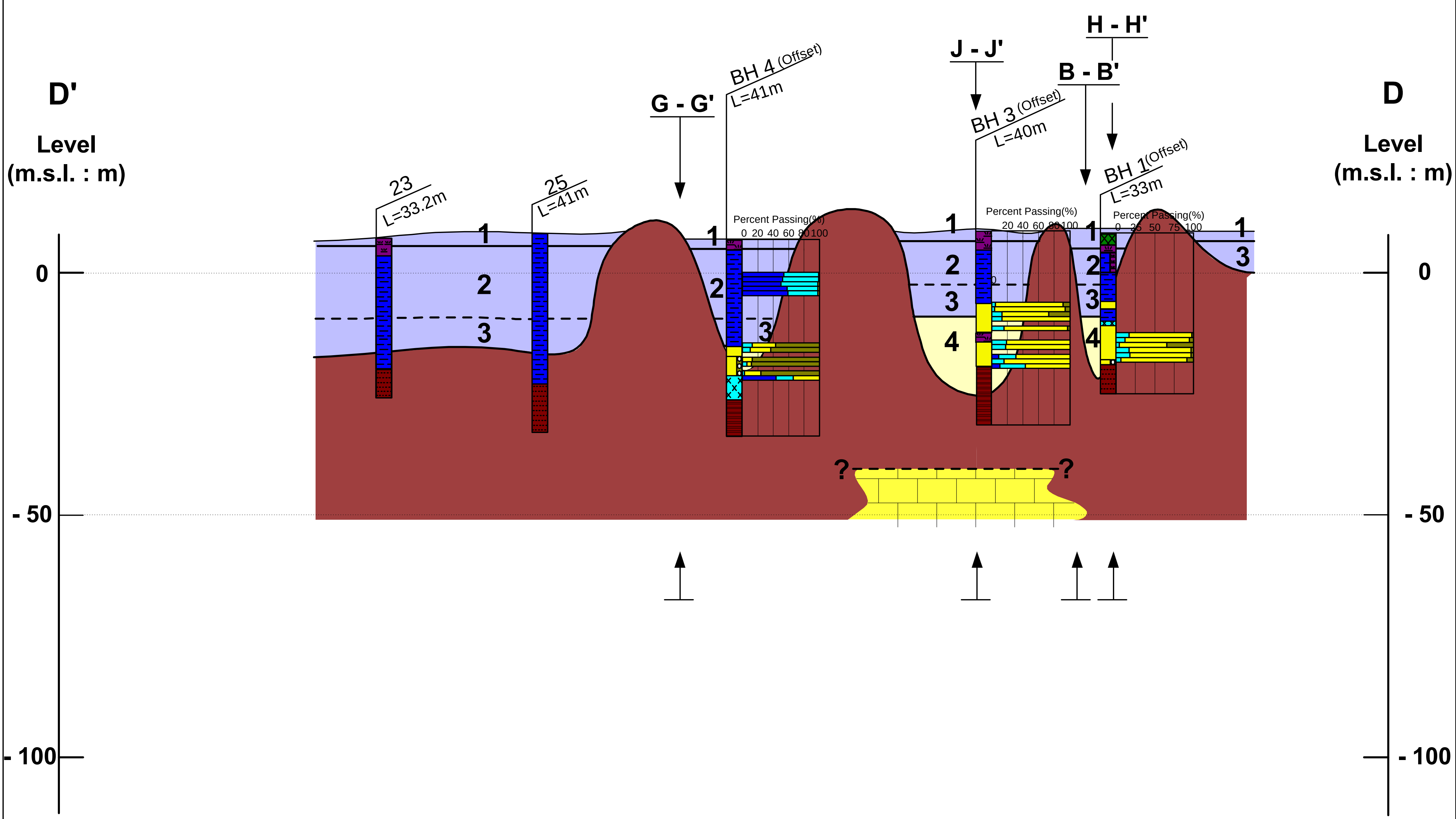
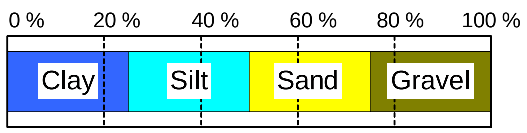
Annex Figure F.4.3

Geological Profile with Grain Size Characteristics, Profile D -D'



LEGEND

Grain Size Analysis



Key of BoreholeLog

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

1 - 4 :Layer Number

Boundary of Geology

Horizontal Scale

0 5km

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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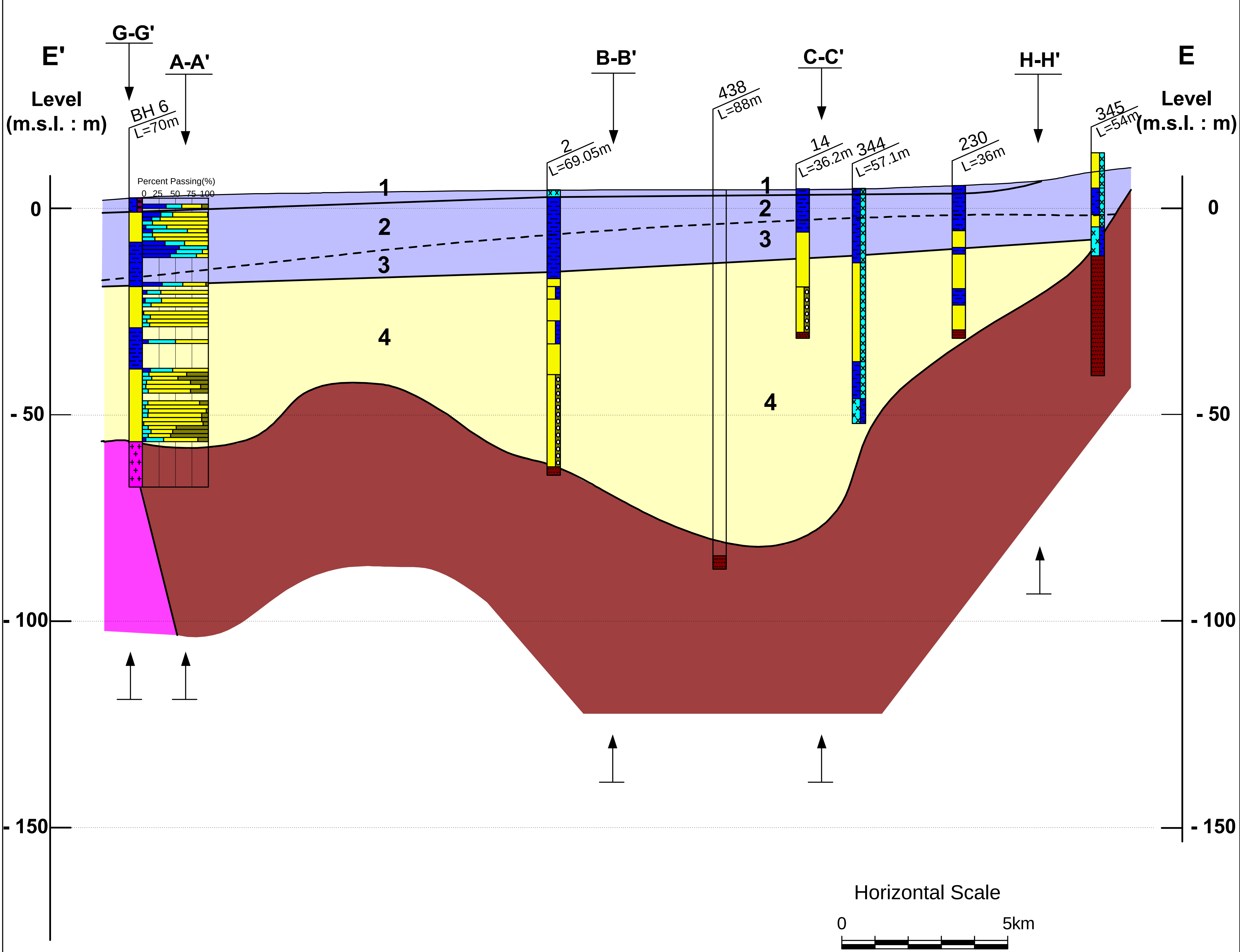
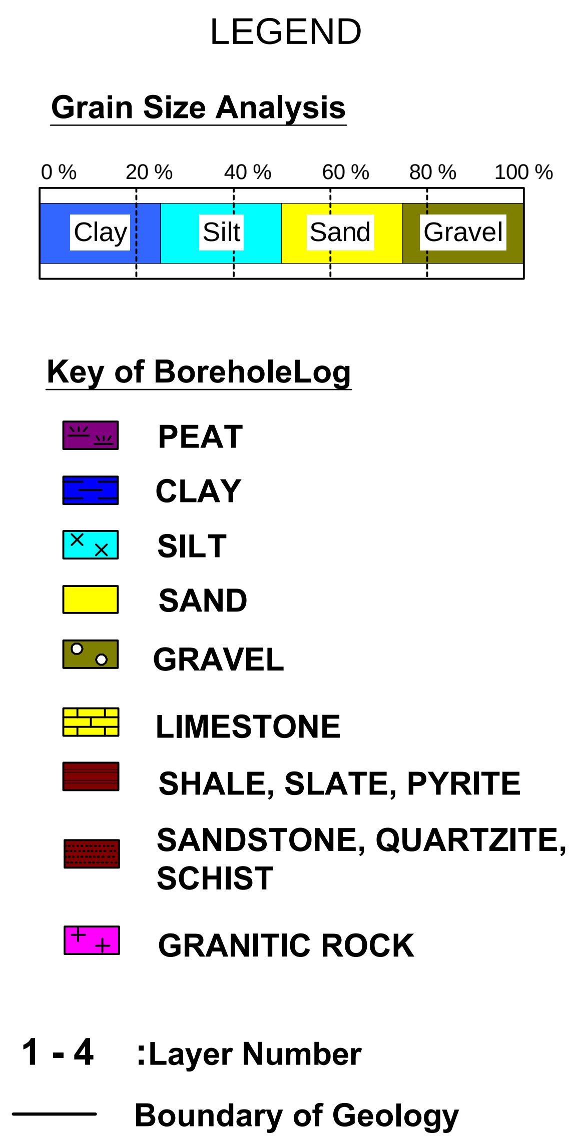
Annex Figure F.4.4

Geological Profile with Grain Size Characteristics, Profile E -E'





Horizontal Scale

0 5km

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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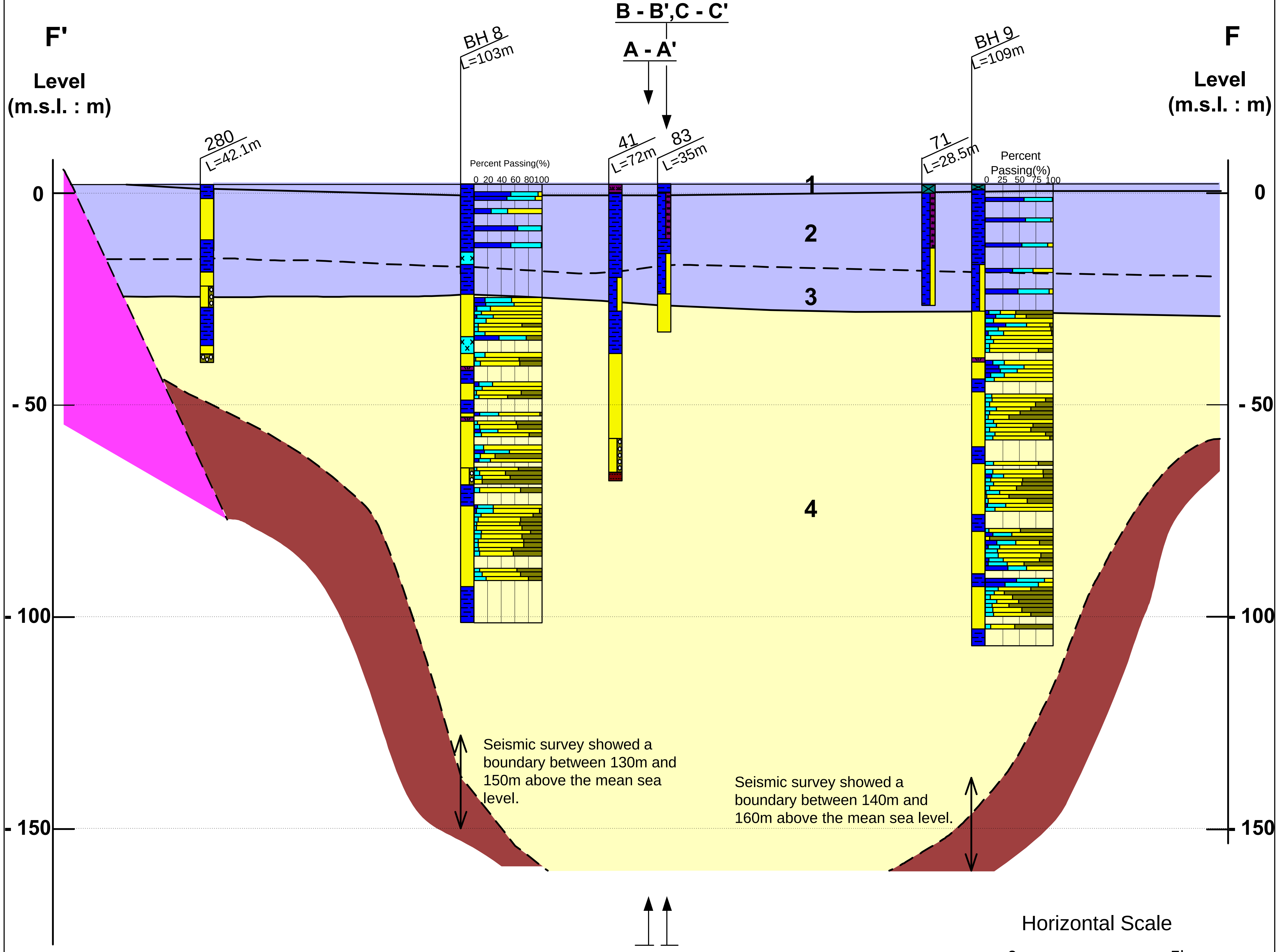
Annex Figure F.4.5

Geological Profile with Grain Size Characteristics, Profile F -F'



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.

LEGEND

Grain Size Analysis

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

Clay | Silt | Sand | Gravel

Key of BoreholeLog

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

1 - 4 :Layer Number

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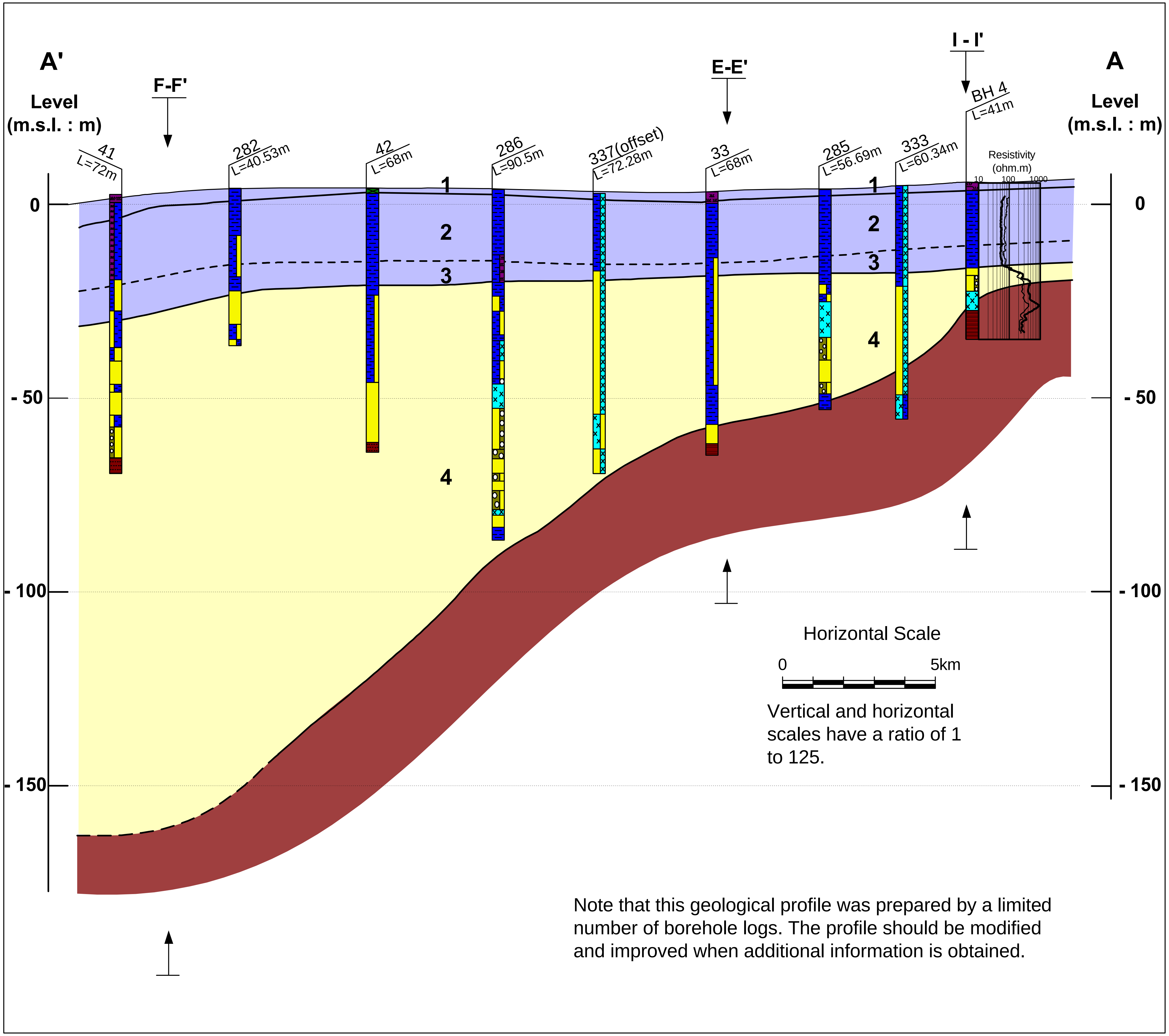
ANNEX F.4.2

GEOLOGICAL PROFILES WITH APPARENT RESISTIVITY

Annex Figure F.4.6

Geological Profile with Apparent Resistivity, Profile A -A'



LEGEND

EL Logging

- Pole Distance 100cm
- Pole Distance 50cm

Key of Borehole Log

- PEAT
- CLAY
- SILT
- SAND
- GRAVEL
- LIMESTONE
- SHALE, SLATE, PHYRITE
- SANDSTONE, QUARTZITE, SHIST
- Granitic rock

1 - 4 :Layer Number

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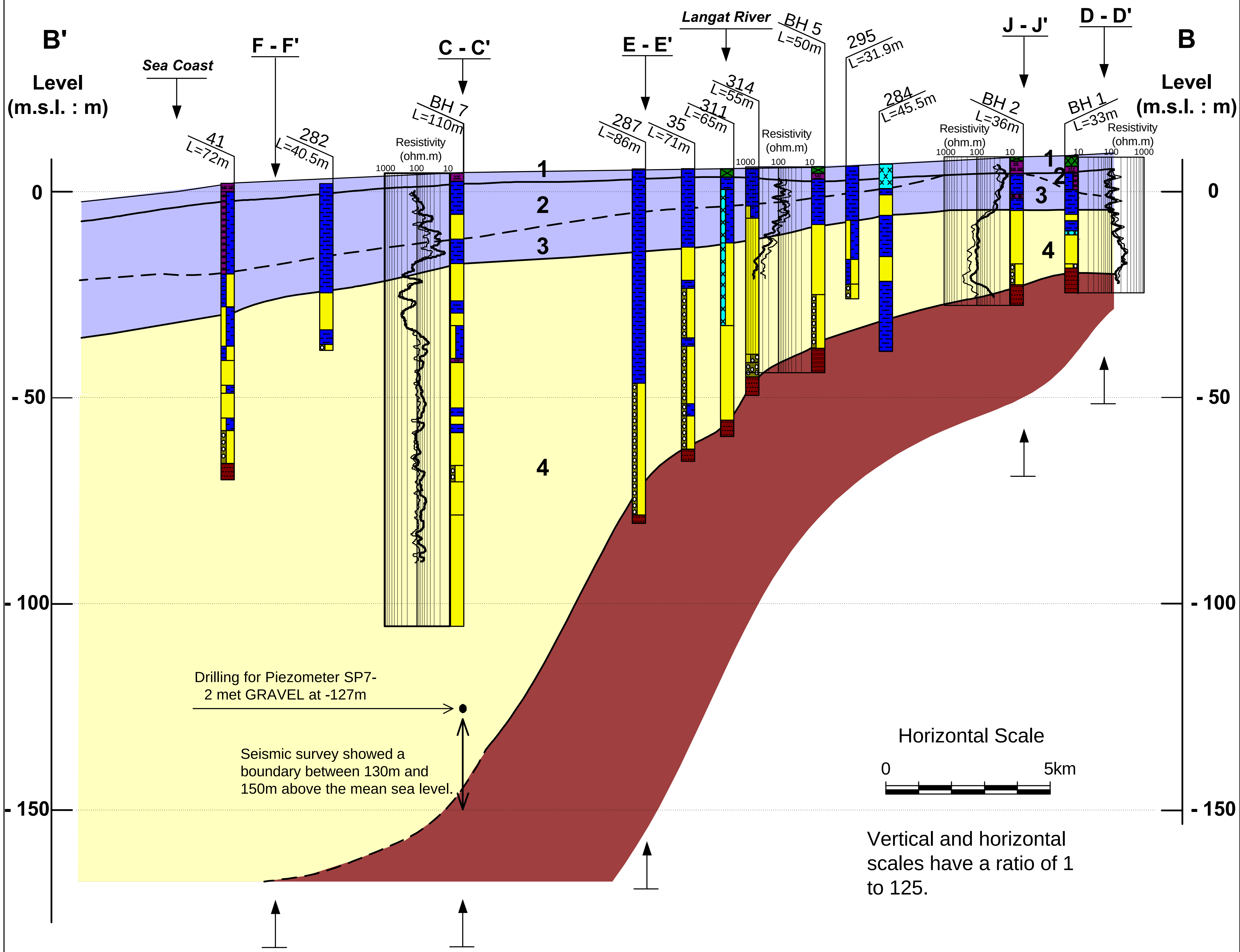

Note that this geological profile was prepared by a limited number of borehole logs. The profile should be modified and improved when additional information is obtained.

Annex Figure F.4.7

Geological Profile with Apparent Resistivity, Profile B -B'

LEGEND

EL Logging

- Pole Distance 100cm
- Pole Distance 50cm

Key of Borehole Log

- PEAT
- CLAY
- SILT
- SAND
- GRAVEL
- LIMESTONE
- SHALE, SLATE, PHYRITE
- SANDSTONE, QUARTZITE, SHIST
- Granitic rock

1 - 4 :Layer Number

Boundary of Geology

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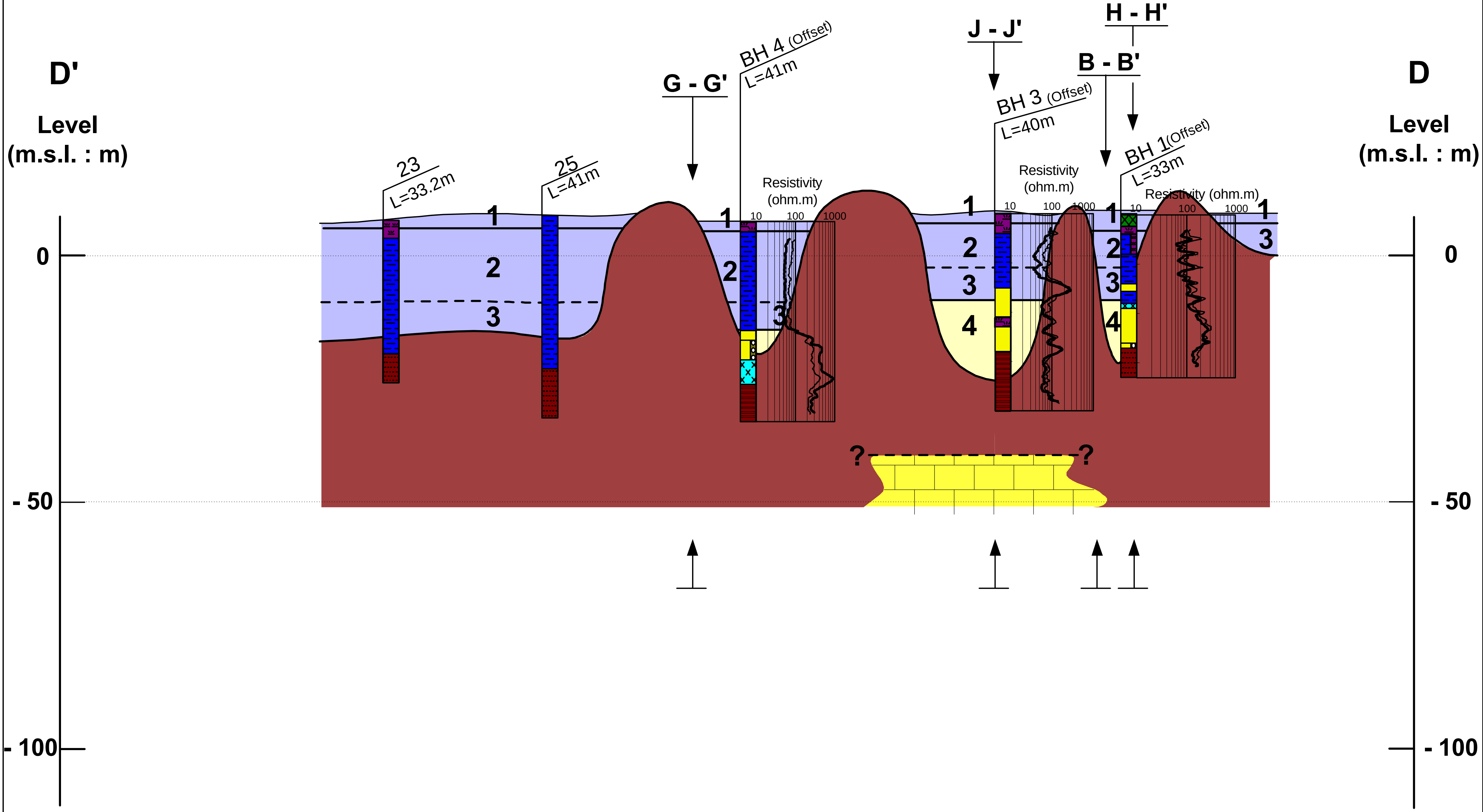
Annex Figure F.4.8

Geological Profile with Apparent Resistivity, Profile 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.

Horizontal Scale

0 5km

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

LEGEND

EL Logging

- Pole Distance 100cm
- Pole Distance 50cm

Key of Borehole Log

- PEAT
- CLAY
- SILT
- SAND
- GRAVEL
- LIMESTONE
- SHALE, SLATE, PHYRITE
- SANDSTONE, QUARTZITE, SHIST
- Granitic rock

1 - 4 :Layer Number

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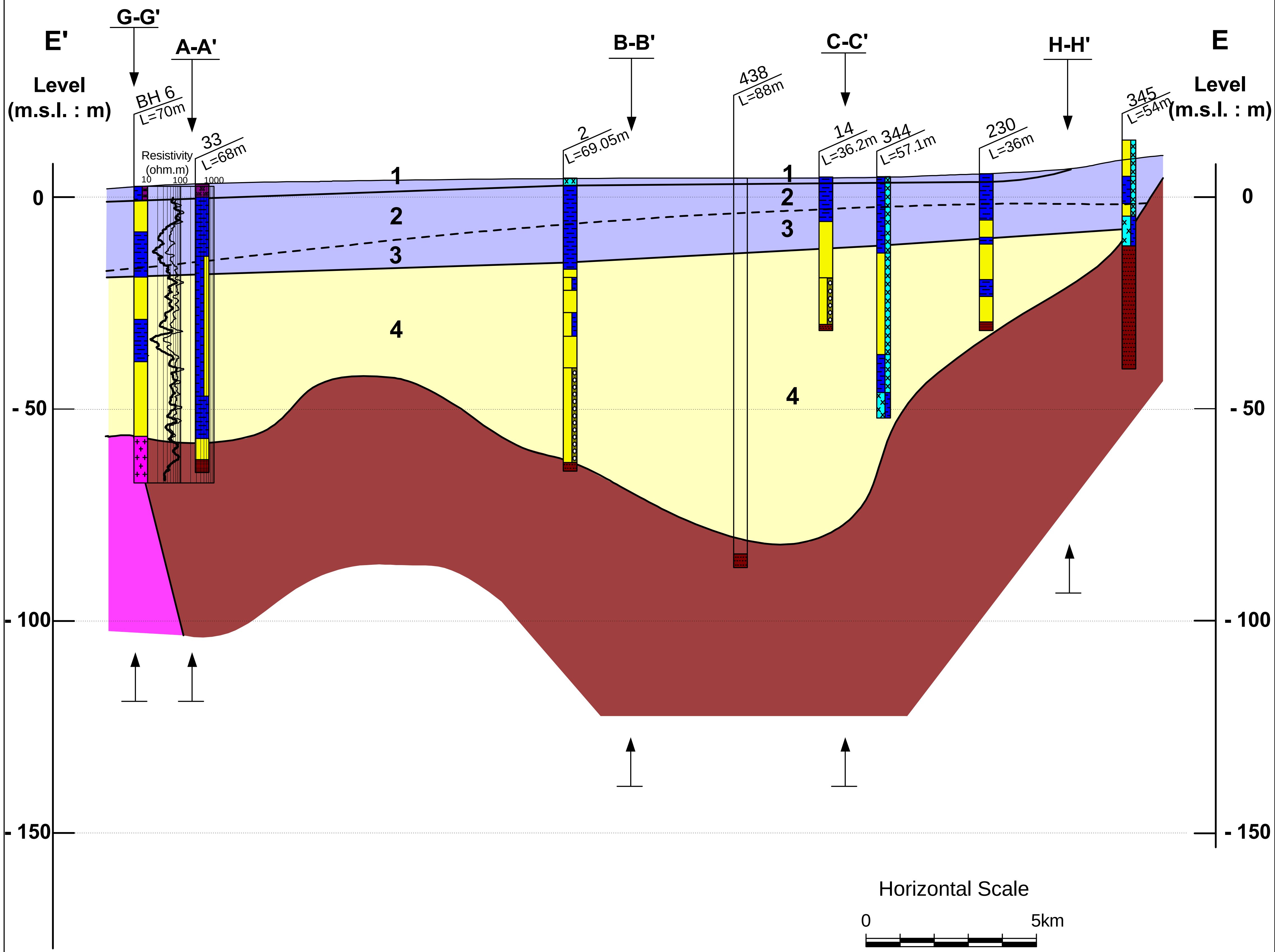

Note that this geological profile was prepared by a limited number of borehole logs. The profile should be modified and improved when additional information is obtained.

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

Annex Figure F.4.9

Geological Profile with Apparent Resistivity, Profile E -E'

LEGEND

EL Logging

- Pole Distance 100cm
- Pole Distance 50cm

Key of Borehole Log

- PEAT
- CLAY
- SILT
- SAND
- GRAVEL
- LIMESTONE
- SHALE, SLATE, PHYRITE
- SANDSTONE, QUARTZITE, SHIST
- 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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OYO CORPORATION

SECTOR G

GROUNDWATER MODELLING

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

FINAL REPORT

SECTOR G

GROUNDWATER MODELLING

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SECTOR G

GROUNDWATER MODELLING

1. BACKGROUND

A groundwater flow model may be defined as a simplified version of the aquifer that approximately simulates the groundwater flow processes. This simplification relates mainly to the geometry of geological domain (configuration of basement of the model, configuration of geological layers, ground surface, geological heterogeneities), hydraulic parameters, hydrogeological data (groundwater levels, discharges, recharges), nature of the water (fresh, brackish), and other parameters. Because the model is a simplification of the real aquifer, there exists no unique model for an aquifer.

To understand and analyse the complex relationships, which affect the groundwater, regime require multidisciplinary expertise in combination with advanced mathematical modelling techniques. The overall objectives of groundwater simulation are to estimate groundwater resources potential and to predict environmental impacts caused by groundwater abstraction. The elaborated simulation model will be used as a tool for planning of the sustainable groundwater resources development. The model should enable the authorities to formulate optimal management strategies leading to a protection of the water resources and ecological development of the area.

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.

2. INPUT DATA FOR GROUNDWATER MODEL

2.1 Introduction

Visual MODFLOW is a generalised tool with comprehensive applicability range, which needs to accommodate the very special environment and problems observed in the Langat Basin. The quality of modelling results depends strongly on availability and quality of various input data. This may be data for setting up model; for instance river cross-sections, surface topography, geological layer boundaries; or data for calibration and validation of the model, for instance time series of measured groundwater level in monitoring wells, water level in rivers, abstraction of groundwater from wells, rainfall, or evapotranspiration.

The existing data within the project area did not provide a good basis, in terms of quantity and quality, for model set up, calibration and verification. Hence, the intensive field investigation, measurements and collection of various data had to be performed to support all steps of model application.

The following section describes the data status from the modelling point of view.

2.2 Surface Topography

The topographical surface is the place, where rain, evaporation, infiltration and surface run-off take place. It is the first of the most important physical model boundary.

The surface topography of the modelling area was prepared using available topographic maps and additional control points of different origin. The basic data set was built of known elevations of benchmarks for land subsidence measurements, reported elevations of existing JMG and other wells in the area, ground elevations measured during the geodetical survey at newly constructed monitoring wells, as well as the control points from the topographical map.

The totally available 681 ground surface control points are shown in **Figure G.2.1**. The control points show inconvenient distribution for automatic generation of digital elevation model, especially in the central part of Langat Basin area. The interpretation of ground surface elevation in the model area was performed during final data processing for Visual MODFLOW model set up, with the result as shown in **Figure G.2.2**. The lowest surface elevation may be expected along the Langat River. The surface elevations above 20 metres above sea level (a.s.l.) cover the North and East edge of the model area.

Topographical surface of the large area of the Study is covered by peat and peaty soils (formed in tropical swamp forest and plantations, associated with high rainfalls and humidity), which are of high plasticity and water bearing capacity and contain a large portion of organic matter. These peats are supplied with surplus rainwater and are drained by a shallow surface drainage system. The surface topography and configuration of drains determine the directions of flow in the shallow groundwater horizon.

2.3 Geology and Aquifer Characteristics

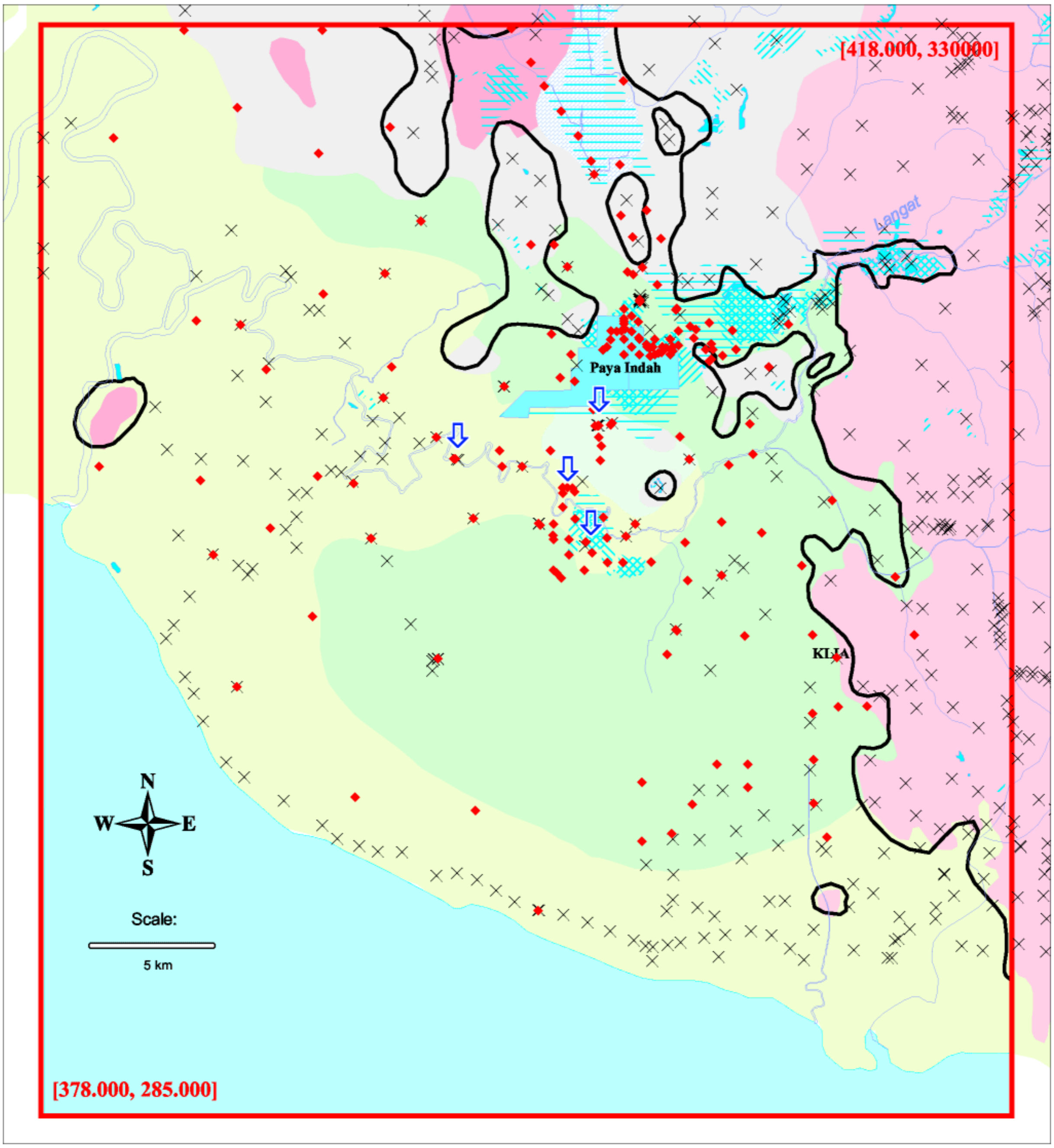
2.3.1 Geological Units

Five (5) geological units are encountered in the Study Area; namely:

- Beruas Formation, consisting of terrestrial sediments (clayey/silty peat and peat with decayed wood and roots) deposited during the later Holocene period. The presence of organic materials has caused the acidity and brown colour of the peat and surface water. This formation is up to few metres thick.
- Subsurface Gula Formation consists of grey to greenish grey Holocene clay, silt and sand with shells, detritus remains and minor amount of gravel deposited under estuarine and shallow shelf marine environments (aged at approximately 10,000 years). The Gula Formation acts as a nearly impermeable layer confining the formations beneath it.
- Kempadang Formation (Upper clay member of Simpang Formation) – The formation consists of Late Pleistocene age clay, silt and sand deposited in shallow marine environment (approximately 0.6 - 0.12 million years). The clayey sediments of Kempadang Formation are considered as very low permeable. The Gula and Kempadang Formations are of similar composition and therefore are generally described as one unit. The distribution area of Kempadang Formation is uncertain and thought to be limited.
- Lower sand member of Simpang Formation – The main aquifer consists of terrestrial Pleistocene (10,000 to 1.8 million years) deposits made up of largely sand and gravel with minor clay and silt content. Alternatives of sand/gravel layers and clay layers are common futures. The coarse and very coarse sand and gravel occurred at the base of the formation.
- Bedrock – Pre-Quaternary weathered hard-rocks like sandstone, quartzite, shale, limestone, schist, slate, mudstone, or granite (mainly Kenny Hill, Kajang, or Hawthornden Formation).

The model, which simplifies the actual geological conditions, consists of the following four layers:

- Layer 1 - peat and peaty soil (Beruas Formation)
- Layer 2 - clayey soil (Gula Formation and Kempadang Formation, if exist)
- Layer 3 - the Aquifer, alternatives of sandy soils/gravelly soil and clayey soil (Lower Member of Simpang Formation)
- Layer 4 - bedrock



LEGEND

×	Ground surface control points	—	Interpreted aquifer boundary
◆	Boreholes with geological log		Mining areas (compiled from different sources)
—	Model boundary	⇩	Groundwater abstractions

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Figure G.2.1

Model Boundaries

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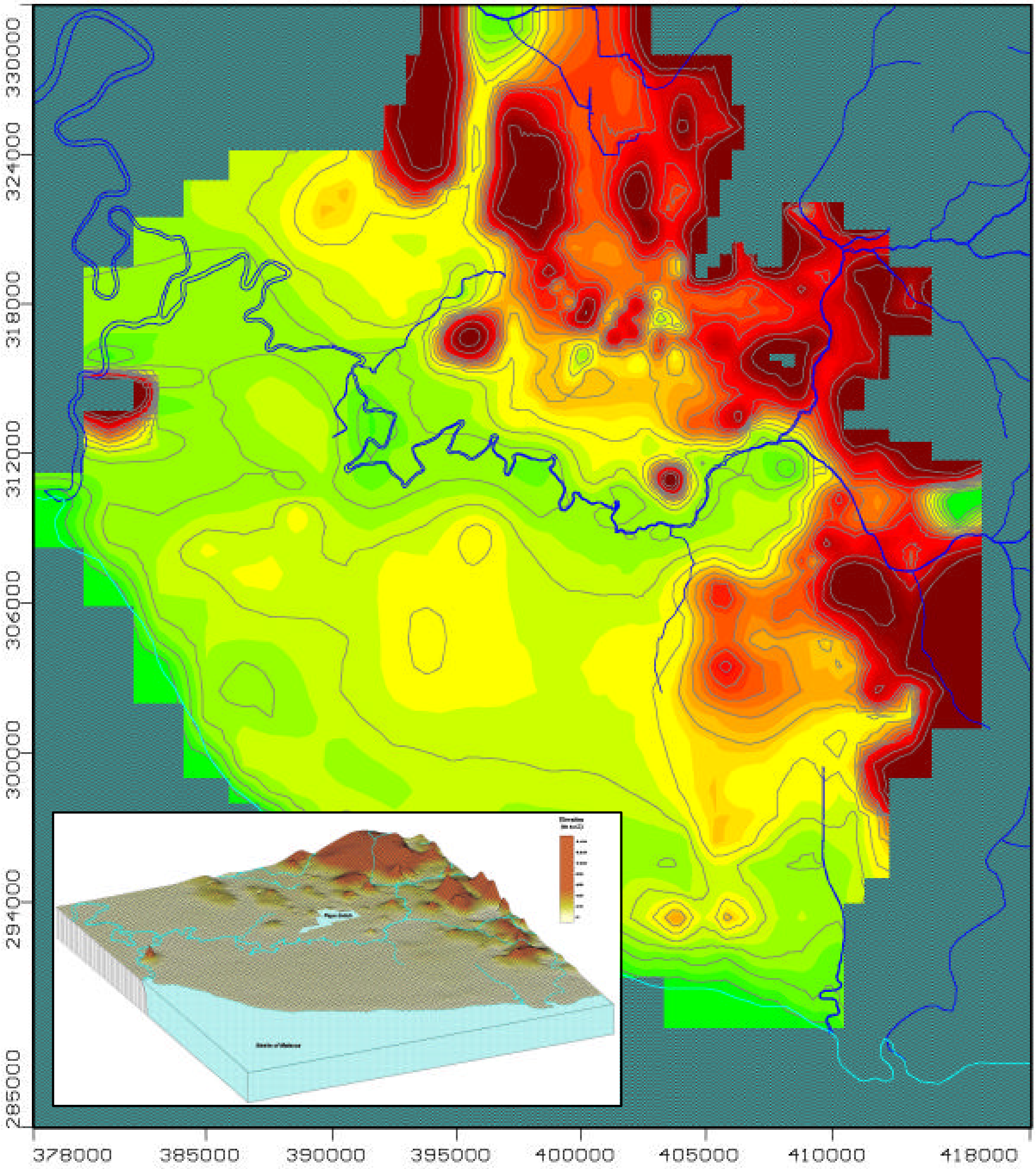
ro_setup01



LEGEND

Inactive cells

Contour lines of ground surface

Elevation (m a. s. l.)

0

5

20

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Figure G.2.2

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Elevation of Ground Surface

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To simulate the alternative nature of Aquifer Layer 3, it was divided into four sub-layers, as follows:

- Layer 3a - sandy soil and gravel
- Layer 3b - clayey soil
- Layer 3c - sandy soil and gravel
- Layer 3d - sandy soil with gravel

Layers 3c and 3d are considered as the main body of the Aquifer.

2.3.2 Bedrock

Bedrock is the second main topographical aquifer boundary, which is defined in the model as an impervious or low permeable bottom boundary. The topography of the bedrock in the modelling area was interpreted using available topographic maps of terrain, geological logs from existing and new boreholes, and geological profiles available in existing reports.

As could be seen in **Figure G.2.1**, the number and distribution of boreholes with reliable geological logs is very limited. The interpretation of bedrock topography was based on the total amount of 187 boreholes. Due to this limited amount and inconvenient distribution of data, the bedrock topography prepared for modelling purposes may show a high degree of schematisation. The boundary with alluvial sediments is interpreted at around EL 0-5 m a.s.l.

Bedrock itself was introduced in the model set up with uniform thickness of 20 m as the model layer No 7 (last model layer). The weathered and to some degree permeable bedrock enables infiltration of rainwater and further aquifer recharge in the zone of the bedrock outcrop (**Figure G.4.6**).

2.3.3 Topography and Properties of Aquifer Layers

The topography of the first peat layer follows the topography of surface and is modelled with thickness of 2 m. This layer inhabits input of net precipitation (rainfall minus evaporation) and surface outflow including run-off in drains or canals.

The topography of underlying layers (2 and 3) is based on evaluation of geological logs from existing and new boreholes (**Figure G.2.1**). For existing boreholes, where the elevation of ground surface and geological boundaries was not known, the elevation of the ground surface was derived from the digital model of terrain (surface topography).

The most reliable and important data from modelling point of view were obtained from comprehensive evaluation of geological logs, soil investigation, and pumping tests results performed at three pumping test localities – Paya Indah, Kajibumi WF 2, and Kanchong Darat (**Figure G.2.3**). The detail location of the three pumping test sites together with the situation of boreholes is shown in **Figures G.2.4 and G.2.5** (Paya Indah), **Figures G.2.9 and G.2.10** (Kajibumi WF 2), and **Figures G.2.14 and G.2.15** (Kanchong Darat).

Figures G.2.6, **G.2.11 and G.2.16** contain the interpretation of typical geological logs. During drilling, the samples of sediments for sieve analyses were taken from every metre of depth. Particle size distribution logs in figures document the heterogeneity of aquifer in vertical and horizontal direction. Additional particle size distribution logs for Paya Indah (Locality 2) are presented in **Data Book G.2.1**.

The sediments of individual layers are characterised by groups of particle size distribution curves shown in **Data Book G.2.2**, and by characteristic particle size distribution curves (**Figures G.2.7**, **G.2.12 and G.2.17**). For every sample of sediment, the conductivity coefficient using the Carman-Kozeny method was calculated. The results of calculation are graphically compared with conductivity coefficients interpreted from pumping tests, to allow more representative interpretation of soil investigation results also at other soil investigation localities, where no pumping test was performed. **Figures G.2.8**, **G.2.13 and G.2.18** contain the calculation of parameters d_{60}/d_{10}, specific yield, specific surface, and effective grain diameter.

All parameters are graphically presented in the form of vertical logs to allow the comparison of sediment properties between different localities and to compare the sediments in different depth. Based on such an evaluation, the aquifer was divided into 7 layers (including sub-layers), with the following hydrogeological characteristics (**Figures G.2.6**, **G.2.11 and G.2.16**):

(1) Peat, represents 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 inter-bedded with clayey horizons (Layer 3a);

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

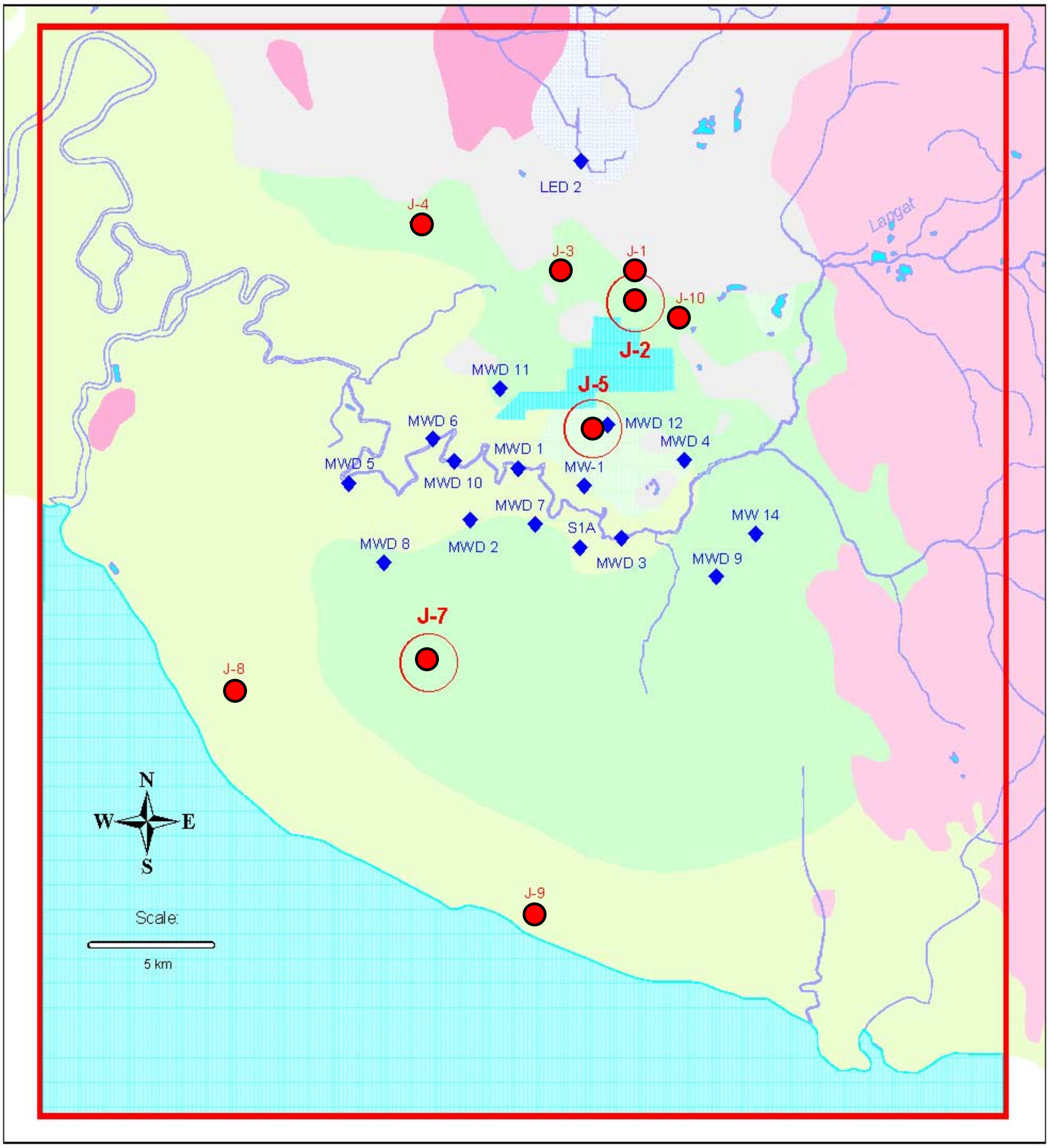
(5) Silty sand and gravel, sometimes with occurrence of layers of sandy clays, is characteristic with higher anisotropy and represents the upper part of the main highly permeable regionally spread aquifer (Layer 3c);

(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).

The model vertical discretisation is based on lithological composition and hydrogeological properties of sediments, which need not correspond to encountered geological formations. The morphology of main model layers was introduced in Visual MODFLOW modelling package as shown on model cross-section **Figure G.4.7**.

From the hydrogeological and modelling point of view, layer numbers 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.



LEGEND

New wells (JICA study)	Existing wells (JMG)
New wells at pumping test site (JICA study)	Model boundary

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Figure G.2.3

Monitoring Wells and Pumping Test Sites

LEGEND

Pumping Test Well at Paya Indah

Monitoring Wells

N W E S

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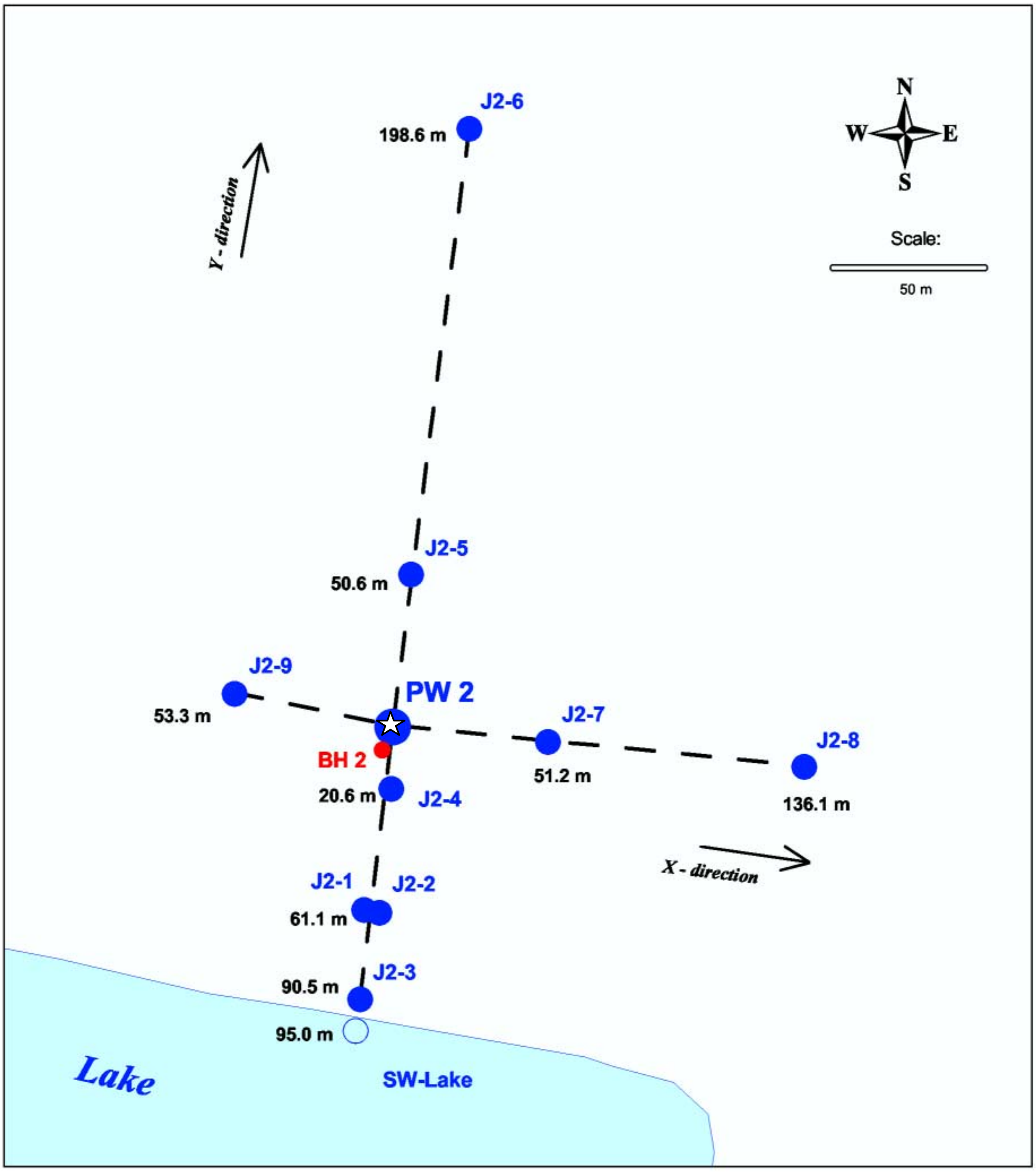
Figure G.2.4

Location of Pumping Well Site at Paya Indah



LEGEND

J2-3	Monitoring well (piezometer)		Pumping Well
90.5 m	Distance from pumping well		
	SW gauge (Lake)		Soil investigation borehole

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Figure G.2.5

Situation of Pumping Well and Monitoring Wells at Paya Indah

Aquifer Characteristics at Paya Indah (Locality No. 2)

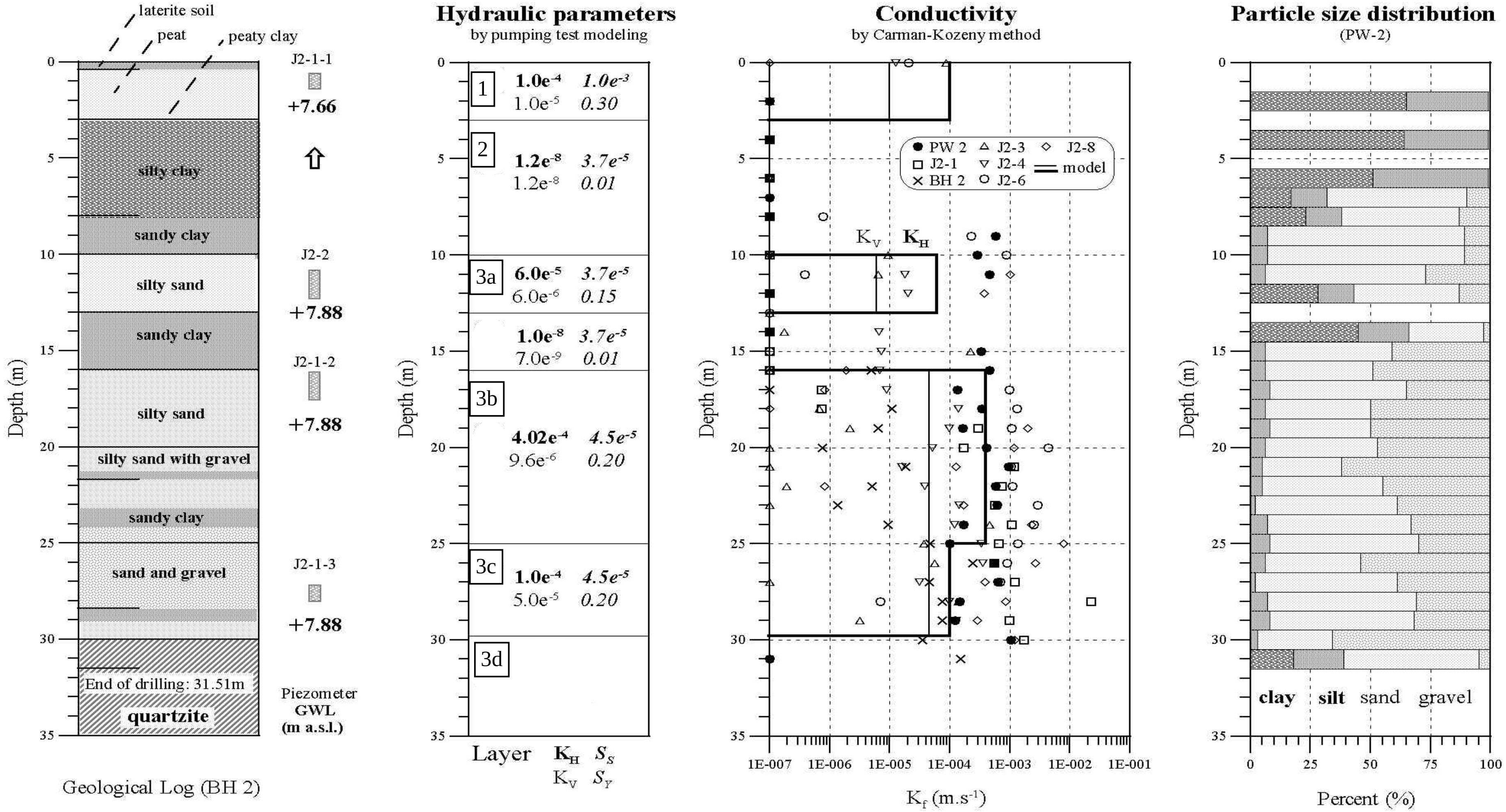

Figure G.2.6 Aquifer Characteristics at Paya Indah

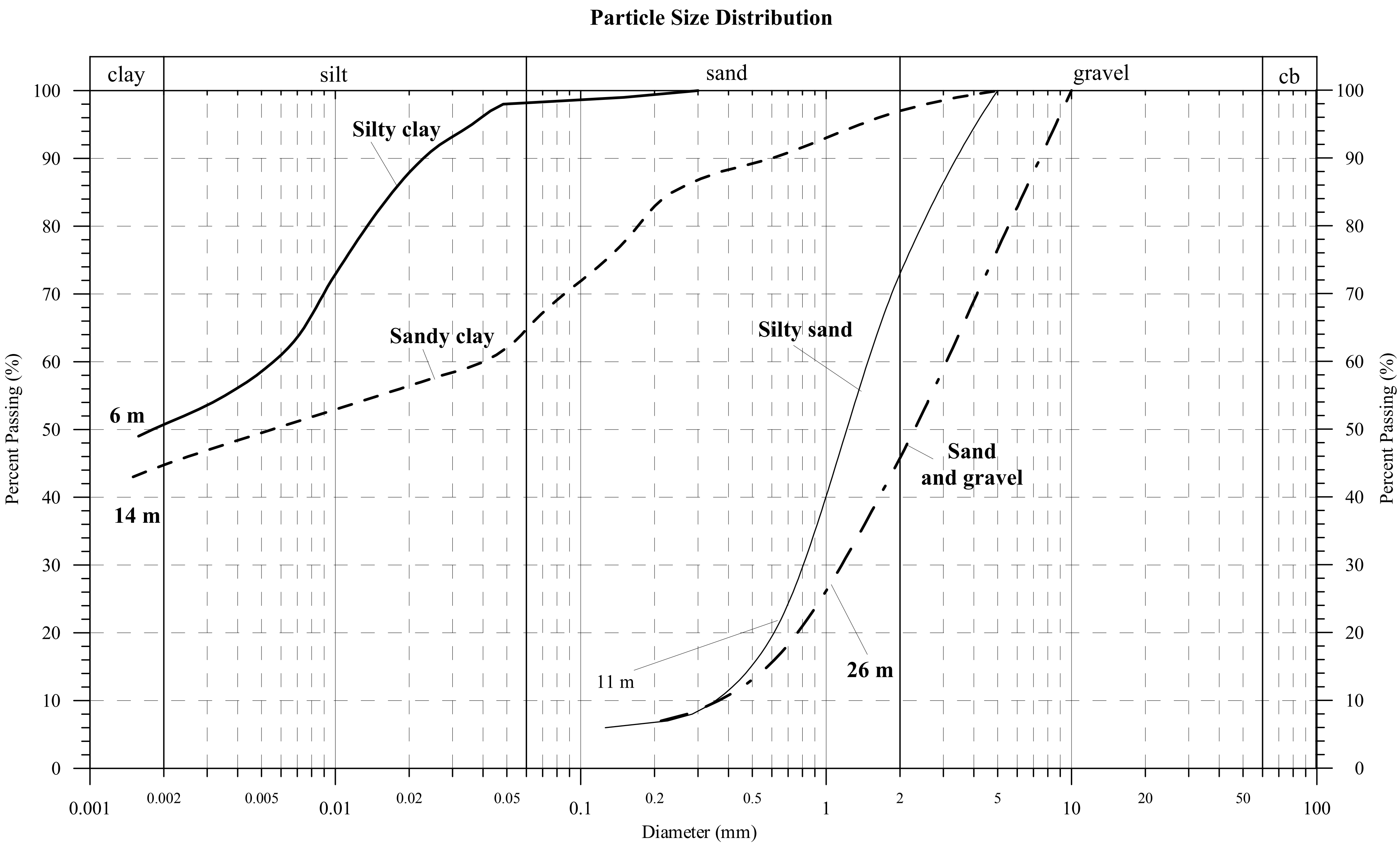

Figure G.2.7 Characteristic Particle Size Distribution Curves at Paya Indah

Aquifer Characteristics at Paya Indah (Locality No. 2)

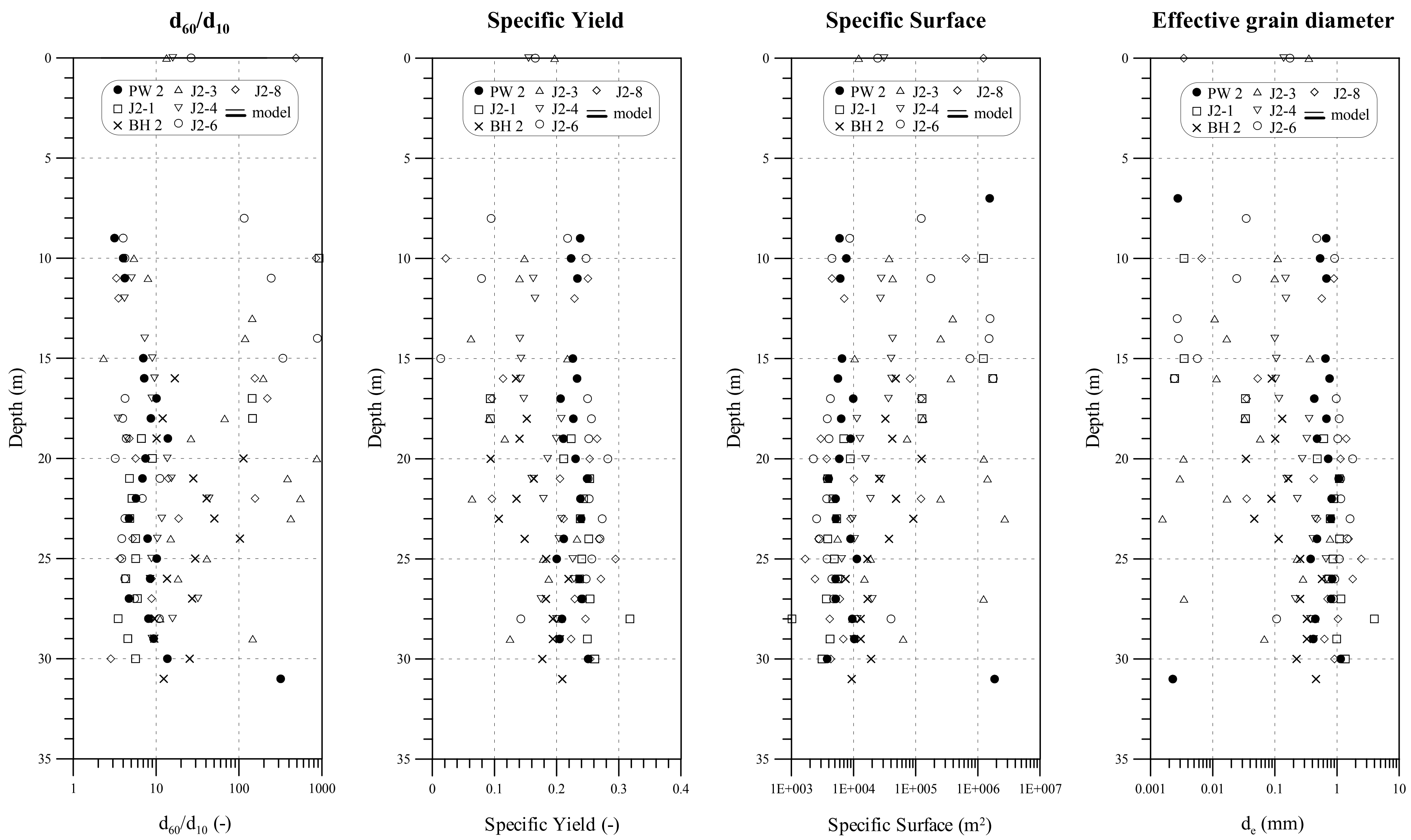

Figure G.2.8 Aquifer Characteristics at Paya Indah (4/4)

ro_grain2p3

LEGEND

Pumping Test Well at Kajibumi WF 2

Monitoring Wells

N
W E
S

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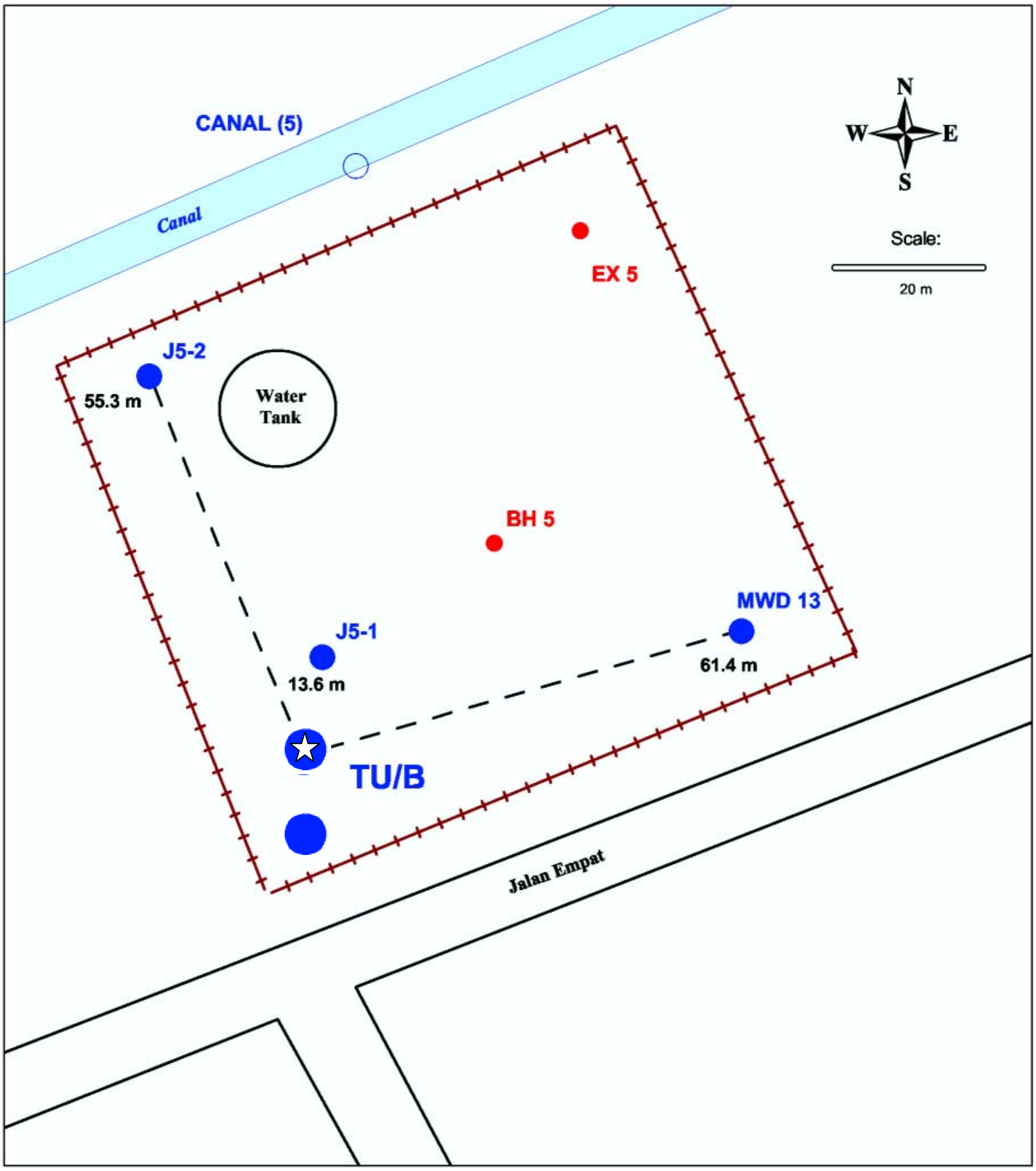
Figure G.2.9

Location of Pumping Well Site at Kajibumi Well Field 2



LEGEND

J2-3	Monitoring well (piezometer)		Pumping Well
90.5 m	Distance from pumping well		
	SW gauge [Canal (5)]		Soil investigation borehole

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Figure G.2.10

Situation of Pumping Well and Monitoring Wells at Kajibumi Well Field 2

Aquifer Characteristics at Kajibumi WF 2 (Locality No. 5)

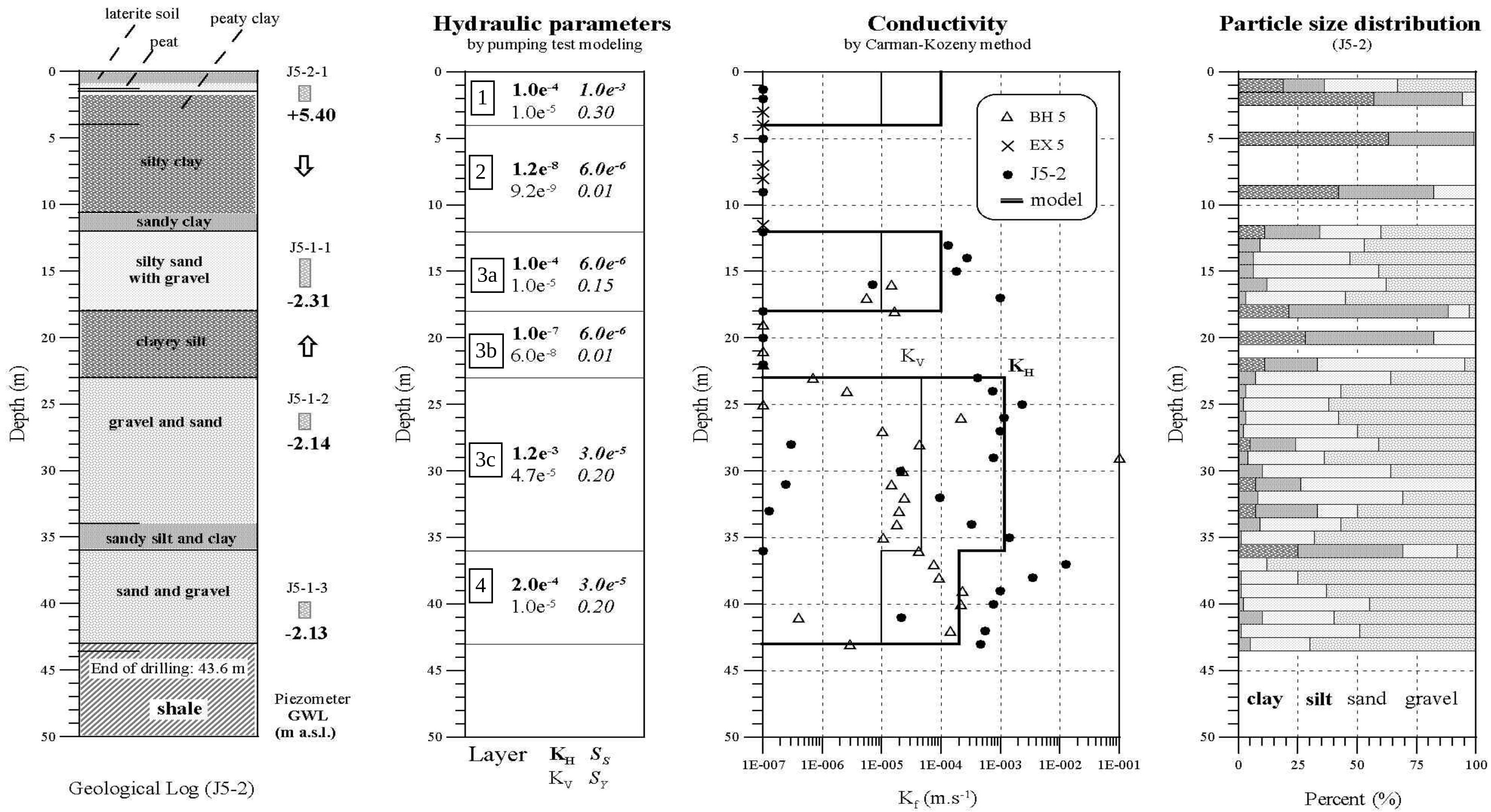

Figure G.2.11 Aquifer Characteristics at Kajibumi Well Field2

Particle Size Distribution

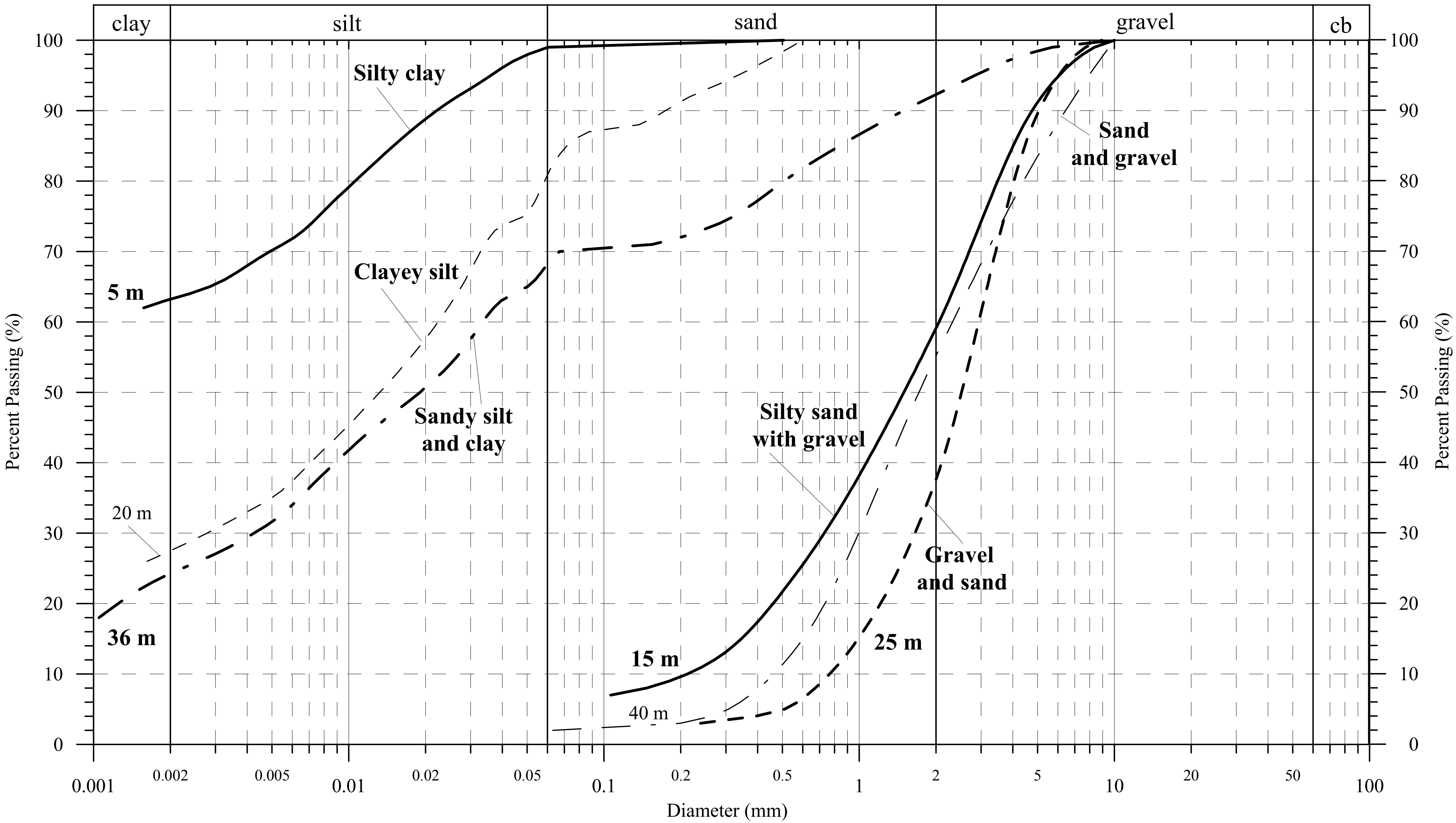

Figure G.2.12 Characteristic Particle Size Distribution Curves at Kajibumi WF 2

ro_sieve5-ch

Aquifer Characteristics at Kajibumi Well Field 2 (Locality No. 5)

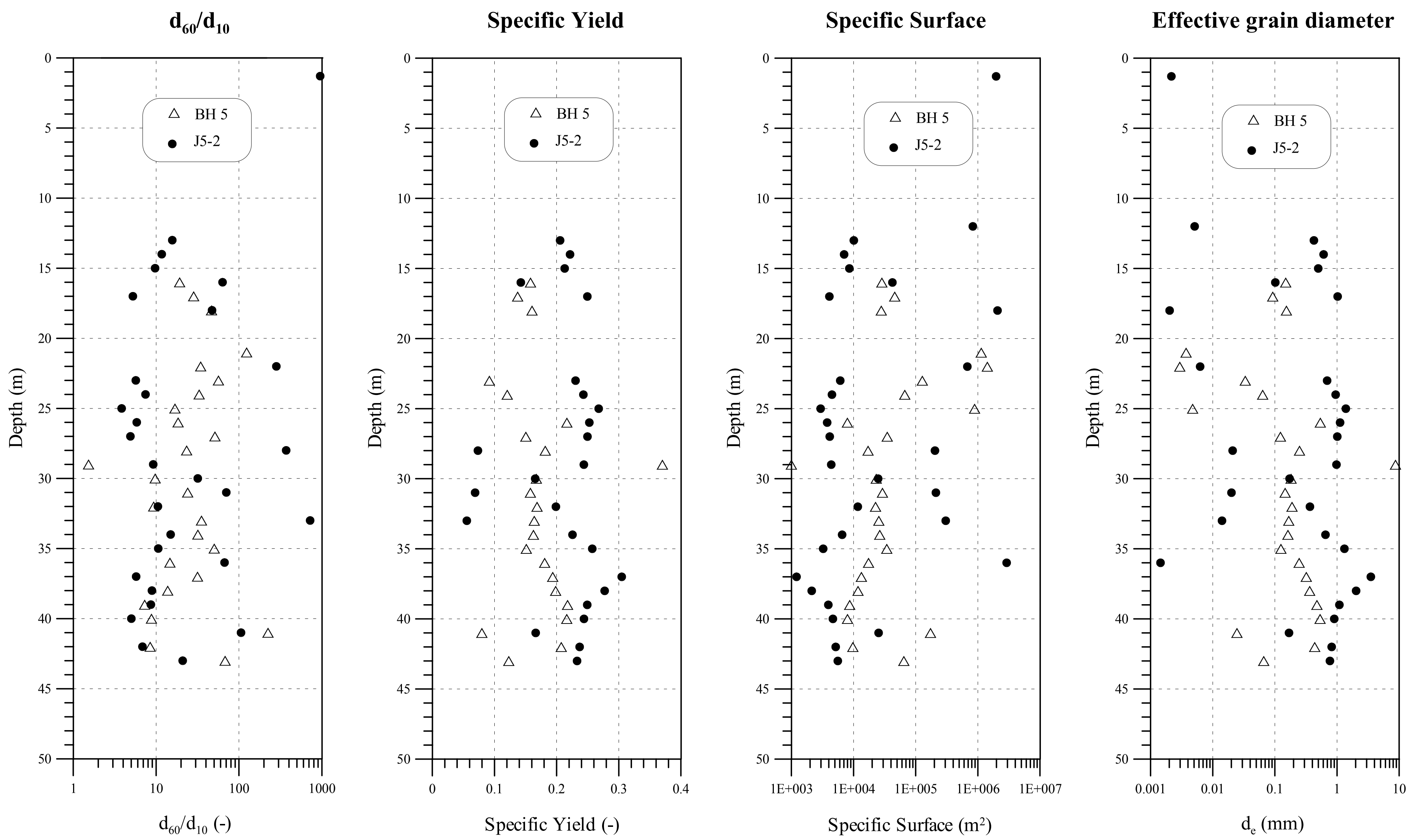

Figure G.2.13 Aquifer Characteristics at Kajibumi Well Field 2 (2/2)

ro_grain5p

LEGEND

★ Pumping Test Well at Kanchong Darat

N
W E
S

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Figure G.2.14

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Location of Pumping Well Site at Kanchong Darat

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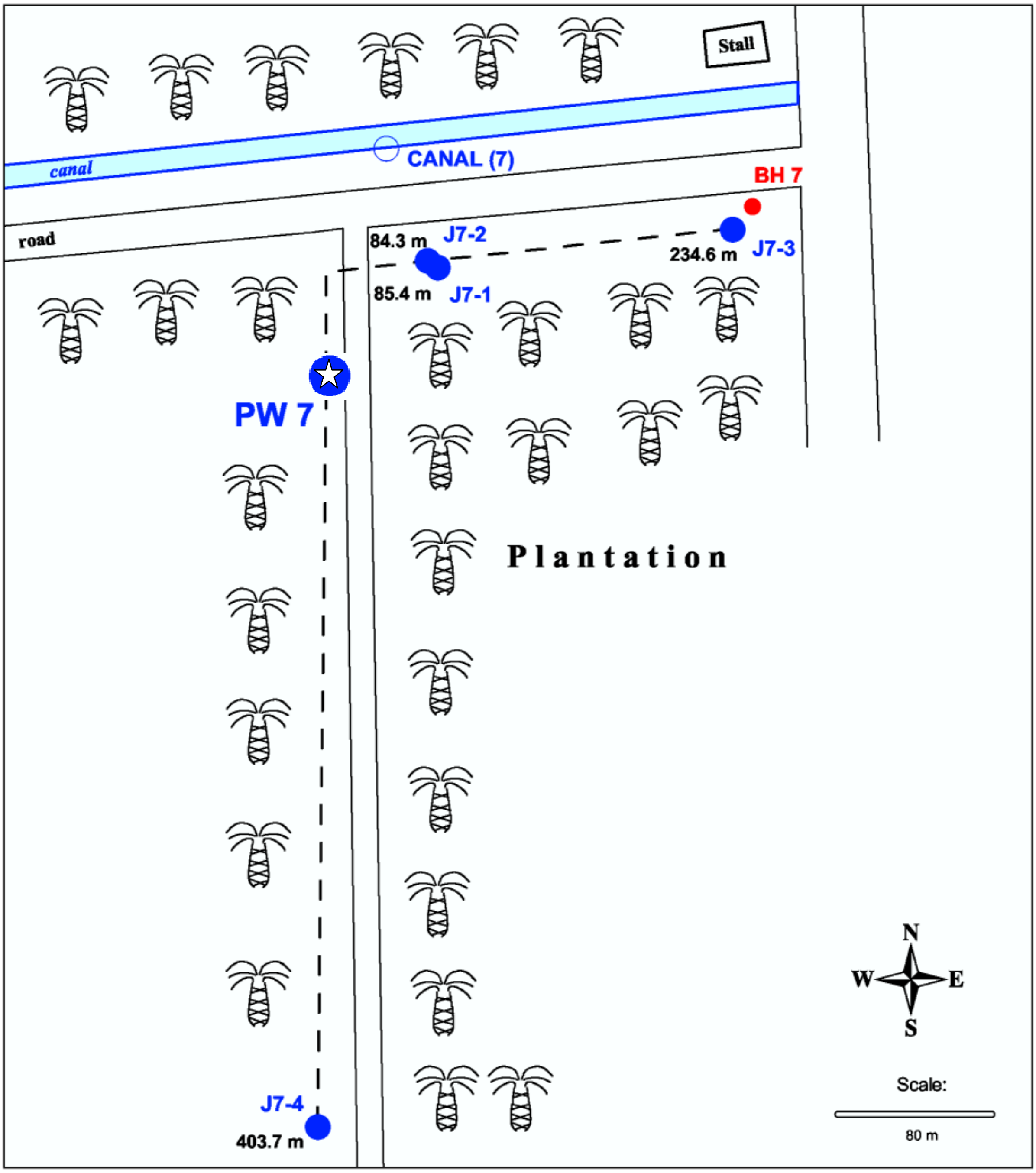

LEGEND

J2-3 (●)	Monitoring well (piezometer)	★	Pumping Well
90.5 m	Distance from pumping well		
○	SW gauge [Canal (7)]	●	Soil investigation borehole

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Figure G.2.15

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Situation of Pumping Well and Monitoring Wells at Kanchong Darat

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Aquifer Characteristics at Kanchong Darat (Locality No. 7)

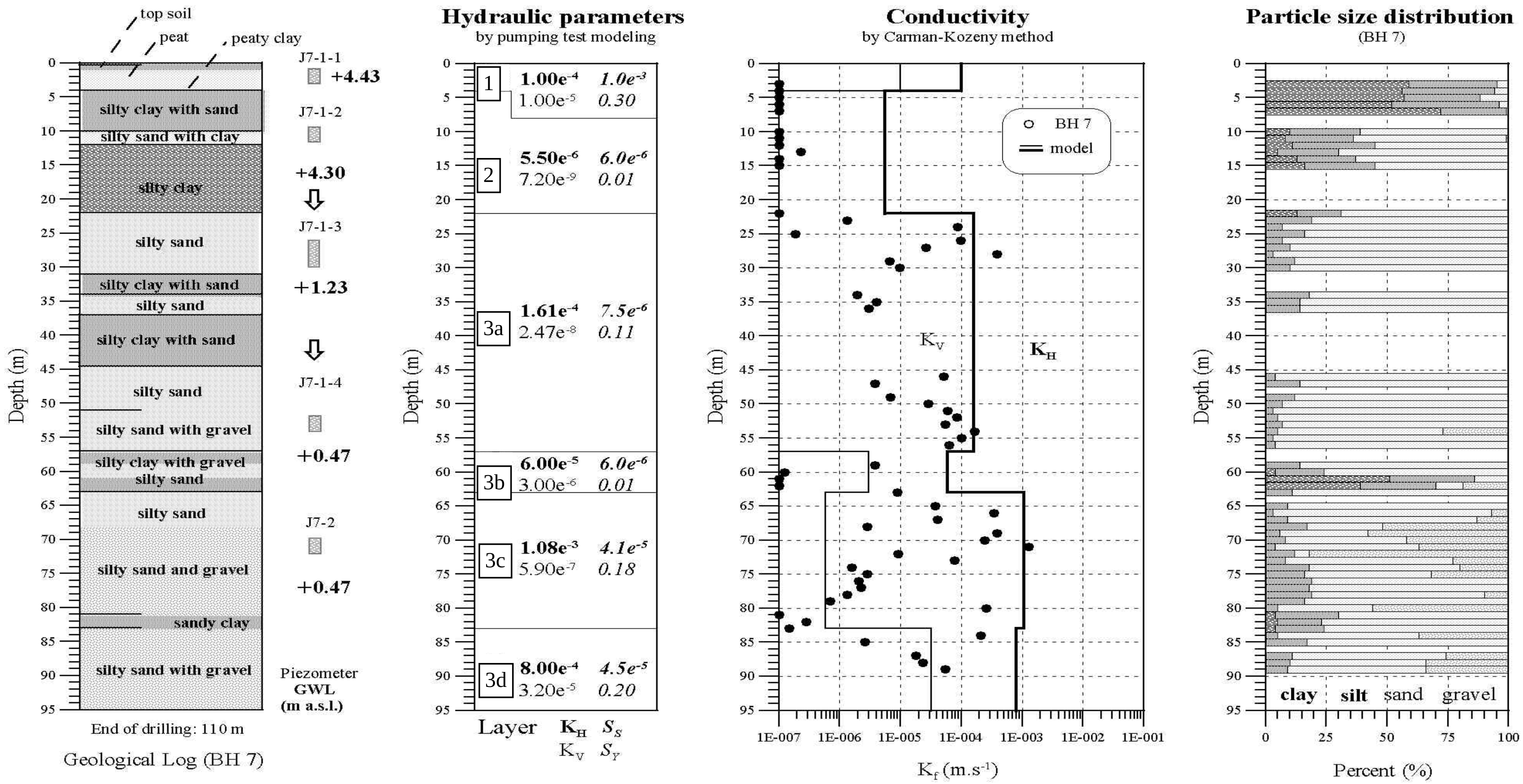

Figure G.2.16 Aquifer Characteristics at Kanchong Darat

Particle Size Distribution

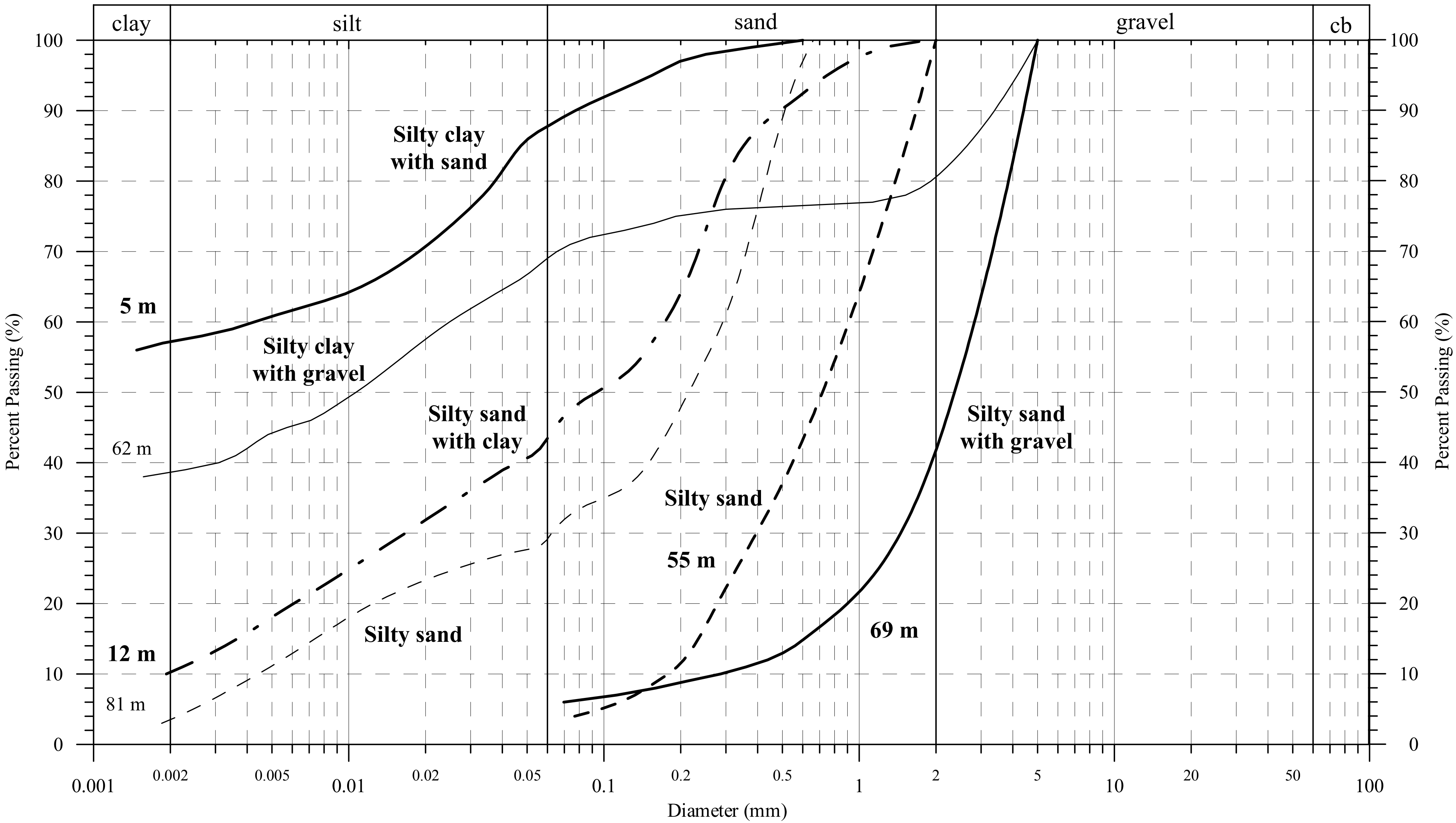

Figure G.2.17 Characteristic Particle Size Distribution Curves at Kanchong Darat

ro_sieve7-ch

Aquifer Characteristics at Kanchong Darat (Locality No. 7)

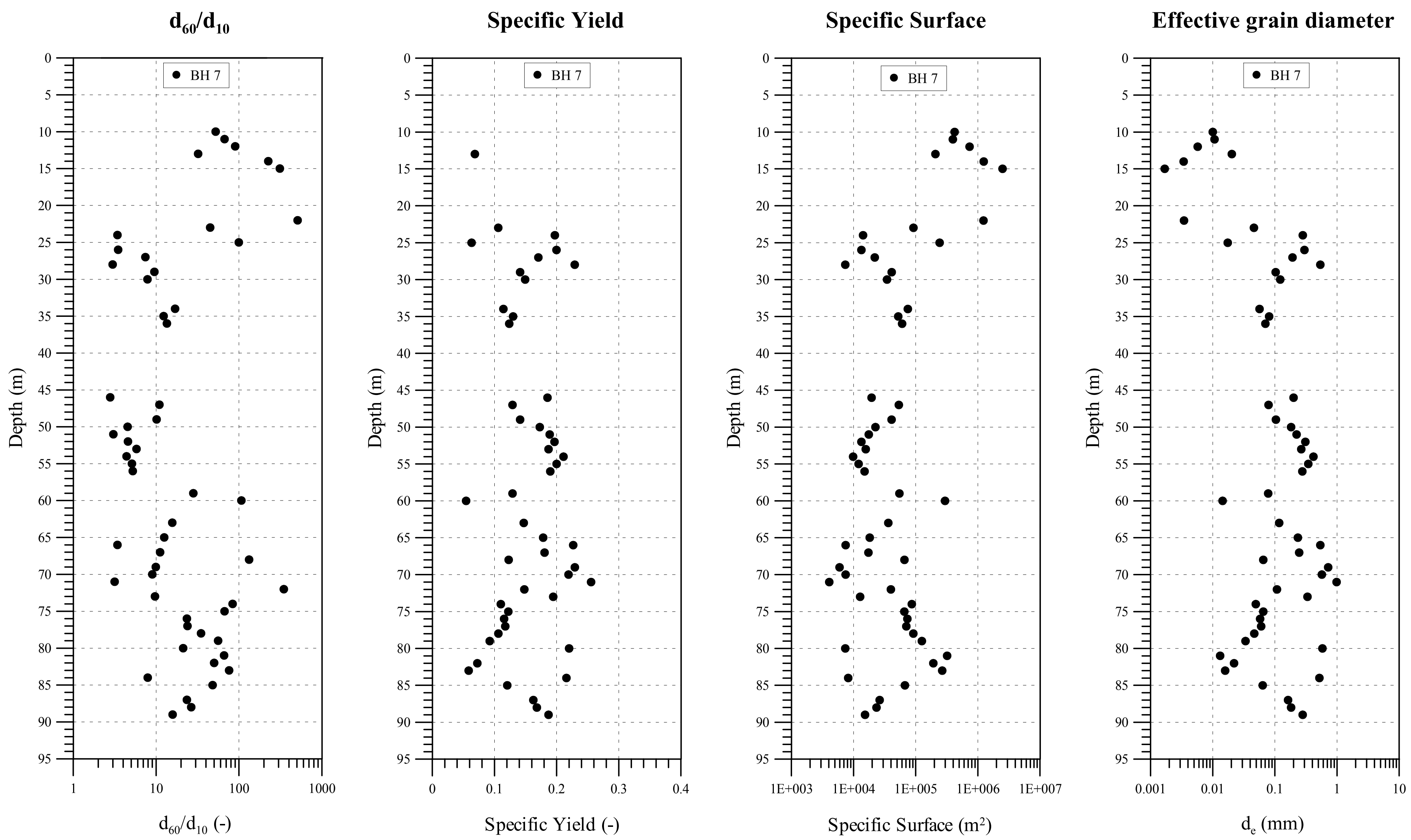

Figure G.2.18 Aquifer Characteristics at Kanchong Darat (2/2)

2.4 Hydrogeology and Groundwater Flow

The main aquifer is recognised as confined. Groundwater is recharged from rainfall by 1) Downward flow through the aquitard, 2) Infiltration of water around the edges of bedrock outcrop where the aquitard is thin or absent, 3) Flow from relatively more permeable bedrock, 4) Infiltration from riverbed in stretches where the river bottom is in contact with more permeable sandy horizons, and 5) Infiltration from ponds and wetland areas where the upper aquifer and the aquitard have been removed and replaced by more permeable materials. Natural groundwater discharge is considered primary at the seaside and secondary, to some very small degree, into the river and drainage system.

Confining clayey layers are low and leaky (aquitard). In the past natural conditions, the piezometric levels in main aquifer near the recharge zones were probably higher than the peat water level. The leakage was in upward direction. At present, in the areas with lower aquifer piezometric level, the leakage is directed from the surface downwards to the main aquifer (compare piezometric heads measured at multiple piezometers in **Figures G.2.6 and G.2.16**).

The natural groundwater flow is affected by abstraction of water from existing well fields and from the active tin mines (**Figure G.2.1** and **Photograph G.2.1**). In the area of Imuda sand mining pit the lowering of the water table down to the gravels (or bedrock) has taken place (estimated 40 m below the ground surface). This is to enable the alluvial sand-gravel deposits to be exploited.

Photograph G.2.1 Imuda Tin Mine

The regional groundwater flow is characterised by measurements of piezometric heads performed during the Project (**Figures G.2.19-21**). The figures show that a depression cone has developed at the Megasteel/Amsteel II area and Imuda sand mining pit. The drop in piezometric level to about –8 m from mean sea level gives the evidence here. Before putting the Megasteel well fields into operation, the drop of piezometric level was reported at –3.6 m a. s. l.[6] The long-term groundwater level monitoring at existing JMG wells also indicates the lowering of groundwater levels during the last two years (**Data Book Figures G.2.12-15 of Data Book G.2.3**).

LEGEND

Piezometric Head (m a.s.l)

- more than 3
- 2 to 3
- 0 to 2
- -2 to 0
- less than -2

Model boundary

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Figure G.2.19

Piezometric Head on March 9-13, 2001

LEGEND

Piezometric Head (m a.s.l)

- more than 3
- 2 to 3
- 0 to 2
- -2 to 0
- less than -2

Model boundary

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Figure G.2.20

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Piezometric Head on May 23-28,2001

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LEGEND

Piezometric Head (m a.s.l)

- more than 3
- 2 to 3
- 0 to 2
- -2 to 0
- less than -2

Model boundary

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Figure G.2.21

Piezometric Head During Groundwater Sampling on Feb. 20 - March 28, 2001

Data Book Figures G.2.16-22 of Data Book G.2.3 show the automatic measurements of groundwater levels in the period May 5 to June 6, 2001 (1 month). The measurements show the systematic decrease of groundwater level at monitoring wells, which may correspond to drier season (no rain), less likely to higher exploitation of water. For more representative interpretation the long-term observations of groundwater levels, rainfall, and pumping rates in duration at least 2-3 years are necessary.

The modelled groundwater flow directions for Simulation Variant 1 (status present during Project field survey) are shown in **Figures G.5.2 and G.5.3**.

The present situation can lead to aquifer overexploitation, when the groundwater flow toward the seaside is lowered and at some places reversed from the seaside towards the inland and cause seawater intrusion.

2.5 Hydrology

The main surface water body in the area is made up of Langat River and its tributaries (Semenyih, Chuah, Labu, Kelambau). Mainly shallow agricultural ditches form the drainage, which discharges into Langat River or into its tributaries.

The basic modelling parameters of Langat River were prepared for the model as shown in **Figure G.2.22(b)** and set up in the model as shown in **Figure G.4.1**.[6)]

The hydrological analyses performed in the frame of the Study summarised the annual water balance in the area in the Upper + Semenyih + Middle Langat River Basin in 1980-1999 as follows (**Figure G.2.22(a)**):

(1) Annual average rainfall in the area is 2238 mm/year.

(2) Annual average pan-evaporation is 1606 mm/year.

(3) Annual average evaporation, estimated as 80% of average pan-evaporation, is 1284 mm/year.

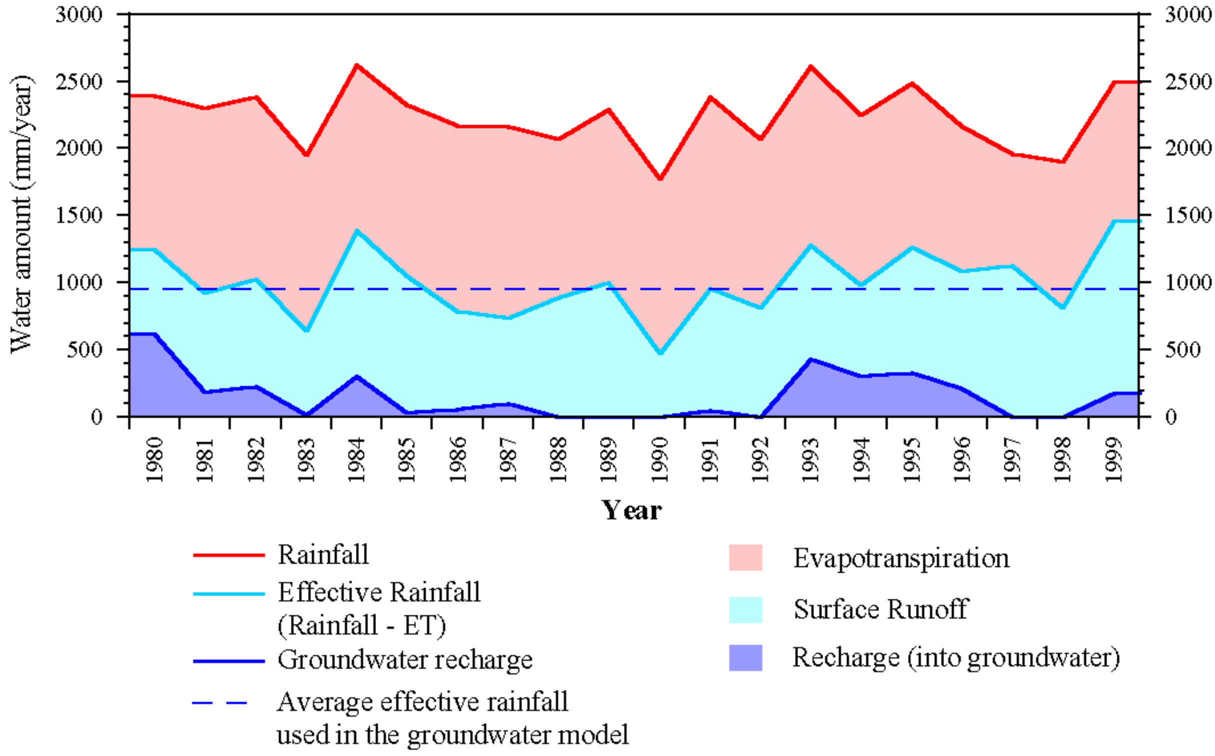
(4) Difference between average rainfall and average evaporation is 954 mm/year (effective rainfall).

(5) Annual measured average discharge (surface run-off) is 846 mm/year.

(6) Annual average Groundwater Recharge was estimated at 108 mm/year.

Annual average Groundwater Recharge in the Upper + Semenyih + Middle Langat River Basin is equivalent to 139 x 10^6 m^3/year and 4.8% of rainfall in the area. It is the average infiltration into the aquifer of this area, which approximately should equal to the groundwater outflow from the area.

(a) Water Balance in the Upper+Semenyih+Middle Langat River Basin in 1980-1999



(b) Langat River Properties in Groundwater Model

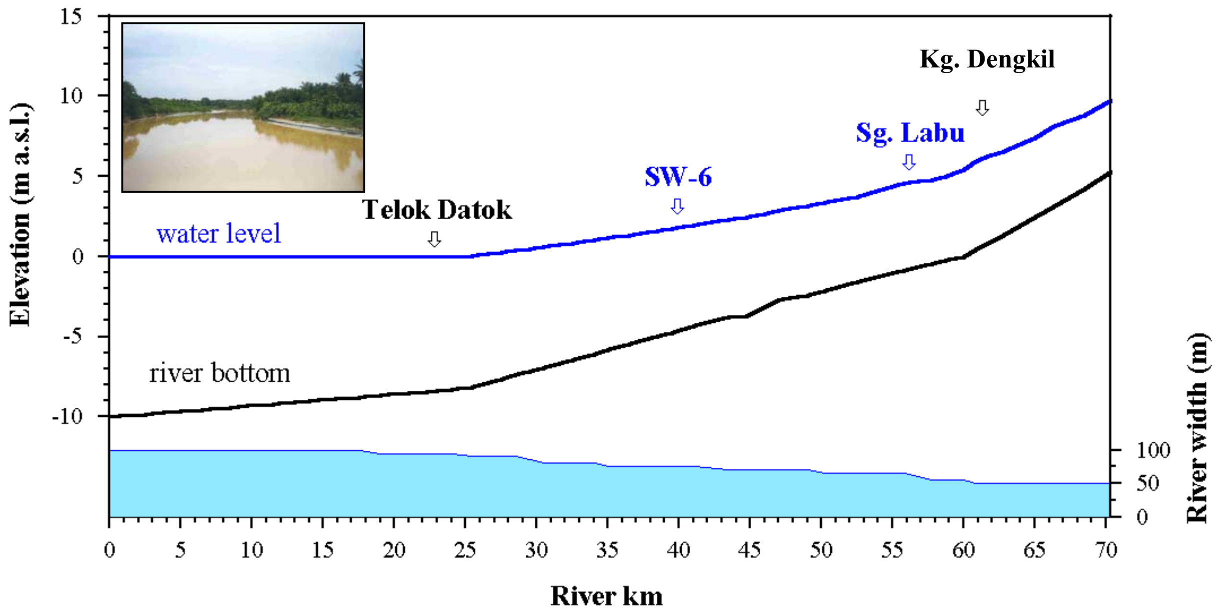


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Figure G.2.22

Water Balance and Langat River Properties

This numbers may not be representative for the whole model area. The area of the Upper + Semenyih + Middle Langat River Basin is situated on the northern boundary of the Lower Langat area, which is the area of the modelled aquifer. For the modelled area similar hydrological analysis is not to disposal.

The most important fact is, that the rainfall highly surpasses the evaporation. This means that there is more water to disposal on the ground surface and in the peaty layer, than is the possible infiltration rate via the low, leaky aquitard (clay). This amount of water is also relatively high for direct infiltration through the bedrock outcrops.

The first estimation of water balance in relation with groundwater recharge into the aquifer in Paya Indah Wetland was recently completed for the period November 2000 to April 2001. In order to identify the accurate annual water balance in the Paya Indah Wetland, further examination with more sufficient data is necessary.

2.6 Groundwater Abstraction

At present the major groundwater abstraction is carried out on several places (**Figure G.2.1**). The main well field is located in 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 WF 1, 4 wells) and in Olak Lempit (Kajibumi WF 2, TU/B). The natural groundwater flow is affected by abstraction of water from Imuda tin mine. Estimated and simulated daily pumping rates from well fields and dewatering pits are listed in **Table G.5.1.**

3 ESTIMATION OF AQUIFER CHARACTERISTICS BY PUMPING TEST

3.1 Activities and Methods

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: 1) Pumping test at Paya Indah, 2) Pumping test at Kajibumi WF 2, and 3) Pumping test at Kanchong Darat (**Figures G.2.3**, **G.2.4**, **G.2.9 and G.2.14**).

At all selected pumping test sites an extensive investigation program was carried out when drilling and sampling boreholes, monitoring wells (piezometers), and pumping wells. The detail situation of pumping wells and monitoring wells is shown in **Figures G.2.5**, **G.2.10 and G.2.15**.

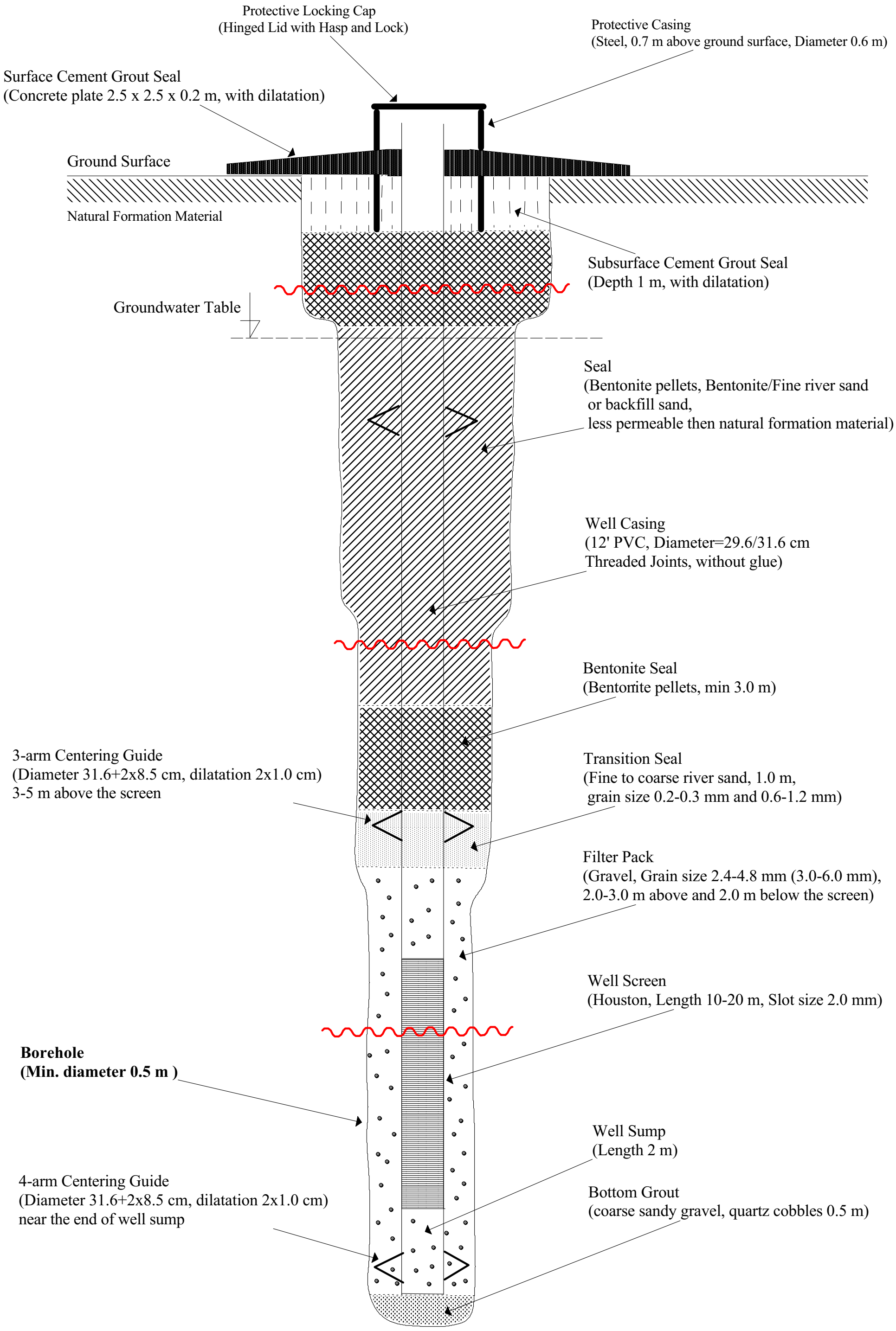
All wells (pumping and monitoring) were proposed in alluvial sediment aquifer, which consists of clay, silt, sand and sandy-gravel deposits. Three types of wells were constructed at each of the selected pumping test localities:

- **Pumping well** with the screen proposed in the most permeable part of the main aquifer.
- **Simple piezometer** for measurement of piezometric level in the deep confined aquifer. This piezometer was drilled and located just above the bedrock, into the most permeable part of main aquifer. Some of these monitoring wells were equipped with another piezometer located in shallow subsurface water bearing horizon, or in horizon just below the covering clayey layer, to allow estimation of possible recharge from surface and groundwater vertical flow.
- **Multilevel piezometer** for measurement of 3D groundwater flow, and estimation of vertical permeability during the pumping test, with uppermost piezometer located in the subsurface water bearing peat horizon and deepest piezometer in confined aquifer just above the bedrock. Two (in Kanchong Darat three) other piezometers are situated between them in the depth where more permeable horizons are expected (based on macroscopic evaluation of sediments or granulometric analyses).

The general construction design of pumping well and multilevel monitoring well is shown on **Figures G.3.1 and G.3.2**. **Figures G.2.6**, **G.2.11 and G.2.16** show the typical geological log and vertical distribution of piezometers at each of the tested localities. Technical specifications for drilling and construction design of wells and for realisation of pumping test are based on proper evaluation of geological logs and results of soil investigation, and they are described in more detail in previous reports.

Duration of each pumping test was planned with constant discharge for 30 days. Pumping rate was measured by flow metre and V-notch tank, and continuously controlled by data logger located in V-notch tank, or by measuring the volume of abstracted water using vessel. After the pumping test, a 10-day long recovery test was recommended.

Construction Design of Pumping Well
(General scheme)



Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

Figure G.3.1

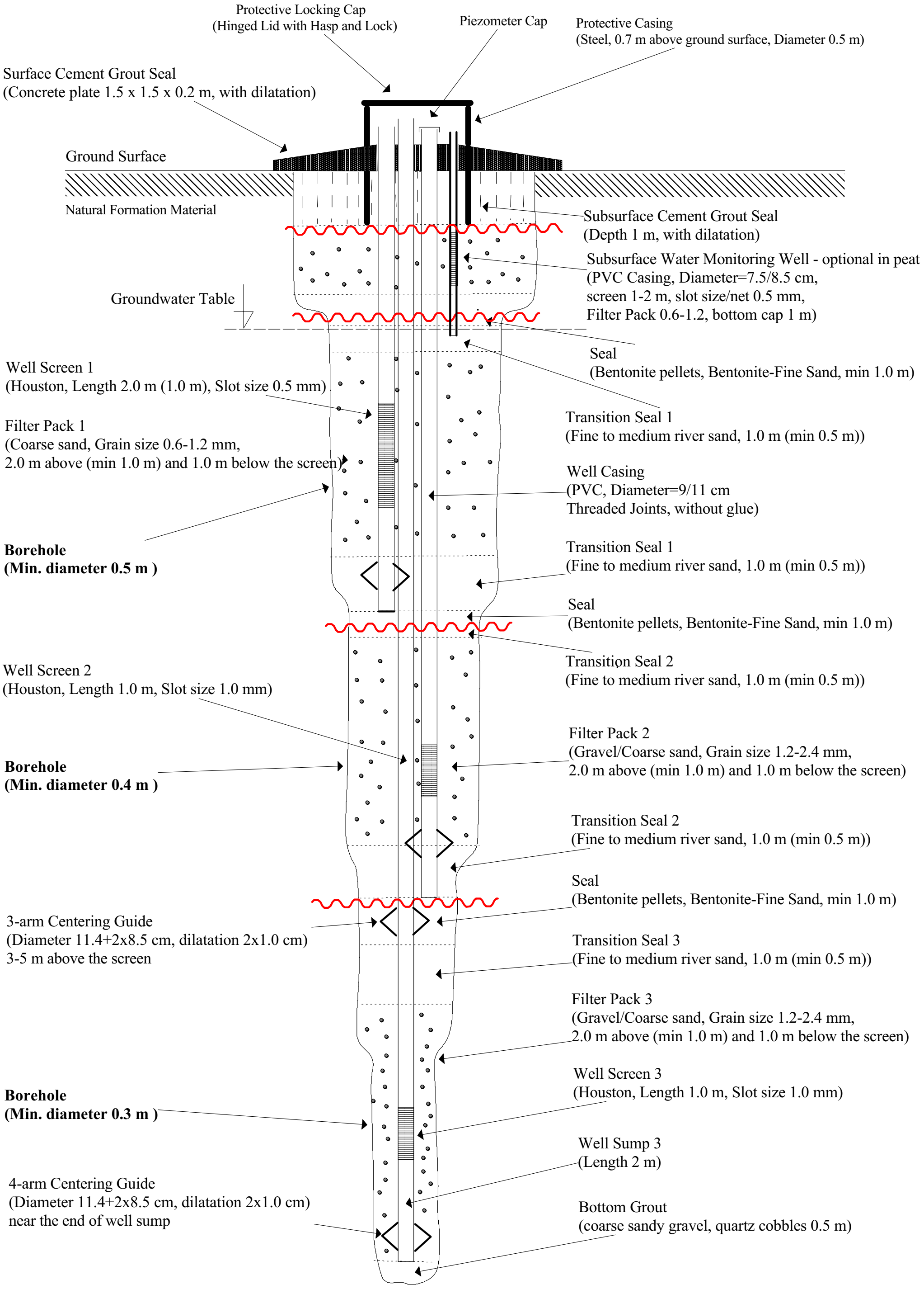
THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

Construction Design of Pumping Well (General Scheme)

CTI Engineering International Co., Ltd.

OYO CORPORATION

Construction Design of Multilevel Monitoring Well
(General scheme)



Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

Figure G.3.2

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

Construction Design of Multilevel Monitoring Well (General Scheme)

CTI Engineering International Co., Ltd.

OYO CORPORATION

During the pumping test the data that characterise rainfall, amount of water abstracted at Megasteel area, changes of barometric pressure, air temperature, and fluctuation of water level in surface water bodies were collected. These data were interpreted together with measurements of groundwater levels.

The measurements of groundwater level were performed using 20 automatic data loggers located in newly constructed wells and in existing monitoring wells selected around the pumping test site. Besides automatic measurements, manual measurements and control measurements were performed in prescribed intervals. The selection of wells and interval of measurements were based on results of previous pumping test modelling.

The measurements collected during pumping and recovery test were processed in database form, corrected and compensated for changes of barometric pressure or other influences (e.g. influence of rainfall at Paya Indah). For recalculation of pressure measurements to height of water column in local conditions, the relation 1 m = 9.74 kPa was used. All measurements are documented in graphical form, both in linear and semi-logarithmic scale (**Annex Figure G.3.1 and Data Book G.3.1**).

In general, the following influences on the course of pumping test may be expected in present hydrogeological conditions:

(1) Leaky confined aquifer and any type of leakage is lowering drawdown in aquifer.

(2) Hydrogeological recharge boundary is lowering drawdown (e.g. river, lake) and creating steady state flow conditions.

(3) Hydrogeological impermeable boundary is raising drawdown (bedrock, ponds).

(4) Recharge from infiltration of rain is lowering drawdown and causes groundwater level fluctuation when occurring during the pumping and recovery test.

(5) Rainwater load on confined aquifer result in piezometric level fluctuation.

(6) Water table conditions are changed during pumping test from elastic storage to water table storage.

(7) Barometric efficiency and tidal fluctuation near the seacoast play an important role in a confined aquifer.

(8) During the pumping test, developing of aquifer sometimes takes place, but on the other hand consolidation and deformation due to the lowering of piezometric pressure can occur, which may cause slight differences in the resulting T and S values.

All three pumping test courses show a sign of slightly leaky artesian condition with water recharge released from elastic storage and water table in peat, and/or recharge boundary conditions in some large distance. Both types of recharges were very similar in the course of the drawdown during the pumping test. In the Study area, both types of aquifer recharge (vertical leakage and recharge in infiltration areas-recharge boundary conditions) are possible. On the other side, the pumping test is still not long enough to reach steady flow conditions. In this case, the resulting values of vertical hydraulic conductivities represent the maximal possible conductivity values.

The basic evaluation of pumping tests was performed using analytical solution, which assumes constant discharge, radial flow to a well of infinitesimally small radius, and homogenous isotropic aquifer of constant thickness and infinite area extent. It is based on Theis's equation and semi-logarithmic straight-line method.

Pumping (and recovery) test data are analytically interpreted as below for every measured piezometer using three types of semi-logarithmic graphs:

(1) Drawdown or residual-drawdown versus time plot – by grouping the piezometers in different direction from pumping well, or grouping piezometers in different depth: **Figures G.3.3-5** and **Figures G.3.8-9** (Paya Indah), **Figures G.3.20-21** and **Figure G.3.23** (Kajibumi WF 2), and **Figures G.3.29-30** (Kanchong Darat). This type of graph is used for estimation of horizontal transmissivity and storage of main aquifer.

(2) Drawdown or residual-drawdown versus t/r^2 plot – **Figures G.3.6-7** (Paya Indah), **Figure G.3.22** (Kajibumi WF 2), and **Figure G.3.31** (Kanchong Darat). This type of graph is used for evaluation of heterogeneities or boundaries of main aquifer in horizontal direction.

(3) Drawdown versus distance plot – by grouping the piezometers in different direction from pumping well, or plotting the selected piezometers in different time: **Figures G.3.10-11** (Paya Indah), **Figure G.3.24** (Kajibumi WF 2), and **Figures G.3.34-35** (Kanchong Darat). This type of graph is used for evaluation of depression cone development during pumping test, and for estimation of its extent at the end of pumping test.

The interpreted hydraulic parameters (e.g. transmissivity, storativity, radius of depression cone) are presented directly in graphs.

The analytical evaluation is based on many limiting assumptions, which are only rarely fulfilled in reality. In the case of stratified and thick aquifer and partially penetrating well, the proper interpretation of basic hydraulic parameters is practically impossible (e.g. at Kanchong Darat).

For representative evaluation of hydraulic parameters, interpretation of boundary conditions, and evaluation of vertical leakage, numerical model of pumping test was applied (Program Well, GROUND WATER Consulting). Well is a radial, symmetrical model based on the finite difference method, which enables computation of drawdown during pumping test and recovery in arbitrary time, depth, and distance from the pumping well. Theoretical background of model is described in Mucha, Schestakov.[5)] The model evaluation can reflect various factors, which influence pumping test data, for example:

(1) Diameter of pumping wells, the water volume in the well according to well radii for individual layers.

(2) Partial penetration of well, position and length of screen (well, piezometer).

(3) Hydraulic anisotropy, heterogeneity, stratification of aquifer.

(4) Water table storage and elastic storage below the water table and their change due to water table fluctuation (groundwater flow in unconfined and/or confined aquifer).

(5) Efficiency of pumping well (linear well loss), non-uniform inflow to the well screen from individual layers and via the well bottom.

(6) Constant or variable discharge (drawdown), with subsequent recovery tests including step-tests, pumping interruptions, etc.

(7) Simplified boundary conditions of type H = const. or q = 0.

(8) Groundwater loss depending on potential evaporation and groundwater table fluctuation, recharge from precipitation.

Set up of pumping test model was prepared for each of pumping tests sites. Discretisation of the aquifer in the vertical direction is based on geological logs, geometric characteristics of the pumping well and position of piezometers (**Figures G.2.6**, **G.2.11 and G.2.16**).

The model was calibrated for the measurements performed during pumping tests using trial & error method. Comparison of modelled and measured drawdown is presented in **Figures G.3.12-19** (Paya Indah), **Figures G.3.25-28** (Kajibumi WF 2), and **Figures G.3.32-35** (Kanchong Darat).

The interpreted hydraulic parameters for every pumping test model layer (conductivity coefficients in vertical and horizontal direction, storage coefficients) are summarised in **Table G.3.1** (Paya Indah), **Table G.3.2** (Kajibumi WF 2), and **Table G.3.3** (Kanchong Darat). Graphical presentation of results (recalculated for discretisation of aquifer which corresponds to 3D groundwater flow model) and comparison with results of sieve analyses is shown in **Figures G.2.6**, **G.2.11 and G.2.16**.

Hydraulic parameters interpreted from three pumping test localities created a base for definition of hydraulic parameters of regional 3D groundwater flow model. The derived parameters, like those introduced in Visual MODFLOW 3D groundwater flow model, are summarised in **Table G.4.1**.

3.2 Realisation and Interpretation of Pumping Tests

3.2.1 Pumping Test at Paya Indah

Paya Indah pumping test site is located at the northeast site of the Main Lake (**Figure G.2.3-5**). Pumping well is situated approximately 100 m from the lake bank. It was expected that the pumping test well and piezometers are located in an alluvial buried valley of south-north direction crossing probably the old mine lakes. Pumping test ran from 11.2.2001 to 12.3.2001 with constant discharge 4.9 l/s abstracted from well PW 2 (well screen in depth 19.8-29.8 m). Location of pumping test site, pumping well and piezometers is shown in **Figures G.2.3**, **G.2.4 and G.2.5**.

The goals of the pumping test were to investigate:

- Detailed geological profile, geological and lithological aquifer characteristics and bedrock composition, permeability distribution along the boreholes (in vertical directions) using sieve analyses;
- Hydraulic conductivity, specific elastic and groundwater table storage and transmissivity of aquifer; Input parameters for the further applied research and groundwater model (interpretation from the pumping test and other collected geological relevant data);
- Impact of lake on pumping test, hydraulic parameters of the lake bank and bottom sediments;
- Changes of groundwater flow towards the lake before and during the pumping test. Possibility of groundwater recharge from the lake;
- Groundwater level and piezometric level distribution in time and space before and during the pumping test;
- Impact of pumping on the groundwater regime (deep and shallow aquifer horizons) in surrounding area;
- Safe yield and permissible drawdown for groundwater use, including interaction to uppermost shallow horizon responsible for soil moisture;
- Surface water quality in the lake infront of pumping test site, in the lake's inflow and outflow; changes of the groundwater quality during pumping test, impact of water inflow from the lake; and
- Other aquifer characteristics, important for the Paya Indah Wetland Sanctuary organisation, mainly for the ecological and groundwater purposes.

(1) Geological Profile

Figure G.2.6 contains derived schematic geological log based on evaluation of driller's logs from borehole BH2, pumping well PW2 and other piezometers.

Laterite soil, peat and peaty clay build first 3 m of geological profile. These peaty sediments are recharged with rainwater. Groundwater level is just under the surface and fluctuates usually only few centimetres (up to 10-20 cm) according to rainy and dry periods. For example, 40 mm of rainfall on February 17, and on March 18 (**Annex Figure G.3.1a**) caused about up to 70 mm increase of water level in shallow well J2-1-1. Shallow peat is typical with high active porosity, high water storage capacity. It is regularly supplied with rainwater and may all the time be a source of leakage water for deeper horizons if the hydraulic gradient is oriented downwards.

In the depth from 3 m down to 10 m is a layer of silty clay and sandy clay. Through this layer the leakage takes place according to the hydraulic gradient. The first permeable layer, clayey sand, is located in the depth from 10 to 13 m. This layer is considered as upper less permeable aquifer. From the deeper aquifer, it is divided by leaky sandy clay lying in the depth from 13 to 16 m. The main aquifer in general consists from silty sand and gravel from 16 to 30 m under the surface. Most permeable sandy gravel alluvial aquifer is relatively thin. The permeability is determined by presence of thin layers of clay. Aquifer bedrock consists from impermeable sandstone (quartzite) found in the depth of 30 m, which is considered as very low permeable or nearly impermeable.

The results of sieve analyses and grain size curves were processed for individual horizons and types of sediments, in the form suitable for a comparison of sediments in different depths and at different localities (**Figures G.2.6-8** and **Data Book Figures G.2.1 to G.2.4**). From granulometric curves, hydraulic conductivity and other hydraulic parameters were computed using Carman-Kozeny method and compared with transmissivity, interpreted from the pumping test (**Figures G.2.6 and G.2.8**).

(2) Aquifer Hydraulic Parameters

Complex interpretation of aquifer characteristics was based on careful evaluation of borehole logs, grain size analyses (granulometric curves), measurements of groundwater levels at piezometers located in different depth, and interpretation of pumping test.

All manual and automatic measurements during pumping test are plotted as time series in bi-linear and in semi-logarithmic scale (**Data Book G.3.1**). The following data measured during pumping test and recovery are presented in bi-linear scale:

- Groundwater level and discharge from pumping well PW 2 measured by flow meter and V-notch (**Data Book Figure G.3.1**);
- Rainfall, air temperature, barometric pressure (**Annex Figure G.3.1**);

- Water level fluctuation in lake and surrounding surface water bodies (**Data Book Figures G.3.2-3**); and
- Drawdown in piezometers (**Data Book Figures G.3.4-9**).

Data Book Figures G.3.10-20 show the same data plotted in semi-logarithmic scale.

Impact of rainfall (**Annex Figure G.3.1a**) can be recognised in increase of water level in lake (**Data Book Figure G.3.3c**) and shallow piezometers located in peat, e.g. J2-1-1, and others (**Data Book Figure G.3.4a**). Deep horizons showed increase of stress caused by rain load on the confined aquifer after heavy rain. The influence of rainfall was compensated using available measurements in Lake.

Comparison of piezometric levels in main aquifer with water levels in shallow peat horizon shows that around the pumping well the piezometric levels are higher than water level in peat. In areas where the terrain surface is in higher position, for example well J2-6, the peat water level is the same or higher than the piezometric water level in aquifer.

Graphical interpretation of drawdown *s* against logarithms *t* in **Figures G.3.3 to G.3.5** documents that there is only a small impact of leakage and/or recharge boundary condition. During the pumping test, an increase of stress from rain load on the confined aquifer after heavy rain on February 17 can be recognised in deep horizons (**Data Book G.3.1**).

The interpreted hydraulic parameters, distance of piezometer from the pumping well and its depth are written directly in graphs for each piezometer. The measurable drawdown caused by pumping was observed also in large distances, e.g., well J10-1-2 and J1-1-2, with distance 1770 and 1323 m, respectively. There was no evidence of drawdown in shallow peat horizon (J2-1-1, J2-6-1).

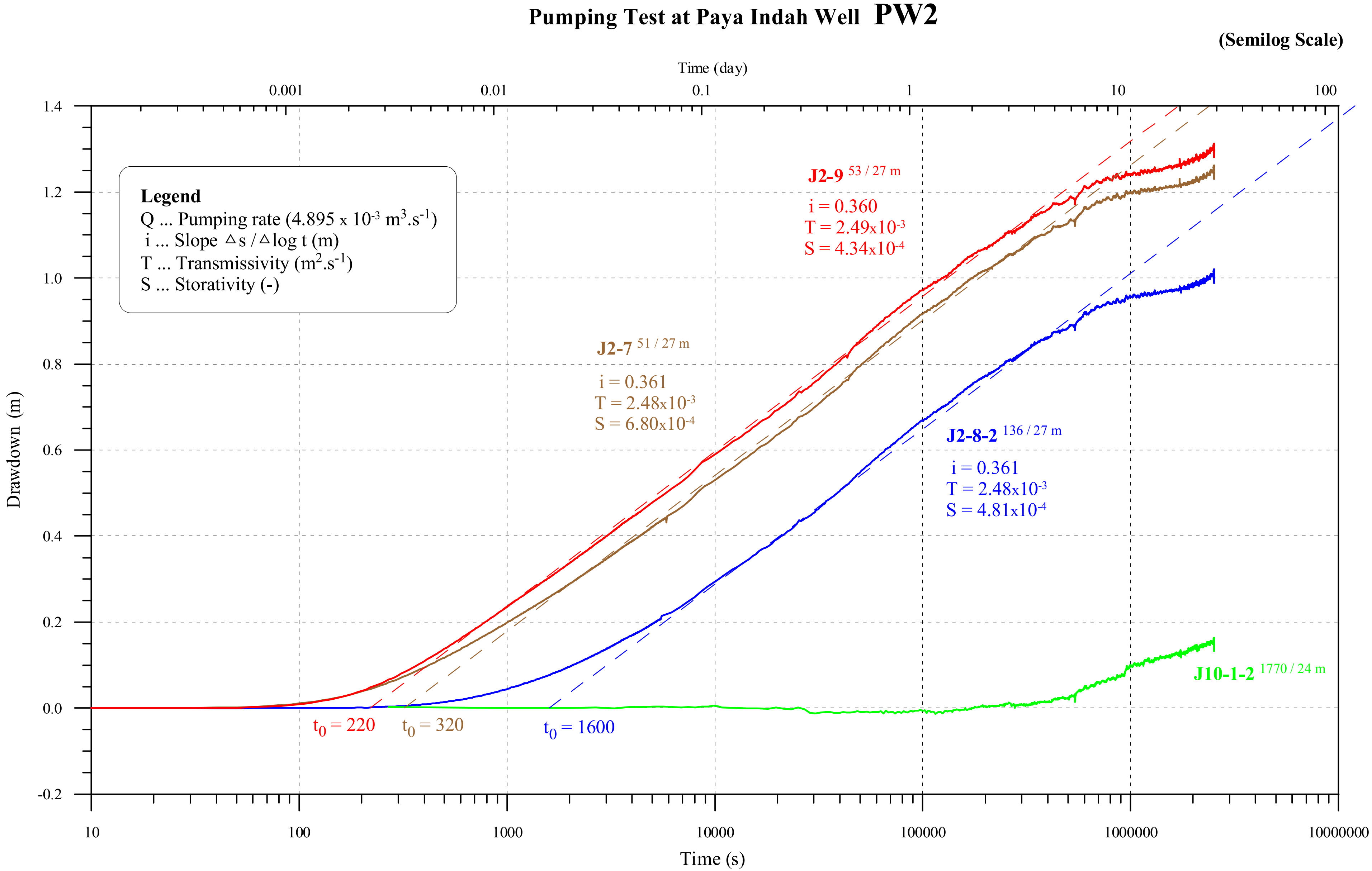


Figure G.3.3 Interpretation of pumping test at Paya Indah - drawdown versus time plot in x direction

ro_cs2_st1

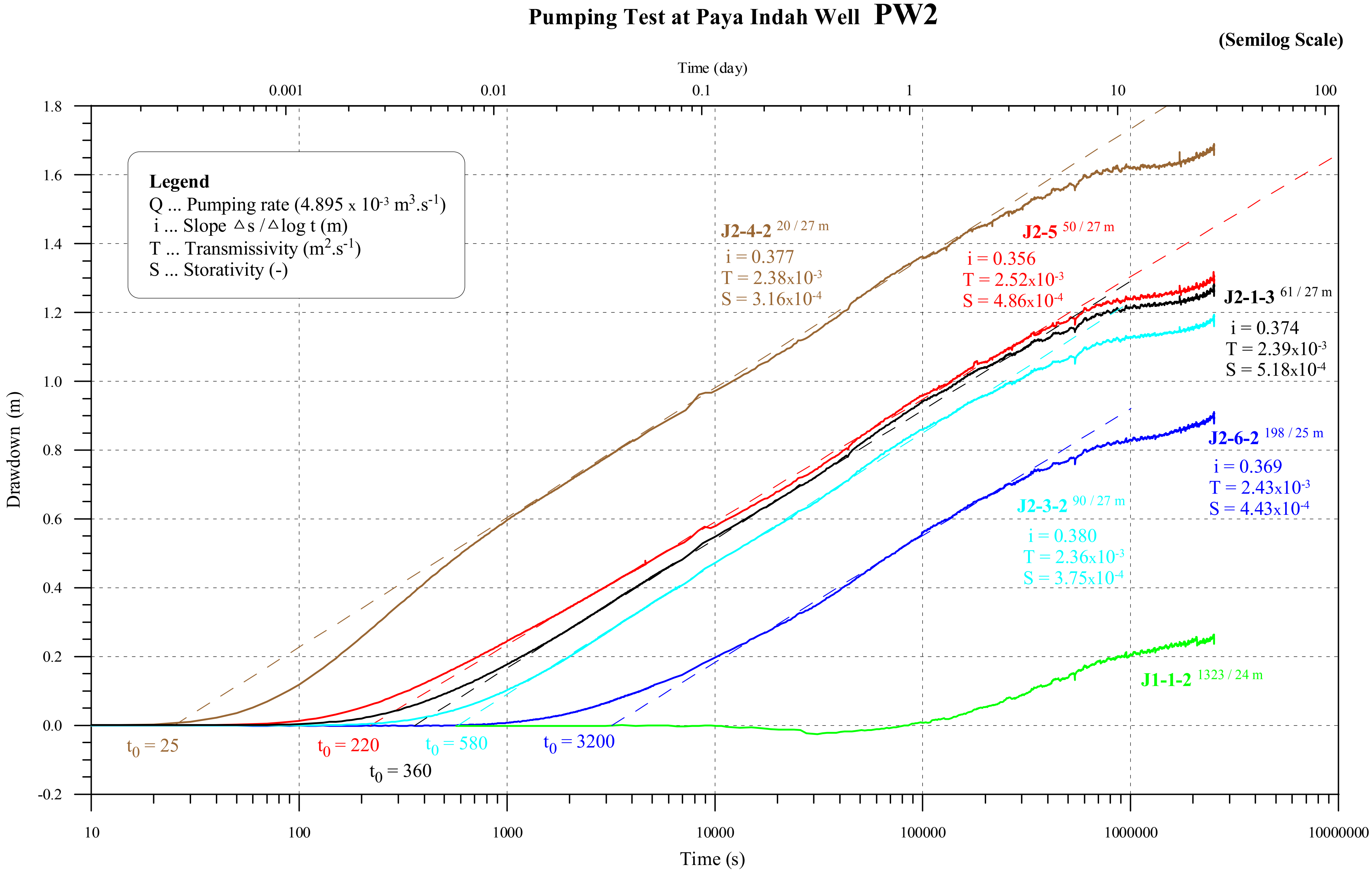


Figure G.3.4 Interpretation of pumping test at Paya Indah - drawdown versus time plot in y direction

ro_cs2_st2

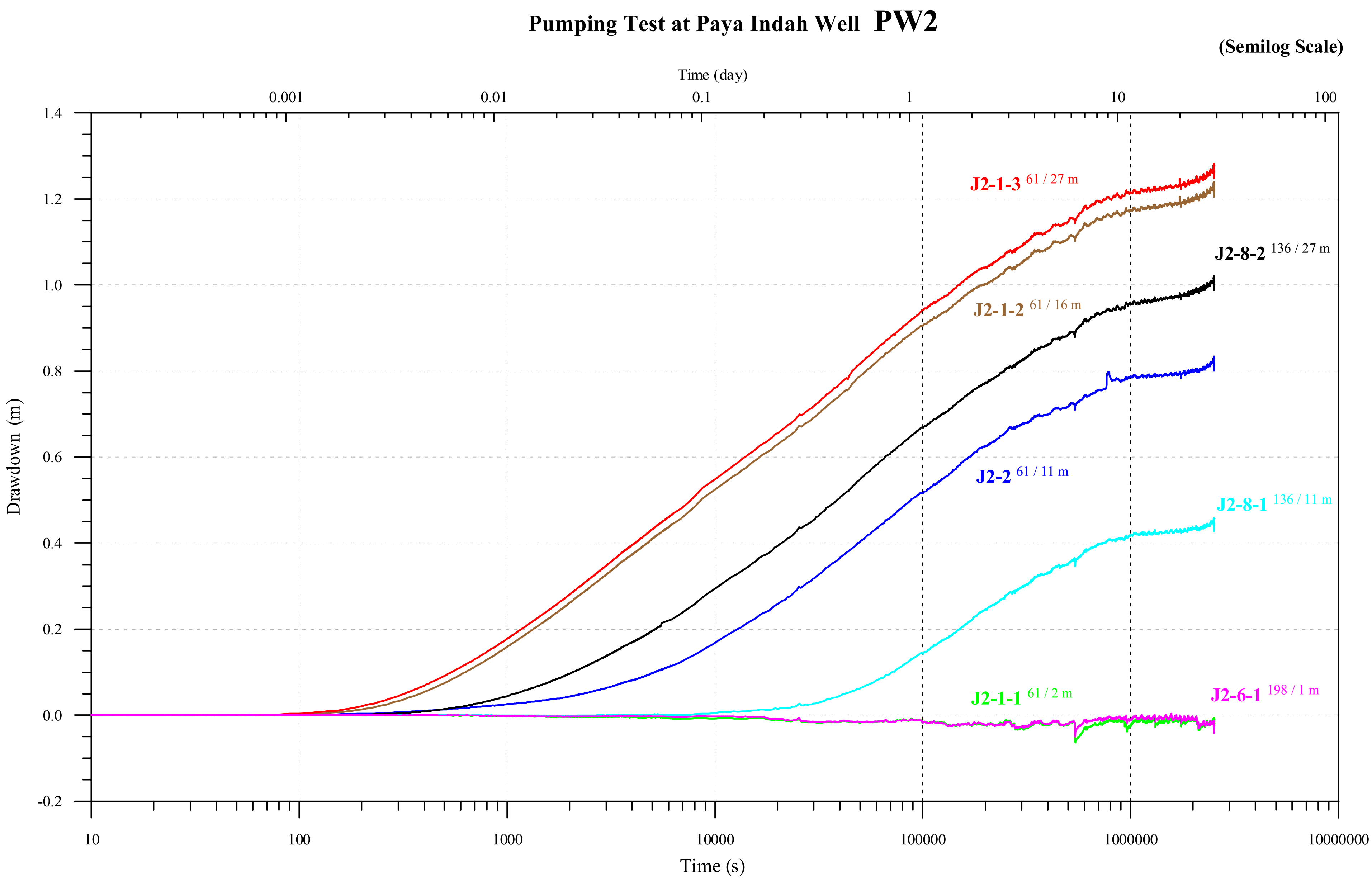


Figure G.3.5 Interpretation of pumping test at Paya Indah - drawdown versus time plot in z direction

ro_cs2_st3

Drawdown *s* versus log t/r^2 graphs in **Figure G.3.6** show, that the drawdown slopes and thus the hydraulic conductivities are very uniform in the investigated area. The elastic storage and transmissivity is the smallest towards the south (toward the Main Lake at Paya Indah). The largest storativity is in the east direction (**Figure G.3.7**). This can be interpreted as an impact of the barrier to the south and an open aquifer with increase of thickness to the east. Interpretation of the recovery test (**Figures G.3.8 and G.3.9**) gives nearly the same values.

The evaluation of depression cone is based on drawdown *s* versus log of distance *r* graphs (**Figures G.3.10 and G.3.11)**. After one day of pumping, the radii of depression cone were around 850 m; in 10 days it reached 2200 m. After 30 days of pumping, the drawdown reached the distance of about 3 km. Still larger radii of depression cone can be expected in the east direction.

The results of pumping test indicate that the aquitard is leaky and/or there exist recharge boundary in some large distance. Most likely, the aquifer is to some small degree recharged by leakage from surface and also from recharge boundary located in larger distance. Possible distance of recharge boundary can be expected in distance R = 1200-1800 m. In natural conditions, without pumping, this recharge from larger distance (and higher elevation) prevails and leakage in the areas that are lower is in the upward direction - from the sandy/gravelly aquifer upwards to the surface. During the exploitation of aquifer, both recharge and leakage will supply the aquifer with water. This statement is important for future groundwater quality prediction and groundwater management.

As described above, the slopes of drawdown are similar for all piezometers and they do not indicate any significant recharge from the lake. The lake is located very close to the pumping well (100 m). On the other side, if the lake creates impermeable boundary, the boundary should be manifested in the drawdown curve very early, which is very difficult to interpret when using only analytical straight-line method. Therefore pumping the test modelling method was applied.

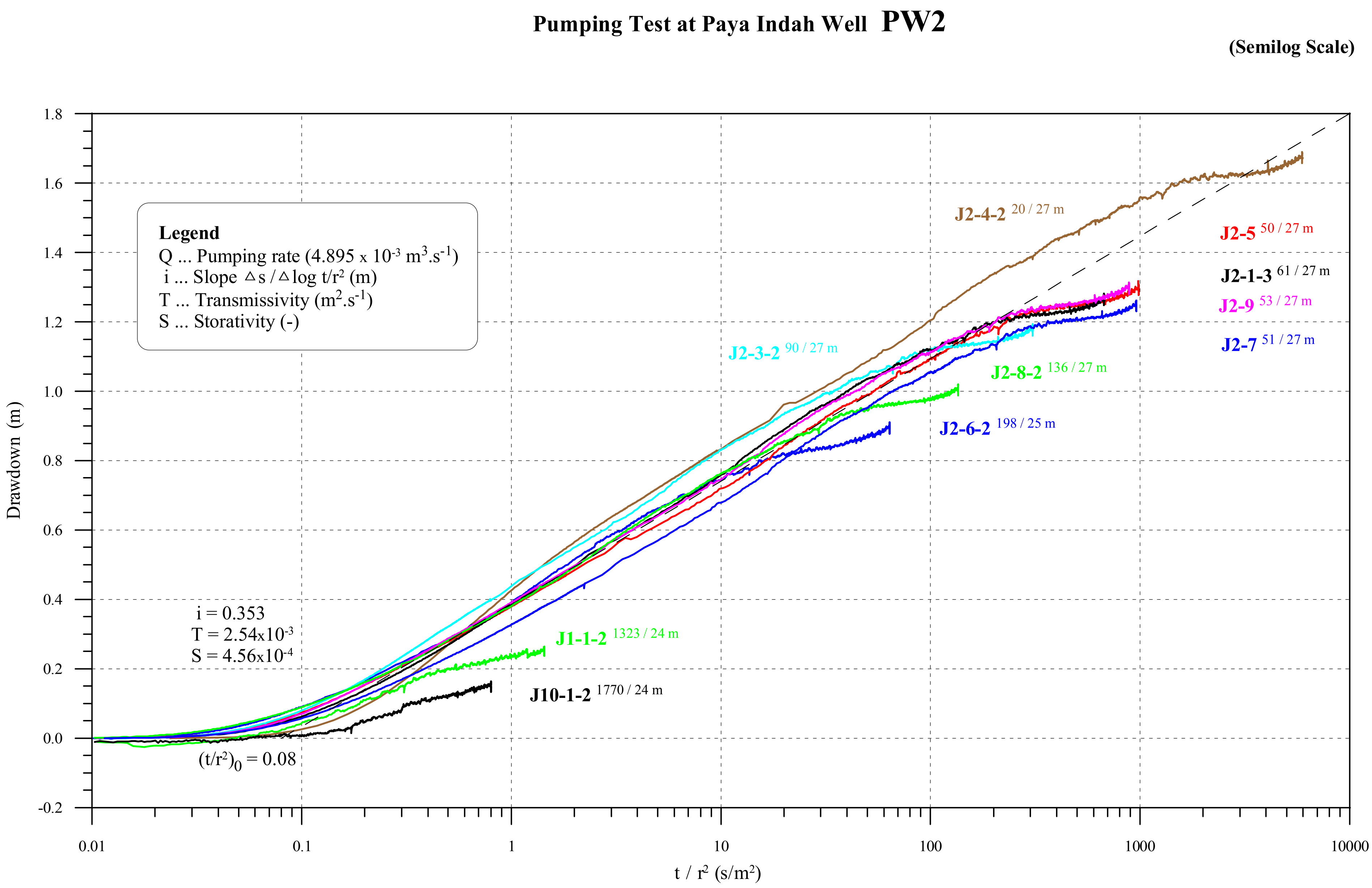


Figure G.3.6 Interpretation of pumping test at Paya Indah - drawdown versus t/r² plot

ro_cs2_str1

Pumping Test at Paya Indah Well PW2

(Semilog Scale)

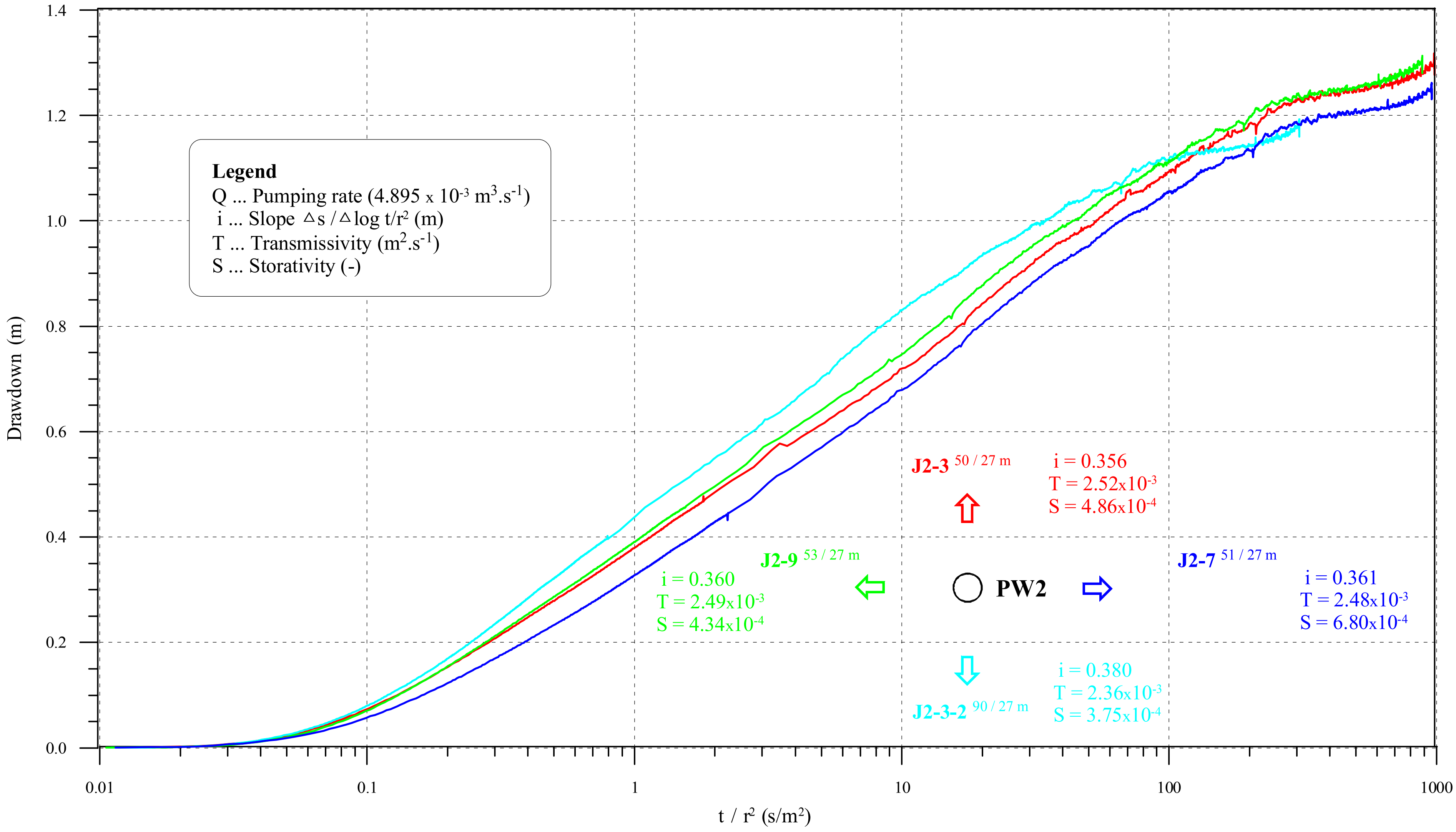


Figure G.3.7 Interpretation of pumping test at Paya Indah - drawdown versus t/r² plot in different direction from pumping well

ro_cs2_str2

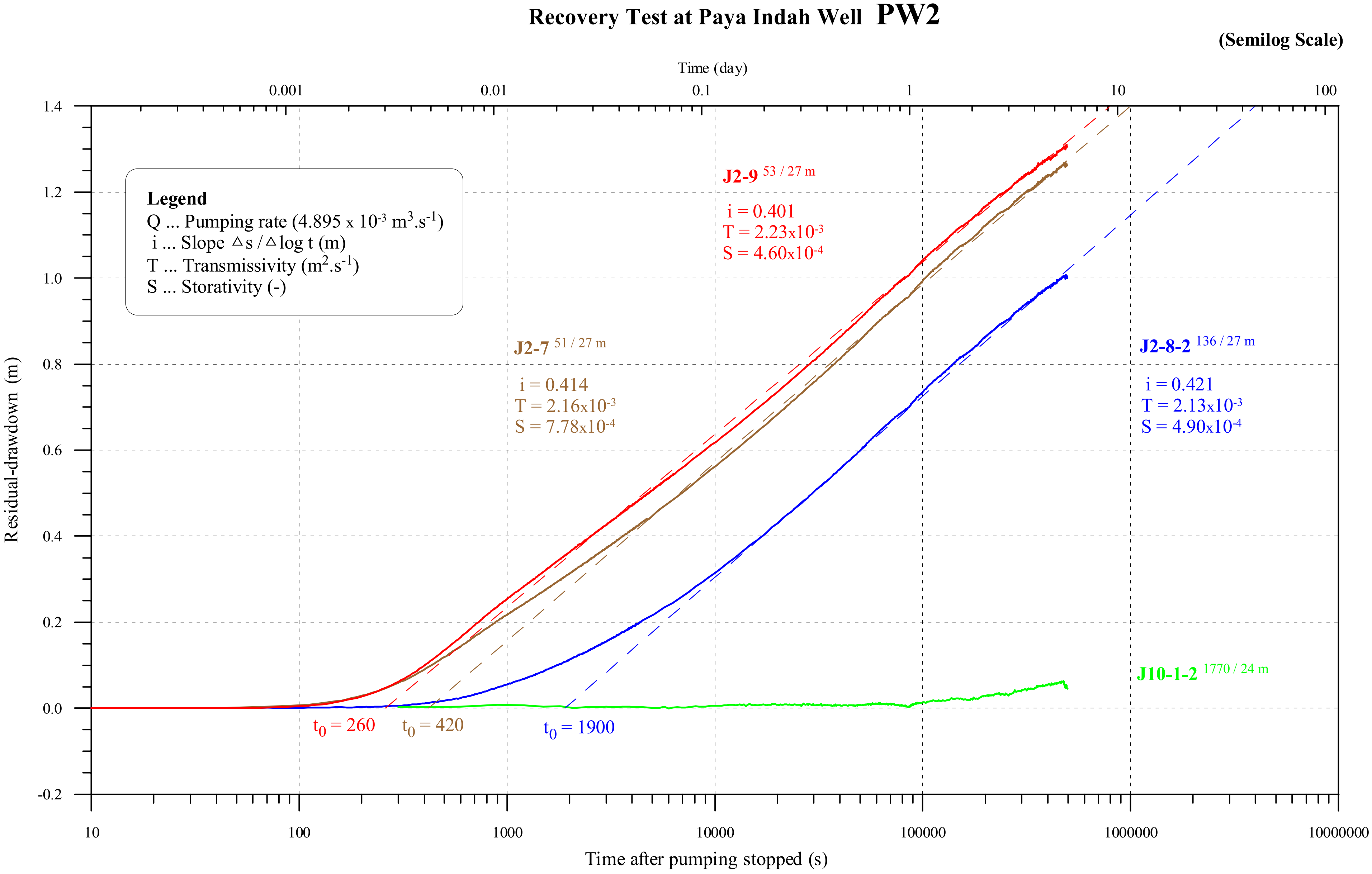


Figure G.3.8 Interpretation of recovery test at Paya Indah - residual-drawdown versus time plot in x direction

ro_ss2_st1

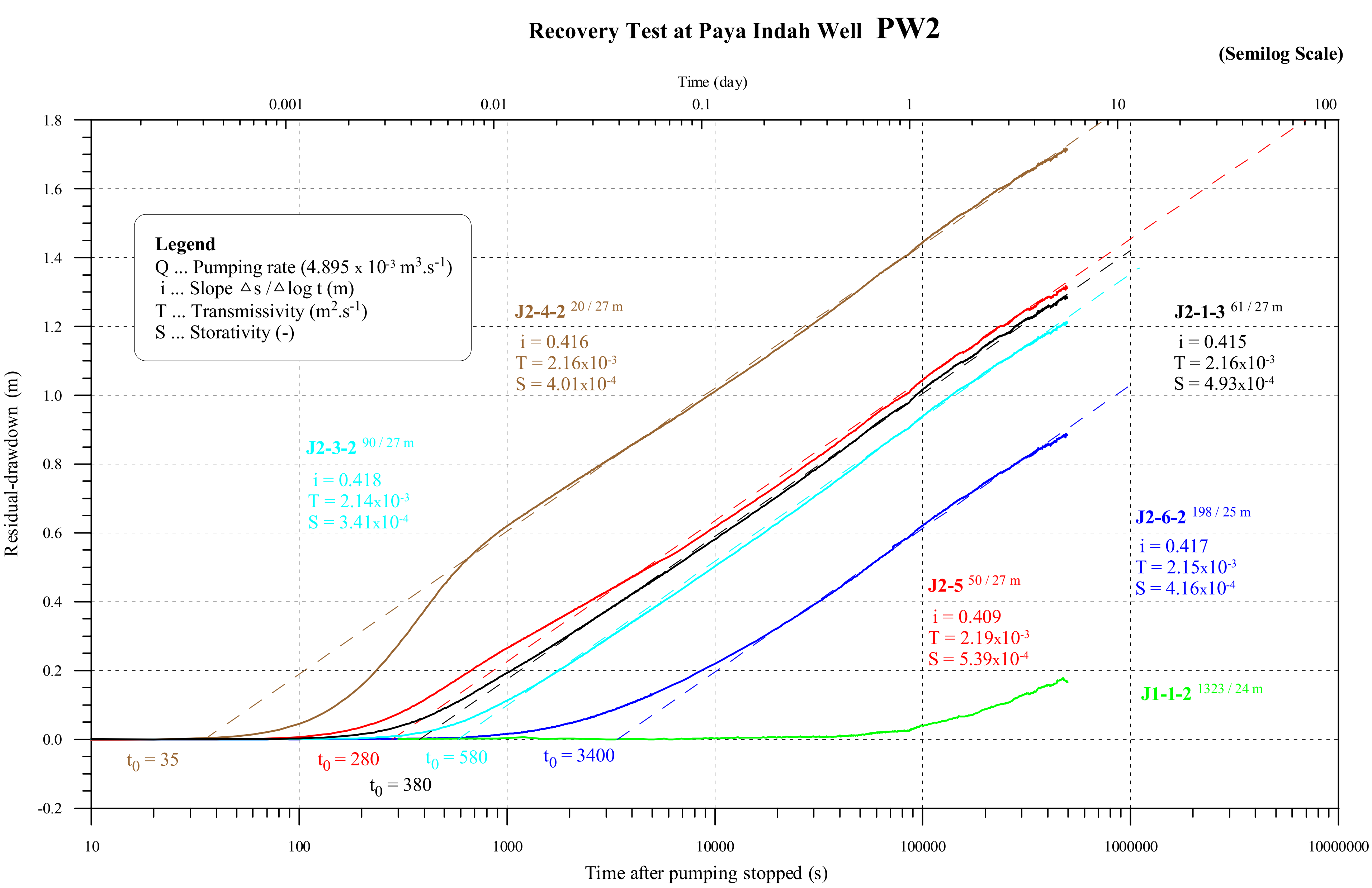


Figure G.3.9 Interpretation of recovery test at Paya Indah - residual drawdown versus time plot in y direction

ro_ss2_st2

Pumping Test at Paya Indah Well PW2

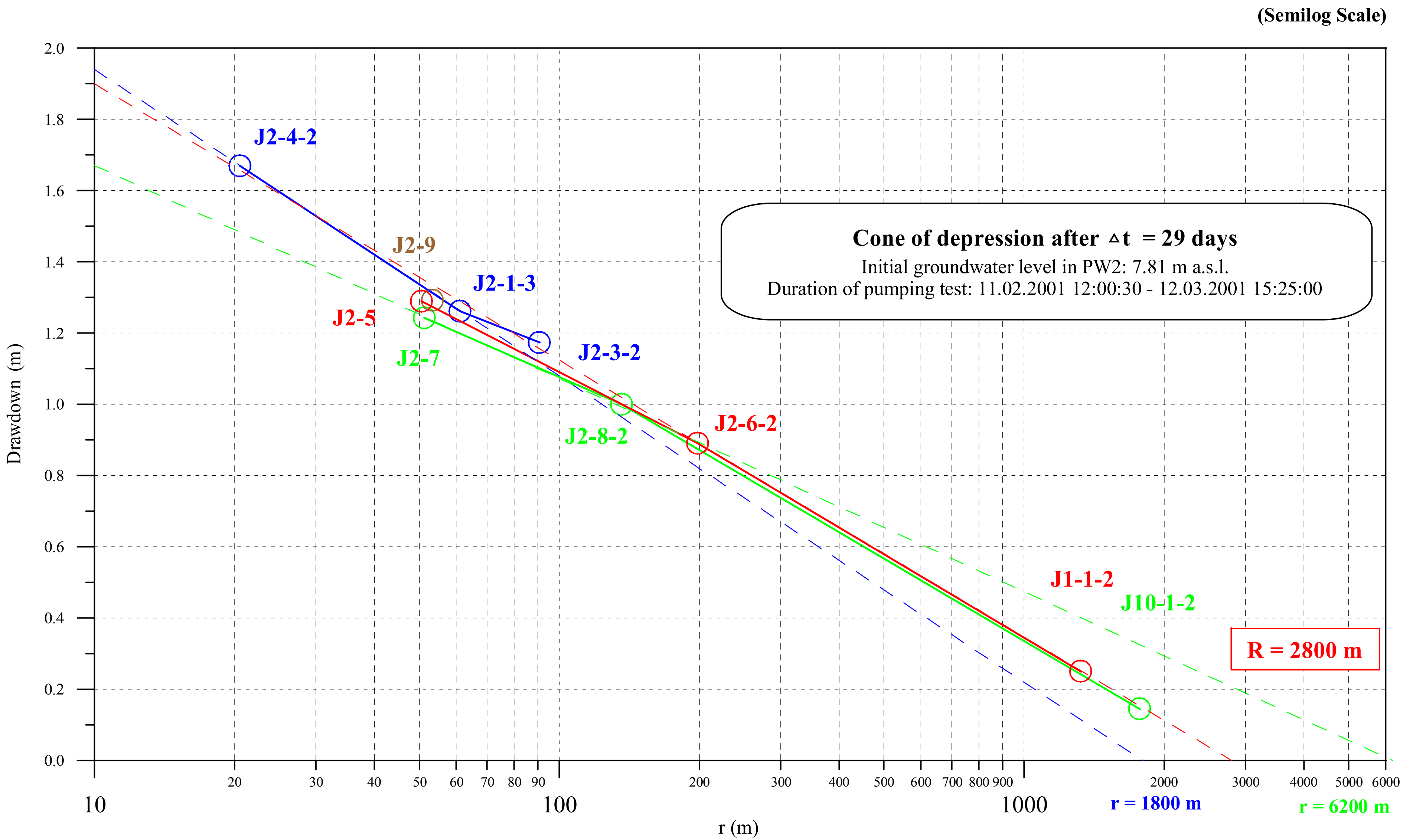


Figure G.3.10 Interpretation of pumping test at Paya Indah - drawdown versus distance plot in different direction from pumping well

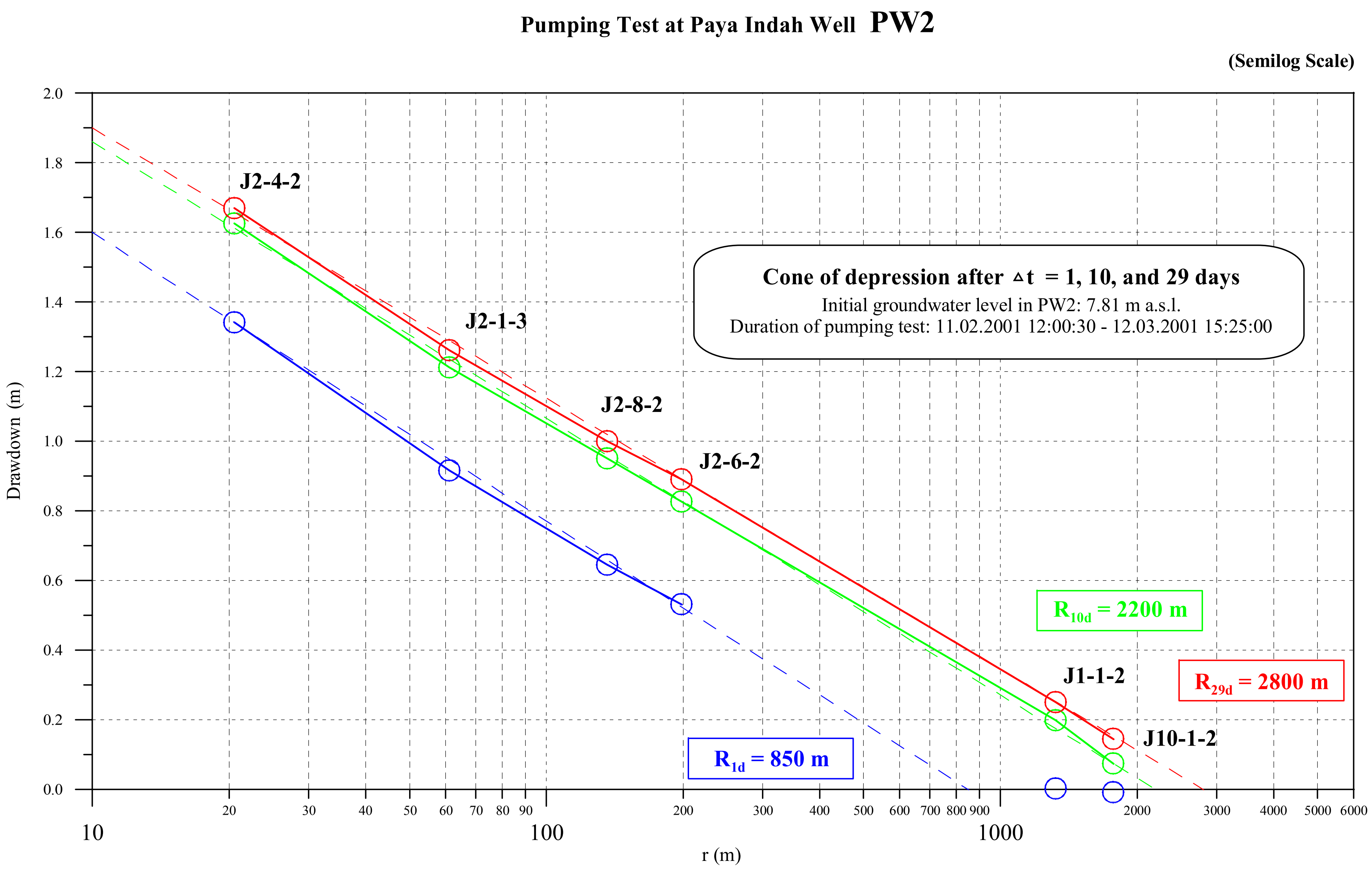


Figure G.3.11 Interpretation of pumping test at Paya Indah - change of depression cone during pumping test

ro_cs2_sr2

Course of real and modelled drawdown during pumping test and recovery, under leaky conditions and under assumption that the lake is creating impermeable boundary, is shown in **Figures G.3.12-15**. Input data and interpreted hydraulic parameters are described in figures and in **Table G.3.1.**

Table G.3.1 Pumping Test Modelling at Paya Indah – Hydraulic Parameters

Layer No.	Depth (m)	Thick. b (m)	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	3.0	3.0	1.00e-4	1.00e-5	10	1e-3	0.3	Peat, laterite soil
2	10.0	7.0	1.20e-8	1.20e-8	1	3.7e-5	0.01	Silty clay
3a	13.0	3.0	6.00e-5	6.00e-6	10	3.7e-5	0.15	Clayey sand
3b	16.0	3.0	1.00e-8	7.00e-9	1.43	3.7e-5	0.01	Sandy clay
3c	19.8	3.8	5.70e-4	1.00e-5	57	4.5e-5	0.2	Silty sand with gravel, sandy clay
	25.0	5.2	2.80e-4	9.33e-6	30	4.5e-5	0.2	
3c avg	25	9.0	4.02e-4	9.60e-6	42	4.5e-5	0.2	
4	29.8	4.8	1.00e-4	5.00e-6	20	4.5e-5	0.2	Silty sand and gravel, sandy clay
3c-3d avg	29.8	13.8	2.97e-4	7.27e-6	41	4.5e-5	0.2	

Note: 3c-3d avg means average (characteristic) value for layer 3c and 3d.

To demonstrate the impact of the lake as a hypothetical recharge boundary, another modelling variant was prepared, using the same parameters, but with the lake as recharge constant head boundary situated in distance of 100 m from the pumping well. Comparison of measured and modelled drawdown is shown in **Figures G.3.16-17**.

Modelling variant presented in **Figures G.3.18-19** considers infinite aquifer, an aquifer without any boundary conditions.

In the above-described pumping test modelling scenarios, the recharge boundary was not modelled and the vertical leakage also served as the potential recharge boundary. That leads to a conclusion that vertical leakage from **Table G.3.1** may be a little overestimated, if some recharge boundary exists. Interpreted vertical leakage of aquitard should be considered as maximal when used in a 3-D model, and can be lowered during calibration procedure if recharge areas exist.

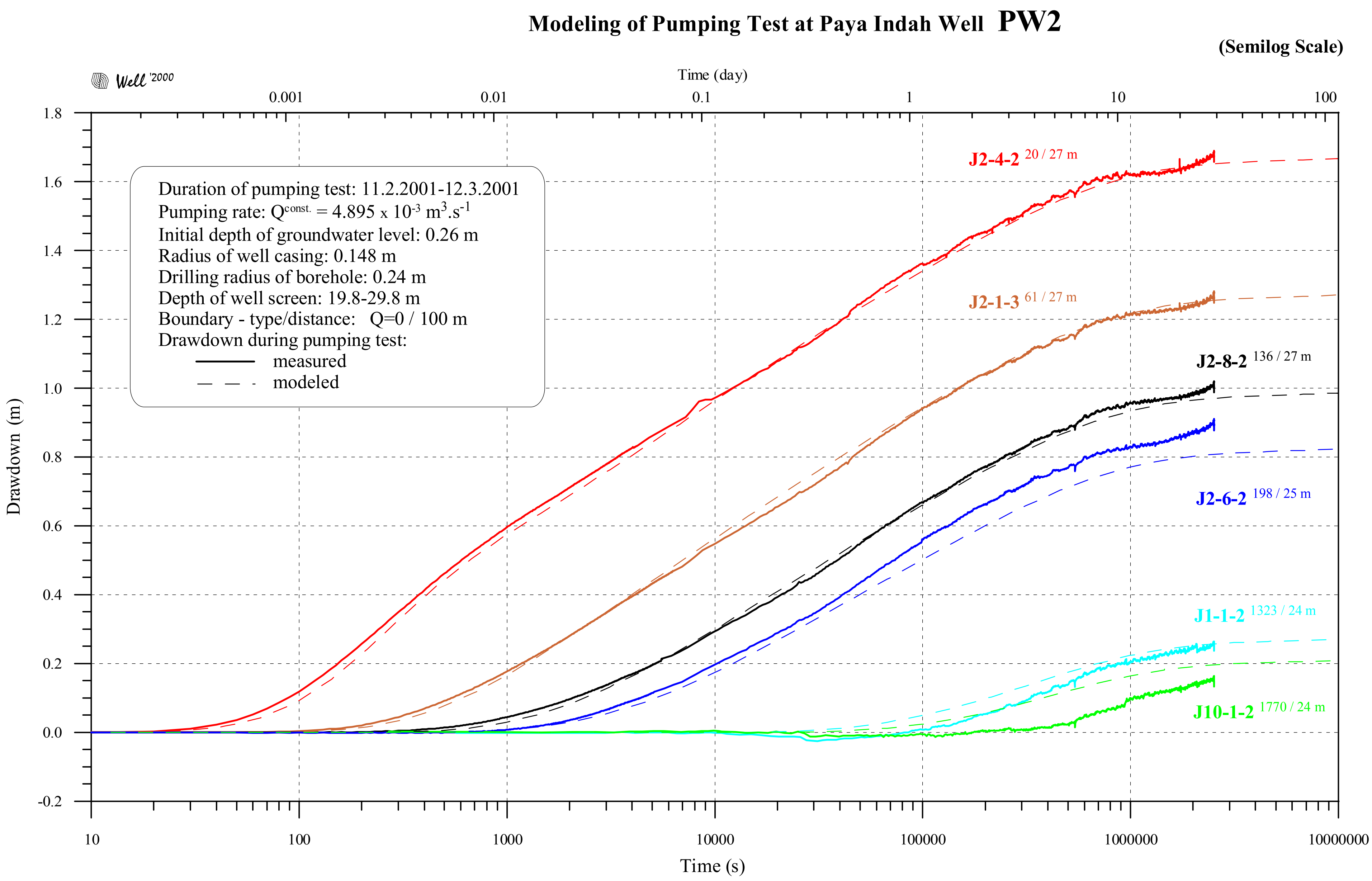


Figure G.3.12 Modeling of pumping test at Paya Indah - modeled and measured drawdown in different distance from pumping well

ro_cs2_mod1h

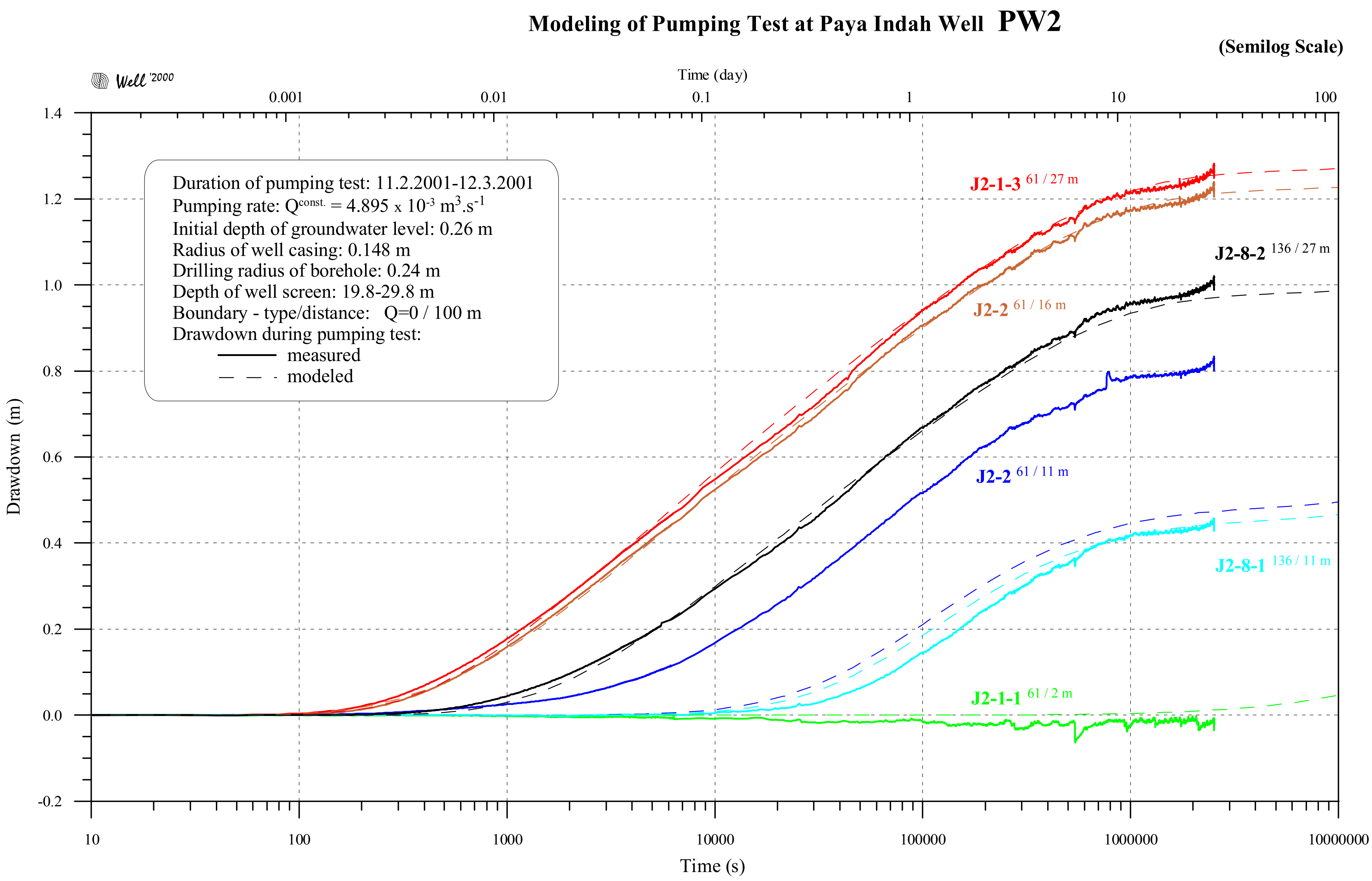


Figure G.3.13 Modeling of pumping test at Paya Indah - modeled and measured drawdown in different depth

ro_cs2_mod1p

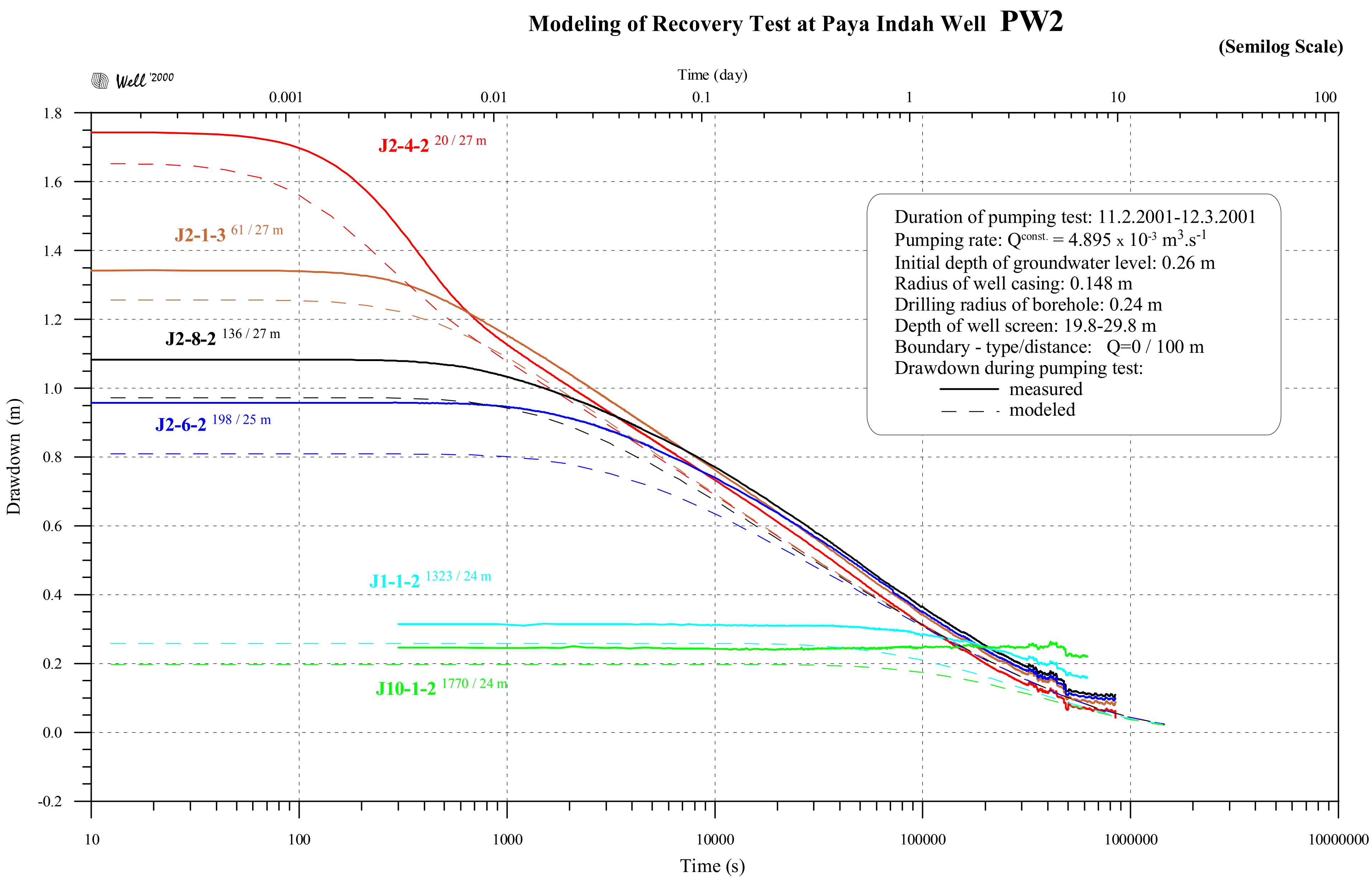


Figure G.3.14 Modeling of recovery test at Paya Indah - modeled and measured drawdown in different distance from pumping well

ro_ss2_mod1h

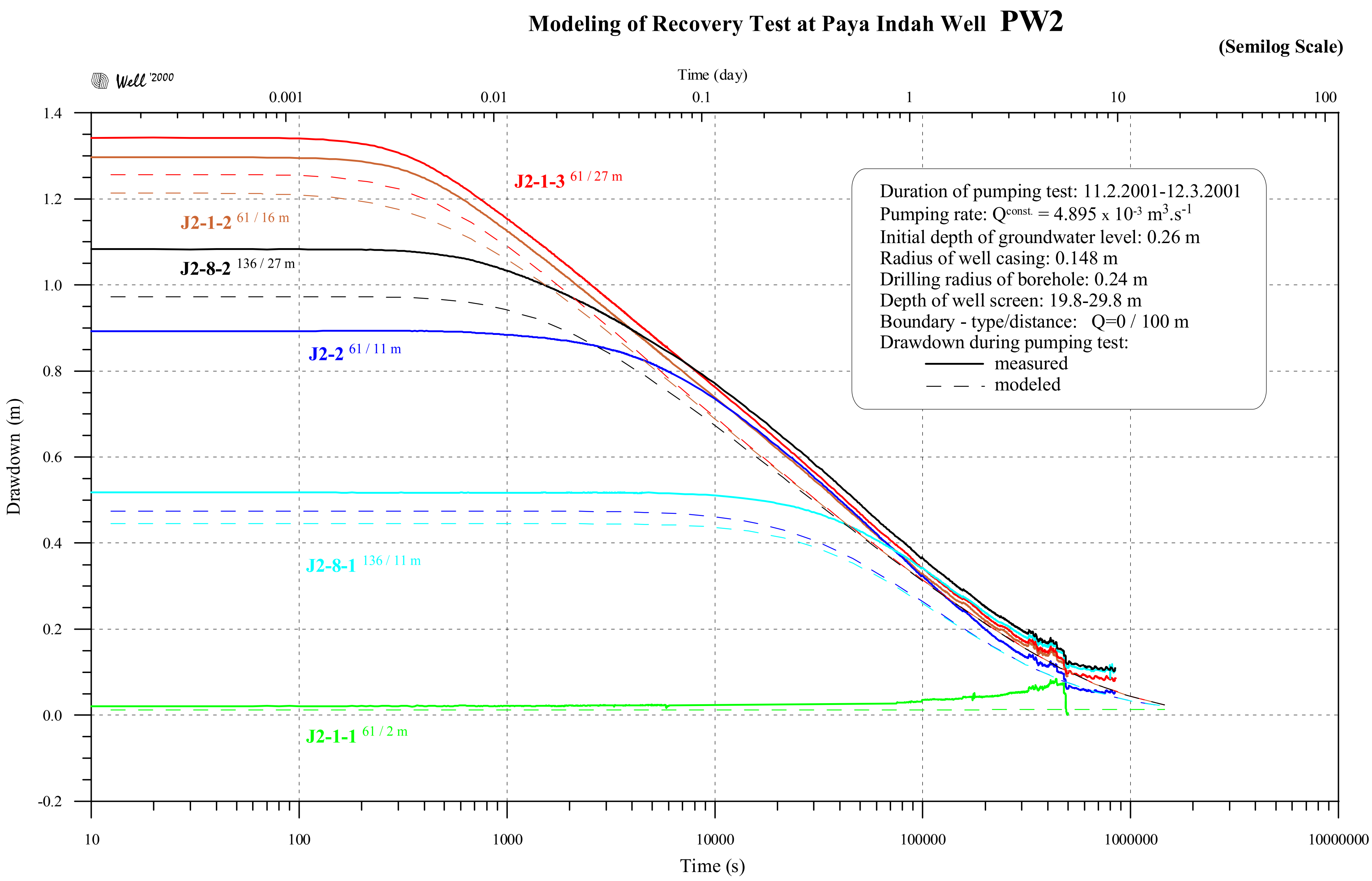


Figure G.3.15 Modeling of recovery test at Paya Indah - modeled and measured drawdown in different depth

ro_ss2_mod1p

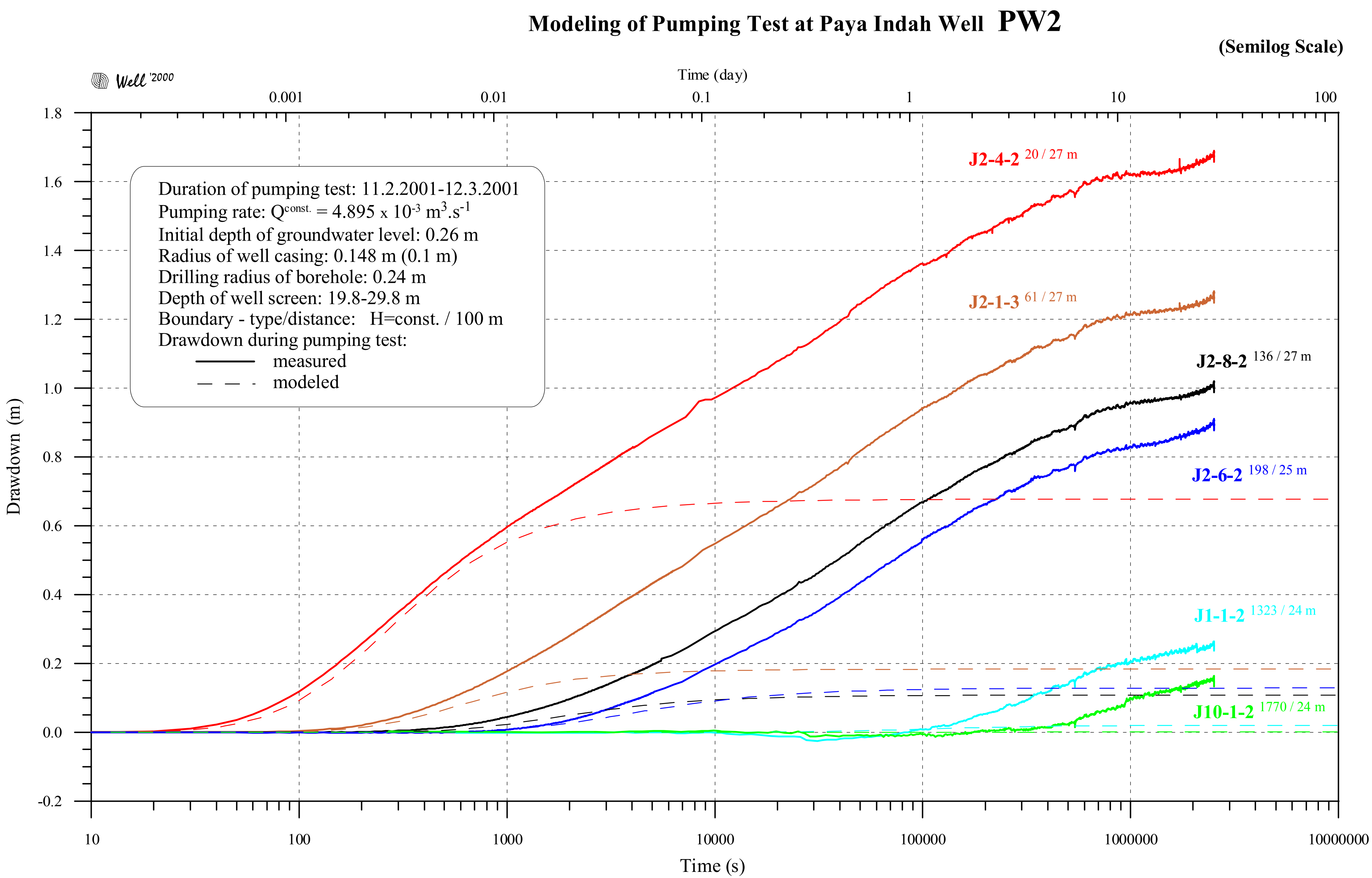


Figure G.3.16 Modeling of pumping test at Paya Indah - influence of constant head boundary in distance 100 m from pumping well (1/2)

ro_cs2_mod3h

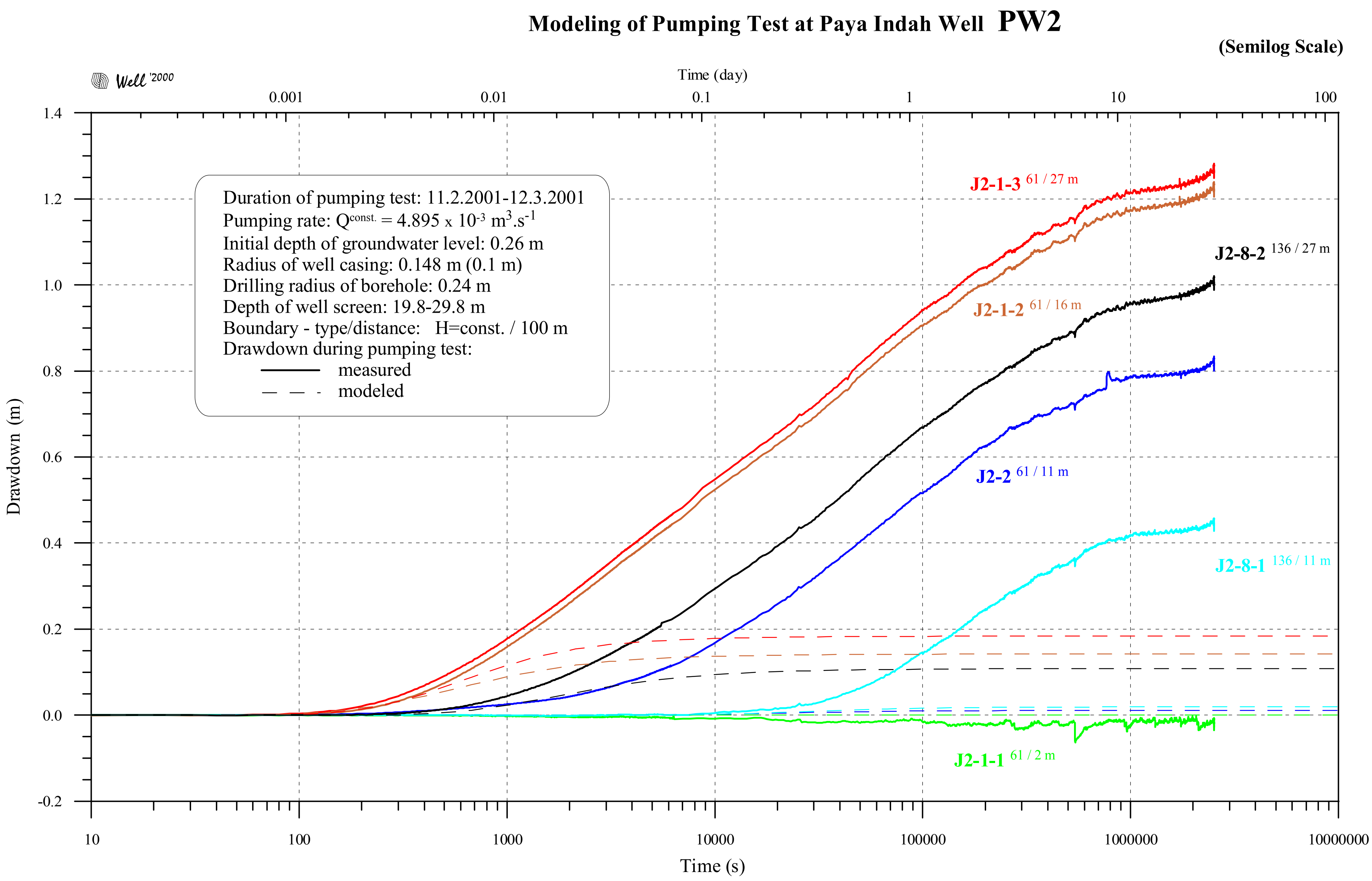


Figure G.3.17 Modeling of pumping test at Paya Indah - influence of constant head boundary in distance 100 m from pumping well (2/2)

ro_cs2_mod3p

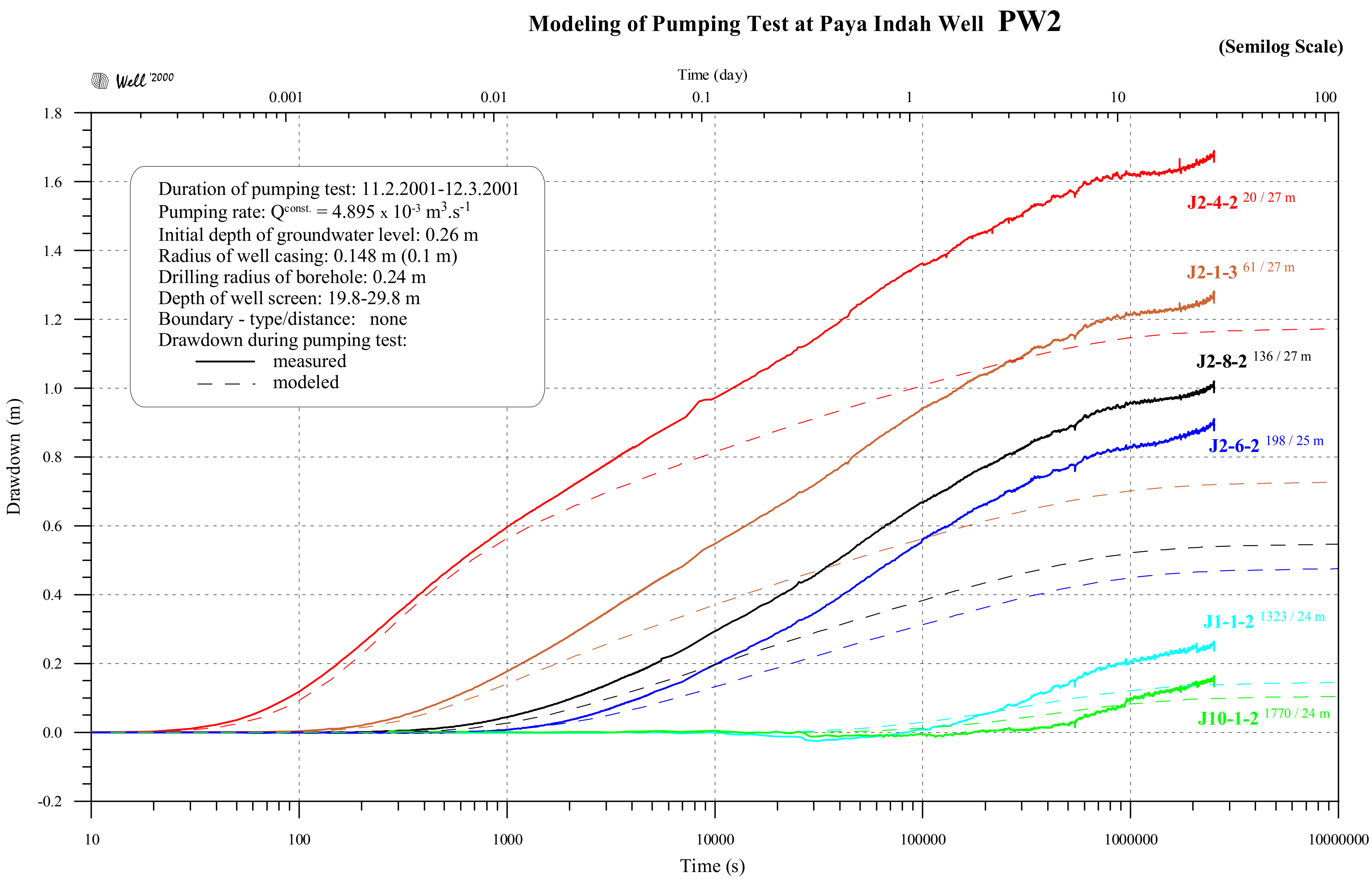


Figure G.3.18 Modeling of pumping test at Paya Indah - no boundaries (1/2)

ro_cs2_mod4h

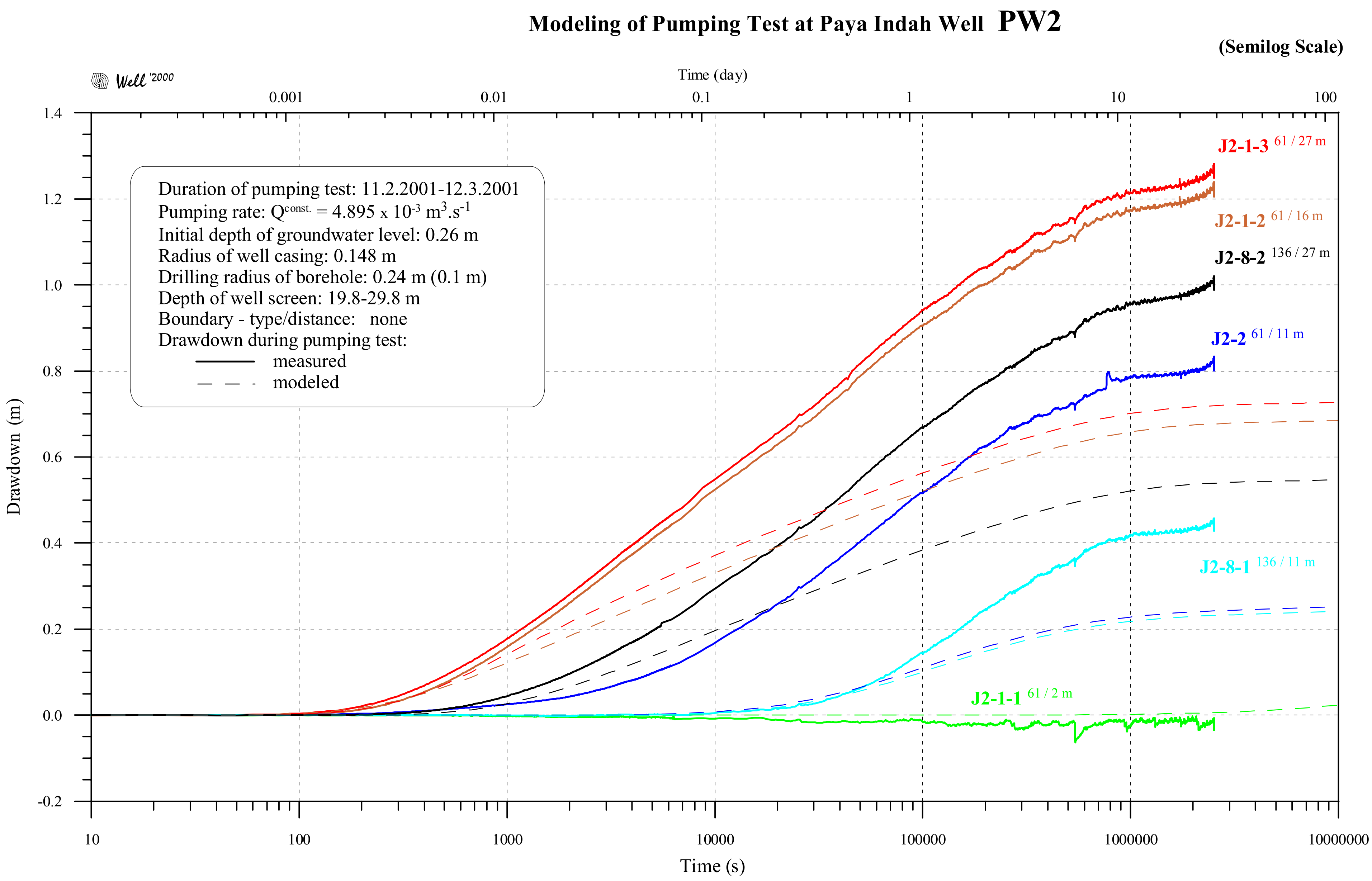


Figure G.3.19 Modeling of pumping test at Paya Indah - no boundaries (2/2)

ro_cs2_mod4p

(3) Impact of Lake

One of the goals of the pumping test at Paya Indah was to investigate relation between the main aquifer and the old mine pit, the present Paya Indah Lakes. The test should have given the answers, if the lake is hydraulically interconnected with the aquifer or not; if the aquifer is supplying the lake with water or not; or if the lake will be a recharge boundary in the case of aquifer exploitation, and to which degree.

The pumping test well was situated close (100 m) to the lake (**Figure G.2.5**), with piezometers situated in 4 directions that create a hydrogeological cross. Based on previous reports and information, it was supposed that the lake and aquifer are hydraulically interconnected. This means that the drawdown on observation piezometers during the pumping test will stabilise and steady state will be reached soon after start of pumping (see the modelling example near the recharge boundary, **Figures G.3.16 and G.3.17**).

The results of modelling indicate another theoretical possibility that the excavated mine pit is filled up with excavated material to some depth, or reaches the confined aquifer. This material is mostly clay, or mixture of excavated sand and silt with clay. The dredge pond, surrounding old lakes to some depth, is nearly impermeable and the lake area represents an impermeable boundary in the aquifer. In this case the drawdown does not stabilise and is steeper as in the case of an infinite aquifer (compare **Figures G.3.18-19 and G.3.12–13**).

(4) Groundwater Flow and Safe Yield

Groundwater flow at the locality of pumping test is from northwest to southeast (**Figure G.5.2**). The lake area is considered as impermeable groundwater flow barrier, and groundwater flows around the lake. It is presumed that the significant portion of aquifer recharge comes from surrounding bedrock outcrops.

Groundwater level decreased during the pumping test according to the time and distance from the pumping well (**Figures G.3.3-5**). The decrease is presented in **Figures G.3.10 and G.3.11**, where drawdown is plotted for specified time against the distance from the pumping well in semi-logarithmic scale. Pumping test with duration of 30 days is still too short for stabilisation of groundwater levels and reaching steady state flow conditions. Prediction of groundwater level for various scenarios shall be done using 3-D modelling.

Two separate groundwater bodies can be distinguished in profile: 1) The main aquifer located in the depth from 16 to 30 m, and 2) Shallow lateritic soil, peat, peaty clay horizon in the depth up to approximately 1-3 m. The shallow horizon is recharged from rainwater. Pumping of water from the main aquifer will not influence the moisture and water regime in the shallow soil and peaty body. This argument may or may not be valid.

The regional estimation of safe yield and permissible drawdown can be computed using the 3-D model. The calculation is based on interpreted hydraulic parameters from the pumping test and defined boundary conditions. The safe yield (or permissible drawdown) will only be the function of groundwater flow from the recharge area towards the northern site of the Main Lake at Paya Indah.

There is no obstruction from the point of vertical leakage, because vertical hydraulic conductivity is very small, and leakage is much smaller than infiltrated or effective rainfall (rainfall minus evapotranspiration). There is also no obstruction from the point of recharge from the lake, because the lake-aquifer boundary is very low permeable in comparison to aquifer permeability.

(5) Interpretation of Pumping Test for 3D Groundwater Model

The following important facts have been 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 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.

Interpreted aquifer parameters are listed in **Table G.3.1**. Comparison of hydraulic parameters of lower aquifer (Model Layer No. 3c and 3d) with other pumping test localities is given in **Table G.3.4**. Based on results of pumping test at Paya Indah, the hydraulic parameters for regional 3D groundwater flow model were derived (**Table G.4.1, Zone A**).

The aquifer water can be used for water supply. It seems that after proper distribution of few production wells, only about 5 to 10 l/s could be disposed in the area. Protection of main recharge areas should be focused on recharge possibilities and infiltrating water quality.

3.2.2 Pumping Test at Kajibumi WF 2

Kajibumi Well Field 2 is located approximately 2 km from the old but still active mining area. The site is considered under the mining area's hydraulic influence. Since the location is relatively far from the seacoast, the threat of fast seawater intrusion is not realistic. However, the aquifer is situated under the sea level, so that seawater intrusion is possible when pumping of large quantity of groundwater continues (mines and wells). The Langat River, located around 3 km away, may be a small source of aquifer recharge. The locality has already been chosen for local water supply. Pumping test was carried out from 12.12.2000 to 11.1.2001 with constant discharge of 73.8 l/s abstracted from well TU/B (well screen in depth 21.0-43.0 m). Locations of pumping test site, pumping well and piezometers are shown in **Figures G.2.3, G.2.9 and G.2.10**.

The goals of the pumping test were to investigate:

- Geological profile, the composition of aquifer bed, permeability distribution along the well (in vertical direction) using sieve analysis;
- Aquifer hydraulic conductivity, storage coefficients (specific elastic, eventually groundwater table) and transmissivity of aquifer;
- Boundary conditions (source of possible groundwater recharge) and its impact on groundwater flow;
- Groundwater level and piezometric level distribution in time and space before and during the pumping test, possibility of vertical flow from surface (soil) to aquifer and vice versa;
- Impact of pumping water on surrounding area (change of groundwater and piezometric levels);
- Impact of other factors and activities in the surrounding area on piezometric level fluctuation (pumping, mining, etc.);
- Safe yield for planed water supply (if duration of pumping test will be sufficient);
- Groundwater quality in the area, changes of groundwater quality during the pumping test;
- To prepare basic aquifer parameters for eventual proposal of pumping well field (waterworks); and
- To interpret the pumping test measurements and results and to prepare parameters characterising the aquifer and area for the groundwater model.

(1) Geological Profile

Figure G.2.11 contains the derived schematic geological log based on the evaluation of driller's logs from borehole BH5 and piezometer J5-2.

The top 4 m of geological profile consist of laterite soil, some peat and peaty clay, followed by silty clay and sandy clay down to 12 m. Laterite soils and peaty horizons can bear water and are recharged with rainwater. The clayey formation is nearly impermeable and creates aquiclude for lower laying aquifer. The upper water bearing horizon is located in the depth from 12 to 18 metres and consists of less permeable silty sands with gravel. In the depth interval from 18 to 23 m, clayey silt layer was documented. In the depth from 23 to the bedrock found in the depth 43 m (nearly impermeable shale), sandy and gravelly well permeable main aquifer is developed. The sediment sequence comprises intercalation of sandy silt and clay in the depth from 34 to 36 m.

The results of sieve analyses and grain size curves were processed for individual horizons and types of sediment, in the form suitable for comparison of sediment in different depths and at different localities (**Figures G.2.11-13** and **Data Book Figures G.2.5-7**). From granulometric curves, hydraulic conductivity and other hydraulic parameters were computed using the Carman-Kozeny method and compared with transmissivity, interpreted from the pumping test (**Figures G.2.11 and G.2.13**).

(2) Aquifer Hydraulic Parameters

Similar to Paya Indah locality, the complex interpretation of aquifer characteristics was based on careful evaluation of borehole logs, grain size analyses (granulometric curves), measurements of groundwater level at piezometers located in different depths and interpretation of pumping test.

All manual and automatic measurements during pumping test are plotted as time series in bi-linear and in semi-logarithmic scale (**Data Book G.3.2**). The following data measured during pumping test and recovery are presented in bi-linear scale:

- Groundwater level and discharge from pumping well TU/B measured by flow metre and V-notch, total abstraction of water at Megasteel wells PWM-1, PWM-2, PWM-3, PWM-4, TW-4 and SECOMEX (**Data Book Figure G.3.21**);
- Rainfall, air temperature, barometric pressure (**Data Book Figure G.3.22**);
- Water level fluctuation in Paya Indah Lotus Lake, in outflow from Paya Indah, in Langat River and in Canal 5 (**Annex Figure G.3.2**); and
- Drawdown in piezometers (**Data Book Figures G.3.23-25**).

Data Book Figures G.3.26-34 show the same data plotted in semi-logarithmic scale.

Impact of rainfall can be recognised in shallow piezometer J5-2-1 (**Data Book Figure G.3.24a**). Intensive rains may cause increase of water level in peat shallow organic sediments up to 0.4 m. In deep horizons this effect cannot be recognised, probably because of other much more dominating influences.

From comparison of piezometric levels in main aquifer with water levels in shallow piezometers and wells can be seen that in the area of pumping test the piezometric levels in the main aquifer are much lower than in shallow peaty horizons (**Figure G.2.11**). Dewatering of mine pits and pumping water from the aquifer at Megasteel well field may cause this low piezometric level.

Analytical and modelling interpretation of pumping test was performed by similar methodology like in Paya Indah, and also graphical presentation of results shall be already self-explanatory and understandable (see **Figures G.3.20-28**).

Graphical interpretation of drawdown *s* against logarithms *t* in **Figures G.3.20 to G.3.21** document that aquifer transmissivity is much higher than at Paya Indah.

After one day of pumping the radii of depression cone was around 2200 m and in 10 days it reached 5800 m. After 30 days of pumping, the drawdown reached about 6 km (**Figure G.3.24**). These values mean more than two times larger depression cone than developed during pumping test at Paya Indah.

Drawdown data was influenced by changing generators that was required every 12 hours, manipulation of data loggers, changes of barometric pressure, tidal fluctuation of Langat River and pumping water from Megasteel wells (see e. g. MW-1 and other curves in **Figure G.3.25**). Based on available data these influences were corrected or compensated to allow representative interpretation.

The results of pumping test mean that the aquitard is very low leaky and/or recharge boundary exists in a very large distance.

Pumping Test at Kajibumi Well TU/B

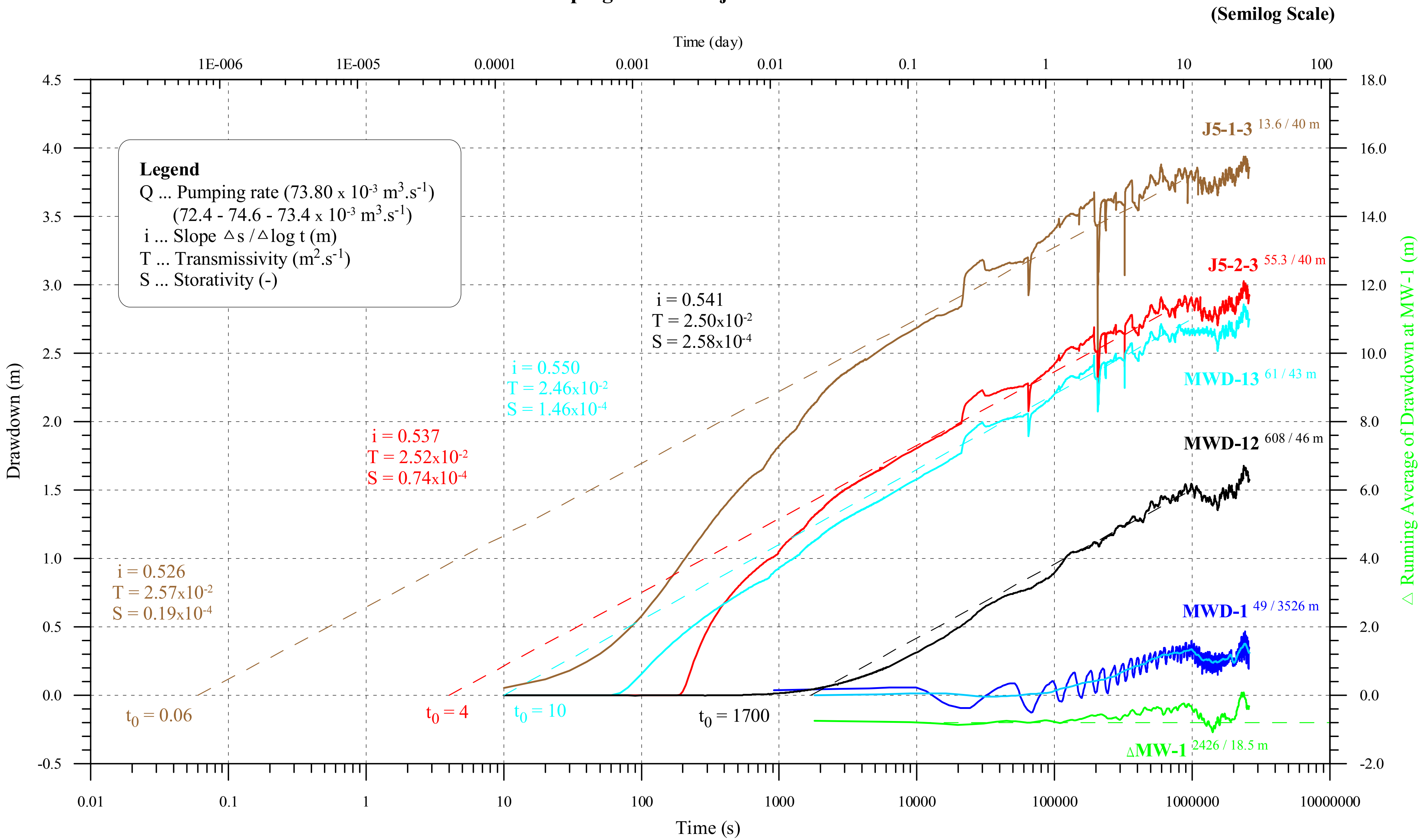


Figure G.3.20 Interpretation of pumping test at Kajibumi WF 2 - drawdown versus time plot in xy direction

ro_cs5_st1

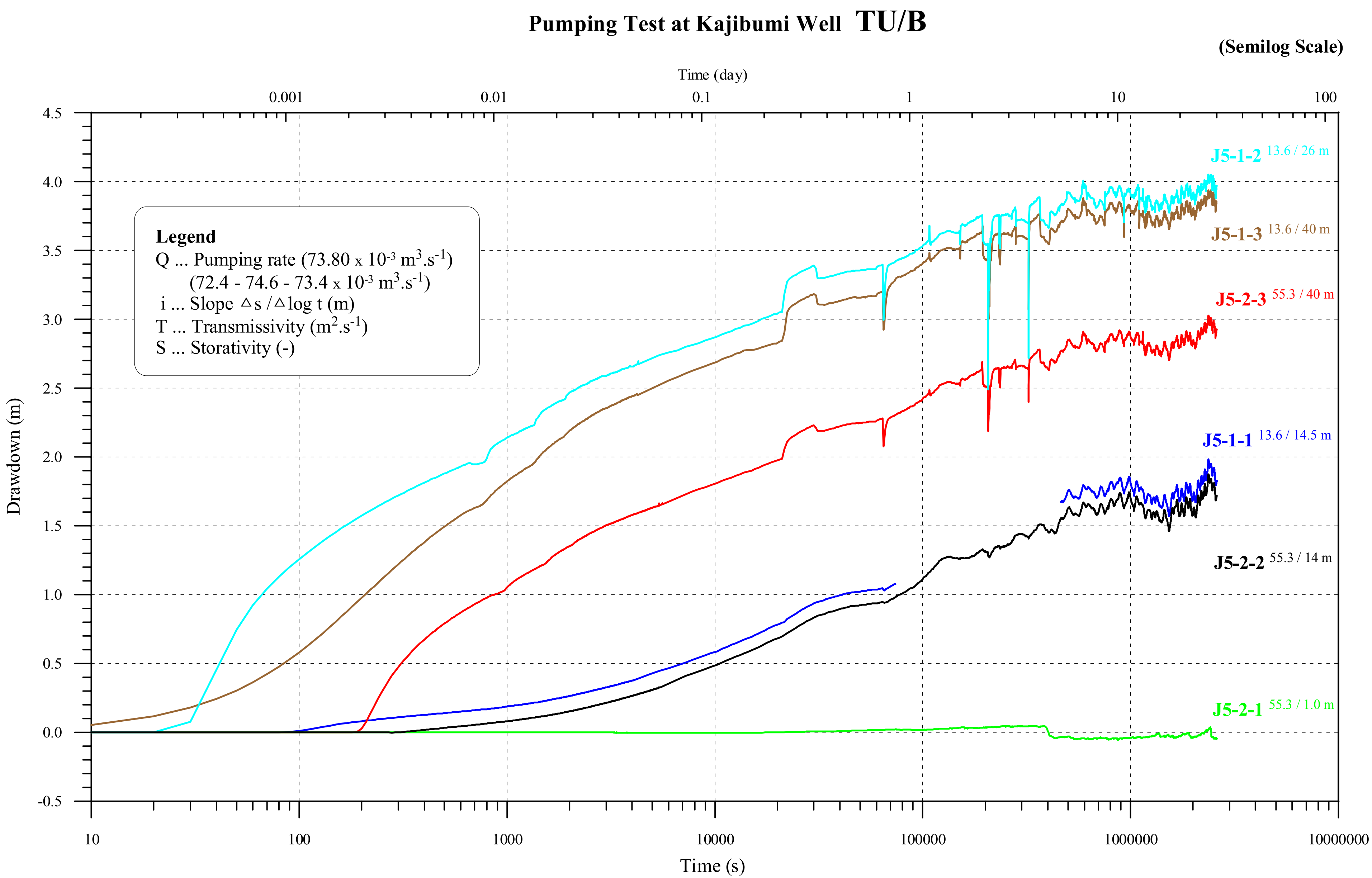


Figure G.3.21 Interpretation of pumping test at Kajibumi WF 2 - drawdown versus time plot in z direction

ro_cs5_st2

Pumping Test at Kajibumi Well TU/B

(Semilog Scale)

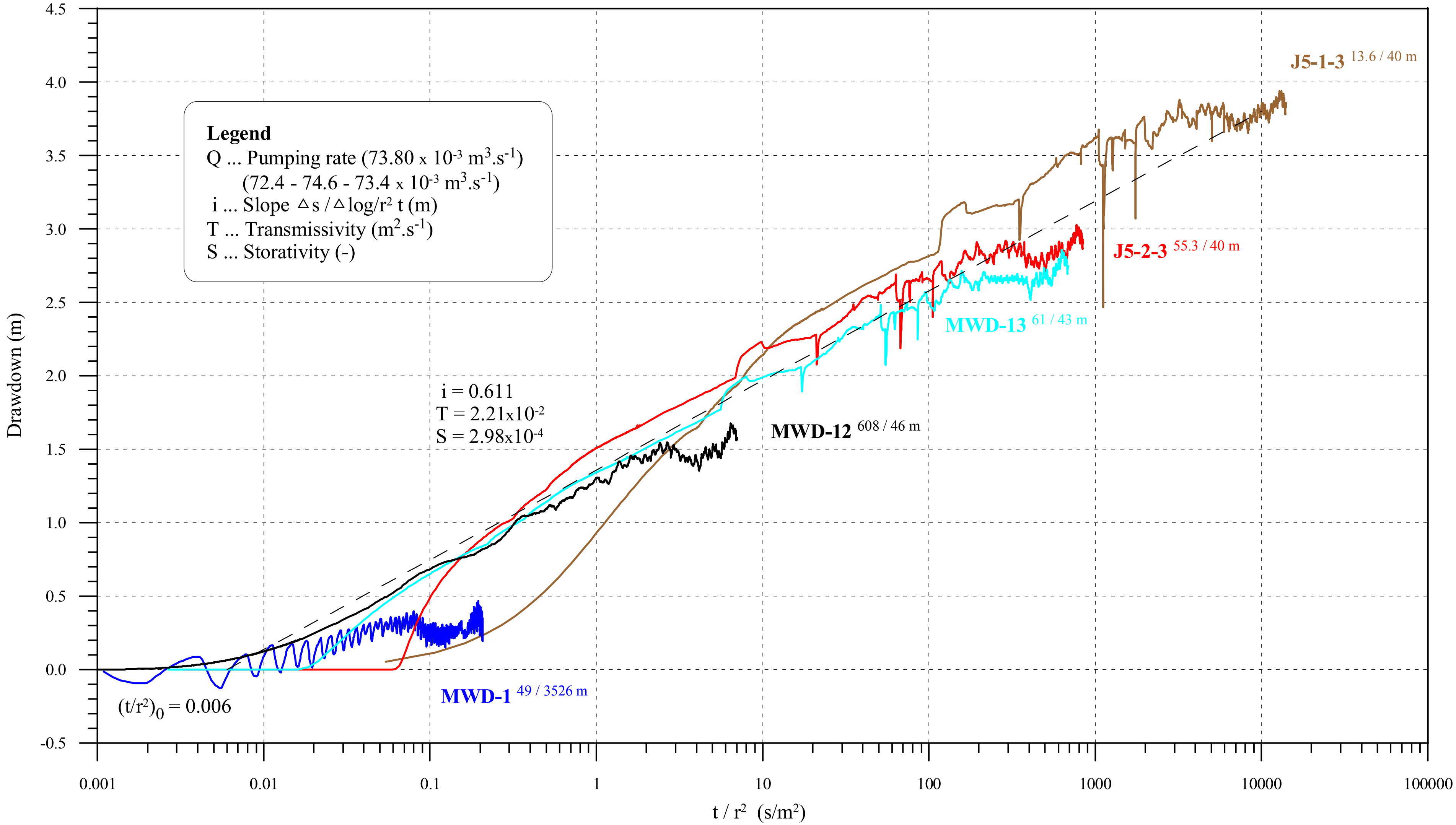


Figure G.3.22 Interpretation of pumping test at Kajibumi WF 2 - drawdown versus t/r^2 plot

ro_cs5_str2

Recovery Test at Kajibumi Well TU/B

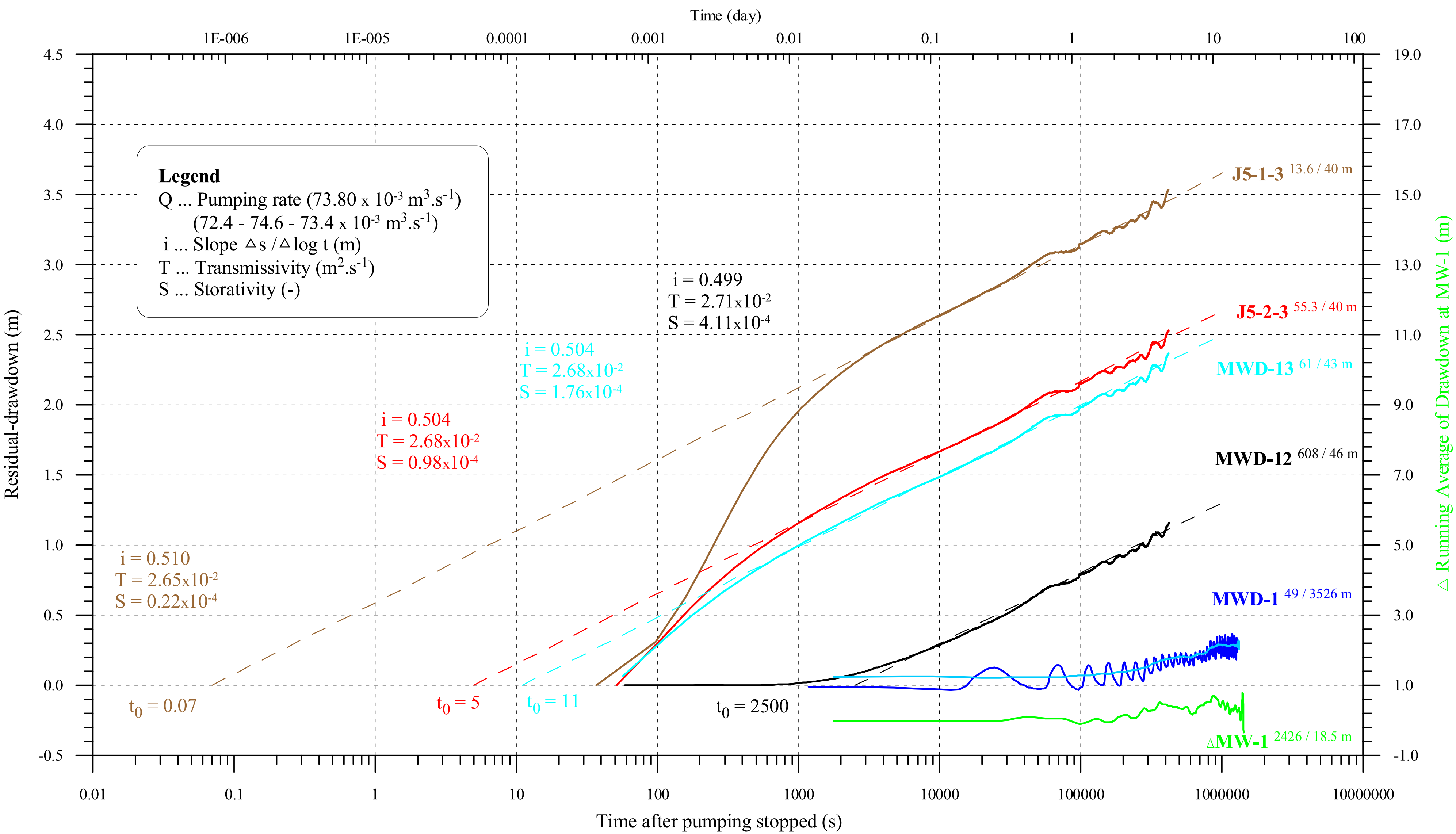


Figure G.3.23 Interpretation of recovery test at Kajibumi WF 2 - residual-drawdown versus time plot in xy direction

ro_ss5_st1

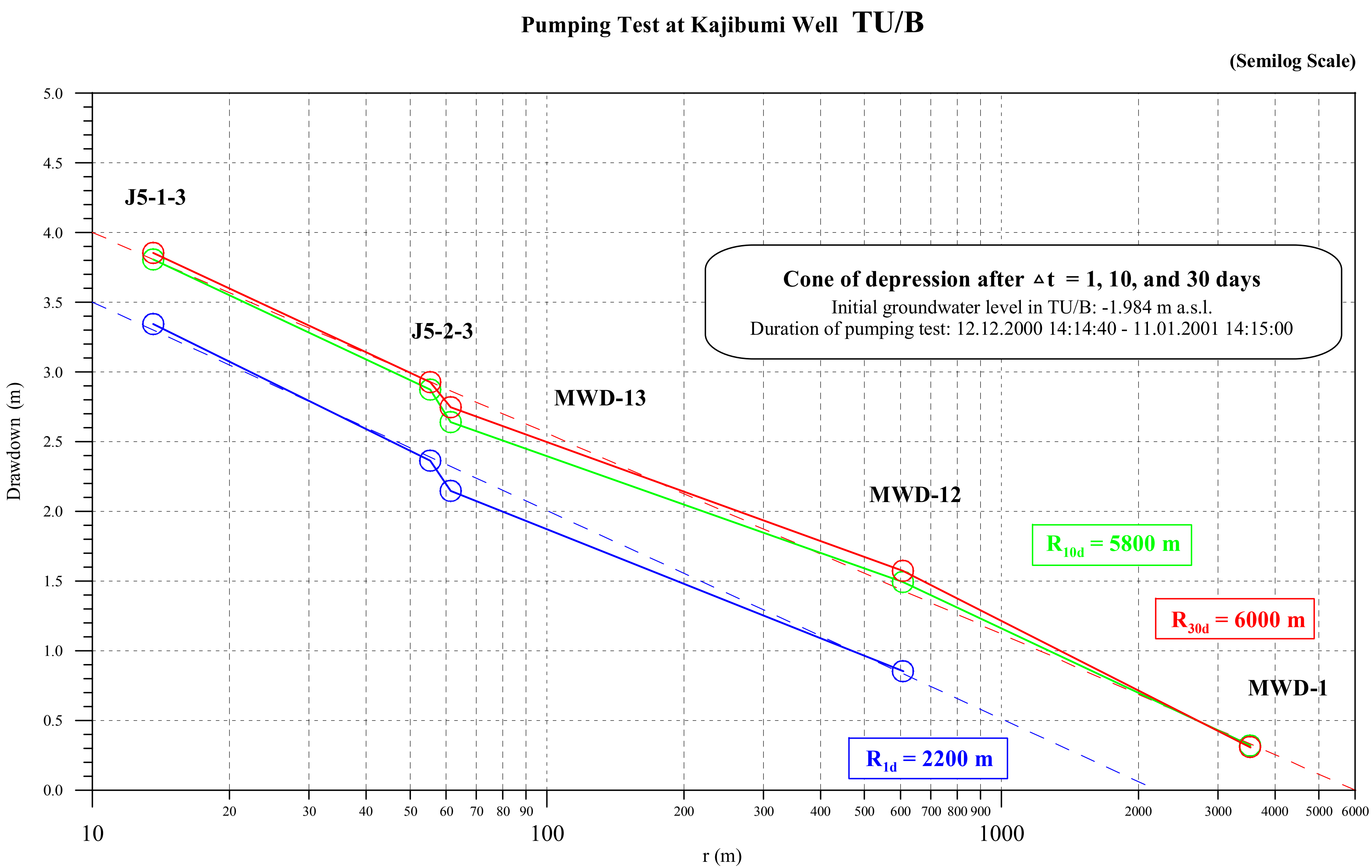


Figure G.3.24 Interpretation of pumping test at Kajibumi WF 2 - change of depression cone during pumping test

ro_cs5_sr1

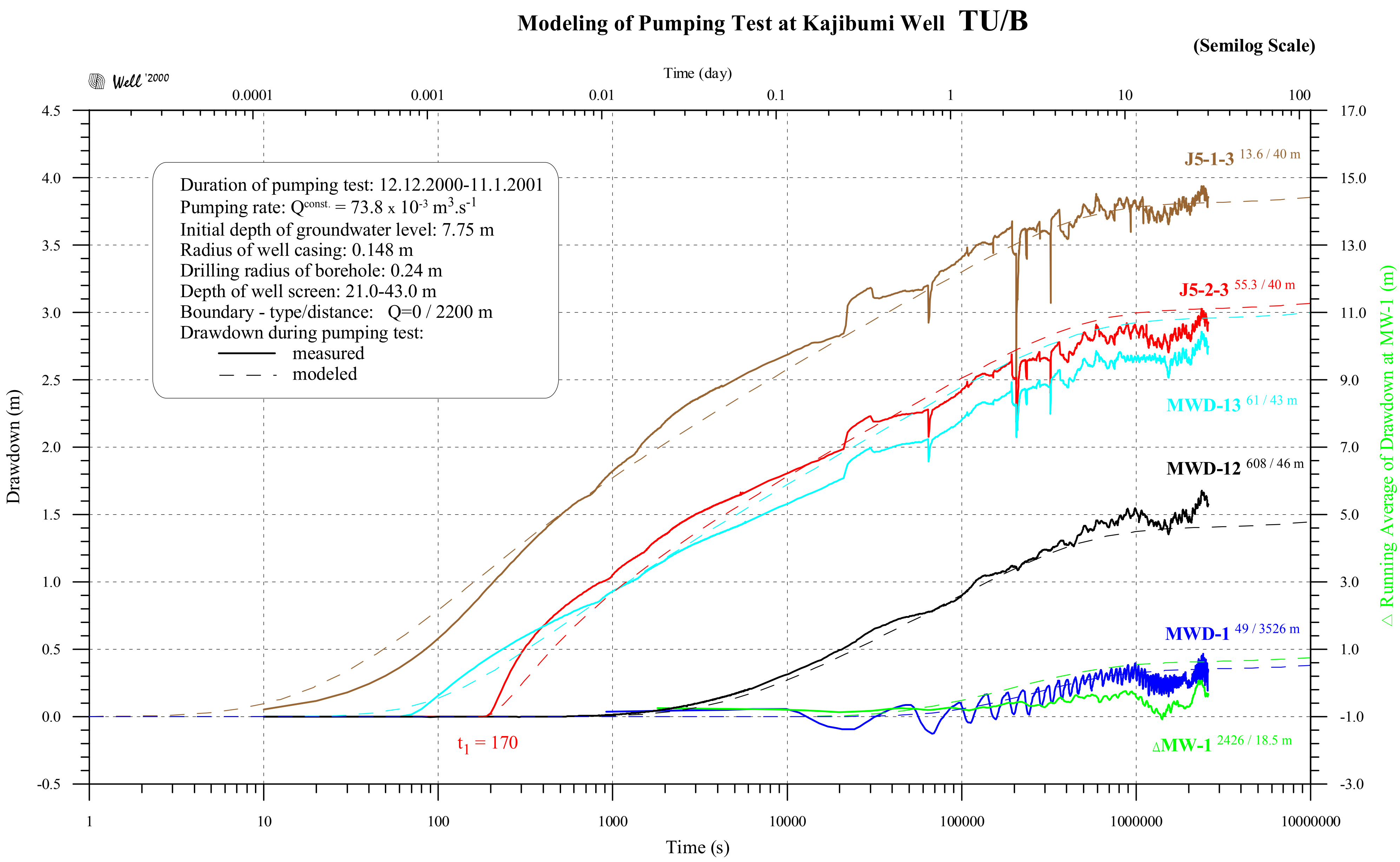


Figure G.3.25 Modeling of pumping test at Kajibumi WF 2 - modeled and measured drawdown in different distance from pumping well

ro_cs5_mod1h

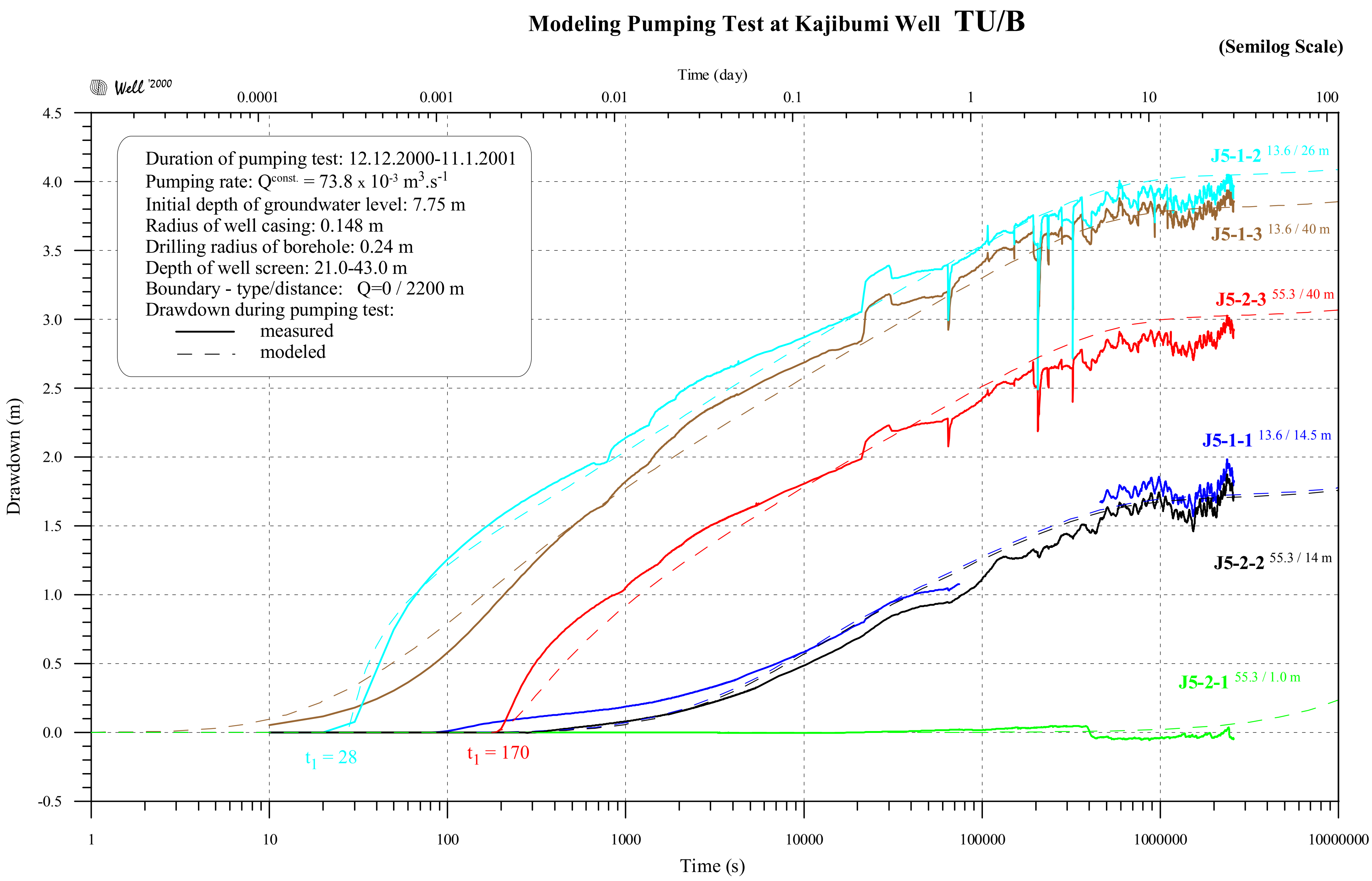


Figure G.3.26 Modeling of pumping test at Kajibumi WF 2 - modeled and measured drawdown in different depth

ro_cs5_mod1p

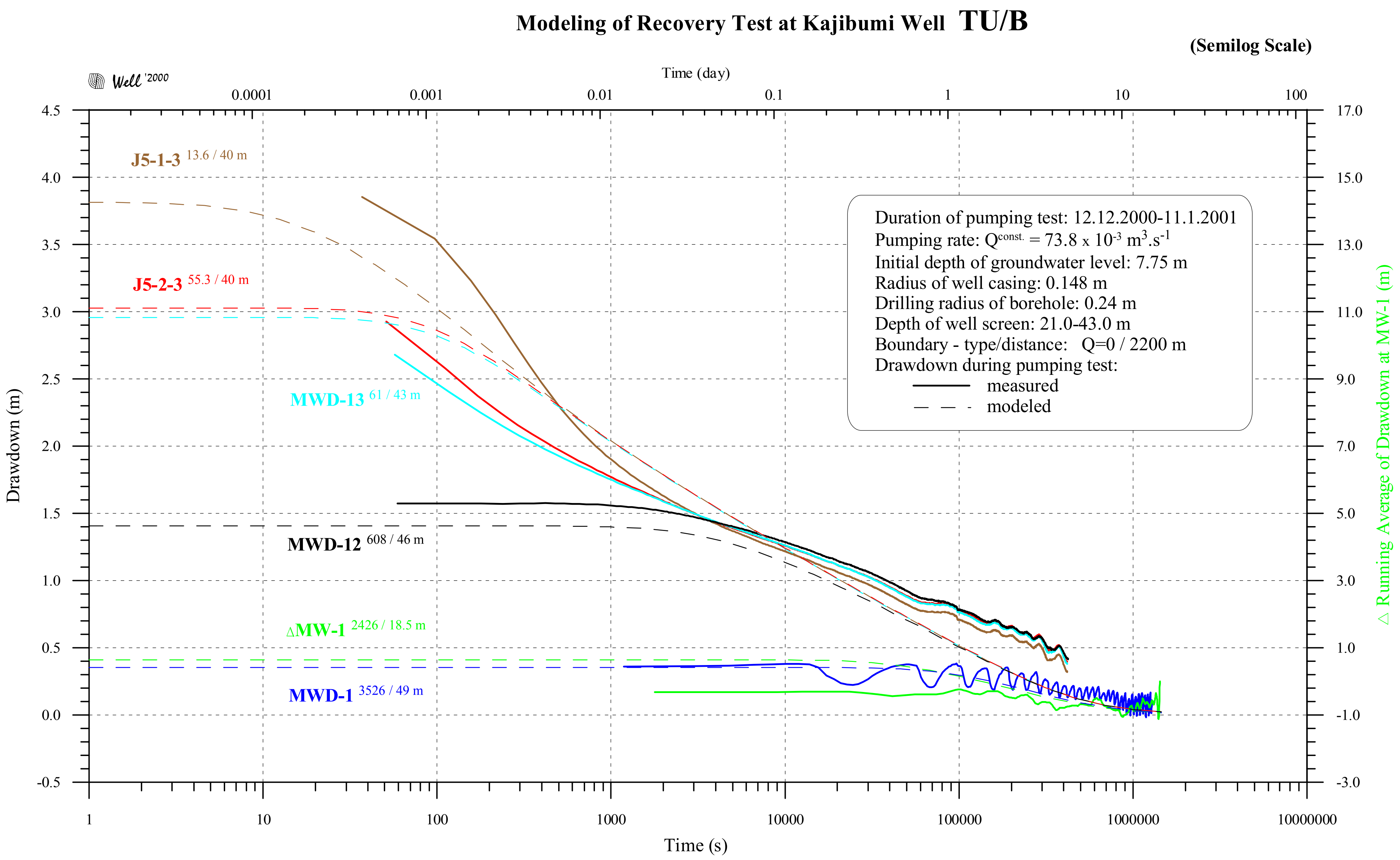


Figure G.3.27 Modeling of recovery test at Kajibumi WF 2 - modeled and measured drawdown in different distance from pumping well

ro_ss5_mod1h

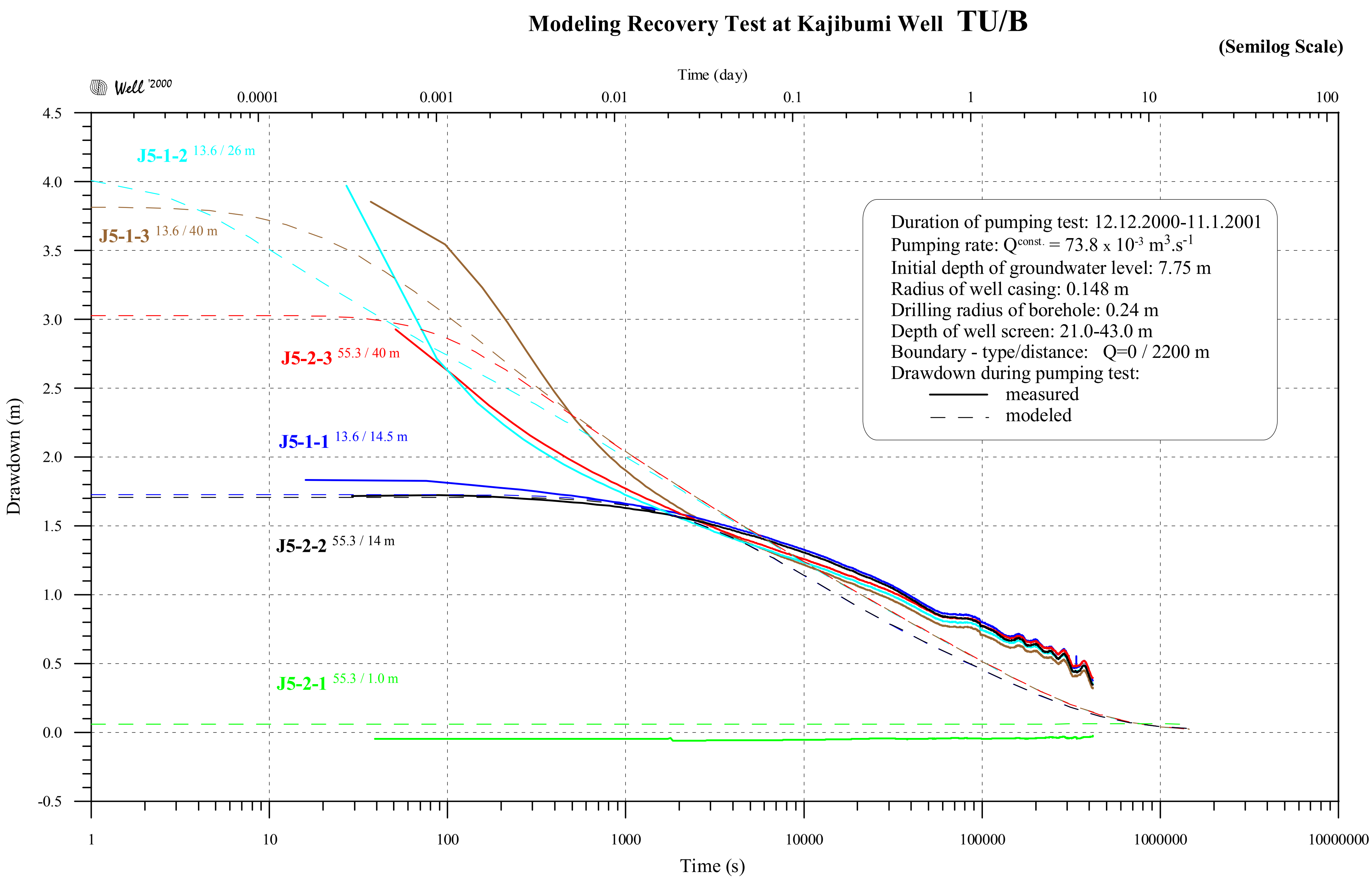


Figure G.3.28 Modeling of recovery test at Kajibumi WF 2 - modeled and measured drawdown in different depth

ro_ss5_mod1p

Course of real and modelled drawdown during pumping test and recovery, under leaky conditions and under the assumption that there exist an impermeable boundary 2200 m away, is shown in **Figures G.3.25-28**. Input data and interpreted hydraulic parameters are described in figures and in **Table G.3.2.**

Table G.3.2 Pumping Test Modelling at Kajibumi WF 2 – Hydraulic Parameters

Layer No.	Depth (m)	Thick. b (m)	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	4.0	4.0	1.00e-4	1.00e-5	10	1e-3	0.3	Peat, laterite soil
2	12.0	8.0	1.20e-8	9.23e-9	1.30	6e-6	0.01	Silty clay
3a	18.0	6.0	1.00e-4	1.00e-5	10	6e-6	0.15	Clayey sand with gravel
3b	23.0	5.0	1.00e-7	6.00e-8	1.67	6e-6	0.01	Clayey silt
3c	34.0	11.0	1.40e-3	1.40e-4	10	3e-5	0.2	Silty sand and gravel, sandy clay
	36.0	2.0	1.00e-5	1.00e-5	1	3e-5	0.2	
3c avg	36	13	1.18e-3	4.67e-5	25	3e-5	0.2	
3d	43.0	7.0	2.00e-4	1.00e-5	20	3e-5	0.2	Silty sand and gravel
3c-3d avg	43	20	8.41e-4	2.04e-5	41	3e-5	0.2	

Legend: 3c – 3d avg - average (characteristic) value for layer 3c and 3d

(3) Boundary Conditions and Impact of Other Activities on Groundwater

The course of drawdown indicates the presence of an impermeable boundary at about 2200 m away. This impermeable or less permeable boundary may probably correspond to dredge ponds around Paya Indah Lakes (**Figures G.2.1 and G.2.3**).

Cone of depression after 30 days reached the distance of 6 km, which means that the possible minimal recharge boundary can be situated more than 3 km from the pumping test site.

Due to very low vertical hydraulic conductivity between the main aquifer and the subsurface peaty horizon, leakage from the surface is very low (**Figures G.3.21**, **26 and 28**, piezometer J5-2-1).

The most important boundary is located towards the seaside, where according to the groundwater overexploitation, seawater intrusion can take place (position of saltwater/freshwater interface).

The most important activities, which affect the regional groundwater regime in the area, are:

- Dewatering of tin mine's pits (Imuda Mine).
- Pumping water from existing water supply wells (Megasteel).

Dewatering of mines takes water from the main aquifer and thus it is using water, which would be possible for water supply. In addition, this water extraction supports groundwater overexploitation and following seawater intrusion into the main aquifer.

Monitoring wells MW1, MWD1, MWD10, and MWS10 located in greater distance from the pumping well were measured during pumping test to document the influence of water exploitation from Magasteel wells and tidal effect and fluctuation of surface water level in Langat River.

Annex Figure G.3.3a and G.3.4a show in linear scale drawdown at well MW1, MWD12 and MWD13. These figures indicate that groundwater level fluctuation at Megasteel (well MW1, located 2426 m from Kajibumi WF 2), caused by periodical groundwater extraction, creates groundwater level fluctuation on well MWD12 and MWD13. Amplitude of groundwater level fluctuation in well MW1 is up to 2.5 m and the response in MWD12 is few centimetres. This demonstrates that in the Study area, confined conditions exist and the extent of cone depression is very large.

Annex Figures G.3.2b and G.3.4c show the drawdown at well MWD1 and fluctuation of water level in Langat River (SW6). Groundwater level on piezometer MWD1 (in the depth of 49 m) fluctuates with amplitude approximately 10 cm as a response to surface water level fluctuation in the Langat River (fluctuation 2 m). This example shows that the groundwater is to some very low degree hydraulically interconnected with the Langat River and slightly influenced by the tidal effect.

Annex Figures G.3.3b and c show drawdown at well MWD10 and MWS10. Shallow piezometer MWS10 (in 12 m depth) and deep piezometer MWD10 (in 43 m depth) are situated near the Langat River. Amplitude of groundwater level fluctuation in shallow piezometer is higher than in the deep one. This figure demonstrates similar interconnection between the Langat River and groundwater. Source of fluctuation is the Langat River, where the amplitude of fluctuation is the highest.

(4) Impact on Surrounding Area

Similar to Paya Indah, there are two separate groundwater bodies: the main aquifer in the depth from 23 to 43 m and that in shallow laterite soil, peat, peaty clay. Pumping of water from the main aquifer does not influence moisture and water regime in the shallow soil and peaty body because the leakage of water is much smaller than infiltrated rain (rain minus evapotranspiration).

If the covering clays are not removed or penetrated, no significant impact of water from peaty horizon is expected in the main aquifer in the surrounding of the pumping test site. The leakage of some quantity of peat water polluted by natural organic matters may lead to deterioration of present groundwater quality of the main aquifer.

(5) Groundwater Flow, Well Fields and Safe Yield

Groundwater flow at the locality of pumping test depends on abstraction of water from neighbouring well fields and mines. The main inflow of fresh groundwater may be expected from northwest and northeast direction (**Figure G.5.2**). The lake area at Paya Indah is considered as impermeable groundwater flow barrier, and groundwater flows around the lake.

The decrease of groundwater level (in time and space) caused by pumping is documented in **Figures G.3.20-21** and **Figure G.3.24**.

Because of relative high hydraulic conductivity and thickness of the main aquifer high discharges from pumping wells could be expected. The safe yield in this area represents the groundwater quantity, which can recharge the aquifer at proposed groundwater exploitation, minus groundwater discharge into the sea, which is necessary to keep the fresh-saline water interface in some safe distance from the waterworks wells. 3-D modelling and groundwater monitoring and management are aimed for estimation of safe yield in regional scale.

The main parameter for proposal of water supply wells and estimation of safe yield is aquifer geometry and transmissivity, which in this area is about $1.7x\ 10^{-2}$ m^2/s. Seawater intrusion and recharge areas should be taken into consideration. Using steady state modelling approach optimal system of production wells should be proposed.

(6) Interpretation of Pumping Test for 3D Groundwater Model

The following important facts have been 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 distance 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 is using water, which can be used for water supply purposes.
- Seaside is a boundary condition with the possible seawater intrusion.
- Basic hydraulic parameters of lower sand and gravel aquifer interpreted from pumping test are as follows: transmissivity T about 1.7 x 10^{-2} m^2/s, and elastic storage S about 6.0 x 10^{-4} (when considering lake at Paya Indah as impermeable boundary).
- Vertical hydraulic conductivity of aquitard is low, approximately 6.0 x 10^{-8} or 9.2 x 10^{-9} m/s.

Interpreted aquifer parameters are listed in **Table G.3.2**. Comparison of hydraulic parameters of lower aquifer (model layer No. 3c and 3d) with other pumping test localities is given in **Table G.3.4**. Based on results of pumping test at Paya Indah the hydraulic parameters for regional 3D groundwater flow model were derived (**Table G.4.1**, zone B).

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 to disposal. Problem of aquifer overexploitation and intrusion of seawater will be the main limiting factor of groundwater safe yield estimation.

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. Except this measures against seawater intrusion, based on monitoring, should be elaborated.

3.2.3 Pumping Test at Kanchong Darat

Kanchong Darat area is located between the Langat River and the seacoast. Marine impermeable clayey sediments cover the aquifer. Aquifer is characterised as confined or semi confined. Large spread of cone of depression was expected during the pumping test. Seawater intrusion was predicted, when exploiting groundwater. Pumping test was running from 18.3.2001 to 17.4.2001 with constant discharge 27.2 l/s abstracted from well PW 7 (well screen in depth 51.5-56.5 m). Location of pumping test site, pumping well and piezometers is shown in **Figures G.2.3**, **G.2.14 and G.2.15**.

Except the piezometers located near pumping well, two piezometers for observation of shallow and deep aquifer were situated and measured directly at the seaside (J8, J9), to monitor the piezometric level fluctuation according to the seawater level fluctuation, and to estimate the seawater intrusion. Available data collected from Megasteel well MW1, MWD2 and other long term monitoring wells were supposed to support interpretation procedure.

The main goals of the pumping test were to investigate:

- Geological profile and bedrock composition, permeability distribution along the soil investigation borehole (in vertical directions) using sieve analyses;
- Hydraulic conductivity, storage and transmissivity of the aquifer;
- Piezometric and groundwater level distribution and groundwater level fluctuation in time and space before and during the pumping test;
- Impact of water pumping on surrounding area, ecological aspects, groundwater flow;
- Groundwater quality in the area, changes of groundwater quality during the pumping test;
- Another factors having impact on groundwater flow and water level fluctuation, for example sea water level fluctuation;
- Safe yield for eventual water supply; and
- Basic aquifer parameters and groundwater level fluctuation for the groundwater flow modelling.

(1) Geological Profile

Figure G.2.16 contains schematic geological log based on evaluation of driller's logs from borehole BH7.

The top 4 metres consist of soil, peat and peaty clay, followed with light grey to grey very soft silty clay with sand. In the depth from 10 to 12 metres a thin layer of silty sand containing shells can be expected. Downwards, from 12 to 22 metres, is silty clay with wooden rests. This entire sequence is mostly impermeable or low permeable and is covering deeper more permeable sediments. More permeable sandy sediments start with silty sand from 22 to 31 m, followed with silty clay with sand (from 31 to 34 m) and silty sand (from 34 to 37 m). From 37 to 44.5 m, again very low permeable silty clay with sand is present. The first more permeable horizon containing in the deepest part also gravel starts in the depth of 44.5 m and reaches the depth of 57 m. In the horizon from 57 to 63 m, two layers of silty clay with gravel and silty sand were documented (in interval 57 to 59 m and 61 to 63 m, respectively).

The main aquifer consists of silty sand with quartz gravels and was confirmed in the depth below 63 m. The interval from 81 to 83 contains the layers of less permeable silty sand and clay. The main aquifer continues at least until 127 m, where the drilling stopped. Bedrock was not reached (estimated to be in the depth of 130 to 150 m).

The results of sieve analyses and grain size curves were processed for individual horizons and types of sediment (**Figures G.2.16-18**, **Data Book Figures G.2.8-11**). From granulometric curves, hydraulic conductivity and other hydraulic parameters were computed using the Carman-Kozeny method and compared with transmissivity, interpreted from the pumping test (**Figures G.2.16 and G.2.18**).

(2) Aquifer Hydraulic Parameters

Similar to other pumping test localities, the complex interpretation of aquifer characteristics was based on careful evaluation of borehole log, grain size analyses (granulometric curves), measurements of groundwater level at piezometers located in different depths and interpretation of pumping test.

All available manual and automatic measurements during pumping test are plotted as time series in bi-linear and in semi-logarithmic scale (**Data Book G.3.3**). The following data measured during pumping test and recovery are presented in bi-linear scale:

- Groundwater level and discharge from pumping well PW 7 measured by flow meter and V-notch (**Data Book Figure G.3.35**);
- Rainfall, air temperature, barometric pressure (**Data Book Figure G.3.36**);
- Water level fluctuation in Paya Indah Lotus Lake, in Langat River (data not available at the time of report writing) and in Canal 7 (**Data Book Figure G.3.37**); and
- Drawdown in piezometers (**Data Book Figure G.3.38-42**).

Data Book Figures G.3.43-51 show the same data plotted in semi-logarithmic scale.

The pumping test interpretation was complicated by intensive rainfall during pumping test, technical problems with data loggers and other influences. The conditions during recovery test were significantly more convenient for representative interpretation. Interpretation procedure was accommodated to minimise the effect of negative influences.

Impact of intensive rainfall can be recognised from the course of drawdown at pumping well PW 7 (**Figure G.3.29**, see also **Data Book Figures G.3.36a and G.3.44a**). Intensive rains caused increase of water level in canals and peat shallow organic sediments (**Data Book Figure G.3.37c**).

From comparison of piezometric levels in main aquifer with water levels in shallow piezometers and other piezometers can be seen that in the area of pumping test the piezometric levels in the main aquifer are lower than in shallow peaty or sandy horizons (**Figure G.2.16**).

The presentation of pumping test results and its interpretation was performed by similar methodology like in Paya Indah and Kajibumi WF 2; the pumping test data were evaluated paralelly with recovery data (see **Figures G.3.30-35**).

Graphical interpretation of drawdown *s* against logarithms *t* in **Figures G.3.30-31** document that aquifer transmissivity is higher than at Kajibumi WF 2.

Since the aquifer at Kanchong Darat is stratified, very thick, leaky, and the pumping well is only partially penetrating it, the analytical evaluation could not provide representative results. In the case of stratified and thick aquifer and partially penetrating pumping well, the proper interpretation of basic hydraulic parameters required application of modelling method. The evaluation of hydraulic parameters, interpretation of boundary conditions, and evaluation of vertical leakage was performed by numerical model of pumping test (Program Well, GROUND WATER Consulting).

Figures G.3.32 to G.3.35 show the comparison of measured and modelled drawdowns in the aquifer (depth 54 m). After one day of pumping the radii of depression cone was around 3300 m; in 10 days it reached 6000 m. After 30 days of pumping, the drawdown reached about 9 km (**Figure G.3.35**). These values represent still larger depression cone than developed during pumping test at Kajibumi WF 2.

The aquifer is stratified and the aquitards are very low leaky. **Figure G.3.34** documents the lowering of groundwater table and piezometric heads in different strata and distance from pumping well.

Input data and interpreted hydraulic parameters are described in figures and in **Table G.3.3.**

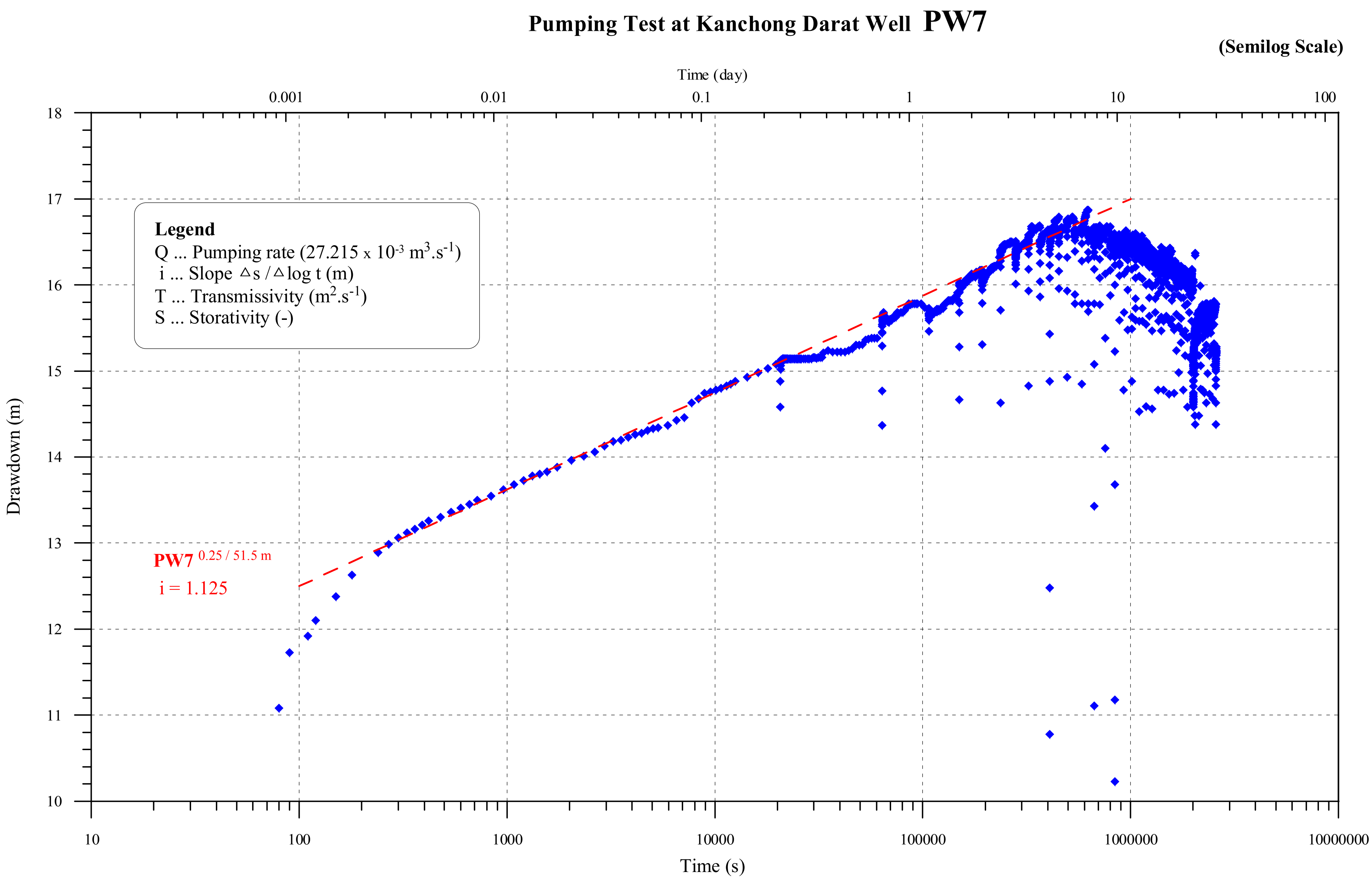


Figure G.3.29 Interpretation of pumping test at Kanchong Darat - drawdown versus time plot at pumping well PW7

ro_cs7_st1x

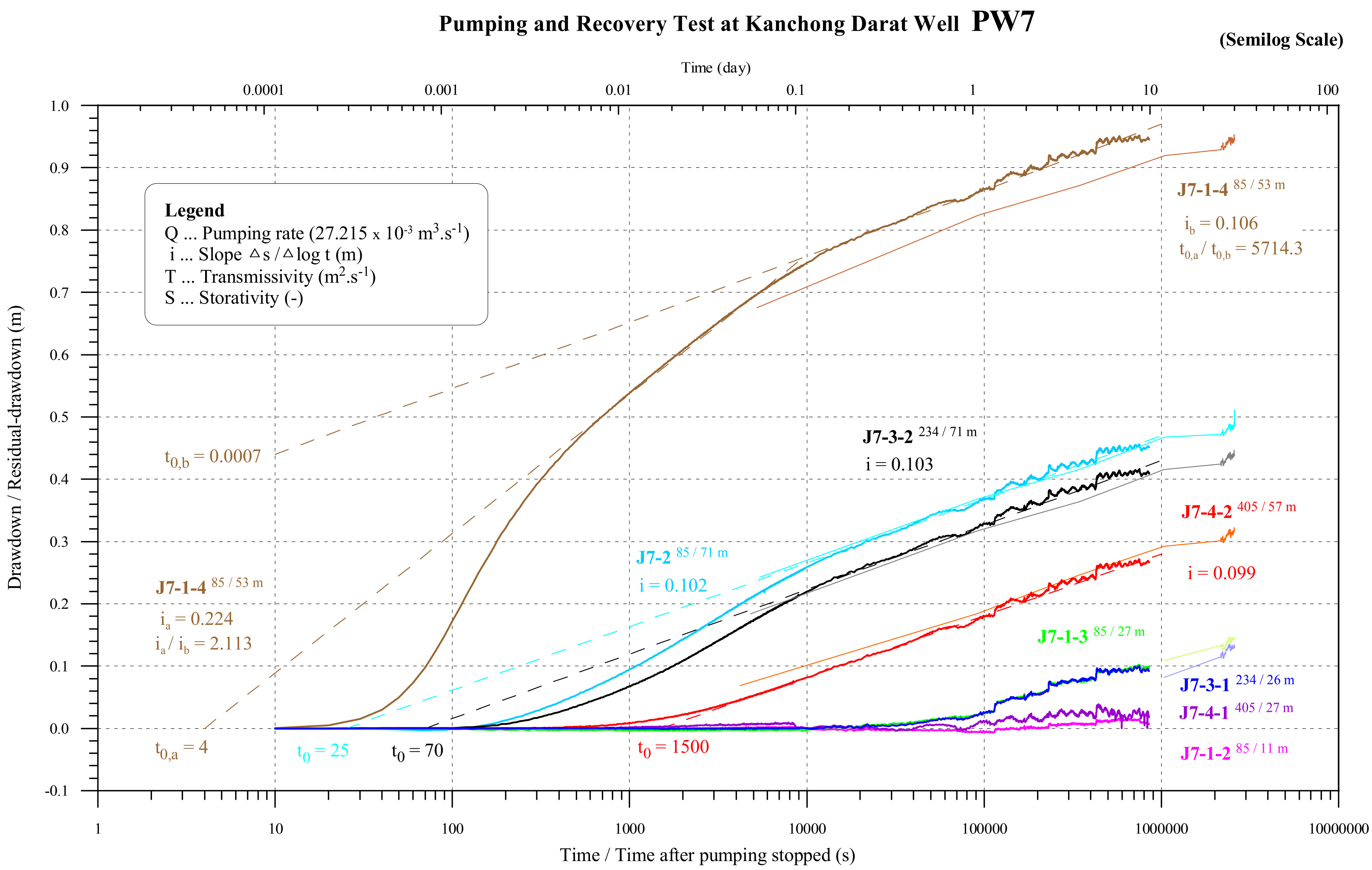


Figure G.3.30 Interpretation of pumping and recovery test at Kanchong Darat - drawdown (residual-drawdown) versus time plot

ro_csss7_st1x

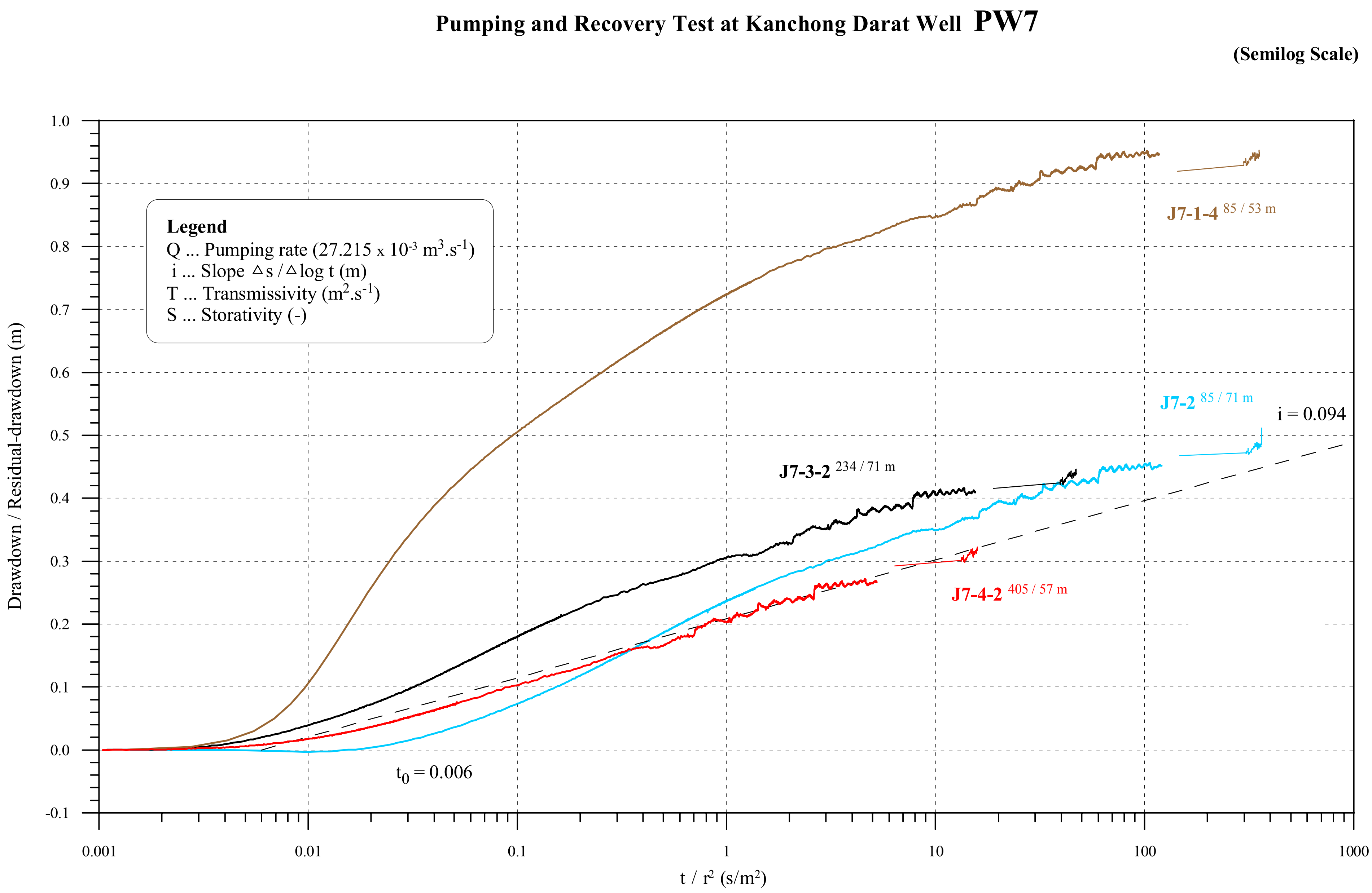


Figure G.3.31 Interpretation of pumping and recovery test at Kanchong Darat - drawdown (residual-drawdown) versus t/r^2 plot

ro_csss7_str2x

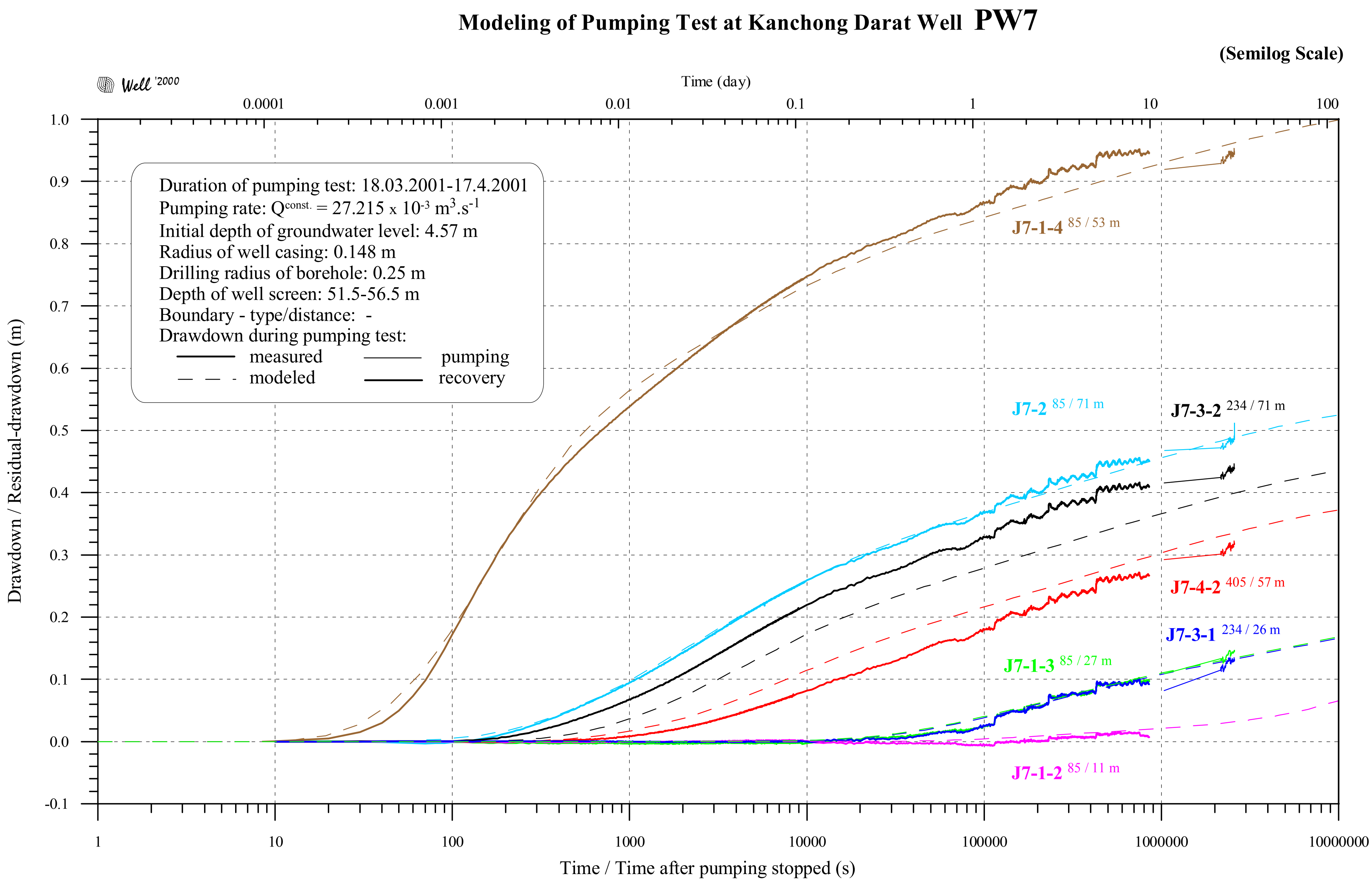


Figure G.3.32 Modeling of pumping test at Kanchong Darat - modeled and measured drawdown (residual-drawdown)

ro_csss7_mod

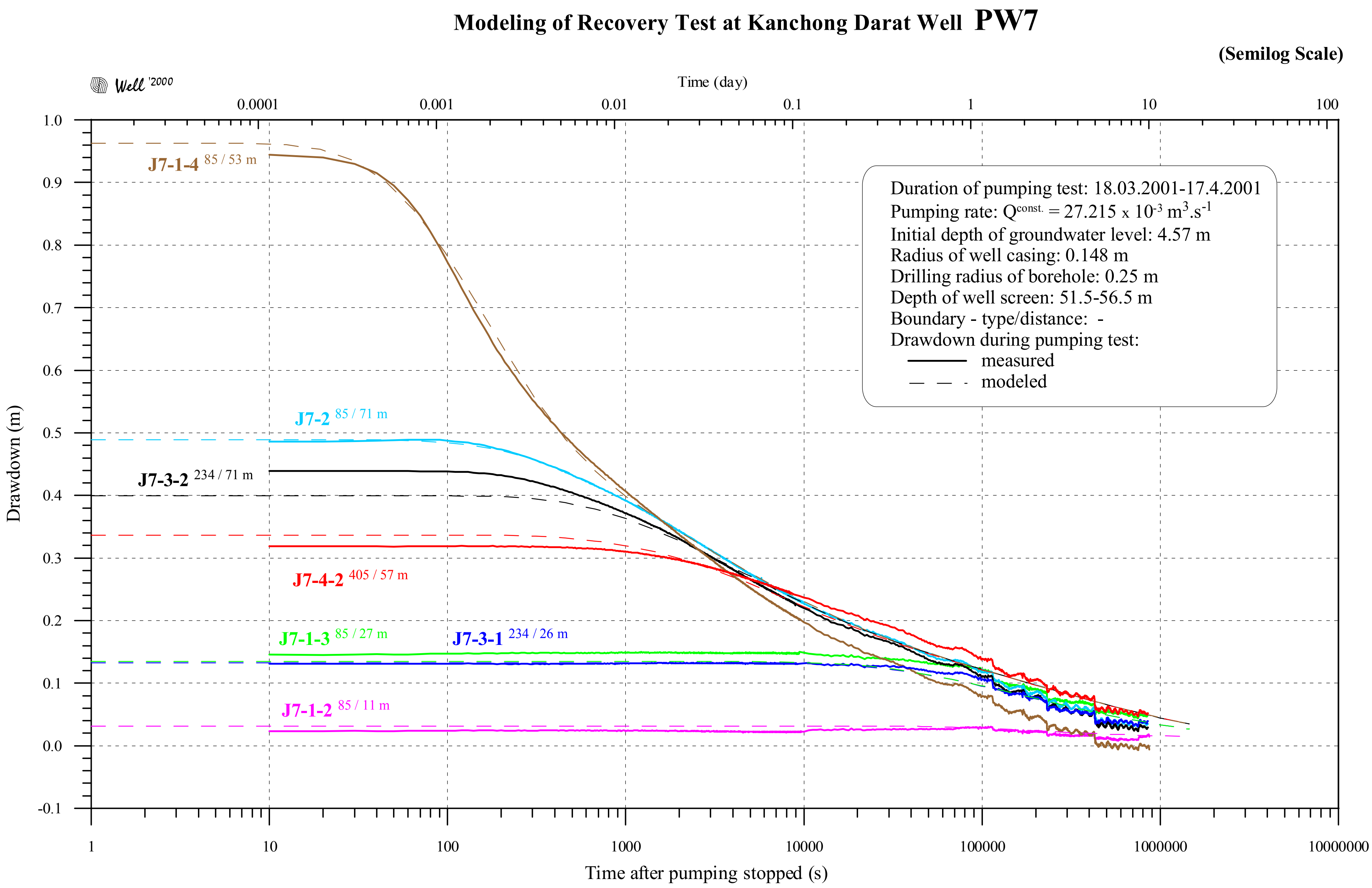


Figure G.3.33 Modeling of recovery test at Kanchong Darat - modeled and measured drawdown

ro_ss7_mod1

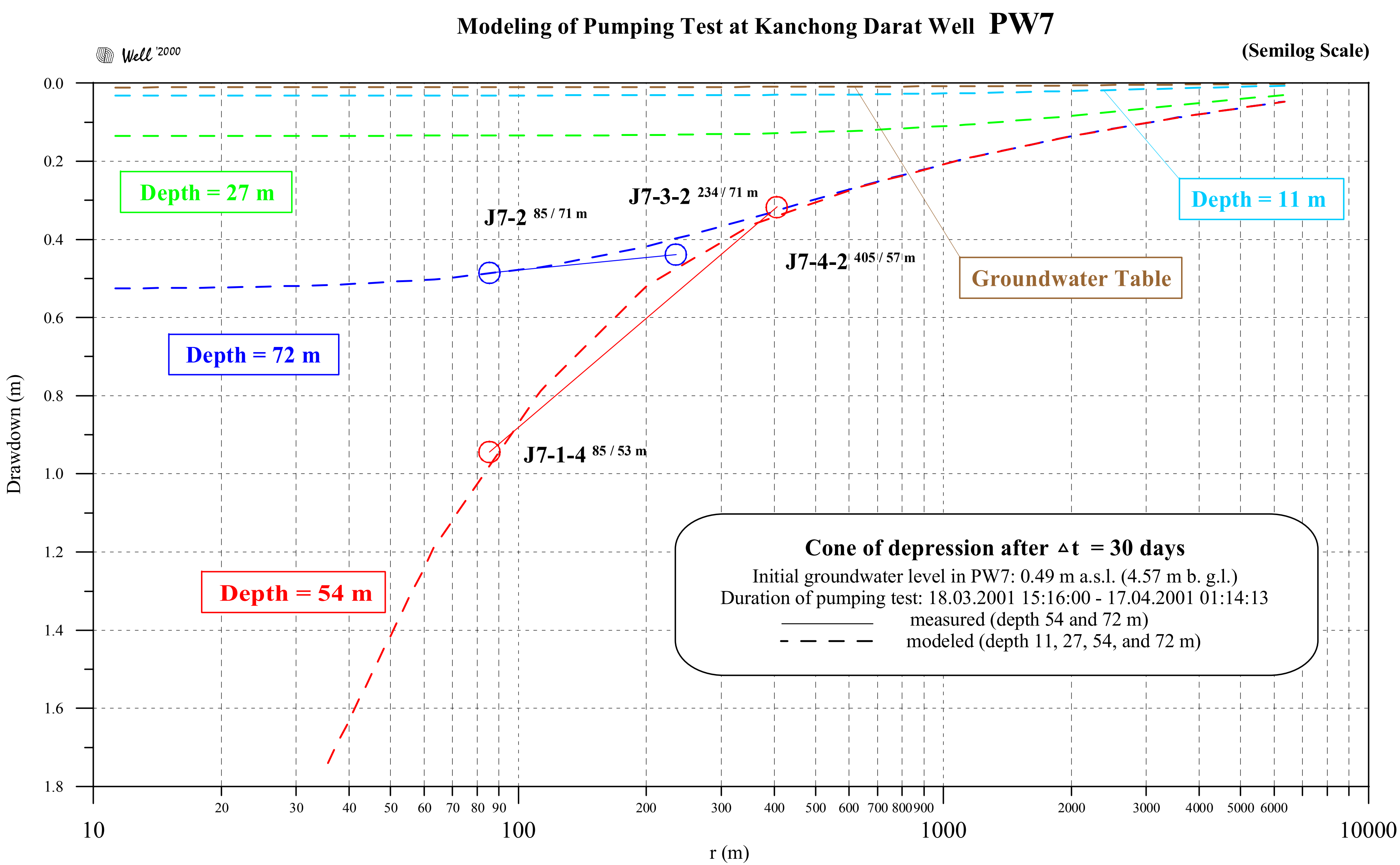


Figure G.3.34 Modeling of pumping test at Kanchong Darat - depression cone in different depth at the end of pumping test

ro_cs7_sr1mod2

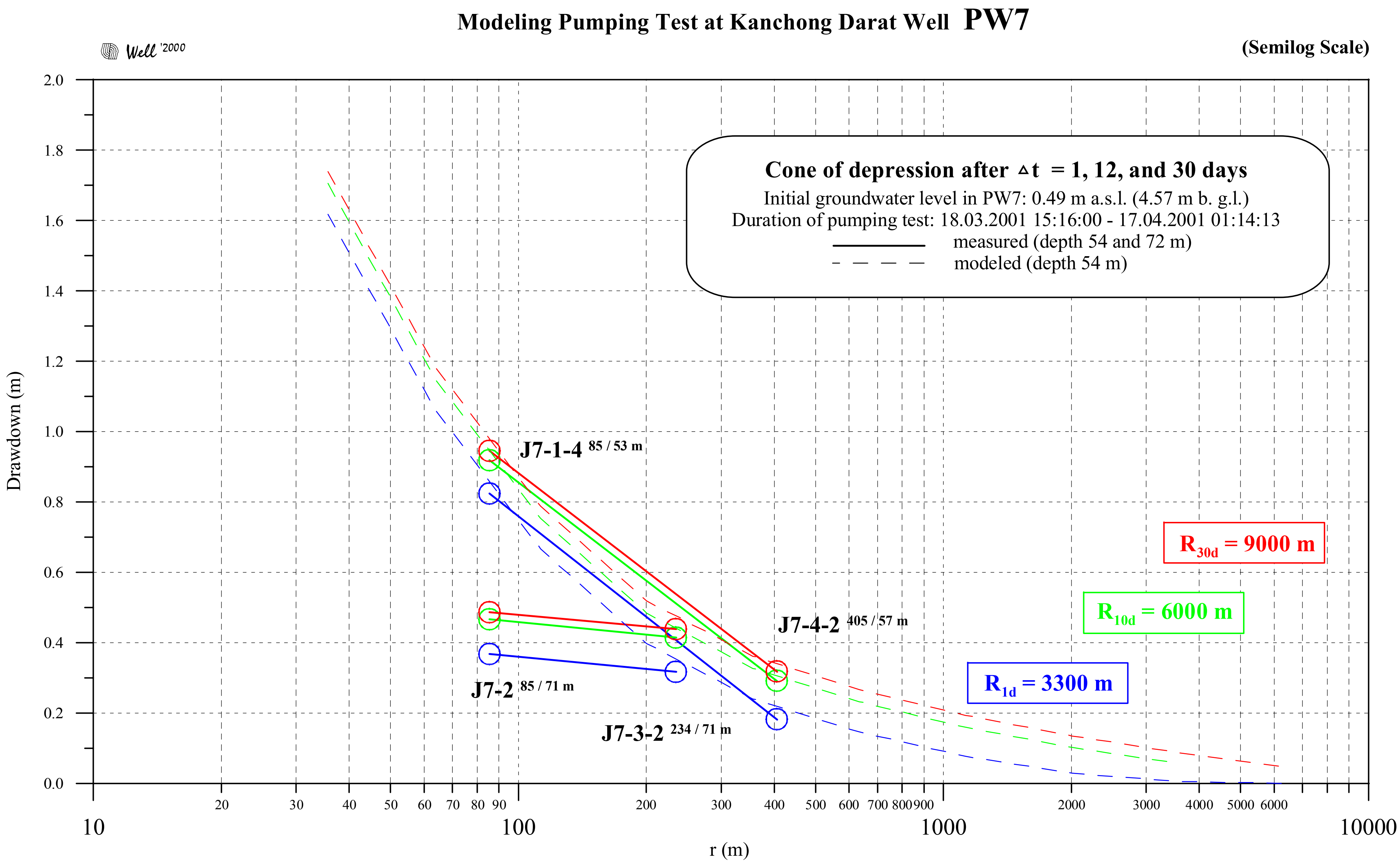


Figure G.3.35 Modeling of pumping test at Kanchong Darat - change of depression cone during pumping test

ro_cs7_sr1mod1

Table G.3.3 Pumping Test Modelling at Kanchong Darat - Hydraulic Parameters

Layer No.	Depth (m)	Thick. b (m)	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	4	4	1.00e-4	1.00e-5	10	1e-3	0.3	Peat, peaty soil
2	10	6	1.20e-8	1.20e-8	1	6e-6	0.01	Silty clay and silty sand
	12	2	6.00-5	6.00e-6	10	6e-6	0.01	
	22	10	1.00e-8	5.00e-9	2	6e-6	0.01	
2 ^{avg}	22	18	5.47e-6	7.20e-9	759	6e-6	0.01	
3a	31	9	1.00e-4	1.00e-5	10	6e-6	0.15	Silty sand and silty clay with gravel
	34	3	1.20e-8	9.23e-9	1.3	6e-6	0.01	
	37	3	6.00e-5	6.00e-6	10	6e-6	0.15	
	44.5	7.5	1.00e-8	7.00e-9	1.43	6e-6	0.01	
	51.5	7	2.80e-4	1.00e-5	28	1e-5	0.15	
	56.5	5	5.00e-4	5.00e-5	10	1e-5	0.15	
3a ^{avg}	56.5	34.5	1.61e-4	2.47e-8	6502	7.5e-6	0.11	
3b	63	6.5	6.00e-5	3.00e-6	20	6e-6	0.01	Silty clay and silty sand
3c	81	18	1.20e-3	4.80e-5	25	4.5e-5	0.2	Silty sand and gravel, sandy clay
	83	2	1.00e-7	6.00e-8	1.67	6e-6	0.01	
3c ^{avg}	83	20	1.08e-3	5.93e-7	1821	4.11e-5	0.18	
3d	120	37	8.00e-4	3.20e-5	25	4.5e-5	0.2	Silty sand with gravel
3c-3d $_{avg}$	115	57	8.98e-4	1.63e-6	549	4.36e-5	0.19	

Note: 3c-3d ^{avg} means average (characteristic) value for layer 3c and 3d.

(3) Boundary Conditions and Other Impacts on Groundwater

The available data and course of drawdown do not indicate the presence of impermeable or recharge boundaries in distance less than 4 km from the pumping test site.

The vertical hydraulic conductivities of layers between the main aquifer and the subsurface peaty horizon and thus leakage from the surface are very low (**Figure G.3.32**, piezometer J7-1-2, **Figure G.3.34**).

Pumping of water from the main aquifer does not influence moisture and water regime in the shallow soil and peaty body because the leakage of water is much smaller than infiltrated rain (rain minus evapotranspiration).

Deterioration of water from old buried peaty horizons may be expected in the main aquifer. The quality of groundwater indicates process of seawater intrusion (see **Section 5.6** with preliminary estimation of freshwater/saltwater interface shown in **Figures G.5.38**, **G.5.39 and G.5.44**).

Groundwater flow at the locality of pumping test depends on recharge and abstraction of water from neighbouring well fields and mines. Already in present conditions, the inflow of saltwater may be expected from seaside (**Figures G.5.2**, **G.5.6 and G.5.10**).

(4) Groundwater Flow, Well Fields and Safe Yield

In the past, the natural groundwater flow in the area was oriented towards the seaside. The main inflow of fresh groundwater may have been expected from northwest or northeast direction. (**Figures G.5.14 and G.5.1**). The modelling results indicate that the recent groundwater flow at the locality of pumping test is from southwest or south to northeast (**Figure G.5.2**). Groundwater flow depends on abstraction of water from existing well fields and mines as well as from effective rainfall (**Figure G.5.6**). The decrease of groundwater level (in time and space) caused by pumping is documented in **Figures G.3.29-30** and **Figures G.3.34-35**.

The main aquifer is located in the depth from 63 to about 130 to 150 m. Shallow lateritic soil, peat, peaty clay horizon is in the depth up to approximately 4 m (**Figure G.2.16**). The shallow horizon is recharged from rainwater. The vertical hydraulic conductivity is very small, and leakage is much smaller than effective rainfall (rain minus evapotranspiration). Pumping of water from the main aquifer is not influencing the moisture and water regime in the shallow soil and peaty body.

The aquifer is characterised by high thickness and good permeability of sands and gravels. The total transmissivity reaches about 5.12 x 10^{-2} m^2/s (compare with other pumping test localities in **Table G.3.4**). Due to relatively high hydraulic conductivity and thickness of the main aquifer high discharges from deep pumping wells could be expected.

For the purposes of this study, safe yield is defined as the amount of groundwater with suitable quality that can be exploited from the aquifer. The estimation of regional safe yield and permissible drawdown is limited by unfavourable groundwater quality for drinking purpose (**Figures G.5.38 and G.5.39**). The sampling and in-situ measurements at Kanchong Darat (Location No. 7 in the figures) show increased values of electric conductivity and higher content of chlorides in deeper groundwater horizons. At present, abstraction of groundwater at this locality may support influence of seawater intrusion. Based on these facts the safe yield of main aquifer at this locality may be considered as negligible.

(5) Interpretation of Pumping Test for 3D Groundwater Model

The following important facts have been 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 from the pumping test area.
- 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.

Interpreted aquifer parameters are listed in **Table G.3.3**. Comparison of hydraulic parameters of lower aquifer (Model Layer No. 3c and 3d) with other pumping test localities is given in **Table G.3.4**. Based on results of pumping test at Kanchong Darat and other localities, the hydraulic parameters for regional 3D groundwater flow model were derived (**Table G.4.1**, Zone C).

Table G.3.4 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	4.5e-5	6.21e-4
Kajibumi WF 2	23 – 43	20	8.41e-4	2.04e-5	1.68e-2	3e-5	6e-4
Kanchong Darat	63 – 120	57	8.98e-4	1.63e-6	5.12e-2	4.36e-5	2.48e-3

3.2.4 Groundwater Quality during Pumping Tests

Quality of groundwater was studied during the pumping tests by in-situ measurement, and chemical analysis on site and at JMG's Ipoh laboratory. Raw data on groundwater quality are tabulated in **Annex G.3.4**.

Chemically pure water at Paya Indah well PW-2 showed very low electrical conductivities; the values during pumping test were measured 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 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.

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. Saltwater intrusion into the Groundwater Basin will be discussed in **Section 5.6**.

3.2.5 Existing Pumping Test Data in the Study Area

(1) Pumping Test at Megasteel and Kajibumi WF 2

To demonstrate the status of existing pumping tests, the results of two pumping tests are presented; namely, (1) pumping test at Megasteel well PWM 1, and (2) pumping test at Kajibumi Well Field 2 well TU/B.

During the pumping test at Megasteel well PWM 1 also the drawdown at piezometers TW 1, HM 1, and TW 3 was observed. During the pumping test at Kajibumi WF 2, the drawdown was measured in pumping well TU/B and in well TU/A.

The graphical interpretation of both tests is shown in **Figures G.3.36 and G.3.37**. The interpretation of hydraulic parameters and estimation of boundary conditions is described in detail in the following paragraphs:

(a) Pumping Test at Megasteel Well No. TPW 1

Pumping test at Megasteel Well No. TPW 1 and observation wells TW 1, HM 1 and TW 3 is described in the Megasteel Wells/Hydrogeology Report prepared by Pacific Industrial & Mining.[1)]

Geophysical resistivity survey profile No. 6. in the "Megasteel Wells / Hydrogeology Report" shows high variability of thickness of alluvial sediments (from a few metres outside of old river erosion valley to 50-70 metres in the old buried river course channel) and also a variable relationship between the alluvial sediments and the bedrock consisting of shale and quartz at this location.

The first step when evaluating pumping test is drawing the pumping test course in linear scale, drawdown versus time, and all other relevant information (discharge, distance from pumping wells, initial groundwater level, etc., **Data Book Figure G.3.52**). From this example can be seen a regular daily impact on groundwater level (up to 0.5 m), which could be caused by various factors and should be explained.

The second step is drawing the pumping test in semi-logarithmic and/or bi-logarithmic scale. For evaluation using the classical Theis's type curve method bi-logarithmic presentation is used. Straight-line method described by Cooper and Jacob uses semi-logarithmic pumping test presentation. Straight-line method, in comparison with the bi-logarithmic method, does not reduce the graphical accuracy and visibility of drawdown (**Figure G.3.36**). This figure is a semi-logarithmic presentation of **Data**

Book Figure G.3.52. From **Figure G.3.36** it is not clear which part of the line should be used as a straight line.

From the geological description it could be supposed, that the aquifer is confined or semi-confined. For such assumption the first period of pumping test, influenced with well bore storage and confined conditions, is missing (first 60 seconds). The interval from 100 to 10,000 seconds could be influenced by boundary conditions or changes in the permeability as the cone of depression rises. Later follows an increase in drawdown, despite the decrease of pumping quantity, characterising impermeable or less permeable boundary. In addition, at approximately 500,000 seconds (6 days), response to groundwater recharge seems to start at some large distance, or from/through the covering sediments, which cannot be estimated, because of missing piezometers at the depth of groundwater level in the uppermost part of alluvial deposits and piezometer in the semi-permeable aquifer covering layer. At the end of the pumping test there exist an increase of drawdown, which is probably a response for not detected (or not measured) increase of pumping test rate.

In such a case the proper interpretation of pumping test using this pumping test data and presentation is problematic. Fortunately, there are the three piezometers available in various distances. Presentation of drawdown for long enough time in semi-logarithmic scale drawdown versus distance (**Data Book Figure G.3.53**), encourage to use straight line method for estimation of transmissivity in the area of pumping and observation wells. Using this graphical presentation, and Cooper-Jacob method, the calculated aquifer transmissivity is $T = 4.99 \times 10^{-2}$ m^2/s.

From **Data Book Figure G.3.54**, it can be seen that drawdown in the pumping well is lower as the ideal drawdown corresponding for the bore diameter of 0.305 m. This is surely because of excellent construction and development of pumping well using an extraordinarily efficient continuous slot wire wound screen (so-called Johnson screen) and proper sized gravel pack. Using this method, with piezometers in various distances, it is possible to verify the quality of pumping well construction and development with high accuracy.

The third step, to improve the pumping test interpretation, is to model pumping test in cylindrical co-ordinates and if necessary to superimpose the impact of boundary conditions. Such pumping test modelling is presented in **Data Book Figure G.3.55**. After a few runs of modelling, the following approximately interpretation can be done.

Parameters of aquifer are as follows:

Aquifer Transmissivity : $T = 8.0 \times 10^{-2}$ m^2/s

Specific Storage (elastic) : $S_S = 3 \times 10^{-5}$ 1/m

There are two parallel impermeable or less permeable boundaries 50 and 350 m away from pumping well. It means that the pumping test well is situated in an old buried alluvial valley 400 m wide approximately 50 m from one boundary. Using more piezometers in various distances and depths and long enough pumping test it is possible to obtain some additional information.

According to recharge, aquifer is confined with two impermeable or semi-permeable parallel boundaries (alluvial valley) with recharge via overlying clayey deposits and/or recharge at some larger distance directly into aquifer. From **Data Book Figure G.3.53** it can be estimated that the cone of depression reaches 2 km of radial flow and in the higher permeable valley some 3.5 km. More precise interpretation would be possible using piezometer in the shallow part of deposits (at the level of groundwater level fluctuation) and at a much larger distance from the pumped well in the direction of the supposed buried alluvial valley and behind the valley boundary. More precise discharge measurements in regular intervals, for example, once in an hour, would be required. Explanation of regular groundwater level fluctuation is necessary.

(b) Pumping Tests at Kajibumi Well Field 2 TU/B and TU/A

The pumping tests at the Kajibumi wells were carried out in confined aquifer consisting of 24 m thick sandy gravel aquifer. Two pumping tests are discussed:

Pumping test on well TU/B with measured drawdown on pumping well TU/B and 54 metres distant from observation well TU/A.

Pumping test on well TU/A with measured drawdown only on pumping well TU/A.

Results of both pumping tests are shown in **Figure G.3.37**. Discharge measurements are not given, they were probably not fully constant and decreasing through the pumping test. Fluctuation of groundwater level similar to the Megasteel pumping test cannot be seen, because of short pumping test.

From comparing the results of pumping test at Megasteel and Kajibumi it is evident that there are different groundwater flow conditions. From the observation well TU/A during the pumping test on well TU/B it seems that the time interval from 100 to 10,000 seconds correspond to the elastic (confined aquifer) groundwater flow. From the following course of drawdown it seems that the cone of depression just touched the recharge area, and/or the flow from the aquifer-covering layer just started. Interruption of the pumping test happened in the most crucial time.

Using the method of linear transformation by Cooper and Jacob, from **Figure G.3.37,** coefficient transmissivity is for:

- pumping on TU/B, drawdown on TU/B: $T = 2.81 \times 10^{-2}$ m^2/s
- pumping on TU/B, drawdown on TU/A: $T = 2.70 \times 10^{-2}$ m^2/s
- pumping on TU/A, drawdown on TU/A: $T = 2.24 \times 10^{-2}$ m^2/s

The most reliable result is obtained from observation well TU/A during pumping test on well TU/B, $T = 2.7 \times 10^{-2}$ m^2/s. This result is partially influenced by the leakage and the real values could be a little bit smaller.

Using the linear transformation method and computed coefficient transmisivity, the ideal drawdown on the pumping well for the pumping time 30 minutes should be 3.58 m instead of measured 9.07 m. Drawdown on observation well TU/A was at the same time 1.10 m.

To show the ideal pumping test on Kajibumi, locality pumping test for ideal aquifer conditions was modelled. Comparison with real pumping test does not need comments (**Data Book Figure G.3.55**). In the same figure the ideal modelled course of pumping test is shown. The modelled parameters are $T = 2.4 \times 10^{-4}$ m^2/s. Specific storage is 2×10^{-5} 1/s, and vertical conductivity from where the leakage can take place is supposed to be 1×10^{-7} m^2/s.

An example of pumping test with impermeable boundary at 800 m distance from the pumping well, in the supposed conditions of aquifer with vertical conductivity 1 x 10-7 m/s (leakage) and water supply from the shallow water table horizon was modelled and the results are shown in **Data Book Figure G.3.56**. From comparing these figures it is clear that the short pumping test using Cooper-Jacob solution did not give fully correct results of transmissivity and there was no information about possible recharge, vertical flow and interconnection with shallow ground water level.

Comparison of Megasteel pumping well drawdown and observation well drawdown (distance 55.5 m) with the Kajibumi pumping well TU/B drawdown and observation well TU/A drawdown (distance 54 m) is shown in **Data Book Figure G.3.57**.

(2) Single Well Tests

A number of single well pumping tests exist in the Study area. The compiled data are listed in **Tables G.3.5 and G.3.6**.

The pumping tests are very short, usually no piezometers exist around the pumping well and the drawdown was measured only at pumping wells. The results of these pumping tests are not suitable for representative evaluation of aquifer properties. As many of listed pumping wells are pumping groundwater from bedrock (e.g. sandstone, limestone, schist, granite), these data can be used for rough estimation of bedrock properties.

For example, the average length of well screens located in sandstones is 56 m. The pumping rate from these wells was about 6.75 l/s, which caused drawdown 49 m, in average.

Based on such a evaluation of single well tests the conductivity coefficients of bedrock with values 3.2 x 10^{-6} m/s and 1.0 x 10^{-8} m/s were assigned in 3D groundwater flow model (**Table G.4.1 and Figure G.4.6**).

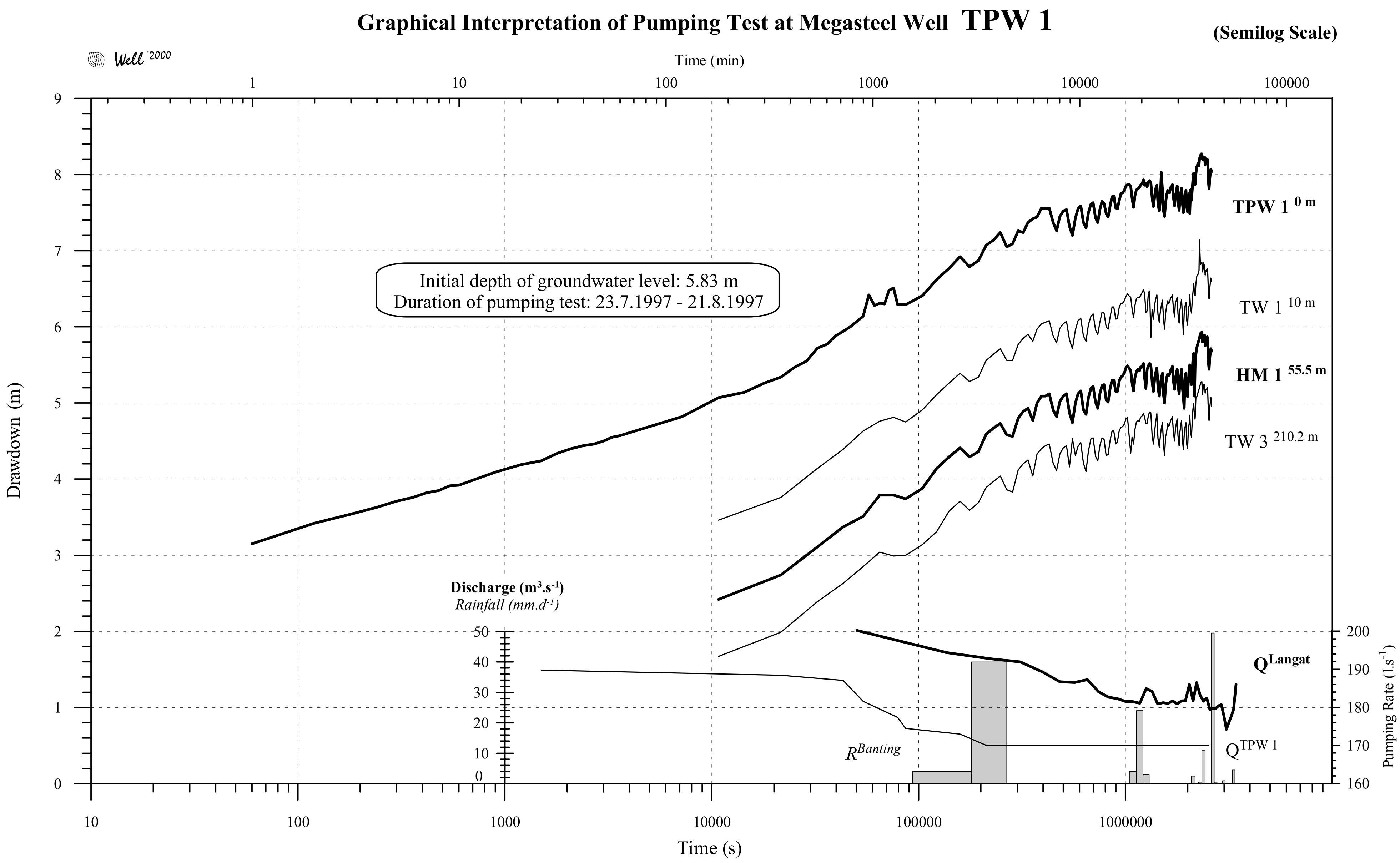


Figure G.3.36 Graphical Interpretation of Pumping Test at Megasteel Well TPW 1 (Drawdown versus Time, Semilog Scale)

Graphical Interpretation of Pumping Test at Kajibumi Well TU/B and TU/A (Semilog Scale)

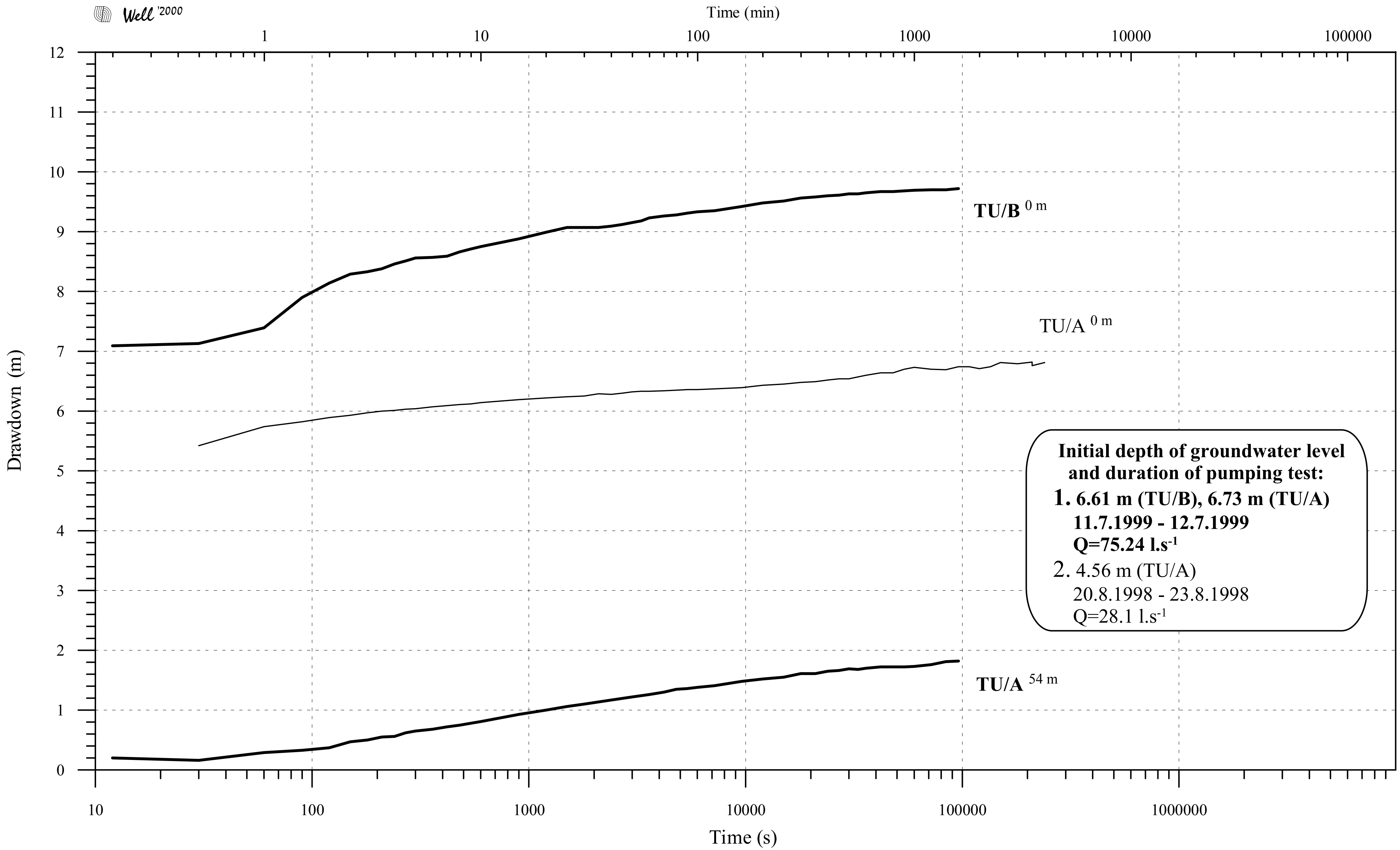


Figure G.3.37 Graphical Interpretation of Pumping Test at Kajibumi Well TU/B and TU/A -Drawdown Versus Time Plot

Table G.3.5 Existing Single Well Tests in the Study Area (1/2)

Field Name	ID	JMG Name	Pumping Rate Q (l/s)	Drawdown s (m)	Time t (s)	Screen Length (m)	Q / s (m2/s)	Aquifer Type
TD 4	50	PB0392	28.06	18.85	1155	18.00	1.49E-03	G
TD 1	47	PB0393	25.00	14.11	3000	18.00	1.77E-03	G
TU/A	57	PB0274	36.39	10.72	1600	18.00	3.39E-03	G
TD 5	64	PB0396	30.28	7.48	3500	18.00	4.05E-03	G
TD 3	49	PB0394	28.06	5.94	2880	18.00	4.72E-03	G
TD 2	48	PB0395	31.67	5.38	3000	18.00	5.89E-03	G
TU/B	253		75.24	9.72	1600	24.00	7.74E-03	G
PWS 1	55	PB0386	38.89	3.77	4320	34.00	1.03E-02	G
PWM 2	52	PB0400	43.28	2.69	4320	30.40	1.61E-02	G
PWM 3	53	PB0402	42.22	2.28	4320	30.00	1.85E-02	G
TPW 1	51	PB0267	170.03	8.04	43440	24.00	2.11E-02	G
PWM 4	54	PB0401	43.28	1.76	270	30.00	2.46E-02	G
AMS 1	238		15.47	0.4	540	24.00	3.87E-02	G
id115	115	PB0271	0.12	22.1	120	80.00	5.66E-06	I
PW 1	101	PB0367	2.14	128.22	1440	110.00	1.67E-05	I
EP 1	109	PB0304	1.98	111.3	600	42.00	1.78E-05	I
TW 01	111	PB0302	2.14	52.37	1440	48.00	4.08E-05	I
PN 1	67	PB0390	2.10	47.96	600	42.00	4.38E-05	I
PW 1	116	PB0270	1.94	40.79	90	133.00	4.77E-05	I
PW 1	60	PB0268	1.52	31.3	1440	115.00	4.85E-05	I
PW 3	112	PB0280	1.89	21.18	1440	17.00	8.92E-05	I
PW 4	110	PB0281	4.39	23.99	1440	20.00	1.83E-04	I
VIT 1	92	PNJ 3	8.40	34.29	540	42.00	2.45E-04	I
PW 5	106	PB0282	5.69	9.3	1440	14.00	6.12E-04	I
id118	118	PB0102	1.47	31.58	2694	3.05	4.64E-05	L
PW 2	113	PB0273	0.67	7.71	720	184.20	8.65E-05	L
NO 6	124	PB0020	8.83	18.23	600	18.30	4.85E-04	L
SDP 2	91	PNJ 2	1.58	58.77	600	113.00	2.69E-05	M
S 3	254	PB0403	0.99	20.14	3000	144.00	4.90E-05	M
NO 2	94	PN405	7.73	36.54	1440	99.00	2.11E-04	M
NO 1	93	PN400	7.58	27.98	1440		2.71E-04	M
NO 3	125	PB0019	10.10	8		95.08	1.26E-03	M
NO 4	119	PB0100	12.76	8	7000	103.63	1.59E-03	M

Table G.3.6 Existing Single Well Tests in the Study Area (2/2)

Field Name	ID	JMG Name	Pumping Rate Q (l/s)	Drawdown s (m)	Time t (s)	Screen Length (m)	Q / s (m2/s)	Aquifer Type
SS 3	56	PB0277	6.69	1.43	1440	28.40	4.68E-03	M
S 5	66	PB0389	0.92	9.58	2880	6.00	9.66E-05	S
BH 1	95	PB0044	3.79	3.5	1440	3.00	1.08E-03	S
TW 02	107	PB0399	1.39	56.64	1440	57.00	2.45E-05	SS
UPM 1	61	PB0276	1.90	41.93	600	24.00	4.53E-05	SS
NO 1	133	PB0007	3.79	79.99		76.70	4.74E-05	SS
NO 1	69	PB0021	2.67	50.8	1440	76.20	5.25E-05	SS
TPI 1	98	PB0275	3.19	54.25	660	42.00	5.89E-05	SS
NO 1	121	PB0015	5.06	60.8	2880	47.50	8.32E-05	SS
NO 1	123	PB0013	3.78	43.6		53.40	8.66E-05	SS
NO 1	127	PB0040	5.31	54.9	4320	68.60	9.66E-05	SS
id130	130	PB0035	5.94	56.9	2880	85.40	1.04E-04	SS
NO 2	128	PB0039	5.06	42.7	4320	94.50	1.18E-04	SS
TW 1	117	PB0269	4.67	35.26	1440	30.00	1.32E-04	SS
GS 1	257		12.78	93.21	2880	102.00	1.37E-04	SS
NO 2	104	PB0024	6.51	46.78		67.10	1.39E-04	SS
id97	97	PB0022	7.08	45.7	2880	58.00	1.55E-04	SS
PW 1	134	PB0006	15.15	74.9	2160	33.60	2.02E-04	SS
id114	114	PB0272	4.17	16.72	660	24.00	2.49E-04	SS
NO 2	122	PB0014	12.64	30.5	480	51.90	4.14E-04	SS
NO 1	96	PB0042	14.53	25.5	2880	61.00	5.70E-04	SS
NO 1	129	PB0038	12.64	18.9	2880	22.90	6.69E-04	SS

Legend: L - limestone/marble; M - schist, phyllite, slate; C - clay; SS - sandstone, quartzite, shale; G - gravel; I - granitic rock; S - sand

4. GROUNDWATER FLOW MODEL

4.1 Modelling Approach

The accuracy of a model is dependent upon the level of understanding of the system the model is to represent. Thus, a complete site investigation and accurate conceptualisation of site hydrogeology are necessary precursors to a successful modelling.

The procedure of model application involves three steps: 1) Model set up, 2) Model calibration, and 3) Model validation. The model calibration implies that sequences of simulation runs are carried out and model results are compared with measured data for a certain time period. Validation of a model demonstrates the ability to reproduce measured data for a period outside the calibration period.

The applied Visual MODFLOW model is a physically based modelling tool, thus most of the data required for the model set up and input data can be measured in the nature. A set up for such a physically based model, as a minimum, always involves a geometrical description of the aquifer and some physical characteristics of the system. This could for instance be the depth of impermeable bedrock, thickness of permeable alluvial sediments or hydraulic conductivities in the saturated zone. In addition, the value of some state variables has to be known on the model boundaries (boundary condition). For hydrodynamic models the boundary conditions are described as groundwater table or groundwater flow. The input data for groundwater flow model were presented and described in **Chapters 2 and 3**.

Langat basin is a typical coastal confined aquifer with geologically defined boundaries and recharge areas. The aquifer is replenished from precipitation. Recharge areas are distributed according to geological conditions (e.g. thin or absent aquitard, bedrock outcrop). The aquifer recharge is simulated as aerially distributed recharge to the groundwater system. The recharge is restricted to uppermost layer and is allowed to pass through inactive cells.

Aquifer can be also replenished (or drained) to some small degree from rivers (stretches with permeable riverbed). Replenishment of an aquifer can happen also by seawater intrusion, if too much water is pumped out from a coastal aquifer.

Surface runoff is simulated by shallow drains, which remove water from the first layer at a rate proportional to the difference between the head in the aquifer and some fixed head or elevation. The drain has no effect if the head in the aquifer falls below the fixed elevation of the drain.

Annual average rainfall in the area northwards from Lower Langat was estimated as 2238 mm/year and evaporation, 1284 mm/year. Thus, at least 954 mm/year could be potentially used as infiltration part into the cells with drains.

4.2 Model Set Up

4.2.1 Model Grid - Discretisation

The modelling domain was selected according to natural hydrogeological boundaries, over an area with *x* coordinate 378000 – 418000 m, and *y* coordinate 285000 – 330000 m (area 40 x 45 km).

The finite difference method, used in Visual MODFLOW, requires replacement of continuous aquifer system by a set of discrete elements in a rectangular grid. The grid is three-dimensional. The points in the grid, called nodes, represent the average for the surrounding rectangular block (cell). Both the space and time variables are treated as discrete parameters.

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 x 76 cell grid in horizontal direction; with minimum cell size 250 x 250 m (well field area at Megasteel, Kajibumi WF 2, Paya Indah area) and maximum cell size 2000 x 2000 m (edges of the model). Generally, node spacing is finer where the hydraulic gradient and flux are subject to greater change (e.g. the areas near extraction wells).

Based on comprehensive evaluation of geological logs, results of soil investigation and evaluation of pumping tests at Paya Indah, Kajibumi WF 2, and Kanchong Darat, the model has been set up with seven layers in vertical direction (**Figures G.2.6**, **G.2.11, and G.2.16**, and **Table G.4.1**).

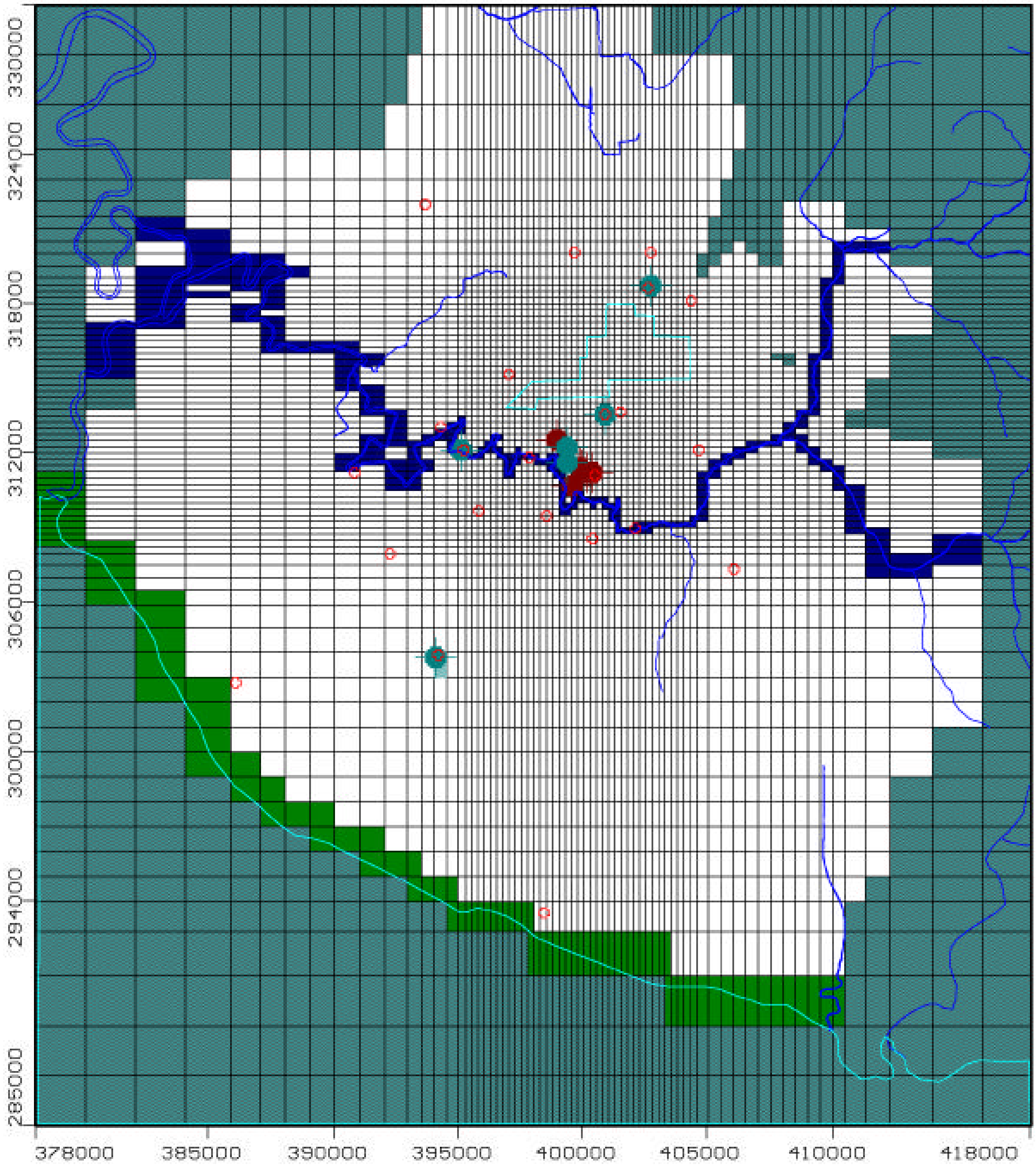
Irregular boundary is represented by 4550 inactive cells (**Figures G.2.1 and G.4.1**).

4.2.2 Aquifer Parameters

Basic aquifer parameters of the groundwater flow model (or of the partial differential equation of the three-dimensional non-stationary groundwater flow) are as follows:

- Hydraulic conductivity in cells in x, y, z direction;
- Differences Δx, Δy, Δz (corresponding to the geological properties of an aquifer);
- Aquifer storage parameters (elastic and water table storage coefficients) in cells;
- Aquifer active porosities for computation of velocities vectors, path lines, etc.; and
- Parameters of boundary conditions (usually geometry, water levels, parameters of leakage for general head boundary, drains, rivers, etc.).

Hydraulic parameters of aquifer used in the 3D model set up are listed in **Table G.4.1**, and some examples are graphically presented in **Figures G.4.2-6**. A model cross-section and elevation map along the centre of the Basin in **Figure G.4.7** documents the geometrical characteristics of model.



LEGEND

Inactive Cells
River
General Head
Pumping Well (Active, Inactive)

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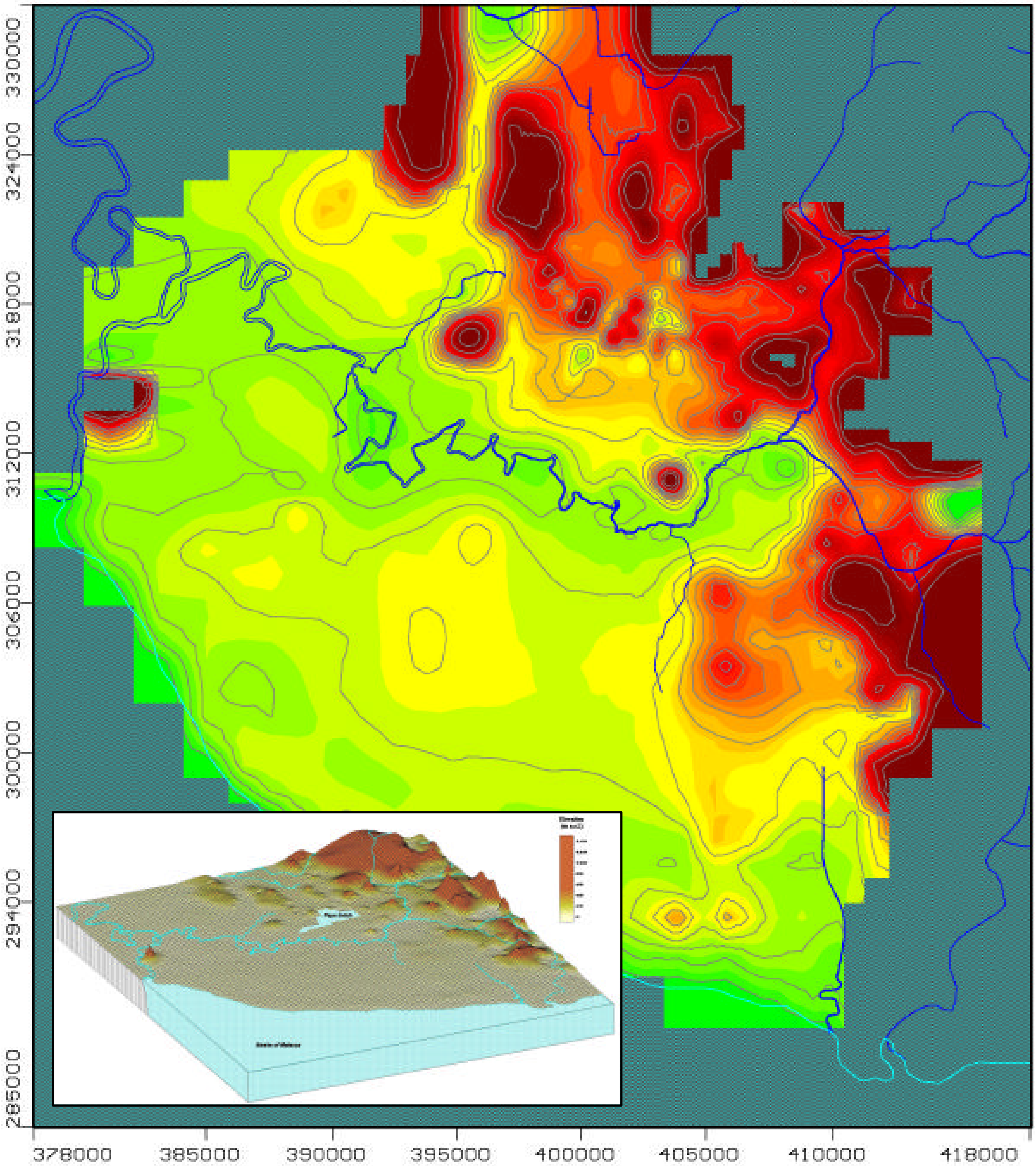
Figure G.4.1

Model Grid and Boundaries



LEGEND

Inactive cells

Contour lines of ground surface

Elevation (m a. s. l.)

0

5

20

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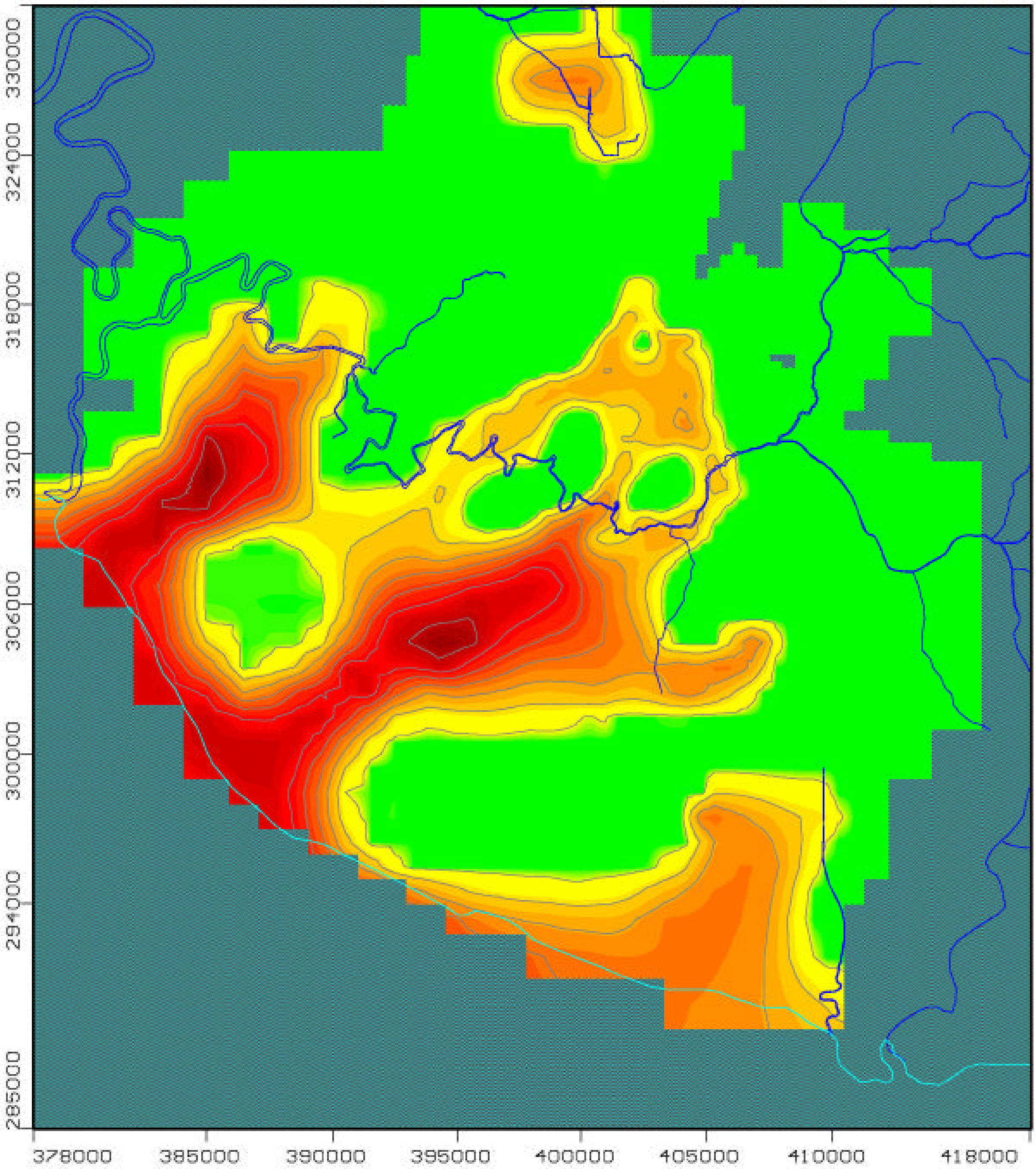
Figure G.4.2

Elevation of Ground Surface



LEGEND

Inactive cells

Contour lines - thickness of layer 3

Thickness (m)

1

25

35

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Figure G.4.3

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Thickness of Model Layer 3a

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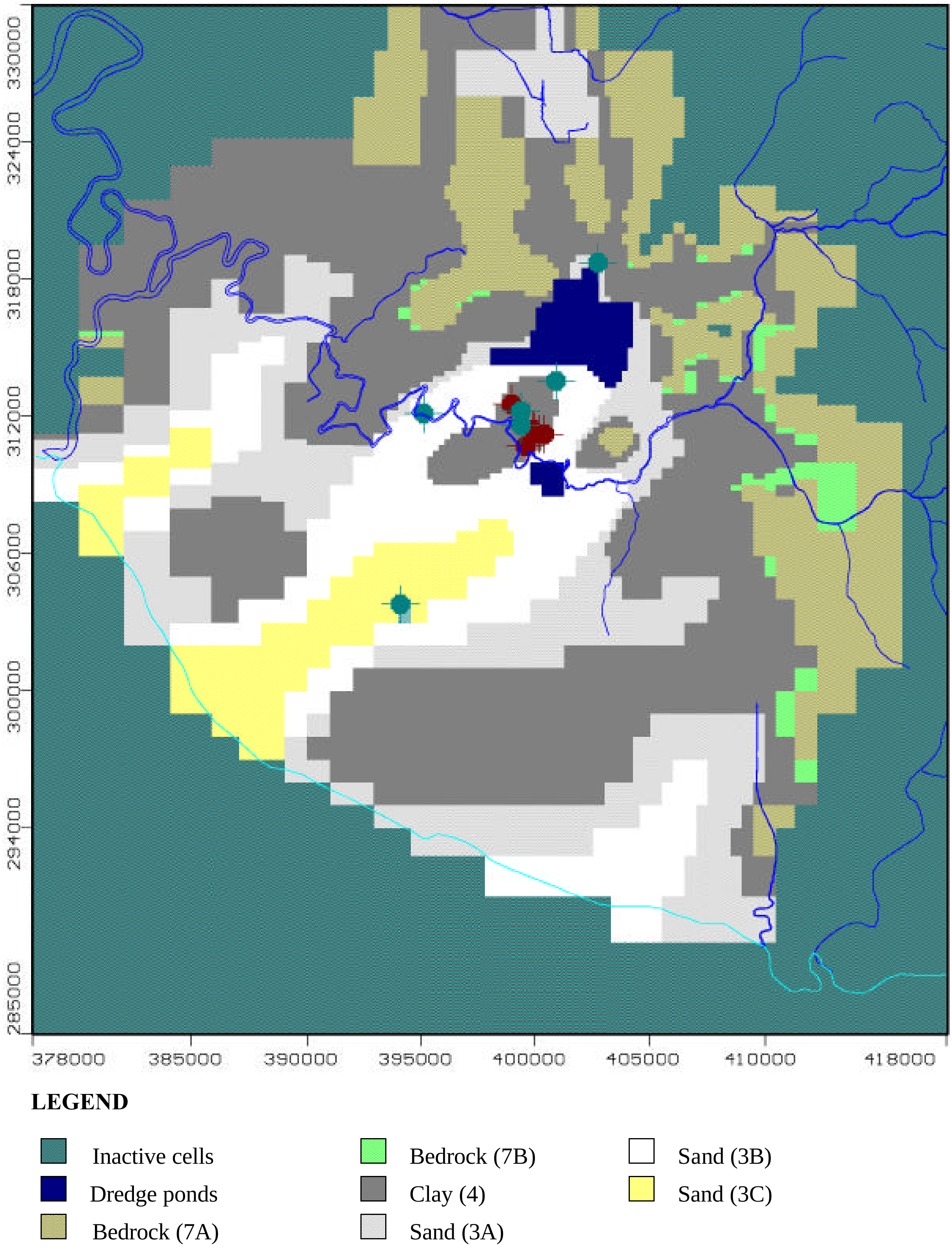

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Figure G.4.4

Conductivities in Model Layer 3a

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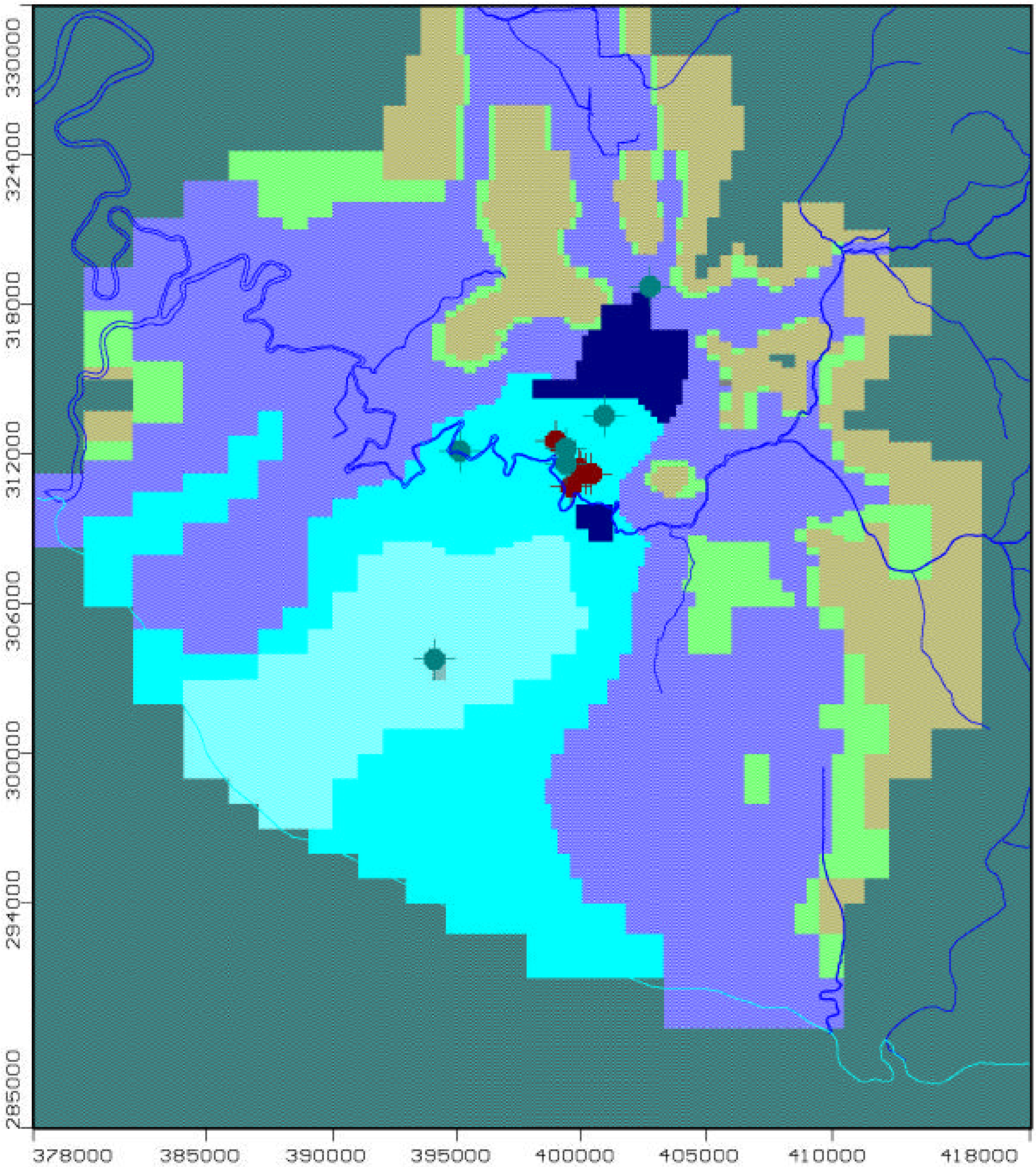

LEGEND

Inactive cells	Bedrock (7B)	Sand and Gravel (5B)
Dredge ponds	Sand and Gravel (5A)	
Bedrock (7A)	Sand and Gravel (5C)	

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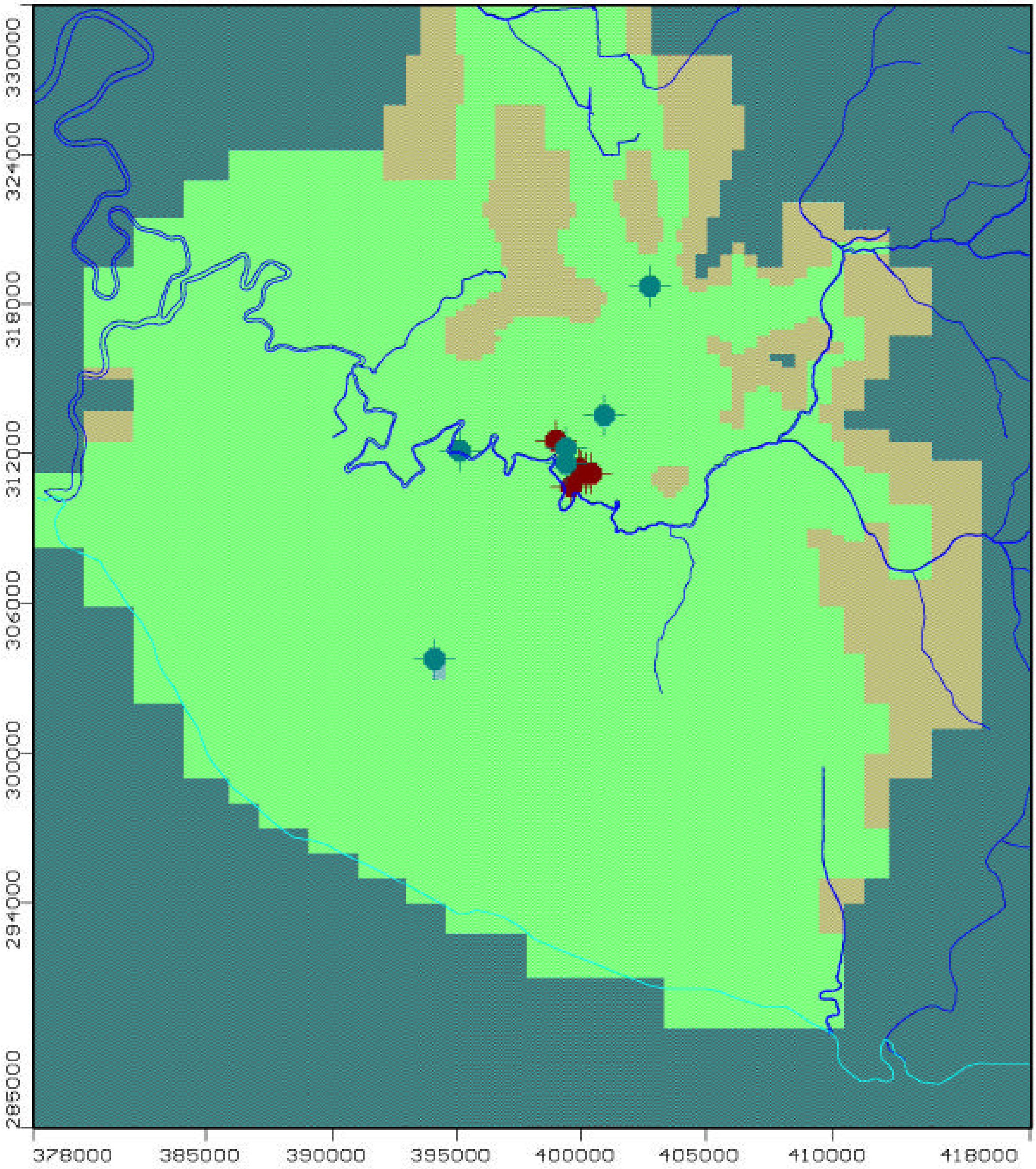
Figure G.4.5

Conductivities in Model Layer 3c



LEGEND

Inactive cells   Bedrock (7A)   Bedrock (7B)

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Figure G.4.6

Conductivities in Model Layer 4

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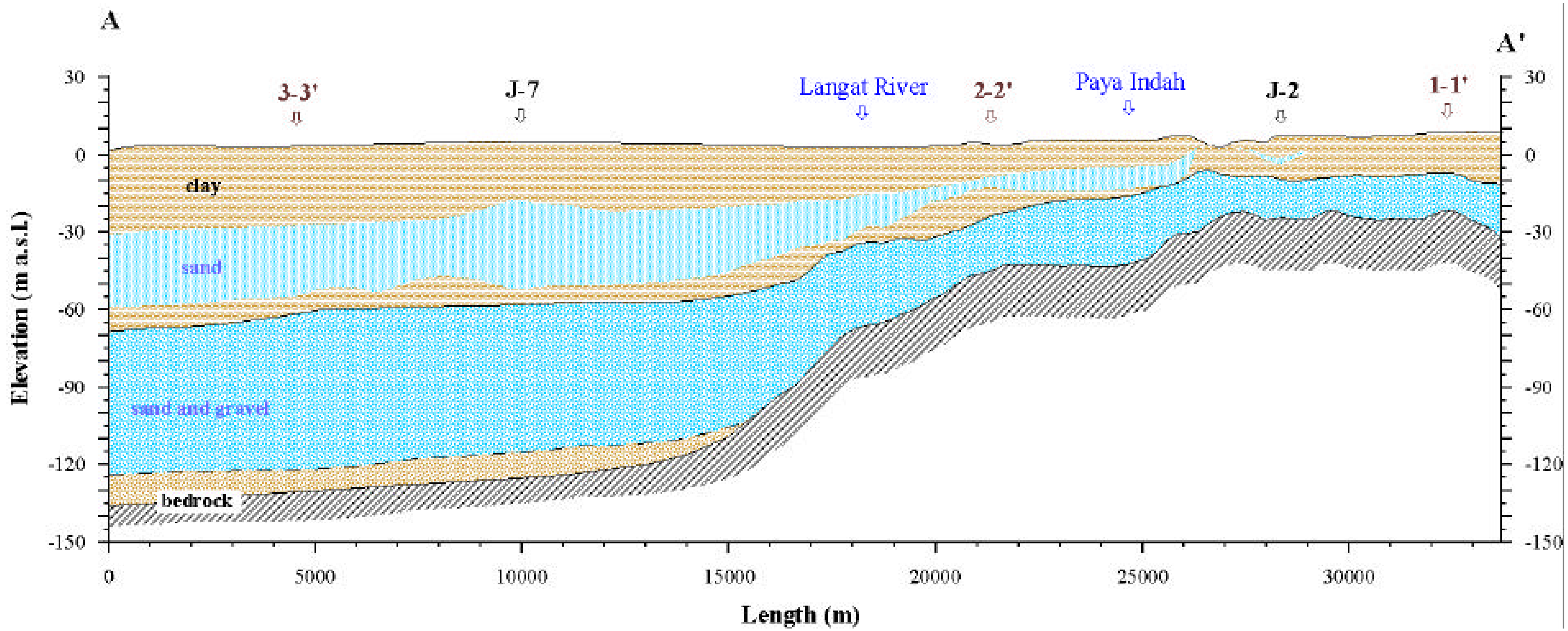

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LEGEND

Figure G.4.7

Morphology of Main Model Layers
Model Cross-Section along the
Centre of the Groundwater Basin

ro_crs_A

Table G.4.1 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

4.2.3 Initial and Boundary Conditions

Initial conditions represent the initial state of the considered model parameters and variables for start of computation. From the point of practical groundwater flow modelling it means primary definition of groundwater level and piezometric head in each active model cell.

All Visual MODFLOW steady-state groundwater flow simulations (Simulation Variants 0, 1, 2, and 3) used the initial head values imported in the Run Module from ASCII file (file InitHead_Zdrain.TXT). The elevation of initial head is 1 m below the ground surface.

The transient simulations (Simulation Variants 4 and 5) used the initial head values imported in the Run Module from previous Visual MODFLOW run (file jica01.HDS). The elevation of initial head corresponds to final head distribution in Simulation Variant 1 (steady-state simulation).

Boundary conditions are constraints imposed on the model grid that express the nature of the physical boundaries of the aquifer being modelled. Boundary conditions have great influence on the computation of flow velocities and heads within the model area.

A no flow boundary (zero-flux, barrier) is defined as 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 boundary. 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 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 (765 cells, **Figure G.4.1**). Elevations of river bottom and elevation of water level were set according to values presented in **Figure G.2.22(b)**. Riverbed conductances reflect 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 is represented in the model by General head boundary (672 cells, **Figure G.4.1**). The water level elevation was set to 1.0 m a.s.l., to compensate for influence of density flow (estimated position of freshwater-saltwater interface is in **Figure G.5.38**). 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 is simulated with 60 drain cells with conductance 250 m^2/d (k/b=4.63e^{-8} s^{-1}). The elevation of drain was set at -35 m a.s.l. Dredge ponds around Paya Indah and Imuda tin mine (**Figure G.4.4**) are simulated using hydraulic parameters listed in **Table G.4.1**.

The location of modelled pumping wells is shown in **Figures G.2.1 and G.4.1**; the assigned pumping rates are listed in **Table G.5.1**.

4.3 Model Calibration and Verification

During the calibration process the model input parameters were adjusted to achieve a desired degree of correspondence between the model simulation and the data describing present groundwater flow system. Manual trial-and-error method was used with adjustments of hydraulic conductivities (model zones of homogeneous hydraulic conductivities), adjustments of leakage across a confining clayey layer, and designation of boundary conditions (river, drains, general head boundary).

Hydraulic parameters of 3D groundwater flow model are based on results of realised pumping tests at Paya Indah, Kajibumi WF 2, and Kanchong Darat (**Figure G.2.3**). 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 comparison of measured and modelled drawdown documents the quality of derived hydraulic parameters (**Figures G.3.12-15, G.3.25-28 and G.3.32-35**).

The 3D model was calibrated against groundwater levels in the model area measured on March 9 to 13, 2001 (**Figure G.2.19**). For model calibration and verification, two other measurements of groundwater levels and time series from long-term groundwater level monitoring at existing wells were to disposal (**Figures G.2.20 and G.2.21**, **Data Book Figures G.2.12-22**).

Calibration runs were made as steady-state simulation with the pumping rate scenario, which corresponds to Simulation Variant 1 (see column Variant 1 in **Table G.5.1**). The hydraulic parameters of model were adjusted only in narrow range, defined with results of three pumping tests. The adjustments of hydraulic conductivities were performed especially for bedrock and dredge ponds material expected to be around Paya Indah and Imuda tin mine.

The analysis during calibration runs 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 to disposal 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. [4), 6)]

Figures G.5.2 and G.5.3 present the calibrated modelling results; namely, the simulated contour lines of piezometric head and directions of groundwater flow in Simulation Variant 1. The comparison of **Figures G.2.19 and G.2.20** with **Figures G.5.2** or **G.5.6** documents the match of modelled and measured piezometric heads. The modelled and measured piezometric heads in the area along the seacoast need not correspond, since this area is supposed to be affected by density flow (preliminary estimation of freshwater-saltwater interface is shown in **Figure G.5.38**).

The computational layers are based on the geological model with seven (7) layers described in previous sections. In some areas, for example near the bedrock, the geological (and model layers) are very thin. The thickness of model layers varies from 0 to more than 10 metres. Sandy layers create lenses inside clays or decline. Contacts of very low permeable dredge ponds or bedrock with high permeable gravelly aquifer create conductivity contrasts.

From hydrogeological point of view, the properties and geometry of all of these seven layers play an important role. The downside of a detail geological model is that convergence problems of model solver may sometimes occur. From computational point of view, some compromise should be found between the quality of geological model and abilities of available modelling software.

During the test runs and calibration some modification and optimisation of initial model set up was done, to minimise convergence problems or to speed up computation. For instance, the layers with thickness less than 0.5 m were assigned with next layer properties.

Slice-Successive Overrelaxation Package (SOR) was applied as the most stable solver for concrete model set up. All Simulations were performed using 0.01 m head change criterion for convergence, with acceleration factor 1. The upper limit on the number of iterations was set to 1000.

The accuracy of a 3D groundwater flow model is dependent upon the level of understanding of the system whose model is to represent: primarily upon amount and quality of available data. Modifications, or more sophisticated calibration and verification of prepared model can be done in the future; it shall be based on compilation and evaluation of data from established long term monitoring and other investigation, which help to understand and characterise boundary conditions and groundwater regime in the model area.

5. MODEL APPLICATION

5.1 Objectives and Scenarios of Model Applications

The overall project objective is to establish a reliable groundwater model for the Langat Basin, which enables the authorities to formulate optimal management strategies leading to a protection of groundwater resources and a sound ecological development for the area. The constructed 3D groundwater flow model represents a technical scientific based management tool and is ready for practical use.

In order to demonstrate the applicability of the established modelling tool, a number of application scenarios have been carried out. The results of nine (9) selected scenarios (Simulation Variants), characterise the groundwater conditions in the Study Area and potentially can support technical decisions and policy making in the Study Area.

The definition of scenarios is based on variation of groundwater abstraction from existing well fields and dewatering pits; and change of groundwater recharge from rainfall. Simulation Variants 0, 1, 2, 3, 6, and 7 represent steady-state flow simulation. Simulation Variants 4, 5, and 8 are performed as transient flow simulation (with duration 3, or 20 years, respectively). **Table G.5.1** provides an overview of simulated pumping rates and recharge that characterise each model scenario.

In brief the characterisation of scenarios is:

- 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 (during field investigation in the Study), with abstraction of groundwater from existing well fields and dewatering pits.
- Variant 2 – near future conditions, with increased abstraction of groundwater, after putting Kajibumi WF 1 and Kajibumi WF 2 into operation.
- Variant 3 and 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 G.5.1 (1/2) Simulated Daily Pumping Rates from Well Fields and Dewatering Pits

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

Table G.5.1 (2/2) Simulated Daily Pumping Rates from Well Fields and Dewatering Pits

Well field	**Variant 6** (m^3/d)	**Variant 7** (m^3/d)	**Variant 8** (m^3/d)
PWM-1	0	6450	6450
Well A (new)	0	0	0
Well B (new)	0	0	0
PWM-2 (JBA-1)	0	2640	2640
PWM-3	0	4440	4440
PWM-4	0	4440	4440
PWS-1	0	1200	1200
TW-4	0	1600	1600
Kajibumi WF 1	0	9200	0
Kajibumi WF 2	0	6900	0
Imuda Tin Mine	0	0	24432
Total	**0**	**36870**	**45202**

5.2 Groundwater Modelling

5.2.1 Natural Groundwater Flow – SV1, SV0

As described in the previous section, Simulation Variant 1 (SV1) represents recent status and calibration variant. The steady-state simulation was performed with pumping rate scenario, which corresponds to conditions during field investigation in the Study period (see column Variant 1 in **Table G.5.1, Figures G.2.19-21**). The modelling results are presented in **Figure G.5.2**. **Figure G.5.3** shows the results of simulation in model cross-section.

Simulated contour lines of piezometric head and directions of groundwater flow in Simulation Variant 1 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. The elevation of groundwater reaches about –10 m a.s.l. in the centre of depression (Imuda Mine)

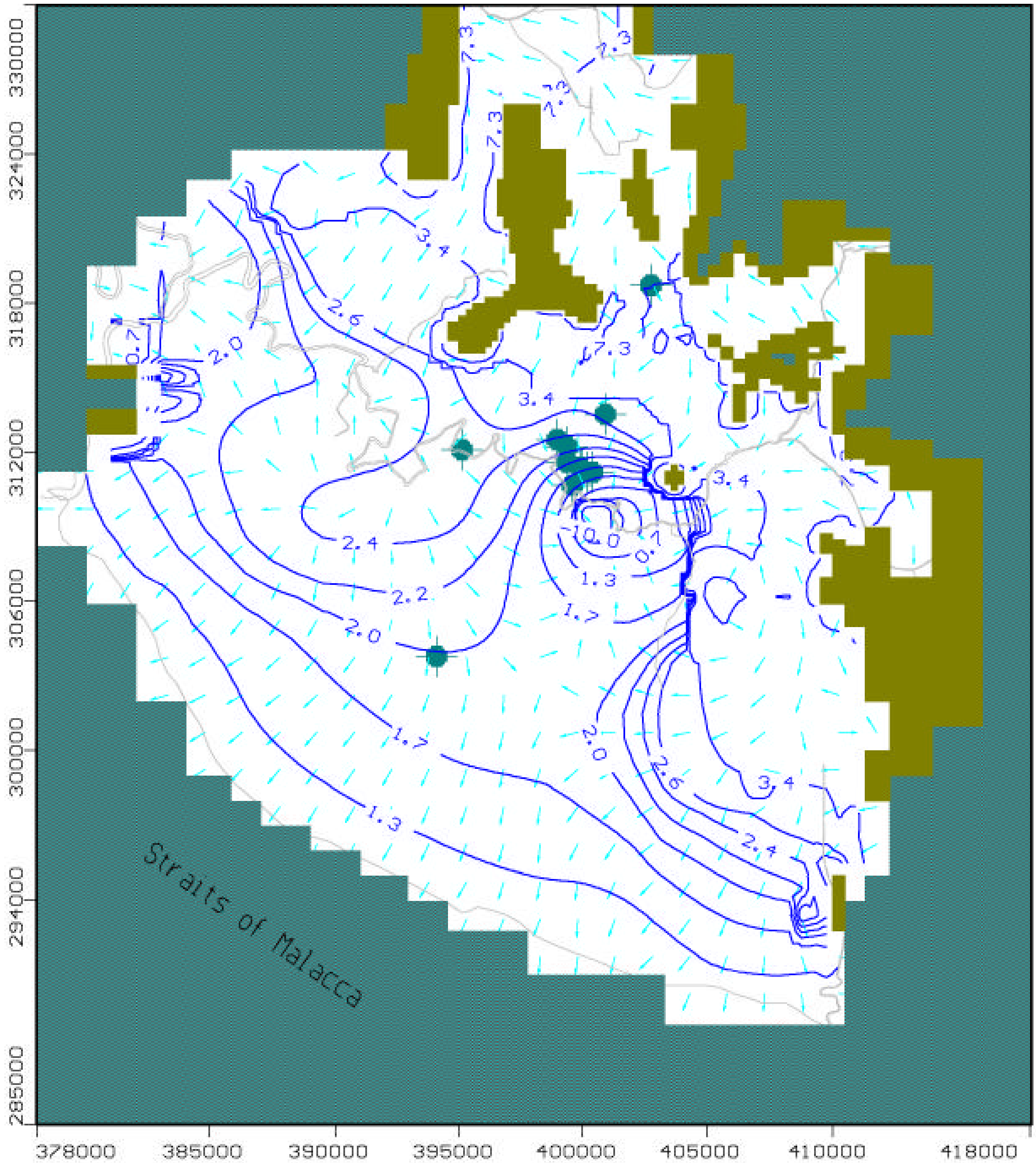
The simulation assumes 954 mm/year of effective rainfall and lower abstraction of groundwater from existing well fields and dewatering pits (**Table G.5.1**). Especially, the amount of abstracted water from Imuda Tin Mine may be underestimated. In spite of this the simulated groundwater divide is located very near the seacoast. It can be expected that some reduction of groundwater recharge from rainfall, or some increase of pumping rate may (might) occur and cause the movement of groundwater divide towards seacoast and create conditions suitable for seawater intrusion.

Simulation Variant 0 (SV0) is similar to Simulation Variant 1, with difference that it considers only abstraction of water from dewatering pits (**Table G.5.1**). The result of simulation is presented in **Figure G.5.1**. The stop of groundwater abstraction from existing well fields leads to reduction of depression cone and movement of groundwater divide inlands. It is believed that the assumptions and results of this simulation variant represent the natural (original) conditions in the past, and the calculated distribution of piezometric heads can be considered as initial state for calculation of land subsidence.

The results of simulated water balance in the model area are listed in **Table G.5.2** (Variant 0, Variant 1).

5.2.2 Impact of Increased Groundwater Abstraction – SV2, SV3, SV5

To test the effects of increased groundwater abstraction, three simulation variants with different configuration of pumping wells at Megasteel/Amsteel II and Kajibumi Well Fields were modelled. These scenarios are based on real status of groundwater exploitation documented during pumping tests and information found in existing reports. [4), 6)]



LEGEND

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

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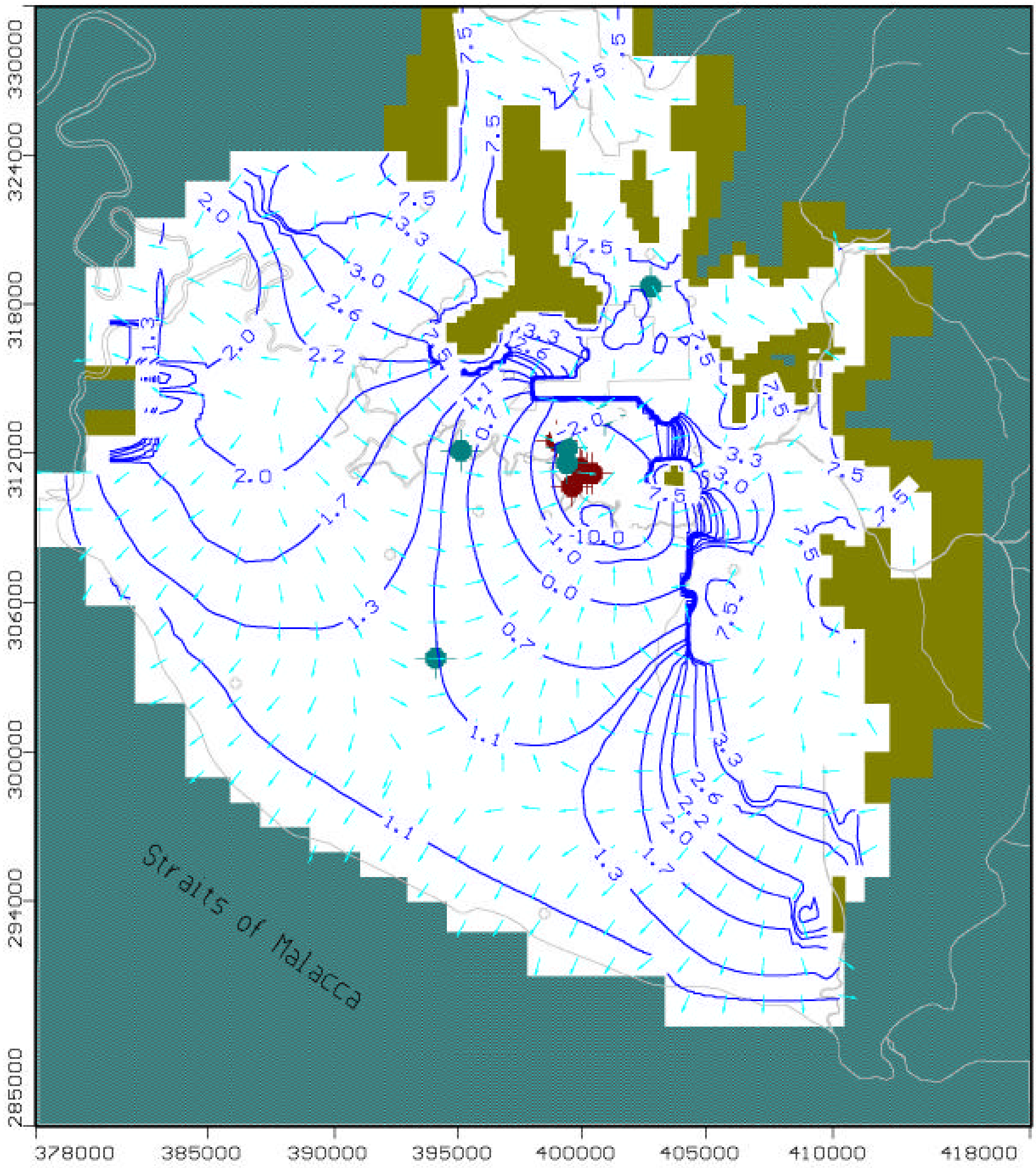
Figure G.5.1

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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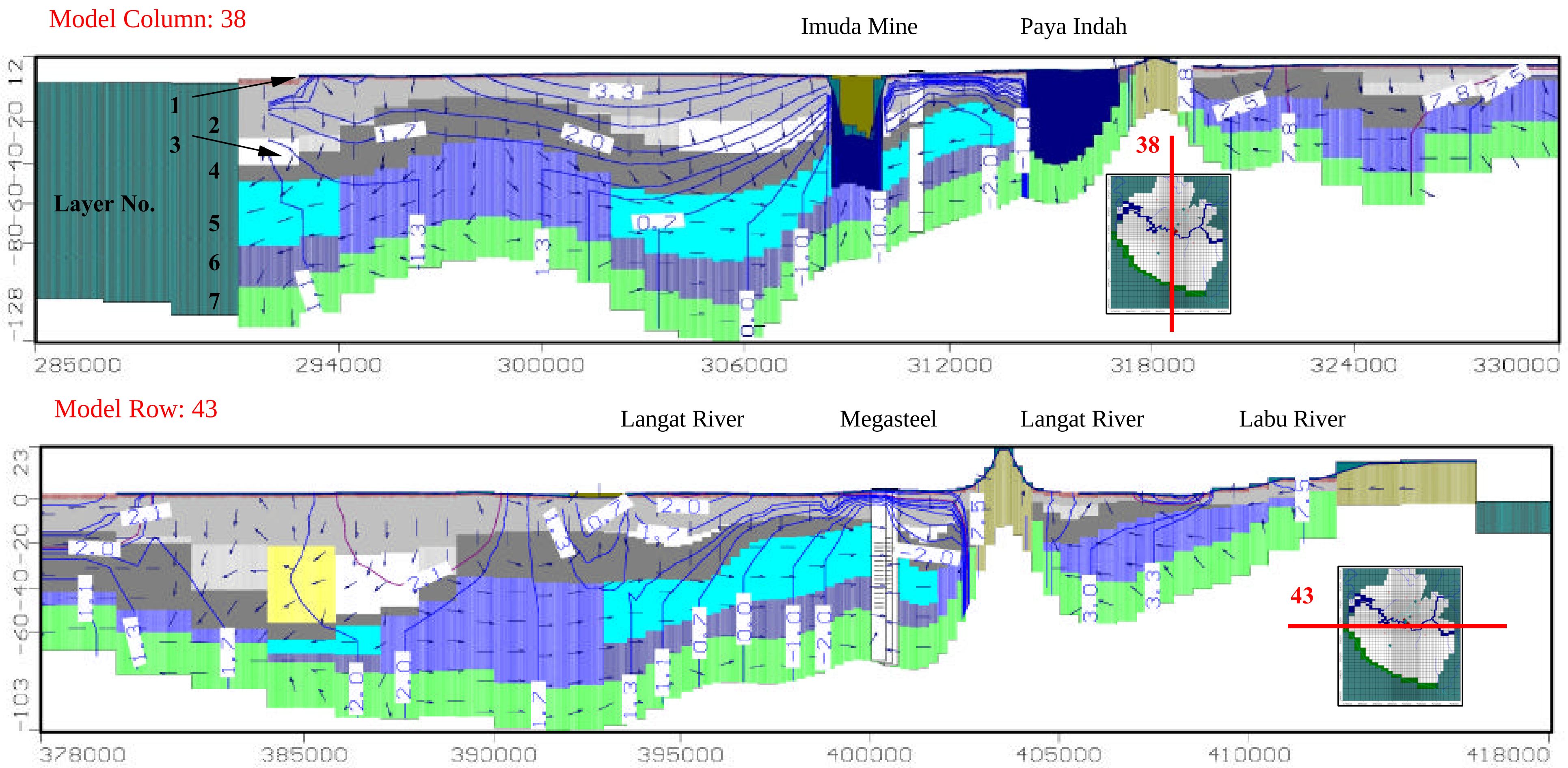
Figure G.5.2

Solution Variant 1 - Head Equipotentials in Model Layer 3c



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

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LEGEND

Contour Lines of Piezometric Head

Direction of Groundwater Flow

Inactive Cells

Figure G.5.3

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

Table G.5.2 (1/2) Simulated Water Balance in Model Area

Model (+ Input / - Output)	Variant 0 (m^3/d)	Variant 1 (m^3/d)	Variant 2 (m^3/d)	Variant 3 (m^3/d)	Variant 4 (m^3/d)	Variant 5 (m^3/d)
1. Recharge (Rain.-Evap.)	2586074	2586074	2586074	2586074	0	2586074
2. Drains, Canals	- 2385000	- 2374800	- 2367300	- 2351800	- 10631	- 2354300
3. Imuda Tin Mine - GW	- 22454	- 20310	- 19182	- 14359	- 20619	- 16357
- SW	- 4574	- 4574	- 4574	- 4574	0	- 4574
4. Leakage from River	2410	3186	3927	7299	4260	6438
5. Leakage into River	- 3576	- 3149	- 2623	- 2040	- 2267	- 2200
6. Pumping Wells	0	- 20770	- 36870	- 71320	- 20770	- 71320
7. Leakage from GHB(sea)	0	0	807	15021	348	11538
8. Storage	0	0	0	0	37771	46
GW Recharge from rain (1.–2.–3.^{SW})	196500	206700	214200	229700	0	227200

Table G.5.2 (2/2) Simulated Water Balance in Model Area

Model (+ Input / - Output)	Variant 6 (m^3/d)	Variant 7 (m^3/d)	Variant 8 (m^3/d)
1. Recharge (Rain.-Evap.)	2586074	2586074	1873358
2. Drains, Canals	- 2394285	- 2380796	- 1660440
3. Imuda Tin Mine - GW	0	0	- 19836
- SW	0	0	- 4574
4. Leakage from River	1586	2475	3680
5. Leakage into River	- 3647	- 2945	- 2557
6. Pumping Wells	0	- 36870	- 20770
7. Leakage from GHB(sea)	0	0	0
8. Storage	0	0	752
GW Recharge from rain (1.–2.–3.^{SW})	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

The assumed pumping rates from well fields are summarised in **Table G.5.1**. The pumping rate scenario in steady-state Simulation Variant 2 is similar to that in Simulation Variant 1 (present status); 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. Simulation Variants 3 and 5 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).

The transient flow Simulation Variant 5 used the initial head values, which represent final head distribution coming from Simulation Variant 1 (steady-state simulation). Steady-state Simulation Variant 2 and 3 used the initial head values 1 m below the ground surface.

The results of all simulations are presented in **Figures G.5.4**, **G.5.5** and **G.5.10-13**.

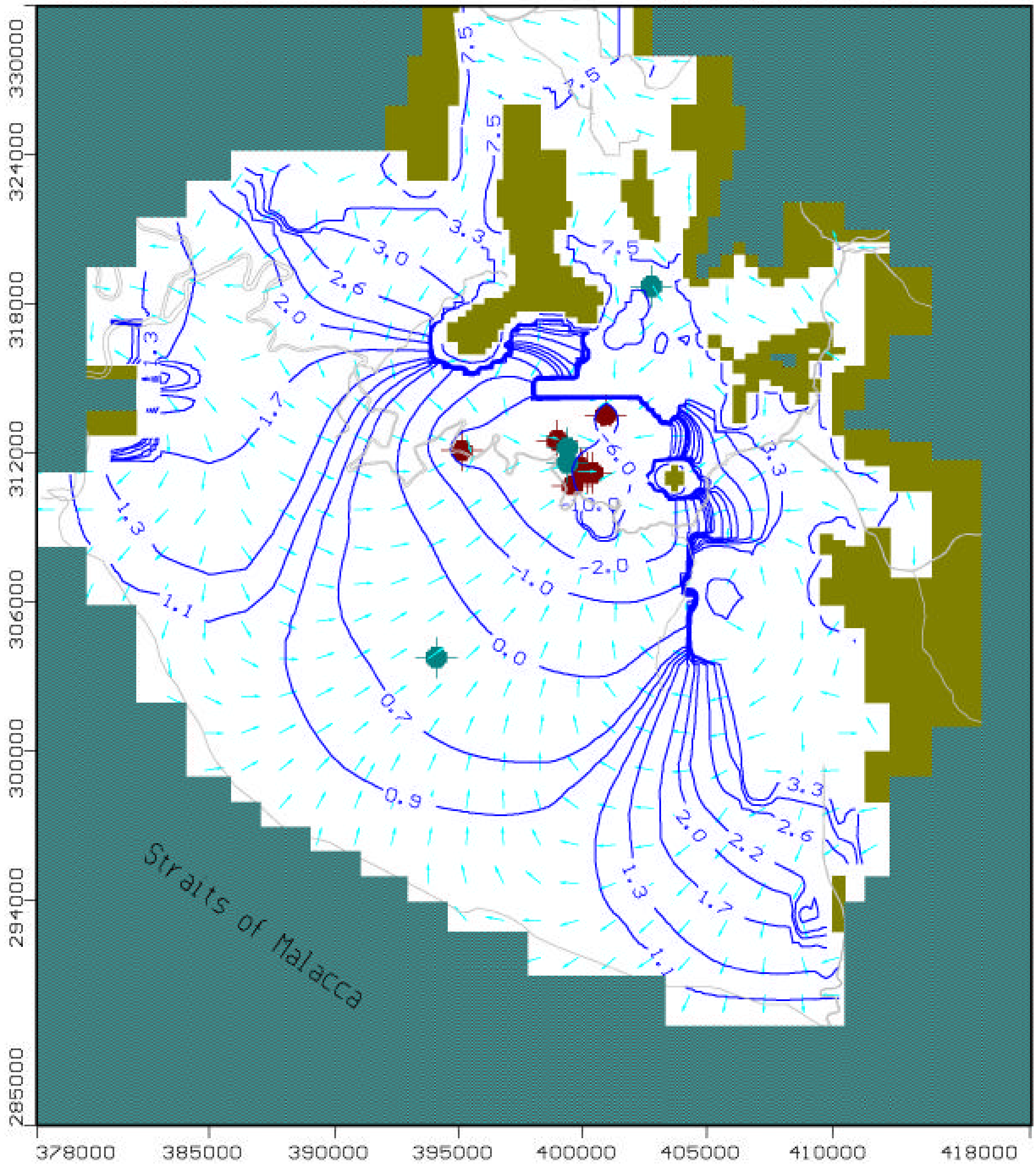
Figure G.5.4 illustrates, that already some small increase of pumping rate causes the movement of groundwater divide towards seacoast and creates more suitable conditions for seawater intrusion (compare with recent status in **Figure G.5.2**).

Significantly increased pumping with duration for 3 years (Simulation Variant 5, **Figure G.5.10**) changed the head equipotentials and direction of flow in the main aquifer significantly (compare with **Figure G.5.2**). Larger cone of depression cause the movement of groundwater divide towards seacoast and creates conditions suitable for intensive seawater intrusion. The calculated drawdown in the area (cells) around Megasteel and Imuda Mine reaches about 10 metres (**Figure G.5.11**).

Drawdown of water levels (piezometric heads) in the upper peat layer, model layer 1, is negligible (**Figure G.5.12**). The small drawdown in shallow horizon is caused by low permeability of clayey aquitard (low leakage through the Model Layer 2), and sufficient replenishment by rainfall recharge. The drawdown in clayey aquitard (Model Layer 2) reaches 8 metres and spreads over a large area to the south of the Paya Indah Wetlands (**Figure G.5.13**).

Steady-state Simulation Variant 3 is a long-term analogue of 3-year transient flow Simulation Variant 5. The comparison of piezometric heads and direction of groundwater flow (**Figure G.5.5**) with results of Simulation Variant 5 (**Figure G.5.10**) shows only minor differences caused by long-term increased pumping.

The results of simulated water balance in the model area are compared in **Table G.5.2** (Variants 2, 3, and 5).



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 G.5.4

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

Solution Variant 2 - Head Equipotentials in Model Layer 3c

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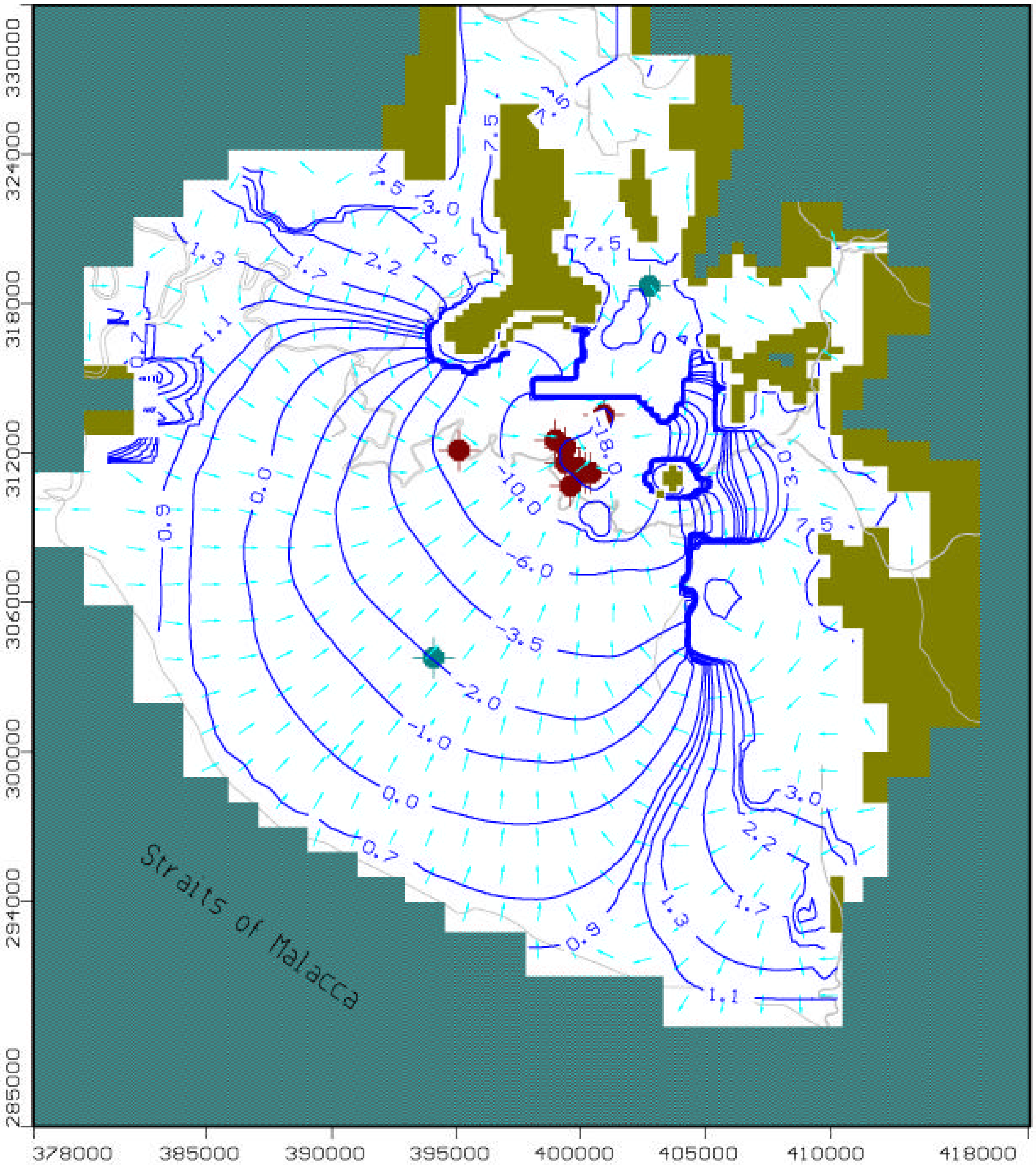

LEGEND

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

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Figure G.5.5

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

Solution Variant 3 - Head Equipotentials in Model Layer 3c

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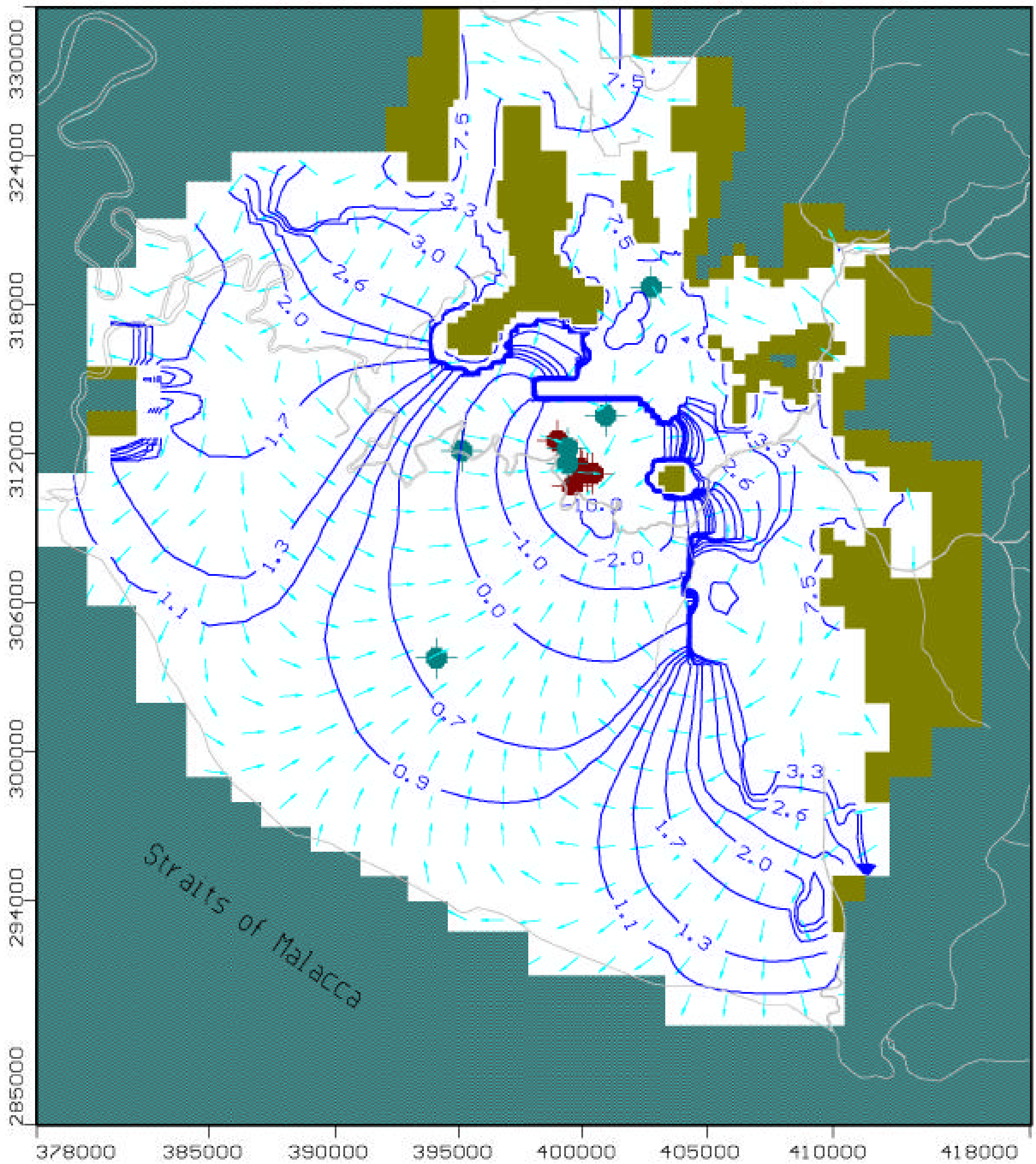

LEGEND

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

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

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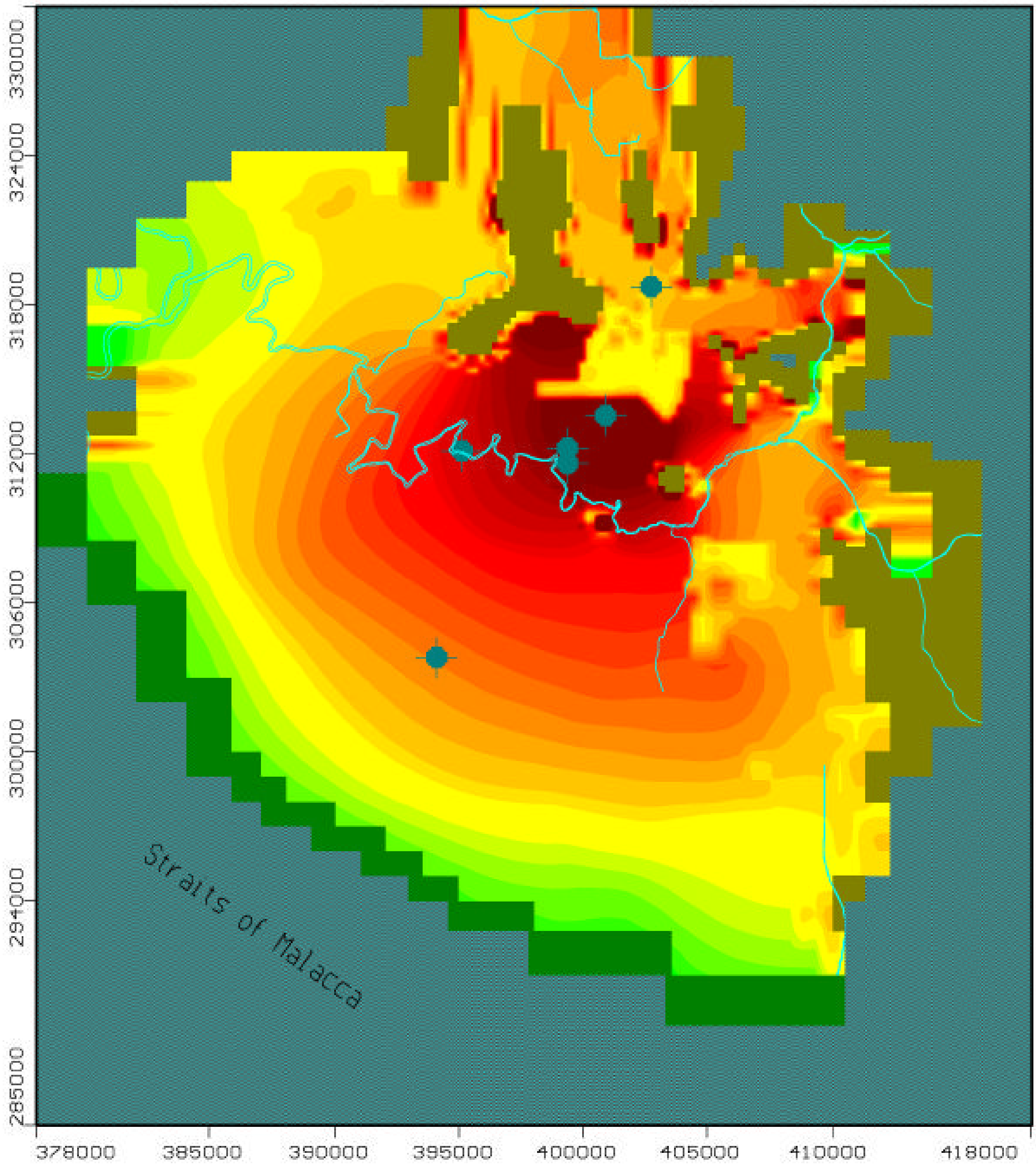
Figure G.5.6

Solution Variant 4 - 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 G.5.7

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

Solution Variant 4 - Drawdown in Model Layer 3c

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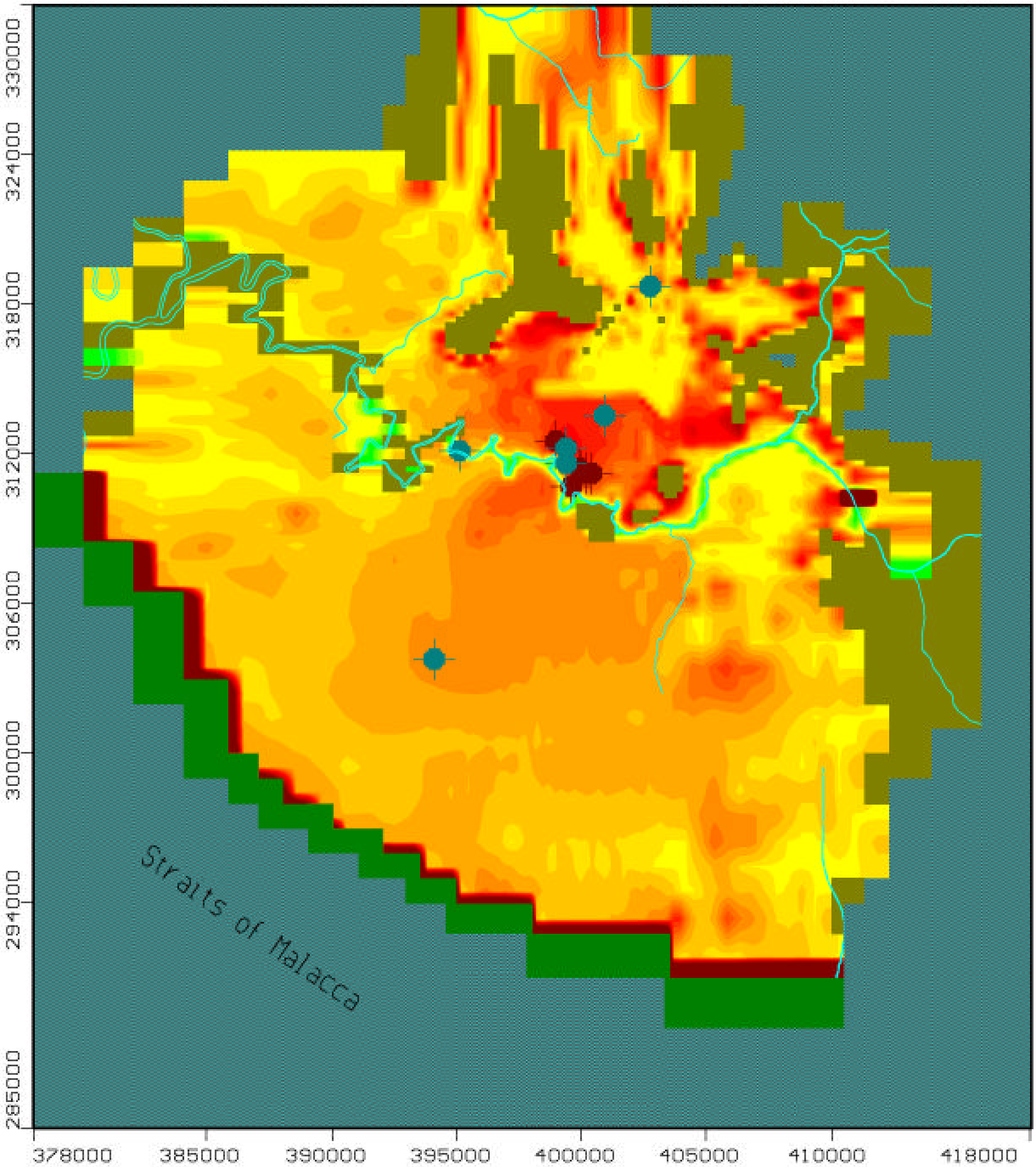

LEGEND

- Inactive cells
- Dry cells
- General head boundary

Drawdown (m)

0	0.8
0.2	1.4

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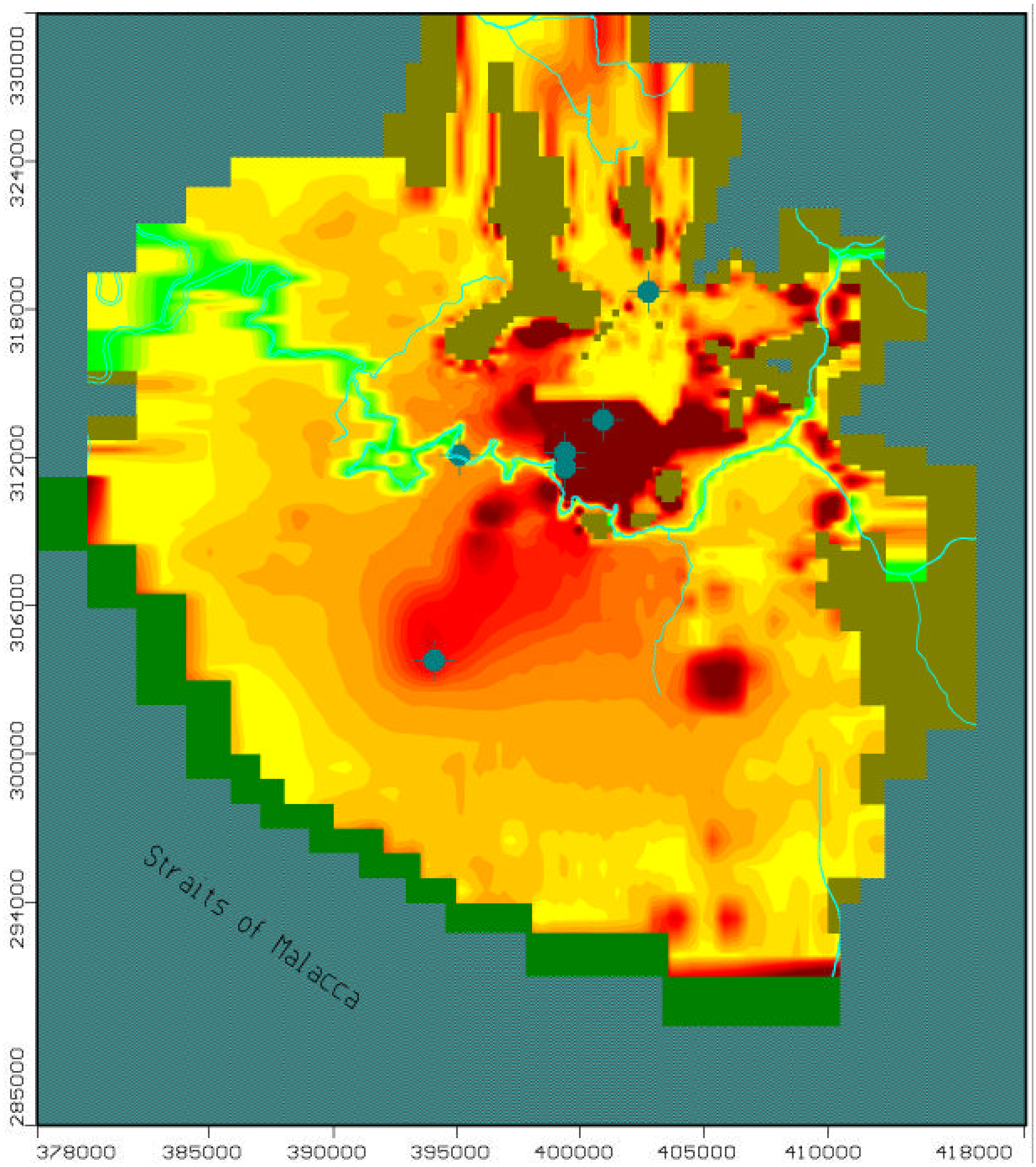
Figure G.5.8

Solution Variant 4 - Drawdown in Model Layer 1



LEGEND

Inactive cells

Dry cells

General head boundary

Drawdown (m)

0

0.2

0.8

1.4

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Figure G.5.9

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

Solution Variant 4 - Drawdown in Model Layer 2

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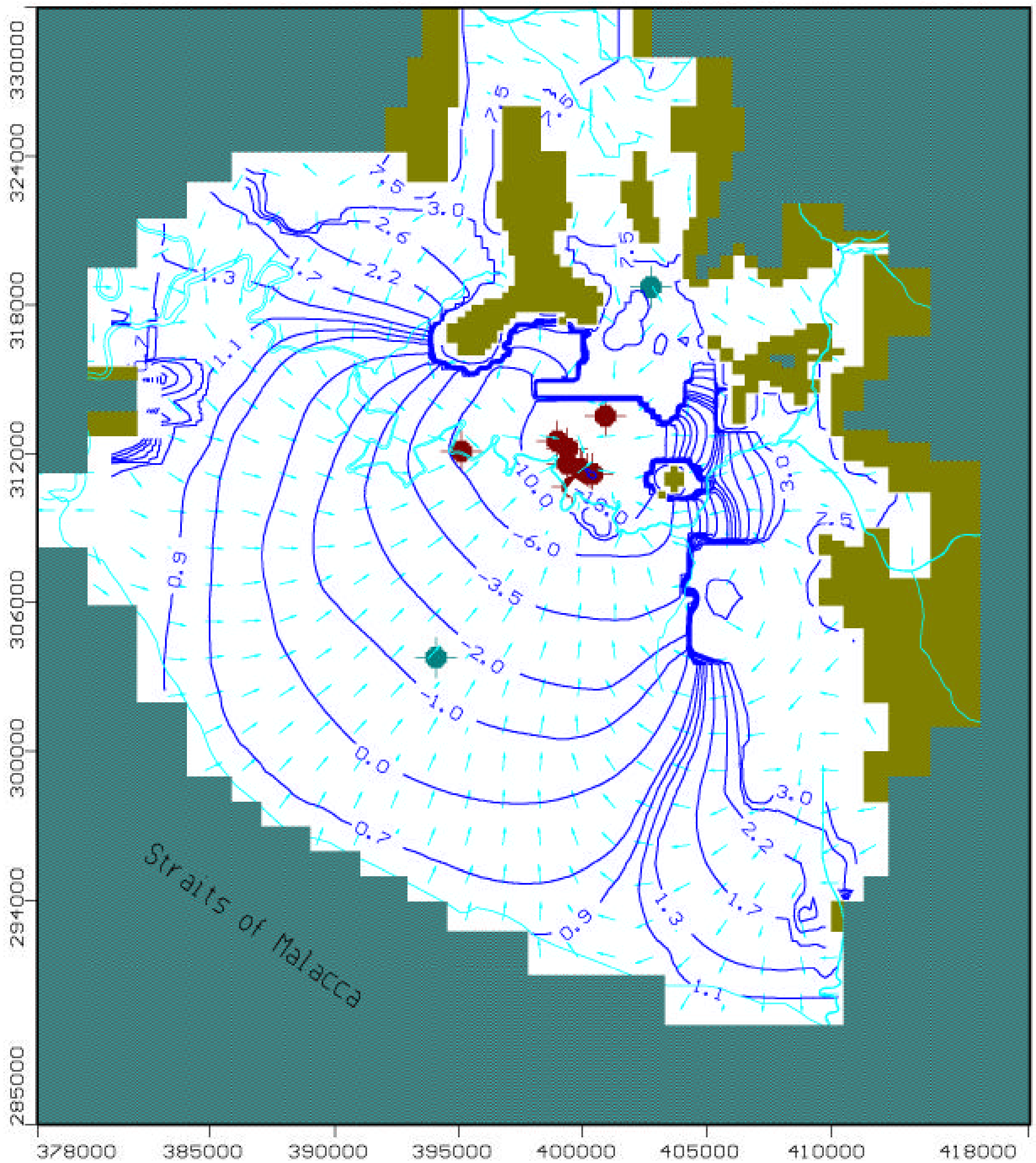

LEGEND

- Contour Lines of Piezometric Head
- 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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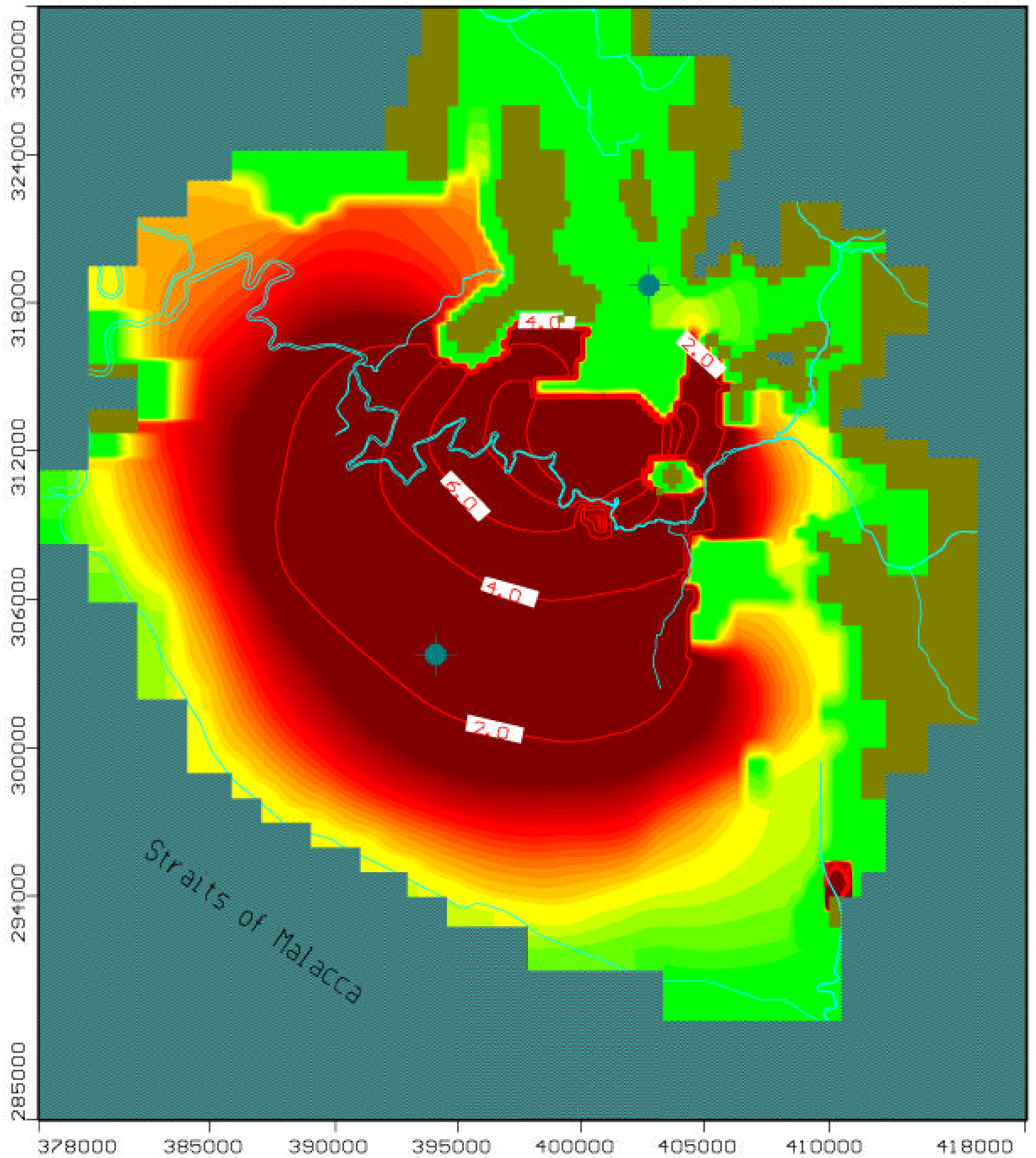
Figure G.5.10

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 G.5.11

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

Solution Variant 5 - Drawdown in Model Layer 3c

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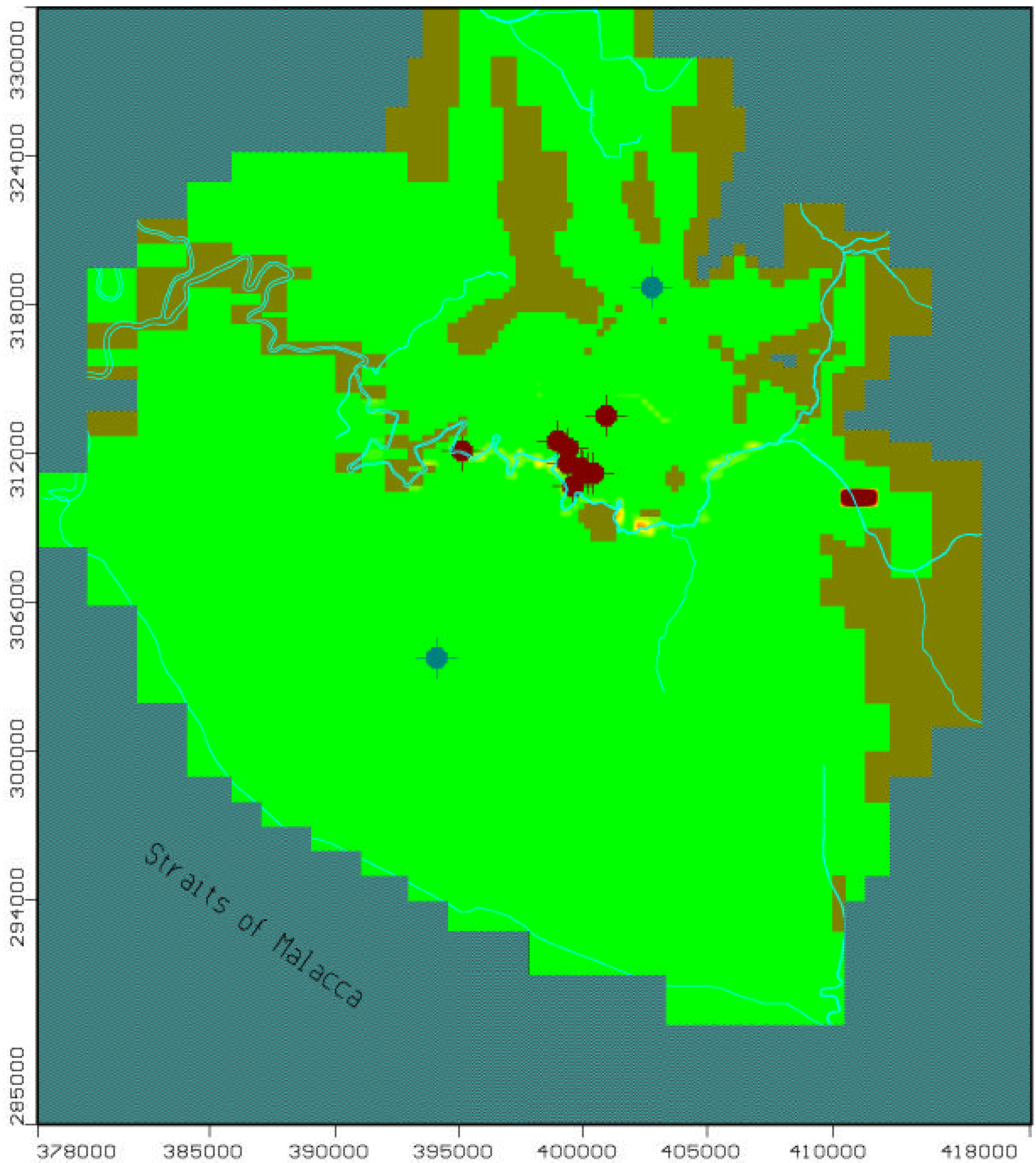

LEGEND

Inactive cells
Dry cells
General head boundary

Drawdown (m)

0
0.2
0.8
1.4

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Figure G.5.12

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

Solution Variant 5 - Drawdown in Model Layer 1

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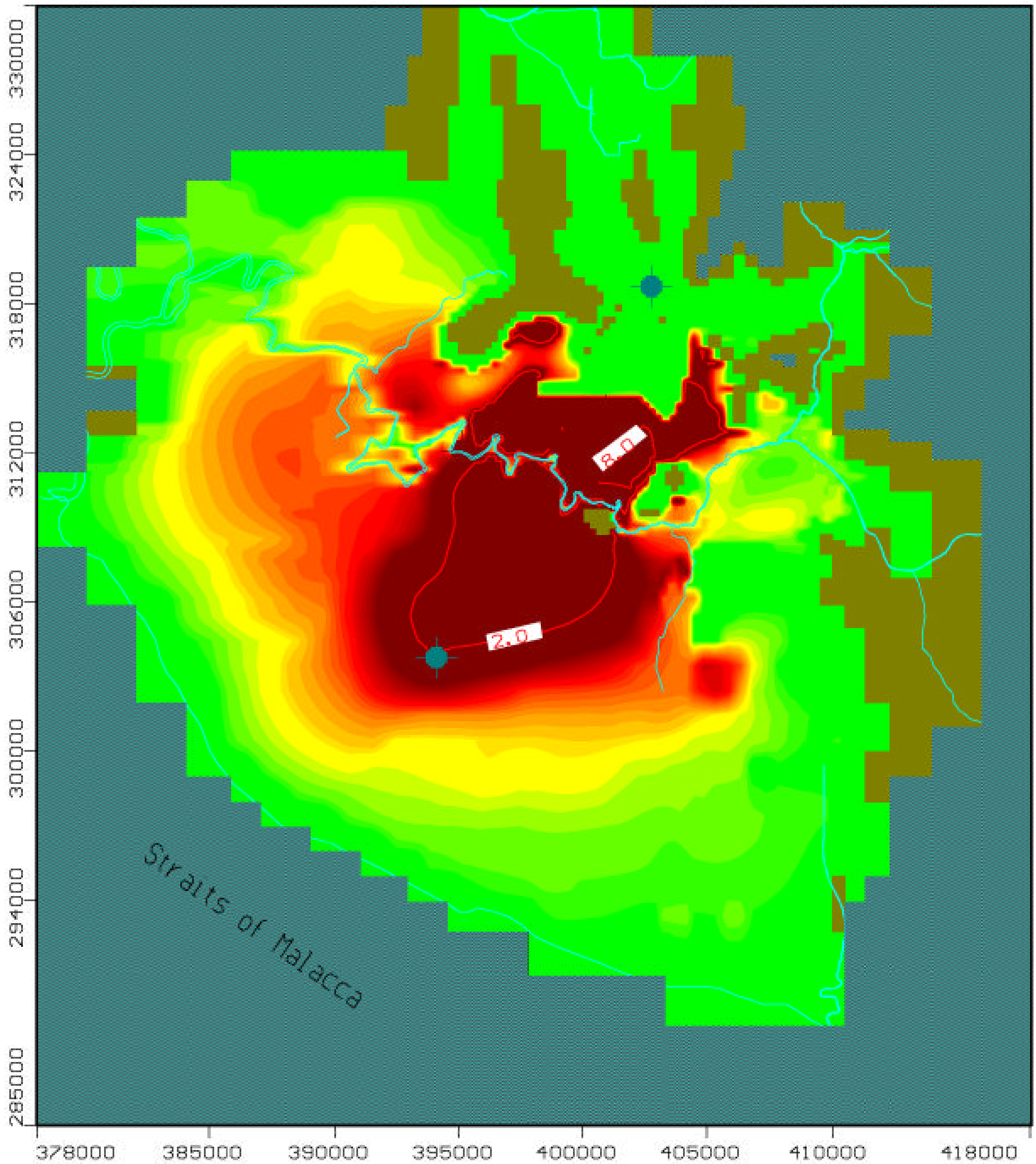

LEGEND

Inactive cells
Dry cells
General head boundary

Drawdown (m)

0
0.2
0.8
1.4

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Figure G.5.13

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

Solution Variant 5 - Drawdown in Model Layer 2

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5.2.3 Impact of Dry Season – SV4

To test the effects of long-term periods of no recharge from rainfall, the transient simulation was run for a 3-year with zero effective rainfall (rainfall minus evapotranspiration). This scenario was chosen according to real status of groundwater recharge documented in the dry period 1988-1992 or 1997-1998 [**Figure G.2.22(a)**].

The simulation is denominated as Simulation Variant 4; the daily pumping rates from active wells are described in **Table G.5.1**. The pumping rate scenario is the same as in Simulation Variant 1 (present status). Also the initial head values correspond to final head distribution in Simulation Variant 1.

The results of simulation are presented in **Figures G.5.6-9**. In the 3 years of zero effective rainfall the head equipotentials and direction of flow in the main aquifer is evidently changed (compare **Figure G.5.6** with **Figure G.5.2**). Larger cone of depression causes the movement of groundwater divide towards seacoast and creates conditions suitable for intensive seawater intrusion. The cut down of groundwater recharge caused up to 1.4 m drop of piezometric heads in the area around Megasteel and Imuda Mine (**Figure G.5.7**).

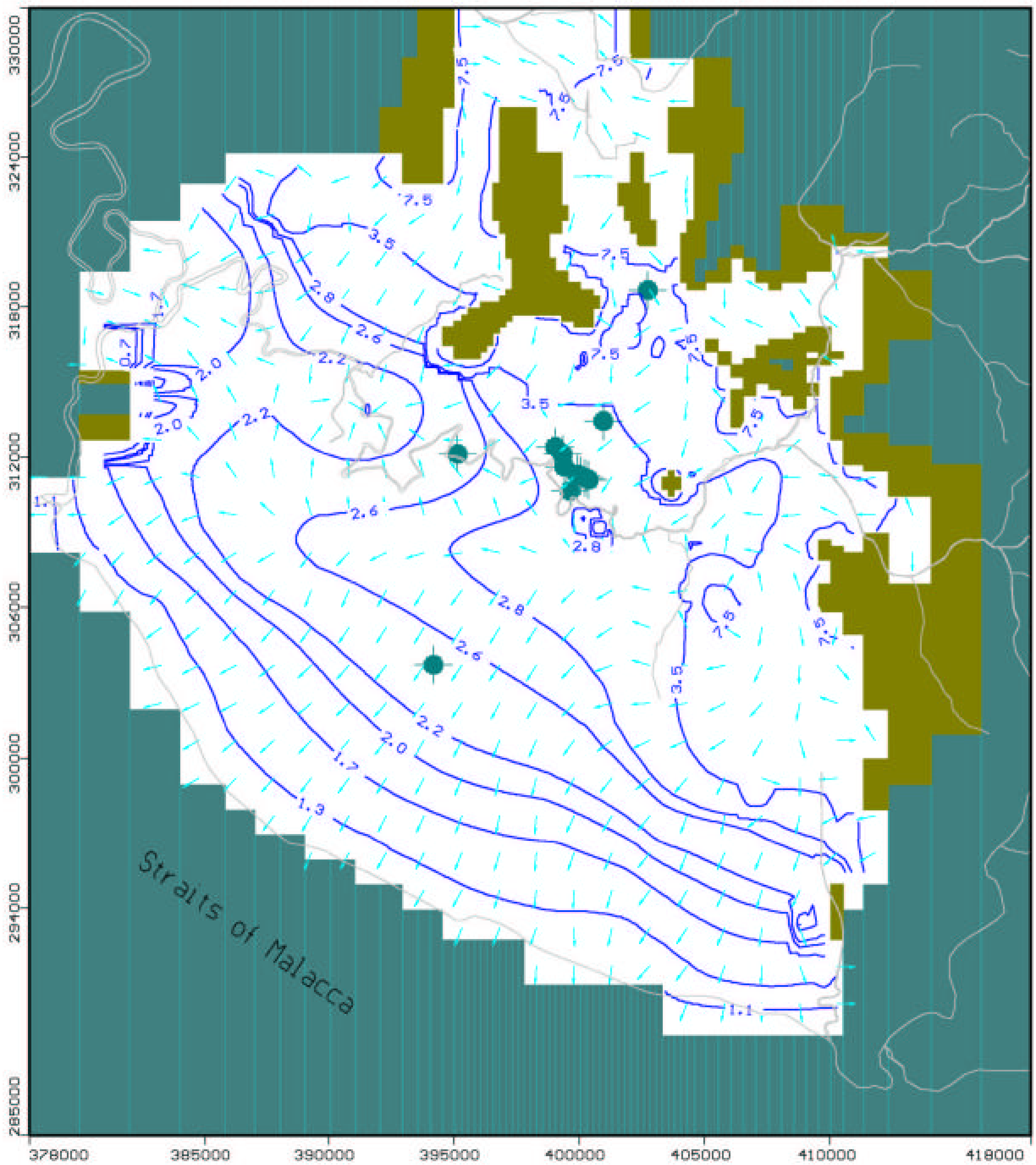
Drawdown of water levels (piezometric heads) in the upper peat and clay layer, model layer 1 and 2, is spread over a large area to the south of the Paya Indah wetlands (**Figures G.5.8** and **G.5.9**). The results of simulated water balance in the model area, which represent the third year of simulation, are listed in **Table G.5.2** (Variant 4).

5.2.4 Impact of Groundwater Abstraction from Imuda Mine– SV6, SV7

To test the effects of reduced groundwater abstraction from Imuda Mine, two simulation variants without any abstraction of water from dewatering pit and with different configuration of pumping wells were modelled.

The assumed pumping rates from well fields are summarised in **Table G.5.1**. The pumping rate scenario in steady-state Simulation Variant 6 is similar to that in Simulation Variant 0 (natural conditions); it differs only with consideration of abolished water abstraction from Imuda Mine. This means a significant decrease of total amount of abstracted water from 27,028 to 0 m^3/day. Simulation Variant 7 assumes pumping from existing pumping wells at Megasteel/Amsteel II and Kajibumi WF 1 and WF 2, similar to Simulation Variant 2 (total amount of abstracted water about 36,870 m^3/day).

Both steady-state simulation variants use the initial head values 1 m below the ground surface. The results of simulations are presented in **Figures G.5.14 and G.5.15**. The results of simulated water balance in the model area are presented in **Table G.5.2** (Variants 6 and 7).



LEGEND

	Contour Lines of Piezometric Head		Inactive Pumping Well
	Direction of Groundwater Flow		Active Pumping Well
	Inactive cells		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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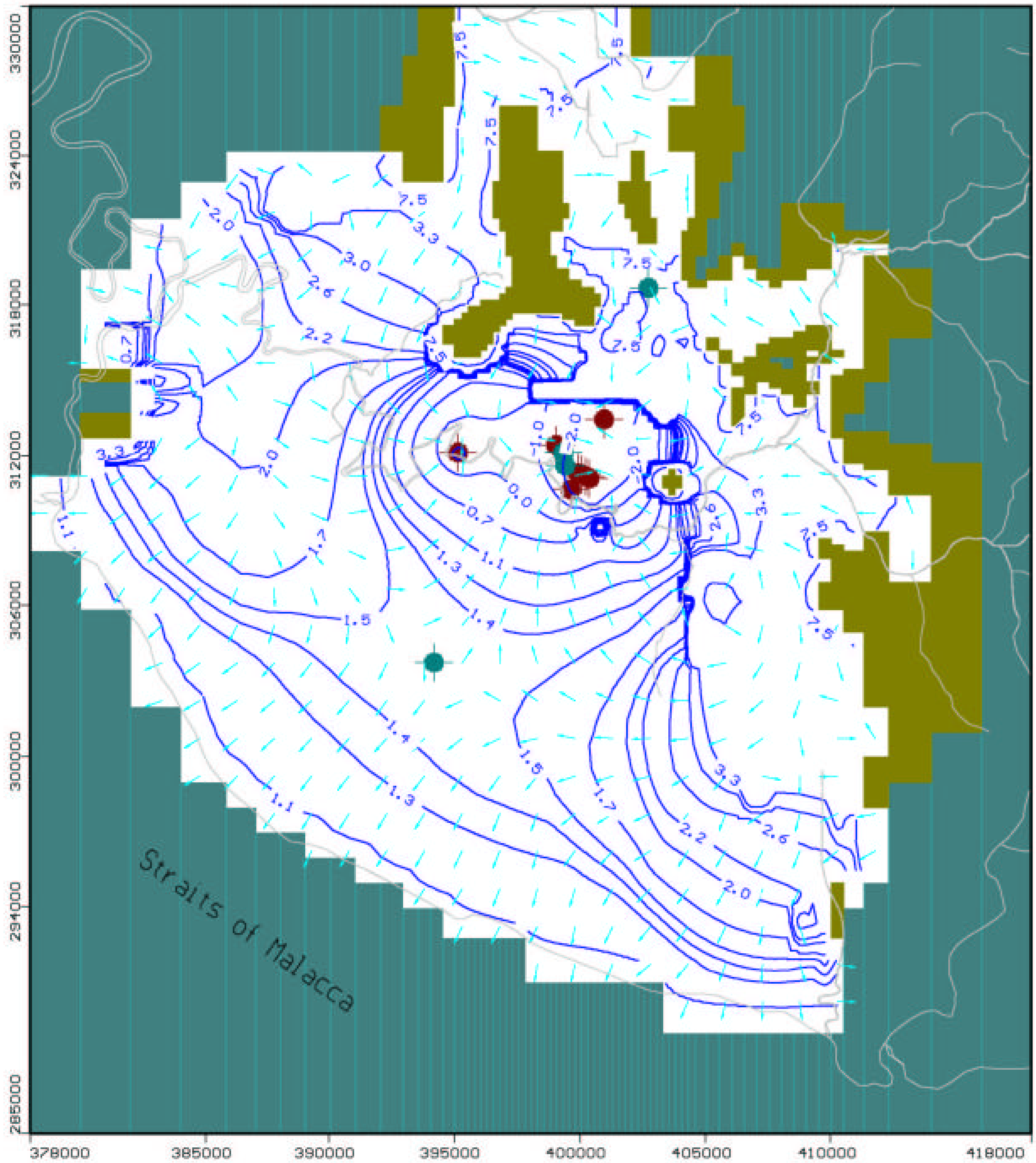
Figure G.5.14

Solution Variant 6 - Head Equipotentials in Model Layer 3c



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 G.5.15

Solution Variant 7 - Head Equipotentials in Model Layer 3c

Figure G.5.14 illustrates the results of Simulation Variant 6. The comparison of piezometric heads and direction of groundwater flow with results of Simulation Variant 1 (**Figure G.5.2**) shows significant differences caused by abolishment of pumping from wells and dewatering pit. The abolishment of pumping creates conditions with intensive fresh water 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. Map of head equipotentials and tabulated water balance document more intensive drainage function of Langat River, apparent for example in the Telok Datok area.

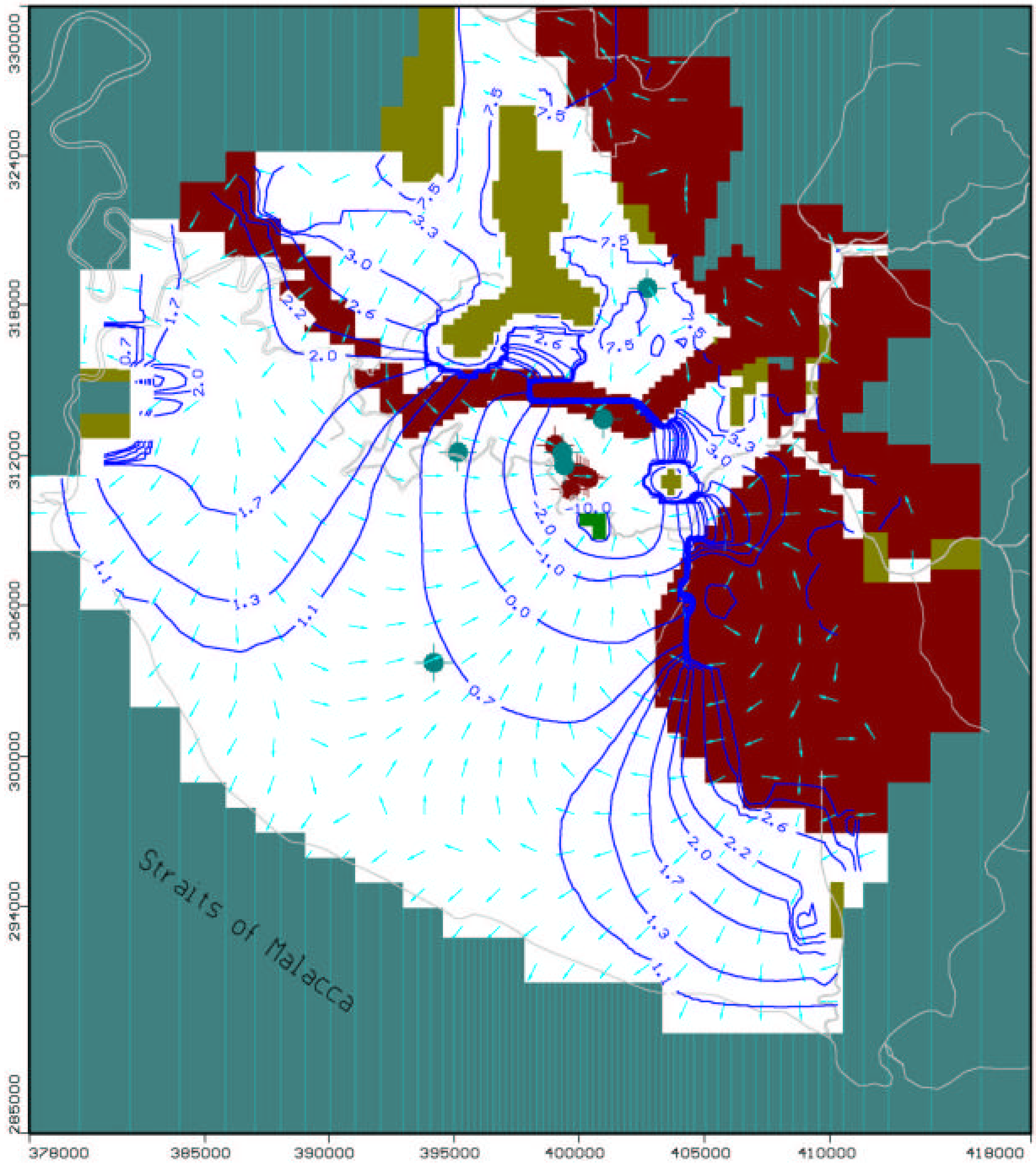
Figure G.5.15 shows the results of Simulation Variant 7. This Simulation Variant is similar to Simulation Variant 2; with difference, that it does not consider any abstraction of water from dewatering pits. The stop of groundwater abstraction from Imuda Mine leads to significant increase of groundwater level in the central part of basin, reduction of depression cone and movement of groundwater divide inlands (compare for example with results of Simulation Variant 2 presented in **Figure G.5.4**).

5.2.5 Impact of Industrial Development – SV8

Simulation Variant 8 demonstrates the effect of reduced recharge from rainfall in the industrially developed Multimedia Super Corridor (MSC) area. The transient simulation was run for 20 years with 45 mm/year of effective rainfall assigned in MSC area. This amount of effective rainfall represents approximately 60% of that simulated in the Simulation Variant 1 (rainfall - evapotranspiration - run off).

The daily pumping rates from active wells are described in **Table G.5.1**. The pumping rate scenario is the same as in Simulation Variant 1 (present status). Also the initial head values correspond to final head distribution in Simulation Variant 1.

The results of simulation are presented in **Figures G.5.16-19**. In the 20 years of reduced effective rainfall in industrially developed MSC area, the head equipotentials and direction of flow in the main aquifer is changed slightly (compare **Figure G.5.2** with **Figure G.5.16**). 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 (**Figure G.5.17**). Drawdown of water levels (piezometric heads) in the upper peat and clay layer, model layer 1 and 2, is less significant, it riches the value less than 0.2-0.5 m (**Figures G.5.18 and G.5.19**). The results of simulated water balance in the model area, which represent the twentieth year of simulation, are listed in **Table G.5.2** (Variant 8).



LEGEND

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

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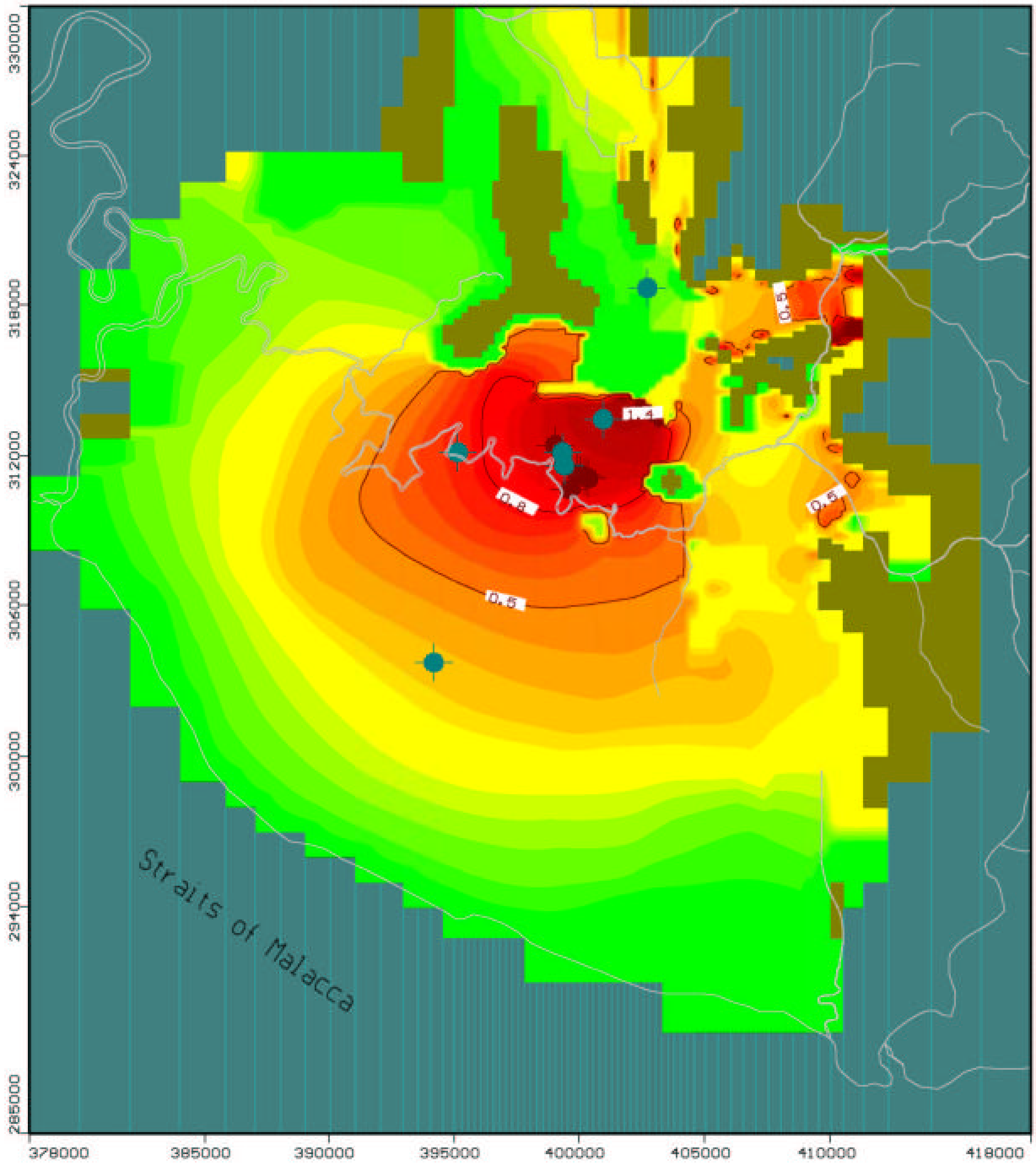
Figure G.5.16

Solution Variant 8 - 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 G.5.17

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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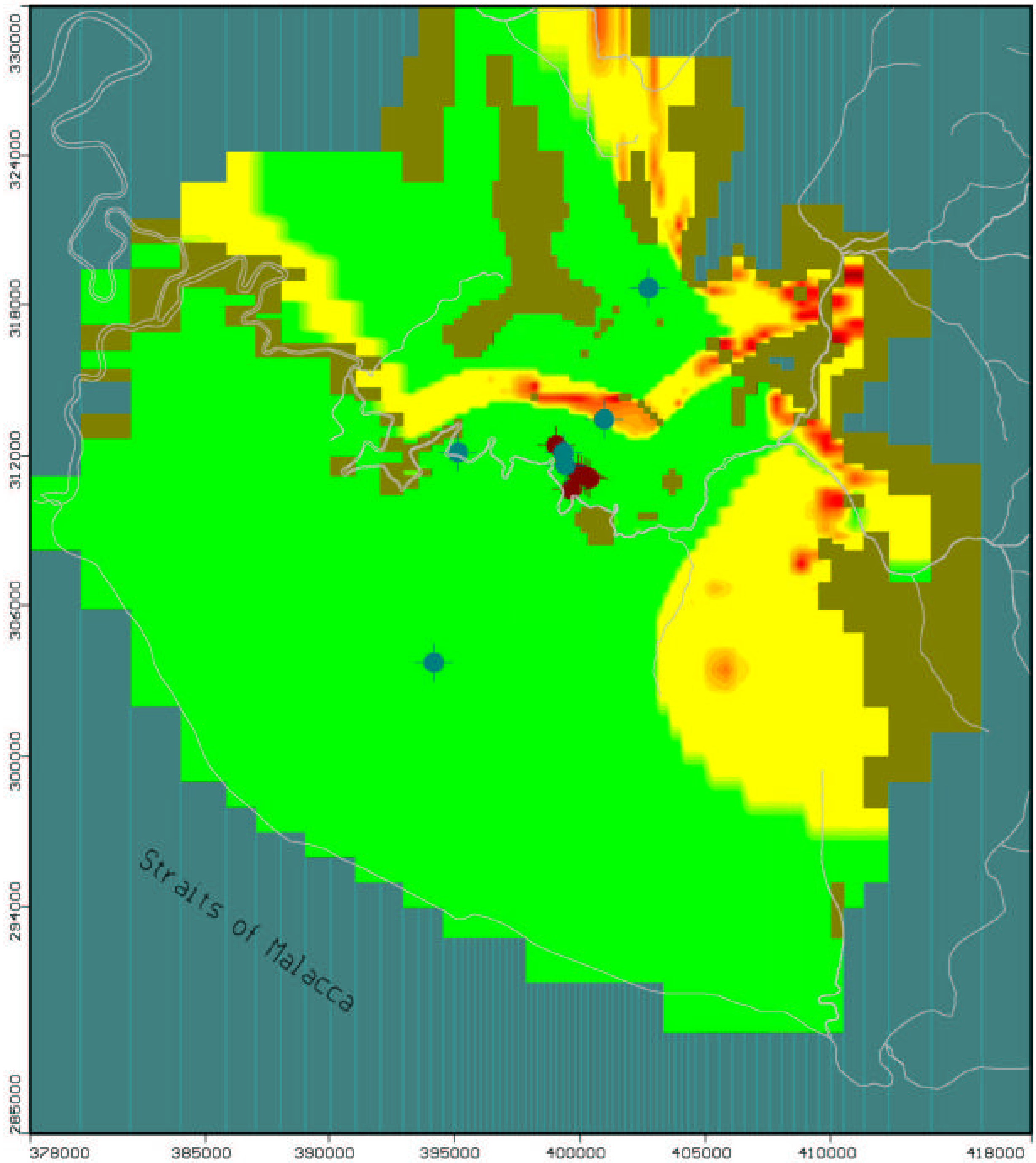

LEGEND

Inactive cells

Dry cells

General head boundary

Drawdown (m)

0

0.2

0.8

1.4

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Figure G.5.18

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

Solution Variant 8 - Drawdown in Model Layer 1

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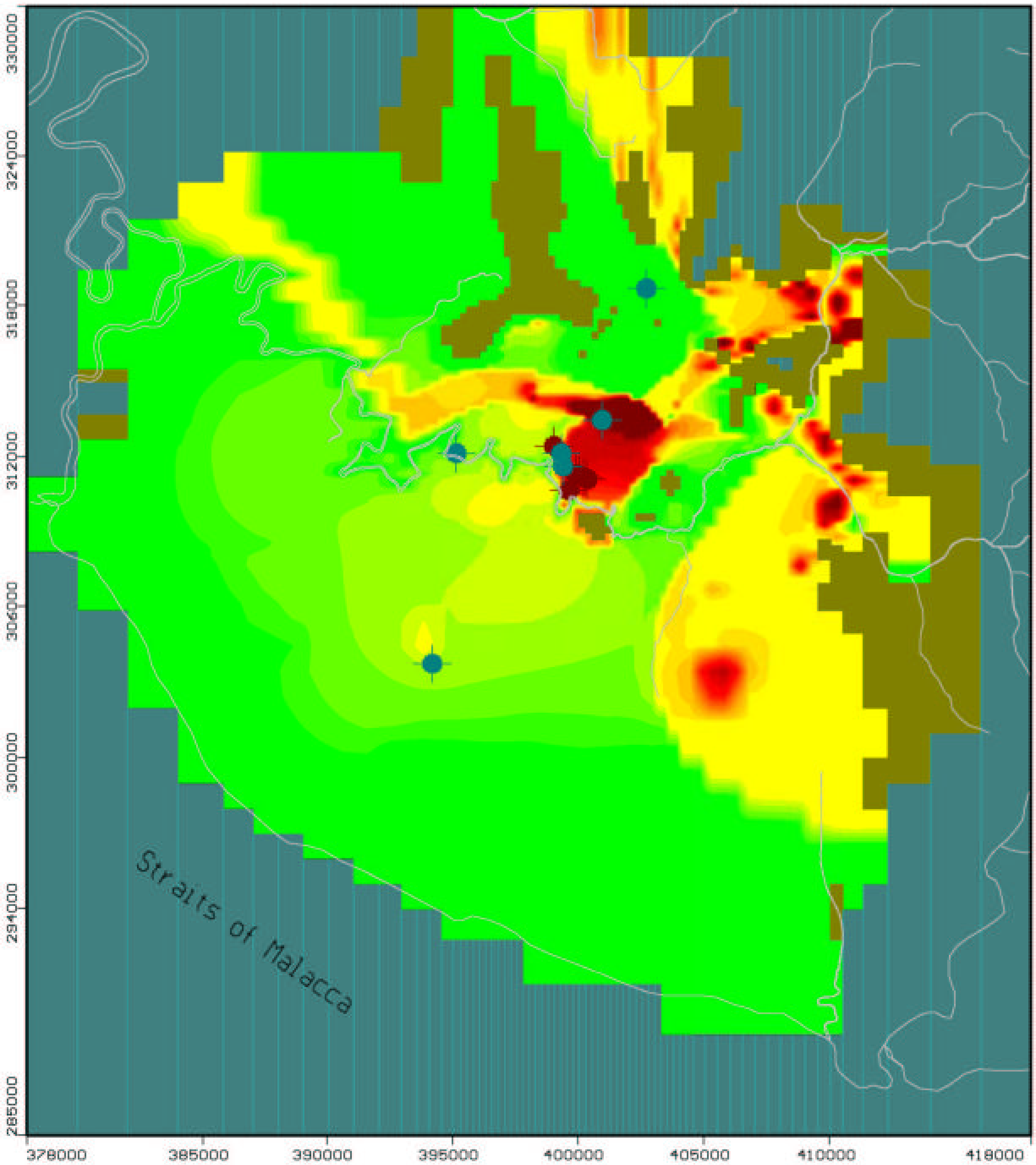

LEGEND

Inactive cells
Dry cells
General head boundary

Drawdown (m)

0
0.2
0.8
1.4

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Figure G.5.19

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

Solution Variant 8 - Drawdown in Model Layer 2

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5.3 Pollution Transport – SV2(b)

The simulated stationary velocity field in Solution Variant 2 forms the basis for the simulation of the pathlines and transport processes in the saturated zone. The model assumes the following parametric values: effective porosity of main aquifer, 0.20; longitudinal horizontal dispersivity, 10 m; transverse horizontal dispersivity, 1 m; transverse vertical dispersivity, 0.1 m.

Results of regional particle tracking simulation and results of fictive conservative pollution transport simulation are shown in **Figures G.5.20 and G.5.21**.

Result of three-dimensional particle tracking calculation is presented in the form of map of pathlines (**Figure G.5.20**). 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 transport velocities increase in the areas near extraction wells and dewatering pit in the central part of basin where the hydraulic gradient and flux is higher. The presented results of simulation allow evaluation of the fate of pollution in regional scale.

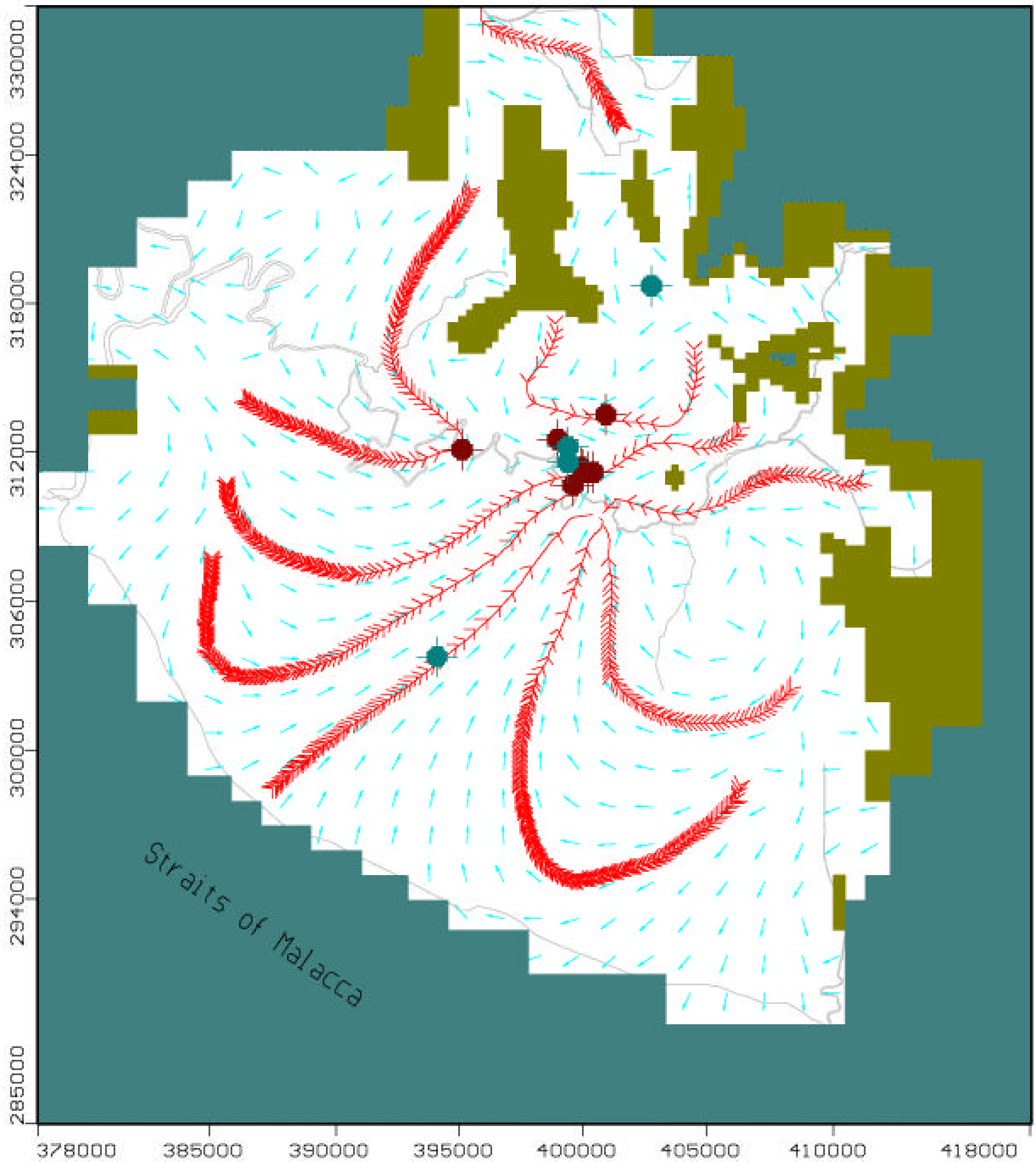
The following simple example of local transport model describes the changes in concentration due to advection and dispersion. All impacts of solid-solute interactions, various chemical reactions, decays or density flows have been ignored. The fictive source of pollution was located near the Langat River, in the west direction from Kajibumi WF 1. 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 G.5.21 shows the simulated concentration contours of contaminant using the Upstream Finite Difference method. In 20 years of continuous pollution the contaminant plume would enter the aquifer and reach the production wells at Kajibumi WF 1.

Visual MODFLOW supports few transport numeric engines. Transport of pollutant can be simulated with specific sorption and chemical reaction options (simulation of advection, dispersion, sorption, kinetic reactions). The presented example of transport simulation demonstrates the general applicability of established modelling tool. More comprehensive and representative simulation in local scale would require specific data and information coming from special field investigation at concrete location.

In general, the low permeable and thick clayey sediments create an efficient protection of main aquifer against migration of pollution from ground surface.

At the time of writing this report the limited amount and quality of available input data did not allow more representative interpretation of groundwater flow and quality processes. The future field investigation and long-term monitoring shall be organised and performed by local organisations according to proposed methodology which ensures gathering of reliable data, improvement of model set up and more detail study of hydraulic and geochemical aspects of groundwater exploitation, including seawater intrusion, transport of pollution, land cover change, etc.



LEGEND

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

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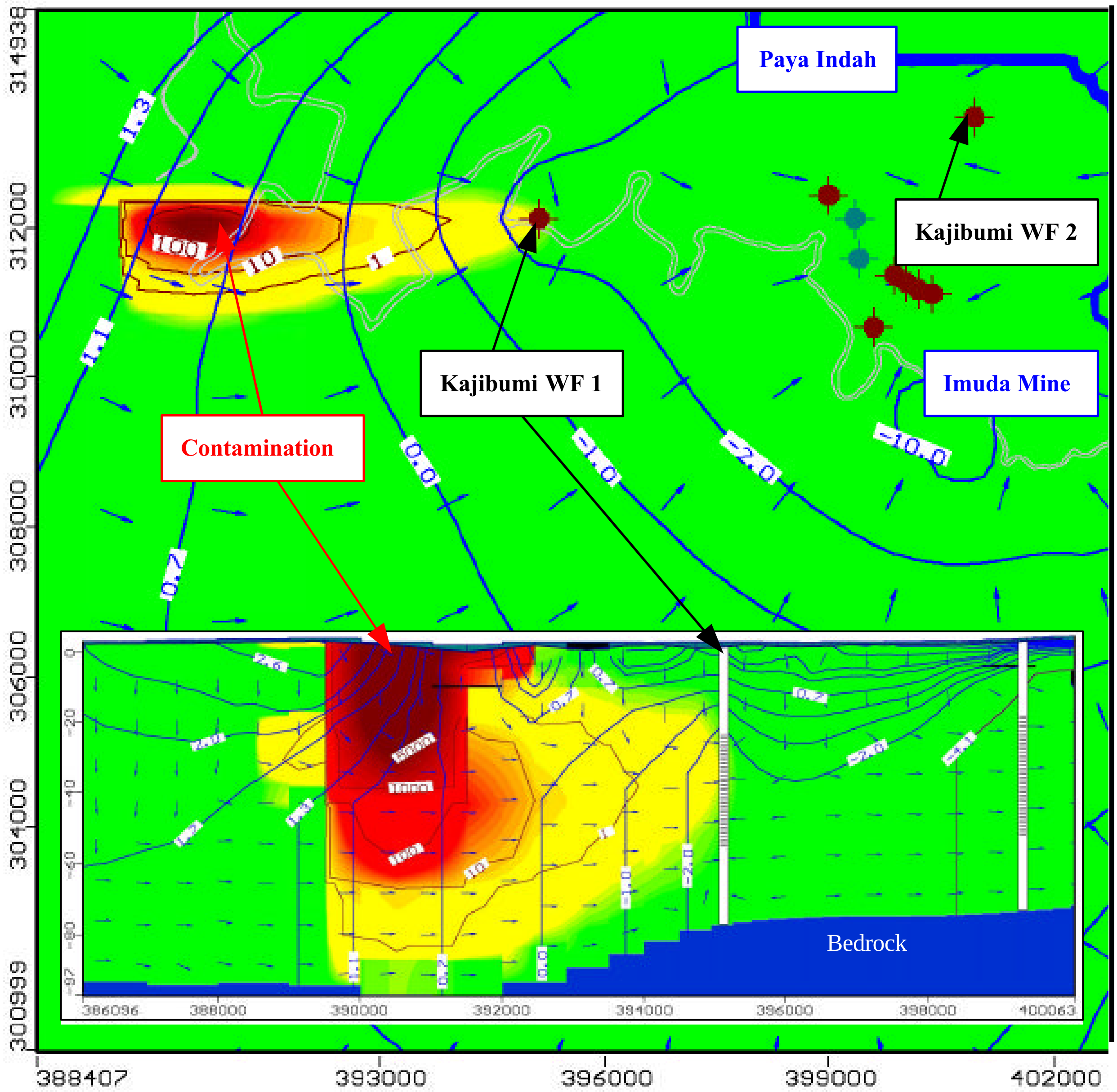
Figure G.5.20

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 G.5.21

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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5.4 Land Subsidence

5.4.1 General

Land subsidence is an important soil-engineering problem mainly in sedimentary basins. It can be ascribed to several causes, for example, tectonic movement, solution, compaction of sedimentary materials due to static loads, vibration, earthquake, water table lowering, and others.

Based on simultaneous records of land subsidence and groundwater levels in the City of Osaka, Japan, Wadachi and Hirono found an obvious correlation between the changes in groundwater levels and the rate of land subsidence[7]. They concluded that land subsidence is caused by the compaction of the soft clay layer following the decline of groundwater levels, and that the pumping of groundwater is the most important cause of land subsidence.

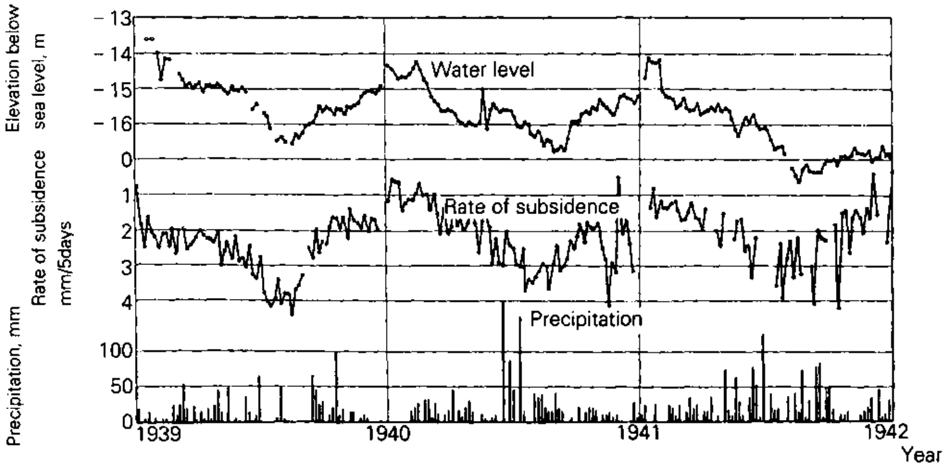

Figure G.5.22 Fluctuation of Water Level and Subsidence Rate at Kujo Mini-Park, Osaka[7]

Many of the observations of the rate of groundwater piezometric level decline and the rate of subsidence exhibit a fair degree of linearity (**Figure G.5.22**). Land subsidence actually stopped in response to the rise in water levels, but did not reverse[9]. Once the ground had subsided, the rise in water level did not bring it back to its original state. Adequate monitoring is therefore necessary in advance of groundwater exploitation to estimate the possible land subsidence.

There are two basic components of land subsidence:

- permanent compression – settlement due to consolidation[8]; and
- elastic component of compression [9].

The first component is a major part of land subsidence and occur in clayey soils by reduction of groundwater level; the second occur in sandy/gravelly soils.

5.4.2 Methodologies

The elastic settlement of sandy/gravelly soil layer, $\mathbf{s_e}$, and the consolidation settlement of clayey soil layer, $\mathbf{s_c}$, are calculated separately and summed up to obtain land subsidence, **s**.

$$s = s_e + s_c$$

For calculation of both components of land subsidence, the following basic inputs are required:

- piezometric level change in the layer,
- thickness of the layer and
- compressibility parameters of the layer.

(1) Elastic Settlement of Sandy/Gravelly Soil Layer

Elastic component of compression of the sandy/gravelly soil layer is related to their specific storage[9)]. The elastic storage of the layers, S_E, can be expressed as:

$$S_E = h_a.n.\beta_w + h_a.\beta_a$$

Where,

- h_a : thickness of the layer (water-bearing horizon),
- n : porosity of the layer,
- β_w : compressibility of water ($4.582.10^{-6}$ m^{-1}) and
- β_a : compressibility of the soil skeleton.

The first member ($h_a.n.\beta_w$) assigns expansion of water as a result of decrease of piezometric pressure, and this is recoverable if the pressure recovers to its original (pre-pumping) value. The second member ($h_a.\beta_a$) assigns compression of the soil skeleton (pores) as a result of decrease of piezometric pressure. This is only partially recoverable.

Since ($n.\beta_w + \beta_a$) corresponds to the compressibility of sandy/gravelly soil, the elastic settlement of sandy/gravelly soil can be estimated as:

$$s_e = \Delta p.h_a.(n.\beta_w + \beta_a)$$

where,

- Δp : change of piezometric level in the layer.

Table G.5.3 gives typical values of compressibility parameter ($n.\beta_w + \beta_a$), which were derived from results of laboratory determinations published by the Bureau of Reclamation in 1960 [9].

Table G.5.3 Approximate Parameters of Compressibility

Type of sediments	$n.\beta_w + \beta_a$ (m^{-1})
Gravel	$5 \times 10^{-6} - 2 \times 10^{-5}$
Sand	$6 \times 10^{-6} - 2 \times 10^{-5}$
Loose sand and silt	$1 \times 10^{-5} - 1 \times 10^{-4}$

(2) Consolidation Settlement of Clayey Soil Layer

Consolidation settlement of the clayey soil layer can be calculated by using the following equation[8]:

$$s_c = h_c . \frac{e_0 - e_f}{1 + e_f}$$

where,

- h_c : thickness of the clayey soil layer,
- e_0 : void ratio of clayey soil before piezometric level change, Δp,
- e_f : void ratio of the clayey soil after consolidation due to piezometric level change, Δp, is completed.

Relationships of void ratio and pressure change of the clayey soil were obtained by the laboratory consolidation tests and presented in **Sector F**.

Consolidation time is calculated by using the following equation:

$$s_{ct} = s_c . \overline{U}$$

where,

- s_{ct} : settlement at an arbitrary time,
- s_c : final settlement,
- $\overline{U}$: average degree of consolidation of the clayey soil layer.

The average degree of consolidation, $\overline{U}$, can be obtained by:

$$\overline{U} = f\left(\frac{C_v . t}{{h_c}^2}\right)$$

where,

- C_v : coefficient of consolidation,
- t : time.

Relationships between coefficient of consolidation and consolidation pressure were obtained by the laboratory consolidation tests and are presented in **Sector F**.

5.4.3 Elastic Settlement of the Aquifer

Elastic settlements of the Aquifer, which is composed of sandy/gravelly soil layers, were estimated at selected locations No. 5 (Kajibumi Well Field 2, Model A) and No. 7 (Kanchong Darat, Model B) for Variants 1 to 3 (**Section 5.1**). **Figure G.5.23** shows the ground models, A and B, which consist of seven layers as described in **Section 2.3.1**.

The total thickness of model layer 3a to 3d, namely the aquifer system, was taken as the thickness of the Aquifer. Although the Aquifer contains layers of clayey soil, a typical compressibility of gravel/sand, 0.00001, as given in **Table G.5.3**, was used for the calculation.

In **Figure G.5.23** piezometric levels obtained by the groundwater simulation (**Section 5.2**) were plotted for Variants 0 to 3. Since Variant 0 was the initial condition of groundwater level before commencement of the pumping operation, differences in the piezometric level between Variants 1 to 3 and Variant 0 were the pressures to cause elastic settlements of the sandy/gravelly soil layers. The pressure change in layer 3c was considered representative and used for evaluation.

Table G.5.4 summarises calculation results of elastic settlement of the Aquifer.

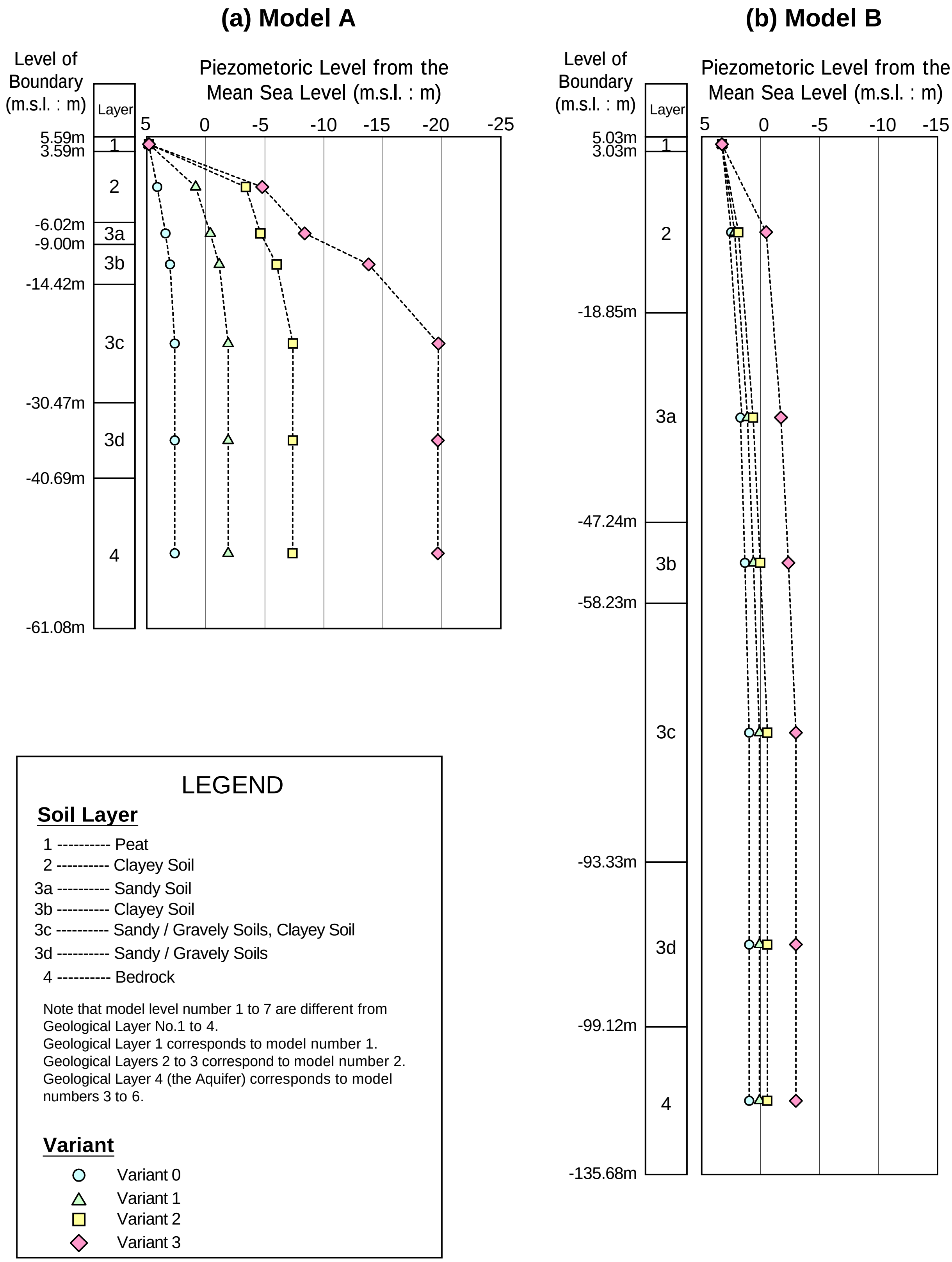

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Figure G.5.23

Typical Profiles of Piezometric Changes

Table G.5.4 Estimation of Elastic Settlement of the Aquifer

Model No.	Variant	Aquifer Thickness h_a (m)	Aquifer Compressibility $n\ \beta_w + \beta_a$ (1/m)	Drawdown Δp (m)	Elastic Settlement s_e (m)
A (Kajibumi Well Field 2)	1	34.67	0.00001	4.52	0.002
	2			10.01	0.003
	3			22.34	0.008
B (Kanchong Darat)	1	80.27	0.00001	0.87	0.001
	2			1.53	0.001
	3			3.95	0.003

The calculated elastic settlements showed a range of 1 to 8 mm. These values were small compared to the consolidation settlement of the clayey soils; around 5% of the consolidation settlement near Kajibumi Well Field 2 and around 1% near Kanchong Darat.

5.4.4 Consolidation Settlement of Clayey Soil Layer

(1) Calculation Model

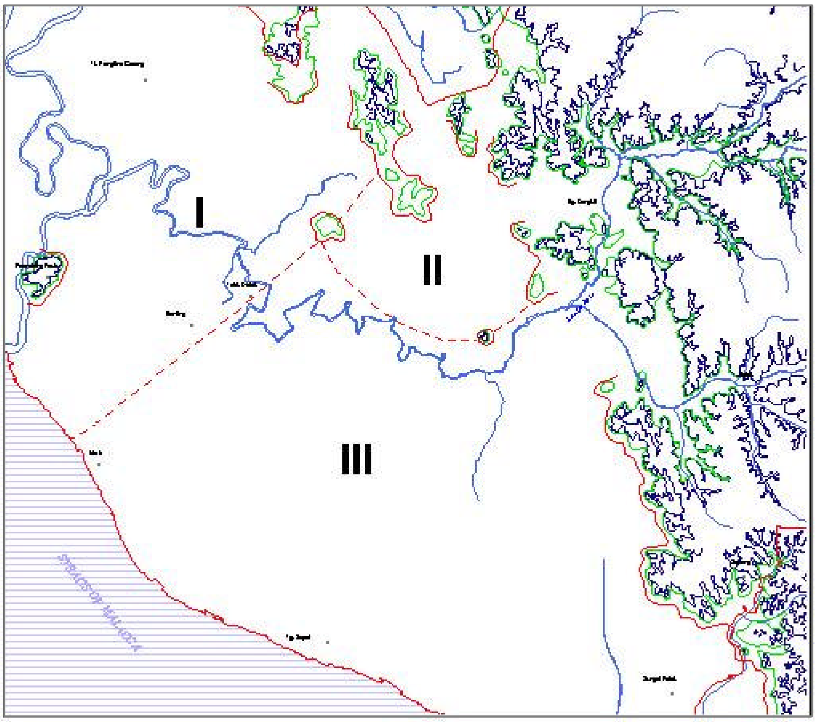
To calculate consolidation settlement, the clayey soil layer (Layer 2) was divided into two sub-layers that show different stiffness or consolidation properties. These were the soft clayey soil layer (Layer 2a) and the medium to stiff clayey soil layer (Layer 2b). Based on the properties of each layer, which are described in **Sector F**, the soft clayey soil layer (Layer 2a) in the Groundwater Basin was divided into three areas (Area I to III in **Figure G.5.24**). Similarly, the medium to stiff clay soil layer (Layer 2b) was divided into two areas (Area A and B in **Figure G.5.24**).

The Groundwater Basin was divided into meshes (725 metres by 725 metres in size), and the settlement at each mesh was estimated.

Three basic input parameters required for the evaluation are given in the following sections:

- **Section (2)** : thickness of the clayey soil layers,
- **Section (3)** : compressibility parameters of the clayey soil layers and
- **Section (4)** : piezometric level changes in the clayey soil layers.

(a) Zoning of Soft Clayey Soil Layer



(b) Zoning of Medium to Stiff Clayey Soil Layer

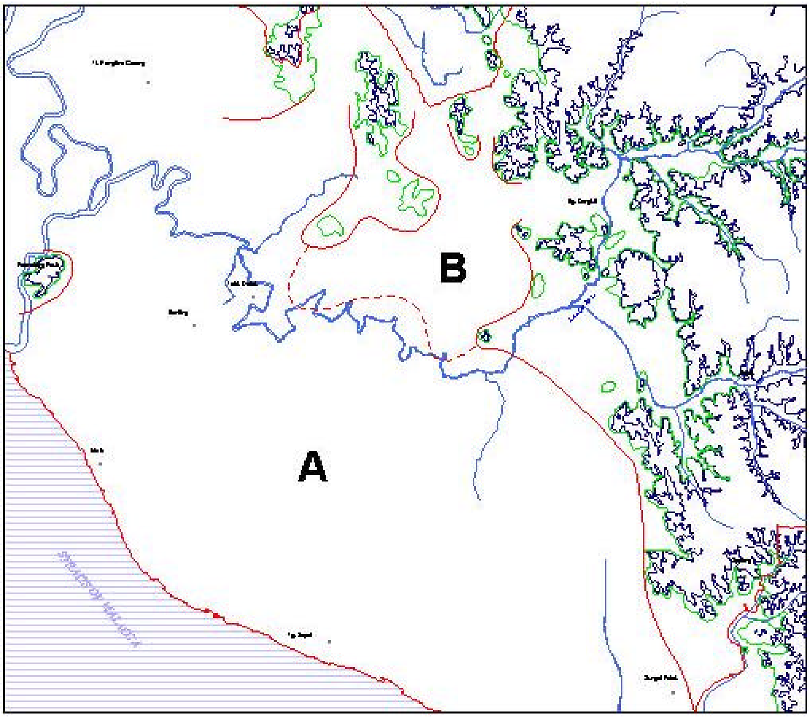


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Figure G.5.24

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Zoning of Clayey Soil Layers

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(2) Thickness of the Clayey Soil Layers

Distribution area and the thickness of the soft clayey soil layer (Layer 2a), and the medium to stiff clayey soil layer (Layer 2b) are presented in **Figures G.5.25** and **G.5.26**, respectively. The boundaries and the contour maps of thickness were determined from the existing borehole logs and the current soil investigation.

(3) Parameters of Clayey Soil Layers

Design values or design lines of bulk density, e – log p curves and coefficient of consolidation were selected for three areas of the soft clayey soil, and two areas of medium to stiff clayey soil were selected as presented in **Figures G.5.27**, **G.5.28** and **G.5.29**. **Table G.5.5** summarises the selected design values and design lines for each area.

Table G.5.5 Design Values of Soil Parameters

Soil Parameter	Soft Clayey Soil Layer (Geological Layer No.2)			Medium to Stiff Clayey Soil Layer (Geological Layer No.3)	
	Area I	Area II	Area III	Area A	Area B
Bulk Density (Mg/m^3)	1.43	1.78	1.47	1.47	1.85
e - log P Curves	e=-0.07Ln(p)+2.19 e=-0.42Ln(p)+3.82	e=-0.03Ln(p)+1.08 e=-0.11Ln(p)+1.38	e=-0.05Ln(p)+1.64 e=-0.28Ln(p)+2.61	e=-0.06Ln(p)+1.55 e=-0.28Ln(p)+2.61	e=-0.02Ln(p)+0.82 e=-0.05Ln(p)+1.01
Coefficient of Consolidation (m^2/year)	2.0	3.5	3.0	3.5	3.0

(4) Piezometric Level Changes in Clayey Soil Layers

Contour maps of piezometric level changes at the centre of the clayey soil layers (at the centre of the total thickness of Layers 2a and 2b) are presented in **Figures G.5.30**, **G.5.31** and **G.5.32** for Variants 1 to 3, respectively. The changes from the initial condition, Variant 0, are shown in the figures.

(5) Consolidation Settlement of Clayey Soil Layers

Consolidation settlements of the soft clay layer (Layer 2a) and of the medium to stiff clay layer (Layer 2b) were calculated separately and summed up to obtain the total consolidation settlement. Contour maps of the total consolidation settlement for Variants 1 to 3 are presented in **Figures G.5.33**, **G.5.34** and **G.5.35**, respectively. Since the elastic settlement of the Aquifer which lays beneath the clayey soil layers was small, the total consolidation settlement could be considered here as the land settlement within the Groundwater Basin.

For Variant 1 the maximum settlement of around 0.1 m was obtained near the current groundwater abstraction activities (**Figure G.5.33**). An area subjected to settlement of 0.05 m was limited.

Additional pumping of groundwater from the current existing wells (Variant 2) expanded the area subjected to the consolidation settlement (**Figure G.5.34**). 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.

As shown in **Figure G.5.35**, an increase of groundwater abstraction by adding new wells increased the settlement and spread the influence area (Variant 3). The maximum of nearly 0.9 m of settlement was estimated, and an area of 0.4 m settlement covered the most of the groundwater abstraction area. An area of 0.05 m settlement spread to Banting in the west and to the seacoast in the south.

(6) Time Settlement Relationship

Since the consolidation settlement is time dependent, time-settlement curves at selected locations were prepared for Variant 3. **Figure G.5.36** shows the curves near Megasteel (Case 1), Kanchong Darat (Case 2) and Kajibumi Well Field 2 (Case 3). As shown in the figure, the consolidation settlement would continue for a long period and, for example, 50% of the maximum settlement was predicted to occur after 5 to 15 years. Note that the contour maps of **Figures G.5.33**, **G.3.34 and G.3.35** show the maximum settlements for Variants 1 to 3.

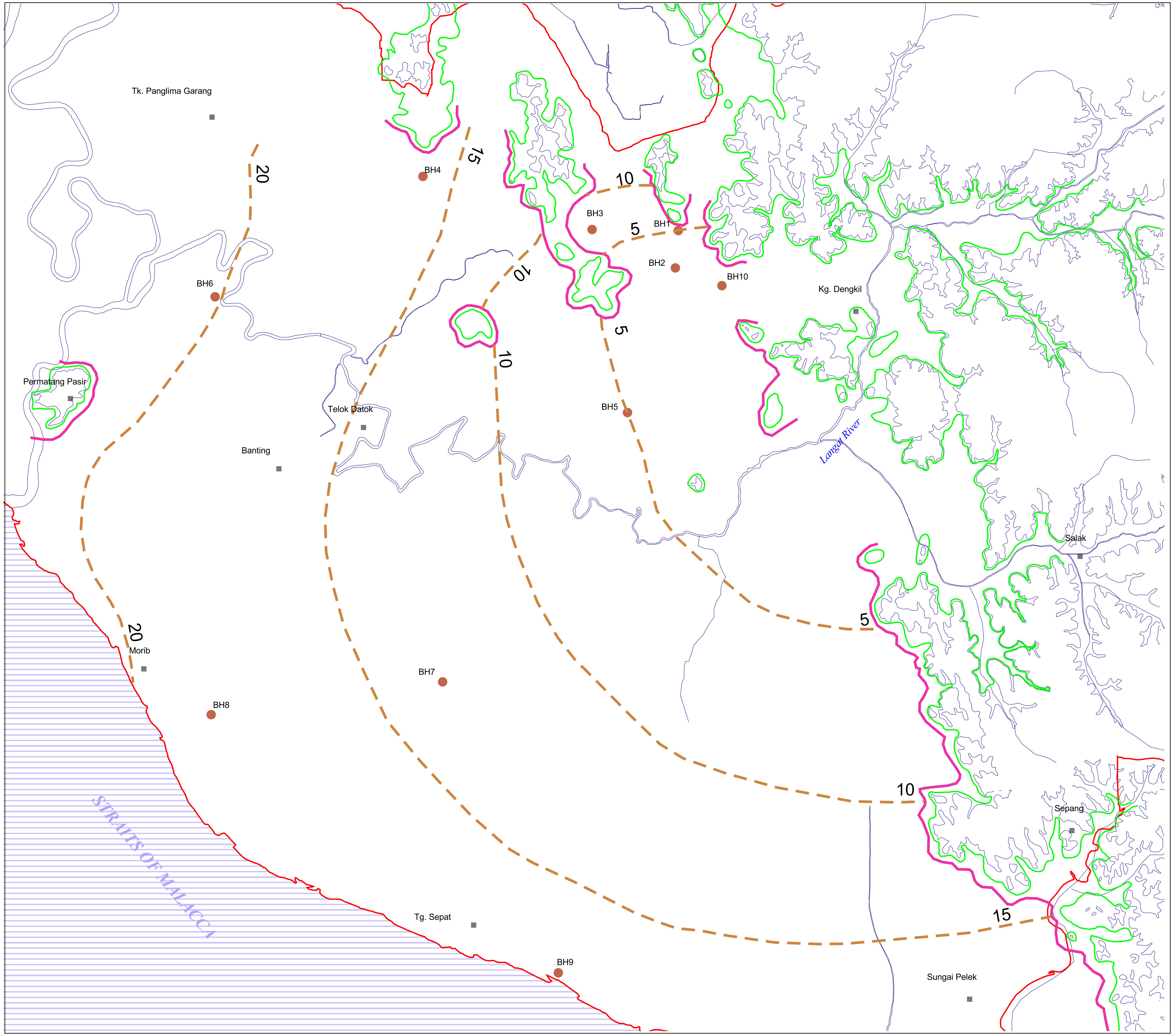
5.4.5 Summary

Land subsidence was predicted in this report as the sum of the elastic settlement of the Aquifer and the consolidation settlement of the clayey soil layers. Since the settlement in the Aquifer was relatively small, the settlement in the clayey soil layers was considered as the major contributor of the land subsidence. The settlement contours in **Figures G.5.33** to **G.5.35** can be regarded as those of the land subsidence over the Groundwater Basin.

With the current rate of groundwater abstraction (Variant 1), land subsidence is predicted to occur in a relatively small area surrounding the abstraction wells, and the subsidence is estimated small. Increasing the abstraction rate of the current wells (Variant 2) and increasing the number of new wells (Variant 3) will cause the expansion of influence area of land subsidence as well as the increase of amount of subsidence. The land subsidence will continue for a long period of time.

Figure G.5.25

Boundary of Soft Clayey Soil Layers and Their Thickness



LEGEND

- Boundary of Soft Clayey Soil Layers
- Thickness of Soft Clayey Soil Layers (Numbers are in meter)
- Boring Point (Present Study)
- Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation
- Topographic Contourline of 20m Height
- Rivers
- Towns
- Study Area

Note that the thickness of the soft clayey soil layer is determined by a limited number of boreholes. The contourlines are simplified the actual irregular conditions.

Scale 1 : 200,000

2 0 2 4 Kilometers

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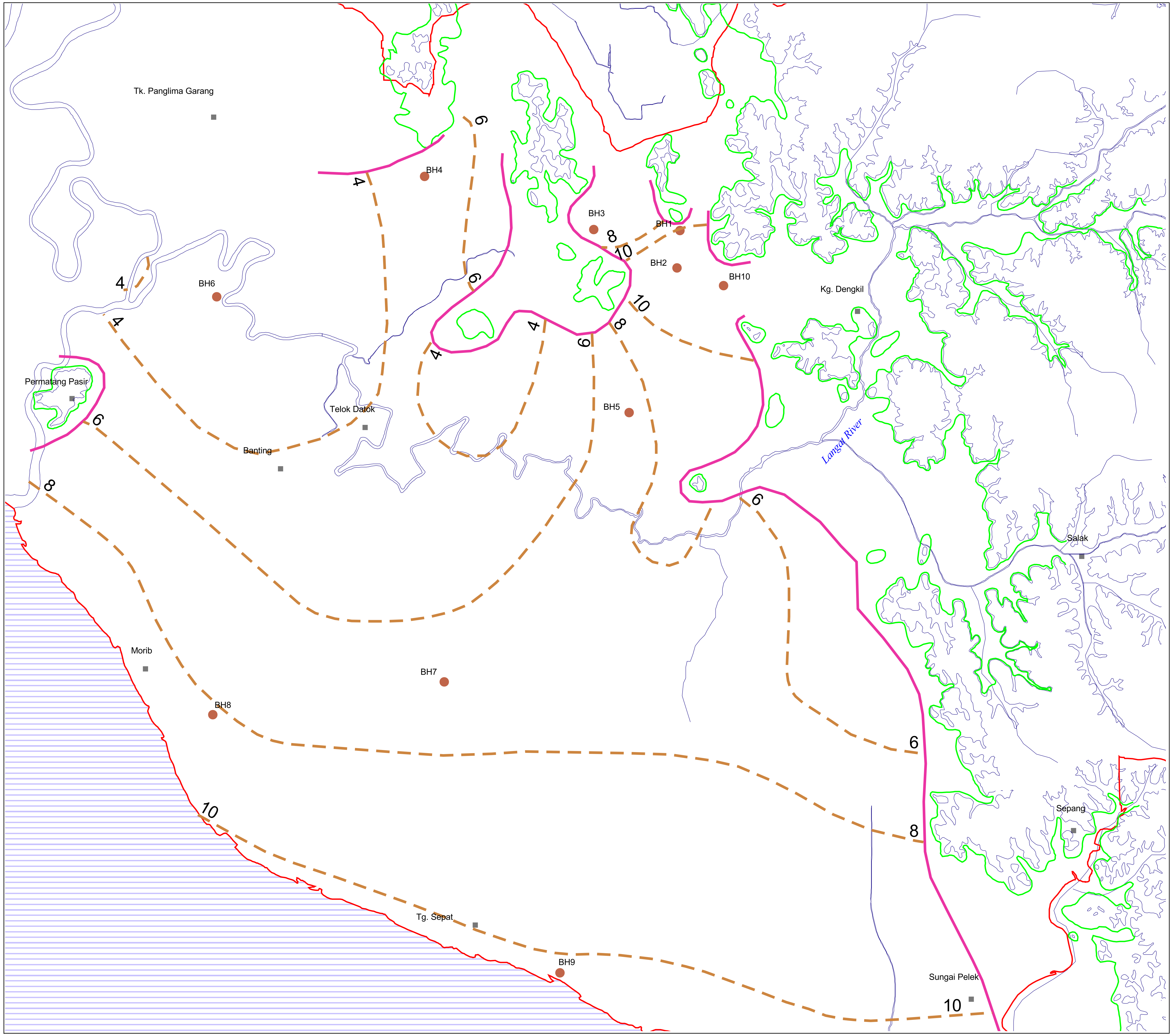
Figure G.5.26

Boundary of Medium to Stiff Clayey Soil Layers and Their Thickness



LEGEND

- Boundary of Medium to Stiff Clayey Soil Layers
- Thickness of Medium to Stiff Clayey Soil Layers (Numbers are in meter)
- Boring Point (Present Study)
- Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation
- Topographic Contourline of 20m Height
- Rivers
- Towns
- Study Area

Note that the thickness of the medium to stiff Clayey Soil layers is determined by a limited number of boreholes. The contourlines are simplified the actual irregular conditions.

N W E S

Scale 1 : 200,000

2 0 2 4 Kilometers

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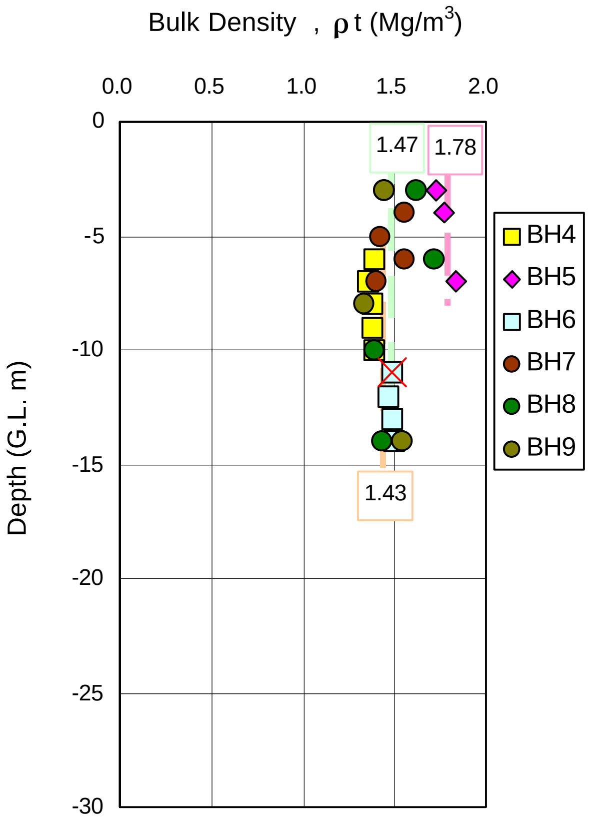
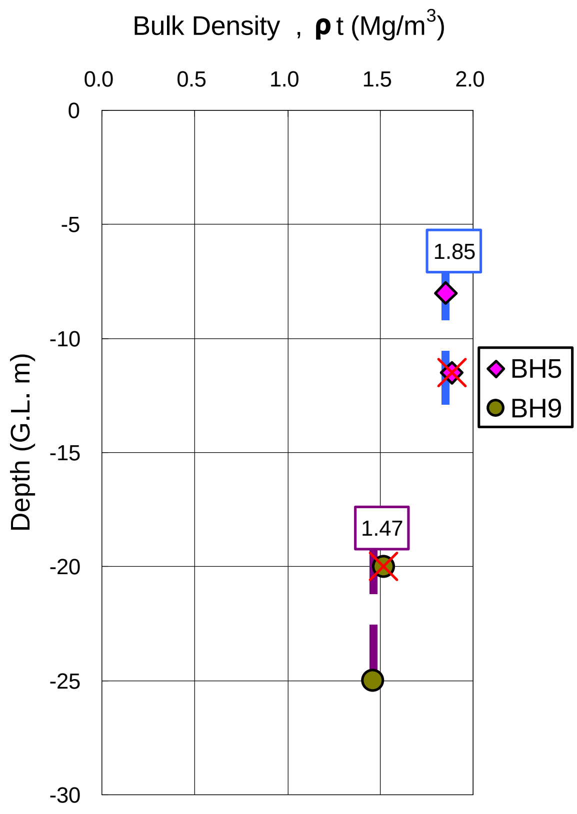


(a) Layer2a-----Soft Clayey Soil



(b) Layer2b-----Medium to Stiff Clayey Soil

□••••• Area I
◇••••• Area II
○••••• Area III

◇••••• Area B
○••••• Area A

Design Value, ρt (Mg/m^3)

Area	Layer 2a	Area	Layer 2b
I	1.43	A	1.47
II	1.78	B	1.85
III	1.47	A	1.47

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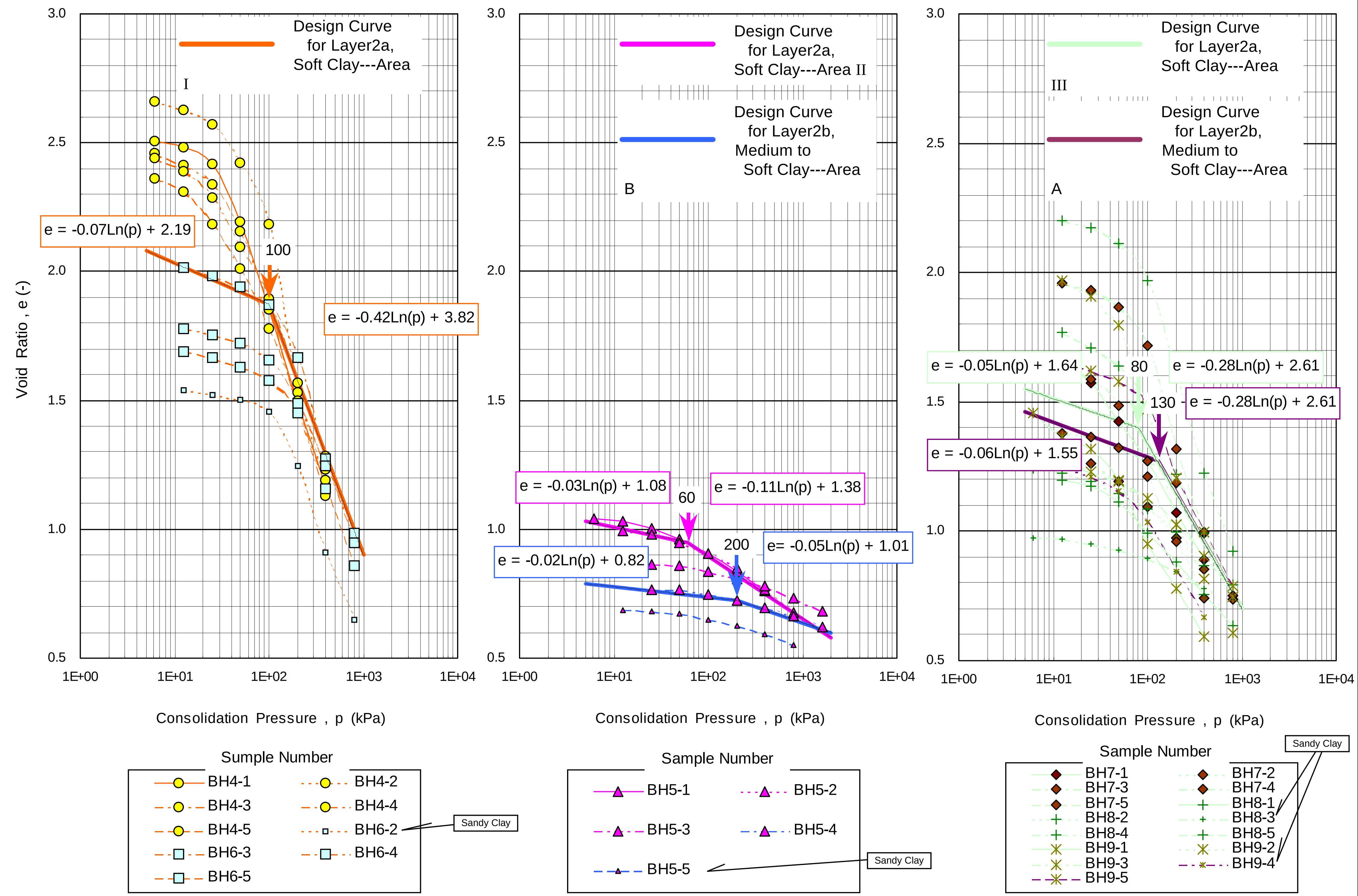
Figure G.5.27

Selection of Parameter of Clayey Soil Layers, Bulk Density

Figure G.5.28

Selection of Parameter of Clayey Soil Layers, e ~ log p Curves



(a) e～log p Curves ,
Western Part of the Lowlands,
Soft Clay ----- Area I

(b) e～log p Curves ,
North Eastern Part of the Lowlands,
Soft Clay ------------------ Area II
Medium to Stiff Clay ----- Area B

(c) e～log p Curves ,
Southern Part of the Lowlands,
Soft Clay ------------------ Area III
Medium to Stiff Clay ----- Area A

LEGEND

Borehole Number

- ○ BH4
- △ BH5
- □ BH6
- ◆ BH7
- + BH8
- ＊ BH9

Soil Property

e : Void Ratio
p : Consolidation Pressure

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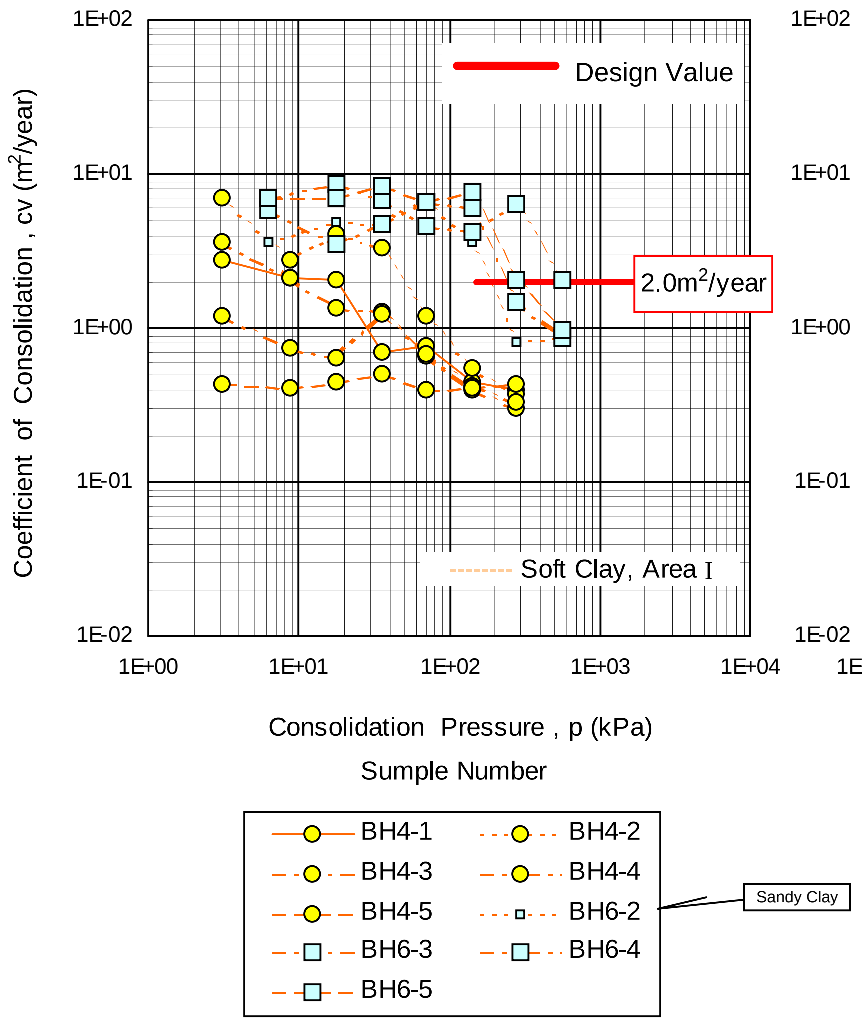
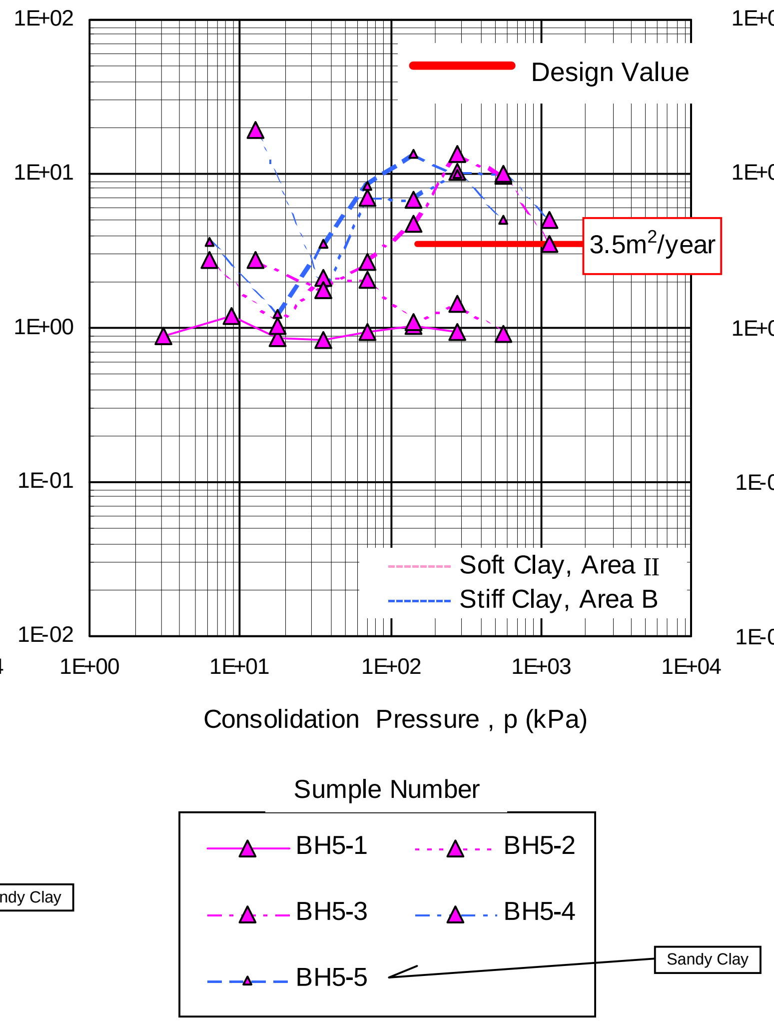
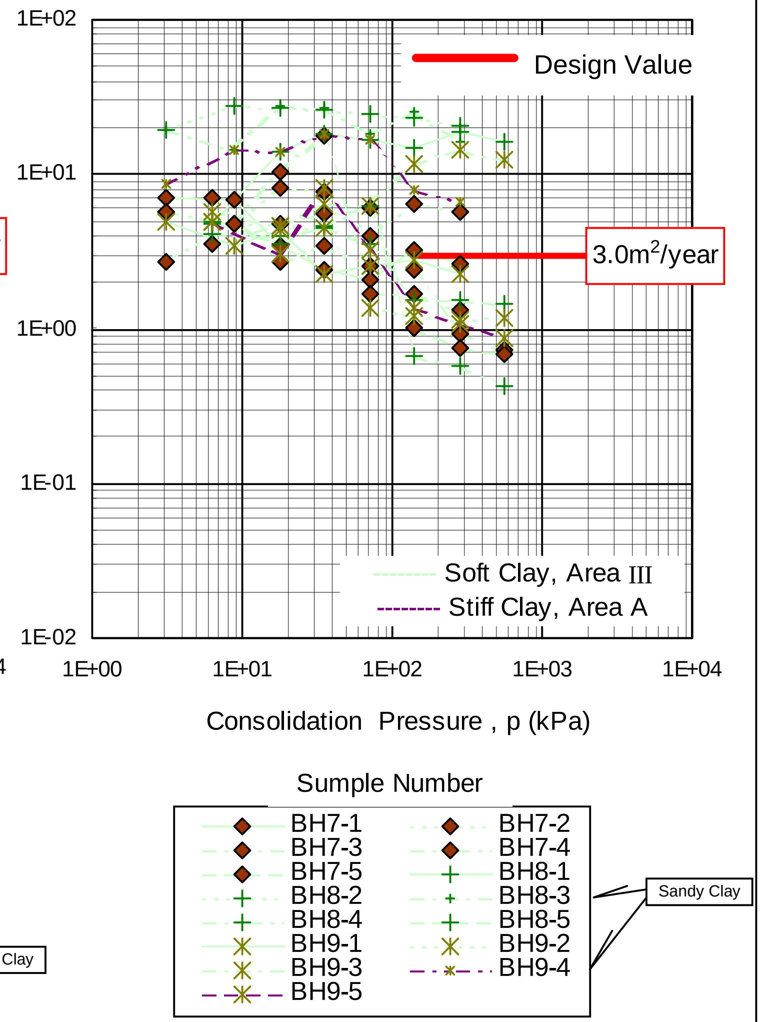


(a) Coefficient of Consolidation, Western Part of the Lowland, Soft Clay ----- Area I



(b) Coefficient of Consolidation, North Eastern Part of the Lowland, Soft Clay ------------------ Area II Medium to Stiff Clay ----- Area B



(c) Coefficient of Consolidation, Southern Part of the Lowland, Soft Clay ------------------ Area III Medium to Stiff Clay ----- Area A

Figure G.5.29

Selection of Parameter of Clayey Soil Layers, Coefficient of Consolidation

LEGEND

Borehole Number

- ○ BH4
- △ BH5
- □ BH6
- ◆ BH7
- + BH8
- * BH9

Soil Property

cv : Coefficient of Consolidation
p : Consolidation Pressure

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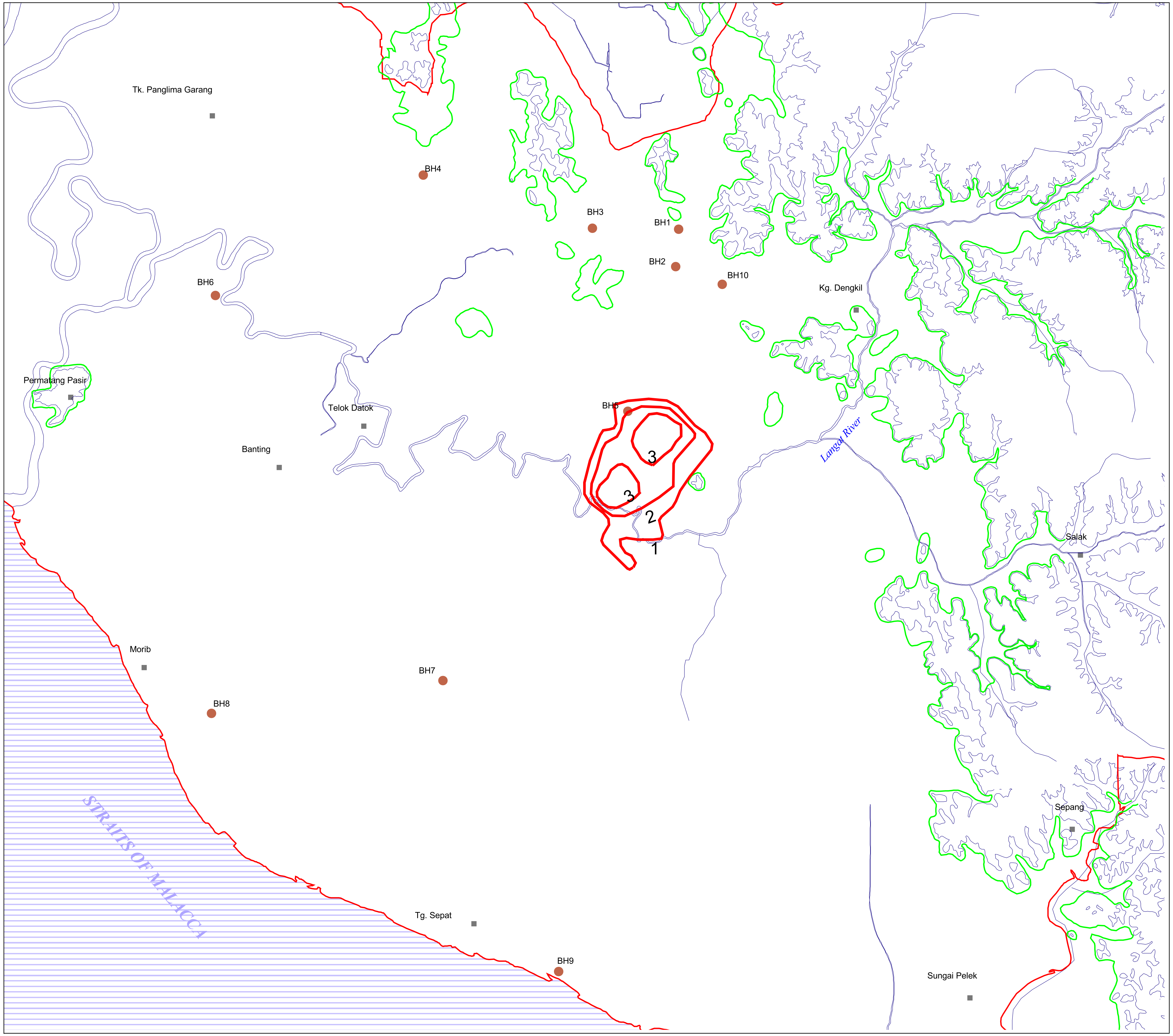
Figure G.5.30

Piezometric Level Change at the Centre of the Clayey Soil Layers (Variant 1)



LEGEND

- Piezometric Level Change in Meter
- Boring Point (Present Study)
- Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation
- Topographic Contourline of 20m Height
- Rivers
- Towns
- Study Area

Scale 1 : 200,000

2 0 2 4 Kilometers

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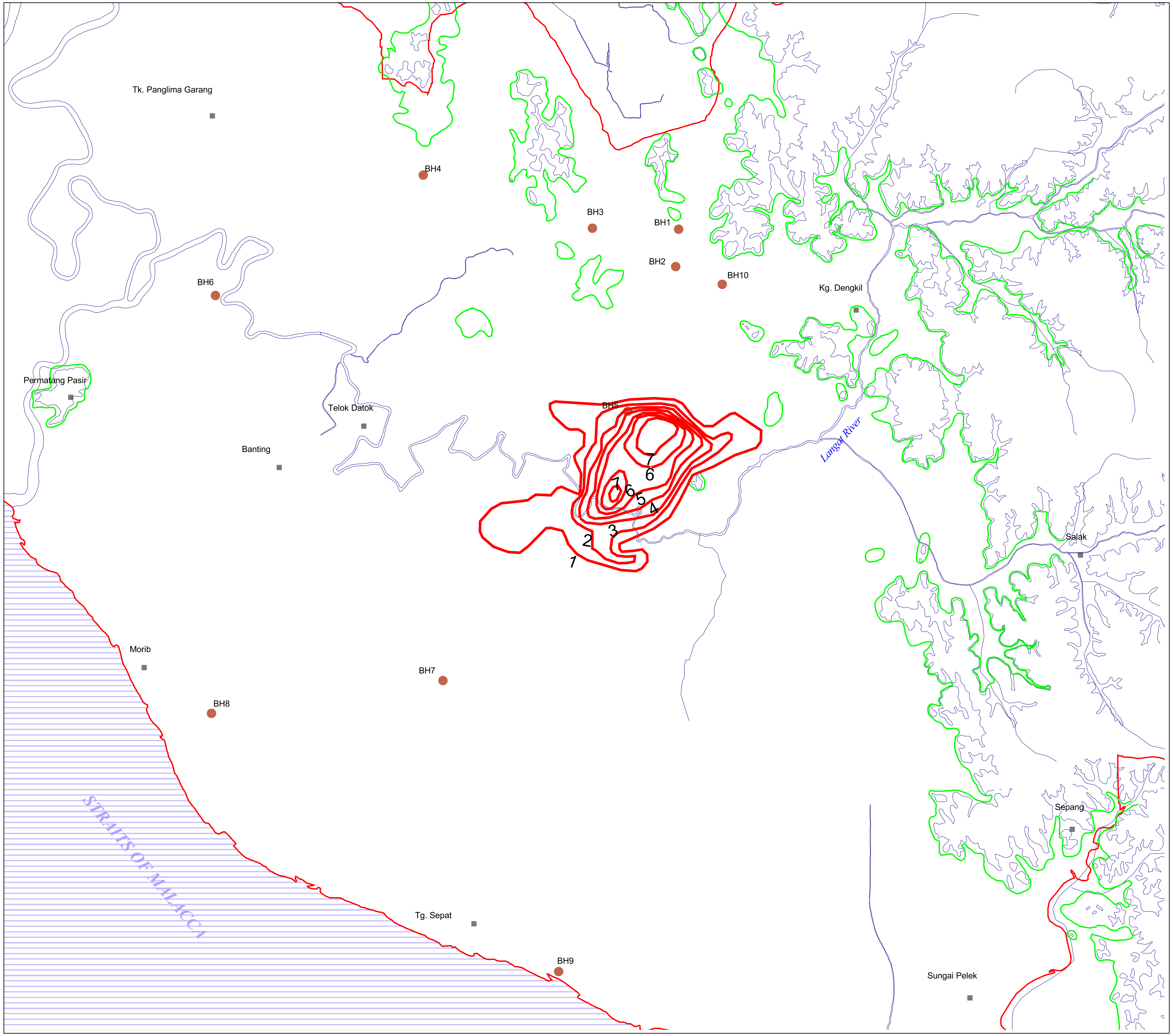

Figure G.5.31

Piezometric Level Change at the Centre of the Clayey Soil Layers (Variant 2)

LEGEND

- Piezometric Level Change in Meter
- Boring Point (Present Study)
- Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation
- Topographic Contourline of 20m Height
- Rivers
- Towns
- Study Area

N W E S

Scale 1 : 200,000

2 0 2 4 Kilometers

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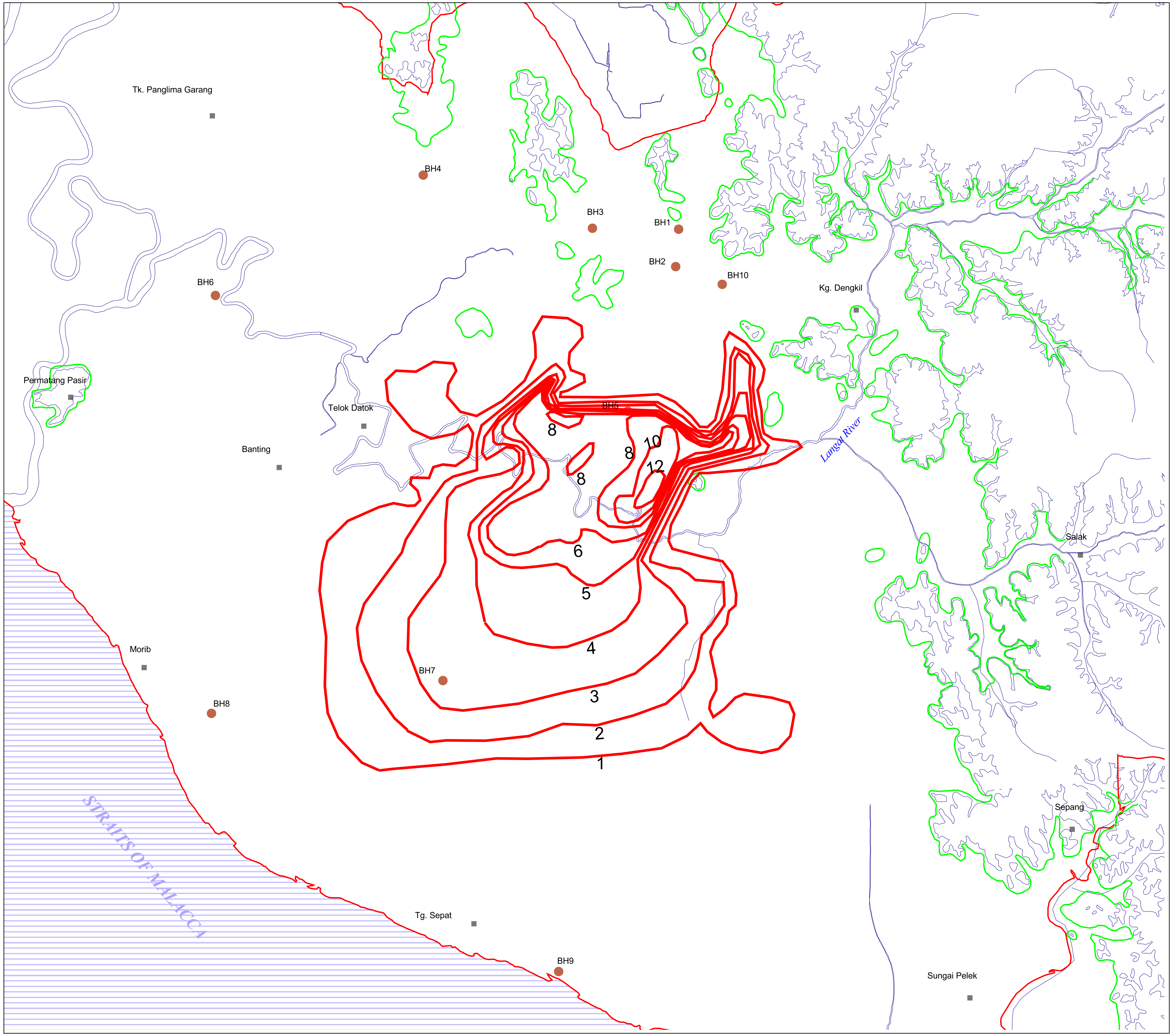

Figure G.5.32

Piezometric Level Change at the Centre of the Clayey Soil Layers (Variant 3)

LEGEND

Piezometric Level Change in Meter

Boring Point (Present Study)

Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation

Topographic Contourline of 20m Height

Rivers

Towns

Study Area

N W E S

Scale 1 : 200,000

2 0 2 4 Kilometers

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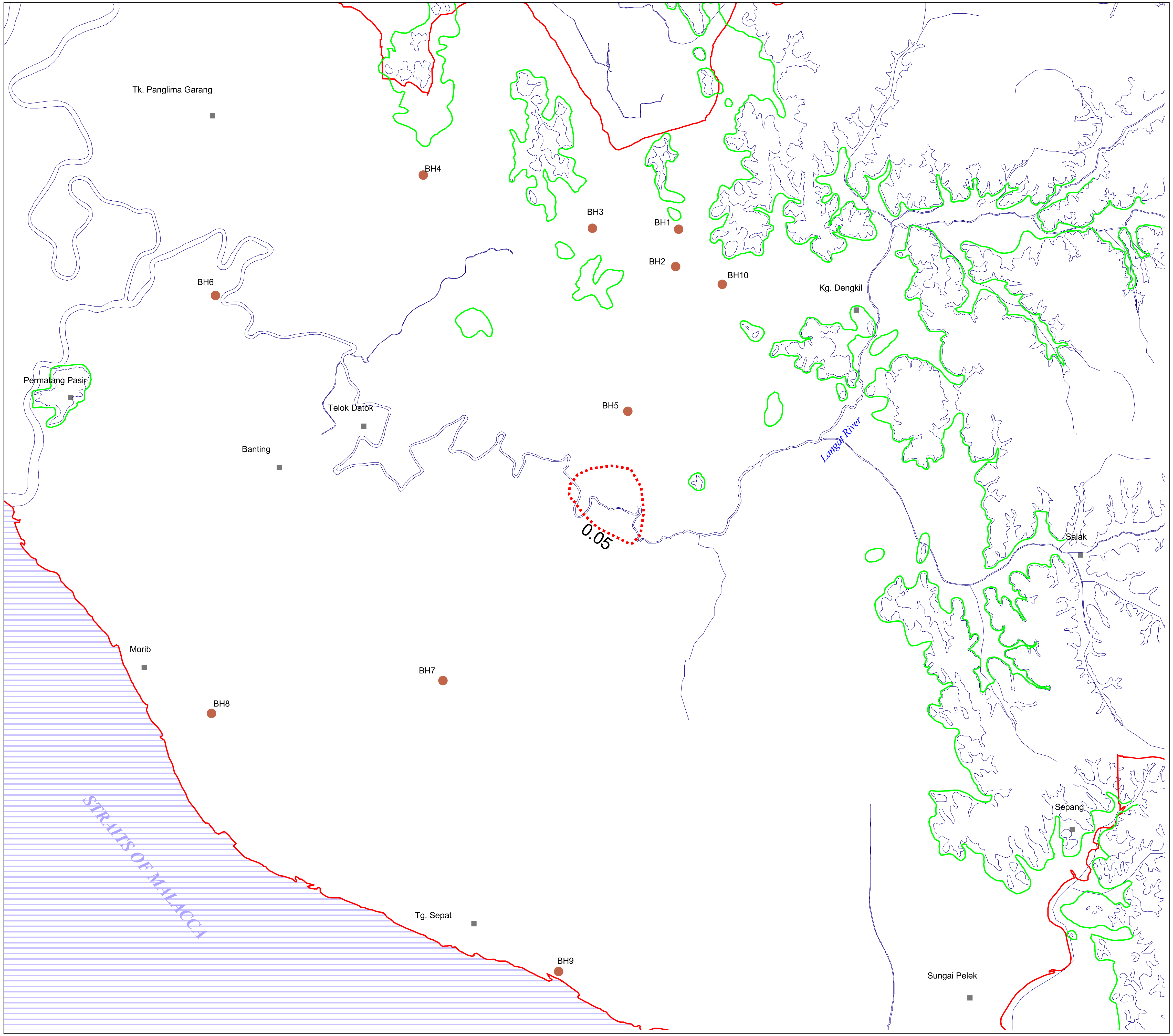

Figure G.5.33

Contour Map of Land Subsidence (Variant 1)

LEGEND

Estimated Land Subsidence (Number is in Meter)

Boring Point (Present Study)

Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation

Topographic Contourline of 20m Height

Rivers

Towns

Study Area

N W E S

Scale 1 : 200,000

2 0 2 4 Kilometers

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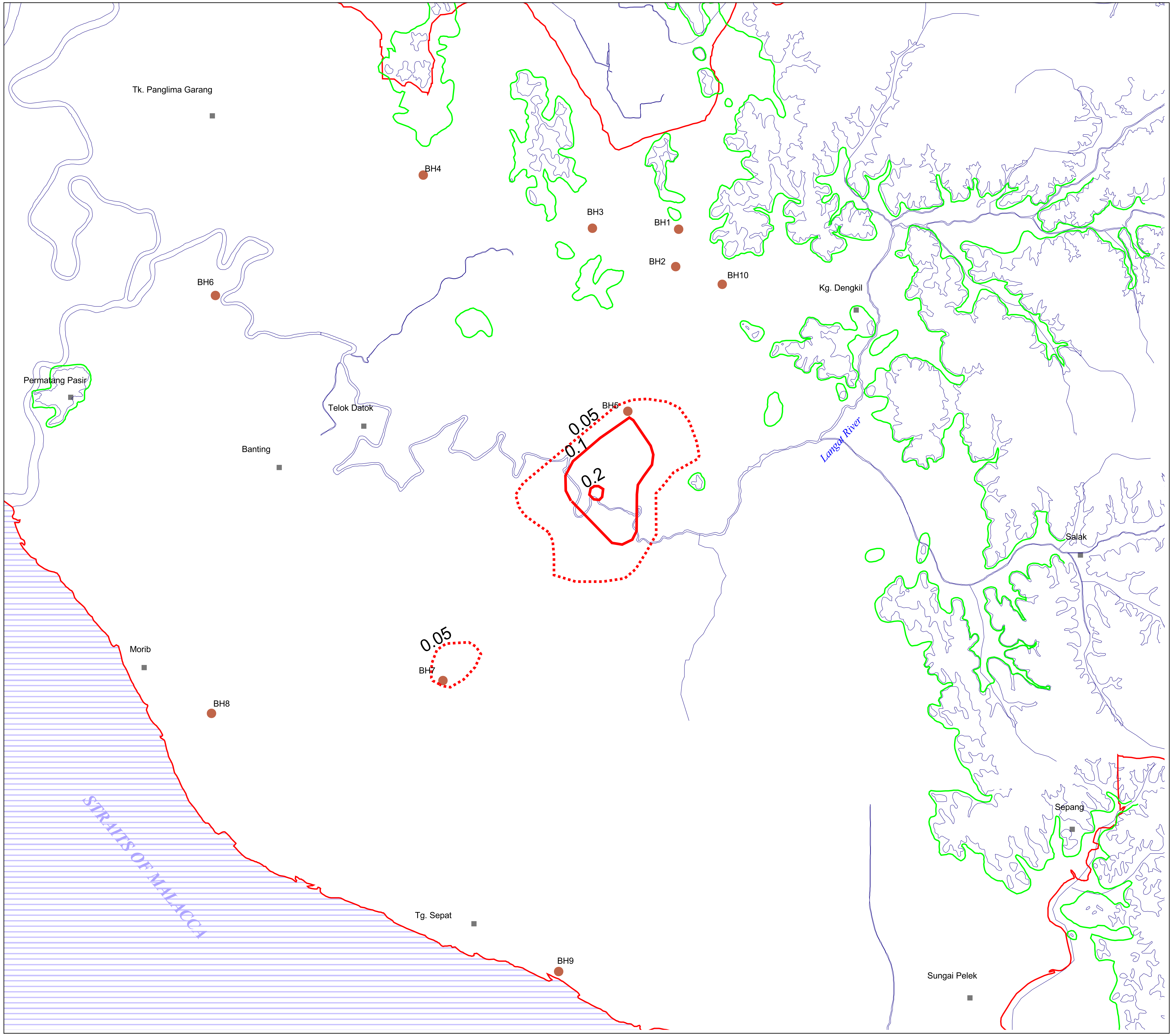
Figure G.5.34

Contour Map of Land Subsidence (Variant 2)



LEGEND

Estimated Land Subsidence
(Number is in Meter)

Boring Point (Present Study)

Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation

Topographic Contourline of 20m Height

Rivers

Towns

Study Area

Scale 1 : 200,000

2 0 2 4 Kilometers

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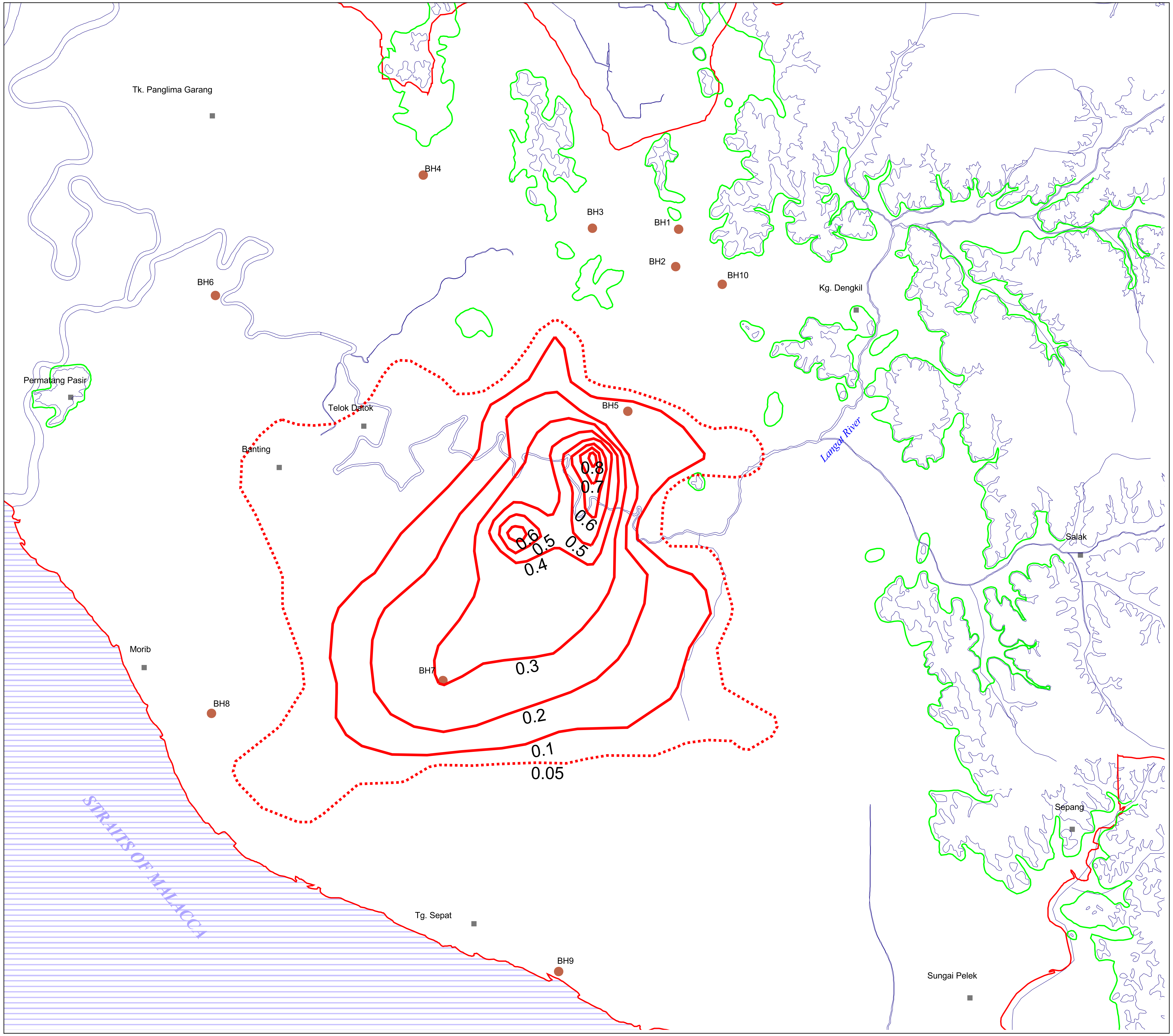
Figure G.5.35

Contour Map of Land Subsidence (Variant 3)



LEGEND

Estimated Land Subsidence

(Number is in Meter)

Boring Point (Present Study)

Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation

Topographic Contourline of 20m Height

Rivers

Towns

Study Area

N W E S

Scale 1 : 200,000

2 0 2 4 Kilometers

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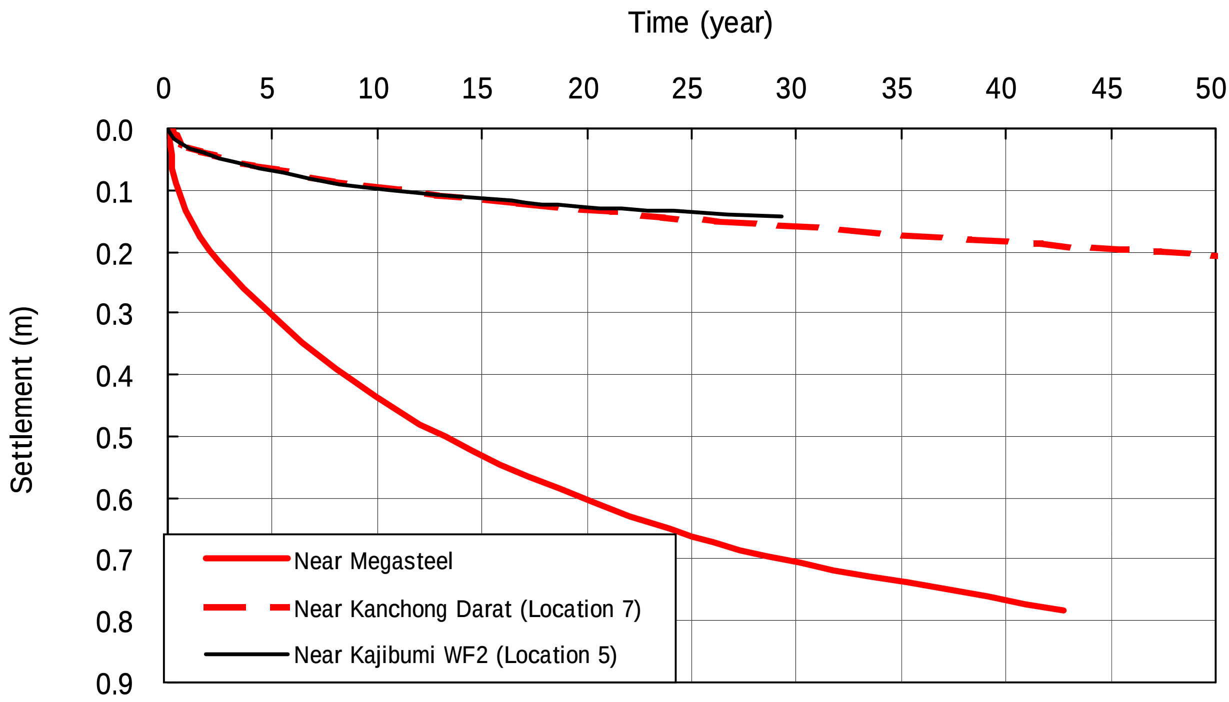
Calculation Condition (Variant 3)

Case	Location	Piezometric Level Change at the Upper Level of the Aquifer (m)	Maximum Settlemet (m)
1	Near Megasteel	12.4	0.87
2	Near Kanchong Darat (Location 7)	3.2	0.30
3	Near Kajibumi WF2 (Location 5)	8.4	0.16

Time - Settlement Curves



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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 G.5.36

Typical Time - Settlement Curves

5.5 Saltwater Intrusion

Current knowledge of the seawater intrusion into the Groundwater Basin was reviewed by interpreting the available information, including the results of the geophysical survey (**Sector F**) and the groundwater quality study (**Sector E**).

Figure G.5.37 presents the results of the geophysical survey, TEM (Transient Electro-Magnetic Survey), which was carried out over the coastal plains of Selangor. A line that divides the low resistivity zone (< 10 ohm-m) and high resistivity zone (> 10 ohm-m) is drawn in the figure. Concerning the Langat Basin, three areas, namely A, B, and C, can be recognised. Zone A has resistivity of less than 1 ohm-m, and this low value is considered reflecting the influence of saltwater intrusion. It is interesting to mention that Area A spreads along the channel of the Langat River. Saline water recharged from the river may be one of the causes of low resistivity.

Area B has a resistivity value of between 1 and 10 ohm-m, which corresponds to those of mixture of freshwater and seawater. Since the resistivity value obtained by TEM is an integration of the ground to a depth of survey depth, the value may include influence from factors such as the marine clay distributing above the Aquifer. Zone C, distributing along the border of the hilly area, shows a resistivity value of more than 10 ohm-m. Groundwater here is regarded as freshwater.

Figure G.5.38 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 standard for Drinking Water Quality in Malaysia is 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 Nos. 3 and No.4 are unknown.

Distribution of chloride contents along a profile crossing the centre of the Groundwater Basin is presented in **Figure G.5.39**. Location of the profile line is shown in **Figure G.5.38**. The values presented in the figure are those of groundwater sampled from the Aquifer during the second measurement of groundwater quality in May 2001. Circles in the figure show the depths of screen of the monitoring wells where groundwater samples were taken, and the numbers attached are chloride content in mg per litre. 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. Although the data on chloride content is not sufficient and also scattered, contour lines of selected values may be drawn as shown in **Figure G.5.39**. The contour line of 250 mg/l extends to the Langat River. It is important to mention that distribution of chloride contents does not show the distinct boundary between seawater with high chloride content and brackish and freshwater with low chloride content, as shown in **Figure G.5.40**.

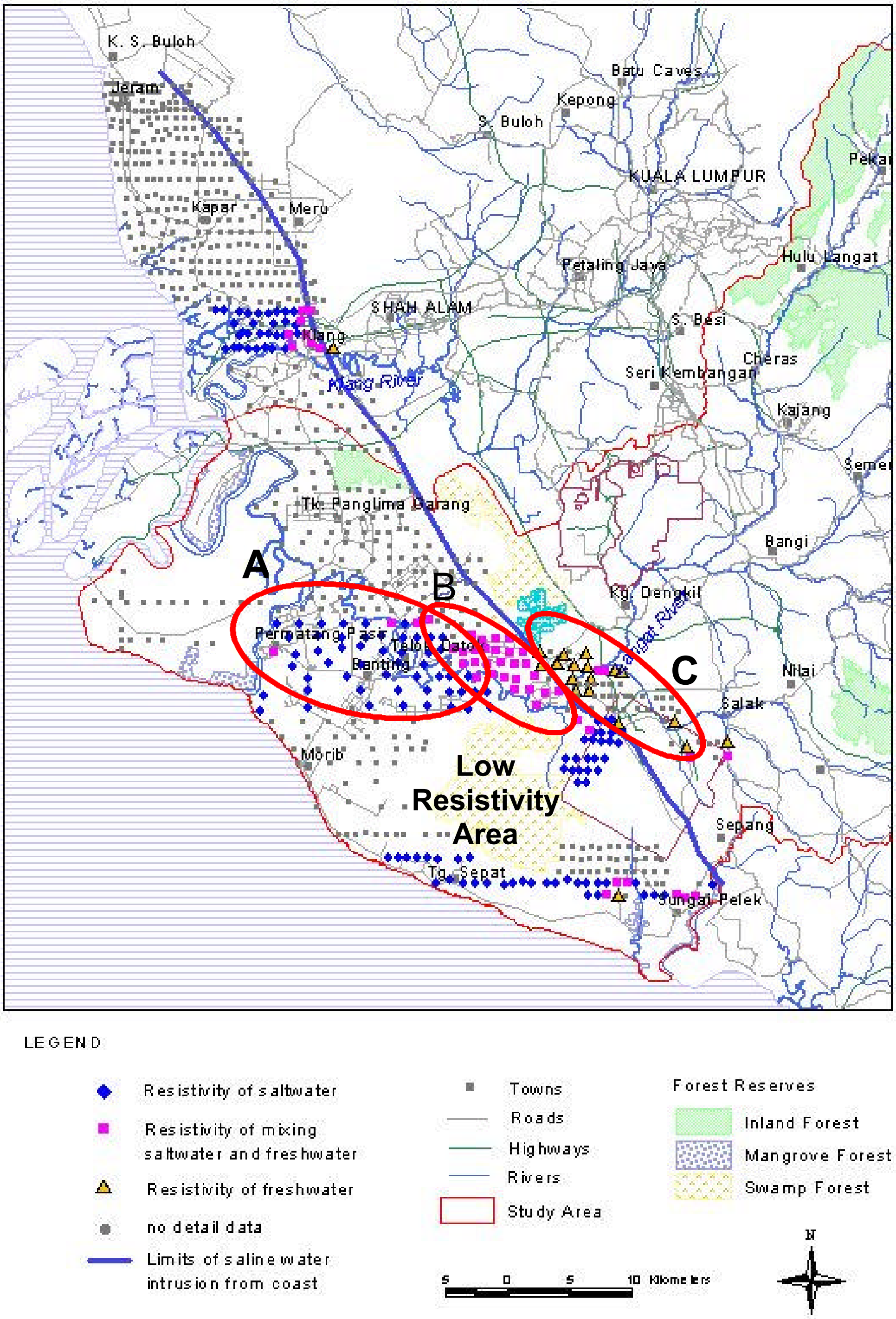

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Figure G.5.37

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

Classification of the Groundwater Basin by Resistivity

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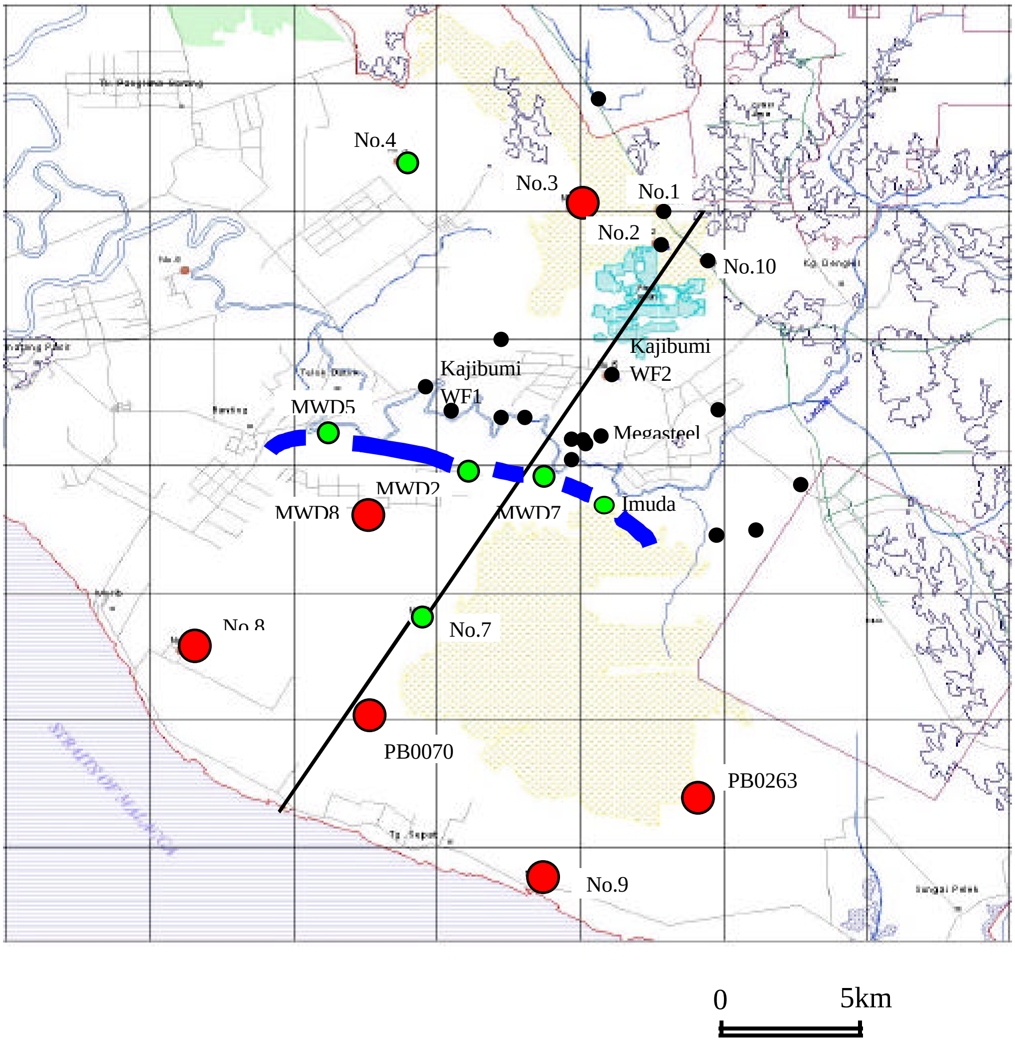

Legend

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 G.5.38

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

Current Status of Saltwater Intrusion

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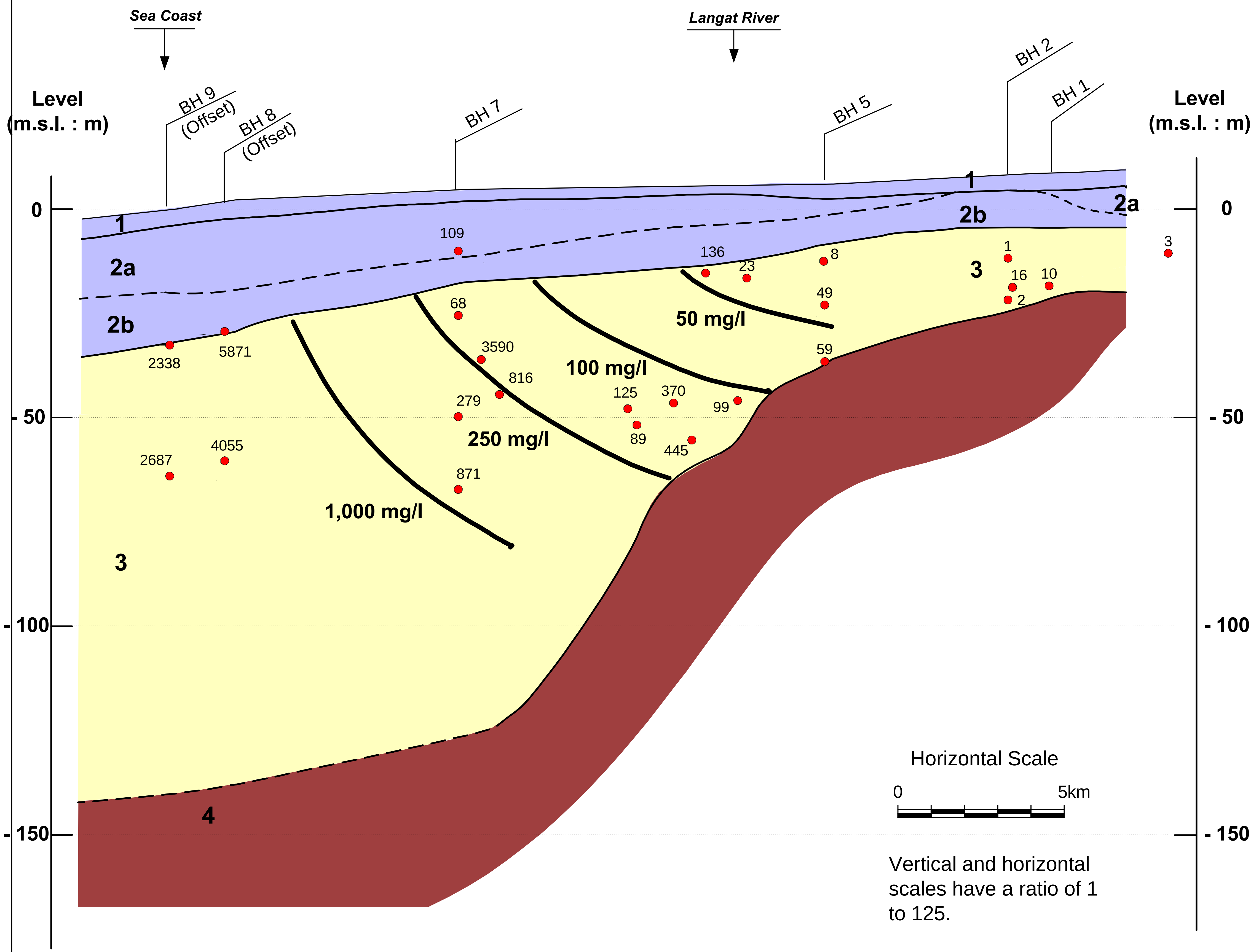
Figure G.5.39

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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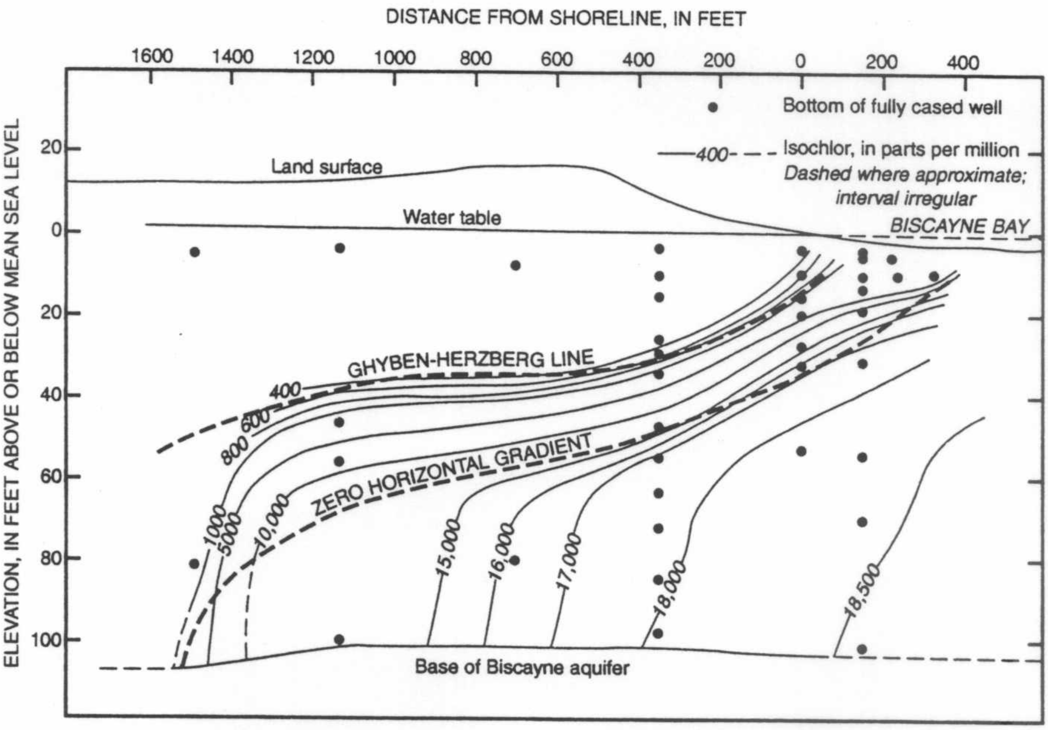
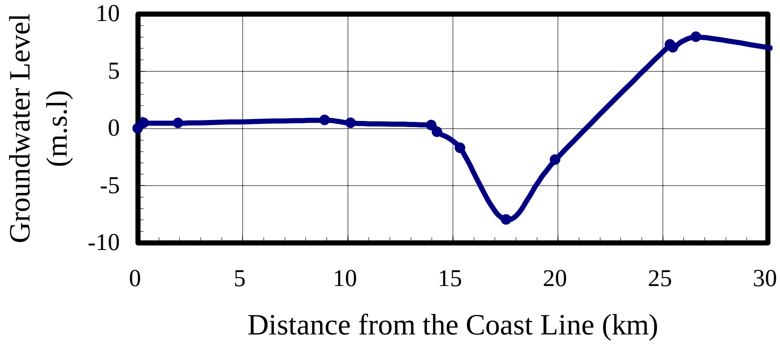


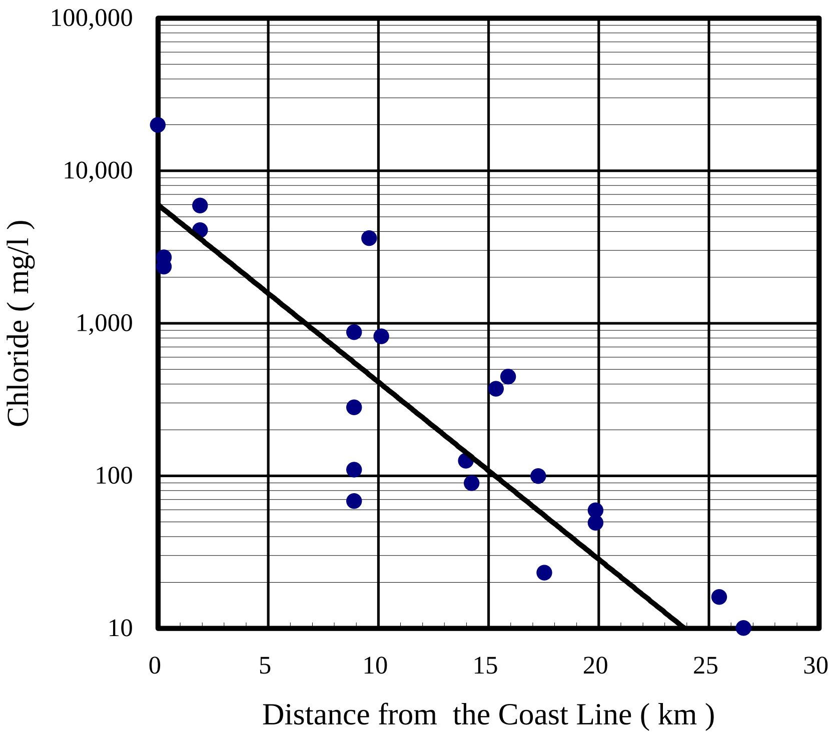
Figure G.5.40 Saltwater Boundary Observed in Miami[12)]

Characteristics of saltwater intrusion into the Groundwater Basin can be seen in **Figures G.5.41 and G.5.42**. In the figures, gradual changes of chloride content and electric conductivity from the seacoast to the hilly area are demonstrated, respectively. In both figures, piezometric level changes in the Aquifer along the profile line in **Figure G.5.38** are plotted. In spite of the large drop of piezometric level at around 17 km from the seacoast due to the current pumping operation at Megasteel and Imuda Mine, abrupt changes of both parameters, or a clear wedge type of saltwater intrusion, are not observed, but rather gradual changes are recognised. Probably, a small rise of piezometric level between the seacoast and the pumping area will prevent the abrupt intrusion of saltwater into the Aquifer.

It is difficult to explain the current conditions of saltwater intrusion with the available knowledge, but one of the possible assumptions would be a sequence of a large volume of groundwater abstraction from the tin mines in the past, following saltwater intrusion, push back of saltwater by freshwater flow from the upstream after termination of the abstraction of large volume of groundwater, and diffusion of saltwater by freshwater recharged from the surrounding hillsides, from the ground surface and from the channels. A tangible balance of current conditions (shown in **Figures G.5.39**, **G.5.41 and G.5.42**) between the present groundwater abstraction and saltwater intrusion is maintained with a small margin, i.e., a height of piezometric level of around 0.5 m above the mean seawater level.



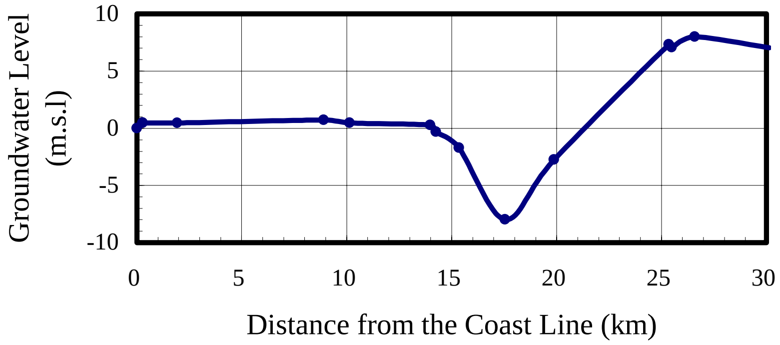
(a) Change of Piezometric Level along the Centre of the Groundwater Basin



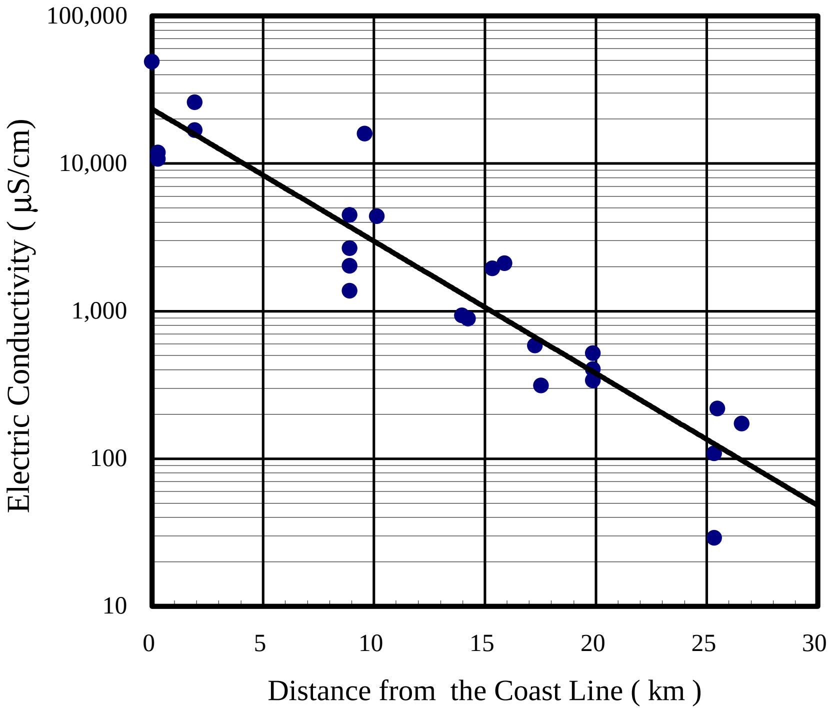
(b) Change of Chloride Content within the Groundwater Basin

Figure G.5.41

Change of Chloride Content of Groundwater within the Groundwater Basin



(a) Change of Piezometric Level along the Centre of the Groundwater Basin



(b) Change of Electric Conductivity within the Groundwater Basin

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Figure G.5.42

Change of Electric Conductivity of Groundwater within the Groundwater Basin

Additional abstraction may destroy this margin and may cause an abrupt saltwater intrusion. The results of simulation for Variants 2 and 3 demonstrate a large reduction of piezometric level, as shown in **Figure G.5.43**. Note that Variant 1 is the current condition. As presented in **Section 5.2** the direction of groundwater flow reverses from sea-bound (**Figures G.5.2** for Variant 1) to towards inland (**Figure G.5.4** for Variant 2 and **Figure G.5.5** for Variant 3). The simulation for Variants 2 and 3 also predict the maximum reach of the seawater, namely to Megasteel and Kajibumi Well Field 2 (refer to **Figures G.5.4** and **G.5.5**). The boundary of the estimated influence zone of saltwater intrusion is shown in **Figure G.5.44**. Locations of boundary at both sides of the Groundwater Basin will be influenced by the recharge flows from the surrounding areas in northwest and the east directions, and can be estimated also from the simulation results as **Figure G.5.44**.

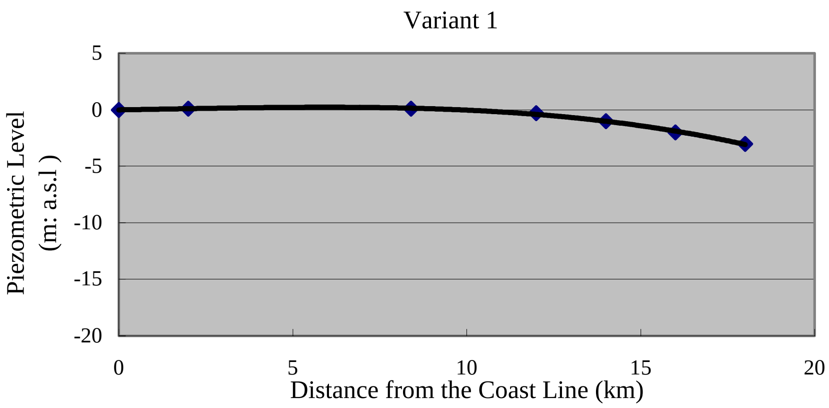
Seawater with high chloride content found at the seacoast may reach to the northern boundary of the influence zone after as long as 20 years as predicted and presented in **Figure G.5.5.20**. The required time may be influenced by the freshwater flows from the surrounding area, recharge from the ground surface and the channels and others. Before the maximum value, a gradual increase of chloride content at the boundary may occur as brackish water with different levels of chloride content in the Aquifer shown in **Figure G.5.39** shifts towards inland.

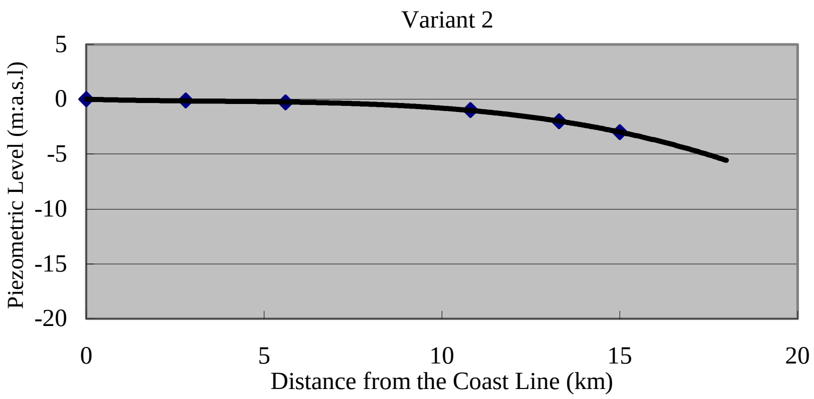
5.6 Summary and Conclusions for Environmental Interpretation of Modelling Results

The results of groundwater flow modelling in the form of piezometric heads or drawdown create a base for ecological predictions and evaluation of environmental impacts caused by groundwater abstraction. The following problems may be considered as actual in the model area: 1) Decrease of groundwater level in wetlands, 2) Land subsidence, 3) Groundwater pollution, and 4) Seawater intrusion.

The decrease of groundwater level can be calculated for any combination of modelling scenarios; the piezometric heads are simulated in all calculation nodes of discretised model layers. All results of performed modelling scenarios were stored in ASCII files and can be used for detail evaluation. The results of pumping tests and groundwater flow modelling indicate that groundwater abstraction in the main aquifer will cause only negligible drawdown in the wetlands and shallow peat layer. The shallow layer is affected more by lowering of surface recharge (rainfall). Influence of 3-year long dry season or increased abstraction of groundwater was studied in Simulation Variant 4 and 5, which are presented in **Figures G.5.7-9 and Figures G.5.11-13**. Model is based on assumption that the old dredge ponds consist of low-permeable backfill.

Land subsidence is an important soil-engineering problem mainly in sedimentary basins. It can be ascribed to several causes. In the Study Area, compaction of the soft clay layer following the decline of groundwater levels is the most important cause of land subsidence.





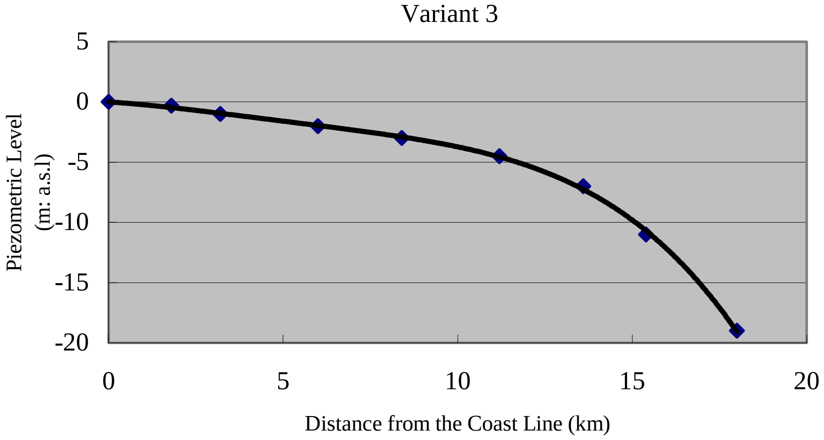


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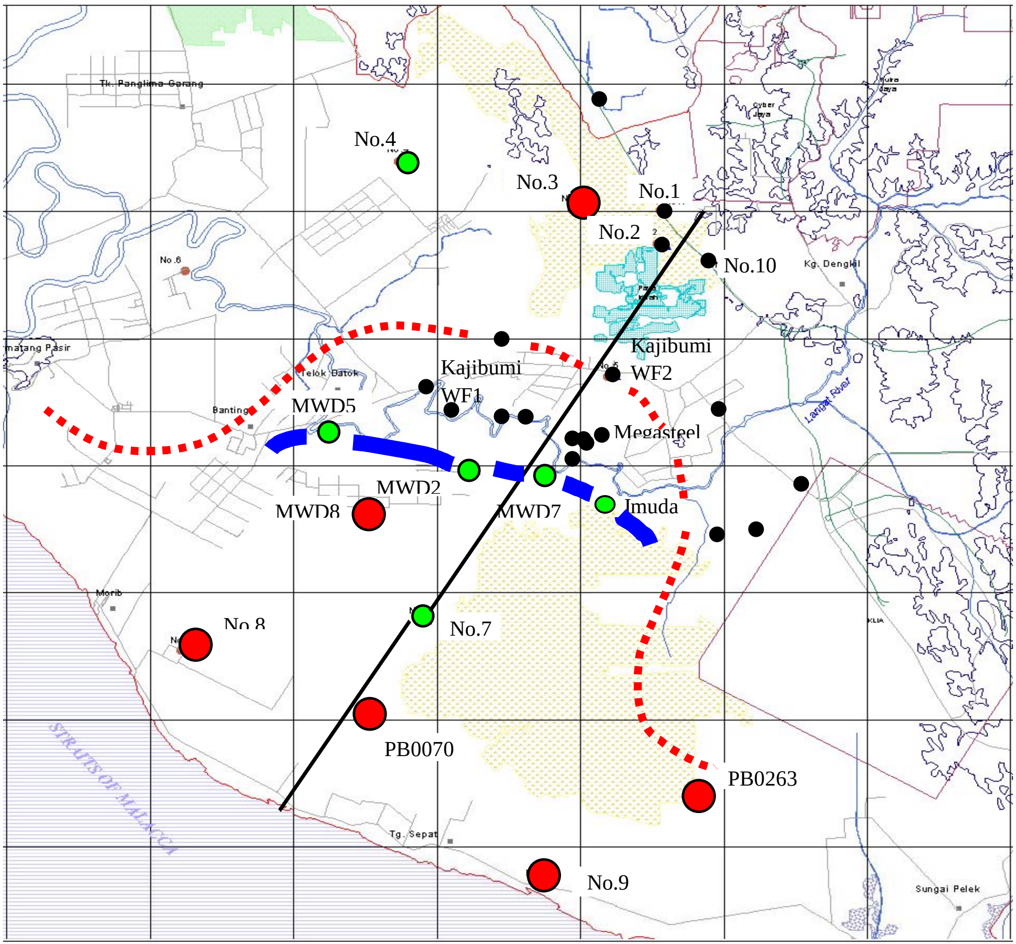
Figure G.5.43

Piezometric Level Changes along the Centre of the Groundwater Basin



Scale

0 5km

Legend

Fresh water- Saltwater Interface; Line of Chloride Content of 250mg/l (Current Status)

Estimated Boundary for Influence Zone of Saltwater Intrusion

Profile Line

Chloride (mg/l)

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

(Current Status)

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Figure G.5.44

Estimated Boundary for Influence Zone of Saltwater Intrusion

The estimation of total subsidence that might occur in given hydrogeological structure in response to the lowering of piezometric groundwater level is based on the following input parameters:

- Lowering of piezometric groundwater level;
- Thickness of compressible layers; and
- Compressibility parameters of layers.

The piezometric groundwater level (or groundwater table) was calculated by groundwater flow model for nine (9) groundwater management scenarios. Simulation Variant 0 (or any other Simulation Variant) represents the initial state for calculation of changes of piezometric levels. The piezometric heads for each steady-state simulation variant are stored in eight (8) ASCII files. Seven (7) files contain the calculated piezometric heads; each of seven (7) model layers is stored in one file (format: X, Y of node, piezometric head), one file contains the results of calculation for all layers together (format: X, Y, Z of node, piezometric head). The lowering of piezometric level (or groundwater table, drawdown) can be calculated for any combination of simulation variants by simple subtraction of generated files.

The parameters of elastic component of compression can be derived from results of performed pumping and recovery tests (S_s in **Table G.4.1**). The permanent part of compression – settlement due to consolidation – can be estimated from simultaneous monitoring of land subsidence and groundwater level or from laboratory tests.

The thickness and distribution of layers is based on results of hydrogeological study and field investigation; the geometry and thickness of seven layers can be used for calculation. Since the modelling and calculation of land subsidence is performed for steady-state groundwater flow (long-term lowering of piezometric groundwater level), the results represent the maximal expected land subsidence. The theoretical background and applied approach for estimation of land subsidence using results of groundwater flow modelling is described in **Section 5.4** of this report.

Visual MODFLOW Software Package has no capability to simulate directly saltwater intrusion (density flow). Thus the simulated groundwater level and piezometric head is not representative in the saltwater zone. In this zone, the measured and simulated water level need not correspond. In the prepared 3D model, the rough compensation for influence of saltwater was done by increase of water level at general head boundary along seacoast. This compensation ensures correct results in neighbouring freshwater zone. The results of modelling allow the estimation of regional flow pattern and rough estimation of saltwater intrusion possibility and the influence zone of saltwater intrusion.

Interpretation of saltwater intrusion in **Section 5.5** shall be considered as a first attempt to define the recent and future boundaries between freshwater and brackish water. The long-term monitoring and the field investigation to obtain for instance the characteristics of hydraulic connection between aquifer and sea, and the explanation of the occurrence and origin of brackish groundwater especially in the area south of Langat River and in Imuda Mine are required to understand the geochemical aspects of groundwater exploitation, including evaluation of saltwater intrusion.

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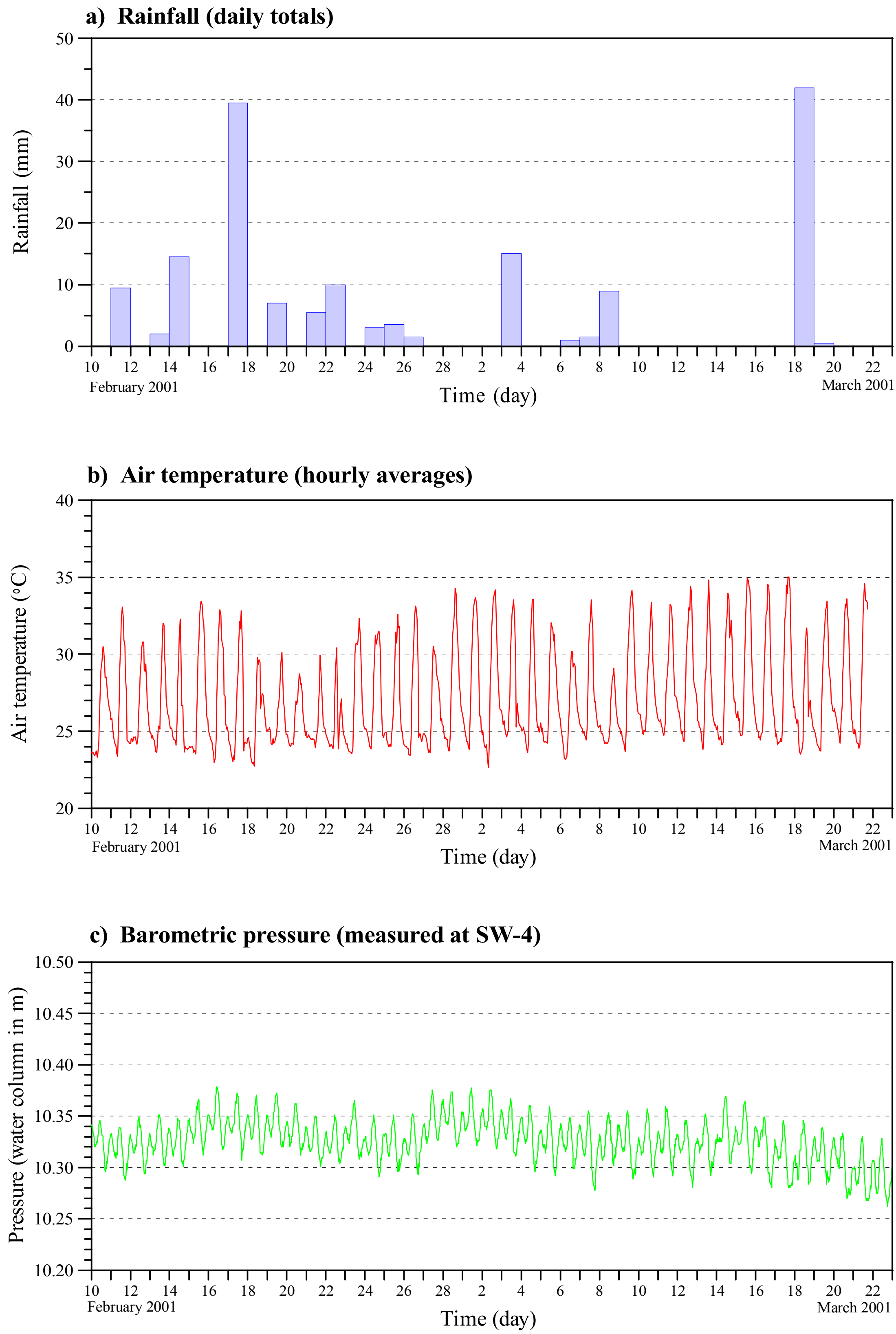
ANNEX G.3.1

RAINFALL, AIR TEMPERATURE AND BAROMETRIC PRESSURE DURING PUMPING AND RECOVERY TEST AT PAYA INDAH

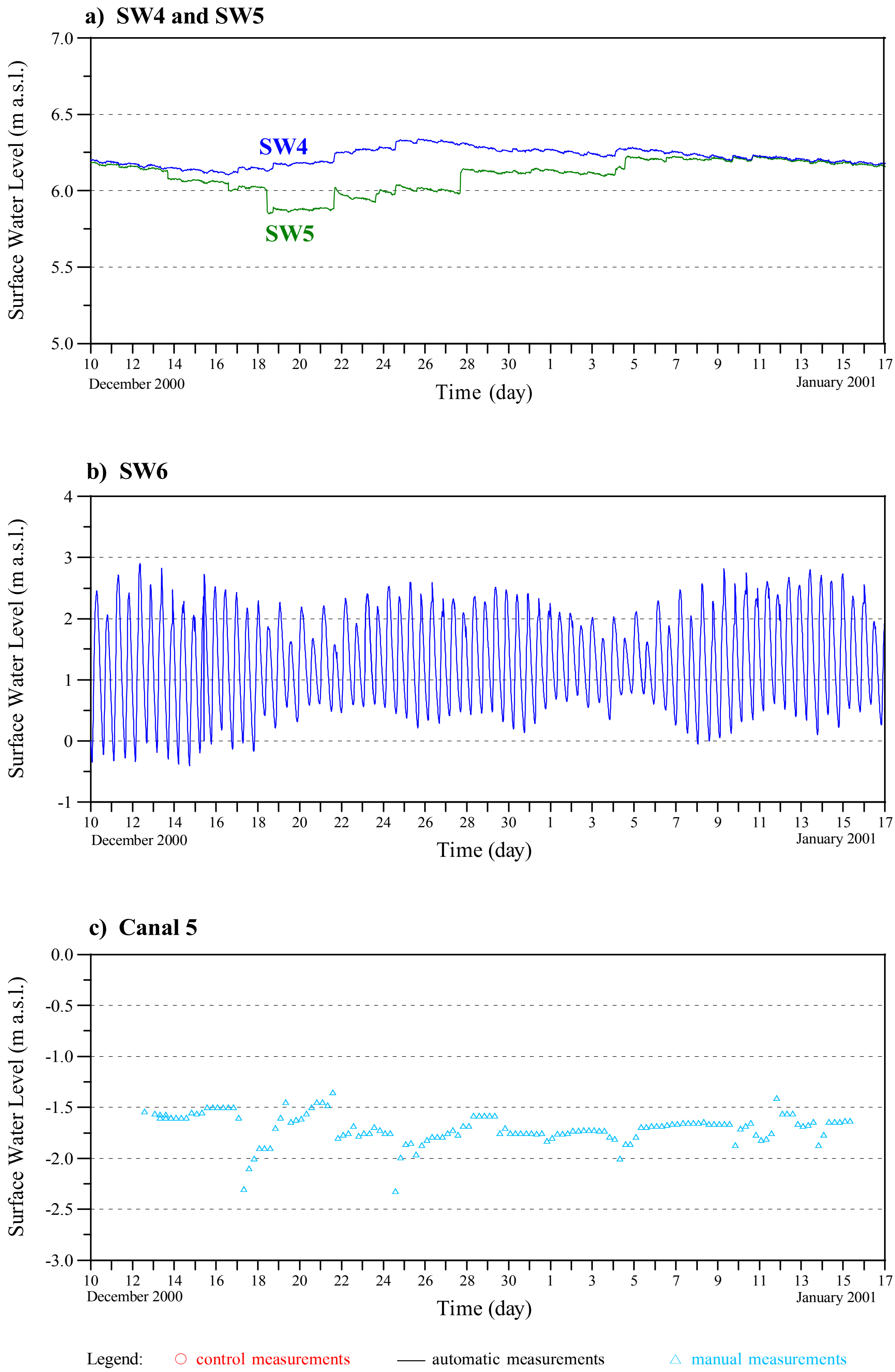


Annex Figure G.3.1 Paya Indah - Rainfall, Air temperature and Barometric pressure during pumping and recovery test (linear scale)

ro_rain_lin

ANNEX G.3.2

SURFACE WATER LEVEL DURING PUMPING AND RECOVERY TEST AT KAJIBUMI WELL FIELD 2



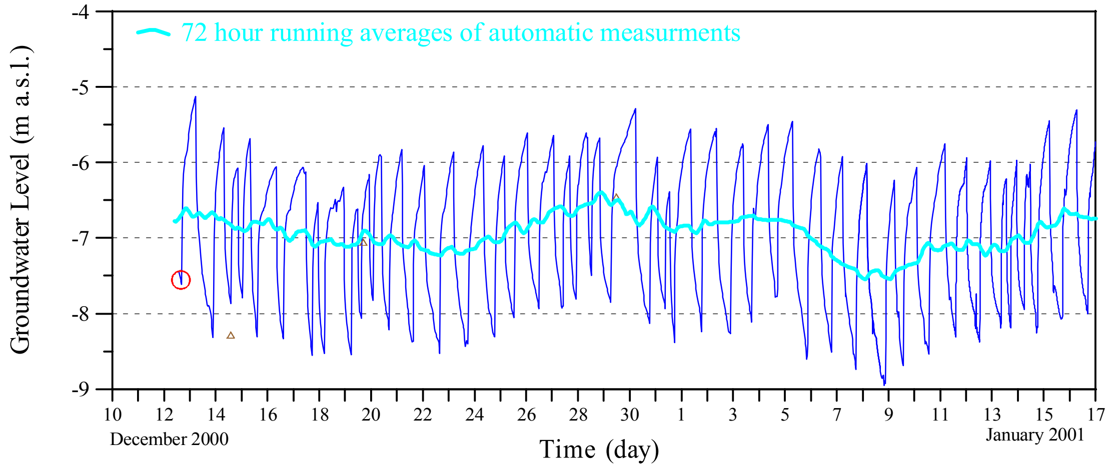
Annex Figure G.3.2 Kajibumi WF2 - SW4, SW5, SW6 and Canal 5 surfacewater level during pumping and recovery test (linear scale)

ro_sw4_lin

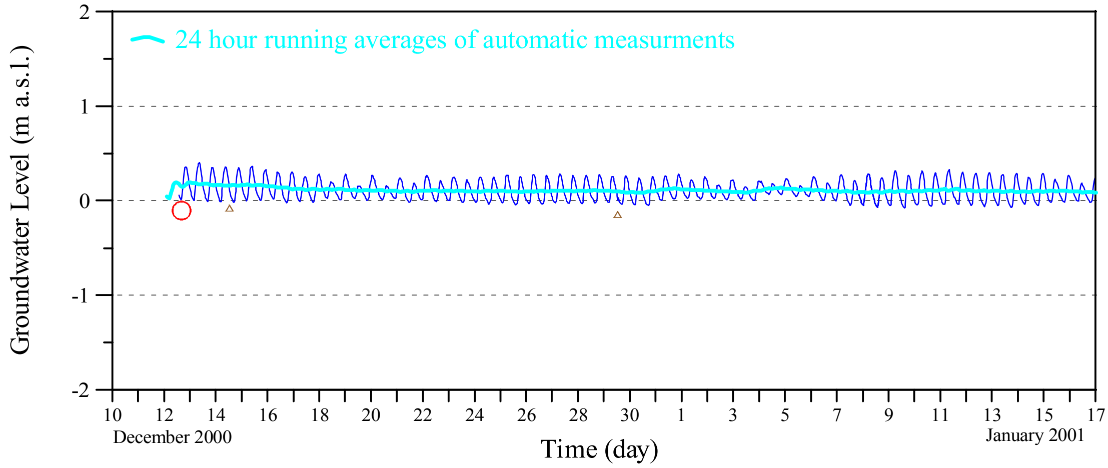
ANNEX G.3.3

GROUNDWATER LEVEL DURING PUMPING AND RECOVERY TEST AT KAJIBUMI WELL FIELD 2

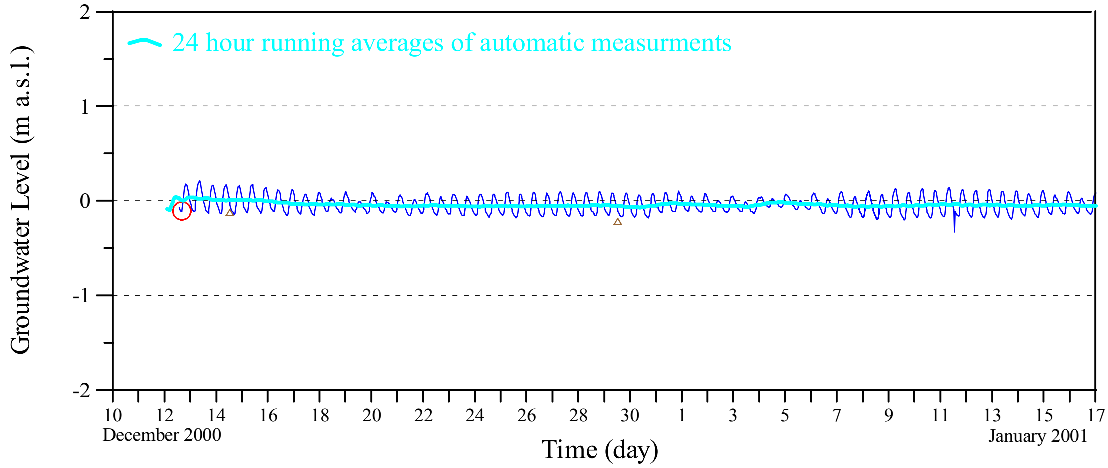
a) Well MW-1



b) Well MWS-10



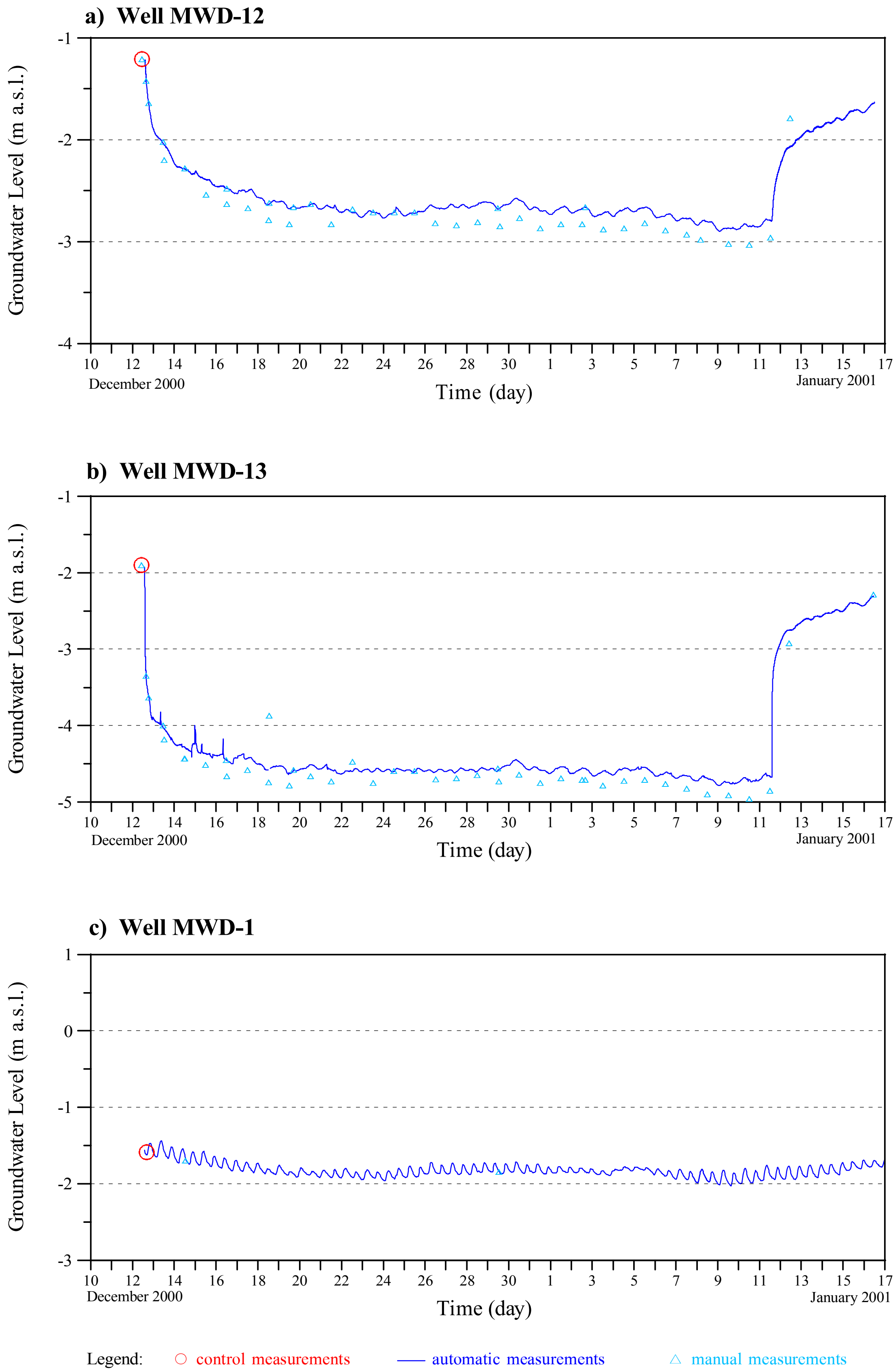
c) Well MWD-10



Legend: ○ control measurements —— automatic measurements △ manual measurements

Annex Figure G.3.3 Kajibumi WF2 - well MW-1, MWS-10 and MWD-10 groundwater level during pumping and recovery test (linear scale)

ro_mw1_lin



Annex Figure G.3.4 Kajibumi WF2 - well MWD-12, MWD-13 and MWD-1 groundwater level during pumping and recovery test (linear scale)

ro_mwd12_lin

ANNEX G.3.4

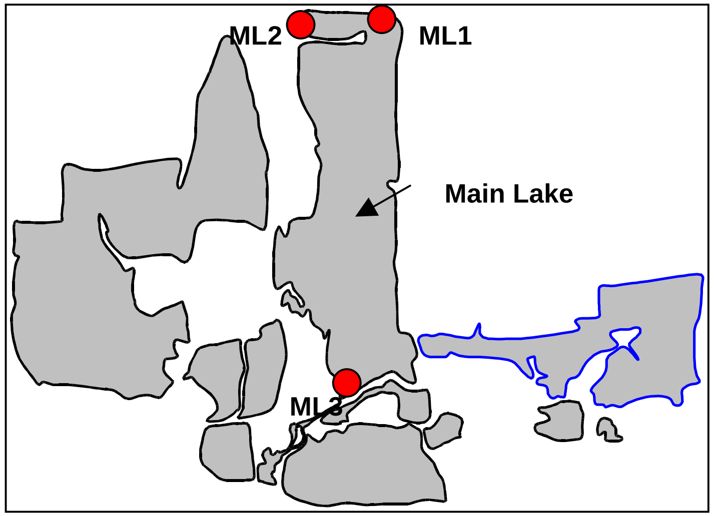
WATER QUALITY DURING PUMPING AND RECOVERY TEST

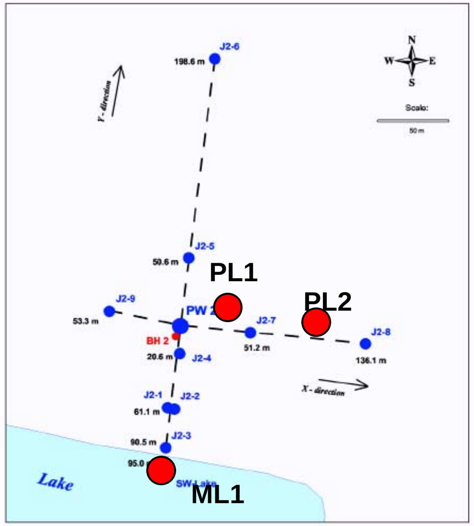
Annex Table G.3.1 Pumping Test at Paya Indah : Water Quality Test, 11 February - 21 March 2001 (1/2)

No.	Sample No	Sampling Date	In-situ						On Site										
			Temp. (oC)	Cond. (us/cm)	TDS (mg/l)	pH	DO (mg/l)	Turb (ntu)	COD	BOD	Nitrate (mg/l)	Nitrite (mg/l)	Tot. Iron (mg/l)	Ferrous (mg/l)	Sulfide (mg/l)	PO_4 (mg/l)	Mn (mg/l)	Ca(CaCO3) (mg/l)	Mg(CaCO3) (mg/l)
1	PW2(A)	11.02.01	27.3	22.7	9.7	4.9	1.24	4.90	0.04	2.73	0.021	1.1	0.54	0.41	12	0.88	0.2	3.79	4.18
2	PW2(B)	27.02.01	29.3	30.5	12.2	5.2	1.17	3.72	0.06	2.63	0.014	0.9	0.47	0.26	9	0.81	0.1	3.41	4.22
3	PW2(C)	03.03.01	27.2	38.2	18.7	4.8	1.26	1.89	0.07	2.67	0.011	1.3	0.32	0.24	8	0.92	0.1	3.22	4.02
4	PW2(D)	13.03.01	27.3	28.8	11.7	4.7	1.2	1.90	0.07	2.63	-	-	-	-	-	-	-	-	-
5	J2-1-2	16.03.01	31.4	34.2	15.9	4.8	1.9	4.00	1.31	-	4.622	2.1	1.68	1.02	26	1.88	0.1	2.01	2.62
6	J2-1-3	16.03.01	31.6	28.6	12.9	4.5	2.0	4.00	0.02	-	2.661	1.4	1.07	0.97	17	1.22	0.1	2.23	2.84
7	J2-6-2	16.03.01	31.5	35.7	14.9	4.7	-	6.00	1.16	-	-	-	-	-	-	-	-	-	-
8	J2-8	16.03.01	22.3	26.3	12.9	4.5	1.4	4.00	1.73	-	0.026	1.2	0.96	0.41	18	0.86	0.1	3.01	3.22
9	PL1	08.03.01	32.3	37.4	15.6	4.0	1.7	4.00	1.57	-	0.010	0.8	0.47	0.38	6	0.65	0.1	2.24	2.72
10	PL2	08.03.01	30.8	39.8	18.9	3.8	2.0	5.00	2.22	-	0.013	0.8	0.57	0.43	7	0.67	0.1	2.23	2.71
11	ML1	08.03.01	32.2	45.2	21.1	4.5	2.2	5.00	3.04	-	0.029	1.3	0.84	0.39	9	0.68	0.1	1.84	1.89
12	ML2	08.03.01	31.1	46.3	22.7	4.1	2.1	5.00	2.23	-	0.010	4.3	1.84	0.27	5	0.34	0	1.38	1.72
13	ML3	08.03.01	31.3	42.9	19.2	4.3	1.89	4.00	1.65	-	0.014	5.2	1.65	0.31	6	0.41	0	1.24	2.01

Note : ML1- Main lake 1
ML2- Main lake 2
ML3- Main lake 3
PL1- Peat swamp 1
PL2- Peat swamp2

BOD-DO meter was not functioning.



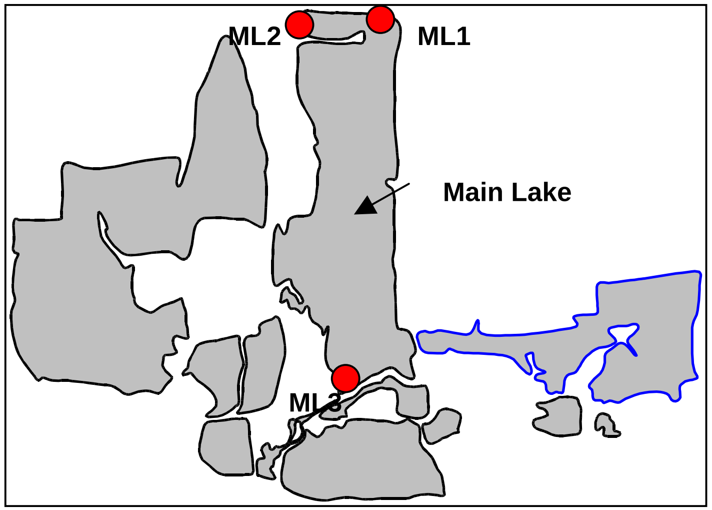


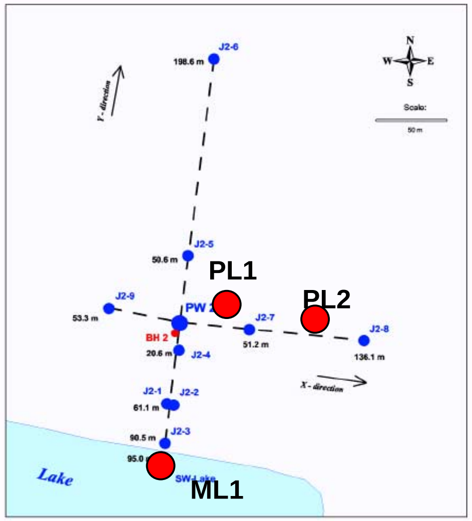
Annex Table G.3.2 Pumping Test at Paya Indah : Water Quality Test, 11 February - 21 March 2001 (2/2)

No.	Sample No	Sampling Date	Ipoh Lab.*																			
			pH	Colour	Cond. (us/cm)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	NH_4 (mg/l)	SiO_2 (mg/l)	SO_4 (mg/l)	CO_3 (mg/l)	HCO_3 (mg/l)	F (mg/l)	As (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)	Se (mg/l)	Hardness (mg/l)	Alkalinity (mg/l)	TS (mg/l)
1	PW2(A)	11.02.01	5.5	5	5.0	2.7	1.0	0.9	0.5	<1	-	7.9	3	<1	7	<0.5	<0.005	<0.1	<0.01	<0.1	<0.005	4	11	-
2	PW2(B)	27.02.01	5.7	5	5.0	1.9	0.8	0.9	0.5	2	-	8.9	<3	<1	7	<0.5	<0.005	<0.1	0.01	0.8	<0.005	4	11	-
3	PW2(C)	03.03.01	5.4	5	5.0	2.4	1.3	0.9	1.3	<1	-	8.1	12	<1	8	<0.5	<0.005	<0.1	<0.01	<0.1	<0.005	8	13	-
4	PW2(D)	13.03.01	5.6	5	24	1.7	1.0	1.7	<0.1	2	<0.5	12.0	<3	<1	10	0.5	<0.005	<0.1	<0.01	0.2	<0.005	4	16	-
5	J2-1-2	16.03.01	5.8	5	36	3.6	1.0	3.4	0.5	2	-	12.0	<3	<1	17	<0.5	0.025	<0.1	<0.01	0.1	<0.005	11	28	-
6	J2-1-3	16.03.01	5.4	5	22	1.8	1.0	1.7	<0.1	3	-	11.0	<3	<1	5	<0.5	<0.005	<0.1	<0.01	<0.1	<0.005	4	8	-
7	J2-6-2	16.03.01	6.0	5	41	5.0	1.9	1.3	1.3	3	-	9.8	<3	<1	18	<0.5	<0.005	<0.1	<0.01	<0.1	<0.005	9	30	-
8	J2-8	16.03.01	5.7	5	5.0	1.6	1.1	1.7	0.5	<1	-	8.4	<3	<1	9	<0.5	<0.005	<0.1	0.04	0.2	<0.005	6	15	-
9	PL1	08.03.01	4.8	500	500	1.4	1.1	2.4	1.2	<1	-	1.3	<3	<1	<1	<0.5	<0.005	<0.1	<0.01	<0.1	<0.005	11	0	-
10	PL2	08.03.01	4.6	500	500	1.1	1.2	2.2	0.8	<1	-	0.5	<3	<1	<1	<0.5	<0.005	<0.1	<0.01	<0.1	<0.005	9	0	-
11	ML1	08.03.01	4.8	500	500	1.9	2.2	2.3	1.1	3	-	1.8	<3	<1	<1	<0.5	0.007	<0.1	<0.01	<0.1	<0.005	10	0	-
12	ML2	08.03.01	4.8	500	500	2.2	2.2	2.1	1.1	<1	-	2.0	<3	<1	<1	<0.5	0.005	<0.1	<0.01	<0.1	<0.005	10	0	-
13	ML3	08.03.01	-	-	-	-	-	-	-	-	<0.5	-	-	-	-	-	-	-	-	-	-	-	-	-

Note : ML1- Main lake 1
ML2- Main lake 2
ML3- Main lake 3
PL1- Peat swamp 1
PL2- Peat swamp2

*Results from Ipoh Lab. did not show the date of sampling. The sampling date of each result was thus assumed to be filled up in this table.





Annex Table G.3.3 Pumping Test at Kajibumi Well Field 2 : Water Quality Test, 8 December 2000 - 21 January 2001 (1/2)

No.	Sample No	Sampling Date	In-situ						On Site											Ipoh Lab.*				
			Temp. (oC)	Cond. (us/cm)	TDS (mg/l)	pH	DO (mg/l)	Turb. (ntu)	COD	BOD	Nitrate (mg/l)	Nitrite (mg/l)	Tot. Iron (mg/l)	Ferrous (mg/l)	Sulfide (mg/l)	PO_4 (mg/l)	Mn (mg/l)	Ca(CaCO3) (mg/l)	Mg(CaCO3) (mg/l)	pH	Colour	Cond. (us/cm)	Na (mg/l)	K (mg/l)
1	J5-1-1	08.12.00	29.3	46.2	20.8	6.2	18.2	4.78	0.09	2.68	-	-	-	-	-	-	-	-	-	-	-	-	47	-
14	J5-1-1(A)	26.12.00	29.4	47.2	21.6	6.4	19.3	3.96	0.1	3.08	-	-	-	-	-	-	-	-	-	-	-	-	90	-
2	J5-1-2	08.12.00	29.3	47.2	21.5	6.4	18.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	41	-
15	J5-1-2(B)	26.12.00	29.5	47.5	21.7	6.5	17.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	26	-
3	J5-1-3	08.12.00	28.6	43.7	21.4	6.5	17.5	-	-	36.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	J5-1-3(C)	26.12.00	28.1	43.5	21.5	6.3	13.1	-	-	34.4	-	-	-	-	-	-	-	-	-	-	-	-	52	-
4	TUB/1	12.12.00	28.5	-	-	6.6	38.0	1.50	136	3.3	1.6	0.045	2.7	0.01	?	2.75	0.4	?	0.16	-	-	-	29	-
6	TUB/2	15.12.00	28.3	-	-	6.6	36.4	2.40	131	6.2	2.1	0.014	2.89	2.21	1.0	0.41	0.3	4.15	1.25	-	-	-	27	-
7	TUB/3	20.12.00	28.0	-	-	6.7	8.1	#	64	5.1	1.9	0.009	2.91	2.27	1.0	0.39	0.2	4.14	1.27	-	-	-	30	-
11	TUB/4	05.01.01	28.0	261.0	128.0	6.7	9.5	14.20	165.0	0.3	2.0	0.007	2.94	2.84	1.0	0.36	0.2	4.16	1.34	-	-	-	28	-
12	TUB/5	11.01.01	25.2	332.0	136.6	6.8	141.1	14.90	158.0	0.38	3.4	0.006	3.15	0.06	0.0	0.18	0.1	4.16	1.16	-	-	-	28	-
5	Canal/1 *	12.12.00	28.8	145.0	48.0	4.7	-	15.00	148	4.1	2.0	0.912	1.14	0.12	?	0.4	0.0	1.09	0.12	-	-	-	4.7	-
13	Canal/2	11.01.01	28.8	132.7	53.2	4.3	8.9	19	167.0	3.7	1.8	1.012	0.86	0.06	26.0	1.02	0.6	2.12	0.26	-	-	-	5.1	-
8	SL	05.01.01	28.1	96.7	-	6.0	3.0	4.90	**	1.9	2.1	0.004	2.56	0.51	0.8	2.98	0.1	0.98	0.06	-	-	-	4.4	-
9	Paya Indah	05.01.01	28.9	136.0	-	7.2	4.3	6.70	165.00	1.9	2.0	0.003	2.88	0.6	0.7	3.64	0.1	1.02	0.29	-	-	-	2.7	-
10	Imuda-1	05.01.01	28.3	116.1	52.4	7.2	9.8	8.90	9.0	4.5	1.1	0.023	0.93	0.02	92.0	0.46	0.3	1.12	0.18	-	-	-	284	-

Note :
(-) = No data
(?) = Pillow problem
(#) = SEBA cannot functions
(**) = Over range
Canal * No data from Geologist assistant

SL = Langat River

*Results from Ipoh Lab. did not show the date of sampling. The sampling date of each result was thus assumed to be filled up in this table.

Annex Table G.3.4 Pumping Test at Kajibumi Well Field 2 : Water Quality Test, 8 December 2000 - 21 January 2001 (2/2)

No.	Sample No	Sampling Date	Ipoh Lab.*																					
			Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	NH_4 (mg/l)	SiO_2 (mg/l)	SO_4 (mg/l)	CO_3 (mg/l)	HCO_3 (mg/l)	F (mg/l)	Nitrate (mg/l)	P (mg/l)	As (mg/l)	Al (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)	Se (mg/l)	Detergent (mg/l)	Hardness (mg/l)	Alkalinity (mg/l)	SS (mg/l)	TS (mg/l)	Diss. Solids (mg/l)
1	J5-1-1	08.12.00	3.6	5.4	10	1.9	11	18	<1	137	<0.5	2.9	<0.02	-	0.3	-	-	-	-	0.3	31	225	26	168	142
14	J5-1-1(A)	26.12.00	5.8	7.3	28	1.7	9.2	59	<1	196	<0.5	2.9	<0.02	-	0.1	-	-	-	-	<0.25	45	321	46	316	270
2	J5-1-2	08.12.00	5.8	7.3	22	2.0	9.8	15	<1	123	<0.5	3.0	0.03	-	<0.1	-	-	-	-	<0.25	45	202	14	192	178
15	J5-1-2(B)	26.12.00	7.1	6.5	22	1.8	11	<3	<1	93	<0.5	3.2	<0.02	-	<0.1	-	-	-	-	<0.25	44	153	16	136	120
3	J5-1-3	08.12.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16	J5-1-3(C)	26.12.00	12	3.5	20	1.5	9.8	26	<1	129	<0.5	2.2	<0.02	-	<0.1	-	-	-	-	<0.25	44	212	-14	188	202
4	TUB/1	12.12.00	4.9	7.3	30	1.8	9.5	<3	<1	87	<0.5	3.5	0.03	-	<0.1	-	-	-	-	<0.25	42	143	10	150	140
6	TUB/2	15.12.00	4.9	7.3	28	2.0	10	<3	<1	89	<0.5	6.5	0.05	-	<0.1	-	-	-	-	<0.25	42	146	4	138	134
7	TUB/3	20.12.00	5.3	7.5	30	1.8	8.8	<3	<1	89	<0.5	2.7	0.13	-	0.1	-	-	-	-	<0.25	44	146	26	150	124
11	TUB/4	05.01.01	6.2	6.5	28	2.1	10	<3	<1	89	<0.5	3.1	0.08	-	0.1	-	-	-	-	<0.25	42	146	0	128	128
12	TUB/5	11.01.01	4.4	7	28	1.8	10	<3	<1	91	<0.5	2.9	0.05	-	<0.1	-	-	-	-	<0.25	40	149	18	132	114
5	Canal/1 *	12.12.00	5.3	4.3	5	1.6	5.2	30	<1	2	<0.5	<0.5	<0.02	-	0.3	-	-	-	-	0.42	31	3	40	112	72
13	Canal/2	11.01.01	7.1	2.7	8	1.6	10	31	<1	<1	<0.5	4.4	0.03	-	0.5	-	-	-	-	<0.25	29	0	80	164	84
8	SL	05.01.01	4.4	4.3	4	2.0	7.2	42	<1	<1	<0.5	0.7	<0.02	-	1.0	-	-	-	-	0.28	29	0	58	126	68
9	Paya Indal	05.01.01	3.1	5.1	4	1.6	7.8	<3	<1	24	<0.5	<0.5	<0.02	-	1.0	-	-	-	-	<0.25	29	39	30	78	48
10	Imuda-1	05.01.01	20	41	448	3.4	30	87	<1	272	<0.5	4.1	0.05	-	0.5	-	-	-	-	<0.25	219	446	74	1154	1080

Note :

(-) = No data

(?) = Pillow problem

(#) = SEBA cannot functions

(**) = Over range

Canal * No data from Geologist assistant

SL = Langat River

*Results from Ipoh Lab. did not show the date of sampling. The sampling date of each result was thus assumed to be filled up in this table.

Annex Table G.3.5 Kanchong Darat : Water Quality Test, 19 March - 27 April 2001 (1/2)

No.	Sample No	Sampling Date	In-situ						On Site											Ipoh Lab.*	
			Temp. (oC)	Cond.* (us/cm)	TDS (mg/l)	pH	DO (mg/l)	Turb (ntu)	COD	BOD	Nitrate (mg/l)	Nitrite (mg/l)	Tot. Iron (mg/l)	Ferrous (mg/l)	Sulfide (mg/l)	PO_4 (mg/l)	Mn (mg/l)	Ca(CaCO3) (mg/l)	Mg(CaCO3) (mg/l)	pH	Colour
1	PW7	19.03.01	29.3	350	0.19	6.50	-	2.00	4.0	-	1.213	2.2	2.11	1.07	32	1.46	0.100	5.23	5.61	7.2	150
2	PW7(A)	23.03.01	29.5	350	0.18	6.37	-	1.50	2.0	-	1.016	1.9	2.31	1.85	26	1.42	0.100	5.02	5.26	-	-
3	PW7	28.03.01	30.5	270	0.15	6.50	-	2.86	3.6	-	0.010	0.002	3.3	1.65	31	2.75	0.001	4.91	4.20	7.2	150
4	PW7	06.04.01	30.1	146200	58.20	6.69	-	6.02	3.0	-	36.000	0.269	0.03	1.12	38	2.76	0.205	5.01	5.32	6.9	150
5	PW7	17.04.01	28.8	146200	40.50	5.72	-	5.76	1.0	-	2.200	0.048	1.65	0.65	24	0.4	0.001	5.22	5.02	7.0	100
6	J7-1-2	27.04.01	27.1	1000	1.00	7.00	-	3.30	51.0	-	1.417	3.8	0.69	0.51	38	2.62	0.100	0.29	0.42	7.3	500
7	J7-1-3	27.04.01	29.2	1000	1.00	7.40	-	6.10	3.0	-	2.162	4.8	0.82	0.76	3.1	2.01	0.100	0.69	0.82	7.1	150
8	J7-1-4	27.04.01	27.0	1000	1.00	7.30	-	22.60	51.0	-	1.762	3.2	1.02	0.98	24	1.02	0.100	4.21	4.82	6.9	150
9	J7-2	27.04.01	28.1	4580	1.00	7.00	-	3.00	-	-	0.962	2.4	1.89	1.22	22	1.16	0.100	1.42	1.69	6.8	100

Note: BOD-DO meter was not functioning.

*Results from Ipoh Lab. did not show the date of sampling. The sampling date of each result was thus assumed to be filled up in this table.

Annex Table G.3.6 Kanchong Darat : Water Quality Test, 19 March - 27 April 2001 (2/2)

No.	Sample No	Sampling Date	Ipoh Lab.*																		
			Cond. (us/cm)	Na (mg/l)	K (mg/l)	Ca (mg/l)	Mg (mg/l)	Cl (mg/l)	NH_4 (mg/l)	SiO_2 (mg/l)	SO_4 (mg/l)	CO_3 (mg/l)	HCO_3 (mg/l)	F (mg/l)	As (mg/l)	Cu (mg/l)	Pb (mg/l)	Zn (mg/l)	Se (mg/l)	Hardness (mg/l)	Alkalinity (mg/l)	TS (mg/l)
1	PW7	19.03.01	2200	395	22	16	33	413	1.6	29	<3	<1	570	0.5	<0.005	<0.1	<0.01	<0.1	<0.005	176	935	-
2	PW7(A)	23.03.01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	PW7	28.03.01	2230	395	22	17	33	407	2.3	30	<3	<1	563	0.5	<0.005	<0.1	<0.01	<0.1	<0.005	178	923	-
4	PW7	06.04.01	2050	450	22	15	37	423	2.3	35	<3	<1	546	0.5	<0.005	-	<0.01	<0.1	<0.005	190	896	-
5	PW7	17.04.01	2200	460	23	16	37	445	2.0	33	<3	<1	594	<0.5	<0.005	-	<0.01	<0.1	<0.005	192	974	-
6	J7-1-2	27.04.01	2340	520	36	42	27	122	1.8	22	<3	<1	1423	0.8	0.284	-	<0.01	<0.1	<0.005	216	2334	-
7	J7-1-3	27.04.01	1050	152	39	28	30	83	<0.5	47	<3	<1	564	0.6	0.103	-	<0.01	<0.1	<0.005	193	925	-
8	J7-1-4	27.04.01	1890	405	26	18	37	321	0.7	39	<3	<1	633	0.6	0.054	-	<0.01	<0.1	<0.005	197	1038	-
9	J7-2	27.04.01	4150	840	35	49	57	974	0.7	19	<3	<1	898	<0.5	<0.005	-	<0.01	<0.1	<0.005	357	1473	-

Note: BOD-DO meter was not functioning.

*Results from Ipoh Lab. did not show the date of sampling. The sampling date of each result was thus assumed to be filled up in this table.

SECTOR H

GROUNDWATER MONITORING

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

FINAL REPORT

SECTOR H

GROUNDWATER MONITORING

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LIST OF ANNEXES

SECTOR H

GROUNDWATER MONITORING

1. INTRODUCTION

This sector covers groundwater monitoring for the Langat Basin by measuring the groundwater level and quality, and land subsidence. The groundwater monitoring system for the Langat Basin is to be carried out based on the following five (5) parameters:

(1) Groundwater Level;

(2) Surface Water Level;

(3) Land Subsidence;

(4) Groundwater Quality; and

(5) Surface Water Quality.

Figure H.1.1 shows an overview of the groundwater monitoring system for the Basin. The system consists of monitoring wells (including the existing wells), barometric pressure transducers, surface water level instrument, settlement gauges and deep datum, and an extensometer. The figure also summarises parameters to monitor, monitoring method, recording method and equipment.

The following **Chapter 2** introduces the groundwater monitoring system established in this Study, focusing on both the existing groundwater monitoring wells in the Minerals and Geoscience Department Malaysia (JMG) and newly constructed wells. The succeeding **Chapter 3** presents groundwater level and quality observation carried out in this Study while the result and analysis of the observation are stated in **Sector E**. Measurement of land subsidence by installation of benchmarks and borehole extensometer in this Study is described in **Chapter 4**. Finally, **Chapter 5** proposes the future monitoring plan for sustainable development of groundwater in the Langat Basin.

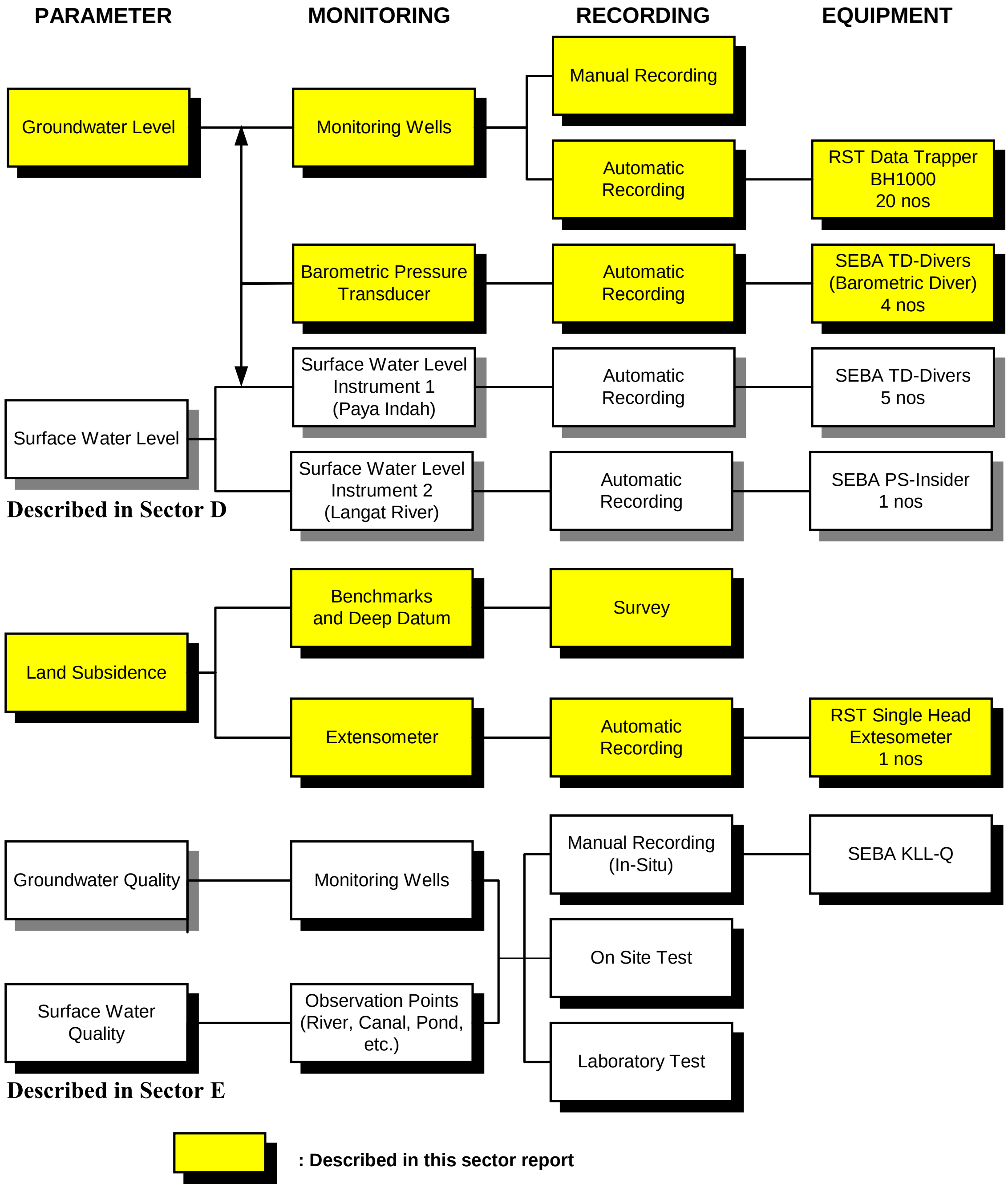


Figure H.1.1 Groundwater Monitoring System for the Langat Basin

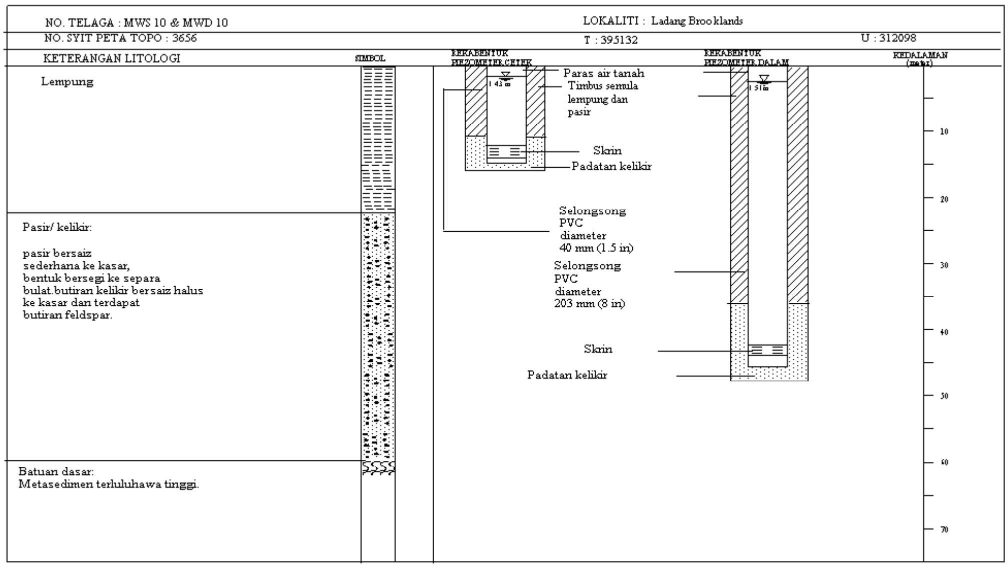
2. ESTABLISHMEMT OF GROUNDWATER MONITORING SYSTEM

2.1 Existing JMG Groundwater Monitoring Wells

Twenty-four (24) monitoring wells have been installed in the Telok Datok–Olak Lempit area in the district of Kuala Langat during the groundwater resources study by JMG upon the request of the Selangor State Government.[1)] JMG had added monitoring wells from time to time to this monitoring system. The wells are identified either as MW(number), MWD(number) or MWS(number), where MW stands for Monitoring Well, MWD stands for Monitoring Well at Deep Depth and MWS stands for Monitoring Well at Shallow Depth. Usually, a pair of one MWD and one MWS is installed at the same location. In MWD a piezometer was installed in the Aquifer and in MWS a piezometer was installed in the upper clayey layer. Typical well structure of MWD and MWS are presented in **Figure H.2.1** and their photograph is shown in **Photograph H.2.1**.

The Hydrogeological potential of the coastal alluvium from Kapar-Meru in Kelang in the north to Banting-Sepang in the south, covering an area of approximately 1,150 km^2, was investigated by JMG during 1994–1995.[2)] During the study, a total of 32 exploratory holes, one (1) test well and four (4) observation wells were constructed. They are identified as LK(number). Some of these observation wells may be placed in the long-term groundwater monitoring system.

Location of the monitoring wells is shown in **Figure H.2.2** and the list of wells is given in **Table H.2.1**.



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LOG GEOLOGI DAN REKA BENTUK TELAGA PEMANTAUAN MWS 10 & MWD 10
DI LADANG BROOKLANDS, TELOK DATUK

Figure H.2.1 Typical Well Structure of JMG Monitoring Wells

Figure H.2.2

Location Map of Groundwater Monitoring System

LEGEND

Monitoring Well

- Five Piezometers at One Location
- Four Piezometers at One Location
- Three Piezometers at One Location
- Two Piezometers at One Location
- One Piezometer at One Location

Barometric Pressure transducer

- Topographic Contourline of 20m Height
- Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation
- Highway
- Roads
- Rivers
- Towns

Forest Reserve

- Inland Forest
- Mangrove Forest
- Swamp Forest
- Study Area

Scale 1 : 200,000

2 0 2 4 Kilometers

N S W E

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

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

CTI Engineering International Co., Ltd.

OYO CORPORATION

Photograph H.2.1

JMG Monitoring Wells (MWD8 and MWS8)

Table H.2.1 List of Existing Observation Wells for Long-Term Monitoring

No	Well Name	Location	Coordinates			Well Depth (m)	Screen Depth (m)	Geology	PVC Diameter (mm)	Water Level Measured by	Water Sampling
			x (East)	y (North)	z (EL.m)						
1	MWD1	Jambatan Batu, Jln. ke Sg. Kelambu	397837	311786	2.369	50.25	44.3-50	Sand	76	Logger	Yes
2	MWD2	Jln. Dahilia, Sg. Kelambu	395828	309646	4.407	60.5	57.6-60.5	Sand	76	Logger	Yes
3	MWD4	Mutiara Telekom, Jln ke Salak Tinggi-KLIA	404709	312097	3.460	25.75	23-25	Sand	40	Manual	Yes
4	MWD5	Pintu Air, Sg. Lang, detak pekan Banting	390840	311177	1.891	46.65	44.3-46.65	Sand	40	Manual	Yes
5	MWD6	Kg. Sg. Manggis, Telok Datok	394306	313008	3.294	51.6	47.9-51.6	Sand (thin)	80	Logger	Yes
6	MWD7	Kg. Sg. Kelambu	398523	309450	2.747	48.9	47.6-48.9	Sand	70	Manual	Yes
7	MWD8	Jl. Idaman, Sg. Lang Tengah	392268	307906	4.702	42.3	37.3-41.3	Sand	75	Manual	Yes
8	MWD9	FELCRA, Bt. Changang	406044	307309	5.186	21.0	17-18.4	Sand	65	Logger	Yes
9	MWD10	Kajibumi WF1	395202	312060	2.724	58.5	53.5	Sand	80	Logger	Yes

Table H.2.1 List of Existing Observation Wells for Long-Term Monitoring (cont'd)

No	Well Name	Location	Coordinates			Well Depth (m)	Screen Depth (m)	Geology	PVC Diameter (mm)	Water Level Measured by	Water Sampling
			x (East)	y (North)	z (EL.m)						
-	MW14	FELCRA, Bt. Changang	407652	309113	?	12.6	9.8 – 12.3	Sand	76	(Manual)*	(Yes)*
10	LED2	Express Highway KLIA-Subang-Nilai	400458	324469	?	17.35	16.8 - 17.8	Sand	52	Logger	Yes
-	LED3	-ditto-	400521	324496	?	16.7	16.5 - 17.5	Sand	52	(Manual)*	(Yes)*
11	MW1	Magasteel	400548	311069	4.253	20.25	18.5 - 19.5	Sand	82	Logger	Yes
-	EXPL2	Pintu Air, Sg. Lang, detak pekan Banting	390840	311177	?	53.6	50.85 - 53.6	Sand	76	(Manual)*	(Yes)*

Note: *Parentheses means that measurement was made in the first time only; therefore, these wells will not be used for long term monitoring.

2.2 Installation of Groundwater Monitoring System

2.2.1 General

To strengthen the existing groundwater monitoring system of JMG, the new monitoring wells were installed during the Phase II Study.

This section describes the newly installed monitoring wells; namely, the selection of monitoring locations, types of groundwater monitoring well, their installation methods, recording equipment of groundwater level, system of groundwater level monitoring and records of barometric pressure changes. Locations of monitoring wells in the Groundwater Basin are as previously shown in **Figure H.2.2**. Results of groundwater monitoring are presented in both **Sectors E and G**.

2.2.2 New Groundwater Monitoring Wells

(1) Selection of Monitoring Locations

The total number of well locations were set at 10, covering the Groundwater Basin, and the objectives of installing new wells at each location are summarised as follows:

(a) Two (2) monitoring locations were selected in the upstream of Paya Indah (**Numbers 1 and 10**) and a total of four (4) monitoring wells were constructed (**J1-1-1, J1-1-2, J10-1-1 and J10-1-2**). The objective of these monitoring wells is to monitor the inflow of groundwater (and pollutant) into the area of Paya Indah; one from Putrajaya and Cyberjaya area, and the other from the old mining area at Dengkil and those along the Langat River.

(b) Two (2) monitoring locations were selected along the northern boundary of the Aquifer system (**Numbers 3 and 4**) and a total of four (4) monitoring wells were constructed (**J3-1, J3-2, J4-1 and J4-2**). The objective of these wells is to monitor the inflow of groundwater (and pollutant) into the Aquifer system.

(c) Two (2) monitoring wells were selected on the shoreline (**Numbers 8 and 9**) and a total of four (4) monitoring wells were constructed (**J8-1, J8-2, J9-1 and J9-2**). The objective of these wells is to monitor the groundwater outflow from the Aquifer into the sea. The other objective is to improve knowledge of geological conditions and seaside boundary conditions, including the piezometric level fluctuation caused by tidal effect. The wells also monitor seawater intrusion into the Aquifer.

(d) One (1) monitoring well was placed at the western boundary of the Aquifer (**Number 6**) and one (1) monitoring well was constructed (**J6-1**). The objective of the well is to monitor the groundwater outflow from the Aquifer.

(e) Three (3) monitoring locations were selected at the sites of pumping tests: Paya Indah (**Number 2**), Kajibumi Well Field 2 (**Number 5**) and Kanchong Darat (**Number 7**). There are 10 wells installed at these locations. The objective of the wells at Paya Indah (**J2-1-2 and J2-1-3**) is to monitor groundwater conditions within Paya Indah. The wells at Kajibumi Well Field 2 (**J5-2-2 and J5-2-3**), which is located at the centre of the existing monitoring wells, serve as the standard well among these wells. A total of six (6) wells at Kanchong Darat (**J7-1-1, J7-1-2, J7-1-3, J7-1-4, J7-2 and J7-5**) monitor the gradient of groundwater flow and seawater intrusion.

A list of these new wells is given in **Table H.2.2**, and installation diagrams of wells are presented in **Data Book Figure H.2.1** to **H.2.29**. Photographs of monitoring wells are given in **Data Book Photograph H.2.1 to H.2.19**.

Table H.2.2 List of New Observation Wells for Long-Term Monitoring

No	Well Name	Location	Coordinates			Well Depth (m)	Screen Depth (m)	Geology	PVC Diameter (mm)	Water Level Measured by	Water Samplin g
			x (East)	y (North)	z (EL.m)						
1	J1-1-1	South of Bt. Baja	402777	319993	8.597	6.36	3-4	Peat/ Clay	52	Manual	Yes
2	J1-1-2	-ditto-	402777	319993	8.597	22.34	24-25	Sand	100	Logger	Yes
3	J2-1-2	Paya Indah	402685	318614	7.802	20.84	16-18	Sand	100	Logger	Yes
4	J2-1-3	-ditto-	402685	318614	7.802	30.5	27-28	Sand	100	Logger	Yes
5	J3-1	Northwest of Paya Indah	399894	320336	7.484	21.44	17-19	Sand	52	Manual	Yes
6	J3-2	-ditto-	399895	320337	7.417	27.48	24-26	Sand	52	Logger	Yes
7	J4-1	Kg. Jenjarom	393661	321921	5.757	7.47	7.0 - 7.3	Clay	25	Manual	NA
8	J4-2	-ditto-	393660	321931	5.775	28.07	24.5-25.5	Sand	52	Logger	Yes
9	J5-2-2	Kajibumi WF2	400897	313508	5.682	19.06	14-16	Sand	100	Logger	Yes
10	J5-2-3	-ditto-	400897	313508	5.682	43.7	40-41	Sand	100	Logger	Yes
11	J6-1	Sg. Buaya	386415	317920	2.481	11.67	13.45-13.8	Clay	25	Manual	NA
12	J7-1-1	Kanchong Darat	394197	303838	4.813	5.87	3-4.5	Sand	100	Manual	NA
13	J7-1-2	-ditto-	394197	303838	4.813	13.47	11-12.5	Sand	100	Manual	Yes
14	J7-1-3	-ditto-	394197	303838	4.813	31.43	27-29	Sand	100	Logger	Yes
15	J7-1-4	-ditto-	394197	303838	4.813	56.66	53-54	Sand	100	Logger	Yes
16	J7-2	-ditto-	394192	303841	4.983	75.4	71-73	Sand	100	Manual	Yes
17	J7-5	-ditto-	394362	303866	4.797	?	71-73	Clay	25	Manual	NA
18	J8-1	Kg. Endah	386090	302702	2.291	35.68	28-31	Sand	52	Logger	Yes
19	J8-2	-ditto-	386090	302700	2.288	65.3	61-63	Sand	100	Logger	Yes
20	J9-1	Ladang Tumbuk	398497	293485	2.329	35.18	32-34	Sand	100	Manual	Yes
21	J9-2	-ditto-	398496	293486	2.355	68.5	65.5-66.5	Sand	100	Logger	Yes
22	J10-1-1	East of Paya Indah	404338	318038	8.866	5.43	3-4	Peat/ Clay	52	Manual	Yes
23	J10-1-2	-ditto-	404338	318038	8.866	27.93	24.5-25.5	Sand	100	Logger	Yes

Note: "NA" stands for Not Applicable; that is, water sampling is not carried out in these wells.

(2) Types of Groundwater Monitoring Wells

Three (3) types of well were installed in order to meet the requirements from groundwater level measurement, groundwater sampling, and ground and site conditions. The three types are as follows:

- Houston type screen with PVC pipe;
- Casa Grande type piezometer with PVC pipe; and
- Slotted PVC pipe.

Two types of Houston type screen, Type A and Type B, and the stainless steel continuous slot wire wound screen, were used for sandy and gravelly soils. Specifications of the screen are summarised in **Table H.2.3**. Type A was used for coarser sandy soils and gravelly soils, and Type B was used for finer sandy soils. Diameters of PVC were either 100 mm or 50 mm.

Table H.2.3 Specifications of the Houston Type Screen

Type	Length (m)	Diameter (mm)	Slot Size (mm)	Opening Ratio (%)
A	1.0	100	1.0	33
B	2.0	100, 50	0.5	25

Casa Grande type piezometer was installed for clayey soils. Piezometer tip (20 mm in diameter and 300 mm long) was installed in the clayey soil layer. The above and below the piezometer tip was sealed by bentonite. Diameter of PVC pipe was 25 mm (1”).

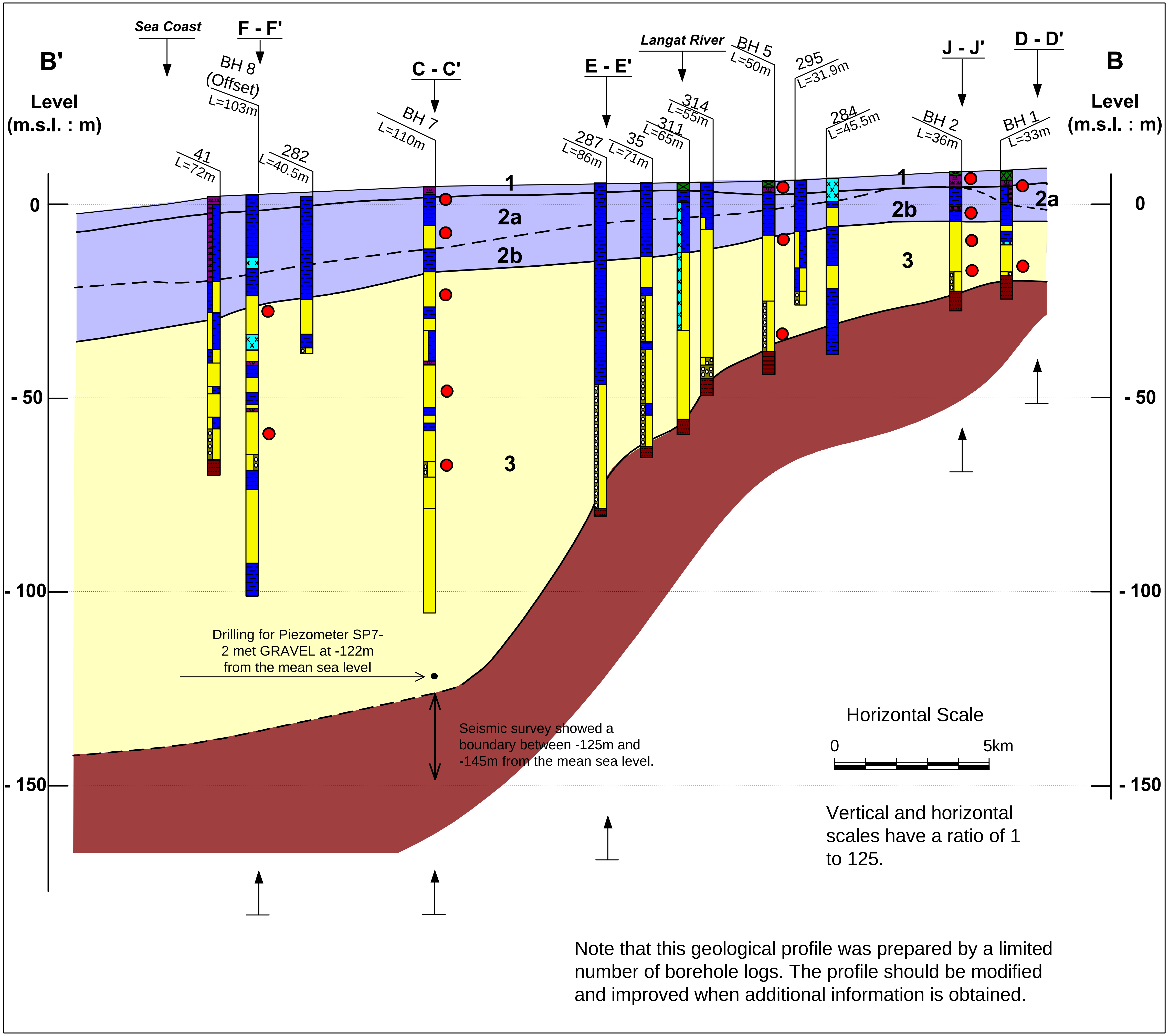
Slotted PVC pipe was installed in peat or peaty soil distributed at shallow depth. Diameter of PVC pipe was either 75 mm (3”) or 50 mm (2”). The slot had a width of 2 mm and was arranged at 100 mm interval. Opening ratios were 0.5% for 75 mm PVC pipe and 0.8% for 50 mm PVC pipe.

At some locations two to four piezometers were installed in a single well (multi-level monitoring well). Construction design of the multi-level monitoring well is introduced in **Chapter 3 of Sector G**. In view of its capability of monitoring of piezometric heads at different levels in the Aquifer that has alternating sandy/gravelly soil layers and clayey soil layers, the multi-level monitoring well has benefits for characterising:

- vertical flow direction at the moment of measurement (could change, for example, as a function of precipitation, evaporation, pumping quantity in production or pumping test well);
- possibility of pollution flow from surface into the aquifer;
- vertical permeability around the observation point (during the pumping test); and
- groundwater quality characteristics in shallow to deep horizons and their changes.

Figure H.2.3

Groundwater Monitoring System along Groundwater Basin



LEGEND

Piezometer

Key of Borehole Log

- 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 H.2.2, location map of monitoring wells, also shows the number of piezometers at each location. Some of the piezometers were installed in the multi-level monitoring well. **Figure H.2.3**, in the previous page, shows locations and depths of piezometers along a typical geological section crossing the centre of the Groundwater Basin. Location of the cross section and description of geological conditions can be found in **Sector F**.

(3) Automatic Recording Equipment of Groundwater Level

Twenty (20) sets of water pressure transducer and data logger (RST Data Trapper BH1000 System) were installed for automatic recording of groundwater level. Thirteen (13) sets were installed for the wells constructed in Phase II, and seven (7) sets were for the JMG’s existing wells during the Study.

Figures H.2.4 and H.2.5 show the components, system and data flow of the Data Trapper BH1000 System. Either a palm top computer (**Figure H.2.4**) or a notebook computer (**Figure H.2.5**) can be used for data retrieval. Specifications of the sensor (pressure transducer) and Data Trapper (data logger) are summarised in **Table H.2.4**.

<Component>

- Sensor (pressure transducer)
- Data Trapper (data logger)
- Palm – PC Running Windows CE and Interface Cables)
- Wintrapper CE Software for Windows CE
- PC Data Retrieval Utility/Wintrapper

<System and Data Flow>

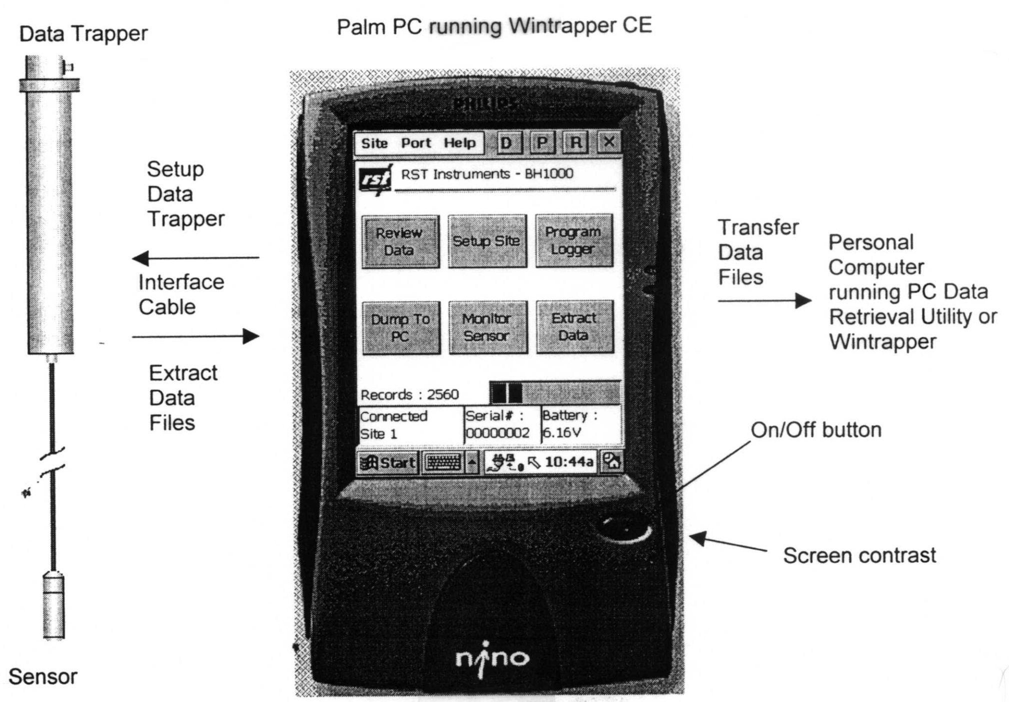

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Figure H.2.4

Water Pressure Transducer and Data Logger System (Configuration 1)

<Component>

- Sensor (pressure transducer)
- Data Trapper (data logger)
- Notebook Computer and Interface Cable
- Wintrapper Software for Windows

<System and Data Flow>

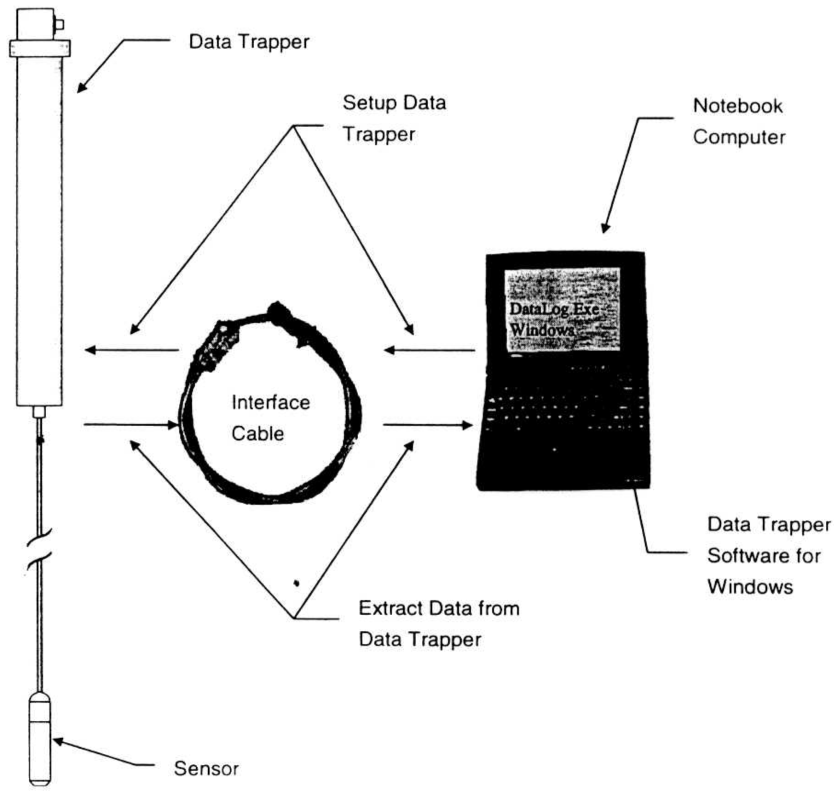

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Figure H.2.5

Water Pressure Transducer and Data Logger System (Configuration 2)

Table H.2.4 Specifications of Water Pressure Transducer and Data Logger

Parameter	Specification
Sensor (Pressure Transducer)	
Excitation	9 ~ 30 V DC
Current consumption	20 mA maximum
Output	0 ~ 2.5 V DC
Output impedance	< 10 ohms
Range	100 kPa or 200 kPa
Accuracy	± 0.1 % full scale
Thermal error	± 0.005 % full scale / ºC
Operating temperature range	- 10 to 60 ºC
Dimensions (H x Dia.)	96 x 25 mm
Enclosure material	Titanium (all wetted parts)
Cable strength	200 lbs
Cable jacket	Polyurethane
Cable length	10 m or 20 m
Data Trapper (Data Logger)	
Power Supply	4 x AA Alkaline batteries
Current consumption	< 0.1 mA quiescent; 60 mA when sampling
Communications	RS232C: 9600, N, 8, 1
Memory	32 kB
Maximum file length	16,360 data records
Sample start time	24 hour clock
Sample interval	1 second minimum, 24 hours maximum, Logarithmic
Resolution	15 bit
Clock	Quartz crystal
Connector	MIL - C, 6 way, socket
Operating temperature range	- 20 to 70 ºC
Humidity	0 ~ 100 %, condensing
Seals	O ring
Dimensions	560 x 63.5 mm
Enclosure material	Anodised Aluminium

(4) Automatic Recording Equipment of Barometric Pressure

Four (4) barometric pressure transducers were installed for monitoring of barometric pressure changes over the Groundwater Basin. One transducer (Transducer No. SWL 4) was installed with a surface water level transducer at Lotus Lake of Paya Indah. Three (3) additional transducers were installed in one of the PVC pipes of multi-level monitoring wells at Location No. 5 (Kajibumi

Well Field 2), Location No. 7 (Kanchong Darat) and Location No. 8 (Ladang Tumbuk). A schematic installation diagram of the barometric pressure transducer is shown in **Figure H.2.6**.

Specifications of the barometric pressure transducers are summarised in **Table H.2.5** below.

Table H.2.5 Specifications of Barometric Pressure Transducer

Parameter	Specification
Sampling rate	0.5 sec to 99 hrs
Memory	2 x 24,000 measurements
Metal housing	Stainless steel (AISI 316L)
Material pressure sensor	ceramic
Temperature range	- 20 to 80 ºC
- accuracy	± 0.1 ºC
- resolution	± 0.01 ºC
- compensation range	- 10 to 40 ºC
Battery life	8 - 10 years
Dimensions (dia. X length)	22 x 125 mm
Weight	160 grams
Range	1.5 m or 4.0 m water column
Accuracy	± 0.1 % full scale

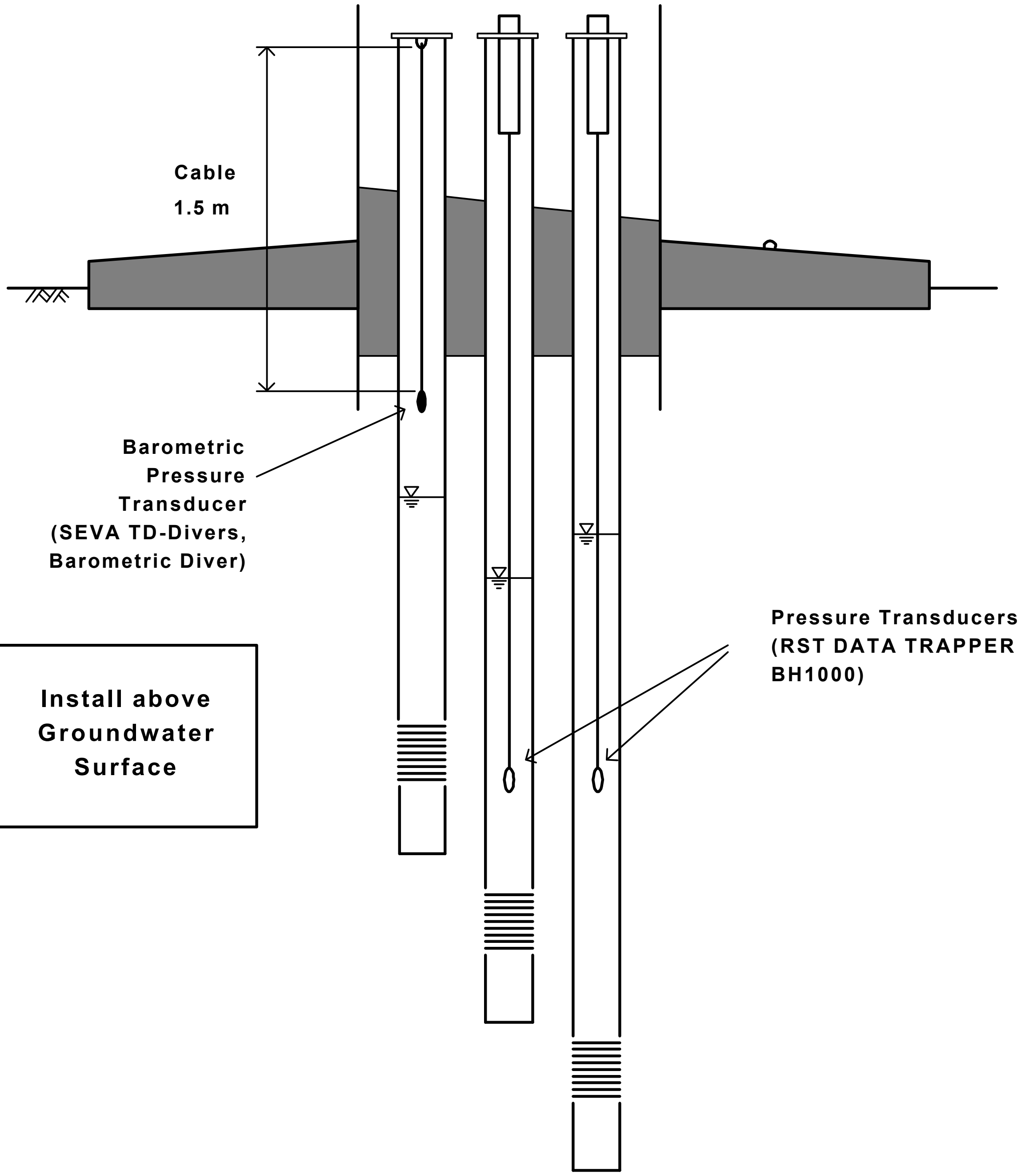

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Figure H.2.6

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Installation of Barometric Pressure Transducer

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(5) System of Groundwater Level Monitoring

(a) System Composition

The system for groundwater level monitoring is composed of the groundwater monitoring wells, either of automatic recording or of manual recording, and the barometric pressure transducers. Locations of these wells and barometric pressure transducers are shown in **Figure H.2.2**. Lists of the monitoring wells of automatic recording are given in **Tables H.2.1 and H.2.2**, and a list of barometric pressure transducers is given in **Table H.2.6**.

Table H.2.6 List of Barometric Pressure Transducers

Barometric Pressure Transducer No.	Location	Transducer Serial No.	Installed Piezometer	Capacity	Elevation of Survey Point (m.s.l.: m)
BT1	Kajibumi WF 2	SN25273	J5-2-3	1.5 m water column	5.682
BT2	Kanchong Darat	SN25275	J7-1-3	1.5 m water column	5.088
BT3	Kg. Endah	SN25281	J8-1	1.5 m water column	2.291
SWL-4	Paya Indah	SN19664	Installed with surface water level transducer	4.0 m water column	6.639

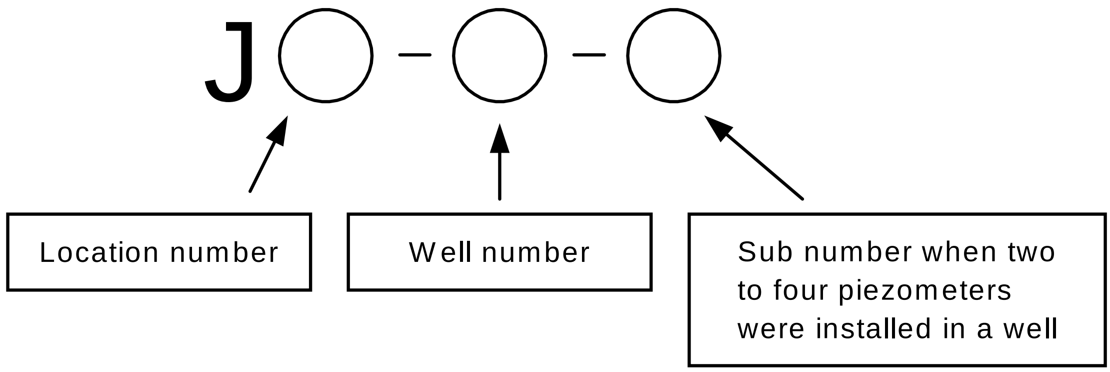
(b) Numbering System of Piezometer

Piezometers were numbered according to the numbering system described in **Figure H.2.7**. They were numbered by location (1 to 10), well number, and by sub-number when two to four piezometers were installed in a well.

(c) Nameplate of Piezometer

A nameplate, as shown in **Figure H.2.7**, was placed on top or beside the protection cap of the well. The plate shows piezometer numbers, screen depths of piezometer, bottom depths and diameters of PVC pipe, the elevation of a survey point placed on a concrete base, and coordinates.

(a) Numbering System of Piezometer



(B) Name Plate

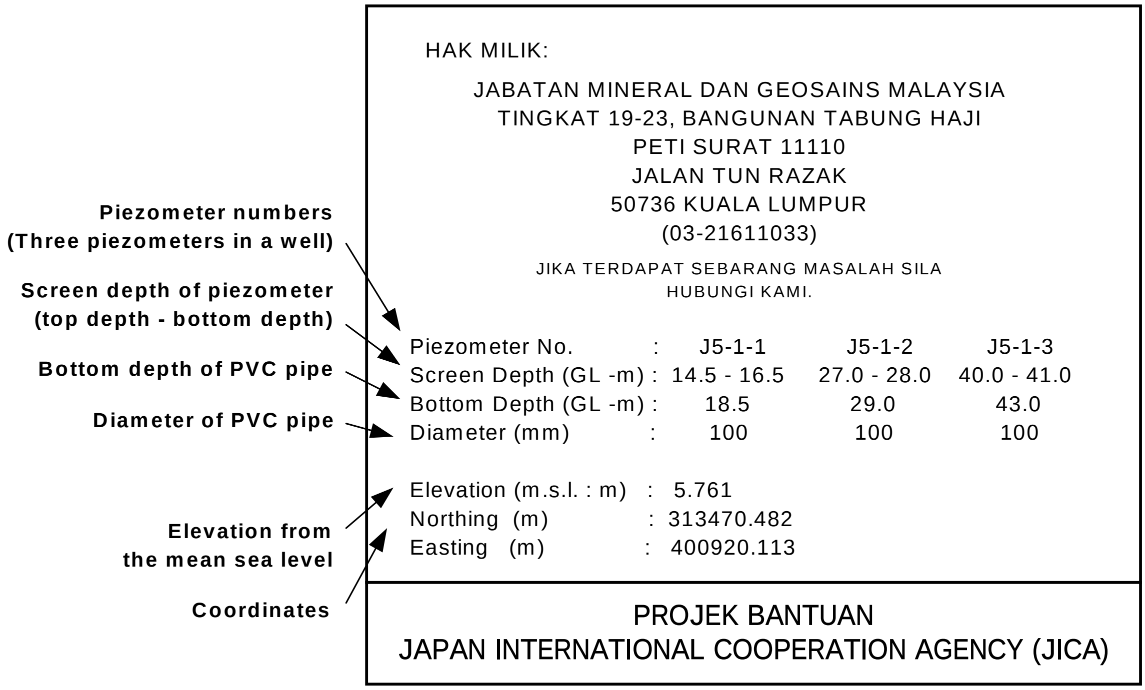


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Figure H.2.7

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Numbering System of Piezometer and Name Plate

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(d) Reference Point of Piezometer

As shown in **Figure H.2.8**, a V-shape cut at the top edge of the PVC pipe indicates the reference point from which groundwater level in a well is measured. In the multi-level monitoring well, a reference point is made for each monitoring well. Number of V-shape cuts increases from one (1) to a maximum four (4) as the depth of piezometer increases. The shallowest piezometer has one (1) V-shape cut and the deepest piezometer has the maximum of four (4) cuts, as shown in **Figure H.2.9**.

(e) Calculation of Groundwater Level

The elevation of groundwater surface from the mean sea level is calculated according to the formulas shown in **Figures H.2.10 and H.2.11**.

The manual recording measures the depth of groundwater surface from the reference point placed at the top of the PVC pipe (**Figure H.2.10**). Knowing the elevation of a survey point from the mean sea level and the distance between the survey point and the reference point, the elevation of the groundwater level can be calculated.

The automatic recording measures the depth of the pressure transducer from the groundwater surface (**Figure H.2.11**). Knowing the elevation of the survey point from the mean sea level, the distance between the survey point and the reference point as well as the length of cable of the transducer, the elevation of the groundwater surface can be calculated.

The elevation of survey point, distances between the survey point and the reference point, and the cable length for the wells of automatic recording are given in **Table H.2.7.**

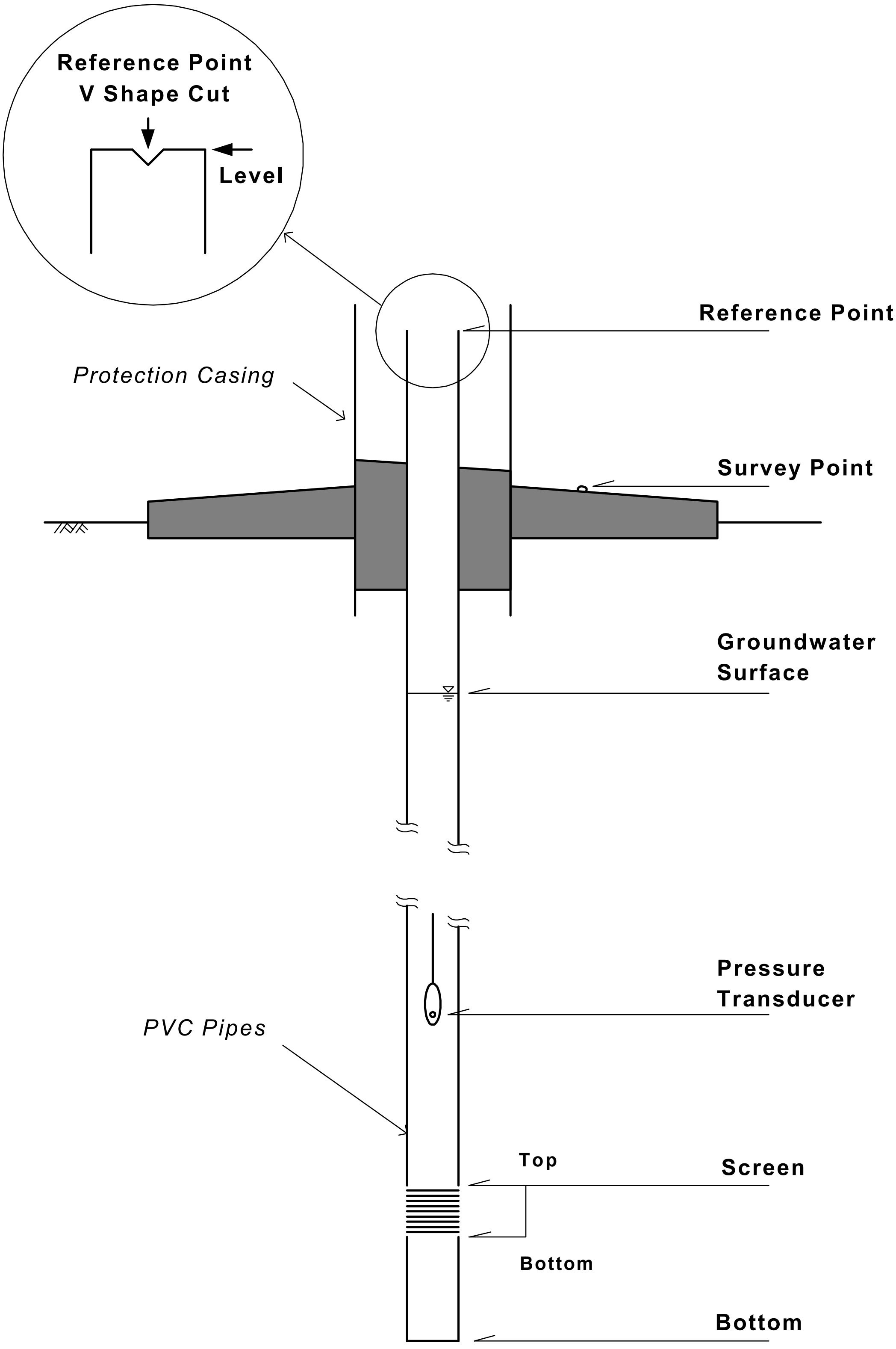

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Figure H.2.8

Reference Point of Monitoring Well

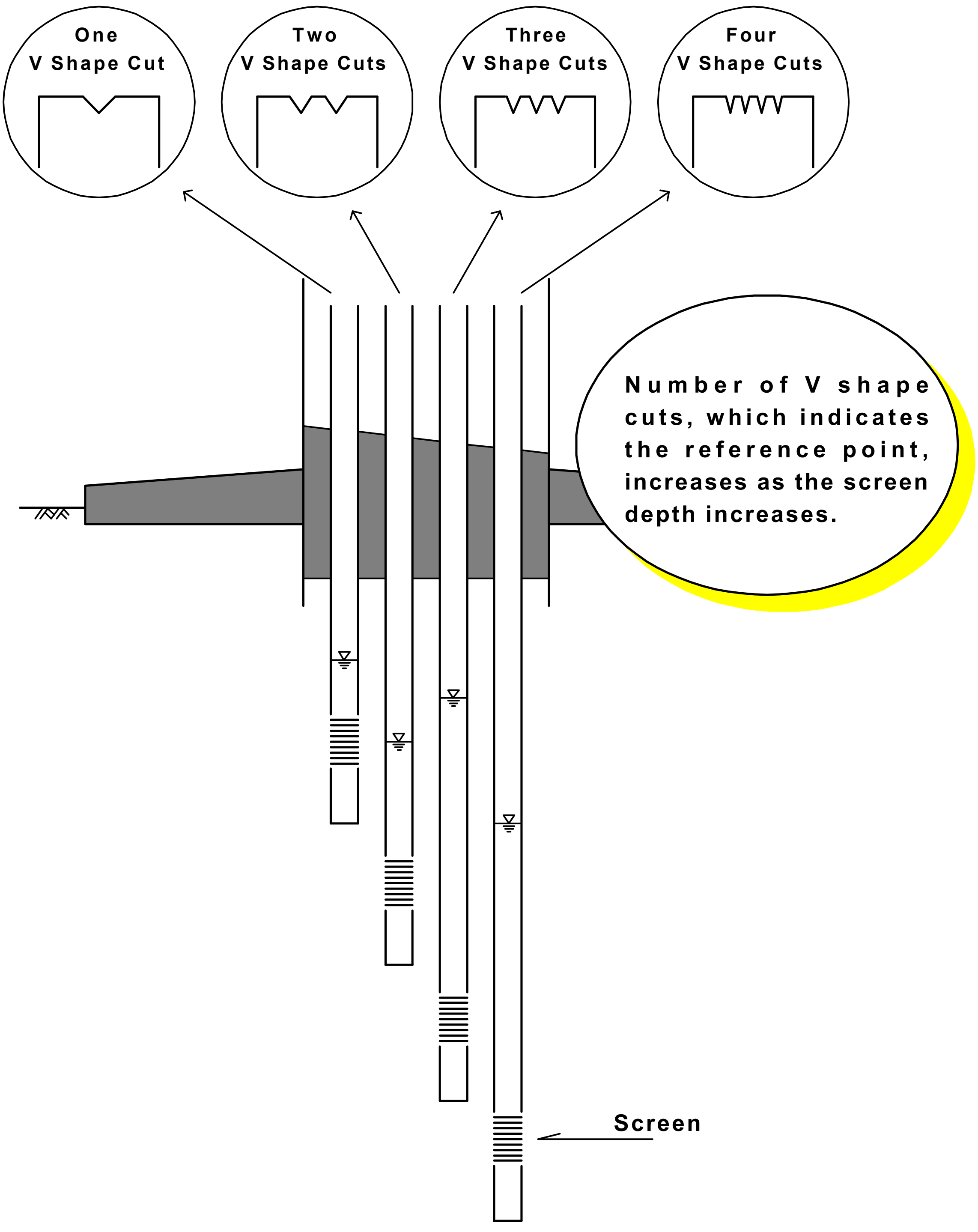

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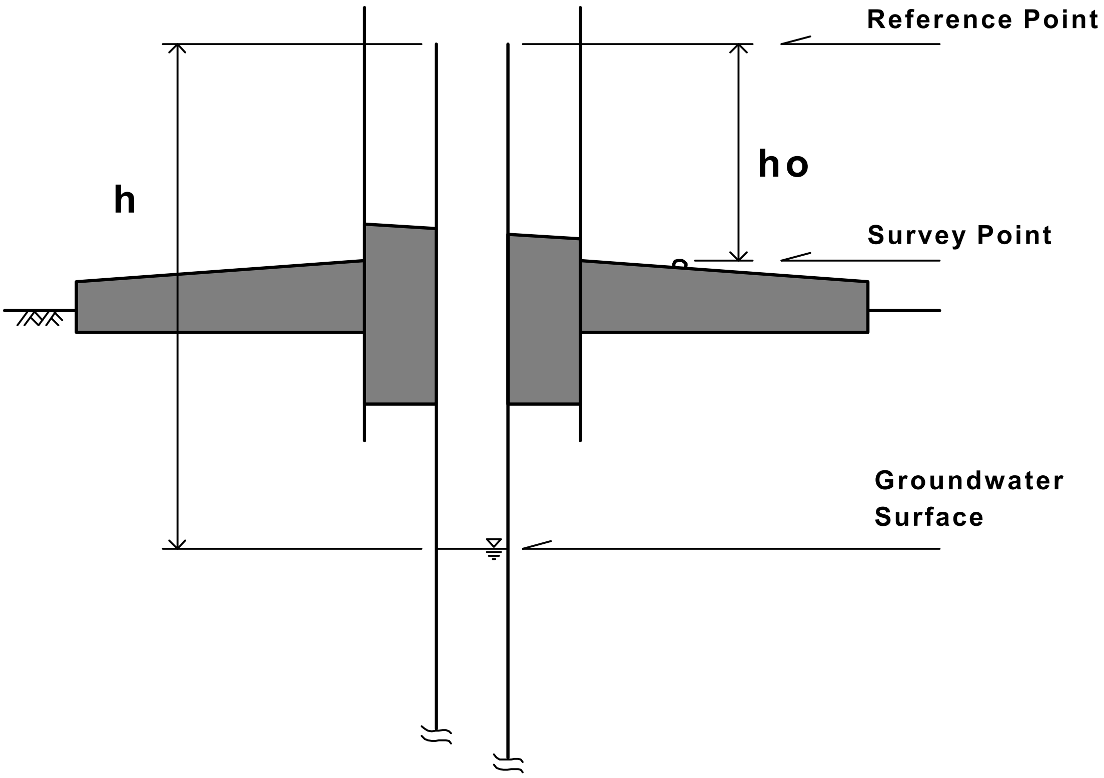
Figure H.2.9

Reference Points of Multi-Level Monitoring Well



h (m) : Depth of groundwater surface from the reference point (Manual measurement)

ho (m) : Distance between survey point and reference point

SPEL (m.s.l. : m) : Elevation of the survey point from the mean sea level

Elevation of the groundwater surface from the mean sea level (m.s.l. : m) :

$$GWL = (SPEL + ho) - h$$

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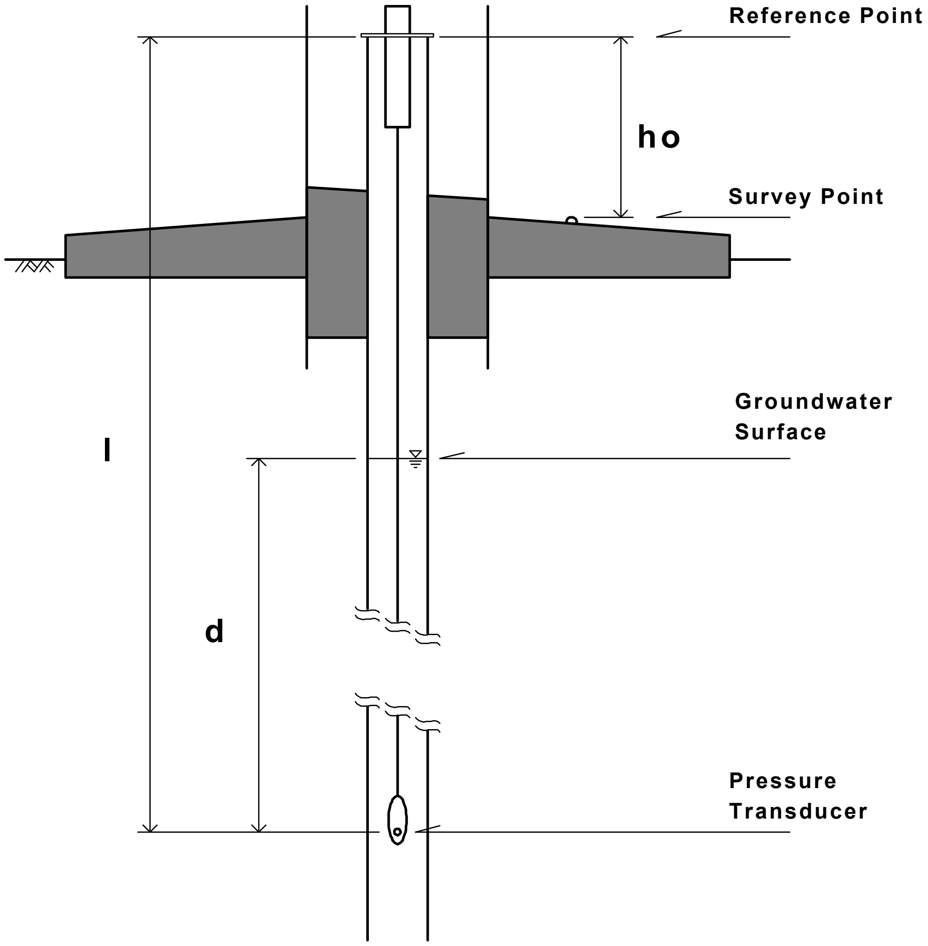
Figure H.2.10

Calculation Method of Groundwater Level, Manual Recording



d (m) : Depth of pressure transducer from groundwater surface

l (m) : Length of cable

ho (m) : Distance between survey point and reference point

SPEL (m.s.l. : m) : Elevation of the survey point from the mean sea level

Elevation of the groundwater surface from the mean sea level (m.s.l. : m) :

GWL = (SPEL + ho) - l + d

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Figure H.2.11

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Calculation Method of Groundwater Level, Automatic Recording

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Table H.2.7 List of Piezometers for Automatic Recording

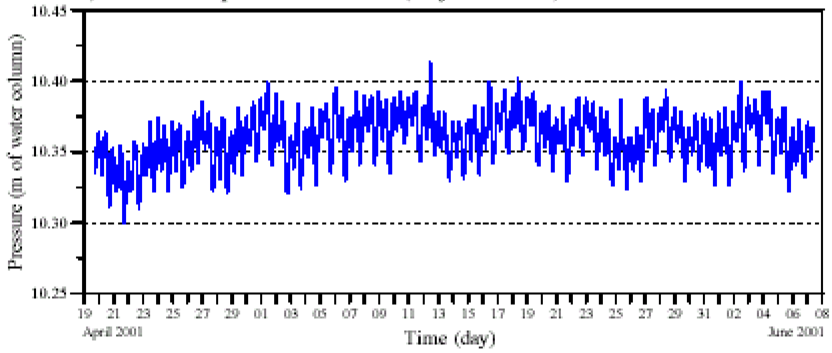
No.	Piezometer No:.	Location	Data Logger Serial No.	Capacity of Pressure Transducer (kPa)	Cable Length l (m)	Distance between Survey Point and Reference Point ho (m)	Elevation of Survey Point (m.s.l. :m)
1	J1-1-2	South of Bukit Baja	20132810	200	20	0.331	8.597
2	J2-1-2	Paya Indah	20132803	100	10	0.230	7.802
3	J2-1-3	Paya Indah	20132808	200	20	0.225	
4	J3-2	Northwest of Paya Indah	20132813	200	20	0.280	7.417
5	J4-2	Kg. Jenjarom	20132814	200	20	0.300	5.775
6	J5-2-2	Kajibumi WF 2	20132804	100	10	0.588	5.682
7	J5-2-3	Kajibumi WF 2	20132809	200	20	0.601	
8	J7-1-3	Kanchong Darat	20132807	200	20	0.215	5.088
9	J7-1-4	Kanchong Darat	20132817	200	20	0.240	
10	J8-1	Kg. Endah	20132816	200	20	0.321	2.291
11	J8-2	Kg. Endah	20132820	200	20	0.327	2.288
12	J9-2	Ladang Tumbok	20132806	200	20	0.418	2.355
13	J10-1-2	East of Paya Indah	20132811	200	20	0.324	8.866
14	MWD 1	Jambatan Batu, Sg Kelambu	20132812	200	20	0.330	2.369
15	MWD 2	Jalan Dahlia, Sg Kelambu	20132819	200	20	0.380	4.407
16	MWD 6	Kg Sg.Manggis, Tlk Datok	20132815	32	20	0.300	3.294
17	MWD 9	FELCRA Bkt.Changang	20132801	100	10	0.370	5.186
18	MWD 10	Kajibumi WF 1	20132802	100	10	0.330	2.724
19	LED 2	Express Highway KLIA	20132805	100	10	0.420	-
20	MW 1	Megasteel	20132818	200	20	0.210	5.224

(6) Barometric Pressure Measurement

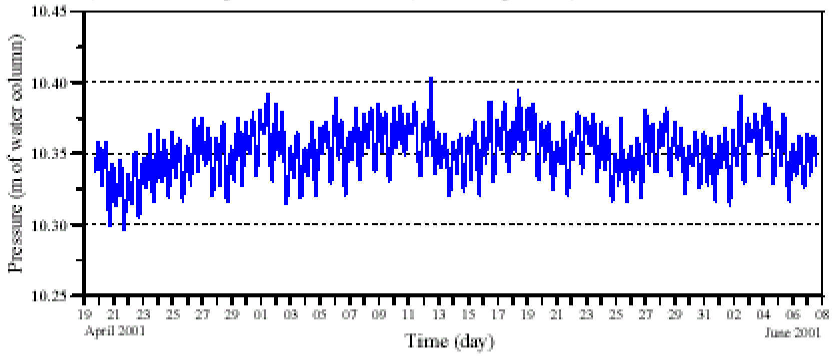
Barometric pressure changes were measured at an interval of 30 minutes between 19 April 2001 and 8 June 2001 at location No. 5 (Kajibumi Well Filed 2), No. 7 (Kanchong Darat) and No. 8 (Kg. Endah). Three locations are distributed at the northern part (No. 5), the centre (No. 7) and the southern part (No. 8) of the Groundwater Basin. No. 8 is located at the seacoast.

Figure H.2.12 summarises the barometric pressure changes during the period. Variations of the changes were within ± 5 cm of water column during around 2 months. Variations over the Groundwater Basin were, as shown in **Figure H.2.13**, within around ± 1 cm of water column.

a) Barometric pressure at site J-5 (Kajibumi WF2)



b) Barometric pressure at site J-7 (Kanchong Darat)



c) Barometric pressure at site J-8 (Kg. Endah)

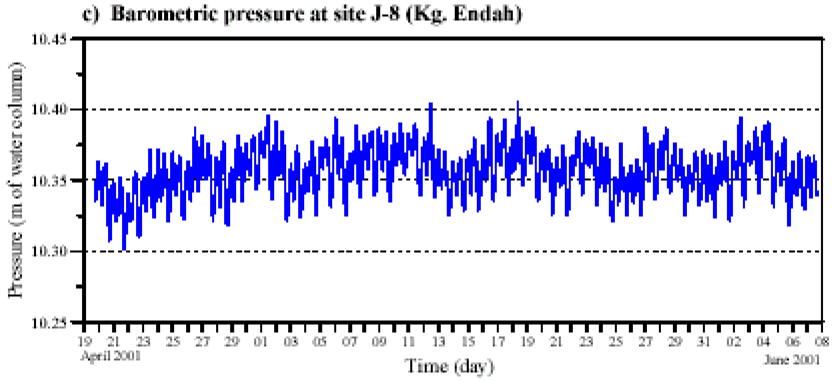


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Figure H.2.12

Barometric Pressures Measured at J-5, J-7 and J-8

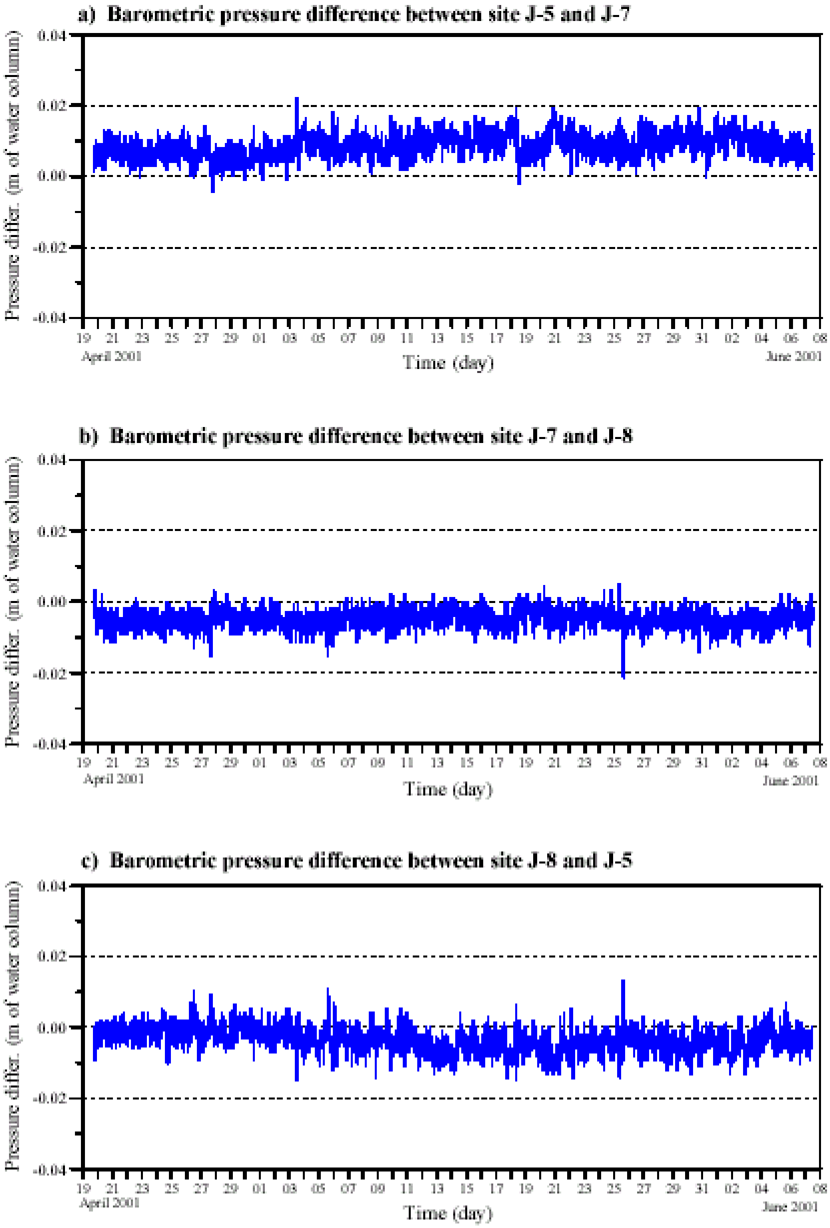

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Figure H.2.13

Barometric Pressure Differences at J-5, J-7 and J-8

3. GROUNDWATER LEVEL AND QUALITY OBSERVATION

3.1 Objective of the Observation

The objective of the observation is to identify regional variation and long-term change on groundwater level and quality in the Study Area. In addition, surface water quality is measured for background information to simulate the groundwater quality.

3.2 Location of Observation Points

As described in the previous chapter, a total of 34 wells comprising 23 newly developed wells in this Study and 11 exiting wells were selected for the groundwater level measurement. Among these wells, in terms of groundwater quality, 30 wells, i.e., 19 new wells and 11 existing wells have been used for the measurement. Simultaneously, the surface water quality was measured at 10 locations, such as mine lakes, canals in a plantation and the Langat River.

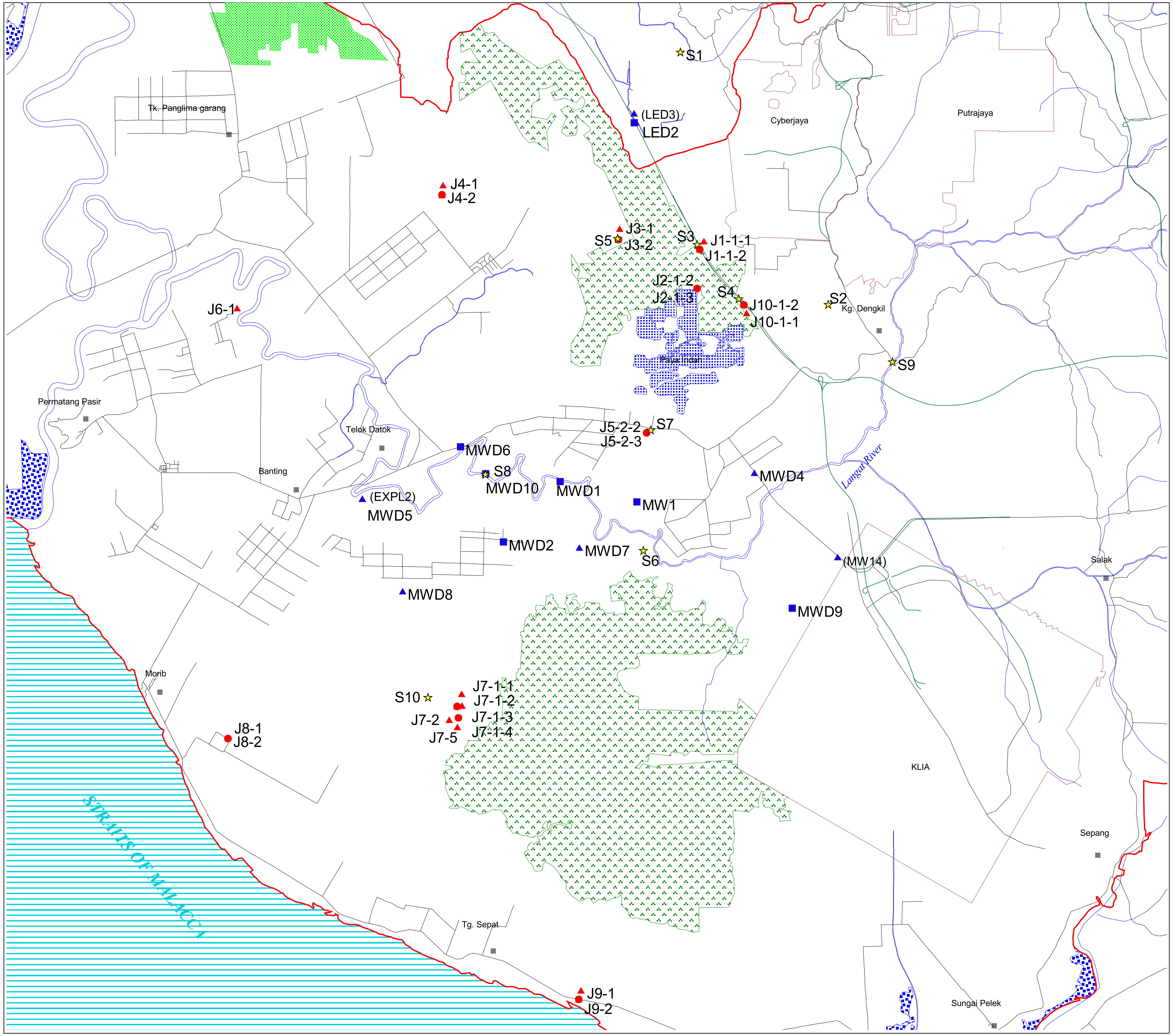
Lists of the observation wells are shown in the preceding **Tables H.2.1 and H.2.2**, and surface water sampling points are given in **Tables H.3.1**. Location of observation points is illustrated in **Figure H.3.1**.

Table H.3.1 List of the Surface Water Observation Points for Long Term Monitoring

No	Point Name	Location	Coordinates		Current Land Use
			East	North	
1	S1	Puchong Mine	326973	402093	Active mine
2	S2	Dengkil Mine	318056	407322	Abandoned mine
3	S3	Paya Indah Inflow (SW1)	320173	402684	Beside the Expressway
4	S4	Paya Indah Inflow (SW2)	318249	404154	-ditto-
5	S5	Bt. Cheeding	320379	399872	Oil Palm Plantation
6	S6	Sand Mine	309360	400779	Active mine
7	S7	Kajibumi WF2	313611	401049	River beside plantations
8	S8	Langat River (Kajibumi WF1)	312046	395191	River
9	S9	Langat River (Dengkil)	316027	409589	-ditto-
10	S10	Kanchong Darat	304168	393160	Oil Palm Plantation

Figure H.3.1

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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3.3 Procedures of the Observation

The observation of groundwater level and quality as well as surface water quality has been executed at the site where water samples were taken in principle. KLL-Q, a handy water quality analyser that was procured by JICA, was used for the site observation. Apart from parameters that can be measured at the site, chemical tests in a laboratory regarding heavy metals, chemical substances and some organic matters were carried out.

Parameters analysed by JMG and the JICA Study Team are given in **Table H.3.2**. These parameters have been tested at four (4) locations, namely in-situ, on-site, JMG Ipoh laboratory and a private laboratory. "In-situ" means that the parameters are measured at the site by using KLL-Q. "On-site" means that water samples are analysed by test kits with reagents and small equipment at the site.

Sampling procedures of the groundwater are described in detail in **Annex H.3.1**. The systematic procedures, as a matter of routine, should be applied in order to obtain a representative water sample from each site and to avoid physically and chemically altering the water.

Table H.3.2 List of Parameters for the Groundwater and Surface Water Quality Analysis

Category	*Parameters to be analysed*	*Responsibility of measurement/analysis*	*Test Location*
Group I (Physical)	Temperature	JMG	In-situ
	Turbidity	JMG	In-situ
	Color	JMG	In-situ
	pH	JMG	In-situ
	Conductivity	JMG	In-situ
	Salinity	JMG	In-situ
Group II (Inorganic)	Dissolved Oxygen (DO)	JMG	In-situ
	Biochemical Oxygen Demand (BOD)	JMG	On-site
	Chemical Oxygen Demand (COD)	JMG	On-site
	Manganese (Mn)	JMG	On-site
	Iron (Fe)	JMG	On-site
	Total Iron (Fe-T)	JMG	On-site
	Nitrate Nitrogen (NO_3-N)	JMG	On-site
	Nitrite Nitrogen (NO_2-N)	JMG	On-site
	Total Dissolved Solids (TDS)	JMG	Ipoh Laboratory
	Total Solids (TS)	JMG	Ipoh Laboratory
	Chloride (Cl)	JMG	Ipoh Laboratory
	Anionic Detergent MBAS	JMG	Ipoh Laboratory
	Ammoniacal Nitrogen (NH_3-N)	JMG	Ipoh Laboratory
	Fluoride (F)	JMG	Ipoh Laboratory
	Carbonate (CO_3)	JMG	Ipoh Laboratory
	Hydrogen Carbonate (HCO_3)	JMG	Ipoh Laboratory
	Total Hardness ($CaCO_3$)	JMG	Ipoh Laboratory
	Sodium (Al)	JMG	Ipoh Laboratory
	Aluminium (Al)	JMG	Ipoh Laboratory
Group III (Heavy metals and others)	Magnesium (Mg)	JMG	Ipoh Laboratory
	Mercury (Hg)	JMG	Ipoh Laboratory
	Cadmium (Cd)	JMG	Ipoh Laboratory
	Selenium (Se)	JMG	Ipoh Laboratory
	Arsenic (As)	JMG	Ipoh Laboratory
	Cyanide (CN)	JMG	Ipoh Laboratory
	Lead (Pb)	JMG	Ipoh Laboratory
	Chromium (Cr)	JMG	Ipoh Laboratory
	Silver (Ag)	JMG	Ipoh Laboratory
	Copper (Cu)	JMG	Ipoh Laboratory
	Zinc (Zn)	JMG	Ipoh Laboratory
	Sodium (Na)	JMG	Ipoh Laboratory
	Sulphate (SO_4)	JMG	Ipoh Laboratory
	Silica (SiO_2)	JMG	Ipoh Laboratory
	Phosphorus (P)	JMG	Ipoh Laboratory
	Oil & Grease	JICA Study Team	Private Laboratory
	Phenol	JICA Study Team	Private Laboratory
	Chloroform	JICA Study Team	Private Laboratory
Group IV (Biocides and others)	Organochlorine Pesticides	JICA Study Team	Private Laboratory
	Organophosphorus Pesticides	JICA Study Team	Private Laboratory
	BTEX	JICA Study Team	Private Laboratory
	VOC (Volatile Organic Compounds)	JICA Study Team	Private Laboratory
	SVOC (Semivolatile Organic Compounds)	JICA Study Team	Private Laboratory
	Total Petroleum Hydrocarbon (TPH)	JICA Study Team	Private Laboratory
Group V (Organic)	Total Coliform Bacteria	JICA Study Team	Private Laboratory
	E. Coli.	JICA Study Team	Private Laboratory

3.4 Frequency and Schedule of the Observation

The observation of the groundwater level and quality as well as surface water quality was carried out in every three (3) months during the Study period. Total number of observations was therefore three (3) in this Study. The first measurement was conducted between the middle of February and the beginning of March 2001, the second was done from the middle to the end of May 2001, and finally the last measurement was carried out in late August 2001. The results of these measurements are presented in **Sector E**.

4. LAND SUBSIDENCE MEASUREMENT

4.1 General

The land subsidence measurement network consists of twenty (20) datum points (No. DP 1 to 20), twenty (20) shallow benchmarks (No. BM 1 to 20) and one (1) borehole extensometer for monitoring of the upper clayey layer of the Lower Langat Basin (No. EX5). The datum points include thirteen (13) deep datum points, which were installed during the First Phase of the Study (Phase I), three (3) JMG datum points and four (4) existing structures, which are embedded deep in firm foundations. Twenty (20) shallow benchmarks were also installed besides the datum points during Phase I.

The land subsidence metre or borehole extensometer in the Kajibumi Well Field 2 was installed in the Second Phase of the Study. Location of the benchmarks (BM), datum points (DP) and borehole extensometer is shown in **Figure H.4.1**. During the First to the Third Phase of the Study, four (4) levelling surveys have been carried out.

4.2 Land Subsidence Measured by Benchmarks

4.2.1 Objectives of the Work

The objective of installation of the settlement plates or benchmarks (BM) is to monitor the land subsidence in the Lower Langat Basin as part of the establishment of level survey network. Location of the benchmarks is therefore scattered on the Basin.

4.2.2 Scope of the Work

The work covered the following two (2) items, and Jurukur Perunding Services Sdn. Bhd. conducted the work as a subcontractor under the supervision of the JICA Study Team:

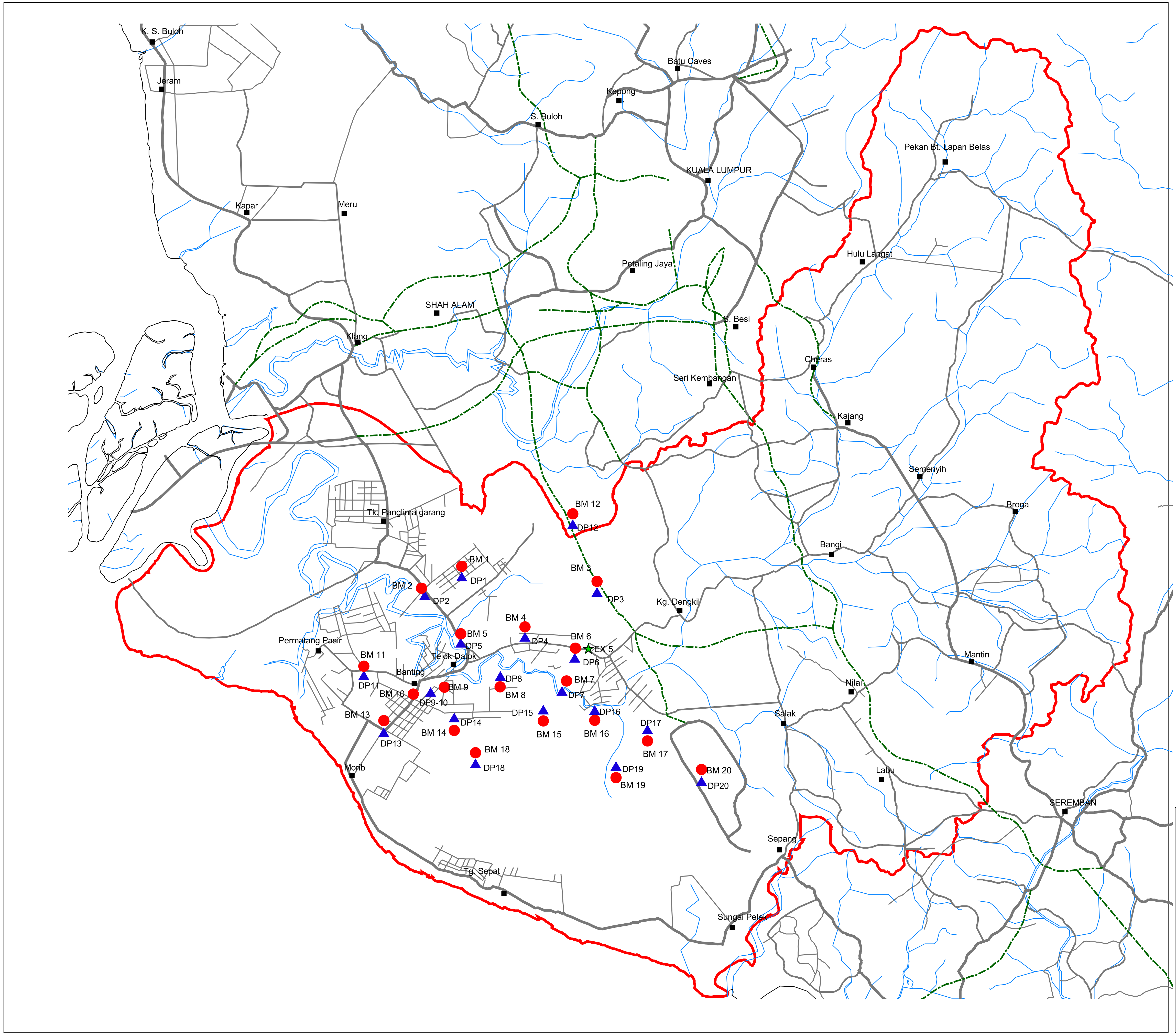
(1) Installation of new benchmark stations and datum points for land subsidence monitoring; and

(2) First order precise levelling.

The contents of each work item are presented below.

Figure H.4.1

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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4.2.3 Installation of New Benchmark Stations and Datum Points for Land Subsidence Monitoring

(1) Selection Criteria for Location of New Benchmarks

The locations of new benchmarks (BM) were selected in consideration of the following criteria:

- Location and area of the aquifer;
- Location, area and thickness of clay layer;
- Distance from the current well fields;
- Existing important facilities, such as KLIA and highways;
- Location of the existing JMG monitoring datum points;
- Ease of land occupation for construction and installation of benchmarks and datum points; and
- Ease of operation and maintenance for the future monitoring.

The aquifer is thought to spread out in the lower Langat Basin, and the clayey soil is also widely laid along the lower reaches of Langat River. The location of the new benchmarks was therefore selected in the lower Langat Basin, near the river course in particular where many wells currently exist.

The installation of benchmarks is required in the existing important facilities, such as Kuala Lumpur International Airport (KLIA) and the highway between Kuala Lumpur and KLIA to monitor the land subsidence at these facilities.

In addition, it is recommended that benchmarks are to be set up near the existing JMG monitoring stations. The installation cost can be reduced as much as possible because a new datum point is not required in these stations. Currently, JMG has three (3) datum points as well as monitoring wells in the lower Langat Basin: Ladang Brookland (JMG well number MWD10 & MWS10), FELCRA Bt. Changgang (MWD9 & MWS9) and JBA station Olak Lempit (MWD12 & MWS12). These sites are thus chosen for the benchmark locations.

Furthermore, government-owned land is preferable to a private one due to permission required for the installation. Public schools are therefore mainly selected for the site.

(2) Installation of Datum Points

Datum points (DP) are to be established in accordance with every benchmark station as mentioned in Item (a) above. The datum points should be installed on immovable ground or the foundation of buildings, bridges or electric power lines on solid soil or bedrock. When there is no immovable ground or the building, bridge or other structures stand on the foundation of the bedrock within three (3) kilometres from the benchmark station, a new datum point is established by digging a hole with auger machine or other appropriate equipment on the solid soil or bedrock. A galvanised iron pipe for the datum point is set in the hole up to the solid soil or bedrock.

Only thirteen (13) deep datum points, namely, DP 1, 3, 4, 5, 11, 12, 13, 14, 15, 16, 18, 19 and 20, need to be installed, whereas the rest can use other existing JMG datum points and permanent structures such as telephone line tower and water supply tank as the datum.

(3) Location of Benchmarks and Datum Points

Considering the criteria mentioned above, twenty (20) new benchmark locations were selected as previously shown in **Figure H.4.1**. Geographical coordinates, such as latitude, longitude and elevation, of all the new benchmarks and datum points were measured and recorded.

(4) Structure of Benchmarks and Datum Points

The structure of datum points and benchmarks should allow easy carrying out the levelling and should not be affected by climatic conditions at the site, such as rain and wind, as well as mischief by children or intruders.

As shown in **Figures H.4.4 and H.4.5**, the surface of both structures is to be the same as the original ground level. Additionally, fencing is to be installed to prevent people from approaching the structures, as presented in **Figure H.4.2** below. In addition, an identification tag including contact address and telephone number is put on the cover of all benchmarks and datum points, as illustrated in **Figure H.4.3**.

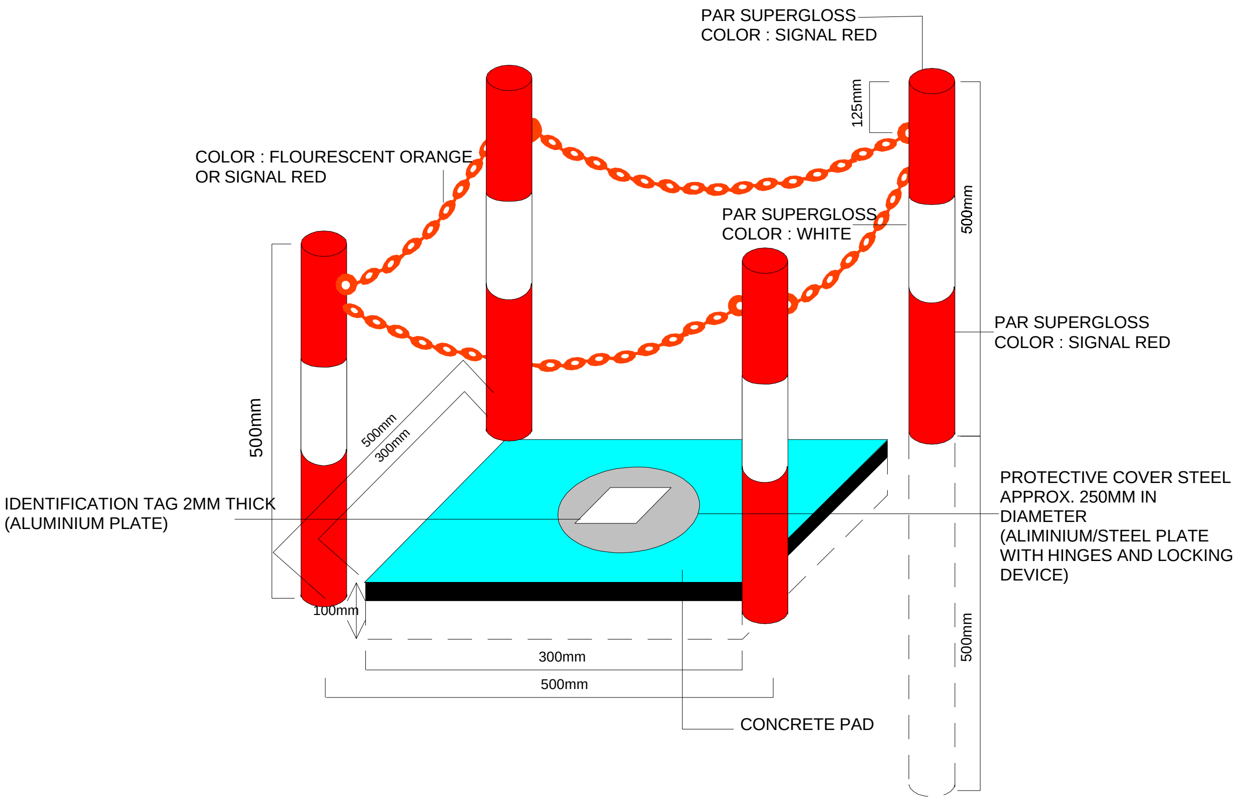

Figure H.4.2 Typical Design for Deep Datum Protective Fencing

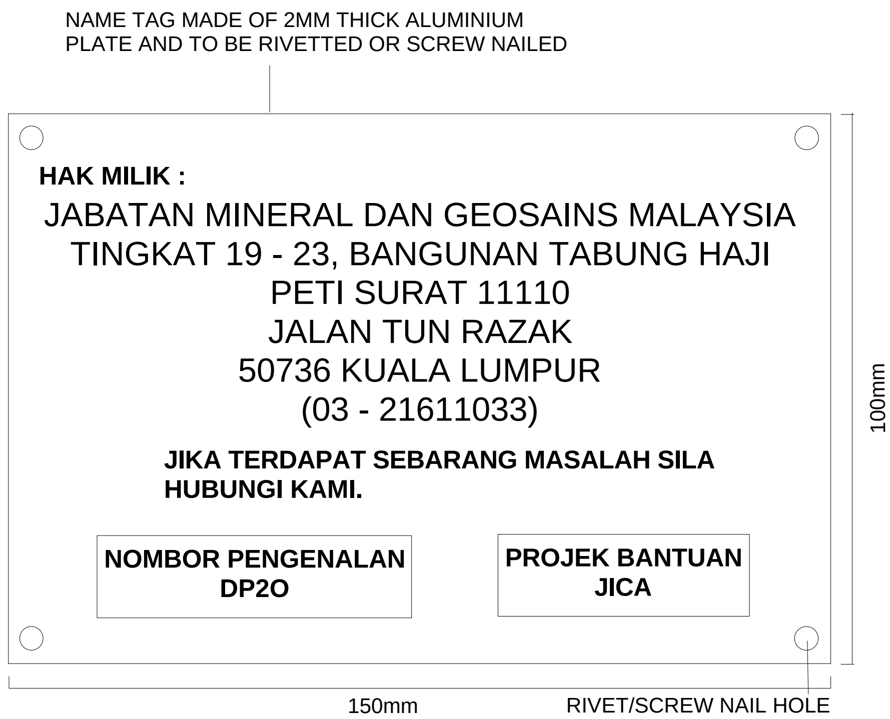

Figure H.4.3 Details of the Identification Tag

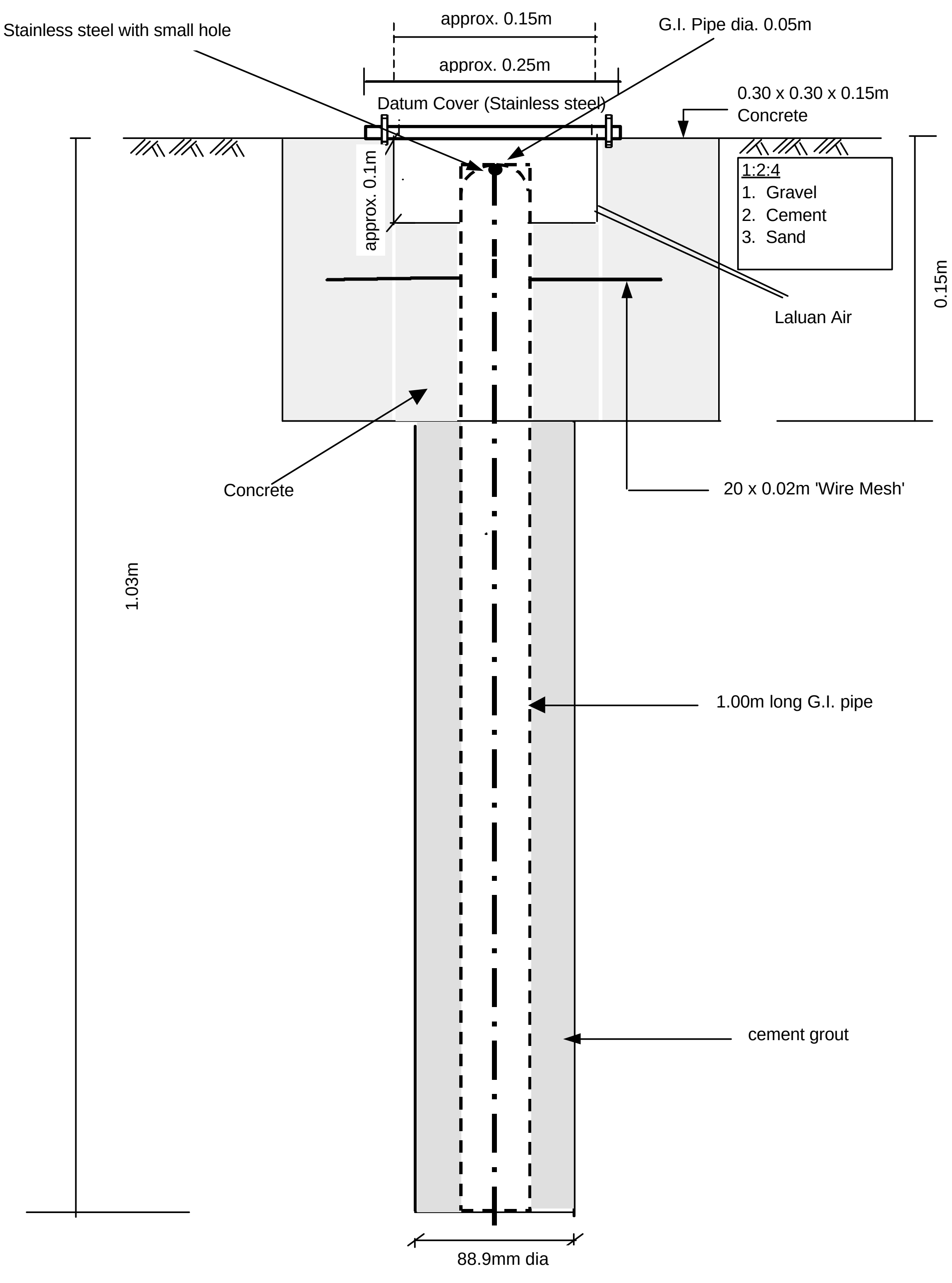

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Figure H.4.4

Cross Section of Bench Mark Reference Station (BM)

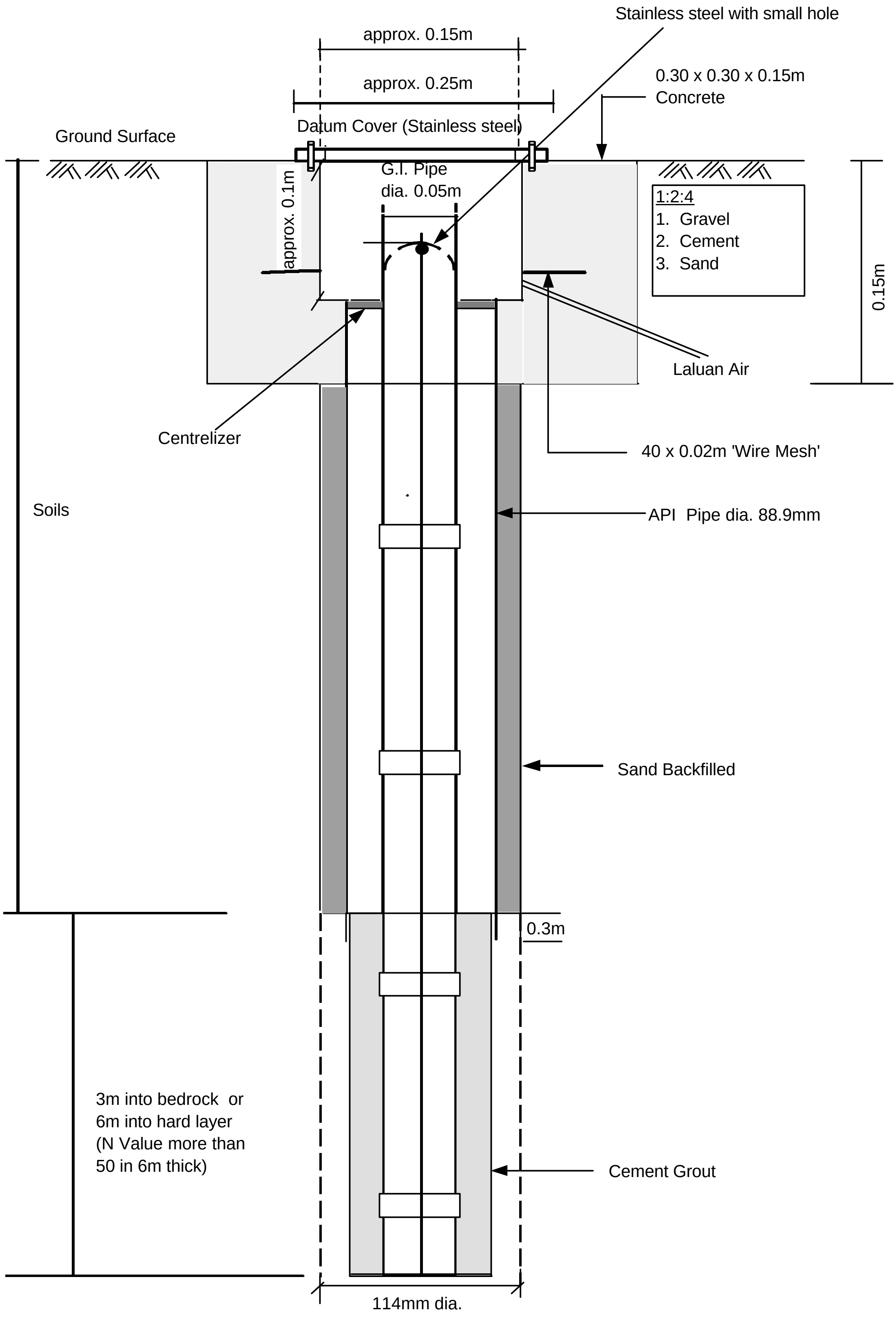

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Figure H.4.5

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Cross Section of Deep Datum Point (DP)

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(5) Work Schedule and Finished Benchmark Stations and Datum Points

Four (4) units of drilling machine were used for the installation work. The installation work commenced on the 10th of June 2000 and ended on the 18th of July 2000. One of the finished benchmark stations and datum points is shown below. Please refer to **Data Book H.4.1** for the depth, drilling work schedule, and geographical log and station description of each deep datum point.

Photograph H.4.1 Finished Benchmark Station (BM1: Left) and Datum Point (DP1: Right)

Photograph H.4.2 Close View of Finished Benchmark (BM1)

4.2.4 First Order Precise Levelling

(1) Standard Benchmarks Used in the Levelling

The first order precise levelling was carried out in accordance with standards or guidelines of the Department of Survey and National Mapping Malaysia (JUPM). In the first session, the first order precise levelling was executed from the nearest first order standard bench mark installed by JUPM, i.e., S 0067, to all the datum points and new benchmark stations specified in Item (3) above.

A separate levelling to Standard Benchmark S 0375 was done for checking purposes. The total distance of the levelling work was 124.57 km.

These two (2) JUPM Standard Benchmarks were also used as the height datum in this survey. Their respective height values are shown in **Table H.4.1** below.

Table H.4.1 Height of JUPM Standard Benchmarks

Standard Benchmark Number	Mean Sea Level (meter)	Location
S 0067	3.569	Banting Police Station
S 0375	10.036	Dengkil Police Station

(2) Work Procedure

The precise levelling was conducted in the following procedure.

(a) The levelling is carried out in sections of 1 km loop along the route. This means a loop will have a total distance of approximately 2 km.

(b) Temporary benchmark (TBM) is installed at every 1 km (loop) by means of nail on permanent, solid and stable structure such as metal road or building foundations. In places where there are no permanent structures, nail on pipe is used.

(c) Two peg tests are carried out every morning to ensure that the level instruments are in good working condition before carrying out the actual levelling. Line of sight (collimation error) correction should not exceed 60 seconds during the test. If the tolerance is less than 60 seconds, then the line of sight correction is stored in the instrument. This correction is automatically applied to the level readings each time an observation is recorded in the RAM cards.

(d) At the end of each working day, instead of one (1), three (3) TBMs are installed. On the next day, the surveyor will start his work by first checking those three TBMs in a small loop. With this test, the surveyor is confident that his datum for that day is reliable and good.

(3) Work Schedule and Results of the Levelling

The work commenced on the 22nd of May 2000 and ended on the 12th of July 2000. Precise levelling was carried out from Standard Benchmark S 0067 to all deep datum points and benchmarks in routes agreed by the JICA Study Team. The levelling work schedule and a route map that shows all the routes, deep datum, benchmark and temporary benchmark points are shown in **Data Book H.4.2**.

The result of the levelling and coordinates of all the benchmarks and datum points is presented in **Tables H.4.2 and H.4.3**, but the latitude and longitude have a plus-minus 30m tolerance because of accuracy of GPS (geographical positioning system) equipment.

Table H.4.2 Geographical Coordination of the Benchmark Stations

Number	Longitude	Latitude	RSO*		Elevation (m)
			X (m)	Y (m)	
BM 1	101 ^{O} 31’34.7”	2 ^{O} 53’20.4”	392187.83629	319764.39205	4.66052
BM 2	101 ^{O} 29’53.8”	2 ^{O} 52’31.2”	389068.08996	318260.97908	3.70296
BM 3	101 ^{O} 37’14.6”	2 ^{O} 52’42.7”	402681.46537	318580.79958	7.60638
BM 4	101 ^{O} 34’13.6”	2 ^{O} 50’48.7”	397083.46989	315092.72012	4.76860
BM 5	101 ^{O} 31’32.9”	2 ^{O} 50’32.9”	392119.44958	314619.60230	2.82318
BM 6	101 ^{O} 36’20.4”	2 ^{O} 49’56.9”	400995.51585	313492.20827	5.68458
BM 7	101 ^{O} 35’58.7”	2 ^{O} 48’41.2”	400319.79987	311168.64214	4.67254
BM 8	101 ^{O} 33’11.3”	2 ^{O} 49’10.9”	395152.14481	312093.40008	2.66211
BM 9	101 ^{O} 30’52.0”	2 ^{O} 48’40.7”	390847.76271	311176.36856	1.87459
BM10	101 ^{O} 29’33.9”	2 ^{O} 48’22.8”	388434.33526	310632.55901	2.70476
BM11	101 ^{O} 27’29.4”	2 ^{O} 49’10.8”	384592.96149	312116.68329	2.54265
BM12	101 ^{O} 36’13.1”	2 ^{O} 55’33.5”	400794.95253	323831.48330	9.06237
BM13	101 ^{O} 28’19.9”	2 ^{O} 46’47.1”	386141.46333	307698.69436	3.72925
BM14	101 ^{O} 31’16.6”	2 ^{O} 47’24.3”	391601.70558	308827.74633	3.52472
BM15	101 ^{O} 35’00.7”	2 ^{O} 47’45.1”	398524.42428	309449.78066	3.28221
BM16	101 ^{O} 37’09.4”	2 ^{O} 47’44.4”	402499.10548	309418.80290	3.54635
BM17	101 ^{O} 39’21.8”	2 ^{O} 46’55.7”	406584.58858	307913.37883	4.13343
BM18	101 ^{O} 32’10.2”	2 ^{O} 45’29.3”	393248.47134	305291.27372	5.12656
BM19	101 ^{O} 38’03.4”	2 ^{O} 45’23.1”	404156.64414	305074.76223	4.33098
BM20	101 ^{O} 41’38.6”	2 ^{O} 44’45.4”	410800.34085	303901.47760	6.81241

Note: * ”RSO” stands for Rectified Skew Orthomorphic that is a coordinate system widely used in Malaysia.
Source: JICA Study Team

Table H.4.3 Geographical Coordination of the Datum Points

Number	Longitude	Latitude	RSO*		Elevation (m)
			X (m)	Y (m)	
DP 1	101°31'34.6"	2°53'20.3"	392184.74050	319761.32817	4.95802
DP 2	101°30'01.4"	2°52'33.0"	389302.93231	318315.67667	4.30952
DP 3	101°37'14.7"	2°52'42.7"	402684.55345	318580.79221	7.71928
DP 4	101°34'13.7"	2°50'48.7"	397086.55812	315092.71261	5.10100
DP 5	101°31'32.8"	2°50'33.0"	392116.36891	314622.68158	2.91833
DP 6	101°36'19.2"	2°49'56.1"	400958.39817	313467.72448	6.16016
DP 7	101°35'47.0"	2°48'32.5"	399957.82655	310902.28011	5.32261
DP 8	101°33'12.5"	2°49'10.3"	395189.15981	312074.87990	3.05286
DP 9-10	101°30'17.5"	2°48'28.9"	389781.35903	310816.56493	3.36848
DP11	101°27'29.2"	2°49'10.8"	384586.78463	312116.69903	2.56594
DP12	101°36'13.1"	2°55'33.6"	400794.95996	323834.55479	9.26208
DP13	101°28'19.9"	2°46'46.9"	386141.44785	307692.55094	3.66470
DP14	101°31'16.6"	2°47'24.4"	391601.71316	308830.81799	3.57333
DP15	101°35'00.7"	2°47'45.0"	398524.41690	309446.70907	3.29037
DP16	101°37'09.3"	2°47'44.2"	402496.00260	309412.66709	3.65698
DP17	101°39'22.3"	2°46'56.2"	406600.06605	307928.70065	4.42807
DP18	101°32'10.1"	2°45'29.2"	393245.37528	305288.20960	5.01820
DP19	101°38'03.4"	2°45'22.9"	404156.62979	305068.61909	4.70254
DP20	101°41'38.6"	2°44'45.7"	410800.36177	303910.69217	6.96375

Note: * "RSO" stands for Rectified Skew Orthomorphic that is a coordinate system widely used in Malaysia.
Source: JICA Study Team

(2) Result of the Measurement

The first levelling work commenced on the 22nd of May 2000 and ended on the 12th of July 2000. Precise levelling was carried out from Standard Benchmark S 0067 to all deep datum points and benchmarks in routes agreed by the JICA Study Team. The second survey was done from 7th to 9th November 2000, and the third levelling was finally conducted between 8th and 12th March 2001. Finally, the fourth survey was carried out from 20th to 22nd August 2001 in the Third Phase of the Study. This Study covered these four (4) levelling work.

The result of three levelling surveys is as summarised in **Table H.4.4 and Figure H.4.6**. The maximum rise of the elevation between the first and second levelling surveys, the second and third one and the third and fourth one is calculated at 2.71 mm, 7.11 mm and 0.40 mm, respectively, at different locations. In terms of sinkage, the minimum records are –13.47 mm for the second from the first, –11.71 mm for the third from the second and –16.98 mm for the fourth from the third surveys at the same location in KLIA, BM20.

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 (8) 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 4 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.

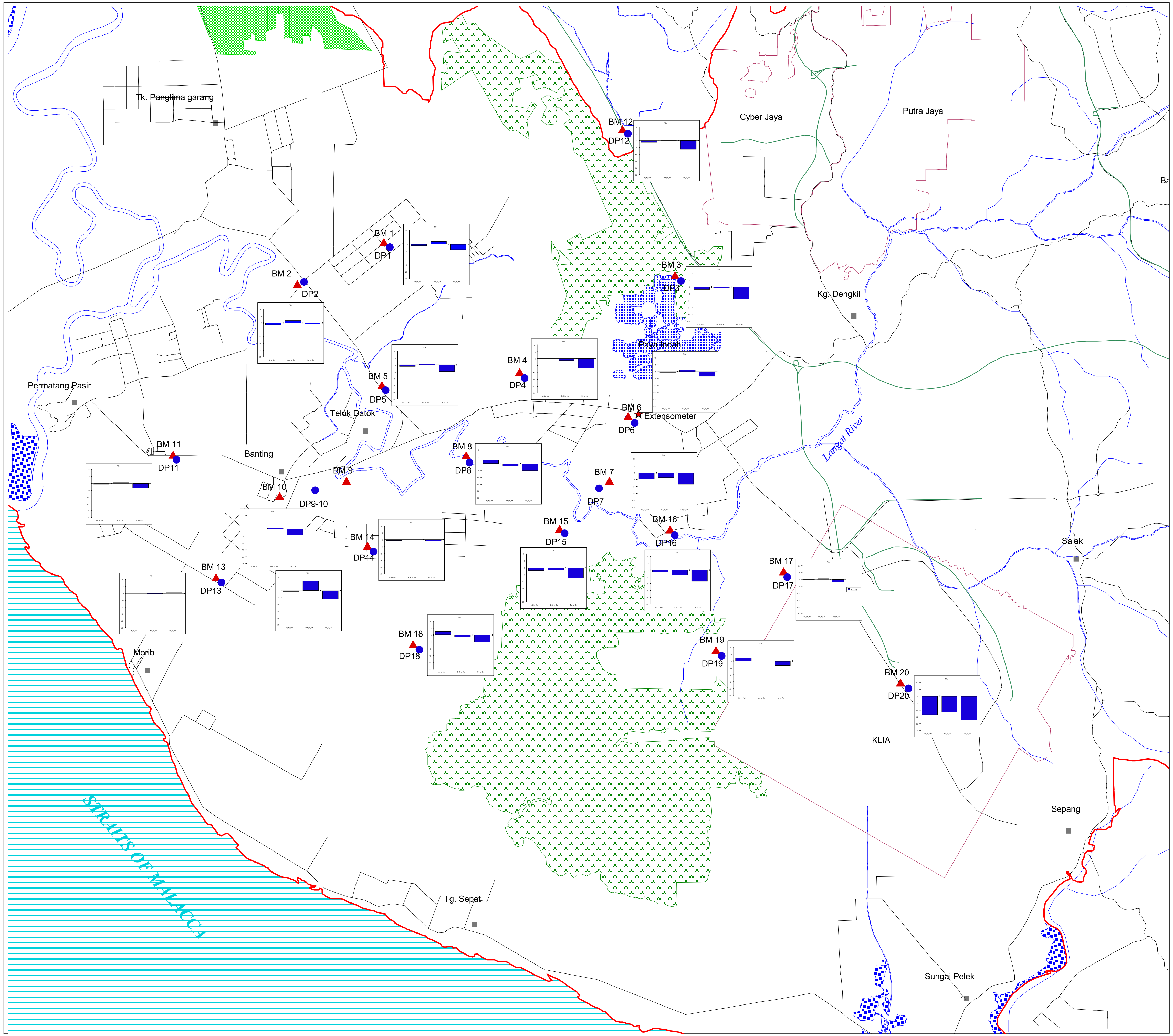
The same tendency was given by seven (7) benchmarks, i.e., BM1, 2, 5, 6, 8, 10 and 11; that is, firstly settlement arose, secondly these benchmarks were elevated and finally sunk again. Especially, BM10 in the backyard of the Banting Hospital had a record of 7 mm that is the highest rise of twenty benchmarks 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.

Table H.4.4 Elevation Difference between the First, Second, Third and Fourth Levelling Survey

Deep Datum	Elevation (m)	Bench-mark	Elevation (m)				Difference (mm)			
			First	Second	Third	Fourth	1st to 2nd	2nd to 3rd	3rd to 4th	1st to 4th
DP 1	4.76077	BM 1	4.66185	4.66073	4.66274	4.65880	**-1.12**	**2.01**	**-3.94**	**-3.05**
DP 2	4.30952	BM 2	3.70385	3.70230	3.70401	3.70291	**-1.55**	**1.71**	**-1.10**	**-0.94**
DP 3	7.56103	BM 3	7.59964	7.59785	7.59748	7.58897	**-1.79**	**-0.37**	**-8.51**	**-10.67**
DP 4	4.92062	BM 4	4.77087	4.77080	4.76961	4.76286	**-0.07**	**-1.19**	**-6.75**	**-8.01**
DP 5	2.91833	BM 5	2.82516	2.82401	2.82449	2.81973	**-1.15**	**0.48**	**-4.76**	**-5.43**
DP 6	6.16016	BM 6	5.68421	5.68376	5.68493	5.68160	**-0.45**	**1.17**	**-3.33**	**-2.61**
DP 7	5.32261	BM 7	4.67127	4.66674	4.66316	4.65481	**-4.53**	**-3.58**	**-8.35**	**-16.46**
DP 8	3.05286	BM 8	2.66756	2.66552	2.66686	2.66156	**-2.04**	**1.34**	**-5.30**	**-6.00**
DP 9 & 10	3.36848	BM 9	1.87121	1.87126	1.87234	1.86833	**0.05**	**1.08**	**-4.01**	**-2.88**
		BM 10	2.70279	2.70230	2.70941	2.70339	**-0.49**	**7.11**	**-6.02**	**0.60**
DP 11	2.56594	BM 11	2.54350	2.54302	2.54361	2.54045	**-0.48**	**0.59**	**-3.16**	**-3.05**
DP 12	9.10890	BM 12	9.06287	9.06165	9.06151	9.05514	**-1.22**	**-0.14**	**-6.37**	**-7.73**
DP 13	3.66470	BM 13	3.72964	3.72974	3.72918	3.72958	**0.10**	**-0.56**	**0.40**	**-0.06**
DP 14	3.57333	BM 14	3.52519	3.52465	3.52444	3.52336	**-0.54**	**-0.21**	**-1.08**	**-1.83**
DP 15	3.29037	BM 15	3.28042	3.27834	3.27671	3.26932	**-2.08**	**-1.63**	**-7.39**	**-11.10**
DP 16	3.50590	BM 16	3.54858	3.54717	3.54368	3.53534	**-1.41**	**-3.49**	**-8.34**	**-13.24**
DP 17	4.42807	BM 17	4.13413	4.13426	4.13481	4.13298	**0.13**	**0.55**	**-1.83**	**-1.15**
DP 18	5.01820	BM 18	5.12695	5.12966	5.12816	5.12306	**2.71**	**-1.50**	**-5.10**	**-3.89**
DP 19	4.70254	BM 19	4.33001	4.33214	4.33211	4.32879	**2.13**	**-0.03**	**-3.32**	**-1.22**
DP 20	6.96375	BM 20	6.80861	6.79514	6.78343	6.76645	**-13.47**	**-11.71**	**-16.98**	**-42.16**

Figure H.4.6

Results of the Land Subsidence Measurement



LEGEND

- Borehole Extensometer
- Bench Mark
- Deep Datum

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

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4.3 Land Subsidence Measured by Borehole Extensometer

4.3.1 Objectives of the Work

As part of the land subsidence measurement network in the Lower Langat Basin, a borehole extensometer was installed to measure subsidence in upper soft soil layers at the Kajibumi Well Field 2. Location is as shown in the preceding **Figure H.4.1**.

4.3.2 Borehole Extensometer

A borehole extensometer was selected to measure the subsidence in the upper soft soil layers. The borehole extensometer consisted of a reference head (grout collar) fixed to a concrete pad at the ground surface and an anchor fixed to the firm bed beneath the upper soft soil layers. As the upper soft soil layers settled, the distance between the surface reference point and the lower anchor changed. These changes were measured by a displacement transducer and recorded by a data logger.

Major specifications of the borehole extensometer are as follows:

- Measurement range 250 mm
- Resolution 0.02 mm
- Measurement length 16 metre

4.3.3 Soil Profile at Kajibumi Well Field 2

Soil investigation was carried out before the installation of the borehole extensometer. A simplified borehole log and installation diagram of the extensometer is drawn in **Figure H.4.7**. Soil profiles at the Kajibumi Well Field 2 can be summarised as in **Table H.4.2**.

Table H.4.5 Soil Profile at Kajibumi Well Field 2

Layer	Soil	Depth (G.L.-m)	Consistency/ Compaction	N Value
1	Fill	0.00 to 1.30	Loose	3
2	Peat/Peaty Clay	1.30 to 3.00	Very soft	0
3	Clay	3.00 to 6.45	Very soft	0 to 1
4	Silty Clay/Sandy Clay	6.45 to 13.00	Soft to stiff	5 to 17
5	Silty Sand	13.00 to 14.25	Medium	18 to 19
6	Sand with Gravel	14.25 to 34.00	Medium to dense	8 to 31
7	Sand/Gravel	34.00 to 44.00	Dense to very dense	26 to 50>
8	Bedrock	44.00>	-	50>

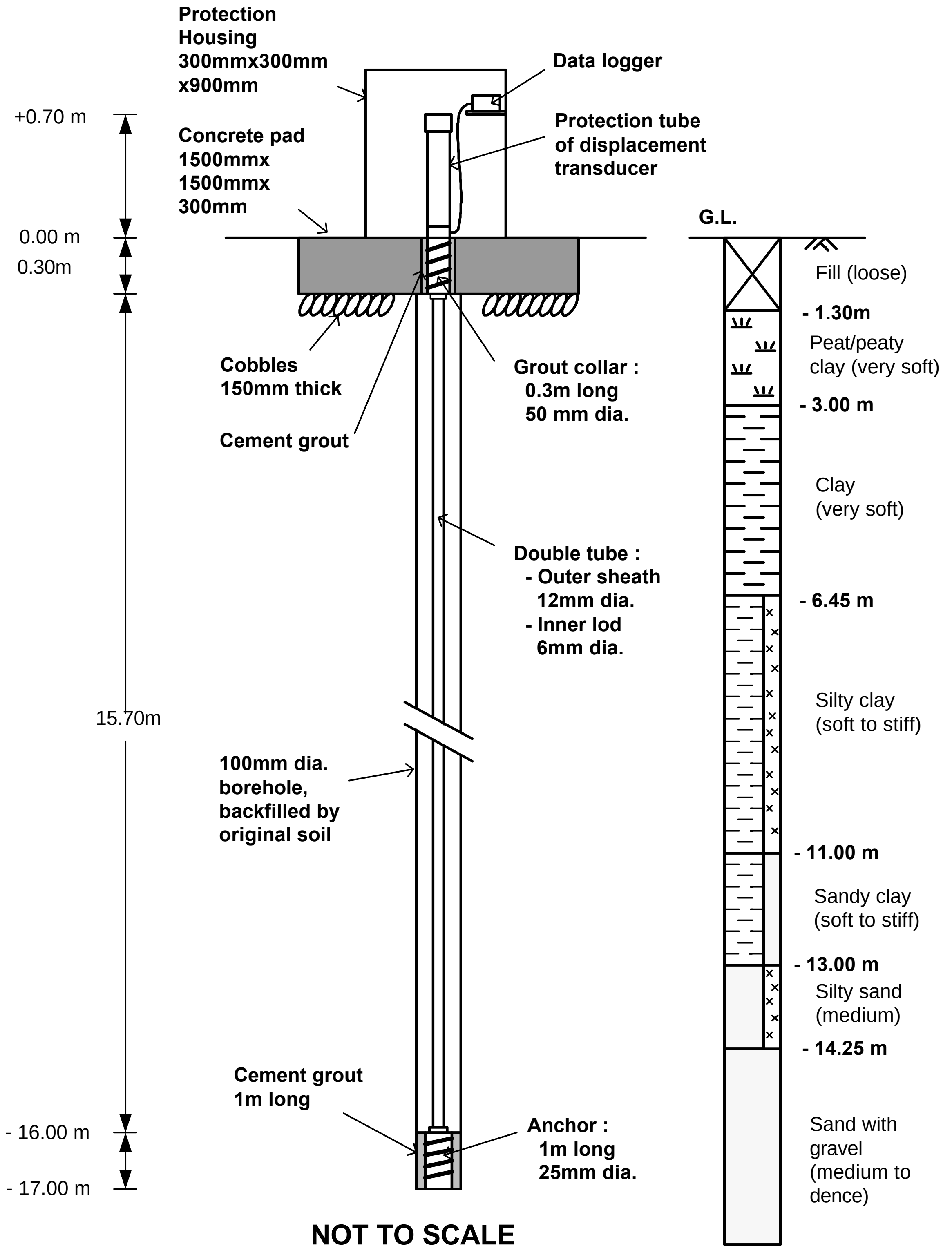

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Figure H.4.7

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

Installation Diagram of Borehole Extensometer

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Since the objective of the borehole extensometer is to measure settlements in the upper soft soil layers, which are layers 1 to 5 at this locality, the location of the lower anchor was chosen within layer 6, sand with gravel. The depth of the anchor was fixed at -16 meter from the ground surface where the sand becomes dense or N value is 31.

4.3.4 Installation of the Extensometer

The borehole extensometer was installed within the compound of JBA (Kajibumi Well Field 2) during 29 and 31 October 2000. Location map and site map are presented in **Data Book Figure H.1.5 of Sector F**. Within the same compound, the datum point DP 6 (JMG's existing datum) and the benchmark BM 6 are located.

A borehole of 100 mm in diameter was drilled and the lower anchor was grouted between G.L. –16 and –17 meter with sand layer 6. After backfilling the hole with the original soil, the surface reference head was grouted to the surface concrete pad. A protection tube of displacement transducer and the data logger were installed within the protection housing.

4.3.5 Measurement

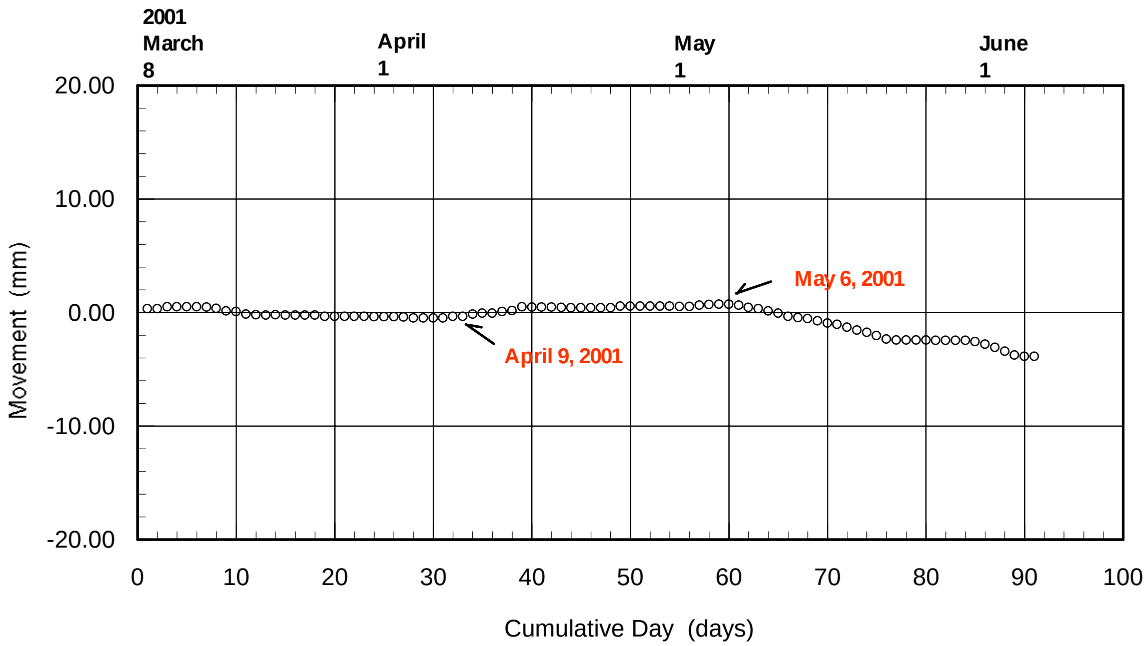
After adjusting the extensometer electronically, measurement was started from 16 December 2000. Recorded movement up to 25 January 2001 fluctuated within 0.016 mm. Since this is less than the resolution of 0.02 mm, any conclusion cannot be drawn from the measurement. Additional measurements of borehole extensometer were carried out between 8 March2001 and 6 June 2001. Although the measurements were taken at 30 minutes interval during this period, in order to see the overall movement, measurements at midnight of each day were plotted as shown in **Figure H.4.8**. The figure includes rainfall data at Paya Indah, which is located at around 5 km north-northeast of the borehole extensometer.

From 8 March 2001 and 6 May 2001, the readings showed small movements fluctuating within 1 mm. Variation in a single day during this period was very small, typically around 0.05 mm. After the rainfall on 9 March 2001, upward movement (heaving) was recognised.

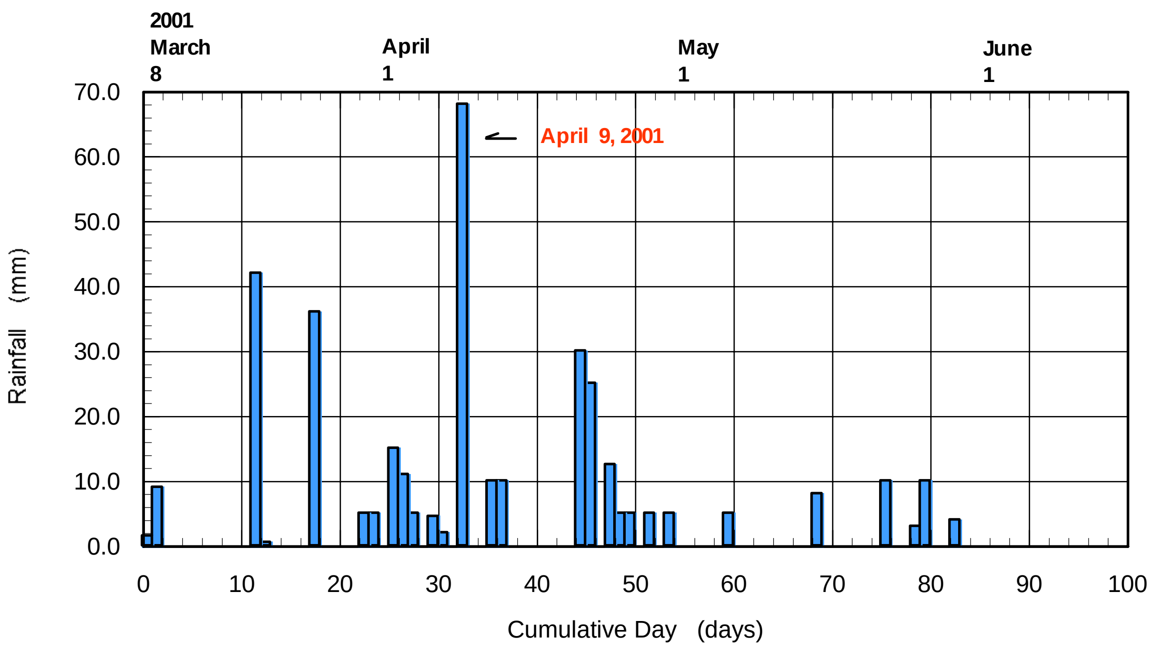
The readings showed downward movement (settlement) after 6 May 2001. The movement continued to June 6, and the total movement was around 4 mm. During this period, rainfall was less compared to the previous days.

It is still early to correlate these movements to the land subsidence that will be caused by consolidation settlement of the clayey soil layers found from 3 m below the ground surface at this locality. The movements may be those of the surface soil that is affected easily by temperature, rainfall and other external conditions.

(a) Reading of Borehole Extensometer (March 8, 2001 – June 6, 2001)



(b) Rainfall Data at Paya Indah (March 8, 2001 – May 31, 2001)



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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 H.4.8

Summary of Borehole Extensometer Reading

4.3.6 Preliminary Evaluation

As a result of the above observation, groundwater abstraction may cause land subsidence. BM7, 15 and 16 in this area show prominent sinkage at the levels of 4 to 8 mm in a year, since the groundwater has been pumped up in Megasteel and Olak Lempit, near the Langat River. Although concrete evaluation now cannot be made due to lack of observation data in the long run, it is necessary to estimate the relationship between volume of the abstracted groundwater and levels of the land subsidence by analysing the result of soil investigation and hydrogeological mechanism in this area.

5. PROPOSED FUTURE MONITORING PLAN

5.1 General

To obtain data and information necessary for execution of the Management Plan, regular monitoring is required to be conducted by JMG staff. Since the Langat Basin has originally few accumulations of required data and information for groundwater management, the monitoring to be conducted in the future is the only way to realise changes in groundwater environment. The 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;
- Groundwater Level;
- Groundwater Quality;
- Land Subsidence; and
- Surface Water Level.

The volume of groundwater abstraction is one of the basic information for groundwater management. This issue should be discussed with improvement of the legal framework; therefore, this manual deals with four (4) items except for Groundwater Abstraction Volume.

Much attention is usually given to matters something new or something in high levels, e.g., sophisticated simulation, information technology (IT), etc. However, continuous execution of the monitoring work, though it is very basic and monotonous, is indispensable for the implementation of the Management Plan.

This chapter gives only a summary of the regular monitoring. The details are given in **Annex H.3.1** of this sector report.

5.2 Summary of Work Items

Proposed work items of the regular monitoring are summarised in **Table H.5.1** below.

Table H.5.1 Summary of Work Items for the Regular Monitoring

Work Item	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.

Note: "N.A." stands for Not Applicable.
*Budget required for the subcontract shall be confirmed by asking several contractors before planning.

Table H.5.2 presents the rough price of equipment necessary for the laboratory test to be conducted by a private laboratory. This is to reduce the outsourcing of the work. As presented in the table, the total price of the equipment is approximately the double of the cost needed for outsourcing cost of one year.

Table H.5.2 Price of Equipment necessary for Laboratory Test to be Outsourced

Test Item and Necessary Equipment	Price
Oil and Grease	
1. Shaker	200,000
2. Hot Plate	120,000
3. Clean Bench	850,000
(Sub-total)	(1,170,000)
Phenol	
5. Steam Pistillation Device	500,000
6. Spectrophotometer	1,000,000
(Sub-total)	(1,500,000)
Chloroform	
7. Rotary Evaporator	1,500,000
8. Gas Chromatograph	2,500,000
(Sub-total)	(4,000,000)
Organochlorine Pesticides	
9. Detector (with 7. and 8. above)	500,000
Organophosphorus Pesticides	
10. Detector (with 7. and 8. above)	500,000
BTEX	
11. Detector (with 7. and 8. above)	500,000
VOC	
(11. above)	-
SVOC	
(11. above)	-
Total Petroleum Hydrocarbon	
(11. above)	-
Total Coliform Bacteria and E coliform	
12. Automatic Autoclave	400,000
13. Automatic Incubater	400,000
(Sub-total)	(800,000)
Total in Japanese Yen	\8,970,000
Total in Malaysia Ringgit (MR 1=Yen33.6)	MR267,000

Besides the monitoring work, the following cost will be needed to the maintenance of the Management Information System. Maintenance cost for ArcIMS and ArcSDE is RM8,270 and RM17,545, respectively per year.

5.3 Summary of Work Frequency

Proposed work frequency for the regular monitoring is given in **Table H.5.3** below.

Table H.5.3 Work Frequency for Regular Monitoring

Work Items		Month						Frequency
		Jan.-Feb.	Mar.-Apr.	May-Jun.	Jul.-Aug.	Sep.-Oct.	Nov.-Dec.	
Groundwater Level	Measurement	O	O	O	O	O	O	Every 2 months
	Well Maintenance	O	O	O	O	O	O	Every 2 months
Groundwater and Surface Water Quality		-	-	O	-	-	O	Twice a year
Land Subsidence	Retrieval of Data from Data Logger	O	O	O	O	O	O	Every 2 months
	First Order Levelling	-	-	O	-	-	-	Once a year
	BM Maintenance	O	-	O	-	O	-	Every 4 months
Surface Water Level		O	O	O	O	O	O	Every 2 months

Note: O mark means monitoring is conducted.

References

1) Geological Survey Department (1998), Groundwater Potential at Telok Datok – Olak Lempit Area, Kuala Lumpur District, Selangor, Report No. (hidro) 01/98.
2) Saffeen Baharuddin, (1998), Hydrogeological Investigation in the General alluvium of Kelang –Banting – Sepang Area, Selangor, GPH 8/98.

ANNEX H.3.1

MANUAL OF REGULAR MONITORING

TABLE OF CONTENTS

ANNEX H.3.1

MANUAL OF REGULAR MONITORING

1. INTRODUCTION

1.1 Monitoring Items Covered by this Manual

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

- Groundwater Abstraction Volume;
- Groundwater Level;
- Groundwater Quality;
- Land Subsidence; and
- Surface Water Level.

The volume of groundwater abstraction is one of the basic information for groundwater management. Since this issue should be discussed together with the improvement of legal framework, this manual deals with four (4) items except the Groundwater Abstraction Volume.

General information and summary of the regular monitoring is in **Chapter 1**. **Chapter 2** to **Chapter 5** describe the outline of each monitoring item respectively, including preparatory work, procedure of each monitoring, and the arrangement of results. Detailed information about each monitoring and how to manipulate new instruments for this monitoring is placed at the end of this manual as **Attachment**.

1.2 Objective and Principles of Regular Monitoring

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

Much attention is usually given to matters something new or something in high levels, e.g. sophisticated simulation, information technology (IT), etc. However, the continuous execution of monitoring work, though it is very basic and monotonous, is indispensable for the implementation of the Management Plan.

1.3 Summary of Work Items

The summary of work items covered in this manual is given in **Annex Table H.3.1** below.

Annex Table H.3.1 Summary of Work Items for the Regular Monitoring

Work Item	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.

1.4 Summary of Work Frequency

Work frequency for the regular monitoring is as summarised in **Annex Table H.3.2** below.

Annex Table H.3.2 Work Frequency for Regular Monitoring

Work Items		Month						Frequency
		Jan.-Feb.	Mar.-Apr.	May-Jun.	Jul.-Aug.	Sep.-Oct.	Nov.-Dec.	
Groundwater Level	Measurement	**O**	**O**	**O**	**O**	**O**	**O**	Every 2 months
	Well Maintenance	**O**	**O**	**O**	**O**	**O**	**O**	Every 2 months
Groundwater and Surface Water Quality		-	-	**O**	-	-	**O**	Twice a year
Land Subsidence	Retrieval of Data from Data Logger	**O**	**O**	**O**	**O**	**O**	**O**	Every 2 months
	First Order Levelling	-	-	**O**	-	-	-	Once a year
	BM Maintenance	**O**	-	**O**	-	**O**	-	Every 4 months
Surface Water Level		**O**	**O**	**O**	**O**	**O**	**O**	Every 2 months

Note: **O** mark means monitoring is conducted.

2. GROUNDWATER LEVEL

2.1 Objective of Groundwater Level Monitoring

The objective of groundwater level monitoring is to identify regional and seasonal variations and long-term changes of groundwater level in the Langat Aquifer.

2.2 Frequency of Monitoring

The measurement of groundwater level shall be conducted in every two months. Especially in connection with the memory storage capacity of data logger, two months interval should be the maximum. Therefore, data extraction from the data logger as well as the water level measurement should be carried out in this frequency. For the future long-term monitoring, a different frequency may be applied depending on the degree of variation and changes.

Well maintenance, such as clearing of the well site including removal of grasses and weeds around the site, putting grease in the keyhole to smoothen the lock movement, etc. shall be conducted together with the above data collection work. As to well protection, painting is required to prevent metallic parts from rusting, if necessary. A standard frequency of this maintenance work is two times in a year.

2.3 Method of Measurement

Two methods of groundwater level measurement are applied: automatic and manual measurement.

Thirty-four (34) wells have been selected and developed for the long-term groundwater level measurement. Twenty (20) of these wells have an automatic data logger with sensor for measurement of the static groundwater table. Measurement in the remaining 14 wells is to be made manually.

2.4 Location of Measurement

Eleven (11) of the wells have been selected as observation wells from among the existing JMG's monitoring wells. The other 23 wells were newly built during Phase II of this Study.

Lists of all the observation wells for regular monitoring are shown in **Annex Tables H.3.3** and **H.3.4**. Location of the wells is as shown in **Annex Figure H.3.1**, while the details of each location of new wells are shown in **Annex F.2.2** of **Sector F**.

Annex Table H.3.3 List of Existing Observation Wells

No	Well Name	Location	Coordinates			Well Depth (m)	Screen Depth (m)	Geology	PVC Diameter (mm)	Water Level Measured by	Water Sampling
			x (North)	y (East)	z (EL.m)						
1	MWD1	Jambatan Batu, Jln. ke Sg. Kelambu	397837	311786	2.369	50.25	44.3-50	Sand	76	Logger	Yes
2	MWD2	Jln. Dahilia, Sg. Kelambu	395828	309646	4.407	60.5	57.6-60.5	Sand	76	Logger	Yes
3	MWD4	Mutiara Telekom, Jln ke Salak Tinggi-KLIA	404709	312097	3.460	25.75	23-25	Sand	40	Manual	Yes
4	MWD5	Pintu Air, Sg. Lang, detak pekan Banting	390840	311177	1.891	46.65	44.3-46.65	Sand	40	Manual	Yes
5	MWD6	Kg. Sg. Manggis, Telok Datok	394306	313008	3.294	51.6	47.9-51.6	Sand (thin)	80	Logger	Yes
6	MWD7	Kg. Sg. Kelambu	398523	309450	2.747	48.9	47.6-48.9	Sand	70	Manual	Yes
7	MWD8	Jl. Idaman, Sg. Lang Tengah	392268	307906	4.702	42.3	37.3-41.3	Sand	75	Manual	Yes
8	MWD9	FELCRA, Bt. Changgang	406044	307309	5.186	21.0	17-18.4	Sand	65	Logger	Yes
9	MWD10	Kajibumi WF1	395202	312060	2.724	58.5	53.5	Sand	80	Logger	Yes
10	LED2	Express Highway KLIA-Subang-Nilai	400458	324469	?	17.35	16.8-17.8	Sand	52	Logger	Yes
11	MW1	Magasteel	400548	311069	5.224	20.25	18.5-19.5	Sand	82	Logger	Yes

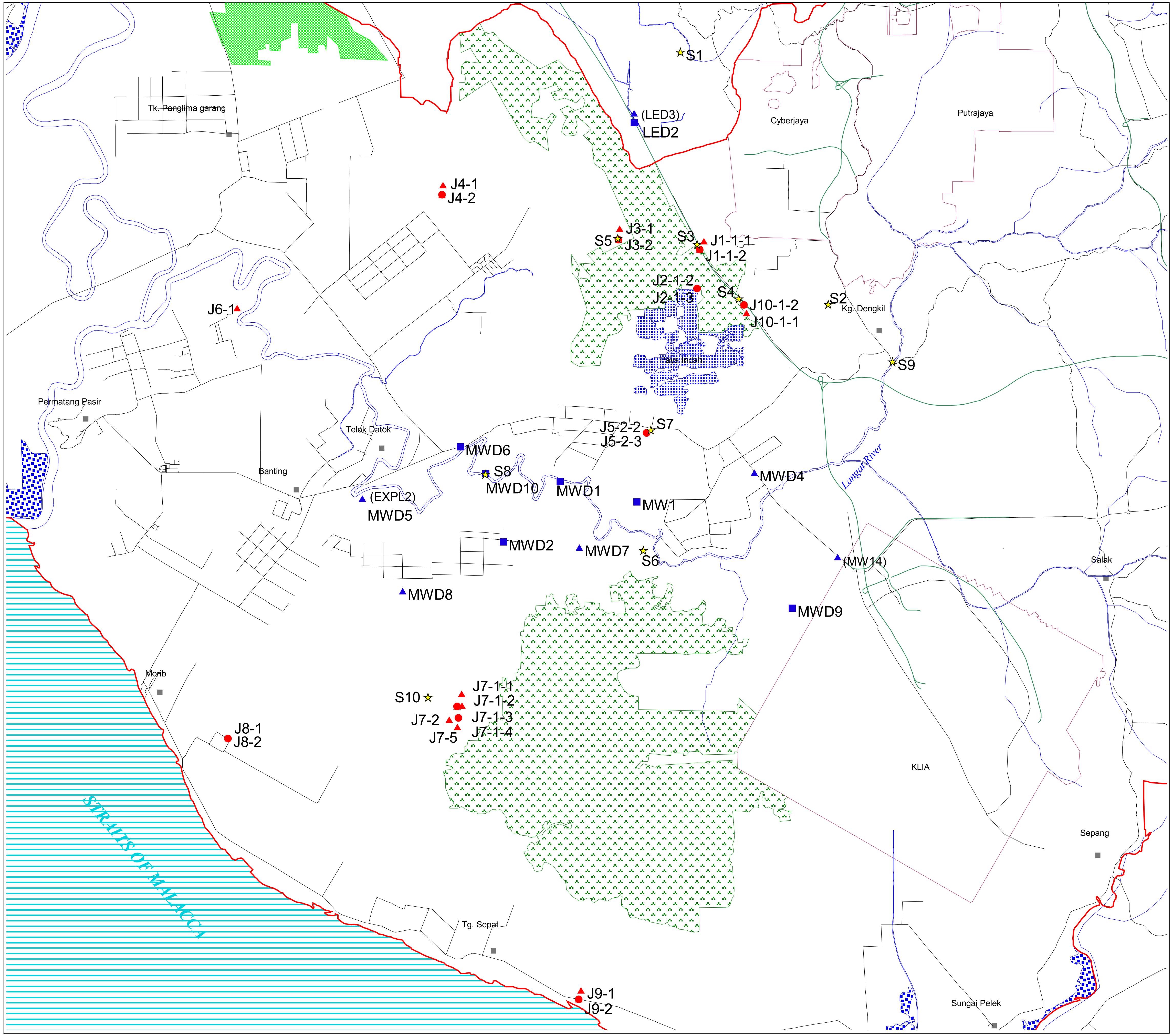
Annex Table H.3.4 List of New Observation Wells

No	Well Name	Location	Coordinates			Well Depth (m)	Screen Depth (m)	Geology	PVC Diameter (mm)	Water Level Measured by	Water Sampling
			X (North)	Y (East)	Z (EL.m)						
12	J1-1-1	South of Bt. Baja	402777	319993	8.597	6.36	3-4	Peat/ Clay	52	Manual	Yes
13	J1-1-2	-ditto-	402777	319993	8.597	22.34	24-25	Sand	100	Logger	Yes
14	J2-1-2	Paya Indah	402685	318614	7.802	20.84	16-18	Sand	100	Logger	Yes
15	J2-1-3	-ditto-	402685	318614	7.802	30.5	27-28	Sand	100	Logger	Yes
16	J3-1	Northwest of Paya Indah	399894	320336	7.484	21.44	17-19	Sand	52	Manual	Yes
17	J3-2	-ditto-	399895	320337	7.417	27.48	24-26	Sand	52	Logger	Yes
18	J4-1	Kg. Jenjarom	393661	321921	5.757	7.47	7.0 - 7.3	Clay	25	Manual	NA
19	J4-2	-ditto-	393660	321931	5.775	28.07	24.5-25.5	Sand	52	Logger	Yes
20	J5-2-2	Kajibumi WF2	400897	313508	5.682	19.06	14-16	Sand	100	Logger	Yes
21	J5-2-3	-ditto-	400897	313508	5.682	43.7	40-41	Sand	100	Logger	Yes
22	J6-1	Sg. Buaya	386415	317920	2.481	11.67	13.45-13.8	Clay	25	Manual	NA
23	J7-1-1	Kanchong Darat	394197	303838	4.813	5.87	3-4.5	Sand	100	Manual	NA
24	J7-1-2	-ditto-	394197	303838	4.813	13.47	11-12.5	Sand	100	Manual	Yes
25	J7-1-3	-ditto-	394197	303838	4.813	31.43	27-29	Sand	100	Logger	Yes
26	J7-1-4	-ditto-	394197	303838	4.813	56.66	53-54	Sand	100	Logger	Yes
27	J7-2	-ditto-	394192	303841	4.983	75.4	71-73	Sand	100	Manual	Yes
28	J7-5	-ditto-	394362	303866	4.797	?	7.45-7.8	Clay	25	Manual	NA
29	J8-1	Kg. Endah	386090	302702	2.291	35.68	28-31	Sand	52	Logger	Yes
30	J8-2	-ditto-	386090	302700	2.288	65.3	61-63	Sand	100	Logger	Yes
31	J9-1	Ladang Tumbuk	398497	293485	2.329	35.18	32-34	Sand	100	Manual	Yes
32	J9-2	-ditto-	398496	293486	2.355	68.5	65.5-66.5	Sand	100	Logger	Yes
33	J10-1-1	East of Paya Indah	404338	318038	8.866	5.43	3-4	Peat/ Clay	52	Manual	Yes
34	J10-1-2	-ditto-	404338	318038	8.866	27.93	24.5-25.5	Sand	100	Logger	Yes

Note: "NA" stands for Not Applicable; that is, water sampling is not carried out in these wells.

Annex Figure H.3.1

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

N E S W

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

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

CTI Engineering International Co., Ltd.

OYO CORPORATION

2.5 Preparatory Works

The following preparatory works should be carried out before visiting the observation points to complete the measurement on schedule and to keep measurement accuracy.

(1) Operation Check of Groundwater Level Measurement Device

Batteries and operation of the groundwater level measurement device should be checked before the fieldwork. The measurement device is composed of a measuring tape and a sensor that beeps if it touches the water.

(2) Application to the Expressway Office

A written application for permission to conduct the measurement work along the expressway should be filed with the person in charge of expressway security at the expressway office (ELITE) at least one (1) month in advance to obtain a written approval before starting the fieldwork.

(3) Notification to the Paya Indah Office

The Malaysian Wetlands Foundation (MWF) should be notified of the schedule of monitoring and names of persons in charge of the work before conducting the fieldwork in Paya Indah.

A summary of the preparatory works is given below.

Annex Table H.3.5 List of Preparatory Works of Groundwater Level Monitoring

Work Items	Required Completion Time	References
Operation check of manual groundwater level measurement device	1 week before the fieldwork	Device manual
Application to the Expressway Office (ELITE)	1 month before the fieldwork	-
Notification to the Paya Indah Office	2 weeks before the fieldwork	-

2.6 List of Required Equipment and Materials for Fieldwork

A list of equipment and materials necessary for the fieldwork is given in **Annex Table H.3.6** below. The required equipment should be prepared before conducting fieldwork.

Annex Table H.3.6 List of Required Equipment and Materials for Fieldwork of Groundwater Level Monitoring

No.	Equipment	Quantity	Check	Remarks
1	Groundwater level measurement device	1		For manual measurement
2	Water depth measurement device (tape)	1		-ditto-
3	Instrument to retrieve data from data logger	1		For data retrieval
4	Spare battery	2		Two AA size batteries for the data logger
5	Keys of wells	30		
6	Mower	1		For cutting grass
7	Forms	50		For recording results
8	Pens	3		-ditto-
9	Paint and grease	1 each		For well maintenance
10	Emergency cones	6		For expressway warning signs
11	Safety vest	6		Depending on the number of staff
12	Permission letters of the Expressway Office and MWF	1 each		-ditto-

2.7 Procedure of Monitoring

2.7.1 Automatic Measurement of Groundwater Level

Two types of automatic recording equipment are used; one is the Data Logger (Automatic Recording Equipment for Groundwater Level) and the other is the Automatic Recording Equipment for Barometric Pressure. The following describes the procedure of data retrieval from the former, i.e., the Data Logger. Data retrieval by the latter is presented in **Chapter 5** of this manual.

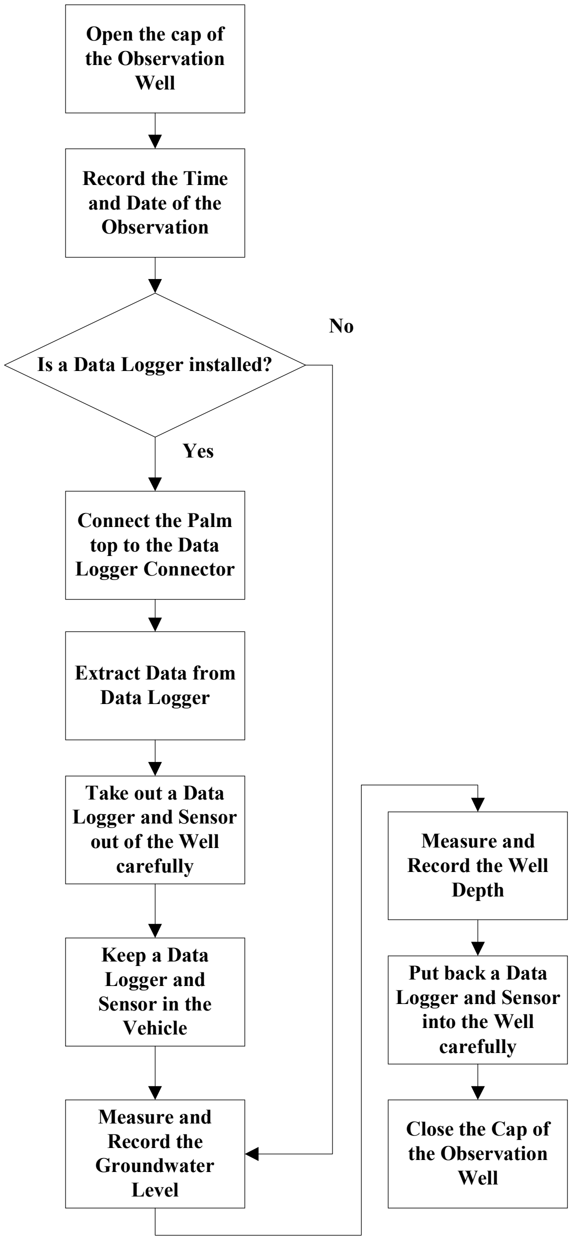
(1) Data Retrieval from a Data Logger (Automatic Recording Equipment for Groundwater Level)

Data loggers (Automatic Recording Equipment for Groundwater Level) are set at 20 wells to store daily records of groundwater level. Retrieval of data is carried out using a retriever and a laptop computer.

Procedures of groundwater level measurement are illustrated in **Annex Figure H.3.2** and summarised as follows:

1. Open the protection cap of the observation well to be measured.
2. Data extraction from the data logger (Automatic Recording Equipment for Groundwater Level) should proceed in accordance with **Attachment 1.** Detailed technical information and equipment procedures can be found in manuals listed in **Annex Table H.3.7**.
3. After extracting data, carefully take out the data logger and sensor from the well and keep them in a container or dark place.
4. Measure and record the groundwater level by manual measurement to compare the data. After that, measure and record the well depth.
5. Carefully put back the data logger and sensor into the well.

6. Close the cap of the well and fasten it with the lock.



Annex Figure H.3.2 Procedure of Groundwater Level Monitoring

(2) Data Arrangement and Evaluation

The groundwater level measured by the Data Logger has to be revised because the actual records are affected by barometric pressure changes. For revision of the original data, two types of raw data are used, namely, raw data of groundwater level and raw data of barometric pressure change.

Each data is defined as the following data format:

(a) Raw Data of Groundwater Level

Raw data of groundwater level, which is stored in the data logger, consists of a header and four (4) columns of measured data, namely, reference number, measurement time, measurement date and time, and depth of pressure transducer. The data is stored in the Microsoft Excel Format (.xls).

(b) Raw Data of Barometric Pressure Change

Raw data of barometric pressure, which is stored in the barometric pressure transducer, consists of a header and five columns of measured data, namely, reference number, date, time, barometric pressure change in water column and temperature. These are stored in Microsoft Excel CSV Format (.csv). Originally, data from the data logger is in its own format (.mon) that can be converted into CVS format by the simple operation within the data extraction program.

The raw data from the groundwater level measurement and the barometric pressure change measurement should be evaluated and, if necessary, corrected before performing the barometric pressure change correction.

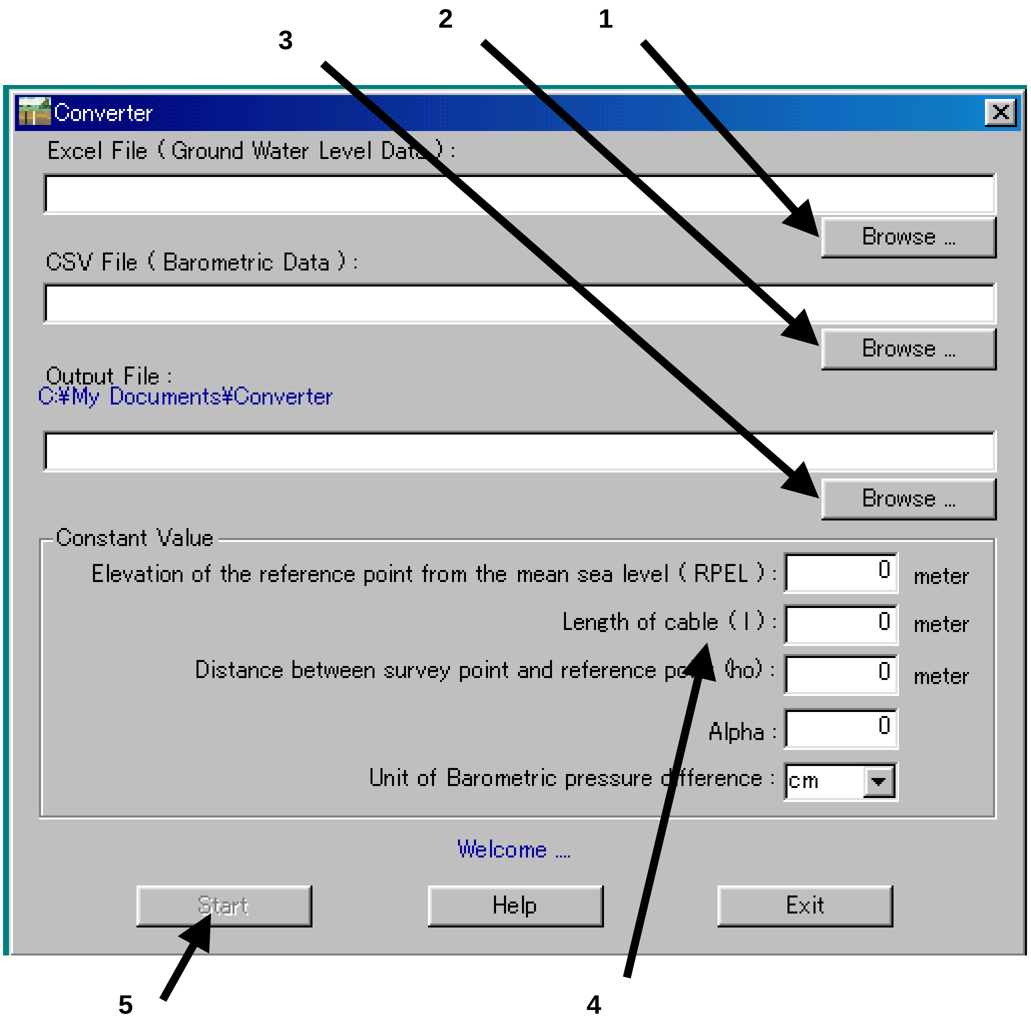
The program 'Convert' can be used to convert the groundwater level to the barometric pressure change. Operation of the program is simple and its conversion procedure is summarised as follows:

1. Select a file of groundwater level measurement.
2. Select a file of barometric pressure change measurement.
3. Select a folder to store the output file and then name the output file.
4. Select constants of monitoring well from **Annex Table H.3.8** and input into appropriate boxes.
5. Start the program.

*[Note: Items 1 to 5 above coincide with those given in **Annex Figure H.3.3** below.]*

In the program the specific time from which the barometric pressure change is calculated is fixed at the starting time of each monitoring session. The efficiency, α (alpha), can be set between 0 to 1. At the start of the long-term monitoring, the efficiency α =1 can be used. Modification is required after accumulation of data.

Since the variation of barometric pressure change over the Langat Basin is minimum, the barometric pressure measurement at Kajibumi Well Field 2 (BT1) can be used for all locations of the groundwater level measurement.



Annex Figure H.3.3 Screen Image of the Program 'Convert' for Correction of Groundwater Level to the Barometric Pressure Change

Annex Table H.3.7 List of Detailed Manuals for Groundwater Level Monitoring

No.	Title	Publisher	Quantity
1	Data Trapper BH1000 Borehole Data Logger Win trapper CE User's Manual	RST Instrument Ltd.	1 Volume
2	Win Trapper BH1000 DT1000 Borehole Data Logger Windows User's Manual	RST Instrument Ltd.	1 Volume
3	Debrief TE1000 Communication Software, Ver. 2.1	RST Instrument Ltd., 1997	1 Floppy Disk
4	Win Trapper 95~BH1000, Ver. 2.2	RST Instrument Ltd.	1 Floppy Disk
5	Data trapper BH1000 Data logger CALIBRATION CERTIFICATE	RST Instrument Ltd.	1 Volume
6	Single Point Electric/Manual Head Extensometer Operating Manual	RST Instrument Ltd.	1 Volume
7	Palm size PC User's Guide	Microsoft	1 Volume
8	Windows CE Program	Microsoft	1 CD
9	Palm - size PC Certificate of Authenticity	Microsoft	1 Sheet
10	Microsoft Registration Card	Microsoft	1 Sheet
11	Nino Owner's Guide	Philips	1 Volume
12	Nino 300 Modem Click-on Owner's Guide	Philips	1 Volume

Annex Table H.3.8 List of Piezometers for Automatic Measurement of Groundwater Level

No.	Piezometer No..	Location	Data Logger Serial No.	Capacity of Pressure Transducer (kPa)	Cable Length (m)	Distance between Survey Point and Reference Point (ho: m)	Elevation of Survey Point (MSL: m)
1	J1-1-2	South of Bukit Baja	20132810	200	20	0.331	8.597
2	J2-1-2	Paya Indah	20132803	100	10	0.230	7.802
3	J2-1-3	Paya Indah	20132808	200	20	0.225	
4	J3-2	Northwest of Paya Indah	20132813	200	20	0.280	7.417
5	J4-2	Kg. Jenjarom	20132814	200	20	0.300	5.775
6	J5-2-2	Kajibumi WF 2	20132804	100	10	0.588	5.682
7	J5-2-3	Kajibumi WF 2	20132809	200	20	0.601	
8	J7-1-3	Kanchong Darat	20132807	200	20	0.215	5.088
9	J7-1-4	Kanchong Darat	20132817	200	20	0.240	
10	J8-1	Kg. Endah	20132816	200	20	0.321	2.291
11	J8-2	Kg. Endah	20132820	200	20	0.327	2.288
12	J9-2	Ladang Tumbok	20132806	200	20	0.418	2.355
13	J10-1-2	East of Paya Indah	20132811	200	20	0.324	8.866
14	MWD1	Jambatan Batu, Sg Kelambu	20132812	200	20	0.330	2.369
15	MWD2	Jalan Dahlia, Sg Kelambu	20132819	200	20	0.380	4.407
16	MWD6	Kg Sg.Manggis, Tlk Datok	20132815	32	20	0.300	3.294
17	MWD9	FELCRA Bkt.Changgang	20132801	100	10	0.370	5.186
18	MWD10	Kajibumi WF 1	20132802	100	10	0.330	2.724
19	LED 2	Express Highway KLIA	20132805	100	10	0.420	-
20	MW 1	Megasteel	20132818	200	20	0.210	5.224

2.7.2 Manual Measurement of Groundwater Level

Only manual measurement of groundwater level using a groundwater level measurement device will be conducted for the 14 monitoring wells where data logger is not installed. In the regular monitoring, manual measurement of groundwater level at all 34 wells will be carried out for comparing the data based on the procedures given in **Annex Figure H.3.2**.

The results of manual measurement shall be recorded on **FORM-1** in **Attachment 3**. Accomplished forms should be kept properly after the measurement.

2.7.3 Well Maintenance

The procedure of well maintenance is as summarised below.

(1) Remove grasses and weeds by mower or by hand, and clear the area around the well.

(2) Put grease in the keyhole.

(3) If necessary, paint the well to protect it against rust.

3. GROUNDWATER AND SURFACE WATER QUALITY

3.1 Objective of Groundwater and Surface Water Quality Monitoring

The objective of groundwater and surface water quality monitoring is to identify regional and seasonal variation and long-term changes of groundwater quality in the target Aquifer. In addition, surface water quality is measured for background information.

3.2 Frequency of Monitoring

The measurement of groundwater and surface water quality is to be conducted twice a year; namely, once in May or June and once in November or December. Sampling for water quality analysis shall be carried out when the groundwater level data is retrieved at the site.

3.3 Method of Measurement

Groundwater and surface water quality analysis shall be conducted in four (4) different modes, as follows:

- In-situ: the analysis is to be conducted in-situ (i.e., in original place) using KLL-Q, a handy water quality analyser.
- On-site: the analysis is to be conducted at the site using test kits with reagents and small equipment.
- Ipoh Laboratory, JMG: samples taken at the site and sent to Ipoh are to be analysed at the Ipoh Laboratory of JMG.
- Subcontracted to Private Laboratory: the analysis of parameters that cannot be tested by the Ipoh Laboratory of JMG is to be conducted by a private laboratory on subcontract basis.

In-situ tests shall be conducted directly at the site. On-site test shall be conducted after sampling by JMG staff. Laboratory test shall be carried out after delivery of samples to the Ipoh Laboratory of JMG or a subcontracted private laboratory.

Parameters for the above analysis together with the mode of testing are given in **Annex Table H.3.9** below.

Annex Table H.3.9 List of Parameters for Groundwater and Surface Water Quality Analysis

Category	Parameters to be Analysed	Test Location
Group I (Physical)	Temperature	In-situ
	Turbidity	In-situ
	Colour	In-situ
	pH	In-situ
	Conductivity	In-situ
Group II (Inorganic)	Dissolved Oxygen (DO)	In-situ
	Biochemical Oxygen Demand (BOD)	On-site
	Chemical Oxygen Demand (COD)	On-site
	Manganese (Mn)	On-site
	Iron (Fe)	On-site
	Total Iron (Fe-T)	On-site
	Nitrate Nitrogen (NO_3-N)	On-site
	Nitrite Nitrogen (NO_2-N)	On-site
	Total Dissolved Solids (TDS)	Ipoh Laboratory
	Total Solids (TS)	Ipoh Laboratory
	Chloride (Cl)	Ipoh Laboratory
	Anionic Detergent MBAS	Ipoh Laboratory
	Ammoniacal Nitrogen (NH_3-N)	Ipoh Laboratory
	Fluoride (F)	Ipoh Laboratory
	Carbonate (CO_3)	Ipoh Laboratory
	Hydrogen Carbonate (HCO_3)	Ipoh Laboratory
	Total Hardness ($CaCO_3$)	Ipoh Laboratory
	Sodium (Na)	Ipoh Laboratory
	Calcium (Ca)	Ipoh Laboratory
	Potassium (K)	Ipoh Laboratory
	Aluminium (Al)	Ipoh Laboratory
Group III (Heavy metals and others)	Magnesium (Mg)	Ipoh Laboratory
	Mercury (Hg)	Ipoh Laboratory
	Cadmium (Cd)	Ipoh Laboratory
	Selenium (Se)	Ipoh Laboratory
	Arsenic (As)	Ipoh Laboratory
	Cyanide (CN)	Ipoh Laboratory
	Lead (Pb)	Ipoh Laboratory
	Chromium (Cr)	Ipoh Laboratory
	Silver (Ag)	Ipoh Laboratory
	Copper (Cu)	Ipoh Laboratory
	Zinc (Zn)	Ipoh Laboratory
	Sulphate (SO_4)	Ipoh Laboratory
	Silica (SiO_2)	Ipoh Laboratory
	Phosphorus (P)	Ipoh Laboratory
	Oil & Grease	Private Laboratory
	Phenol	Private Laboratory
	Chloroform	Private Laboratory
Group IV (Biocides and others)	Organochlorine Pesticides	Private Laboratory
	Organophosphorus Pesticides	Private Laboratory
	BTEX	Private Laboratory
	VOC (Volatile Organic Compounds)	Private Laboratory
	SVOC (Semivolatile Organic Compounds)	Private Laboratory
	Total Petroleum Hydrocarbon (TPH)	Private Laboratory
Group V **(Organic)**	Total Coliform Bacteria	Private Laboratory
	E. Coli (Escherichia Coli)	Private Laboratory

3.4 Location of Measurement

The observation wells subject to groundwater and surface water quality monitoring are exactly same as those for groundwater level monitoring. The observation points for surface water are given in **Annex Table H.3.10** below.

Location of wells and surface water monitoring points is as shown in the preceding **Annex Figure H.3.1**.

Annex Table H.3.10 List of Surface Water Observation Points

No	Point Name	Location	Coordinates		Current Land Use
			x (North)	y (East)	
1	S1	Puchong Mine	402093	326973	Active mine
			402083	326966	
2	S2	Dengkil Mine	407322	318056	Abandoned mine
			407322	318067	
3	S3	Paya Indah Inflow (SW1)	402684	320173	Beside the Expressway
			402684	320173	
4	S4	Paya Indah Inflow (SW2)	404154	318249	-ditto-
			404154	318249	
5	S5	Bt. Cheeding	399872	320379	Oil Palm Plantation
			399873	320362	
6	S6	Sand Mine	400779	309360	Active mine
			400722	309312	
7	S7	Kajibumi WF2	401049	313611	River beside plantations
			401049	313611	
8	S8	Langat River (Kajibumi WF1)	395191	312046	River
			395188	312040	
9	S9	Langat River (Dengkil)	409589	316027	-ditto-
			409572	316018	
10	S10	Kanchong Darat	393160	304168	Oil Palm Plantation
			393160	304168	

3.5 Preparatory Works

(1) Operation Check of KLL-Q and Submersible Pumps

Preparatory operation check of KLL-Q and submersible pumps is very important to be carried out in advance in order to perform accurate measurement in accordance with the schedule.

(2) Calibrating Sensors and Charging the Battery of KLL-Q

Calibration of sensors and charging of the battery of KLL-Q should be carried out in advance in accordance with the SEBA manual in order to perform accurate measurement.

(3) Washing and Labelling of Containers

Containers to be used for on-site tests and laboratory tests should be washed. In addition, labels showing site name, date, time, and contents should be prepared and put on the containers before the fieldwork.

(4) Subcontracting Arrangement with a Private Laboratory

Some parameters that cannot be tested in the JMG Ipoh laboratory should be analysed by a private laboratory. An experienced and reliable contractor should be selected and subcontracted. Scope of work, schedule and budget of the analysis shall be clarified through careful discussions with the contractor.

The above work items are summarised as follows:

Annex Table H.3.11 List of Preparatory Works for Groundwater and Surface Water Quality Monitoring

Work Item	Required Completion Time	References
Operation check of KLL-Q and submersible pumps	1 week before the fieldwork	SEBA KLL-Q Manual
Calibration of sensors of KLL-Q	-ditto-	-ditto-
Charging of battery of KLL-Q	Previous day	-ditto-
Washing and labelling of containers	-ditto-	-
Subcontracting arrangement with a private laboratory	1 month before the fieldwork	-

3.6 List of Required Equipment and Materials for Fieldwork

A list of equipment and materials for fieldwork is shown in **Annex Table H.3.12** below. The required equipment should be prepared before the fieldwork.

Annex Table H.3.12 List of Required Equipment and Materials for Fieldwork of Groundwater and Surface Water Quality Monitoring

No.	Equipment	Quantity	Check	Remarks
(For In-situ Test)				
1	SEBA KLL-Q	1		
2	Tap Water	30 litres		For washing equipment
3	Distilled Water	30 litres		
4	Screw Driver	1		To open a probe of KLL-Q
5	Calibration set (pH, Conductivity, etc.)	1		
6	Forms for In-Situ test	50		For recording results
7	Generator	1		For pumping
8	Submersible pump	1		Need to check the well size
9	Fuel (Diesel)	40 litres		-ditto-
10	Engine oil	40 litres		-ditto-

Annex Table H.3.12 List of Required Equipment and Materials for Fieldwork of Groundwater and Surface Water Quality Monitoring (Cont'd.)

No.	Equipment	Quantity	Check	Remarks
11	Hose	1		-ditto-
12	Cloth	1		For covering around the well
13	Small Pail	1		For pumping
14	Big Pail	1		-ditto-
15	Rope for holding hose	1		-ditto-
16	Gloves	5 pairs		-ditto-
17	Spare electric battery for KLL-Q	8		Size D battery
18	Barometer with a watch	1		Measuring air pressure & time
(For On-site and LabTests)				
19	Forms for On-site test	50		
20	BOD test kit	1		
21	DO test kit	1		
22	DR2000 spectrophotometre	1		
23	COD test kit (COD digestion reagent, Hach reactor Model 45600, COD vial, distilled water)	1		
24	Distilled water	30 litres		
25	Tissue paper	1 box		
26	Good morning towel	5		
27	Sample bottle (container) 1.0 litre	120		
28	Sample bottle (container) 0.5 litre	80		
29	Preserver (HNO_3-50%, nitric acid: pH < 2 (5ml))	1 litre		
30	Preserver (NaOH (pH>12))	0.5 litre		
31	Preserver (H_2SO_4 (5ml))	0.5 litre		
32	Strainer with a diameter of 47mm	1		
33	Membrane filter (Whatman) 0.45µm	1		
34	Portable instrument test kit: pipette, beaker, cylinder (100ml)	1		
35	Marker pen	2		
36	Label	200		
37	Tape	1		
38	Scissors	1		
39	Letter for sending the samples to the laboratory	As required		
40	Reagent (Ferrover Iron p/pillow)	1		
41	Reagent (Nitri Ver 3 p/pillow)	1		
42	Reagent (Buffer p/pillow)	1		
43	Reagent (Sodium Periodate p/pillow)	1		
44	Reagent (Nitra Ver p/pillow)	1		
45	Reagent (Cellulose membrane filter)	1		
46	Reagent (Microfibre filter)	1		
47	Reagent (pH storage solution)	1		
48	Reagent (Sulfide (PO_4))	1		

3.7 Procedure of Monitoring

3.7.1 Sampling Procedure of Groundwater and Surface Water for In-Situ Test

The measurement of groundwater quality and surface water quality is executed in-situ or at the original place where water samples are taken, in principle. This systematic procedure, as a matter of routine, should be applied to obtain a representative water sample from each site and to avoid altering the water physically and chemically.

(1) Groundwater

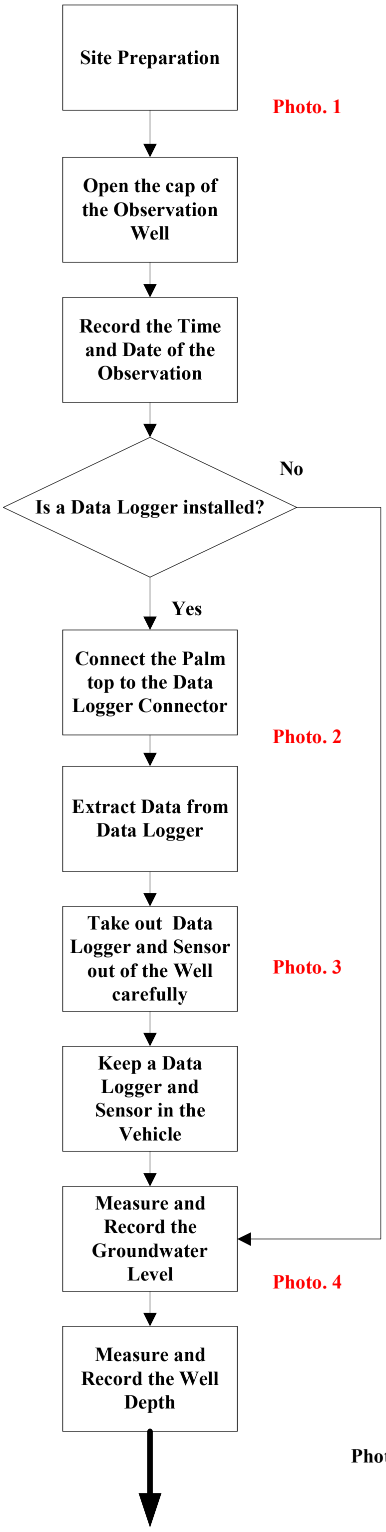
Groundwater sampling should be done after the measurement of groundwater level to avoid the effect of sample taking on the groundwater level. Regarding the in-situ groundwater quality measurement, all measured results shall be recorded on **FORM-1** in **Attachment 3** together with the results of groundwater level measurement.

Sampling procedures for groundwater are shown in **Annex Figure H.3.4** and summarised as follows:

1. Measure and record the groundwater level and well depth referred to in **Annex Figure H.3.2.**
2. Prepare KLL-Q for in-situ measurement. Detailed instructions on how to handle and operate the equipment at the site are given in **Attachment 2.**
3. If the well diameter is enough to insert KLL-Q, conduct in-situ measurement by KLL-Q at 3 or 4 different water depths (ex. 10m, 20m, 30m and screen depth) and record the measured parameters. Refer to **Annex Table H.3.9** for parameters to be measured in-situ. If the diameter is too small to insert KLL-Q, skip to the next step.
4. Prepare to pump up the groundwater. Insert a submersible pump into the well and fix it at the same depth as the well screen.
5. Turn on the engine of generator.
6. Start the pump and a stopwatch simultaneously. Record the starting time on the form.
7. Measure and record the in-situ parameters in the pail of KLL-Q after 10, 20 and 30 minutes from the start of pumping. If there is not enough water in the well for pumping up, adjust the power of the pump and measure parameters after 15 and 30 minutes from the starting time. This work is made for confirming the stability of groundwater quality.
8. During pumping up, prepare some containers for collecting samples for the on-site and laboratory tests.
9. Measure and record the in-situ parameters by KLL-Q after 35 minutes from the start of pumping, and compare them with the previous values.

10. If the stability of each parameter value is confirmed, collect water samples for the on-site and laboratory tests. If the parameters are not stable, continue to pump up the groundwater until a stable value is confirmed.
11. Stop the pumping up and switch off the engine of generator.
12. Take out the pump carefully.
13. If there is a data logger and sensor for recording groundwater level, put them back into the well carefully.
14. Close the cap of the well and lock it securely.

Photo. 1 Site preparation by setting umbrellas as sunshade



To the next page

Photo. 2 Extraction of data from data logger

Photo. 3 Taking out data logger and sensor from the well

Photo. 4 Measurement of groundwater level and well depth

Annex Figure H.3.4 Procedures of Groundwater Sampling

From the previous page

Conduct In-situ Measurement by KLL-Q at 3 or 4 Different Water Depths (ex. 10m, 20m, 30m and Screen Depth) and Record the Parameters

In-situ Measurement Parameters
- pH
- Water Temperature
- Electric Conductivity (EC)
- Turbidity
- Dissolved Oxygen
- Colour

Photo. 5 and 6

Photo. 5 Preparation for setup of the pump

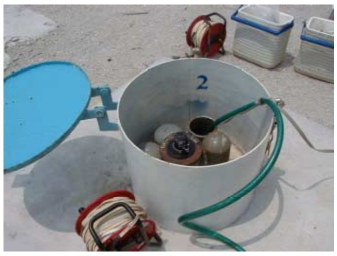


Photo. 6 Holding of a hose by rope

Prepare Pumping Up the Groundwater

Photo. 7

Start the Pump and a Stopwatch Simultaneously

Photo. 7 Starting the pump

Measure and Record the In-situ Parameters by KLL-Q after 10, 20 and 30 Minutes from the Start of Pumping

Photo. 8

Photo. 8 Measurement during pumping up

Measure and Record the In-situ Parameters by KLL-Q after 35 Minutes from the Start of Pumping, and compare them with the above value

Are the Parametres by KLL-Q Stable?

No → Continue to Pump up the Water

Yes → Collect Water Samples

Photo. 9

On-site test
Ipoh Laboratory
Private Laboratory

Photo. 10

Photo. 10 Containers after sampling

Close the Cap of the Observation Well

Photo. 9 Collection of water samples

Annex Figure H.3.4 Procedure of Groundwater Sampling (Cont'd.)

(2) Surface Water

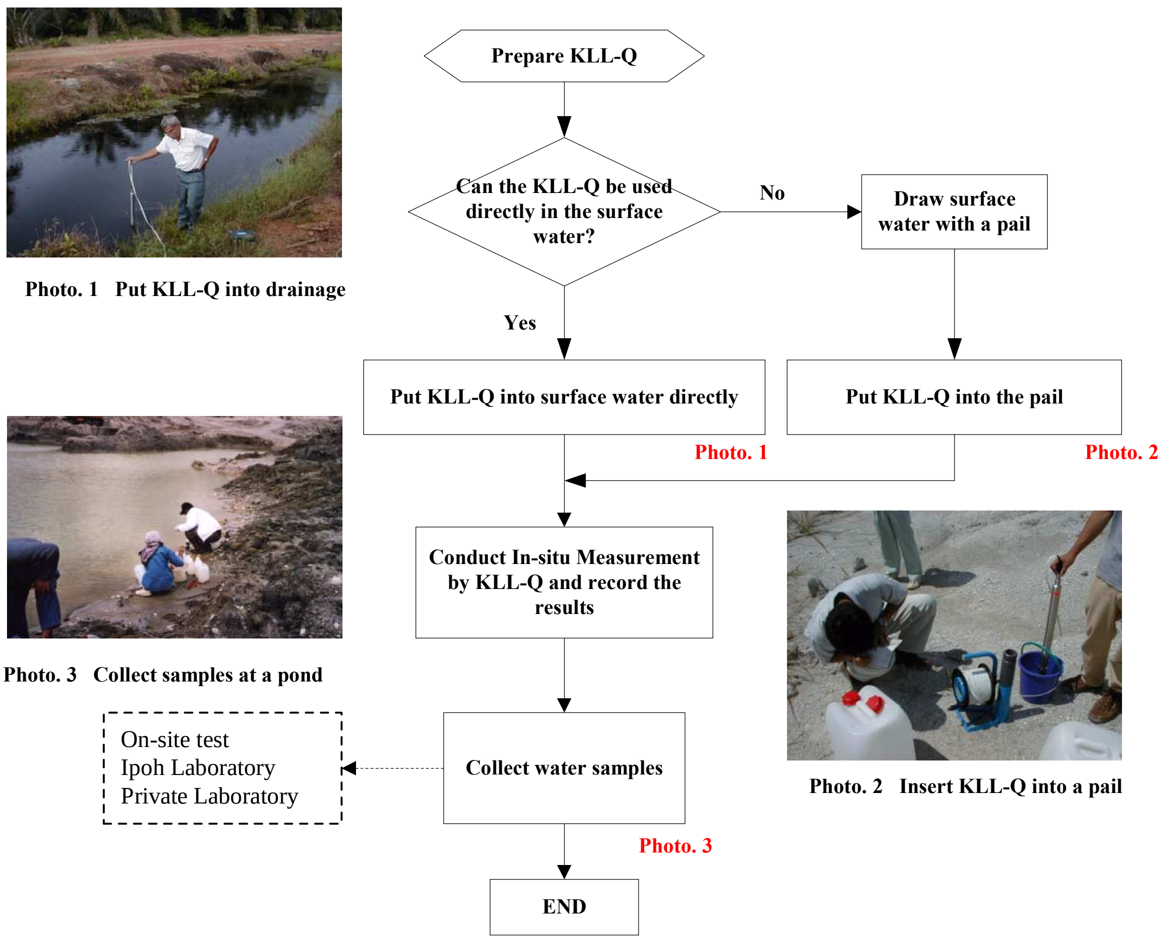
The procedure of the surface water sampling is fundamentally the same way as those of the groundwater sampling, as shown in **Annex Figure H.3.5**. In terms of in-situ surface water quality measurement, all measured results shall be recorded on **FORM-2** in **Attachment 3.**

The procedure of surface water sampling is summarised as follows:

(a) If it is possible to use KLL-Q directly into the surface water, insert KLL-Q into the river or pond. If impossible, draw surface water with a pail and put KLL-Q into it.

(b) Measure and record the in-situ parameters by KLL-Q.

(c) Collect water samples for the on-site and laboratory tests.



Annex Figure H.3.5 Procedure of Surface Water Sampling

3.7.2 On-Site Test

On-site test shall be conducted by JMG staff at the site or in the office using sample water collected during the pumping for in-situ test. The following eight (8) parameters shall be analysed on-site:

(1) Biochemical Oxygen Demand (BOD)

(2) Chemical Oxygen Demand (COD)

(3) Manganese (Mn)

(4) Iron (Fe)

(5) Total Iron (Fe-T)

(6) Nitrate Nitrogen (NO_3-N)

(7) Nitrite Nitrogen (NO_2-N)

(8) Phosphate (PO_4)

The procedure of measurement of each parameter is described as follows:

(1) Biological Oxygen Demand (BOD)

(a) Introduction

BOD contents both in groundwater and surface water shall be measured in the field using HACH DR/2000 Spectrophotometer and HACH Reactor Model 45600.

BOD is the amount of oxygen, expressed in mg/l or parts per million that bacteria take from the water when they oxidise organic matter. Organic matter can be oxidised (combined with oxygen) by burning, by being digested in the bodies of animals and human beings, or by biochemical action of bacteria. Bacteria in water live and multiply when organic matter is available for food and oxygen is available for oxidation. About one-third of the food bacteria consume becomes the solid organic cell material of the organisms. The other two-thirds is oxidised to carbon dioxide and water by the biochemical action of the bacteria on the oxygen dissolved in the water. To determine BOD, the amount of oxygen the bacteria use is calculated by comparing the amount left at the end of five days with the amount known to be present at the beginning. At room temperature, the amount of oxygen dissolved in water is 8 mg/l. At freezing, it increases to 14.6 mg/l; it also increases at high barometric pressures (low altitudes). At the boiling point, the solubility of oxygen is zero.

During the five-day period of a BOD test, the bacteria oxidise mainly the soluble organic matter present in the water. Very little oxidation of the solid (insoluble) matter occurs in that short time. The bacteria grow somewhat slowly, so that in a five-day period, at 20°C, the biological oxidation is never complete. It is approximately 80 percent complete in five days but is not 100 percent complete even after 20 days. When this happens, the test result is lower than the actual amount of organic matter present would suggest.

(b) Equipment

Required equipment for execution of the on-site test is listed below.

(i) HACH DR/2000 Spectrophotometer;

(ii) COD Reactor Model 45600 with shield;

(iii) Vial contains BOD Digestion Reagent;

(iv) Pipette;

(v) Tissue paper;

(vi) Water sample;

(vii) Deionised water;

(viii) Plastic Sample Bottle;

(ix) BOD Nutrient Buffer Pillow;

(x) Nitrification Inhibitor;

(xi) Incubator; and

(xii) BOD Glass Bottle.

(c) Method

<u>Sample Preparation</u>

1. Prepare the water sampling dissolver using BOD Nutrient Buffer Pillow.
2. Identify the ratio of total sample volume.
3. Measure with pipette a series of water samples (groundwater and surface water), at least four (4) or better five (5) or six (6) parts of samples, which are added together in a 300ml BOD bottle covered with glass. Stir the sample before each part is piped in.
4. Mix the samples in every bottle with two drops of Nitrification Inhibitor (approximately 0.16g).
5. Fill every bottle up to the edge with sample added by Nutrient Buffer or otherwise. Avoid making bubbles.

6. Cover the bottle and avoid bubbles from being trapped inside it. Press the bottle cover securely and overturn the bottle a few times to mix the contents properly.
7. Add dissolver water sufficiently to make seal water.
8. Cover every bottle with plastic cover and put the bottled sample in an incubator at approximately 20°C. Store the sample in the dark for five (5) days.

Clarification of BOD Amount

1. Prepare the water sampling dissolver using BOD Nutrient Buffer Pillow.
2. Identify the ratio of total sample volume.
3. After five (5) days, clarify total BOD with the Dissolve Oxygen method, or use dissolve oxygen probe.
4. Clarify total BOD by method (please refer to the copy of procedure of Method 8043 enclosed):
   - Plot mg/l DO remaining in every sample diluted compared to ml sample collected, then draw a straight line through every dot plotted.
   - To calculate the BOD, use the following equation similar to the BOD equation in the Standard Method:

mg/l BOD = (A x 300) - B + C

where,

A = slope

B = Y intercept

C = DO sample

Method to write the formula is as follows:

mg/l BOD = (Steep x 300) – Y intercept + DO sample

BOD test

1. Take a water sample at 200m; for example, if DO%7.5mg/l is taken, DO1 = 7.5.
2. Add dilution water to the water sample.
3. Incubate for five (5) days at 20°C.
4. Measure again DO sample (DO2).
5. BOD = DO1 – DO2/P; where P = 200ml x 7.5 mg/l/300

Data Storage

Fill up BOD value in Form Kajibumi 7802a.

(2) Chemical Oxygen Demand (COD)

(a) Introduction

COD contents both in groundwater and surface water shall be measured at the field using HACH DR/2000 Spectrophotometer and HACH Reactor Model 45600.

(b) Equipment

Equipment required for the execution of on-site test is listed below.

(i) HACH DR/2000 Spectrophotometer;

(ii) COD Reactor model 45600 with partition;

(iii) Vial containing COD Digestion Reagent;

(iv) Pipette;

(v) Tissue paper;

(vi) Water Sample;

(vii) Deionised water; and

(viii) Plastic sample bottle.

(c) Method

<u>Sample Preparation</u>

1. Prepare the water sampling dissolver using BOD Nutrient Buffer Pillow.
2. Prepare the sample collected from the well or surface (river, lake etc.).
3. Turn on COD reactor. Preheat at 150°C and put partition.
4. Open the vial containing COD Digestion Reagent and pipette 200ml water sample into the vial.
5. Cover the vial and overturn it several times, then put the vial into the preheat reactor.
6. Prepare blank sample by following the method above and replace the sample with deionised water.
7. Heat the vial for two (2) hours.
8. Turn off the reactor and wait for 20 minutes so that the vial will turn colder to 120°C or less.
9. Overturn the vial and put it on a rack and wait until the temperature goes down to room temperature.
10. Use the colorimetric method to clarify the COD value.

Colorimetric Determination

1. Turn on the HACH DR/2000 Spectrophotometer and put in the program number by pressing 430. The display will show: **DIAL nm TO 420**.
2. Then dial nm 420 and press **READ/ENTER** button.
3. Place the blank into the adapter and place the cover on the adapter.
4. Press **ZERO**. The display will show: **WAIT,** then: **0. mg/l COD L**
5. Place the water sample into the adapter and place the cover on the adapter.
6. Press **READ/ENTER** button. The display will show: **WAIT,** then the result in mg/l COD will be displayed.

Data Storage

Fill up COD value in Form Kajibumi 7802a.

(3) Manganese (Mn)

(a) Measurement Range

0 to 20.0 mg/l

(b) Reagent Powder Pillows

Buffer Powder Pillow and Sodium Periodate Powder Pillow

(c) Method

1. Enter the stored program for manganese (Mn) periodate oxidation.

   Press: **295 READ/ENTER**
   The display will show **DIAL nm to 525**.

2. Rotate the wavelength dial until the small display shows: **525 nm**.

3. Press: **READ/ENTER**.

   The display will show: **mg/l Mn H**.

4. Fill a clean sample cell with 25ml of sample.

5. Add the contents of one Buffer Powder Pillow, citrate type. Swirl to mix.

   (Note: For proof of accuracy, use a 5.0 mg/l manganese standard solution.)

6. Add the contents of one Sodium Periodate Powder Pillow to the sample cell (the prepared sample). Swirl to mix.

7. Press: **SHIFT TIMER**.

   A 2-minute reaction period will begin.
   (Note: A violet colour will form if manganese is present.)

8. When the timer beeps the display will show: **mg/l Mn H**.

   Fill another sample cell with 25 ml of sample (the blank).

9. Place the blank into the cell holder, and close the light shield.

10. Press: **ZERO**.

    The display will show: **WAIT**.
    Then: **0.0 mg/l Mn H**.

11. Within eight (8) minutes after the timer beeps, place the prepared samples into the cell holder. Close the light shield.

    (If more than five (5) minutes elapses after the blank and press: **ZERO**. *Insert the prepared sample and press*: **READ/ENTER**.*)*

12. Press **READ/ENTER**.

    The display will show: **WAIT**.
    Then the results in **mg/L Mn H** will be displayed.
    (Note: Rinse the sample cell immediately after use to remove all cadmium particles. Clean the sample cells with soap and a brush.)

(4) Iron (Ferrous: Fe)

(a) Measurement Range

0 to 3.00 mg/l

(b) Reagent Powder Pillows

FerroVer Iron Reagent Powder Pillow

(c) Method

1. Enter the stored program for ferrous iron (Fe^{2+}), FerroVer, powder pillows.

   Press: **255 READ/ENTER**
   The display will show **DIAL nm to 510**.

2. Rotate the wavelength dial until the small display shows: **510 nm**.

3. Press: **READ/ENTER**.

   The display will show: **mg/l Fe^{2+}**.

4. Fill a clean sample cell with 25ml of sample.

   (Note: For proof of accuracy, use a 1.0 mg/l ferrous iron standard solution.)

5. Add the contents of one Ferrous Iron Reagent powder pillow to the sample cell. Swirl to mix.

   (Note: An orange colour will form if iron is present.)

6. Press: **SHIFT TIMER**.

   A 3-minute reaction period will begin.

   (Note: Samples containing visible rust should be allowed to react at least five (5) minutes.)

7. When the timer beeps the display will show: **mg/l** $\mathbf{Fe^{2+}}$.

   Fill another sample cell with 25 ml of sample (the blank).

8. Place the blank into the cell holder, and close the light shield.

9. Press: **ZERO**.

   The display will show: **WAIT**.
   Then: **0.00 mg/l** $\mathbf{Fe^{2+}}$.

10. Place the blank into the cell holder, and close the light shield.

    (If more than five (5) minutes elapses after the timer beeps, **ZERO SAMPLE** *may appear. If so, remove the prepared sample. Insert the blank and press:* **ZERO**. *Insert the prepared sample.)*

11. Press **READ/ENTER**.

    The display will show: **WAIT**.
    Then the results in **mg/L** $\mathbf{Fe^{2+}}$ will be displayed.
    (In the constant-on mode, pressing **READ/ENTER** *is not required.* **Wait** *will not appear. When the display stabilizes, read the result.)*

    (Note: Rinse the sample cell immediately after use to remove all cadmium particles. Clean the sample cells with soap and a brush.)

(5) Total Iron (Fe-T)

(a) Measurement Range

0 to 3.00 mg/l

(b) Reagent Powder Pillows

FerroVer Iron Reagent Powder Pillow

(c) Method

1. Enter the stored program for iron (Fe), FerroVer, powder pillows.

   Press: **265 READ/ENTER**
   The display will show **DIAL nm to 510**.

2. Rotate the wavelength dial until the small display shows: **510 nm**.

3. Press: **READ/ENTER**.

   The display will show: **mg/l Fe FV**

4. Fill a clean sample cell with 25ml of sample.

   (Note: For proof of accuracy, use a 1.0 mg/l iron standard solution.)

5. Add the contents of one FerroVer Iron Reagent Powder Pillow to the sample cell. Swirl to mix.

   (Note: An orange colour will form if iron is present.)

6. Press: **SHIFT TIMER**.

   A 3-minute reaction period will begin.
   (Note: Samples containing visible rust should be allowed to react at least five (5) minutes.)

7. When the timer beeps the display will show: **mg/l Fe FV**.

   Fill another sample cell with 25 ml of sample (the blank).

8. Place the blank into the cell holder, and close the light shield.

   (Note: For turbid samples, treat the blank with one 0.2-gram scoop of RoVer Rust Remover. Swirl to mix.)

9. Press: **ZERO**.

   The display will show: **WAIT**.
   Then: **0.00 mg/l Fe FV**

10. Within 30 minutes after the timer beeps, place the prepared samples into the cell holder. Close the light shield.

    (If more than five (5) minutes elapses after the timer beeps, **ZERO SAMPLE** *may appear. If so, remove the prepared sample. Insert the blank and press:* **ZERO**. *Insert the prepared sample.)*

11. Press **READ/ENTER**.

    The display will show: **WAIT**.
    Then the results in **mg/l Fe FV** will be displayed.

(In the constant-on mode, pressing **READ/ENTER** *is not required.* **Wait** *will not appear. When the display stabilizes, read the result.)*

(Note: Rinse the sample cell immediately after use to remove all cadmium particles. Clean the sample cells with soap and a brush.)

(6) Nitrate Nitrogen (NO_3-N): HR

(a) Measurement Range

0 to 30.0 mg/l

(b) Reagent Powder Pillows

NitraVer 5 Nitrate Reagent Powder Pillow

(c) Method

1. Enter the stored program for high range nitrate nitrogen (NO_3-N) powder pillows.

   Press: **355 READ/ENTER**
   The display will show **DIAL nm to 500**.

2. Rotate the wavelength dial until the small display shows: **500 nm**.

3. Press: **READ/ENTER**.

   The display will show: **mg/l NO_3-H**

4. Fill a clean sample cell with 25ml of sample.

   (Note: For proof of accuracy, use a 10 mg/l nitrate nitrogen standard solution.)

5. Add the contents of one NitraVer 5 Nitrate Reagent Powder Pillow to the sample cell (the prepared sample). Shake to dissolve.

   (Note: A pink colour will develop if nitrate nitrogen is present.)

6. Press: **SHIFT TIMER**.

   Shake the cell vigorously until the timer beeps in one minute.

   (Note: A deposit of unoxidized metal will remain after the NitraVer 5 Nitrate Reagent Powder dissolves. The deposit will have no effect on test results.)

7. When the timer beeps press: **SHIFT TIMER**.

   A 15-minute reaction period will begin.

8. When the timer beeps the display will show: **mg/l N NO_3-H**.

   Fill another sample cell with 25 ml of sample (the blank).

9. Place the blank into the cell holder, and close the light shield.

10. Press: **ZERO**.

    The display will show: **WAIT**.
    Then: **0.0 mg/l N NO_3-H**

11. Remove the stopper. Place the prepared sample into the cell holder. Close the light shield.

12. Press **READ/ENTER**.

    The display will show: **WAIT**.
    Then the results in **mg/l nitrate nitrogen (NO_3-N)** will be displayed.

    (Note: Rinse the sample cell immediately after use to remove all cadmium particles. Clean the sample cells with soap and a brush.)

(7) Nitrite Nitrogen (NO_2-N): LR

(a) Measurement Range

0 to 0.300 mg/l

(b) Reagent Powder Pillows

NitriVer 3 Nitrite Reagent Powder Pillow

(c) Method

1. Enter the stored program for low range nitrite nitrogen (NO_2-N) powder pillows.

   Press: **371 READ/ENTER**
   The display will show **DIAL nm to 507**.

2. Rotate the wavelength dial until the small display shows: **507 nm**.

3. Press: **READ/ENTER**.

   The display will show: **mg/l NO_2-L** .

4. Fill a clean sample cell with 25ml of sample.

   (Note: For proof of accuracy, use a 0.10 mg/l nitrite nitrogen standard solution.)

5. Add the contents of one NitriVer 3 Nitrite Reagent Powder Pillow to the sample cell (the prepared sample). Shake to dissolve.

   (Note: A pink colour will develop if nitrite nitrogen is present.)

6. Press: **SHIFT TIMER**.

   A 15-minute reaction period will begin.

7. When the timer beeps the display will show: **mg/l N NO_2-L**.

   Fill a second sample cell with 25 ml of sample (the blank).

8. Place the blank into the cell holder, and close the light shield.

9. Press: **ZERO**.

   The display will show: **WAIT**.
   Then: **0.00mg/l N NO_2-L**.

10. Remove the stopper. Place the prepared sample into the cell holder, and close the light shield.

11. Press **READ/ENTER**.

    The display will show: **WAIT**.
    Then the results in **mg/L nitrite expressed as nitrogen (NO_2-N)** will be displayed.

    (Note: Clean the sample cells with soap and a brush.)

(8) Phosphate (PO_4)

(a) Measurement Range

0 to 2.50 mg/l

(b) Reagent Powder Pillows

PhosVer 3 Reagent Powder Pillow

(c) Method

1. Enter the stored program for reactive phosphorus (PO_4^{3-}) powder pillows.

   Press: **490 READ/ENTER** (for units of mg/l PO_4^{3-}) or
   Press: **496 READ/ENTER** (for units of mg/l P)
   The display will show **DIAL nm to 890**.

2. Rotate the wavelength dial until the small display shows: **890 nm**.

3. Press: **READ/ENTER**.

The display will show: **mg/l PO_4^{3-} PV** or **mg/l P PV**.

4. Fill a clean sample cell with 25ml of sample.

   (Note: For proof of accuracy, use a 1.0 mg/l phosphate (0.33 mg/l P) standard solution.)

5. Add the contents of one PhosVer 3 Reagent Powder Pillow to the sample cell (the prepared sample). Swirl to dissolve.

   (Note: A blue colour will form if phosphate is present.)

6. Press: **SHIFT TIMER**.

   A 2-minute reaction period will begin.

7. When the timer beeps the display will show: **mg/l P PV**.

   Fill a second sample cell with 25 ml of sample (the blank).

8. Press **ZERO**.

   The display will show: **WAIT**.
   Then: **0.00mg/l PO_4^{3-} PV or 0.00 mg/l P PV**

9. Place the prepared sample into the cell holder, and close the light shield.

10. Press **READ/ENTER**.

    The display will show: **WAIT**.
    Then the results in **mg/L PO_4^{3-}** or **mg/l P PV** will be displayed.

    (Note: Clean the sample cells with soap and a brush.)

(9) References

References as listed below may help when detailed information is required.

1. MK-JPKSj, Quality Manual (Section 4.9).
2. HACH DR/2000 Spectrophotometer Handbook, Procedures Manual; HACH Company, USA, 1993.
3. HACH Portable Dissolved Oxygen Meter Model 16046 Manual; HACH Company, USA, 1991.

FORM-3 in **Attachment 3** shall be used for recording measurement results of on-site test. Recorded forms should be kept properly after measurement together with other forms.

3.7.3 Delivery of Samples to Laboratories

Apart from parameters that can be measured by KLL-Q, i.e., in-situ parameters and on-site test parameters, chemical tests in a laboratory regarding heavy metals, chemical substances and some organic matters shall be carried out using sampling water after pumping up.

The announcement of implementing the regular monitoring in advance to the Ipoh laboratory and a private laboratory is very important for preparing the laboratory tests before starting the monitoring.

After all sampling works are finished, containers (samples) must be sent to each laboratory immediately.

4. LAND SUBSIDENCE

4.1 Objective of Land Subsidence Monitoring

The objective of the monitoring is to observe land subsidence in the Lower Langat Basin as a part of establishment of level survey network.

The land subsidence measurement is an important monitoring for the groundwater environment because land subsidence is one of the negative impacts caused by groundwater extraction. The land subsidence measurement network has been established through the Study and the monitoring work by using this network should be conducted continuously.

4.2 Frequency of Monitoring

First order levelling survey for shallow benchmarks of 20 locations from each corresponding datum point shall be conducted once a year.

Retrieval of the data from a data logger installed at Kajibumi Well Field 2 (hereinafter referred to “Kajibumi WF2”) shall be carried out every two months. The period of memory storage capacity of the data logger is about two (2) months, which is the same period as that of the groundwater level measurement.

The shallow benchmarks and deep datum set at 20 locations should be respectively maintained in a good condition by clearing grasses and weeds at the site. This maintenance work shall be conducted every four (4) months.

4.3 Method of Measurement

The established network for land subsidence monitoring consists of a total of 20 shallow benchmarks (Numbers BM 1 to 20) with 20 corresponding datum points (Numbers DP 1 to 20) for the monitoring of land surface subsidence, and one (1) borehole extensometer (Number EX5) for monitoring the change in upper clayey layer thickness at the Kajibumi WF2.

The land subsidence has been measured by the comparison of elevations between the datum point and the benchmark at each location.

On the other hand, the measurement by the extensometer with a data logger has been conducted automatically.

The same equipment has been used in the groundwater level measurement.

4.4 Location of Measurement

Geographical coordinates and elevation measured by the first order levelling of the deep datum are presented in **Annex Table H.3.13**. The geographical coordinates of the shallow benchmarks are presented in **Annex Table H.3.14**. The location of the shallow benchmarks, datum points and borehole extensometer is illustrated in **Annex Figure H.3.6**.

Annex Table H.3.13 Geographical Coordination of the Datum Points

Number	Longitude	Latitude	RSO*		Elevation (m)
			X (m)	Y (m)	
DP 1	101° 31’34.6”	2° 53’20.3”	392184.74050	319761.32817	4.76077
DP 2	101° 30’01.4”	2° 52’33.0”	389302.93231	318315.67667	4.30952
DP 3	101° 37’14.7”	2° 52’42.7”	402684.55345	318580.79221	7.56103
DP 4	101° 34’13.7”	2° 50’48.7”	397086.55812	315092.71261	4.92062
DP 5	101° 31’32.8”	2° 50’33.0”	392116.36891	314622.68158	2.91833
DP 6	101° 36’19.2”	2° 49’56.1”	400958.39817	313467.72448	6.16016
DP 7	101° 35’47.0”	2° 48’32.5”	399957.82655	310902.28011	5.32261
DP 8	101° 33’12.5”	2° 49’10.3”	395189.15981	312074.87990	3.05286
DP 9-10	101° 30’17.5”	2° 48’28.9”	389781.35903	310816.56493	3.36848
DP11	101° 27’29.2”	2° 49’10.8”	384586.78463	312116.69903	2.56594
DP12	101° 36’13.1”	2° 55’33.6”	400794.95996	323834.55479	9.10890
DP13	101° 28’19.9”	2° 46’46.9”	386141.44785	307692.55094	3.66470
DP14	101° 31’16.6”	2° 47’24.4”	391601.71316	308830.81799	3.57333
DP15	101° 35’00.7”	2° 47’45.0”	398524.41690	309446.70907	3.29037
DP16	101°37’09.3”	2° 47’44.2”	402496.00260	309412.66709	3.50590
DP17	101° 39’22.3”	2° 46’56.2”	406600.06605	307928.70065	4.42807
DP18	101° 32’10.1”	2° 45’29.2”	393245.37528	305288.20960	5.01820
DP19	101° 38’03.4”	2° 45’22.9”	404156.62979	305068.61909	4.70254
DP20	101° 41’38.6”	2° 44’45.7”	410800.36177	303910.69217	6.96375

Note: * ”RSO” stands for Rectified Skew Orthomorphic that is a coordinate system widely used in Malaysia.
Source: JICA Study Team

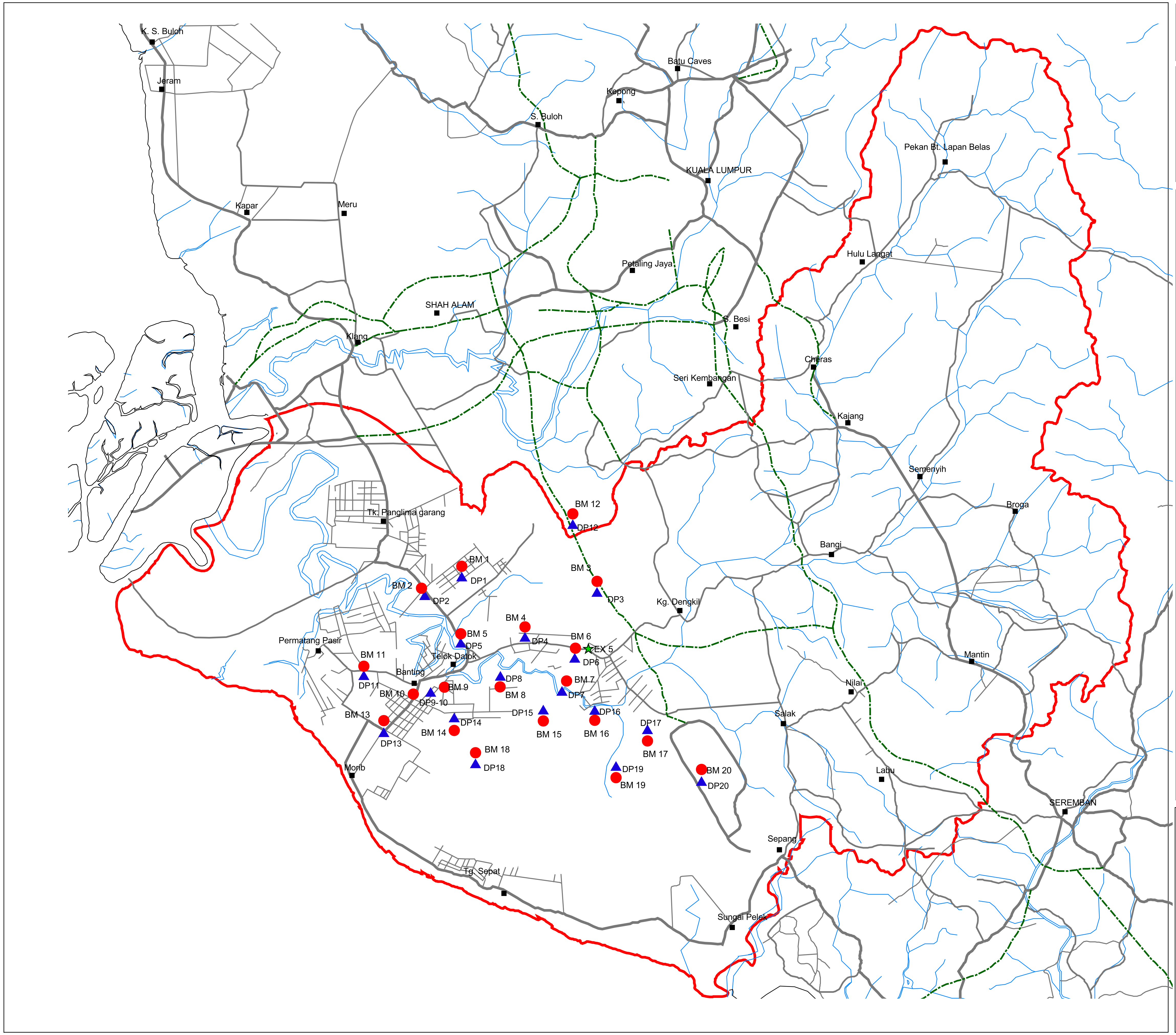
Annex Table H.3.14 Geographical Coordination of the Benchmark Stations

Number	Longitude	Latitude	RSO*	
			X (m)	Y (m)
BM 1	101 ° 31’34.7”	2 ° 53’20.4”	392187.83629	319764.39205
BM 2	101 ° 29’53.8”	2 ° 52’31.2”	389068.08996	318260.97908
BM 3	101 ° 37’14.6”	2 ° 52’42.7”	402681.46537	318580.79958
BM 4	101 ° 34’13.6”	2 ° 50’48.7”	397083.46989	315092.72012
BM 5	101 ° 31’32.9”	2 ° 50’32.9”	392119.44958	314619.60230
BM 6	101 ° 36’20.4”	2 ° 49’56.9”	400995.51585	313492.20827
BM 7	101 ° 35’58.7”	2 ° 48’41.2”	400319.79987	311168.64214
BM 8	101 ° 33’11.3”	2 ° 49’10.9”	395152.14481	312093.40008
BM 9	101 ° 30’52.0”	2 ° 48’40.7”	390847.76271	311176.36856
BM10	101 ° 29’33.9”	2 ° 48’22.8”	388434.33526	310632.55901
BM11	101 ° 27’29.4”	2 ° 49’10.8”	384592.96149	312116.68329
BM12	101 ° 36’13.1”	2 ° 55’33.5”	400794.95253	323831.48330
BM13	101 ° 28’19.9”	2 ° 46’47.1”	386141.46333	307698.69436
BM14	101 ° 31’16.6”	2 ° 47’24.3”	391601.70558	308827.74633
BM15	101 ° 35’00.7”	2 ° 47’45.1”	398524.42428	309449.78066
BM16	101 ° 37’09.4”	2 ° 47’44.4”	402499.10548	309418.80290
BM17	101 ° 39’21.8”	2 ° 46’55.7”	406584.58858	307913.37883
BM18	101 ° 32’10.2”	2 ° 45’29.3”	393248.47134	305291.27372
BM19	101 ° 38’03.4”	2 ° 45’23.1”	404156.64414	305074.76223
BM20	101 ° 41’38.6”	2 ° 44’45.4”	410800.34085	303901.47760

Note: * ”RSO” stands for Rectified Skew Orthomorphic that is a coordinate system widely used in Malaysia.
Source: JICA Study Team

Annex Figure H.3.6

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

N W E S

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

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

CTI Engineering International Co., Ltd.

OYO CORPORATION

4.5 Preparatory Works

This survey work has to be subcontracted to a private company since each levelling survey requires the first class order. Negotiation with the private survey company has to be made before starting the first order leveling. After contracting, detail schedule of the work has to be discussed.

Annex Table H.3.15 List of Preparatory Work for Land Subsidence Monitoring

Work Item	Required Completion Time	References
Arrangement of a private survey company contract	1 month before the fieldwork	-

4.6 List of Required Equipment and Materials for Fieldwork

A list of equipment for fieldwork is shown in **Annex Table H.3.16**; however, this list covers only measurement by extensometer only since the first order leveling is assumed as subcontracted. The required equipment should be prepared before the fieldwork.

Annex Table H.3.16 List of Required Equipment and Materials for Fieldwork of Land Subsidence Monitoring

No.	Equipment	Quantity	Check	Remarks
1	Instrument of data retriever	1		For the extensometer
2	Key	1		-ditto-

4.7 Procedure of Monitoring

4.7.1 Data Retrieval from a Data Logger at the Kajibumi WF2

The data extraction procedure from data logger is fundamentally in the same way as that of groundwater level described in **Chapter 2** of this manual.

Raw data of extensometer consists of a header and four columns of measured data, namely, reference number, measurement time, measurement time and date, and relative movement of the ground. Data is stored in Microsoft Excel Format (.xls).

Before transferring the data to the database of MIS, movement of the ground level should be calculated from the reading of extensometer (relative movement of the ground) by using the following formula:

$$GLEL = SPEL_0 + (EX - EX_0)/1000$$

where,

GLEL : Elevation of ground level (m)

$SPEL_0$: Elevation of survey point (m.s.l.: m); 5.727 m

EX : Reading of extensometer (mm)

EX_0 : Initial reading of extensometer (mm); -60.22186 mm (March 8, 2001)

If the position of the displacement transducer of the extensometer is shifted during the long-term monitoring program, the initial reading of the extensometer should be changed to the new value.

4.7.2 First Order Levelling

A survey company shall conduct first order leveling survey for the shallow benchmarks of 20 locations from each corresponding datum points once a year. Precise directions to the survey company are very important to get a highly precise result.

(1) Standard Benchmarks Used in the Levelling

The first order precise levelling was carried out in accordance with standards or guidelines of the Department of Survey and National Mapping Malaysia (hereinafter referred to "JUPM"). In the first session, the first order precise levelling was executed from the nearest first order standard benchmark, i.e., S 0067, installed by JUPM in all the datum points and new benchmark stations specified in **Annex Tables H.3.13 and H.3.14** above.

A separate levelling to Standard Benchmark S 0375 was done for checking purposes. The total distance of the levelling work was 124.57 km.

These two (2) JUPM Standard Benchmarks were also used as the height datum in this survey. Their respective height values are shown in **Annex Table H.3.17** below.

Annex Table H.3.17 Height of JUPM Standard Benchmarks

Standard Benchmark Number	Mean Sea Level (metre)	Location
S 0067	3.569	Banting Police Station
S 0375	10.036	Dengkil Police Station

(2) Work Procedure

The precise levelling was conducted in the following procedure.

(a) The levelling is carried out in sections of 1 km loop along the route. This means a loop will have a total distance of approximately 2 km.

(b) Temporary benchmark (TBM) is installed at every 1 km (loop) by means of nail on permanent, solid and stable structure such as metal road or building foundation. In places where there are no permanent structures, nail on pipe is used.

(c) Two peg tests are carried out every morning to ensure that the level instruments are in good working condition before carrying out the actual levelling. Line of sight (collimation error) correction should not exceed 60 seconds during the test. If the tolerance is less than 60 seconds, then the line of sight correction is stored in the instrument. This correction is automatically applied to the level readings each time an observation is recorded in the RAM cards.

(d) At the end of each working day, instead of one (1), three (3) TBMs are installed. On the next day, the surveyor shall start his work by first checking those three TBMs in a small loop. With this test, the surveyor is confident that his datum for that day is reliable and good.

(3) Precaution

The misclosure for each loop shall not exceed $3\sqrt{K}$ mm, where K is the distance in kilometre. In order to obtain such accuracy, the following precautions were taken during the levelling work:

(a) Sighting distance for back and foresight was maintained almost equal. By doing this, collimation error will be eliminated.

(b) A maximum sighting distance of approximately 40m between the staff and level instrument was maintained to avoid shimmering effect.

(c) An observation tolerance value of 0.25 mm was set into the instrument for the back and foresight observation readings. If the tolerance exceeded the value, the surveyor redid his observation accordingly.

(d) Refraction and earth curvature correction option in the instrument were activated during observation. Respective to this, reading of staff that is less than 0.3m from ground level was avoided.

(e) Staff holder was used to hold the staff so that it stands firm during observation. Worker who also holds the staff continuously checked staff's bubble.

(f) Staff base plate was made sure gripping the ground firmly. The turning of staff after foresight reading was made carefully.

(g) The instrument was protected from heat by direct sunlight by an umbrella.

(h) To avoid shimmering effect, observation was done only in early morning and when the climate is permissible in the afternoon.

The main problems that the surveyors faced while doing their work were the heavy vehicles such as lorries and trailers that moved along the route causing vibration, which disturbed the observation and made the tolerance out. If misclosure of the loop exceeds the limit, the surveyor shall redo that particular loop again.

(4) Processing and Adjustment

All observations done were recorded into the RAM Card of each instrument on the site. The data from the cards were downloaded into a computer for processing and adjustment of heights on each working day. The software used for processing is as shown in **Annex Table H.3.18**. Minimum constraint adjustment was done by fixing the height of the starting datum of each loop.

Annex Table H.3.18 Instrument and Software Used for Processing and Adjustment the Survey Data

Instrument	Software
Zeiss Dini 10	Dini Line Adjust
Wild NA 3003	Leica LevelPak (Version 1.0)

(5) Horizontal Control

As required, the levelling teams also surveyed the coordinates of all deep datum and benchmarks. Since a high accuracy of horizontal coordinates is not required in this project, GPS locator ***Garmin II Plus***, which has the accuracy of ± 30m, was used to provide the geographical coordinates.

(6) Analysis

For the purpose of checking, the levelling network from Standard Benchmark S 0067 has been extended to Standard Benchmark S 0375. All existing government benchmarks along the route, as listed in **Annex Table H.3.19** below, have been connected. The comparison result between observed heights and government (JUPM) values are also shown.

Annex Table H.3.19 Correlation with Government Benchmarks

Loop No.	From	To	Observed Height	JUPM Height	Difference
4	S 0067	BM 0198	2.89452	2.869	0.02552
21		BM 0957	3.89910	4.044	-0.14490
23		BM 0278	5.49142	5.376	0.11542
25		BM 0955	6.23259	6.183	0.04959
71		BM 0951	22.48827	22.395	0.09327
1		BM 0641	3.71417	3.661	0.05317
73		S 0375	10.11084	10.036	0.07484

The results show that the difference of height ranges from 2.5cm to 14.5cm. Standard benchmark S 0067 has been chosen as the height datum for this project since it is located within the study area. Since this study will correlate with the land cover study as well, it is necessary to reduce all heights to local vertical network. Even though the correlation of height to government benchmarks shows slightly big differences, the observed heights are still useable and reliable for relative monitoring purpose. One reasonable factor of the benchmarks height differences might be the settlement of the benchmark itself due to land subsidence. Most of government benchmarks in the study area were established more than 10 years ago.

4.7.3 Maintenance of Benchmarks and Datum Points

Shallow benchmarks and deep datum set at 20 locations, respectively, shall be cleared of grass and weeds at the site, and be maintained in a good condition.

5. SURFACE WATER LEVEL

5.1 Objective of Surface Water Level Monitoring

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 shall be conducted to obtain the basic hydrological information to be used in the future groundwater simulation.

5.2 Frequency of Monitoring

Retrieval of the data from six (6) data loggers shall be carried out every two months due to the memory capacity of the data logger.

5.3 Method of Measurement

The surface water level measurement has been made by automatic recording equipment with a data logger that is similar to the equipment used in the groundwater level measurement. There are two types of surface water level instruments installed at the Paya Indah Wetland Sanctuary and the Langat River: TD-Diver and SEBA PS-Insider.

5.3.1 TD-Diver

The TD-Diver is a self-recording instrument specially developed for automatic recording of water level and temperature. The TD-Diver uses a built-in pressure transducer and temperature sensor to measure the water level and groundwater temperature accurately within a borehole. The pressure transducer is automatically compensated for the temperature fluctuations giving increased accuracy. The data is stored in its internal memory. The memory can be accessed using a readout unit and a (portable) computer.

5.3.1 SEBA PS-Insider

The SEBA pressure sensor pneumatic gauges type PS-Insider is used for accurate water level measurements. From an integrated mini-compressor with storage tank, air is directed via the proportioning valve and the pressure transmission pipe into the water. The pressure within the pipe corresponds to the static pressure of the water column (h) above the outlet orifice and thus serves as measured variable for the level position. This static pressure of water column is transmitted to a high precision, temperature compensated pressure sensor. In case of water level fluctuation, the pressure sensor sends respectively changed output signal. This output signal, depending on the instrument type, is recorded on a data logger or transferred to an electronically driven servo-motor, which moves the connected writing device to the corresponding actual water level.

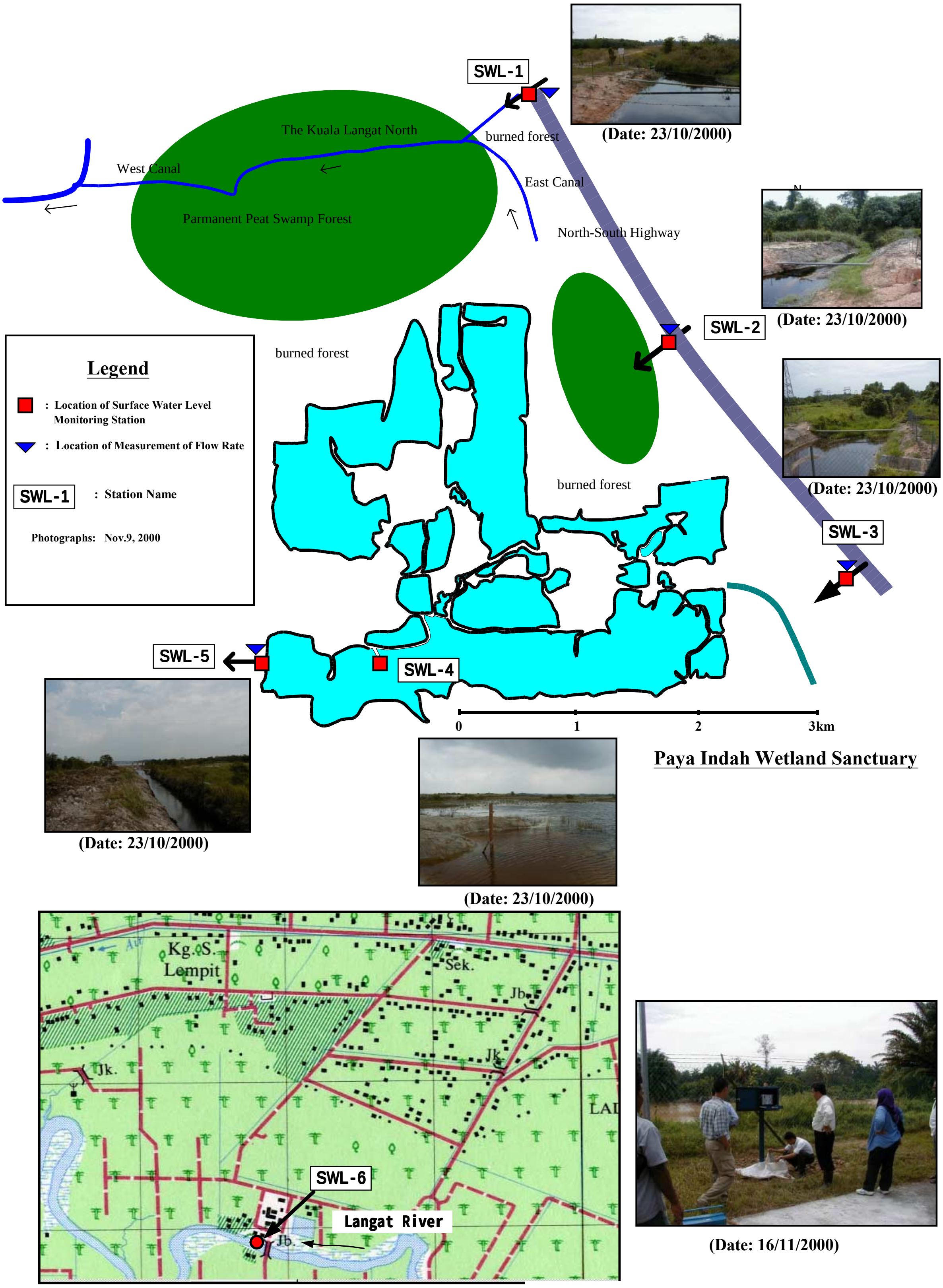
5.4 Location of Measurement

Location and type of surface water level instruments installed at the Paya Indah Wetland Sanctuary and the Langat River are summarised as shown in **Annex Table H.3.20** and **Annex Figure H.3.7**.

Annex Table H.3.20 Location and Type of Surface Water Level Instruments

Station No.	Location	XY-Coordinate	Relevant organisation at the monitoring site*	Instrument type and serial number	Elevation of Bench Mark (m. s. l.)	Elevation of Water Level Sensor (m. s. l.)
SWL-1	Inflow, west side of ELITE Highway, 24.9 km	N02°53.576” E 101° 37.243”	PPN DID ELITE	TD-DIVER SN 19665	9.269	7.787
SWL-2	Inflow, west side of ELITE Highway, 27.45 km	N 02° 52.534” E 101° 38.039”	ELITE DID	TD-DIVER SN 19666	9.586	7.326
SWL-3	Inflow, west side of ELITE Highway, 30.3km	N 02° 51.348” E 101° 38.990”	ELITE DID	TD-DIVER SN 19669	8.151	5.590
SWL-4	The Paya Indah Wetland Sanctuary, Lotus Lake	N 02° 51.681” E 101° 37.580”	MWF	TD-DIVER SN 19670 TD-DIVER (Barometric DIVER) SN 19664	6.639	5.610
SWL-5	Outflow downstream of sluice gate (West edge of Lotus Lake)	N 02° 51.190" E 101° 35.970"	DID	TD-DIVER SN 19671	7.319	5.141
SWL-6	Langat River (Kajibumi Well Field 1)	N 02° 49.167”, E 101° 33.170”	DID JBA	SEBA PS-Insider No. 172	2.846	-1.354

*Acronyms of the organisations stand for the following:
PPNS: *Persatuan Peladang Negri Selangor*, a company that owns land of SWL1.
DID: Drainage and Irrigation Department (JPS: *Jabatan Pengairan dan Saliran*)
MWF: Malaysia Wetlands Foundation
JBA: *Jabatan Bekalan Air,* or Waterworks Department



Paya Indah Wetland Sanctuary

Langat River (Kajibumi Well Field 1)

Annex Figure H.3.7 Location of Surface Water Level Instruments

5.5 Preparatory Works

A notice to the Paya Indah office will be required for the smooth implementation of the work. The schedule of the monitoring and name of persons in charge of the work shall be submitted to the Malaysian Wetlands Foundation (MWF) before the field work.

Annex Table H.3.21 List of Preparatory Work in Advance for Surface Water Level Monitoring

Work Item	Required Completion Time	References
Notice procedure to the Paya Indah Office	2 weeks before the fieldwork	-

5.6 List of Required Equipment and Materials for Fieldwork

A list of equipment for fieldwork is shown in **Annex Table H.3.22**. The required equipment should be prepared before fieldwork.

Annex Table H.3.22 List of Required Equipment and Materials for Fieldwork of Surface Water Level Monitoring

No.	Equipment	Quantity	Check	Remarks
1	Note PC	1		
2	Key of IrDA Interface Connector	1		

5.7 Procedure of Monitoring

5.7.1 Procedure of Data Retrieval

(1) Data Retrieval from TD-Diver

For retrieving the data from TD-Diver (hereinafter referred to as "Diver"), namely, SWL-1, SWL-2, SWL-3, SWL-4 & SWL-5, the following procedure should be carried out.

1. Check the current water level indicated at the stick gauge, and note down the water level value.

2. Remove the Diver from the housing.

3. Connect the read out unit to the PC/laptop, and turn on the computer.

4. Prompt to **'EnviroMon'** software, then open the **'Logger Setting'** window.

5. Open the protecting cap of the Diver and plug it on the appropriate place of the read out unit.

6. Please make sure there is no sand or dirt dropped into the protecting cap and the read out unit.

7. Ensure the read out unit is connected to the correct serial port and select this port in the **'EnviroMon'**.

8. Press on the **'Read Logger Setting'** button.

9. Double-check the instrument's serial number, which is indicated in this window and at the Diver. (The S.N. should tally.)

10. At the main window, click on the **'Data Control'** button.

11. In the **'Data Control'** window, press on the **'Read Data From Logger'** button.

12. To save the data, press **'File'** menu in the main window, and select **'Save Current File As'**.

13. Write the filename in such format as: (Station No.)(Date: day, month). Mon

14. For example: If you save the data for station SWL4 at 6th December 2000.

15. The file name should be: **SWL40612.Mon**

16. Select **'File'** menu in the main window, and select **'exit'**.

In order to prevent the overflow of memory, following procedure should be carried out in case of exceeded period of half a year.

1. Check the current water level indicated at the stick gauge and note down the water level value.

2. Remove the Diver from the housing.

3. Connect the read out unit to the PC/laptop, and turn on the computer.

4. Prompt to **'EnviroMon'** software, then open the **'Logger Setting'** window.

5. Open the protecting cap of the Diver and plug it on the appropriate place of the read out unit.

6. Please make sure that there is no sand or dirt dropped into the protecting cap and the read out unit.

7. Ensure the read out unit is connected to the correct serial port and select this port in the **'EnviroMon'**.

8. Press on the **'Read Logger Setting'** button.

9. Double-check the instrument's serial number, which is indicated in this window and at the Diver. (The S.N. should tally.)

10. Press the **'stop'** button to stop the Diver.

11. At the main window, click on the **'Data Control'** button.

12. In the **'Data Control'** window, press on the **'Read Data From Logger'** button.

13. To save the data, press **'File'** menu in the main window, and select **'Save Current File As'**.

14. Write the filename in such format as: (Station No.)(Date: day, month). Mon

15. For example: If you save the data for station SWL4 at 6^{th} December 2000.

16. The filename should be: **SWL40612.Mon**

17. Press on the **'Logger Setting'** button again, then press **'Start at…'** button. And set the time to start the logger.

18. Select **'File'** menu in the main window, and select **'exit'**.

(2) Data Retrieval from SEBA PS-Insider

For retrieving the data from SEBA PS-Insider Water Level Data Logger (SWL6), the following procedure should be carried out.

1. Plug in the interface-cable to the SEBA PS-Insider and laptop/PC.

2. Restart the laptop in MS-DOS mode. (This can be obtained by pressing **F8** key right after the laptop is turned on and before Windows boots up.)

3. Never run MS-DOS mode under the Window background.

4. To start the "Operate" software, type C:\seba\operate\operate, then press **'Enter'**.

5. Move the cursor to menu "read-read and new start", and then press **'Enter'**.

6. Enter to continue.

7. Key in the filename for output file. The filename should be in this format: SWL6ddmm.152 (dd: date, mm: month)

8. Press any key. The data now is downloaded to the computer.

9. Move the cursor to "info-end of program", press **'Enter'**.

10. You can view your retrieved data through the MGMDS and MLMDS.

5.7.2 Periodic Maintenance of Surface Water Level Equipment

(1) Stations SWL-1 to SWL-5

The periodic maintenance for Stations SWL-1 to SWL-5 in Paya Indah should be carried out by the following procedure:

1. Clear the vegetation or rubbish stuck at the water level station.

2. Check the filter gauze fitted to the HDPE pipe (white pipe). Use a normal soft brush to clear the vegetation (algae) and mud on the filter gauze.

3. Check the outer PVC pipe (whether it is clogged). If necessary, pull the PVC pipe out from the water and clean it.

4. Check the sediment accumulated above the concrete base. If the sediment accumulated is too thick, clear the sediment.

5. Clean the outside and the circulation holes of DIVER with a soft cloth and rinse with freshwater. (DO NOT USE SHARP OBJECT TO CLEAN THE DIVER.)

6. Use acid solutions only when the Diver is extremely dirty and other cleaning methods have failed.

(2) Station SWL-6

The periodic maintenance for Station SWL-6 in the Kajibumi Well Field 1 should be carried out by the following procedure:

1. Before retrieving the data from the logger, check the battery capacity by pressing the battery indicator button on the PS-Insider. It is recommended to double-check the battery voltage and current by using a multi-metre. Replace the battery with the spare battery **(make sure that the battery is fully charged.)**.

2. Activate the purging by pressing on the purging button; consequently, observe the river where the nozzle is placed. Many bubbles will emerge right after the purging.

3. If there is no bubble emerging, it means that the nozzle might be clogged. Clear the objects stuck at the nozzle.

4. Check all the G.I. pipe connections to make sure they are well joined.

Attachment 1 Data Extraction Procedure

1) Plug in the connection of the palm top to data logger connector.
2) Switch on the palm top and the window menu will appear on screen.
Go to 'Start' and select 'RST Wintrapper CE'.
The Main menu will appear on the screen which read :

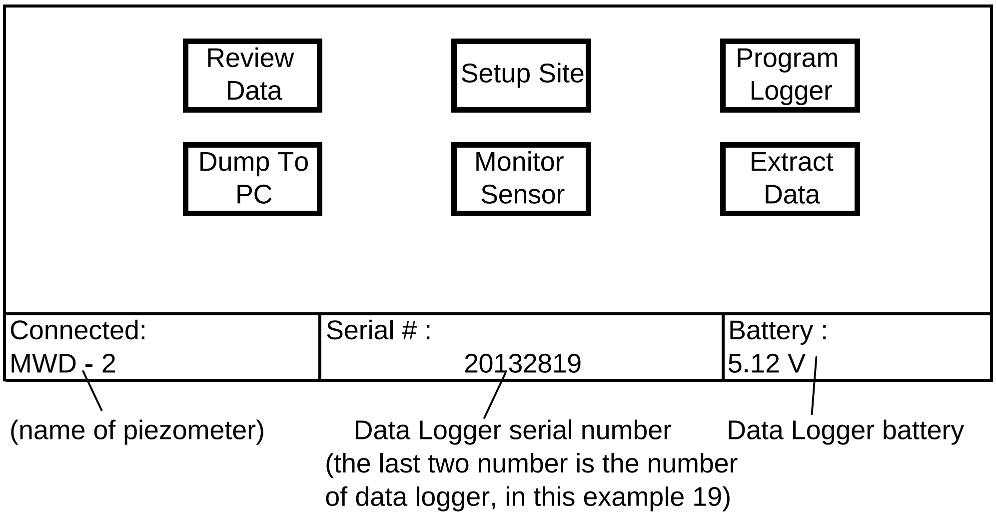


FIGURE 1
(main menu)

3) Check the current water level by select 'Monitor sensor'.
The reading of the current pressure will appear in Kpa unit.Note down the reading.
Select 'Close' and the main menu will reappear.(Figure 1)
4) Select 'Exract Data' to extract out data in the data logger. The following screen will appear.

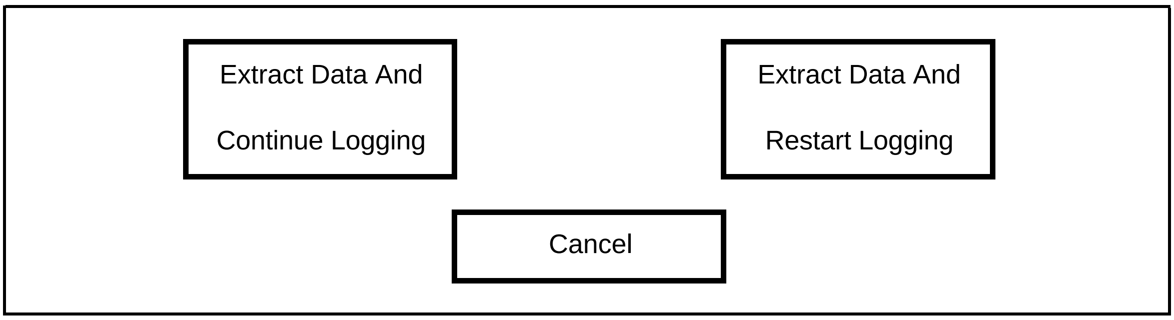


FIGURE 2

Select 'Extract Data and Continue Logging', all the data in the data logger will extract to the palm top.
This following screen will appear.

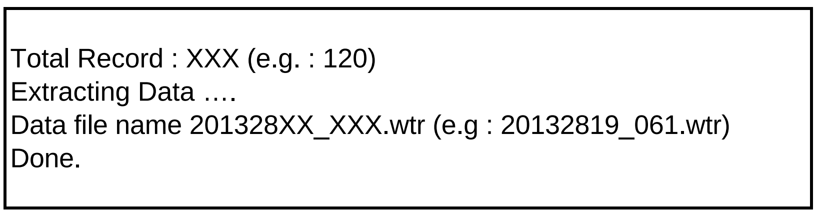


FIGURE 3

Note down the data file name : XX_XXX.wtr (for this example : 19_061)
The process will complete when the main menu re-appear on screen. (Figure 1)

5) Select 'Program Logger' to reprogram the data logger.
This following screen will appear.

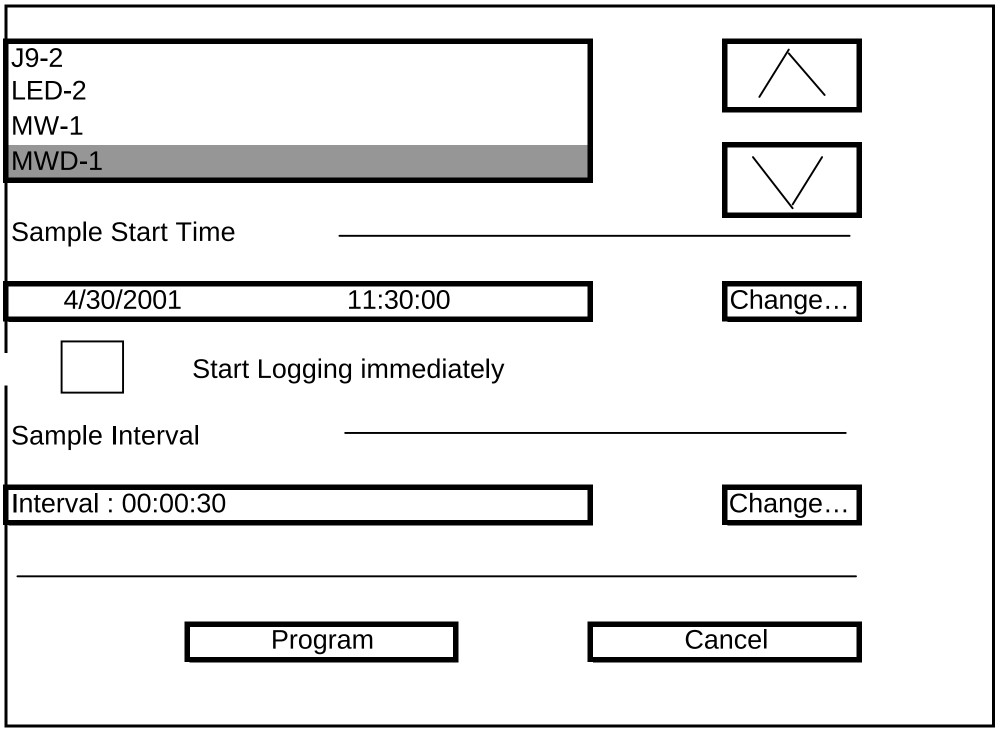


FIGURE 4

i) Select 'Change...' that the same row with the sample start time.
And this following screen will appear.

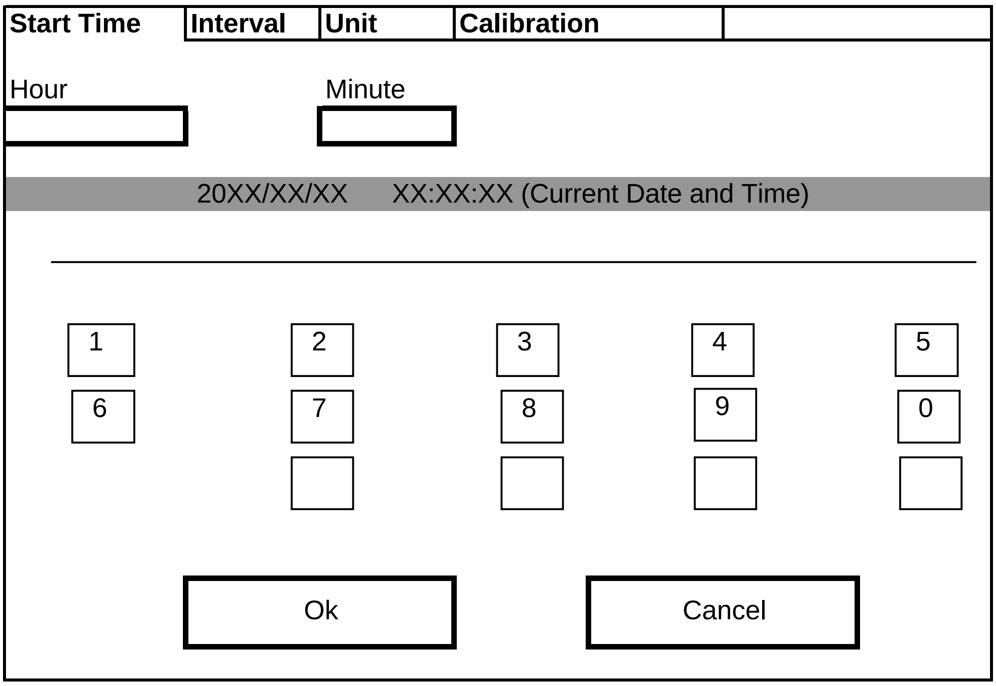


FIGURE 5

ii) You can change the start time of data logger by change the number at hour and minute column.
You can also mark at the 'start logging immediately' if you want the data logger to start take reading immediately.
iii) To change the reading interval you have to point to 'Interval' on top of the screen and the following

will appear :

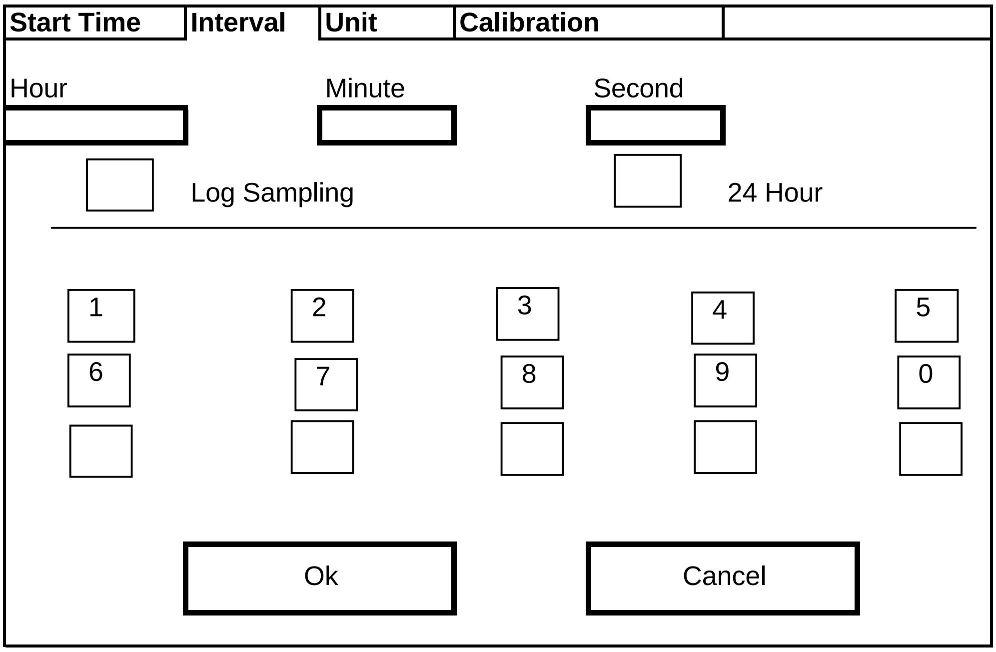


FIGURE 6

You can set the interval from 1sec up to 24 hour time.
iv) After complete, select 'OK'. The screen will back to Figure 4.
Select 'Program' and this will be reprogramming the logger according to the time,date and interval that you have already set. This step will complete when the main menu re-appear.(Figure 1)

6) You can check if the setting is correct by select 'Review Data'.
This following screen will appear.

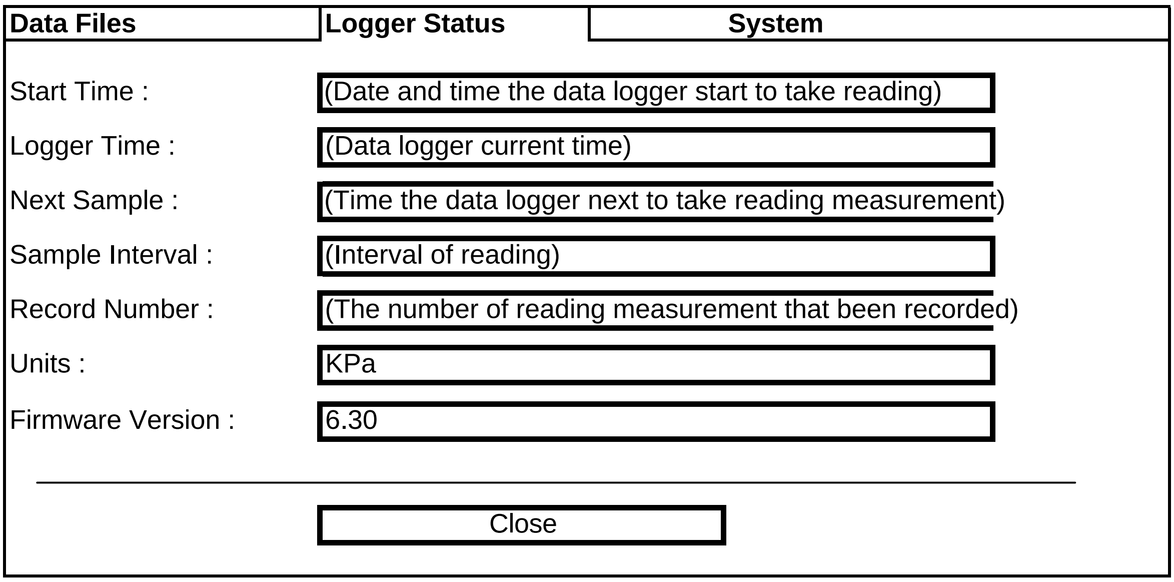


FIGURE 7

7) If all the setting is correct (according to your need) select 'Close', and the main menu will appear.
You can switch off the palm top and disconnect the cable to the data logger.
If you want to make correction of the setting, select 'Program Logger' and change the setting back.
(refer back to step 5).

Attachment 2

MANUAL OF KLLQ

1. PREPARATION FOR MEASUREMENT (IN ROOM)

(1) Charging

♦ The charger will be connected to the socket and so the internal accumulators can be charged.

♦ The charging time is approx. 14hr at 0.25A in case of completely empty accumulators.

(2) Connection of the MPS-D(sensor) to the KLL-Q(drum)

(If they have already attached each other, we don't need this work.)

♦ The connection will be effected by plugging-in the 2-core flat cable to the KKL-Q.

♦ Connection or removal of the sensor must only be effected with switched-off instrument.

♦ The O-ring should be renewed from time to time, and it should be slightly greased.

(3) Calibration of sensor

♦ A calibration of the MPS-D is effected with the program "SEBATERM" at the PC.

♦ We deal with the calibration in detail later.

(4) Route planning at the PC and transferring from the PC into the KLL-Q

♦ If we input the stations for a measuring route at the PC, they can be transferred to the KLL-Q.

♦ With the KLL-Q the measurement values of each station are picked up on the field.

♦ Without inputting the stations before measurement, we can measure values. Then the measurement values are recorded as the temporary names by KLL-Q.

<Route planning and transferring into the KLL-Q>

1) Start the Terminal-program "SEBATERM".
2) Select "Device/preference/KLL-Q" and insert "com5". Then select "Divice/KLL-Q".
3) Switch on the KLL-Q. Select the "dipper mode" of the KLL-Q.

4) Attach the interface extension cord to the IrDa-interface window of KLL-Q.
5) "Current statu of dipper mode" is displayed on the PC. Then we can connect each other.
6) Then select "Command-mode".
7) Select "Memory/Route planning and station names".
8) At first input the station names. Then select "Route", and input the name of new route.
9) Push the "new route" button, and select the stations.
10) Push the "Transfer route" button. If the confirmation message appears, we can transfer the route plan data into the KLL-Q.
11) Close the Terminal-program "SEBATERM".

2. OPERATION (FIELD WORK)

(1) Cover around the entrance of the well with a cloth to protect the flat cable.

(2) Loose the sealing ring, and remove the MPS-D from the "storage and transportation quiver".

(3) Screw in the protection screw and, remove the protection basket carefully.

(4) Take off two small caps from the pH-sensor and the O_2-sensor.

(5) Attach the protection basket, and screw again.

(6) Wash the sensors with tap water.

(7) Switch on the KLL-Q. (The sensors are outside water)

(8) Offset compensation for pressure mode appears. Then select "Yes", and press "ENTRY-key".

(9) Dipper (electric contact meter) mode starts. If "contact" appears, press the "ENTRY"-key".

(10) "Main-menu" appears. Then select "Adj.Airpressure" menu and press the "ENTRY"-key".

(11) Select "Actual airpress", press the "ENTRY"-key", and input the actual air pressure value.

(12) Then select "Default Airpr.", press the "ENTRY"-key", and input the same value.

(13) We finished inputting the actual air pressure value. Then select "Quit" and press "ok".

(14) Select the "Q-Meas. Altern" mode in the main menu, and press the "ENTRY"-key. **(Quality measurement starts.)**

(15) After a few minutes, press the "SCROLL"-key till the second tone.

(16) Select the station name, and press the "ENTRY"-key. (We can also select the temporary station name.) (Storage is activated.)

(17) Switch off the KLL-Q.

(18) Wash the sensors with tap water again.

(19) Return the MPS-D into the "storage and transportation quiver".

(The end of measurement)

From the second station, we can measure values by repeating above operation. After final measurement in a monitoring work period, attach two small caps again with comfortable storage solution.

3. DATA READING OUT AT THE PC (IN ROOM)

(1) Starting the Terminal-program "SEBATERM".

(2) Now we don't need to log in. When we calibrate sensors, we have to input a password and user name. Then input "Operator" as user name, and "SysAdmin" as password.

(3) Select "Device/preference/KLL-Q" and insert "com5". Then select "Divice/KLL-Q".

(4) Switch on the KLL-Q. Select the "dipper mode" of the KLL-Q.

(5) "Current statu of dipper mode" is displayed on the PC. **Then we can connect each other.**

(6) Select "Memory/Read memory". The PC reads out the data in the KLL-Q memory. **(The end of reading out measuring data)**

(7) After reading out we erase the memory in the KLL-Q.

(8) We can read the transferred data by selecting "Standard functions/ Recorded values".

(9) Save the data. We can choose new directory to save into the PC.

4. ILLUSTRATION AT THE PC (IN ROOM)

(1) Start the program “MGMDS”. Then select “File/ open”, and select the transferred files.

(2) We can illustrate each data.

(3) If we choose plural files (parameters), we can illustrate them at the same display.

(4) If we display the measuring data on the plate, start the program “MLMDS”.

5. MAINTENANCE (PLEASE REFER TO PAGE10 IN THE “MPS-D” USER MANUAL.)

♦Each sensor demands different storage conditions. Therefore we need to keep each sensor in the comfortable storage solution.

♦The quiver is filled with a storage solution (approx. 180 ml). And small caps are also filled with other storage solutions.

(1) Short time as replacement storage

(2) Tap water can be used. But never store the pH sensor dry or in distilled water.

(3) Short time (< 2weeks) storage

(4) The quiver should be filled with 1 molar KCL solution (approx. 180 ml).

(5) PH-sensor should be filled with 3 molar KCL solution in a small cap.

(6) O2-sensor should be filled with distilled water in a small cap.

(7) Long time (> 2weeks) storage

(8) The quiver should be dry.

(9) PH-sensor should be filled with 3 molar KCL solution in a small cap.

(10) O2-sensor should be filled with distilled water in a small cap.

(11) Moreover O2-sensor should be removed under above condition.

6. CALIBRATION

We need to calibrate these sensors; Conductivity, pH, and O_2 sensor. Calibration is important for accurate measurement, so please refer to the manual in detail.

<calibration interval>

♦Conductivity-----6-12months

(MPS-D manual p12. “Calibration with a reference instrument” is recommended.)

♦pH----------------2 months (MPS-D manual p15.)

♦O_2 --------------2 months

(MPS-D manual p19. “Manual calibration with reference value” is recommended.)

Attachment 3

In-situ Groundwater Measurements and Sampling for Regular Monitoring

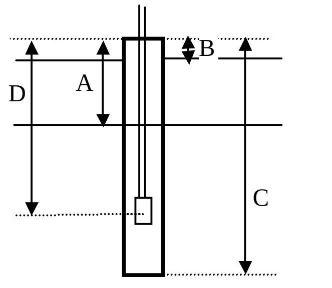
FORM-1

Page of

(1) Basic Information

PROJECT NAME : The Study on the Sustainable Groundwater Resources and Environmental Management for the Langat Basin in Malaysia

Date		Time	:
Location Name		Location No.	
A: G.W.L	m	**C:** Well Depth	m
B: Hight of collor	m	**D:** Depth of Sub. Pump	m
Start of Pumping Time	:	Start of sampling Time	:
Accompany			



(2) Measurement Results in the well before Pumping

Parameters	unit	H= m	H= m	H= m	H= m	
Temperature	℃					
Conductivity	μ s/m					
Turbidity	NTU					
pH-value	ph					
O2-contents	mg/l					
O2-Saturation	%DO					
Water Color	-					
Remarks	-					

(3) Measurement Results after Pumping

Parameters	unit	: **(10 min.)**	: **(20 min.)**	: **(30 min.)**	: **stability**	
Temperature	℃					
Conductivity	μ s/m					
Turbidity	NTU					
pH-value	ph					
O2-contents	mg/l					
O2-Saturation	%DO					
Water Color	-					

In-situ Surface Water Quality Measurements and Sampling for Regular Monitoring

FORM-2

Page   of

PROJECT NAME ： The Study on the Sustainable Groundwater Resources and Environmental Management for the Langat Basin in Malaysia								
Date								
Time								
Location Name								
Location No.								
coordinates								
Accompany								
Temperature	℃							
Conductivity	μ s/m							
Turbidity	NTU							
pH-value	ph							
O2-contents	mg/l							
O2-Saturation	%DO							
Water Color	-							

On-site Test (Chemical Analysis) of Water Quality for Regular Monitoring

FORM-3

Page   of

PROJECT NAME : The Study on the Sustainable Groundwater Resources and Environmental Management for the Langat Basin in Malaysia			
NAME:		DATE:	
ADDRESS:			

Sample Number			On-site test						
Date of sampling	Time	Sampling No.	BOD	COD	MN	Fe	Fe-T	NO3-N	NO2-N
			mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l

SECTOR I

MANAGEMENT INFORMATION SYSTEM

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

FINAL REPORT

SECTOR I

MANAGEMENT INFORMATION SYSTEM

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SECTOR I

MANAGEMENT INFORMATION SYSTEM

1. PRESENT CONDITION OF INFORMATION TECHNOLOGY

1.1 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 1970's, 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 Cooperative Development (MLCD). The management of NaLIS Clearinghouse is handled by the Clearinghouse Technical Committee, comprised of all land related data providers and users. The Minerals and Geoscience Department, Malaysia (Jabatan Mineral dan Geosains - JMG) is one of the member agencies, and it is responsible for geological, mining and geo-technical information.

(1) Standard Geo-Reference for Land Information

The Technical Standard Committee chaired by the Department of Survey and Mapping, Malaysia (DSMM), and consisting of fourteen (14) other agencies including JMG, has initiated the effort to develop the Malaysian Standard Geographic Information System (GIS) in early 1999. The Malaysian Standard Code (MS1074), which was published in 1987, has been revised in conjunction with the development of technology in GIS.

Malaysia became a member of ISO/TC211 in December 1996. The new MS1074 was brought to the TC12 Committee for discussion and approval before it was forwarded to the Department of Standard for accreditation. The NaLIS standard code for land and administrative areas was made available for the member agencies. JMG is preparing the national standard Geology codes. For geo-referencing land information, NaLIS has defined the Rectified Skewed Orthomorphic (RSO) map projection, the Modified Everest 1948 Spheroid and Datum Kertau (West Malaysia). Further, the scale of 1:50,000 has been specified as the national standard for mapping all land related information.

(2) Status of System Networking

The NaLIS Clearinghouse Server has been installed at MLCD, providing a Directory of all the databases, together with the description about the data (Metadata) that can be accessed. A Gateway Server is installed at each of the member agencies, including JMG. The function of the Gateway Server is to extract the data to be used by NaLIS users. Each user can browse the data-directory to select the data, which is required to make a request. Through the Clearinghouse (NaLIS Support Unit), the system automatically routes the request to the agency that keeps the data, and then the requested data is sent to the user. Access to the NaLIS Server at the Clearinghouse is controlled by a password. However, the access from one Gateway Server to another for communication among the users has to pass through the Clearinghouse. GIS software ARC/INFO and ArcIMS (Internet Map Server) are used for implementation of the system.

1.2 Information Technology (IT) Strategy of JMG

The five-year strategic plan of JMG, as stated in the document "Strategi Dan Halatuju Program Mineral Dan Geosains 1999-2005," includes the use of IT (Information Technology) to enhance planning and implementation capabilities of the Department. For this purpose, the Geological Survey Department and the Mines Department have been merged to form the Department of Minerals and Geoscience. It is however stated in the five-year plan that the minerals and geo-science component will still continue as one of the important core activities of the new Department, under the direct supervision of the Ministry of Primary Industries. No privatisation or corporatisation is to be implemented during the plan period.

The plan further addresses international standard quality data and information services strategies, and analyses personnel, hardware/software status, as follows:

(1) Data and Information

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) Quality Development Programme

Quality development programme is to ensure that products and services of the Department shall meet international quality standards. In this aspect, International Standards ISO 9000, ISO Guide 25 and ISO 17000, etc. are adopted.

(3) SWOT Analysis

In the SWOT Analysis (Strength, Weakness, Opportunities, Threats Analysis) attached to the plan, it is stated that there are a number of formally trained personnel in IT, sufficient hardware/software are available, and staff awareness/interest in IT is high. As weaknesses or threats, the lack of IT operational structure and IT posts, as well as the loss of trained personnel are raised.

1.3 Existing Systems of JMG

JMG has set up a GIS Unit in the Head Office in 1994. As of the beginning of this Study in 2000, the unit had seven personnel. 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 and equipped with UPS (uninterruptive power supply) as well as peripherals such as digitizer, plotter, printer, and CD-RW. 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.

JMG at the beginning of this Study was being re-organised. At present, the GIS group belongs to the new IT Section.

(1) Hydro and Engineering Geology Database

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. The Study utilises HYDAT Database.

The original HYDAT database was developed in 1991 and modifications were made in 1996 by JMG. Further 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 JICA Study Team had cooperated in designing the data structure, as well as the input form. The well data obtained from reports, field investigations or borehole log will be entered by using these tools, and stored by differentiating three data types; GENERAL for borehole/well location and design, VARIABLE for groundwater quality, and GEOLOG for geological log of borehole/well.

Each borehole/well is assigned a unique number “WELL_NO” comprising of two (2) characters followed by four (4) numerical digits. “P” for Peninsular Malaysia is assigned as the first character, and the second refers to the car registration numbering system, as shown in **Table I.1.1**, for all States in Peninsular Malaysia. For example, WELL_NO for boreholes/wells in Selangor will be assigned “PBxxxx”, where “xxxx” stands for four numerical digits.

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 in JMG.

Table I.1.1 Index Number for States in Peninsular

No.	States in Peninsular	Index
1	Perak	PA
2	Selangor	PB
3	Pahang	PC
4	Kelantan	PD
5	Johor	PJ
6	Kedah	PK
7	Melaka	PM
8	Negeri Sembilan	PN
9	Pulau Pinang	PP
10	Perlis	PR
11	Terengganu	PT
12	Wilayah Persekutuan Kuala Lumpur	PW

(2) Using GIS for Geology Map Production

Geology maps at a scale of 1:63,360 are being published. JMG is now transforming them to the national standard scale of 1:50,000. Two major issues are to be resolved. One is the generalisation (feature extraction, cleaning) of base maps, and the other is conversion of old codes (MS1074 published in 1987) into NaLIS codes. Some 110 maps of 1:63,360 scales have been converted into ARC/INFO format. The codes however are the MS1074 of 1987, which have to be updated into the new (revised MS1074) codes.

1.4 GIS and IT of Other Related Agencies

"Malaysia: the Way Forward (Vision 2020)" was presented by the Prime Minister 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.

Three related agencies, namely, the Department of Environment (DOE), the Drainage and Irrigation Department (DID) and the Selangor Water Management Authority (SWMA), were visited.

(1) States and Regional Level

At the States level, the Selangor GIS (SGIS) land management system pilot study has been carried out, which initially involved computerisation of the Central State Land Office by Siemens Nixdorf's SICAD system. The Inter/Intranet and GIS facilities were also key aspects of the project. The first phase of the project was to computerise the cadastral information and land registry records in the Mukim of Serandah. The implementation of web application with Netscape's Open Network Architecture was also planned.

SWMA will conduct a pilot project, "Master Plan Study on Integrated Catchment and Urban Stormwater Management for Sg. Damansara," in which the development and application of an interactive GIS system is addressed. It is stressed that this system should also be able to interact with DID's "Integrated River Basin Management Information System" (see also **Figure I.1.1**), and DOE's database system.

The application of GIS for Klang Valley (AGISwlk) was developed from a pilot project initiated in 1995, covering a 4.5 kilometre strip in Phase 1 and the central business district (CBD) in Kuala Lumpur in Phase 2. The third phase was GIS development for the entire Federal Territory of Kuala Lumpur. The system is managed by the "Federal Territory Development and Klang Valley Planning Division, Prime Minister's Department." Universiti Teknologi Malaysia, Universiti Kebangsaan Malaysia, and the Department of Mineral and Geoscience are assisting to maintain the system. The hardware is Windows NT server and Windows NT workstations with peripherals. ARC/INFO with TIN, GRID and Network extensions; ArcView with Network, Spatial Analyst, 3-D Analyst, ArcPress extensions; and Visual Basic are the software platform of the system. Web applications including Map Object IMS (Internet Map Server) are also included in the system composition. However, except e-mail contact, the webpage for general Internet users is not known.

(2) Department, Ministry and Federal Level

In terms of networking and system development, it may be separated into departmental, ministerial and federal levels. At the departmental level, all the regional offices are linked with the Head Office in a network. All those networks will be linked together with the Ministry at the ministerial level systems. The federal level systems are multi-institutional, and an example of which is the National Infrastructure for Land Information System (NaLIS). Another development might be the National Spatial Planning at the Prime Minister's Department, which has been initiated recently, so that no publication is available, yet.

Initial system development studies using GIS was started at the Department of Environment (DOE) in 1995 by the Pilot Project in Negeri Sembilan for Environmental Master Plan. The network infrastructure linking the regional offices with the Head Office has been implemented, and it is now in operational mode. Data acquisition works are outsourced; Regional Offices are involved in legal issues; Head Office is involve in policy issues and monitoring. Environmental information is accessible for the general users at the DOE website (http://www.jas.sains.my). Internet web applications using ArcIMS (Internet Map Server) are being developed. The basic GIS software are the UNIX ARC/INFO with TIN, GRID, Arcpress extensions; Windows ArcView with Spatial Analyst, 3-D Analyst, Network extensions; and the Erdas Imagine for image processing.

The system in DOE is an example of the departmental networking system, i.e. the Ministry to which DOE belongs has no network link at the ministerial level. According to the JMG-IT Section, the Ministry of Primary Industry (MPI) plans to set up a ministerial network in which JMG will be included.

The Ministry of Agriculture’s “AgroLink” is an existing ministerial level networking in Malaysia. The web page is located at http://agrolink.moa.my. The Drainage and Irrigation Department (DID) presents the River Basin Information System (RBIS) in their sub-page of Agrolink website. According to the Department, the RBIS was developed with JICA assistance. The system covers two (2) rivers, Perak River and Muda River. The first one is more complete, and the Muda River is still in the development stage at present. DID executed the Study “National Registry of River Basins” at the end of year 2000. **Figure I.1.1** shows the RBIS web page for the dissemination of Perak River Basin information.

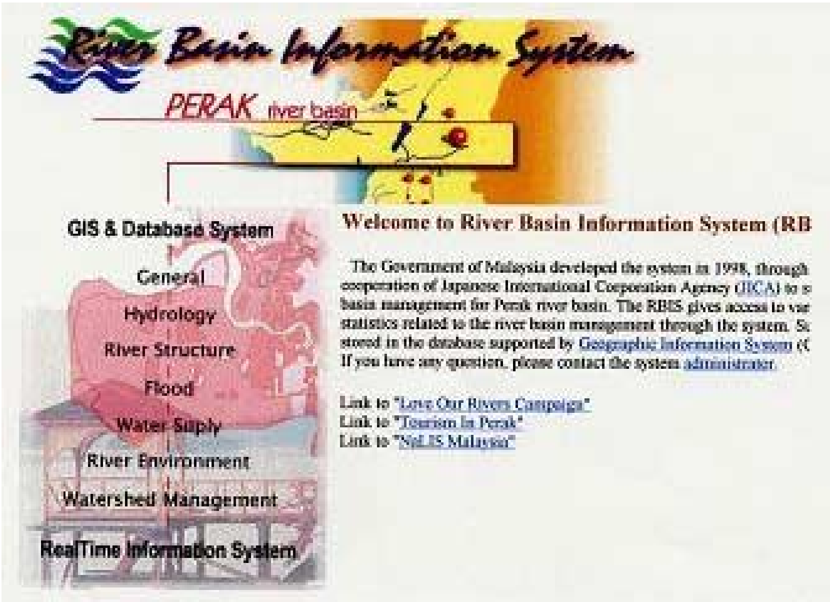


Figure I.1.1 DID's Web Page for Perak River Basin Information

This page can be accessed from the "Main Programs/River Engineering" of the DID-homepage. ArcView IMS is used as the map server software. A download option is also provided in ARC/INFO interchange file (.e00) format for map data.

2. PROPOSED MANAGEMENT INFORMATION SYSTEM (MIS)

2.1 Objective for the Establishment of MIS

For the establishment of the Management Plan for the Sustainable Groundwater Resources and Environment 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 collected and compiled during the study and they have been stored in database files.

JMG, at the same time, is promoting further utilisation of GIS and IT environment as well as updating of database environment utilising Internet environment. The five-year strategic plan of JMG, as stated in the document "Strategi Dan Halatuju Program Mineral Dan Geosains 1999–2005," includes the use of Information Technology (IT) to enhance the planning and implementation capabilities of the Department. For this purpose, the Geological Survey Department and the Mines Department have been merged to form the Department of Minerals and Geoscience. The plan further addresses international standard quality data and information services strategy.

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

2.2 Principles of MIS Establishment

2.2.1 Major Functions

The proposed Management Information System in this chapter will include the following four (4) major functions:

(1) Data Input and Maintenance;

(2) Monitoring;

(3) Evaluation; and

(4) Dissemination of Information to the Public by Annual Report.

The functions and proposed methods for development of these modules are addressed in **Section 2.3**.

2.2.2 Users

Possible users will include the following:

(1) JMG Staff;

(2) Staff of relevant agencies, i.e., SWMA, DOE, DID, Paya Indah Wetland Sanctuary; and

(3) General Public.

The level of access to each of the functions as presented in **Subsection 2.2.1** above will be controlled by the Process Management part of the system, which is addressed in **Section 2.4**. 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.

2.2.3 Basic Structure

The Internet Web-application using ArcIMS (Arc Internet Map Server) will be developed for the MIS. The system will be connected to the existing Internal Router of JMG.

Topographic and thematic maps as well as the other relevant maps have been digitised and prepared in ArcView shapefile format. The available Well data collected by the Study Team in Microsoft Access were converted into Oracle database. Utilisation of these materials will be taken into consideration and necessary software will be determined.

As hardware environment, ArcIMS Server will be newly introduced. One PC procured for the present Study will be utilised as ArcSDE Server, and the remaining PC will be used for data processing.

2.3 Functions

Functions of each module will be presented hereafter.

2.3.1 Data Input and Maintenance

For the purpose to identify regional variation and long-term changes of groundwater level and quality, observations were made regularly at the long-term monitoring wells in this Study.

The Data Input and Maintenance system will allow user to browse, input, and manage the following observed data for monitoring purpose:

- Groundwater Level and Quality;
- Surface Water Level; and
- Top Soil Subsidence and Benchmark Elevation.

Regarding the regular monitoring, **Sector H, Groundwater Monitoring,** presents the detailed procedures and schedule.

(1) Groundwater Level and Quality

Groundwater Level and Quality measurements are done at thirty-four (34) wells in total. Groundwater quality parameters such as pH, water temperature, etc. are measured on-site, or in-situ, where the latter means the measuring of parameters by a handy water quality analyser, KLL-Q. The water samples taken from the monitoring wells are sent to the laboratory. Simultaneously, surface water quality is also measured at ten (10) locations in mine lakes, canals and Langat River.

The locations of Monitoring Wells are stored as ArcSDE (Arc Spatial Database Engine) data in Oracle DBMS (Database Management System), and the water quality parameters are stored in HIDRODAT (revised version of HYDAT), in which the monitoring wells can be linked with the well information by the unique identifier WELL_NO as the key. The time-series data from automatic data logger are stored separately within the Oracle Database of the Study.

(2) Surface Water Level

There are six (6) stations in the Paya Indah Wetland Sanctuary and Langat River for observation of the surface water level. The measurements are done automatically, and the data from the data loggers are loaded into a laptop computer by Windows 95 based software. This software provides data export function into spreadsheet. These data are also stored in the Oracle Database of the Study.

(3) Topsoil Subsidence and Benchmark Elevation

The land subsidence measurement network consists of twenty (20) datum points, twenty (20) shallow benchmark points, and one (1) borehole extensometer for monitoring of the upper clayey layer. By performing periodical First Order Levelling, changes in elevation at the benchmark points are measured. These measurements are, like the other monitoring data, stored in the Oracle Database of the Study.

MIS is not designed for on-line data input and maintenance through the Internet/Intranet infrastructure. At present, JMG regional offices are connected with the Head Office through the dial-up line. However, the JMG Database Information System Version 4.1.3 operates in Client/Server environment, so that the data input and updating in State offices can be performed in their respective Local Area Network (LAN). To integrate these data into ArcIMS application, Oracle export and import functions can be used. MIS will allow a JMG user at the KL Head Office to browse, insert and update the database. This function can be upgraded to an Internet/Intranet structure, when ISDN network is in place at JMG in the future.

The existing HYDAT data provided by JMG for the Study are incorporated into the new HIDRODAT database and supplemented by newly developed wells in this study. It will be advantageous for JMG to further develop the HIDRODAT database. However, a critical issue might arise in maintaining the accomplished database by regular input of water quality parameters measured "on-site" or "in-situ", groundwater level, as well as the chemical data from laboratory analysis. Further, it is suggested to regularly input and manage the data from data logger, as well as the benchmark-surveyed records in the corresponding databases. JMG Database Information System and the appropriate tools developed in this Study will facilitate the database maintenance works. In case, JMG has added new well(s) in the future, the necessary procedures for updating ArcSDE data are described in the Operation Manual.

This module will be solely used by JMG, and no external user will have access to it.

2.3.2 Monitoring

Groundwater level, water quality, land subsidence and the lowering of water level in a reserve area within the Langat Basin are the items to be monitored. The measurements at the monitoring wells for groundwater level and quality, which are addressed in **Subsection 2.3.1,** are the main data sources. Those data can be linked with the monitoring wells to allow an authorised user to display the well locations on top of the basic map features, query the corresponding well attributes, and draw graphs using the time-series data for groundwater monitoring purpose, as shown in the examples in **Figure I.2.1**

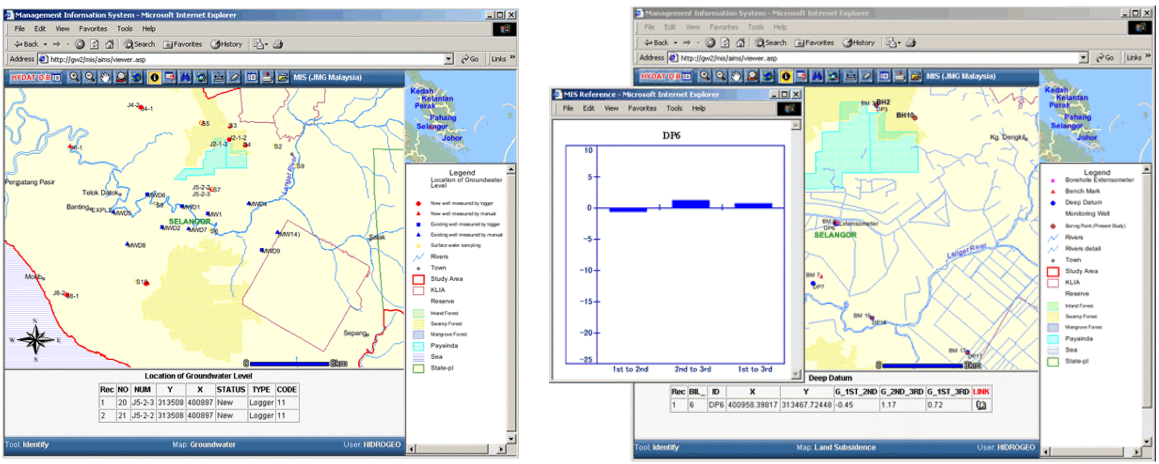


Figure I.2.1 Examples of Display and Query Function for Monitoring

Besides groundwater level and quality, potential pollution sources such as industrial estates, solid waste and wastewater treatment data are also stored in the database. The geological profiles are prepared in MS Visio format. Those profiles are linked with the profile-lines, which are stored in ArcView shapefile format. An authorised user can selectively view the geological profiles by picking on the corresponding profile-line on the web-map. An example is presented in **Figure I.2.2**.

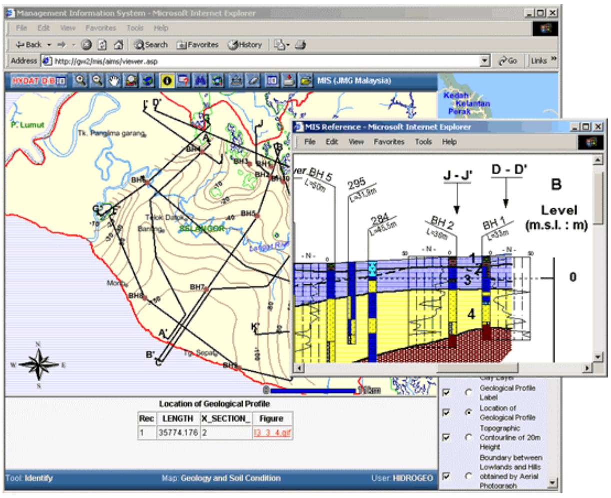


Figure I.2.2 Example of Viewing a Geological Profile

2.3.3 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.

(1) Visual MODFLOW and GIS

MODFLOW was written by Michael McDonald and Arlen Harbaugh, with the U.S. Geological Survey (USGS), and is a three-dimensional finite-difference groundwater flow model. The MODFLOW model is comprised of a main program and several independent subroutines called "modules". The modules are grouped functionally into packages, which include Basic (BAS), Block-Centered Flow (BCF), Output Control (OC), River (RIV), Recharge (RCH), Well (WEL), Drain (DRN), Evapotranspiration (ET), and General-Head Boundary (GHB).

The City of Aurora, in the State of Colorado, has been developing the interface between MODFLOW and ArcView, as well as ARC/INFO. The major effort is made to resolve the difficulties in pre-processing of input data and post-processing for visualisation of the MODFLOW outputs. Extensive programming works have to be done to this concern. At present, a variety of commercial software are available, providing post-processing and visualisation capabilities for the MODFLOW outputs, and the Visual MODFLOW (VM) used in this Study is one of those software. Environmental Visualisation System (EVS) is another visualisation software, which works with ArcView.

However, one major drawback is incompatibility among the software; according to the vendor, the software versions of MODFLOW supported in VM and VS are different, so that the output file of MODFLOW (BAF, BCF, etc.) adapted in VM software in this Study cannot be transferred to EVS. Another drawback is the difficulty to integrate these software in the Internet web application with ArcIMS. EVS was selected because it can run from ArcView system environment. However, to disseminate the model results visually on the Internet webpage, those visualisation programs have to be executed by ArcIMS, which is not possible, at least within the scope of this Study. One option might be the use of screen save image file of the EVS window by ArcIMS. In this case, the quality of web-map may considerably be reduced, especially in zooming the maps on Internet browsers.

(2) MODFLOW Interface

Both pre-processing and post-processing of the data to and from MODFLOW, is performed by the modelling Expert using VM software. Basic topographical data such as DEM (Digital Elevation Model), Contour Lines are generated, and all the positional data, which are required for modelling, are geo-referenced in GIS. Data transfer between GIS and VM is performed in DXF (AutoCAD standard interchange file) and in ASCII (Text file) formats.

The Groundwater Model in this Study consists of a 70-column by 76-row grid, oriented north-south in the Langat Basin. The finite difference grid is digitised, and the active, inactive, or dry cells are transferred to this grid by referring to the VM output file in DXF format. All other features in the DXF-file are converted into GIS as separate layers, except rivers, study area, and so on, which are preliminarily transferred from GIS to VM. Since the input feature data to VM are geo-referenced, any available feature in GIS can be displayed on top of VM output data. The location of cell centres, together with the simulated piezometric heads for each of the model variants are exported from VM in txt (Text string) file. Those data are converted into GIS, the draw-down data are then derived, and isolines are generated using GIS software including ArcView Spatial Analyst extension.

All those 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 conducted land subsidence simulations, and the resulting contour lines were digitised for producing Land Subsidence maps by GIS. Similarly, maps of distribution of Clayey Soil, Aquifer, etc. were also 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 I.2.3**.

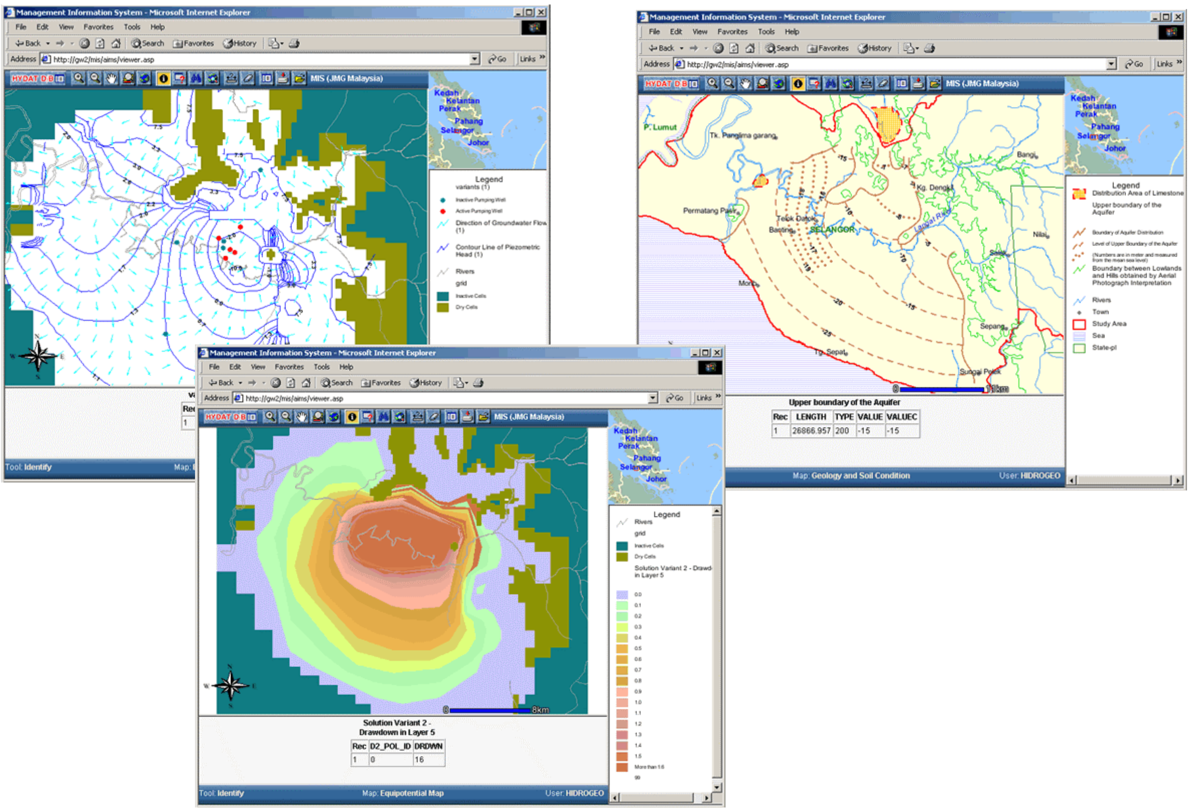


Figure I.2.3 Examples of Viewing MODFLOW Model Simulation

2.3.4 Annual Report

This module is thought for general Internet users; no Password is necessary to access this module. The proposed major items are: (i) Features of Langat Basin, (ii) Monitoring Results2001, (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 are shown on **Figure I.2.4** below.

Figure I.2.4 Examples of Annual Report Page

2.4 Structure with ArcIMS

A separate report, “Overview of the System Definition of the Management Information System,” is attached as **Annex I.2.1** of this report for more detail.

2.4.1 System Architecture

The system employs a web-based three-tier architecture: Client Front-End (User Interface), ArcIMS Middle Tier (Process Management), and Database Back-End (Database Management), as shown in **Figure I.2.5**.

(1) 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.

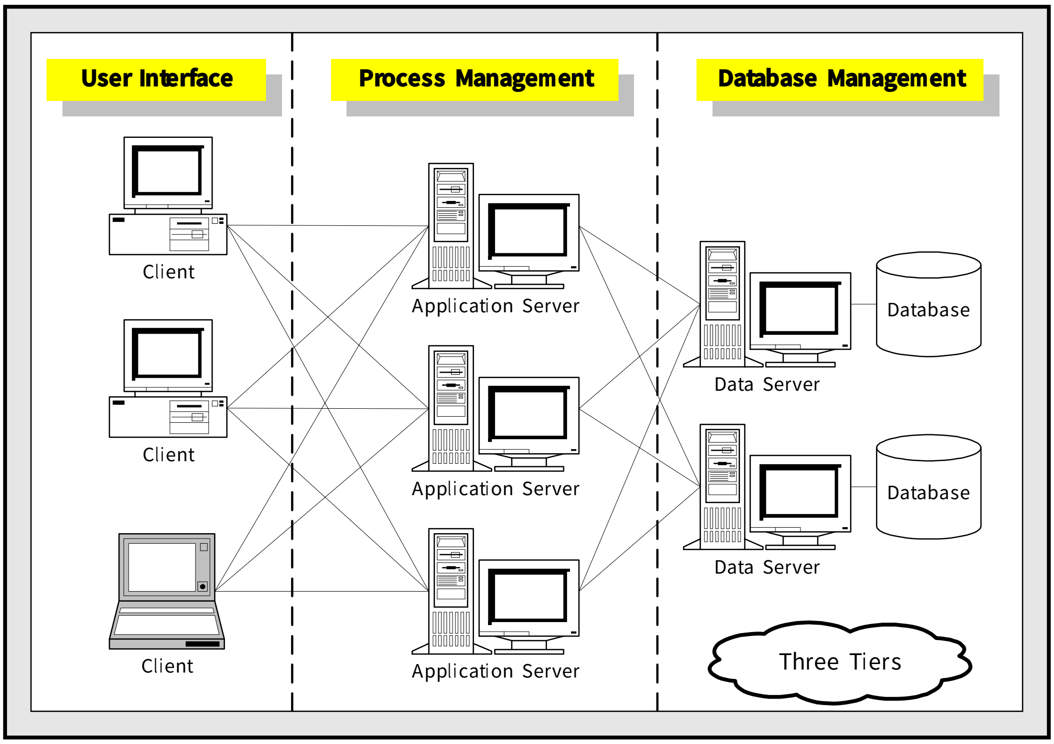


Figure I.2.5 Three-Tier System Architecture

(2) ArcIMS - Middle Tier

This middle tier of the system will have Process Management component. It will determine what kind of data will 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. For further information and password application, a contact e-mail address is provided on the web page.

When a user applies for a password, JMG will proceed to identify the level of access for that specific user, and a Password will be issued electronically.

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.

ArcIMS Ver. 3 has incorporated all the functions performed by ArcView IMS, as well as Map-Object IMS, and enhanced by additional functions. It is said that ArcIMS will be the only ESRI (software maker) Internet Map Server in the future for comprehensive Enterprise GIS implementation.

All components of ArcIMS, namely, ArcIMS Application Server, ArcIMS Spatial Server, ArcIMS Manager are installed on a single server. ArcIMS has the capability to provide five Internet map services; Image Rendering, Query, Data Extraction, Feature Streaming, and Geocoding, among which the later two are not applied for application development.

(a) Image Rendering

It generates and sends maps to web browsers as JPEG, GIF, and so on. Cartographic images can be generated from shapefiles (ArcView data format). This function is utilised in MIS web-application.

(b) Query

It returns associated data for spatial and tabular queries. Queries can be built against shapefiles, ArcSDE data sets, and joined external tables.

(c) Data Extraction

This will send to the data server a request to extract data from shapefiles and ArcSDE layers, and the requested data is sent back to the client, as a zipped shapefile. Download capability is provided in MIS by using this ArcIMS function. For the detail list of layers, which can be downloaded, please refer to the **Annex I.2.1**.

(d) Feature Streaming

It will send shapefiles and ArcSDE (Arc Spatial Database Engine) data sets in a compressed format to a Java Applet in the client Web browser. It is a temporary compressed format that remains only so long as the Java Applet is open. This function is useful for on-line Internet mapping and performing overlay analysis by using the data from different websites.

Feature Streaming function is not utilised in MIS Web application development. The system performance will become very slow in the existing network of JMG, and on-line analysis is also not expected in the near future. Image Rendering function is chosen, instead.

(e) Geocoding

It can locate addresses on maps. This function is commonly applied for example in address matching along a Road Network or in creating very large Parcel Database, etc. This function is not applied in this Study.

All these services such as the content of information to be sent by ArcIMS spatial server to the client are managed by the ArcIMS Manager.

(3) Database Back-End

The Oracle database design of HIDRODAT is 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, were 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.

For detail database design and processing logic, please refer to **Annex I.2.1**.

2.4.2 Hardware and Software

The Hardware and Software configuration is illustrated in **Figure I.2.6**.

The Study Team had procured two (2) units of HP computers in Phase I. For MIS web application development, a new Compaq Proliant server was purchased. The operating system, Windows 2000 Server, is installed on one HP computer and the new Compaq server. The latter is used as the ArcIMS web server and the HP unit is used as Oracle Data server.

In terms of memory and disk requirements, it might be possible to install both data and application on a single server. Since the system is thought to be the basis for further development, the present configuration is recommended. However, a series of command level operations are required for maintenance of the system. The second HP computer is installed for this purpose.

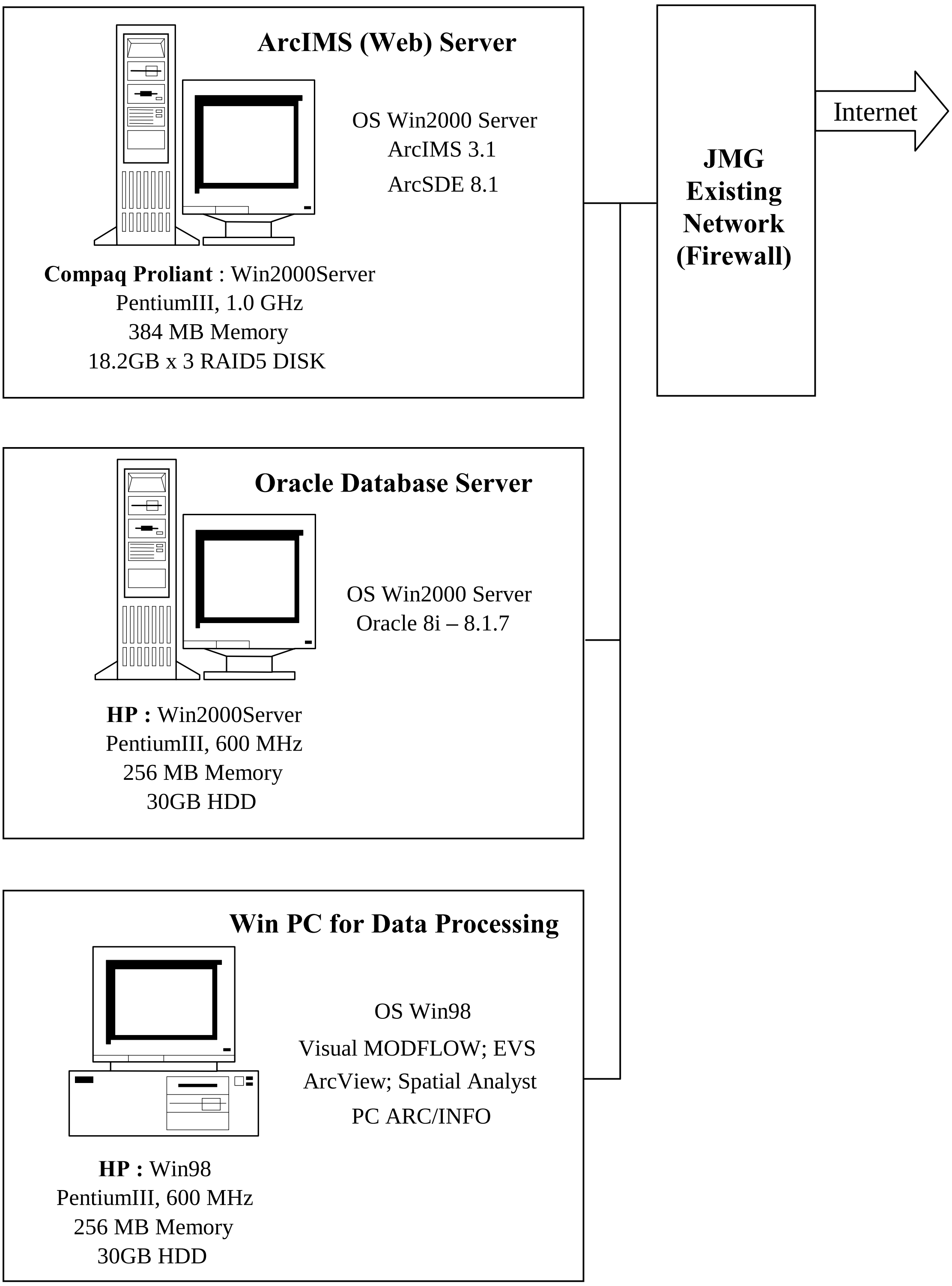


Figure I.2.6 Hardware and Software Configuration

ANNEX I.2.1

OVERVIEW OF THE SYSTEM DEFINITION

OF

THE MANAGEMENT INFORMATION SYSTEM (MIS)

TABLE OF CONTENTS

ANNEX I.2.1

OVERVIEW OF THE SYSTEM DEFINITION OF THE MANAGEMENT INFORMATION SYSTEM (MIS)

1. SYSTEM DEVELOPMENT

1.1 Purpose

The purpose of the Management Information System (MIS) is to manage Groundwater resources. This will be accomplished by consolidating all the diverse geographic and attribute data and disseminating these data through the Internet to be utilised by a wide variety of users who can be in distant

1.2 Development Schedule

Prior to finalise system development of the entire module of the MIS (Management Information System), the latest Database schema should be considered which was altered when the JMGM System was upgraded to the latest version 4.1.3 from the version 3.0.4. It is important to review HYDAT Database update process by analysing new source code of the system so that user requirements can be fully realised into the MIS development. Taking this into account, the system development was implemented as following schedule:

Present – November	:	MIS System Installation (Map Service module)
Early of December	:	System set up and Presentation (Map Service module)
Late of December	:	MIS Database module and Option tool development
Early of January	:	MIS System Installation and System Test (Full module)

1.3 Scope and Objectives

1.3.1 Centralisation of Data

The Management Information System will centralise Geographic Information Data coming from different sources that is collected by the JMG, into one central repository. These data will include both the collection of Geographical Textual attributes (i.e. a well's location and it chemical analysis, etc.) as well as Cartographic data (i.e. Topographic Maps, Land Use Maps, Satellite Images of a particular location, etc.). The benefits that can be derived from a centralised repository are:

- Data Integrity – all the data that the different users will be utilising will always be consistent and up to date.
- Security – the Administrator can have greater control on who can access the data since he has the capability to grant or revoke access rights for each particular user.

- Maintainability – maintenance work such as back-ups, bulk updates, etc. can be facilitated much easier.

1.3.2 Wide Dissemination of Data

The MIS will maximise the IT infrastructure of Malaysia by utilising the Internet in its dissemination of data. The MIS will move away from the traditional client/server model go into a three-tier web based system architecture. Doing so will give the potential of more users the ability to access and query the data even from disparate locations to form analysis for decision-making. The data will also be accessed through a common web browser thereby reducing the cost of having to purchase additional Geographic Information System (GIS) client software such as ArcView or ArcInfo. Also, since a common user-friendly web browser will be used to access the data, no additional training for users will be required. The MIS will be developed utilising common IT tools such as *Java*, *JAVASCRIPT*, and *Active Server Page (ASP)* instead of proprietary vendors' Macro Languages so that further customisation can be achieved easily to react rapidly to future user needs.

1.4 Current System or Procedures

At present, a GIS system is in place at the GIS Unit of the JMG Head Office since 1994. The cartographic data is stored in a Unix machine, which has ArcInfo 7.2.1 with TIN as an optional module. A Personal Computer (PC) which has been installed ArcView 3.0a with Spatial Analyst also accesses this data. The textual attribute data is stored in Oracle, which is also residing in the Unix machine. Additional data is store in dBase in several PCs. Although not part of the GIS Unit, NaLIS has also an additional ArcView 3.2 and ArcIMS. Additional ArcView software are planned to be introduced to other Operational Level Departments. Other Inter-Agencies also have ArcInfo and are in the process of transforming their spatial data, which sometimes are in CAD format, into ArcInfo coverages.

The system is connected to the JMG-LAN that is part of the Government Integrated Telecommunication Network (GITN). Other Inter-Agency Wide Area Networks (WAN) exists using a leased ISDN line within the Kuala Lumpur area.

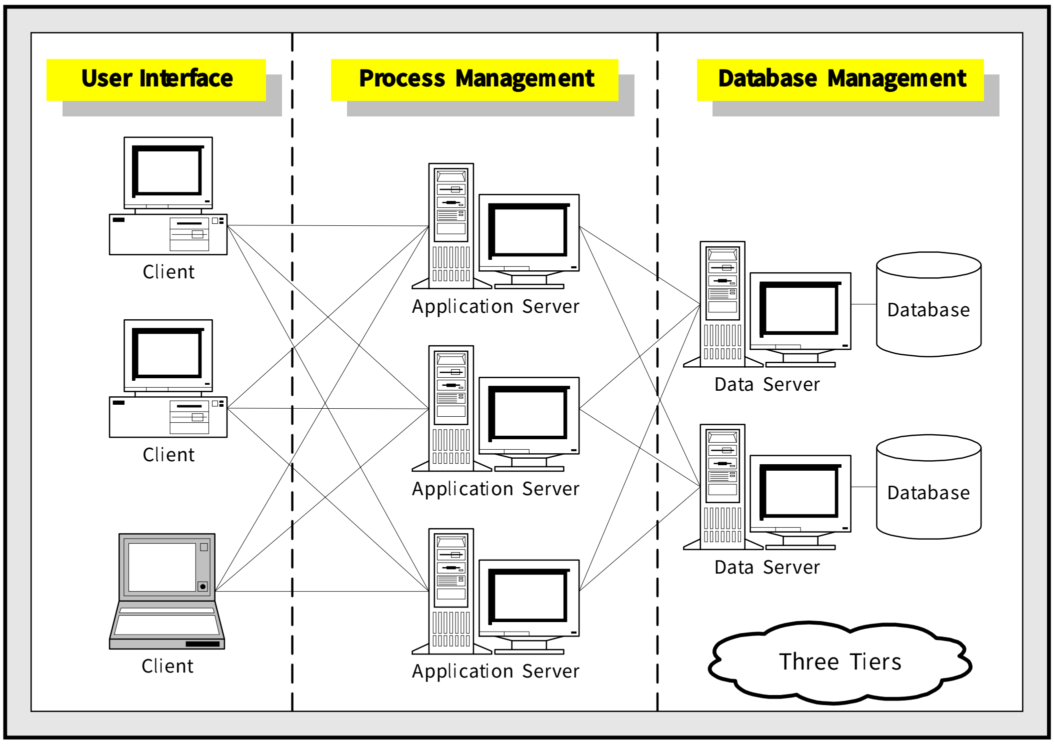
2. SYSTEM DESIGN

2.1 System Architecture

The MIS will employ a web-based, three-tier architecture. This architecture has been chosen because it provides increased performance, flexibility, maintainability, and scalability while hiding the complexities of distributing data from the end user.

In a three-tier architecture, there is a middle tier between the client and the server that serves as an intermediate layer in which both the client (the user-interface) and the server (which typically holds the database) communicate with. It is in the middle tier where the business logic and rules are executed based on the data obtained from the server, which in turn will be passed on to the client.

By taking away the business logic and rules away from both the client and the server, the three-tier system becomes more scalable and capable of handling hundreds of users.



Annex Figure I.2.1 Three-tier Architecture

Some of the advantages of the three-tier Architecture are as follows:

- Clear Separation of Roles

The client front-end application is clearly separated from whatever data manipulation the database backend has to do. The client merely passes on the input requests and receives whatever output parameters. At the same time, the server does not have to concern itself about the business logic or rules nor the presentation GUI and merely concentrate on its primary task of providing data integrity and storage.

- Database Independence

The database backend can be totally restructured, replaced, updated, etc. and still not affect the client programs.

- Front-End Independence

Similarly, the client program can be modified or replaced completely without having any affect on the database back-end.

- Multiple Data Sources

Since it is in the middle tier that manages the data that will be passed on to the client, the middle tier can be configured to obtain data from other sources without affecting either the client or the server.

- Reduction of Load

Since the middle tier can be configured to cache the data from commonly queries, database operations can be minimised as well as network load.

2.2 System Components

2.2.1 Database Back-End

(1) Oracle

Oracle is the world's most widely used Database System currently holding 46% market share and over 66% share in the Unix environment.

Some of the features that make Oracle the most used Enterprise Database are:

- Highly Scalable and able to run in numerous computer architectures (i.e. from desktop PCs to massive IBM mainframes);
- Has continuous data availability which reduces both planned and unplanned downtime;
- Has a secure infrastructure;
- Has native Java and XML support for easier customisation and interoperability with other applications;
- Has a wealth of development tools for enterprise level applications; and
- Oracle has continuously led other databases in speed in transaction processing.

(2) ArcSDE (Spatial Database Engine)

ArcSDE is the GIS gateway that facilitates storage of spatial data together with other business data in a Relational Database Management System (RDBMS) such as Oracle. Since ArcSDE exists within the RDBMS, it inherits all the robustness and scalability of the RDBMS as well as the RDBMS' additional functionalities such as replication, fail-over, etc. With its unique spatial data storage and spatial index architecture, ArcSDE is capable of rapidly serving large amounts of spatial data to large amounts of users.

2.2.2 Middle Tier

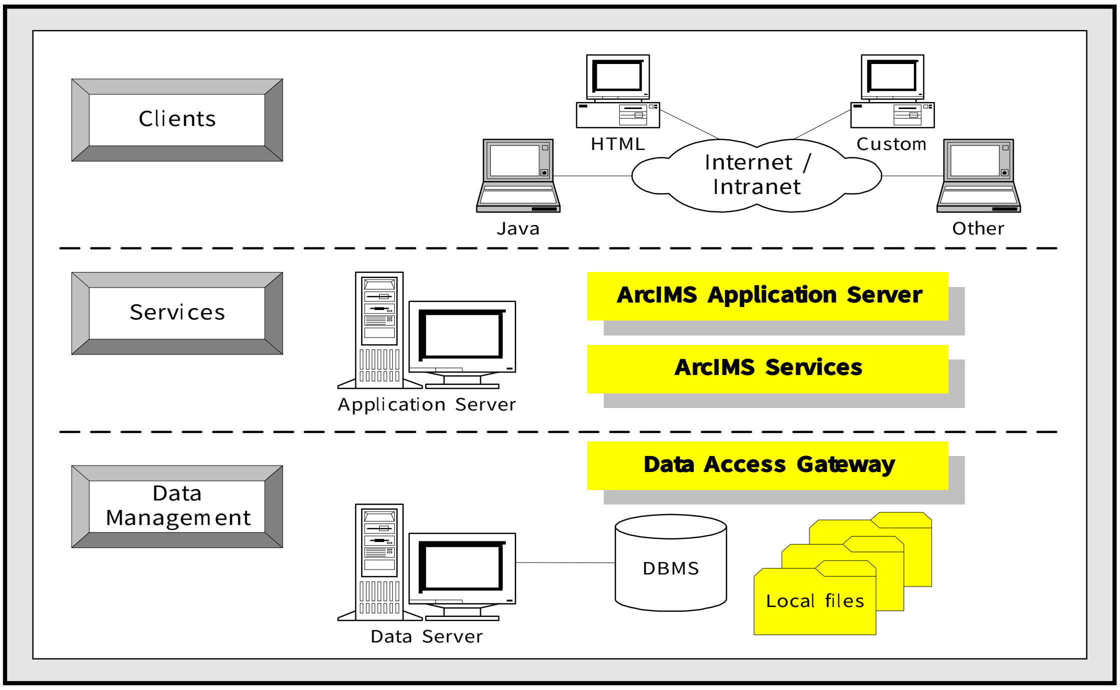
(1) ArcIMS (Internet Map Server)

ArcIMS is a powerful framework for distributing and disseminating GIS services over the Internet. It is capable of fast creation of dynamic maps on very large data sets. It is also able to do specific spatial queries on the created maps such as buffering, overlay, etc. One of the major features of ArcIMS also is its ability to do load balancing, wherein it passes the work process to other ArcIMS servers when the load becomes heavy. Some of the other features of ArcIMS are:

- Highly Scalable System Architecture;
- Can co-exist with any prevalent Internet System configuration;
- Takes advantage of built-in templates for rapid deployment of internet applications;
- Has a secure access to the Map Server (SSL protocol based). ArcIMS also performs user authentication that lets the Administrator to manage access rights of each user; and
- Uses the industry standard based XML for its communication which lets other application easily inter-operate with ArcIMS.

(2) Microsoft IIS (Internet Information Services)

MS IIS is the default Internet web service of WinNT and Win2000 servers. IIS is highly integrated with its Operating system resulting in a reliable, scalable, and high performance web server. An integral part of IIS is Active Server Page (ASP) which lets developers create rapidly dynamic web-based database-driven applications. ASP also acts as a glue that binds other middle-tier applications with the IIS web server.



Annex Figure I.2.2 ArcIMS Architecture

2.2.3 Client Side

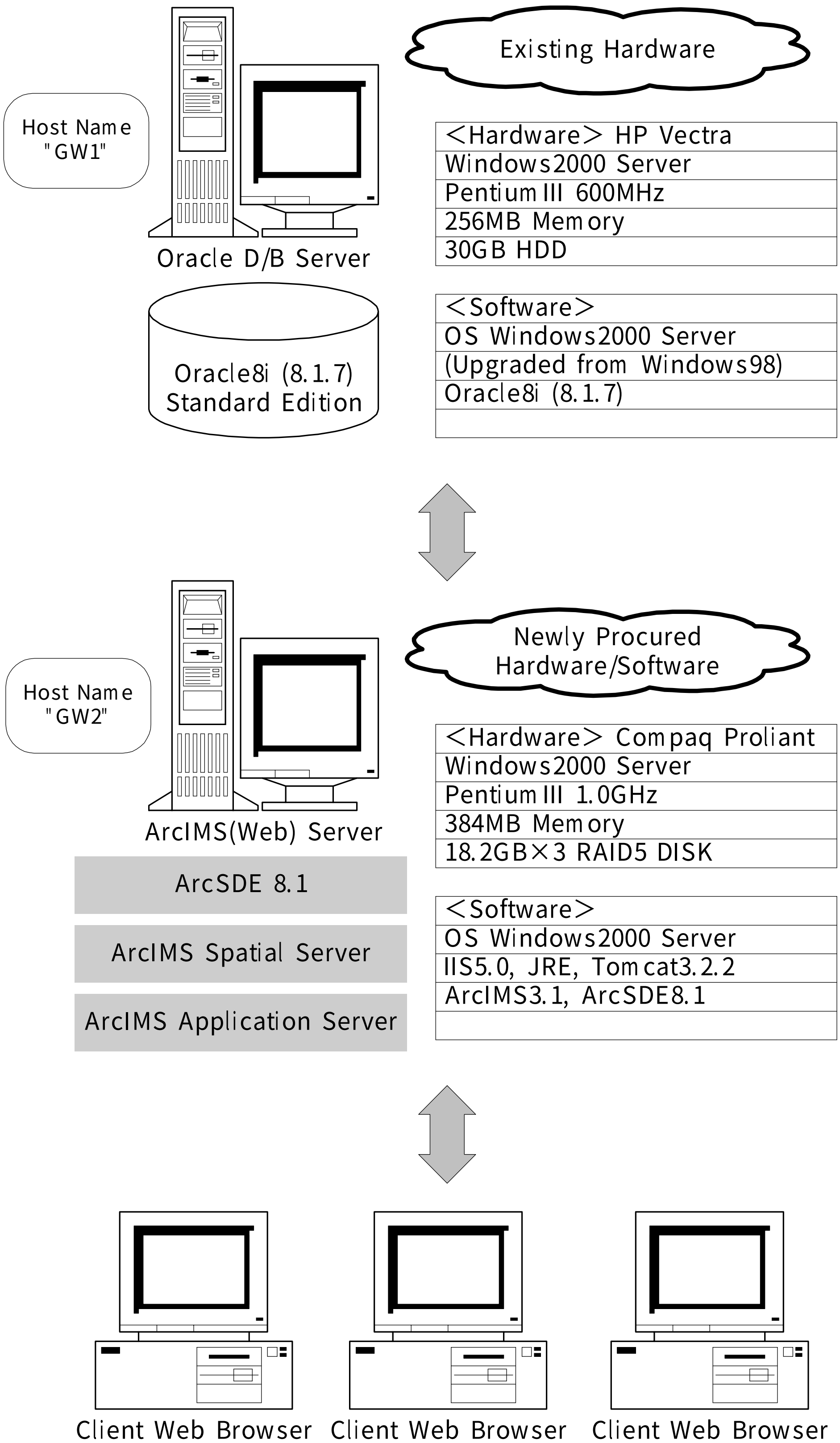
Since the System is utilising a thin client design for user interaction, an internet connection or a leased line intranet connection to the main web server plus any web browser that is compatible to either Netscape Communicator version 4 or Internet Explorer version 4 and above will suffice.

2.3 Hardware/Software

The following figure illustrates the Hardware and Software that will be utilised by the MIS. ArcIMS3.1 and ArcSDE8.1 are both installed on the newly procured server. Although ArcSDE8.1 is better to be installed on the same server on which Oracle DBMS is installed, it was installed on the different server from the Oracle DBMS server considering hardware capacity.

Prior to the installation of ArcIMS3.1, jdk1.3 from the IBM web site and Tomcat Servlet Engine3.2.2 which was downloaded from the Tomcat web site was installed and Tomcat service was properly configured to work with ArcIMS. After the installation of ArcIMS3.1, Image MapServices for theme maps and evaluation maps which will be utilised by the MIS were created from the axl files. These axl files specifies the contents of each map layer.

Although the diagram illustrates the most optimal configuration while considering the network three-tier environment and hardware capacity, it is possible to place the middle-tier and the database backend all into one or two machines.



Annex Figure I.2.3 Hardware/Software

3. DATABASE DESIGN

3.1 Database Architecture

In this system development, the HYDAT Database is utilised which is based on the JMGM Database Information System version 4.1.3, currently being implemented in an Oracle RDBMS within the IPOH Office. The HYDAT Database consists of two schemas, IDIS01 and IDIS02, which are being accessed in the present Client/Server environment by four user accounts: HIDROGEO, HIDROLAB, IMPGEO, IMPLAB. Within the MIS, the IDIS01 is the main access target, containing the basic WELL information. The IDIS01 is being accessed by the HIDROGEO, HIDROLAB, and HIDROALL user accounts which is newly created for just query purposes.

The list of user access privileges which will be used by the system is illustrated below:

Annex Table I.2.1 User Access Level

USER LEVEL	USER NAME	Annual Reports	Map Data	Well Data Attributes		Chemical Attributes	
			Display	Update	Query	Update	Query
0	-	○	×	×	×	×	×
1	OTHERORG	○	△	×	×	×	×
2	HIDROGEO	○	○	○	○	△	○
	HIDROLAB	○	○	×	×	○	○
3	HIDROALL	○	○	×	○	×	○

Note: ○: Full Access Privilege, △: Limited Access Privilege, ×: No Access Privilege

OTHERORG User : Other Organisations and Government Institutions

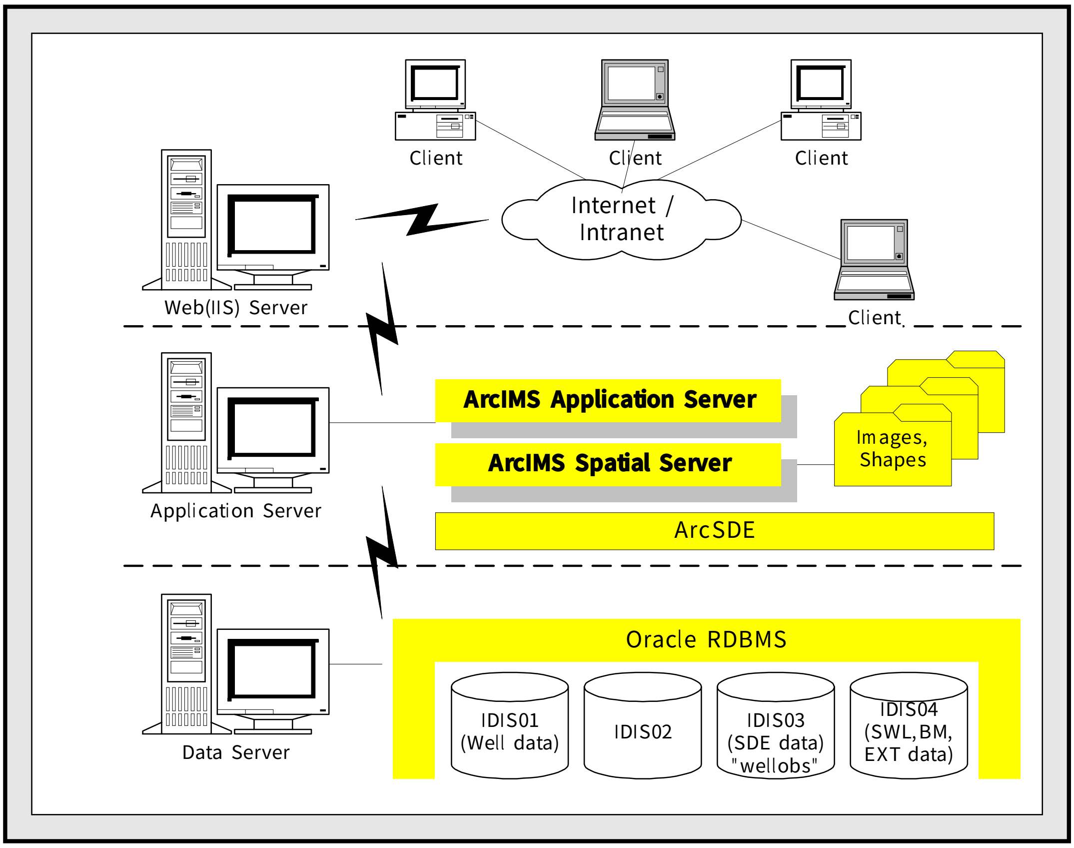
HIDROGEO User : Geologist Organisations within the JMG

HIDROLAB User : Chemist Organisations within the JMG

HIDROALL User : All the Other Organisations within the JMG

No User Necessary : General Dissemination

In order to store Geographic Data, a new schema, IDIS03, is created that will contain large amount of data in the future. This database will be designed effectively in order to acquire various position information through the ArcSDE. Presently, observation well data “WELLOBS” is stored here to better manage referential integrity with the IDIS01 schema which contain well information data. In addition, a new schema IDIS04 is also created for the purpose of storing data which will be acquired from the data logger.



Annex Figure I.2.4 Database Architecture

In particular, in the design of the relational database it is essential to retain the relationship among various entities and its cardinalities and integrates. Accordingly, prior to system development, the source code of the existing Client/Server system was analysed and the necessary information regarding the integrities was retained and was made as the basis of further development.

3.2 Sources of Data / Conversion

3.2.1 WELL Information Data

At first, the tables managed within the Welldb-org.mdb (in MS-ACCESS data format) were used as a source of WELL information data. A conversion process was implemented next since the table schema of the Welldb-org.mdb was different from that of the HYDAT Database's schema within Oracle. This HYDAT Database (IDIS01 and IDIS02 schemas) was constructed from Oracle SQL files (Create_User_JMGM.sql, Tab_idis01.sql, Tab_idis02.sql), which were acquired from JMGM dated 25 September 2001. The source code of the Client/Server system of which version was upgraded from 3.0.4 to 4.1.3 was analysed next. Table relationship information was extracted from which an Entity Relation Diagram was created and the Primary and Foreign Keys along with its Referential Integrity was established (refer to **Section 3.5 Referential Integrity** for more details). Once the Referential Integrity was established, the MS-ACCESS tables were linked to the Oracle tables via ODBC, and the data from the MS-ACCESS tables were inserted into Oracle.

The following is a list of tables and the number of records contained within the Welldb-org.mdb:

General	353 records
General2	353 records
Geolog1	354 records
Geolog2	354 records
Geolog3	341 records
Geolog4	267 records
Variable main	267 records
Variable field	267 records
Variable others	317 records
Well structure	346 records

In addition, a schema IDIS04 was newly created inside the HYDAT Database in order to store data which will be acquired from the data logger. Those data include Surface water level table, Extensometer table, and Bench Mark elevation table. Tentatively, some test data which were acquired from JICA study team dated 14 September 2001 are stored for those tables to verify system function to draw graph.

3.2.2 Geographic Data

For the Geographic Database, the data from the Study on the Sustainable Groundwater Resources and Environmental Management for the Land Basin in Malaysia – Phase II were utilised as the Basic Map. For map queries within the MIS, the Malaysia States Polygon and the Bathymetric Contour Polygon data from the Digital Chart of the World (DCW) were also utilised. Initially, all these data were converted into ESRI's Shapefile data format but in order to better manage geographic data that has the referential integrity with Hydat Oracle D/B, one of these data is housed within ArcSDE. The ArcSDE data "WELLOBS" is stored within the IDIS03 schema of the Oracle database and will be linked to the GENERAL well table using the well number (WELL_NO) as the key. Shapefiles with small amount of geographic data that will be mainly used for map queries and Shapefiles that will be used for theme maps and evaluation maps are both stored as local Shapefiles within the ArcIMS server "GW2" since this will reduce the amount of network overhead.

A consistent Map Projection was used for all the geographic data making it possible to overlay all the data with each other, even if the data came from different sources or was just newly created. The Map Projection was done within the ArcInfo environment using the following Project Parameters:

(1) Map Projection Parameters

OUTPUT

PROJECTION RSO /* Rectified Skewed Orthomorphic

UNITS METERS

SPHEROID MODEVEREST /* Modified Everest 1948

DATUM KEA /* Kertau 1948

PARAMETERS

2 /* Malaysia Option

END

(2) Geographic Data for Theme Maps

The data listing which will be used for Theme Maps in this system are as follows.

Annex Table I.2.2 Geographic Data for Theme Map "Groundwater"

id	Layer_Name	Type	Legend Notation	Download	Max_Scale	Min_Scale
22	observation	point (SHP)	Location of Groundwater Level	○	1:800000	-
21	sw_ph	point (SHP)	pH value (Surface water)	○	1:800000	-
20	gw_ph	point (SHP)	pH value (Groundwater)	○	1:800000	-
24	sw_ec	point (SHP)	Electric Conductivity (us/cm) (Surface water)	○	1:800000	-
23	gw_ec	point (SHP)	Electric Conductivity (us/cm) (Groundwater)	○	1:800000	-
26	sw_cl	point (SHP)	Chloride Values (mg/l) (Surface water)	○	1:800000	-
25	gw_cl	point (SHP)	Chloride Values (mg/l) (Groundwater)	○	1:800000	-
27	mhlead	point (SHP)	Organic Compounds Lead (ug/l)	○	1:800000	-
28	arsenic	point (SHP)	Organic Compounds Arsenic (ug/l)	○	1:800000	-
17	IDIS03.WELLOBS	point (SDE)	Monitoring Well	○	1:600000	-
8	highways	line (SHP)	Highways	×	1:350000	-
7	roads	line (SHP)	Roads	×	1:350000	-
6	road50	line (SHP)	Roads detail	×	1:120000	-
9	rails	line (SHP)	Rails	×	1:350000	-
5	rivers	line (SHP)	Rivers	×	1:800000	-
4	river50	line (SHP)	Rivers detail	×	1:160000	-
10	town	point (SHP)	Town	×	1:500000	-
12	studarea	polygon (SHP)	Study Area	○	1:1800000	-
3	Klia	polygon (SHP)	KLIA	×	1:800000	-
2	reserve	polygon (SHP)	Reserve	×	1:800000	-
1	payainda	polygon (SHP)	Paya Indah	×	1:800000	-
18	pluse	polygon (SHP)	Landuse	×	1:800000	-
19	geology	polygon (SHP)	Geology	×	1:800000	-
0	sea-pol	polygon (SHP)	Sea	×	1:800000	-
11	state-pl	polygon (SHP)	State-pl	×	1:800000	-
15	clsx99r	polygon (SHP)	States boundary	×	1:9000000	1:800000
16	cat7l_r	line (SHP)	Administrative Boundary	×	1:9000000	1:800000
14	bath_rso	polygon (SHP)	Sea	×	1:9000000	1:800000
13	malaysia.tif	image (tif)	Topography Image	×	1:9000000	1:800000

Annex Table I.2.3 Geographic Data for Theme Map "Land Subsidence"

id	Layer_Name	Type	Legend Notation	Download	Max_Scale	Min_Scale
22	extenso	point (SHP)	Borehole Extensometer	×	1:800000	-
21	bnch-mrk	point (SHP)	Bench Mark	×	1:800000	-
20	dp-datum	point (SHP)	Deep Datum	×	1:800000	-
17	IDIS03.WELLOBS	point (SDE)	Monitoring Well	○	1:600000	-
8	highways	line (SHP)	Highways	×	1:350000	-
7	roads	line (SHP)	Roads	×	1:350000	-
6	road50	line (SHP)	Roads detail	×	1:120000	-
9	rails	line (SHP)	Rails	×	1:350000	-
5	rivers	line (SHP)	Rivers	×	1:800000	-
4	river50	line (SHP)	Rivers detail	×	1:160000	-
10	town	point (SHP)	Town	×	1:500000	-
12	studarea	polygon (SHP)	Study Area	○	1:1800000	-
3	Klia	polygon (SHP)	KLIA	×	1:800000	-
2	reserve	polygon (SHP)	Reserve	×	1:800000	-
1	payainda	polygon (SHP)	Paya Indah	×	1:800000	-
18	pluse	polygon (SHP)	Landuse	×	1:800000	-
19	geology	polygon (SHP)	Geology	×	1:800000	-
0	sea-pol	polygon (SHP)	Sea	×	1:800000	-
11	state-pl	polygon (SHP)	State-pl	×	1:800000	-
15	clsx99r	polygon (SHP)	States boundary	×	1:9000000	1:800000
16	cat7l_r	line (SHP)	Administrative Boundary	×	1:9000000	1:800000
14	bath_rso	polygon (SHP)	Sea	×	1:9000000	1:800000
13	malaysia.tif	image (tif)	Topography Image	×	1:9000000	1:800000

Annex Table I.2.4 Geographic Data for Theme Map "Potential Pollution Source"

id	Layer_Name	Type	Legend Notation	Download	Max_Scale	Min_Scale
20	industry	point (SHP)	Industrial Estates	○	1:800000	-
21	animals	point (SHP)	Animal Farms	○	1:800000	-
23	mine-pnt	point (SHP)	Mining (Point)	○	1:800000	-
22	mine-pol	polygon (SHP)	Mining (Polygon)	○	1:800000	-
25	sewage	point (SHP)	Wastewater Treatment Plant	○	1:800000	-
24	sld-wast	point (SHP)	Solid Wastes Landfill Site	○	1:800000	-
17	IDIS03.WELLOBS	point (SDE)	Monitoring Well	○	1:600000	-
8	highways	line (SHP)	Highways	×	1:350000	-
7	roads	line (SHP)	Roads	×	1:350000	-
6	road50	line (SHP)	Roads detail	×	1:120000	-
9	rails	line (SHP)	Rails	×	1:350000	-
5	rivers	line (SHP)	Rivers	×	1:800000	-
4	river50	line (SHP)	Rivers detail	×	1:160000	-
10	town	point (SHP)	Town	×	1:500000	-
12	studarea	polygon (SHP)	Study Area	○	1:1800000	-
3	Klia	polygon (SHP)	KLIA	×	1:800000	-
2	reserve	polygon (SHP)	Reserve	×	1:800000	-
1	payainda	polygon (SHP)	Paya Indah	×	1:800000	-
18	pluse	polygon (SHP)	Landuse	×	1:800000	-
19	geology	polygon (SHP)	Geology	×	1:800000	-
0	sea-pol	polygon (SHP)	Sea	×	1:800000	-
11	state-pl	polygon (SHP)	State-pl	×	1:800000	-
15	clsx99r	polygon (SHP)	States boundary	×	1:9000000	1:800000
16	cat7l_r	line (SHP)	Administrative Boundary	×	1:9000000	1:800000
14	bath_rso	polygon (SHP)	Sea	×	1:9000000	1:800000
13	malaysia.tif	image (tif)	Topography Image	×	1:9000000	1:800000

Annex Table I.2.5 Geographic Data for Theme Map "Geology and Soil Condition"

id	Layer_Name	Type	Legend Notation	Download	Max_Scale	Min_Scale
32	exbh-lst	point (SHP)	Existing Borehole Point	○	1:800000	-
25	rock-typ	point (SHP)	Bedrock Type	○	1:800000	-
26	lm-stone	polygon (SHP)	Distribution Area of Limestone	○	1:800000	-
17	IDIS03.WELLOBS	point (SDE)	Monitoring Well	○	1:600000	-
31	aq-dstr	line (SHP)	Upper boundary of the Aquifer	○	1:800000	-
30	l3-dstr	line (SHP)	Upper boundary of Medium to Stiff Clay Layer	○	1:800000	-
29	thk-soil	line (SHP)	Thickness of Medium to Stiff Clay Layer	○	1:800000	-
28	dst-soil	line (SHP)	Upper boundary of Soft Clayey Layer	○	1:800000	-
27	sft-clay	line (SHP)	Thickness of Soft Clay Layer	○	1:800000	-
24	x-sec_name	point (SHP)	Geological Profile Label	×	1:800000	-
22	x-section	line (SHP)	Location of Geological Profile	○	1:800000	-
21	cont-20	line (SHP)	Topographic Contourline of 20m Height	○	1:500000	-
23	lowland	line (SHP)	Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation	○	1:800000	-
20	br-cont	line (SHP)	Contourline of Bedrock Surface	○	1:800000	-
8	highways	line (SHP)	Highways	×	1:350000	-
7	roads	line (SHP)	Roads	×	1:350000	-
6	road50	line (SHP)	Roads detail	×	1:120000	-
9	rails	line (SHP)	Rails	×	1:350000	-
5	rivers	line (SHP)	Rivers	×	1:800000	-
4	river50	line (SHP)	Rivers detail	×	1:160000	-
10	town	point (SHP)	Town	×	1:500000	-
12	studarea	polygon (SHP)	Study Area	○	1:1800000	-
3	Klia	polygon (SHP)	KLIA	×	1:800000	-
1	payainda	polygon (SHP)	Paya Indah	×	1:800000	-
18	pluse	polygon (SHP)	Landuse	×	1:800000	-
19	geology	polygon (SHP)	Geology	×	1:800000	-
0	sea-pol	polygon (SHP)	Sea	×	1:800000	-
11	state-pl	polygon (SHP)	State-pl	×	1:800000	-
15	clsx99r	polygon (SHP)	States boundary	×	1:9000000	1:800000
16	cat7l_r	line (SHP)	Administrative Boundary	×	1:9000000	1:800000
14	bath_rso	polygon (SHP)	Sea	×	1:9000000	1:800000
13	malaysia.tif	image (tif)	Topography Image	×	1:9000000	1:800000

(3) Geographic data for Evaluation Maps

The data listing which will be used for Evaluation Maps in this system are as follows.

Annex Table I.2.6 Geographic Data for Evaluation Map "Equipotential Map"

id	Layer_Name	Type	Legend Notation	Download	Max_Scale	Min_Scale
4	variant_0	point (SHP)	Variants (0)	○	-	-
19	variant_1	point (SHP)	Variants (1)	○	-	-
7	variant_2	point (SHP)	Variants (2)	○	-	-
10	variant_3	point (SHP)	Variants (3)	○	-	-
13	variant_4	point (SHP)	Variants (4)	○	-	-
16	variant_5	point (SHP)	Variants (5)	○	-	-
3	eqarr_var0	line (SHP)	Direction of Groundwater Flow (0)	○	-	-
18	eqarr_var1	line (SHP)	Direction of Groundwater Flow (1)	○	-	-
6	eqarr_var2	line (SHP)	Direction of Groundwater Flow (2)	○	-	-
9	eqarr_var3	line (SHP)	Direction of Groundwater Flow (3)	○	-	-
12	eqarr_var4	line (SHP)	Direction of Groundwater Flow (4)	○	-	-
15	eqarr_var5	line (SHP)	Direction of Groundwater Flow (5)	○	-	-
1	eqcon_var0	line (SHP)	Contour Line of Piezometric Head (0)	○	-	-
17	eqcon_var1	line (SHP)	Contour Line of Piezometric Head (1)	○	-	-
5	eqcon_var2	line (SHP)	Contour Line of Piezometric Head (2)	○	-	-
8	eqcon_var3	line (SHP)	Contour Line of Piezometric Head (3)	○	-	-
11	eqcon_var4	line (SHP)	Contour Line of Piezometric Head (4)	○	-	-
14	eqcon_var5	line (SHP)	Contour Line of Piezometric Head (5)	○	-	-
2	mod-river	line (SHP)	Rivers	×	-	-
0	grid	polygon (SHP)	grid	○	-	-
20	d5_var1	polygon (SHP)	Solution Variant 1 - Drawdown in Layer 5	○	-	-
23	d5_var2	polygon (SHP)	Solution Variant 2 - Drawdown in Layer 5	○	-	-
22	d5_var3	polygon (SHP)	Solution Variant 3 - Drawdown in Layer 5	○	-	-
21	d5_var4	polygon (SHP)	Solution Variant 4 - Drawdown in Layer 5	○	-	-

Annex Table I.2.7 Geographic Data for Evaluation Map "Zone of Seawater Intrusion"

id	Layer_Name	Type	Legend Notation	Download	Max_Scale	Min_Scale
7	mod-bnd	polygon (SHP)	Model Boundary	○	-	-
5	i45-26-wells	point (SHP)	Chloride (mg/l)	○	-	-
6	i45-26-wells	point (SHP)	Electric Conductivity (uS/cm)	○	-	-
4	saltwater	line (SHP)	Freshwater - Saltwater interface	○	-	-
3	payainda	polygon (SHP)	Paya Indah	×	-	-
2	mod-river	line (SHP)	Rivers	×	-	-
1	mod-sea	polygon (SHP)	Sea	×	-	-
0	mod-geo	polygon (SHP)	Geology	×	-	-

Annex Table I.2.8 Geographic Data for Evaluation Map "Land Subsidence"

id	Layer_Name	Type	Legend Notation	Download	Max_Scale	Min_Scale
20	ls-var1	line (SHP)	Contour Map of Land Subsidence (Variant 1)	×	1:800000	-
22	ls-var2	line (SHP)	Contour Map of Land Subsidence (Variant 2)	×	1:800000	-
24	ls-var3	line (SHP)	Contour Map of Land Subsidence (Variant 3)	×	1:800000	-
17	IDIS03.WELLOBS	point (SDE)	Monitoring Well	○	1:600000	-
23	lowland	line (SHP)	Boundary between Lowlands and Hills obtained by Aerial Photograph Interpretation	×	1:800000	-
21	cont-20	line (SHP)	Topographic Contourline of 20m Height	×	1:500000	-
8	highways	line (SHP)	Highways	×	1:350000	-
7	roads	line (SHP)	Roads	×	1:350000	-
6	road50	line (SHP)	Roads detail	×	1:120000	-
9	rails	line (SHP)	Rails	×	1:350000	-
5	rivers	line (SHP)	Rivers	×	1:800000	-
4	river50	line (SHP)	Rivers detail	×	1:160000	-
10	town	point (SHP)	Town	×	1:500000	-
12	studarea	polygon (SHP)	Study Area	○	1:1800000	-
3	Klia	polygon (SHP)	KLIA	×	1:800000	-
2	reserve	polygon (SHP)	Reserve	×	1:800000	-
1	payainda	polygon (SHP)	Payainda	×	1:800000	-
18	pluse	polygon (SHP)	Landuse	×	1:800000	-
19	geology	polygon (SHP)	Geology	×	1:800000	-
0	sea-pol	polygon (SHP)	Sea	×	1:800000	-
11	state-pl	polygon (SHP)	State-pl	×	1:800000	-
15	clsx99r	polygon (SHP)	States boundary	×	1:9000000	1:800000
16	cat7l_r	line (SHP)	Administrative Boundary	×	1:9000000	1:800000
14	bath_rso	polygon (SHP)	Sea	×	1:9000000	1:800000
13	malaysia.tif	image (tif)	Topography Image	×	1:9000000	1:800000

3.3 Tables/Data Elements

The tables listing and its structure which will be used in this system are as follows.

In the following tables, highlighted portion shows the updated items due to the HYDAT D/B version up. (Ver.3.0.4 → Ver.4.1.3)

As for the MIS development, version 4.1.3's table definition is applied.

Annex Table I.2.9 Main Table "GENERAL" (1/3)

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
WELL_NO	VARCHAR2(6)	VARCHAR2(6)		PK (NOT NULL)
FIELD_NO	VARCHAR2(14)	VARCHAR2(14)		
PROJECT	VARCHAR2(15)	VARCHAR2(15)		
DAY	NUMBER(2)	NUMBER(2)		
MONTH	NUMBER(2)	NUMBER(2)		
YEAR	NUMBER(4)	NUMBER(4)		
SOURCE	VARCHAR2(8)	VARCHAR2(30)	Field Width altered.	
INPUT_DATE	NUMBER(8)	NUMBER(8)		NOT NULL
NAM	VARCHAR2(15)	VARCHAR2(15)		
BASIN	VARCHAR2(15)	VARCHAR2(15)		
DISTRICT	VARCHAR2(15)	VARCHAR2(15)		
NALIS_CODE	NUMBER(19)	NUMBER(19)		
OWNER	VARCHAR2(15)	VARCHAR2(30)	Field Width altered.	
OWN_ADDRESS	VARCHAR2(15)	VARCHAR2(50)	Field Width altered.	
OWN_TEL	NUMBER(11)	NUMBER(11)		
OWN_CONTACT	VARCHAR2(15)	VARCHAR2(30)	Field Width altered.	
LOCATION	VARCHAR2(15)	VARCHAR2(30)	Field Width altered.	
LOCATION_MAP	VARCHAR2(15)	VARCHAR2(15)		
PHOTO	VARCHAR2(15)	VARCHAR2(15)		
MAP_NO	NUMBER(4)	NUMBER(4)		
YIELD_MHR	NUMBER(10)	NUMBER(10)		
MAP_NAME	VARCHAR2(15)	VARCHAR2(15)		
SCALE	VARCHAR2(5)	VARCHAR2(5)		
POSITIONBY	VARCHAR2(10)	VARCHAR2(10)		
NORTHING	NUMBER(6)	NUMBER(6)		
EASTING	NUMBER(6)	NUMBER(6)		
ELEV_M	NUMBER(6,2)	NUMBER(6,2)		
TOPOGRAPHY	VARCHAR2(10)	VARCHAR2(10)		
WELL_USE	VARCHAR2(15)	VARCHAR2(15)		
USE_HR	NUMBER(4,1)	NUMBER(4,1)		
WELL_TYPE	VARCHAR2(15)	VARCHAR2(15)		
WELL_STATUS	VARCHAR2(15)	VARCHAR2(15)		

Annex Table I.2.9 Main Table "GENERAL" (2/3)

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
DRILLBY	VARCHAR2(8)	VARCHAR2(30)	Field Width altered.	
DLL_ADDRESS	VARCHAR2(15)	VARCHAR2(50)	Field Width altered.	
DLL_TEL	NUMBER(11)	NUMBER(11)		
DLL_CONTACT	VARCHAR2(15)	VARCHAR2(30)	Field Width altered.	
DEPTH_M	NUMBER(6,2)	NUMBER(6,2)		
COLLAR_M	NUMBER(4,2)	NUMBER(4,2)		
RIG_TYPE	VARCHAR2(6)	VARCHAR2(6)		
MEMO	VARCHAR2(100)	VARCHAR2(100)		
LANDUSE	VARCHAR2(15)	VARCHAR2(15)		
DRILL1_M	NUMBER(6,2)	-	Field dropped.	
DRILL2_M	NUMBER(6,2)	-	Field dropped.	
DRILL3_M	NUMBER(6,2)	-	Field dropped.	
DRILL4_M	NUMBER(6,2)	-	Field dropped.	
METHOD1	VARCHAR2(11)	-	Field dropped.	
METHOD2	VARCHAR2(11)	-	Field dropped.	
METHOD3	VARCHAR2(11)	-	Field dropped.	
METHOD4	VARCHAR2(11)	-	Field dropped.	
DIA1_MM	NUMBER(4)	-	Field dropped.	
DIA2_MM	NUMBER(4)	-	Field dropped.	
DIA3_MM	NUMBER(4)	-	Field dropped.	
DIA4_MM	NUMBER(4)	-	Field dropped.	
BITTYPE1	VARCHAR2(10)	-	Field dropped.	
BITTYPE2	VARCHAR2(10)	-	Field dropped.	
BITTYPE3	VARCHAR2(10)	-	Field dropped.	
BITTYPE4	VARCHAR2(10)	-	Field dropped.	
LINE1_M	NUMBER(6,2)	-	Field dropped.	
LINE2_M	NUMBER(6,2)	-	Field dropped.	
LINE3_M	NUMBER(6,2)	-	Field dropped.	
LINE4_M	NUMBER(6,2)	-	Field dropped.	
LINE5_M	NUMBER(6,2)	-	Field dropped.	
LINE6_M	NUMBER(6,2)	-	Field dropped.	
L_TYPE1	VARCHAR2(12)	-	Field dropped.	
L_TYPE2	VARCHAR2(12)	-	Field dropped.	
L_TYPE3	VARCHAR2(12)	-	Field dropped.	
L_TYPE4	VARCHAR2(12)	-	Field dropped.	
L_TYPE5	VARCHAR2(12)	-	Field dropped.	
L_TYPE6	VARCHAR2(12)	-	Field dropped.	
L_MAT1	VARCHAR2(17)	-	Field dropped.	
L_MAT2	VARCHAR2(17)	-	Field dropped.	
L_MAT3	VARCHAR2(17)	-	Field dropped.	
L_MAT4	VARCHAR2(17)	-	Field dropped.	
L_MAT5	VARCHAR2(17)	-	Field dropped.	
L_MAT6	VARCHAR2(17)	-	Field dropped.	
L_DIA1_MM	NUMBER(4)	-	Field dropped.	
L_DIA2_MM	NUMBER(4)	-	Field dropped.	
L_DIA3_MM	NUMBER(4)	-	Field dropped.	

Annex Table I.2.9 Main Table "GENERAL" (3/3)

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
L_DIA4_MM	NUMBER(4)	-	Field dropped.	
L_DIA5_MM	NUMBER(4)	-	Field dropped.	
L_DIA6_MM	NUMBER(4)	-	Field dropped.	
SLOT1_MM	NUMBER(5)	-	Field dropped.	
SLOT2_MM	NUMBER(5)	-	Field dropped.	
SLOT3_MM	NUMBER(5)	-	Field dropped.	
SLOT4_MM	NUMBER(5)	-	Field dropped.	
SLOT5_MM	NUMBER(5)	-	Field dropped.	
SLOT6_MM	NUMBER(5)	-	Field dropped.	
PACK1_M	NUMBER(6,2)	-	Field dropped.	
PACK2_M	NUMBER(6,2)	-	Field dropped.	
PACK3_M	NUMBER(6,2)	-	Field dropped.	
PACK4_M	NUMBER(6,2)	-	Field dropped.	
PACK5_M	NUMBER(6,2)	-	Field dropped.	
PACK6_M	NUMBER(6,2)	-	Field dropped.	
P_MAT1	VARCHAR2(12)	-	Field dropped.	
P_MAT2	VARCHAR2(12)	-	Field dropped.	
P_MAT3	VARCHAR2(12)	-	Field dropped.	
P_MAT4	VARCHAR2(12)	-	Field dropped.	
P_MAT5	VARCHAR2(12)	-	Field dropped.	
P_MAT6	VARCHAR2(12)	-	Field dropped.	
P_SIZE1_MM	NUMBER(5)	-	Field dropped.	
P_SIZE2_MM	NUMBER(5)	-	Field dropped.	
P_SIZE3_MM	NUMBER(5)	-	Field dropped.	
P_SIZE4_MM	NUMBER(5)	-	Field dropped.	
P_SIZE5_MM	NUMBER(5)	-	Field dropped.	
P_SIZE6_MM	NUMBER(5)	-	Field dropped.	
AQUIF_TYPE	VARCHAR2(16)	-	Field dropped.	
AQUIF_MAT	VARCHAR2(20)	-	Field dropped.	

Annex Table I.2.10 Table "GENERAL_AQUIFER"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
WELL_NO	VARCHAR2(6)	VARCHAR2(6)		PK (NOT NULL)
AQUIF_TYPE	VARCHAR2(16)	VARCHAR2(16)		
AQUIF_MAT	VARCHAR2(20)	VARCHAR2(20)		PK (NOT NULL)
DEPTHF	-	NUMBER(6,2)	Field added.	
DEPTHT	-	NUMBER(6,2)	Field added.	

Annex Table I.2.11 Table "GENERAL_DRILLING"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
WELL_NO	VARCHAR2(6)	VARCHAR2(6)		PK (NOT NULL)
DEPTH_NO	-	NUMBER(3)	Field added.	
DEPTHF	-	NUMBER(6,2)	Field added.	
DEPTHT	-	NUMBER(6,2)	Field added.	
METHOD	VARCHAR2(11)	VARCHAR2(11)		
DIA_MM	NUMBER(4)	NUMBER(4)		
BIT_TYPE	VARCHAR2(10)	VARCHAR2(10)	Name altered.（BITTYPE→BIT_TYPE）	
DRILL_M	NUMBER(6,2)	-	Field dropped.	
BIL	NUMBER(3)	-	Field dropped.	PK (NOT NULL)
END_DRILL	NUMBER(6,2)	-	Field dropped.	

Annex Table I.2.12 Table "GENERAL_WELL_LINING"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
WELL_NO	VARCHAR2(6)	VARCHAR2(6)		PK (NOT NULL)
DEPTH_NO	-	NUMBER(3)	Field added.	
DEPTHF	-	NUMBER(6,2)	Field added.	
DEPTHT	-	NUMBER(6,2)	Field added.	
LINE_TYPE	-	VARCHAR2(12)	Field added. (Name altered.)	
MATERIAL	-	VARCHAR2(17)	Field added. (Name altered.)	
DIAMETER	-	NUMBER(4)	Field added. (Name altered.)	
SCREEN_SLOT	-	NUMBER(5)	Field added. (Name altered.)	
LINE_M	NUMBER(6,2)	-	Field dropped.	
L_TYPE	VARCHAR2(12)	-	Field dropped. (Name altered.)	
L_MAT	VARCHAR2(17)	-	Field dropped. (Name altered.)	
L_DIA_MM	NUMBER(4)	-	Field dropped. (Name altered.)	
SLOT_MM	NUMBER(5)	-	Field dropped. (Name altered.)	
PACK_M	NUMBER(6,2)	-	Field dropped.	
P_MAT	VARCHAR2(12)	-	Field dropped.	
P_SIZE_MM	NUMBER(5)	-	Field dropped.	
BIL	NUMBER(3)	-	Field dropped.	PK (NOT NULL)

Annex Table I.2.13 Table "GENERAL_WELL_PACKAGING"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
WELL_NO	-	VARCHAR2(6)	Table is newly added.	
DEPTH_NO	-	NUMBER(3)		
DEPTHF	-	NUMBER(6,2)		
DEPTHT	-	NUMBER(6,2)		
MATERIAL	-	VARCHAR2(12)		
PACK_SIZE	-	NUMBER(5)		

Note: This table is assumed to be separated from "GENERAL_WELL_LINING" table for table normalisation purpose.

Annex Table I.2.14 Table "GEOLOG_MASTER"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
WELL_NO	VARCHAR2(6)	VARCHAR2(6)		PK (NOT NULL)
DEPTHF	NUMBER(5,1)	NUMBER(5,1)		PK (NOT NULL)
DEPTHT	NUMBER(5,1)	NUMBER(5,1)		PK (NOT NULL)
LITHO	VARCHAR2(15)	VARCHAR2(15)		
DESCR	VARCHAR2(20)	VARCHAR2(50)	Field Width altered.	
GENESIS	VARCHAR2(15)	VARCHAR2(30)	Field Width altered.	
COLOR	VARCHAR2(15)	VARCHAR2(30)	Field Width altered.	
AGE	VARCHAR2(15)	VARCHAR2(15)		

Annex Table I.2.15 Table "GEOLOG_DETAIL"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
WELL_NO	VARCHAR2(6)	VARCHAR2(6)		
DEPTHF	NUMBER(5,1)	NUMBER(5,1)		
DEPTHT	NUMBER(5,1)	NUMBER(5,1)		
GT4	NUMBER(6,1)	NUMBER(6,1)		
LT4	NUMBER(6,1)	NUMBER(6,1)		
LT2	NUMBER(6,1)	NUMBER(6,1)		
LT1	NUMBER(6,1)	NUMBER(6,1)		
LT05	NUMBER(6,1)	NUMBER(6,1)		
LT025	NUMBER(6,1)	NUMBER(6,1)		
LT0125	NUMBER(6,1)	NUMBER(6,1)		
LT0063	NUMBER(6,1)	NUMBER(6,1)		
GT4P	NUMBER(6,2)	NUMBER(6,2)		
LT4P	NUMBER(6,2)	NUMBER(6,2)		
LT2P	NUMBER(6,2)	NUMBER(6,2)		
LT1P	NUMBER(6,2)	NUMBER(6,2)		
LT05P	NUMBER(6,2)	NUMBER(6,2)		
LT025P	NUMBER(6,2)	NUMBER(6,2)		
LT0125P	NUMBER(6,2)	NUMBER(6,2)		
LT0063P	NUMBER(6,2)	NUMBER(6,2)		
GT4CP	NUMBER(6,2)	NUMBER(6,2)		
LT4CP	NUMBER(6,2)	NUMBER(6,2)		
LT2CP	NUMBER(6,2)	NUMBER(6,2)		
LT1CP	NUMBER(6,2)	NUMBER(6,2)		
LT05CP	NUMBER(6,2)	NUMBER(6,2)		
LT025CP	NUMBER(6,2)	NUMBER(6,2)		
LT0125CP	NUMBER(6,2)	NUMBER(6,2)		
LT0063CP	NUMBER(6,2)	NUMBER(6,2)		
TOTW	NUMBER(6,1)	NUMBER(6,1)		
D10	NUMBER(5,2)	NUMBER(5,2)		
D60	NUMBER(5,2)	NUMBER(5,2)		
UCOEF	NUMBER(5,2)	NUMBER(5,2)		
MEMO	VARCHAR2(100)	VARCHAR2(100)		

Annex Table I.2.16 Table "VARIABLE" (1/3)

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
WELL_NO	VARCHAR2(6)	VARCHAR2(6)		PK (NOT NULL)
YEAR	NUMBER(4)	NUMBER(4)		
MONTH	NUMBER(2)	NUMBER(2)		
DAY	NUMBER(2)	NUMBER(2)		
TIME	NUMBER(4)	NUMBER(4)		
SERIAL_NO	VARCHAR2(10)	VARCHAR2(10)		
SAMPLE_NO	VARCHAR2(20)	VARCHAR2(20)		PK (NOT NULL)
FILE_NO	VARCHAR2(25)	VARCHAR2(25)		
MSAMP	VARCHAR2(11)	VARCHAR2(11)		
GWL	NUMBER(6,2)	NUMBER(6,2)		
FTEMP	NUMBER(4,1)	NUMBER(4,1)		
FPH	NUMBER(4,1)	NUMBER(4,1)		
FDISO2	NUMBER(4,1)	NUMBER(4,1)		
FFE	NUMBER(5,2)	NUMBER(5,2)		
FCL	NUMBER(4,2)	NUMBER(4,2)		
FCOND	NUMBER(5)	NUMBER(5)		
LABNAM	VARCHAR2(10)	VARCHAR2(10)		
FTURB	NUMBER(7,1)	NUMBER(7,1)		
PHL	NUMBER(4,1)	NUMBER(4,1)		
CONDL	NUMBER(5)	NUMBER(5)		
TURB	NUMBER(7,1)	NUMBER(7,1)		
COL	NUMBER(3)	NUMBER(3)		
ODO	VARCHAR2(10)	VARCHAR2(10)		
REDOX	NUMBER(5)	NUMBER(5)		
COD	NUMBER(4)	NUMBER(4)		
BOD	NUMBER(4)	NUMBER(4)		
NAMGL	NUMBER(6,2)	NUMBER(6,2)		
KMGL	NUMBER(6,2)	NUMBER(6,2)		
CAMGL	NUMBER(6,2)	NUMBER(6,2)		
MGMGL	NUMBER(6,2)	NUMBER(6,2)		
FETOT	NUMBER(6,2)	NUMBER(6,2)		
FESMGL	NUMBER(6,2)	NUMBER(6,2)		
CLMGL	NUMBER(7,2)	NUMBER(7,2)		
NO3MGL	NUMBER(5,1)	NUMBER(5,1)		
SO4MGL	NUMBER(4)	NUMBER(4)		
CO3MGL	NUMBER(4)	NUMBER(4)		
HCOMGL	NUMBER(4)	NUMBER(4)		
TOTHARD	NUMBER(5)	NUMBER(5)		
TDS	NUMBER(6)	NUMBER(6)		
TS	NUMBER(6)	NUMBER(6)		
ALMGL	NUMBER(4,1)	NUMBER(4,1)		
NH4MGL	NUMBER(5,2)	NUMBER(5,2)		
FMGL	NUMBER(4,1)	NUMBER(4,1)		
NO2MGL	NUMBER(6,3)	NUMBER(6,3)		
PO4MGL	NUMBER(5,2)	NUMBER(5,2)		
SIO2MGL	NUMBER(4,1)	NUMBER(4,1)		

Annex Table I.2.16 Table "VARIABLE" (2/3)

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
CN	NUMBER(4,2)	NUMBER(4,2)		
B	NUMBER(4,1)	NUMBER(4,1)		
A_S	NUMBER(5,3)	NUMBER(5,3)		
BA	NUMBER(3,1)	NUMBER(3,1)		
CD	NUMBER(5,3)	NUMBER(5,3)		
CU	NUMBER(3,1)	NUMBER(3,1)		
MN	NUMBER(4,2)	NUMBER(4,2)		
NI	NUMBER(4,2)	NUMBER(4,2)		
PB	NUMBER(4,2)	NUMBER(4,2)		
SE	NUMBER(5,3)	NUMBER(5,3)		
SR	NUMBER(4,2)	NUMBER(4,2)		
ZN	NUMBER(3,1)	NUMBER(3,1)		
HG	NUMBER(6,4)	NUMBER(6,4)		
CR	NUMBER(4,2)	NUMBER(4,2)		
AG	NUMBER(4,2)	NUMBER(4,2)		
CO	NUMBER(6,2)	NUMBER(6,2)		
LI	NUMBER(5,2)	NUMBER(5,2)		
BI	NUMBER(4,2)	NUMBER(4,2)		
MO	NUMBER(4,2)	NUMBER(4,2)		
SB	NUMBER(4,2)	NUMBER(4,2)		
TI	NUMBER(4,2)	NUMBER(4,2)		
ADET	NUMBER(5,2)	NUMBER(5,2)		
MOIL	NUMBER(4,2)	NUMBER(4,2)		
PNOL	NUMBER(6,4)	NUMBER(6,4)		
CHLORO	NUMBER(6,4)	NUMBER(6,4)		
BENZ	NUMBER(6,4)	NUMBER(6,4)		
TOLU	NUMBER(6,4)	NUMBER(6,4)		
ETHYL	NUMBER(6,4)	NUMBER(6,4)		
M_P_XY	NUMBER(5,3)	NUMBER(5,3)		
O_XY	NUMBER(6,4)	NUMBER(6,4)		
TOC	NUMBER(5,1)	NUMBER(5,1)		
NA_DET	VARCHAR2(10)	VARCHAR2(10)		
KM_DET	VARCHAR2(10)	VARCHAR2(10)		
CA_DET	VARCHAR2(10)	VARCHAR2(10)		
MG_DET	VARCHAR2(10)	VARCHAR2(10)		
FETOT_DET	VARCHAR2(10)	VARCHAR2(10)		
FES_DET	VARCHAR2(10)	VARCHAR2(10)		
CL_DET	VARCHAR2(10)	VARCHAR2(10)		
NO3_DET	VARCHAR2(10)	VARCHAR2(10)		
SO4_DET	VARCHAR2(10)	VARCHAR2(10)		
CO3_DET	VARCHAR2(10)	VARCHAR2(10)		
HCO_DET	VARCHAR2(10)	VARCHAR2(10)		
TOTHARD_DET	VARCHAR2(10)	VARCHAR2(10)		
TDS_DET	VARCHAR2(10)	VARCHAR2(10)		
TS_DET	VARCHAR2(10)	VARCHAR2(10)		
AL_DET	VARCHAR2(10)	VARCHAR2(10)		

Annex I.2.16 Table "VARIABLE" (3/3)

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
NH4_DET	VARCHAR2(10)	VARCHAR2(10)		
F_DET	VARCHAR2(10)	VARCHAR2(10)		
NO2_DET	VARCHAR2(10)	VARCHAR2(10)		
PO4_DET	VARCHAR2(10)	VARCHAR2(10)		
SIO2_DET	VARCHAR2(10)	VARCHAR2(10)		
CN_DET	VARCHAR2(10)	VARCHAR2(10)		
B_DET	VARCHAR2(10)	VARCHAR2(10)		
A_S_DET	VARCHAR2(10)	VARCHAR2(10)		
BA_DET	VARCHAR2(10)	VARCHAR2(10)		
CD_DET	VARCHAR2(10)	VARCHAR2(10)		
CU_DET	VARCHAR2(10)	VARCHAR2(10)		
MN_DET	VARCHAR2(10)	VARCHAR2(10)		
NI_DET	VARCHAR2(10)	VARCHAR2(10)		
PB_DET	VARCHAR2(10)	VARCHAR2(10)		
SE_DET	VARCHAR2(10)	VARCHAR2(10)		
SR_DET	VARCHAR2(10)	VARCHAR2(10)		
ZN_DET	VARCHAR2(10)	VARCHAR2(10)		
HG_DET	VARCHAR2(10)	VARCHAR2(10)		
CR_DET	VARCHAR2(10)	VARCHAR2(10)		
AG_DET	VARCHAR2(10)	VARCHAR2(10)		
CO_DET	VARCHAR2(10)	VARCHAR2(10)		
LI_DET	VARCHAR2(10)	VARCHAR2(10)		
BI_DET	VARCHAR2(10)	VARCHAR2(10)		
MO_DET	VARCHAR2(10)	VARCHAR2(10)		
SB_DET	VARCHAR2(10)	VARCHAR2(10)		
TI_DET	VARCHAR2(10)	VARCHAR2(10)		
ADET_DET	VARCHAR2(10)	VARCHAR2(10)		
MOIL_DET	VARCHAR2(10)	VARCHAR2(10)		
PNOL_DET	VARCHAR2(10)	VARCHAR2(10)		
CHLORO_DET	VARCHAR2(10)	VARCHAR2(10)		
BENZ_DET	VARCHAR2(10)	VARCHAR2(10)		
TOLU_DET	VARCHAR2(10)	VARCHAR2(10)		
ETHYL_DET	VARCHAR2(10)	VARCHAR2(10)		
M_P_XY_DET	VARCHAR2(10)	VARCHAR2(10)		
O_XY_DET	VARCHAR2(10)	VARCHAR2(10)		
TOC_DET	VARCHAR2(10)	VARCHAR2(10)		
NAM	VARCHAR2(40)	VARCHAR2(40)		
MEMO	VARCHAR2(100)	VARCHAR2(100)		
SAMPLE_TYPE	VARCHAR2(20)	VARCHAR2(20)		
FILE_NO_MAKMAL	VARCHAR2(25)	VARCHAR2(25)		

Annex Table I.2.17 Table "VARIABLE_PESTICIDES"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
WELL_NO	VARCHAR2(6)	VARCHAR2(6)		PK (NOT NULL)
SERIAL_NO	VARCHAR2(10)	VARCHAR2(10)		
SAMPLE_NO	VARCHAR2(20)	VARCHAR2(20)		PK (NOT NULL)
FILE_NO_MAKMAL	VARCHAR2(25)	VARCHAR2(25)		
FILE_NO	VARCHAR2(25)	VARCHAR2(25)		
ADRIN	NUMBER(6,4)	NUMBER(6,4)		
DDRIN	NUMBER(6,4)	NUMBER(6,4)		
DDT	NUMBER(6,4)	NUMBER(6,4)		
A_BHC	NUMBER(6,5)	NUMBER(6,5)		
B_C_BHC	NUMBER(6,4)	NUMBER(6,4)		
D_BHC	NUMBER(6,4)	NUMBER(6,4)		
HEPTA	NUMBER(6,4)	NUMBER(6,4)		
HEPTA_EPO	NUMBER(6,4)	NUMBER(6,4)		
METHOXY	NUMBER(6,4)	NUMBER(6,4)		
ENDOSUL	NUMBER(6,2)	NUMBER(6,2)		
ADRIN_DET	VARCHAR2(10)	VARCHAR2(10)		
DDRIN_DET	VARCHAR2(10)	VARCHAR2(10)		
DDT_DET	VARCHAR2(10)	VARCHAR2(10)		
A_BHC_DET	VARCHAR2(10)	VARCHAR2(10)		
B_C_BHC_DET	VARCHAR2(10)	VARCHAR2(10)		
D_BHC_DET	VARCHAR2(10)	VARCHAR2(10)		
HEPTA_DET	VARCHAR2(10)	VARCHAR2(10)		
HEPTA_EPO_DET	VARCHAR2(10)	VARCHAR2(10)		
METHOXY_DET	VARCHAR2(10)	VARCHAR2(10)		
ENDOSUL_DET	VARCHAR2(10)	VARCHAR2(10)		

Annex Table I.2.18 Table "VARIABLE_PETROL_BIOLOG"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
WELL_NO	VARCHAR2(6)	VARCHAR2(6)		PK (NOT NULL)
SERIAL_NO	VARCHAR2(10)	VARCHAR2(10)		
SAMPLE_NO	VARCHAR2(20)	VARCHAR2(20)		PK (NOT NULL)
FILE_NO	VARCHAR2(25)	VARCHAR2(25)		
FILE_NO_MAKMAL	VARCHAR2(25)	VARCHAR2(25)		
C6_9	NUMBER(5,3)	NUMBER(5,3)		
C10_14	NUMBER(5,3)	NUMBER(5,3)		
C15_C28	NUMBER(4,2)	NUMBER(4,2)		
C29_36	NUMBER(5,3)	NUMBER(5,3)		
TCOLIFM	NUMBER(4)	NUMBER(4)		
ECOLI	NUMBER(4)	NUMBER(4)		
C6_9_DET	VARCHAR2(10)	VARCHAR2(10)		
C10_14_DET	VARCHAR2(10)	VARCHAR2(10)		
C15_C28_DET	VARCHAR2(10)	VARCHAR2(10)		
C29_36_DET	VARCHAR2(10)	VARCHAR2(10)		
TCOLIFM_DET	VARCHAR2(10)	VARCHAR2(10)		
ECOLI_DET	VARCHAR2(10)	VARCHAR2(10)		

The tables listing and its structure which will be newly generated in this system are as follows.

Annex Table I.2.19 Table "SWLGEN"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
GAUGE_NO	-	VARCHAR2(8)		PK (NOT NULL)
LOCATION	-	VARCHAR2(128)		
EASTING	-	NUMBER(8)		
NORTHING	-	NUMBER(8)		
ORG_MSITE	-	VARCHAR2(64)		
INST_TYPE	-	VARCHAR2(64)		
SERIAL_NO	-	VARCHAR2(32)		
BM_MSL	-	NUMBER(8,3)		
WL_MSL	-	NUMBER(8,3)		

Annex Table I.2.20 Table "SWLDATA"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
GAUGE_NO	-	VARCHAR2(8)		PK (NOT NULL)
DATETIME	-	DATE		PK (NOT NULL)
WL	-	NUMBER(6,3)		

Annex Table I.2.21 Table "BMGEN"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
BM_NO	-	VARCHAR2(8)		PK (NOT NULL)
DP_NO	-	VARCHAR2(8)		
DATETIME	-	DATE		PK (NOT NULL)
DP_EL	-	NUMBER(9,5)		

Annex Table I.2.22 Table "BMDATA"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
BM_NO	-	VARCHAR2(8)		PK (NOT NULL)
DATETIME	-	DATE		PK (NOT NULL)
ELEV_NO	-	NUMBER(3)		PK (NOT NULL)
BM_EL	-	NUMBER(9,5)		

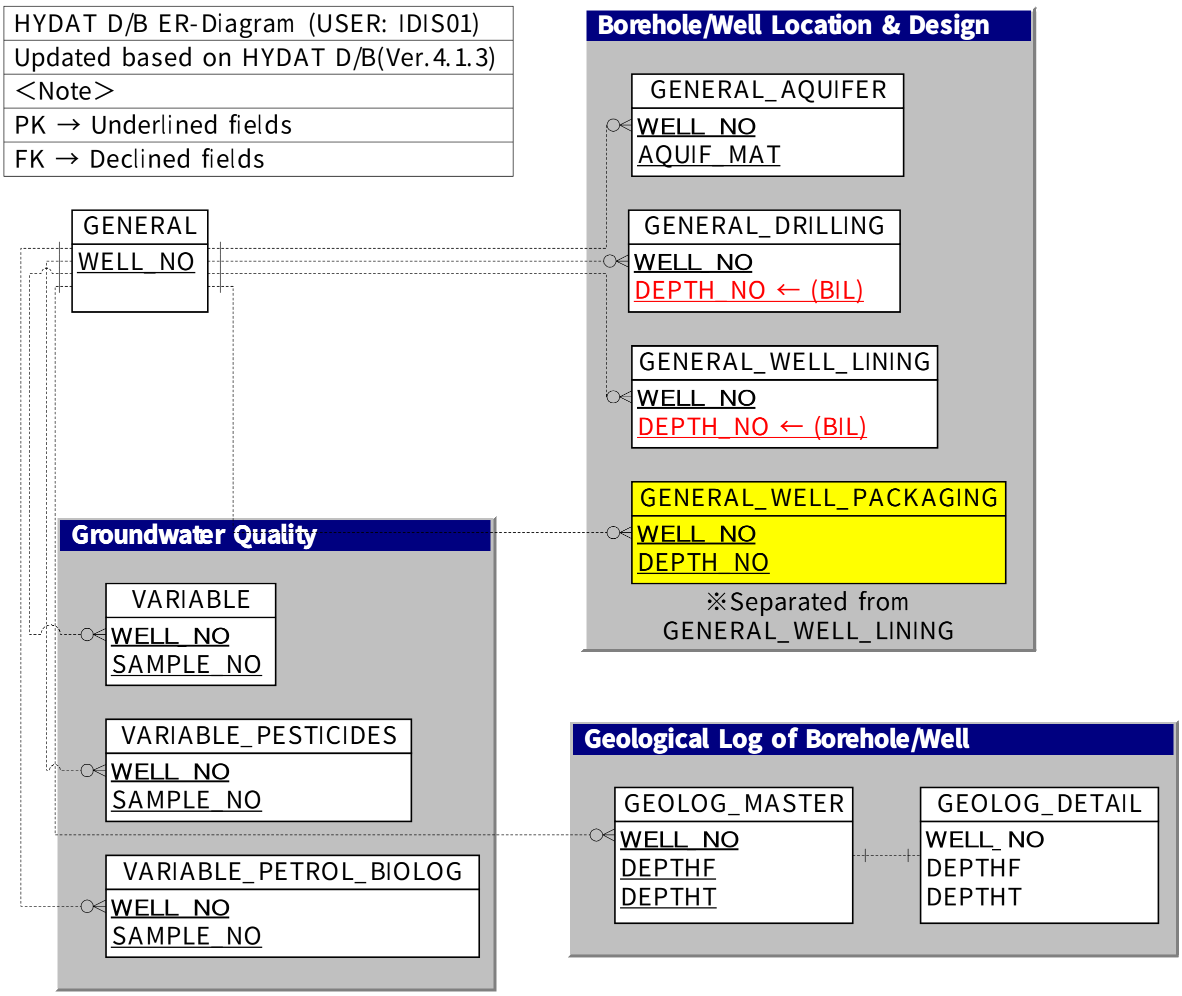
Annex Table I.2.23 Table "EXTDATA"

FIELD_NAME	TYPE (OLD Ver.3.0.4)	TYPE (NEW Ver.4.1.3)	NOTE	CONSTRAINTS
GAUGE_NO	-	VARCHAR2(8)		PK (NOT NULL)
DATETIME	-	DATE		PK (NOT NULL)
GL	-	NUMBER(6,3)		

3.4 Relationship among Tables

As mentioned earlier, it is essential to retain the relationship among various entities and its cardinalities and integrities. The following Entity Relation Diagram (ERD) was derived by analysing the source code of the present Client/Server system:

In the following diagram, highlighted portion shows the updated items or table due to the HYDAT D/B version up. (Ver.3.0.4 → Ver.4.1.3)

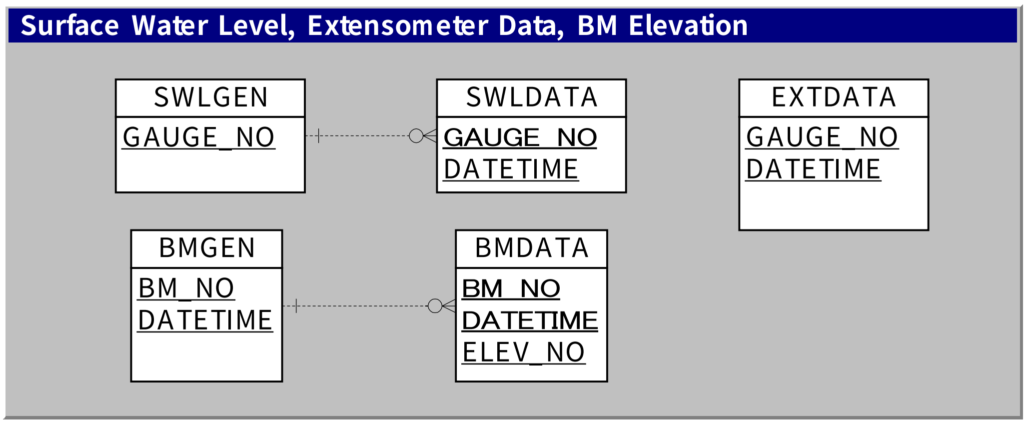


Annex Figure I.2.5 IDIS01 Entity Relationship Diagram

The following Entity Relation Diagram (ERD) was newly created for the MIS:

These tables will incorporate data that will be acquired from the data logger.

NEW D/B ER-Diagram (USER: IDIS04)
Newly constructed D/B for the MIS.
<Note>
PK → Underlined fields
FK → Declined fields



Annex Figure I.2.6 IDIS04 Entity Relationship Diagram

For the Geographic Data to be linked with these tables, each geographic object that contains the field WELL_NO will be used as the key forming a one-to-one cardinality with these tables.

3.5 Referential Integrity

As shown in **Annex Figure I.2.4** Referential Integrity is realised by the establishment of Primary and Foreign Keys. When a field(s) is established as a Primary Key its data becomes unique and mandatory record identifier within the table. When a field becomes a Foreign Key, its data enforces referential integrity by validating the existence of that data in another table and establishing a child-parent relationship between the two tables. **Annex Table I.2.24** shows the list of IDIS01's Tables along with their Primary Keys as well as the Foreign Keys and the table it refers to.

Annex Table I.2.24 Relational Integrity among Tables (IDIS01 scheme)

FIELD_ NAME	DATA TYPE	CONSTRAINTS (Primary Key, Foreign Key)
GENERAL （353 records）		
WELL_NO	VARCHAR2(6)	PK → PK_GENERAL
GENERAL_AQUIFER （285 records）		
WELL_NO	VARCHAR2(6)	FK REFER GENERAL(WELL_NO) → FK_GENERAL_AQUIFER
AQUIF_MAT	VARCHAR2(20)	PK → PK_GENERAL_AQUIFER
GENERAL_DRILLING （440 records）		
WELL_NO	VARCHAR2(6)	FK REFER GENERAL(WELL_NO) → FK_GENERAL_DRILLING
DEPTH_NO	NUMBER(3)	PK → PK_GENERAL_DRILLING
GENERAL_WELL_LINING （673 records）		
WELL_NO	VARCHAR2(6)	FK REFER GENERAL(WELL_NO) → FK_GENERAL_WELL_LINING
DEPTH_NO	NUMBER(3)	PK → PK_WELL_LINING
GENERAL_WELL_PACKAGING （673 records）		
WELL_NO	VARCHAR2(6)	FK REFER GENERAL(WELL_NO) → FK_GENERAL_WELL_PACKAGING
DEPTH_NO	NUMBER(3)	PK → PK_WELL_PACKAGING
GEOLOG_MASTER （848 records）		
WELL_NO	VARCHAR2(6)	FK REFER GENERAL(WELL_NO) → FK_GEOLOG_MASTER
DEPTHF	NUMBER(5,1)	PK → PK_GEOLOG_MASTER
DEPTHT	NUMBER(5,1)	
GEOLOG_DETAIL （481 records）		
WELL_NO	VARCHAR2(6)	FK REFER GEOLOG_MASTER(WELL_NO,DEPTHF,DEPTHT)
DEPTHF	NUMBER(5,1)	→ FK_GEOLOG_DETAIL
DEPTHT	NUMBER(5,1)	
VARIABLE （1397 records）1296 records for Test		
WELL_NO	VARCHAR2(6)	FK REFER GENERAL(WELL_NO) → FK_VARIABLE
SAMPLE_NO	VARCHAR2(20)	PK → PK_VARIABLE
VARIABLE_PESTICIDES （0 record）		
WELL_NO	VARCHAR2(6)	FK REFER GENERAL(WELL_NO) → FK_VARIABLE_PESTICIDES
SAMPLE_NO	VARCHAR2(20)	PK → PK_VARIABLE_PESTICIDES
VARIABLE_PETROL_BIOLOG （5 records）		
WELL_NO	VARCHAR2(6)	FK REFER GENERAL(WELL_NO) → FK_VARIABLE_PETROL_BIOLOG
SAMPLE_NO	VARCHAR2(20)	PK → PK_VARIABLE_PETROL_BIOLOG

Annex Table I.2.25 shows the list of IDIS04's Tables along with their Primary Keys as well as the Foreign Keys and the table it refers to.

Annex Table I.2.25 Relational Integrity among Tables (IDIS04 scheme)

FIELD_ NAME	DATA TYPE	CONSTRAINTS (Primary Key, Foreign Key)
SWLGEN （6 records）		
GAUGE_NO	VARCHAR2(8)	PK → PK_SWLGEN
SWLDATA （4022 records）for Test		
GAUGE_NO	VARCHAR2(8)	PK → PK_SWLDATA
DATETIME	DATE	FK REFER SWLGEN(GAUGE_NO) → FK_SWLDATA
BMGEN （20 records）		
BM_NO	VARCHAR2(8)	PK → PK_SWLGEN
DATETIME	DATE	
BMDATA （60 records）		
BM_NO	VARCHAR2(8)	PK → PK_BMDATA
DATETIME	DATE	FK REFER BMGEN(BM_NO) → FK_BMDATA
ELEV_NO	NUMBER(3)	
EXTDATA （959 records）for Test		
GAUGE_NO	VARCHAR2(8)	PK → PK_EXTDATA
DATETIME	DATE	

4. PROCESSING LOGIC

4.1 Database Query

The basic Database Queries will be similar to the queries of the Client/Server version of the MIS. The queries will be illustrated in the diagram below (**Section 4.4 System Flow**).

4.2 Database Update

Updates (insert, update, delete) of the Database by this system are based on a conversational menu system. So as not to put too much load on the network, Updates by the system will be done on a record per record basis. Multiple Updates of accumulated data will be done using the Oracle Import command by the System Administrator at the local site which houses the JMGM HYDAT database. As an exception, data for the IDIS04's Oracle tables will be inserted by the C/S based option tool. This tool will import specific format data that will be generated by data logger into the database in the closed LAN environment. Groundwater's excel data, Surface water's csv data and Extensometer's excel data will be imported by this tool.

Geographic data will be updated using the append option of the shp2sde command of ArcSDE and will follow the same process as that of the Multiple Updates process mention above.

The database updates will be illustrated in the diagram below (**Section 4.4 System Flow**).

4.3 Map Search

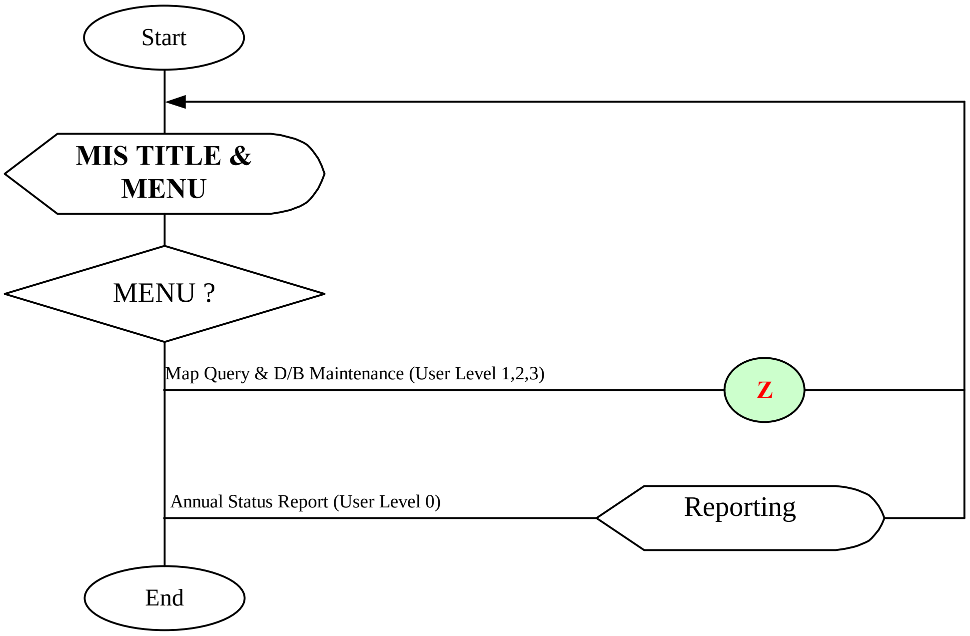
ArcSDE is capable of storing large amounts geographic data. When a user queries the database containing large volume of data, ArcSDE's Spatial Index is utilised to maximise performance. The Spatial Index returns from a query only a limited area/extent of the entire data set thereby reducing the network overhead considerably and providing the client application with fewer geographic objects to process. Considering the architecture of ArcSDE, four (4) basic Map Search Logic has been prepared:

1. Query by STATE
2. Query by TOWN
3. Query by CODE
4. Query by WHERE CONDITION

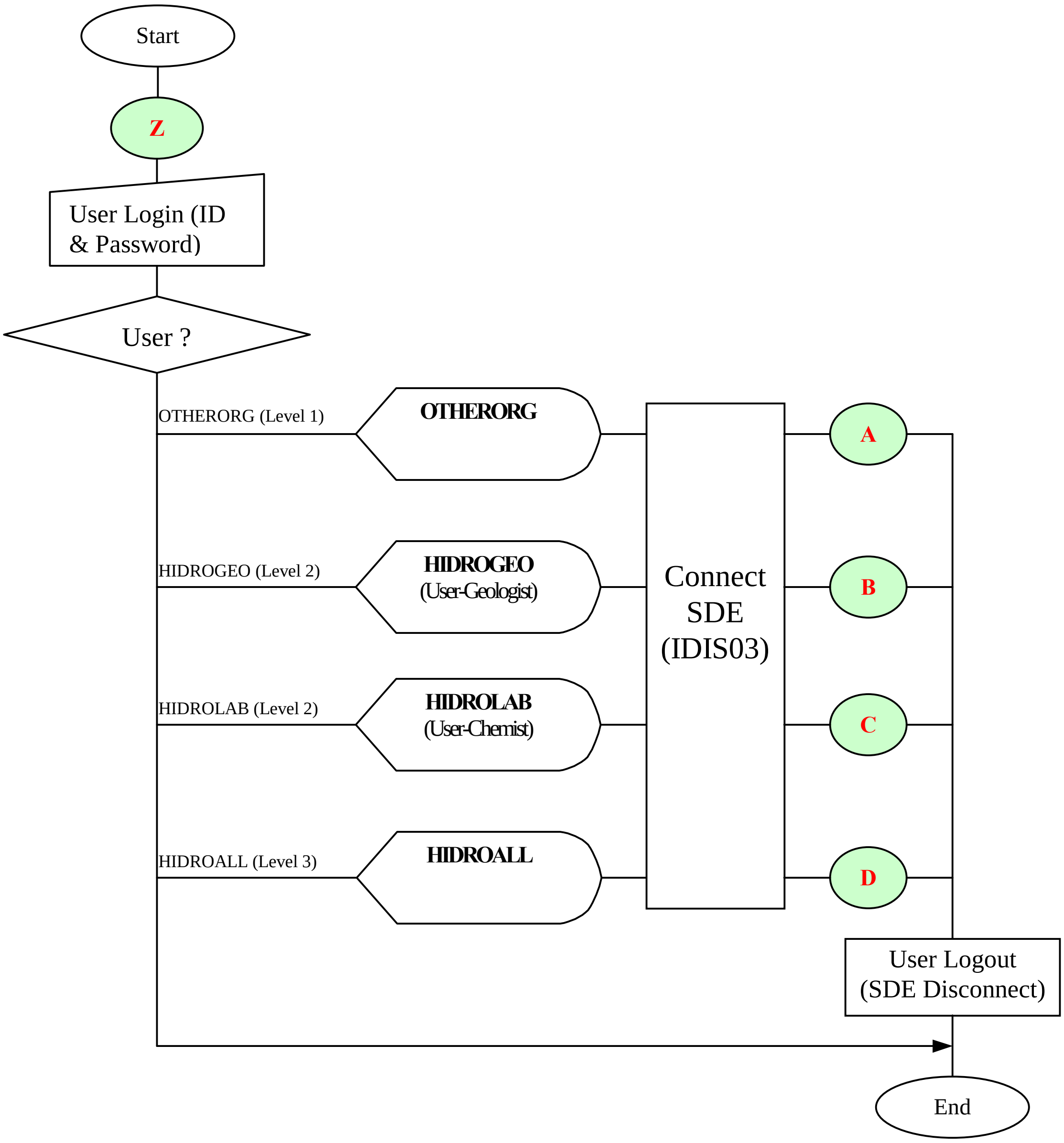
The map searches will be illustrated in the diagram below (**Section 4.4 System Flow**).

4.4 System Flow

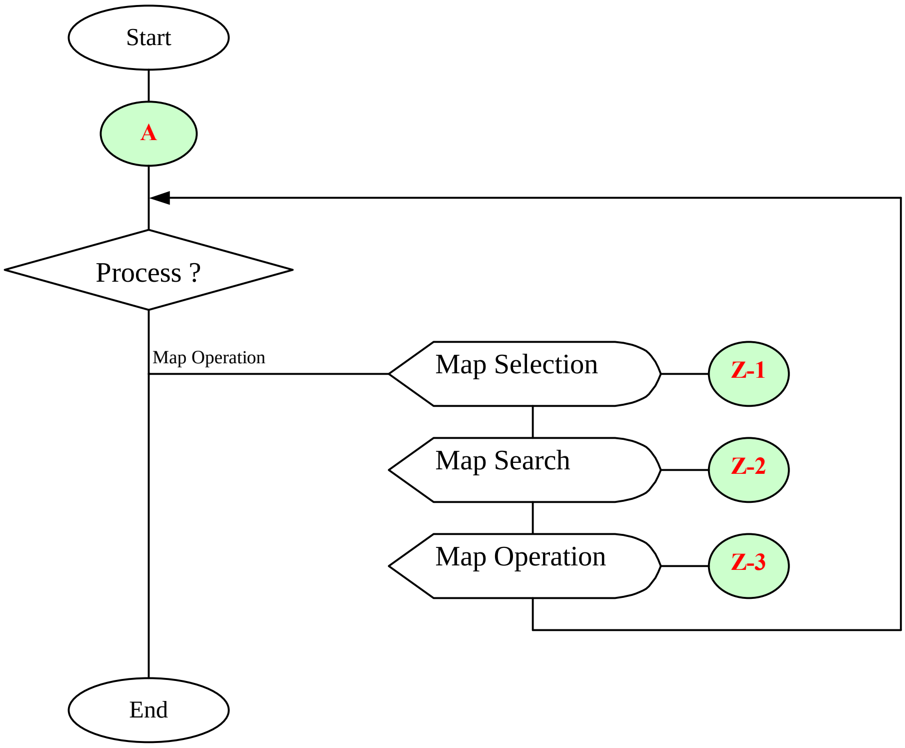
- **START UP PROCESS**



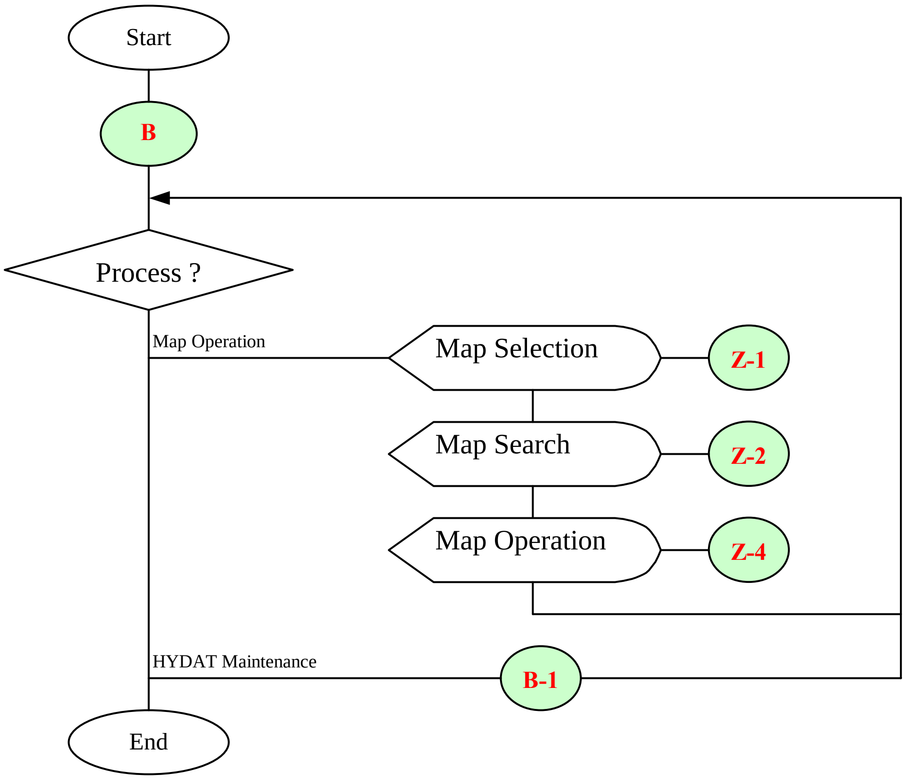
- **USER LOGIN PROCESS (Z)**



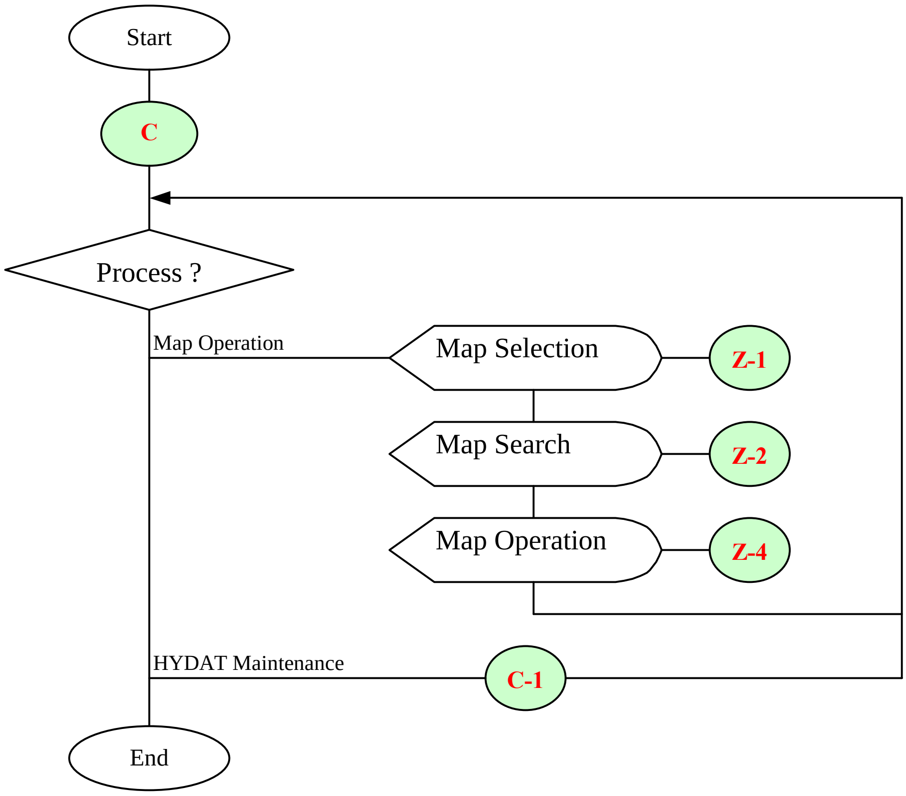
- **OTHERORG::MAIN PROCESS (A)**



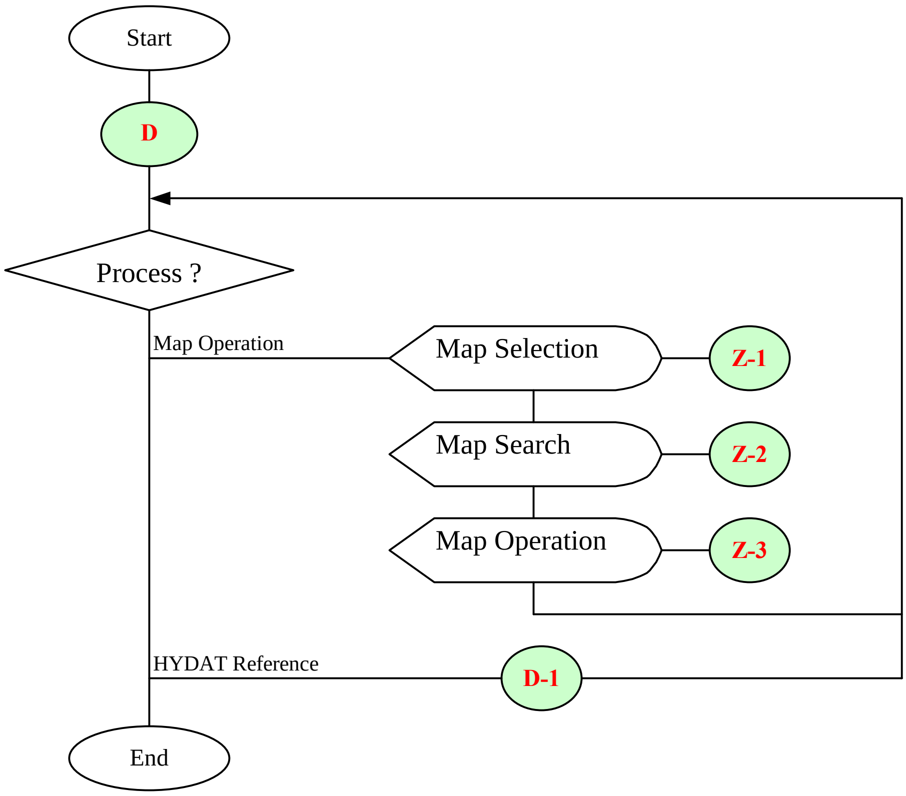
- **HIDROGEO::MAIN PROCESS(B)**



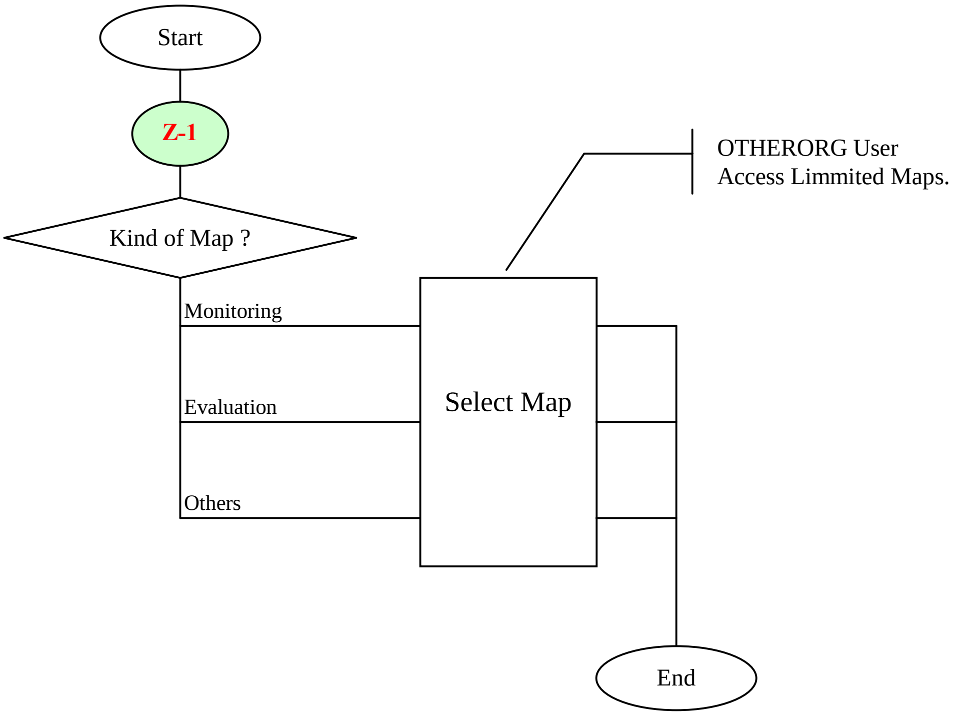
- **HIDROLAB::MAIN PROCESS (C)**



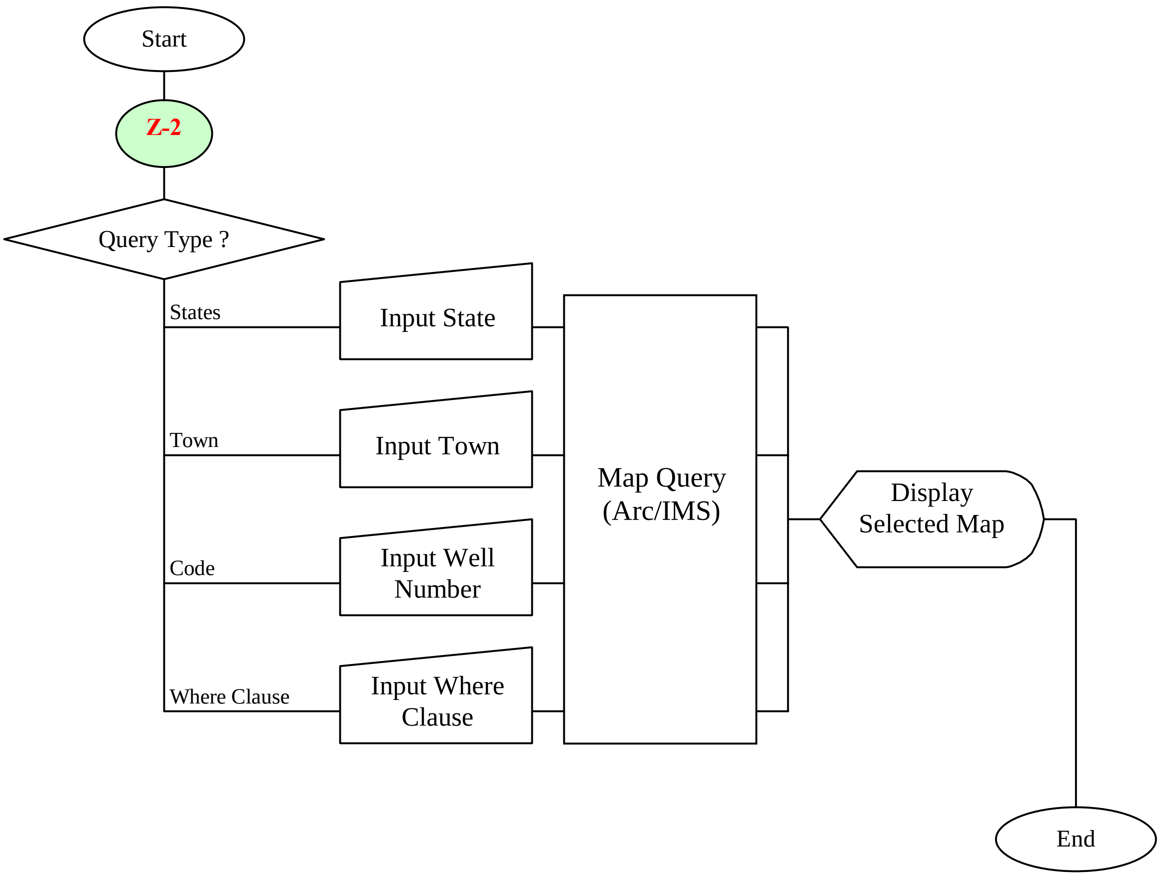
- **HIDROALL::MAIN PROCESS (D)**



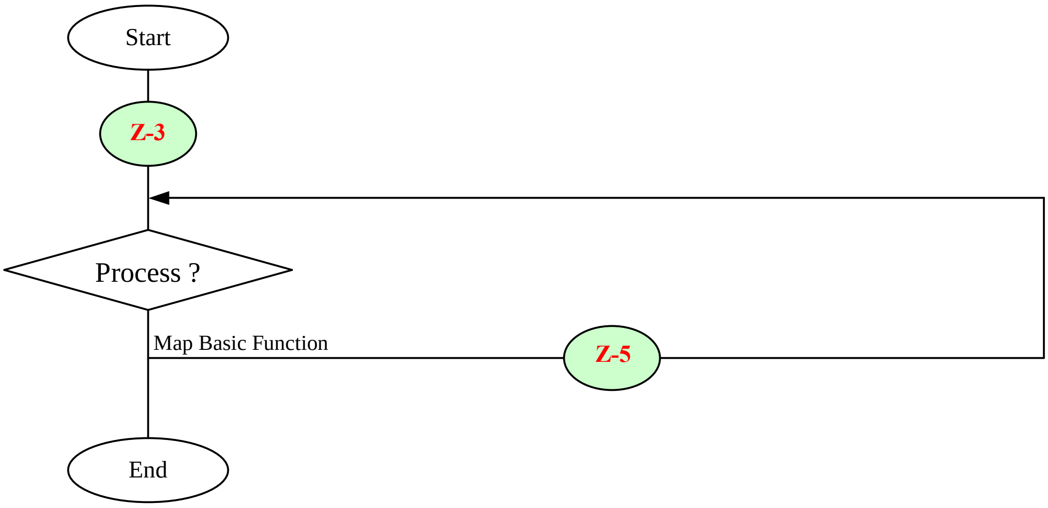
- **MAP SELECTION PROCESS (Z-1)**



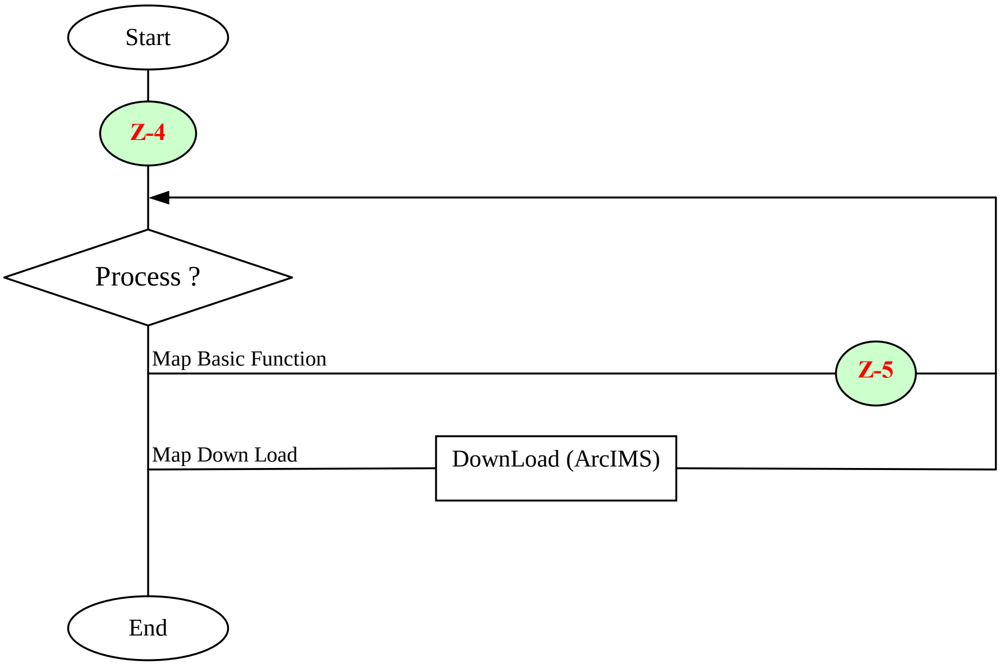
- **MAP SEARCH PROCESS (Z-2)**



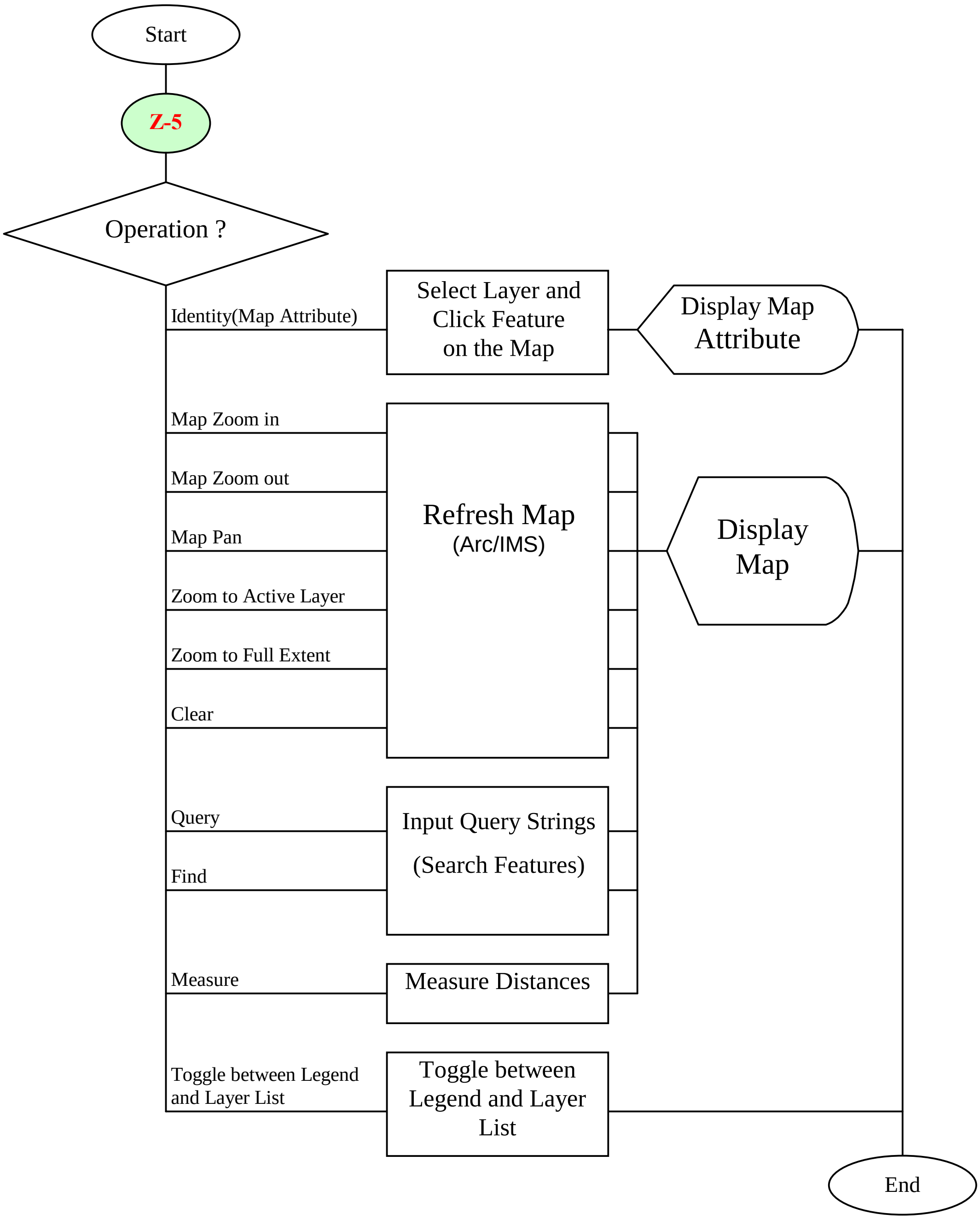
- **MAP OPERATION PROCESS[OTHERORG,HIDROALL] (Z-3)**



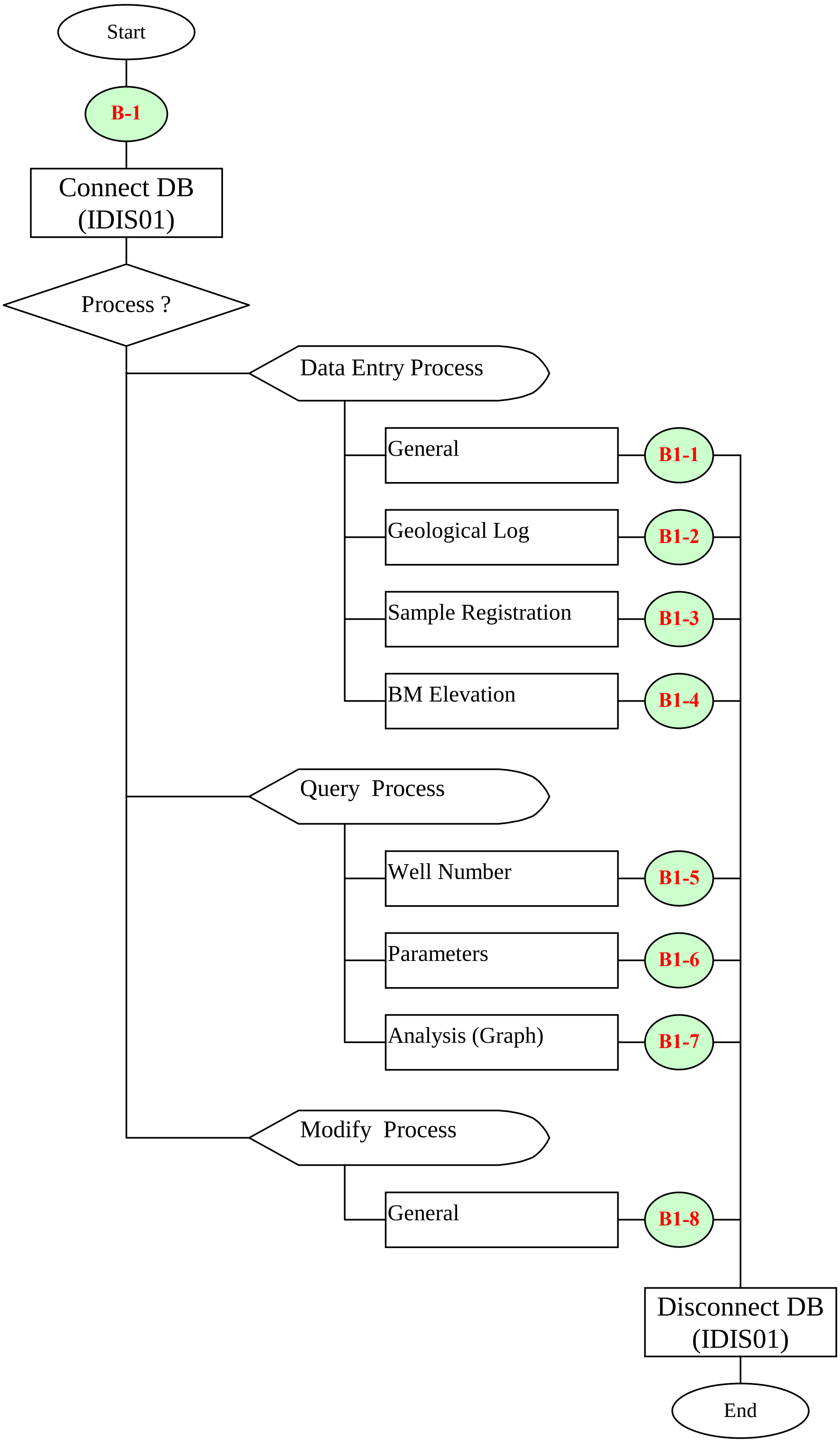
- **MAP OPERATION PROCESS[HIDROGEO,HIDROLAB] (Z-4)**



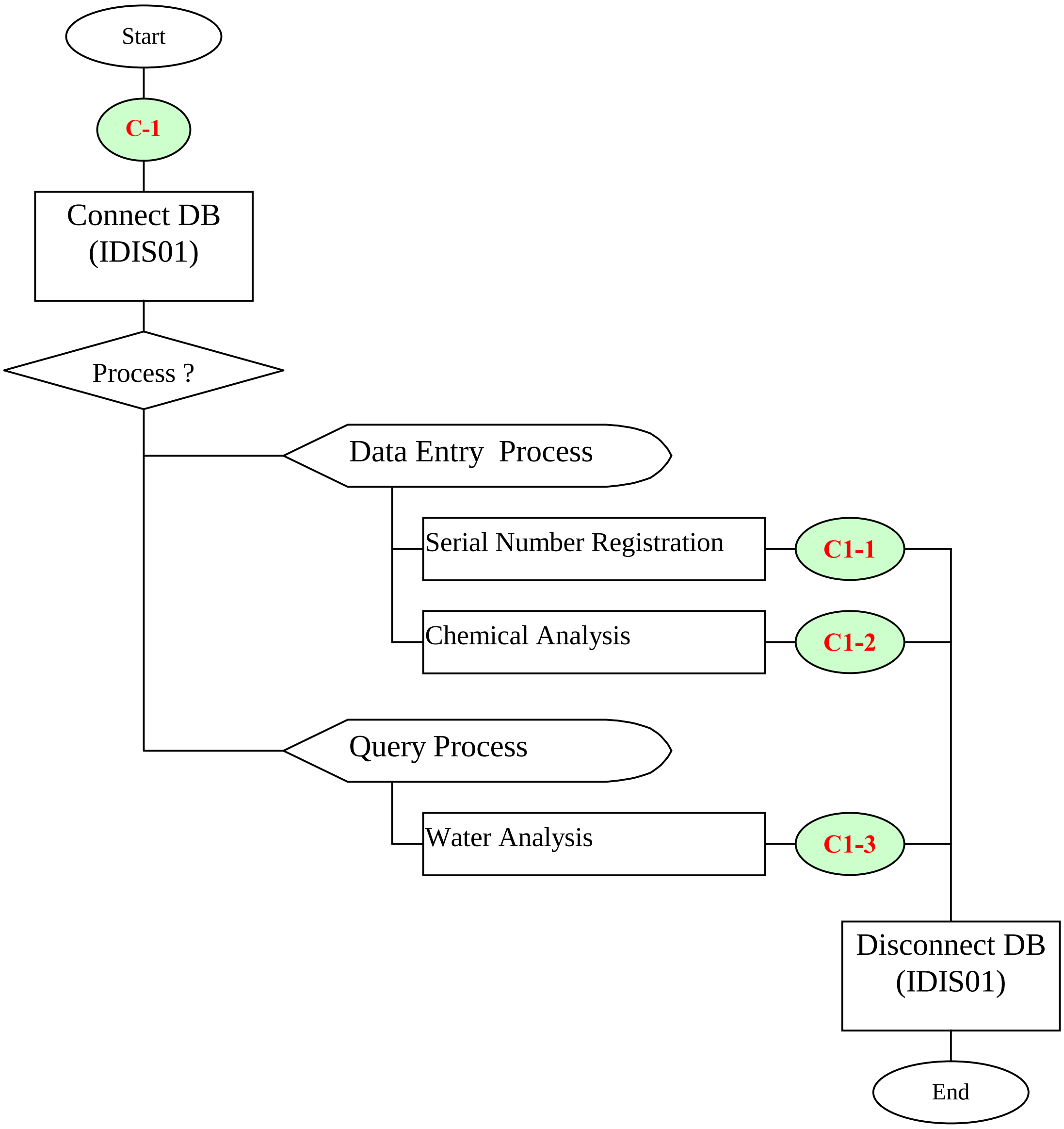
- **MAP BASIC FUNCTION (Z-5)**



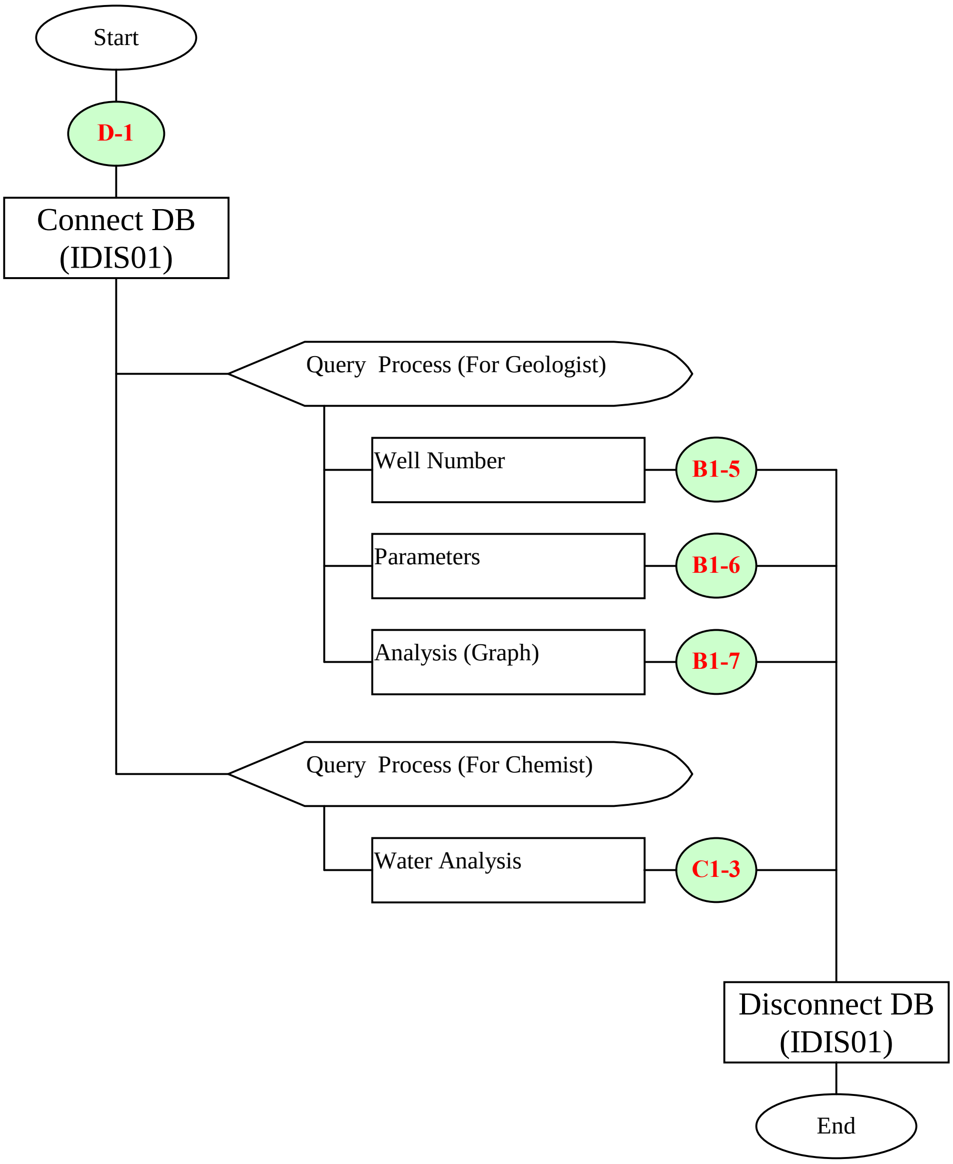
HIIDROGEO::HYDAT MAINTENANCE PROCESS (B-1)



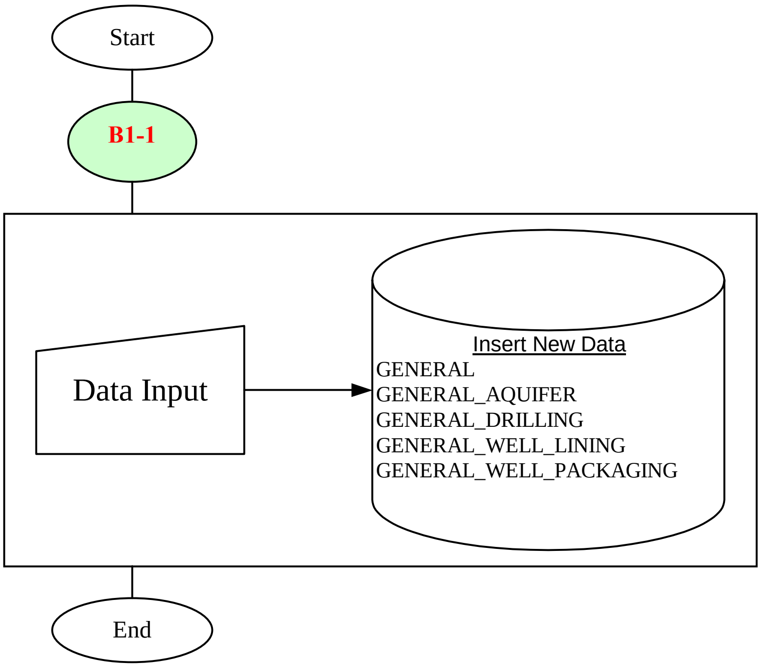
- **HYDROLAB::HYDAT MAINTENANCE PROCESS (C-1)**



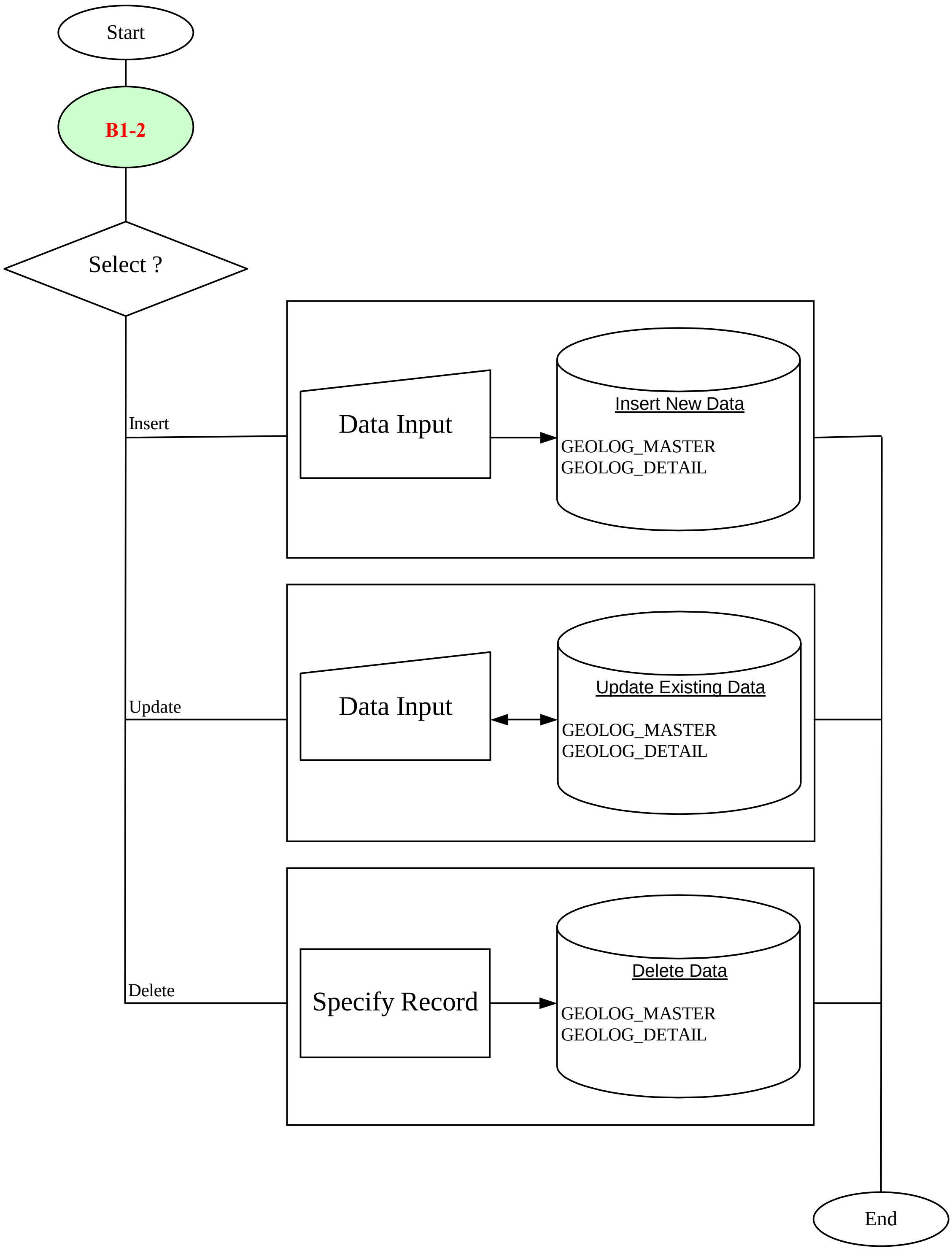
- **HIIDROALL::HYDAT REFERENCE PROCESS (D-1)**



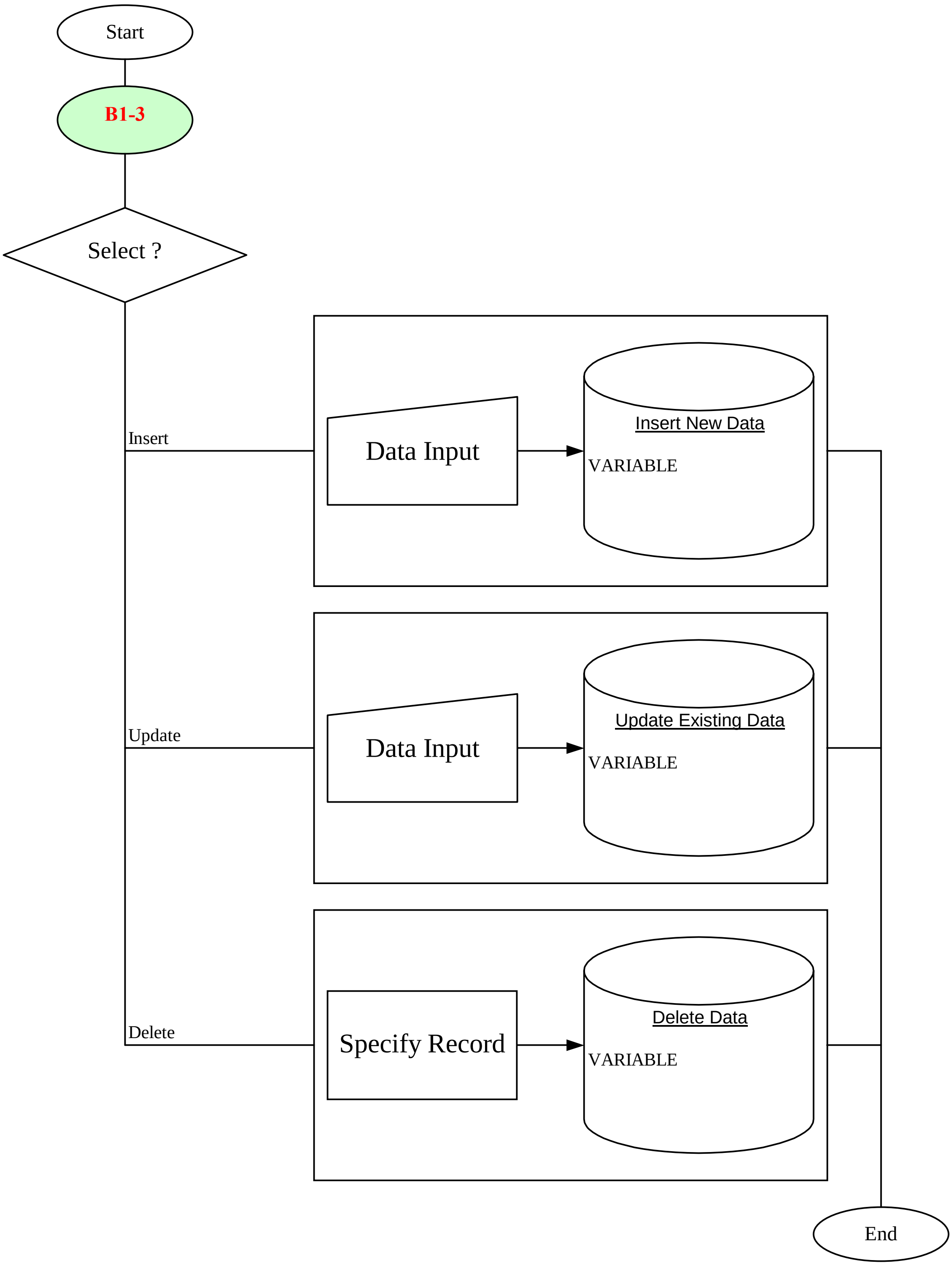
- **HIDROGEO::HYDAT:DATA ENTRY PROCESS – GENERAL (B1-1)**



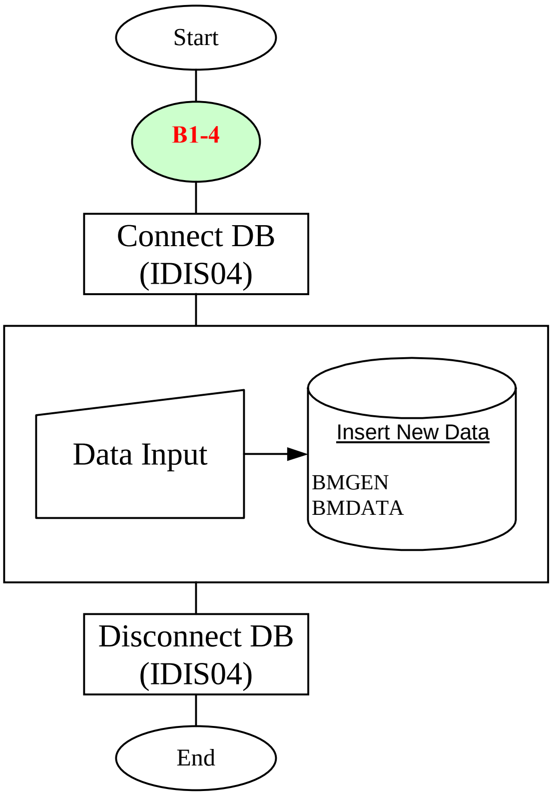
- **HIDROGEO::HYDAT:DATA ENTRY PROCESS - GEOLOG (B1-2)**



- **HIDROGEO::HYDAT:DATA ENTRY PROCESS – SAMPLE REGISTRATION (B1-3)**



- **HIDROGEO::HYDAT:DATA ENTRY PROCESS – BM ELEVATION (B1-4)**



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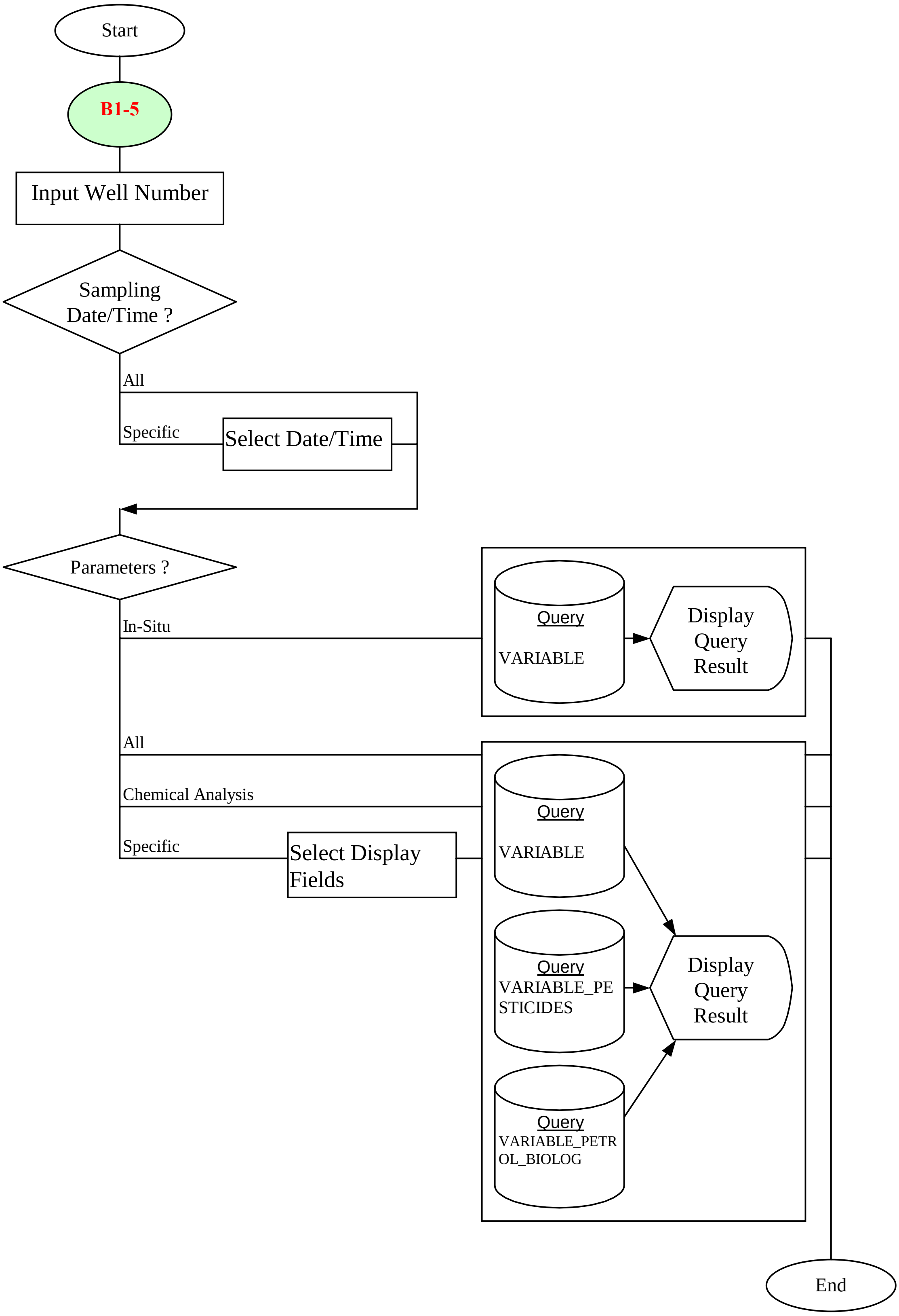
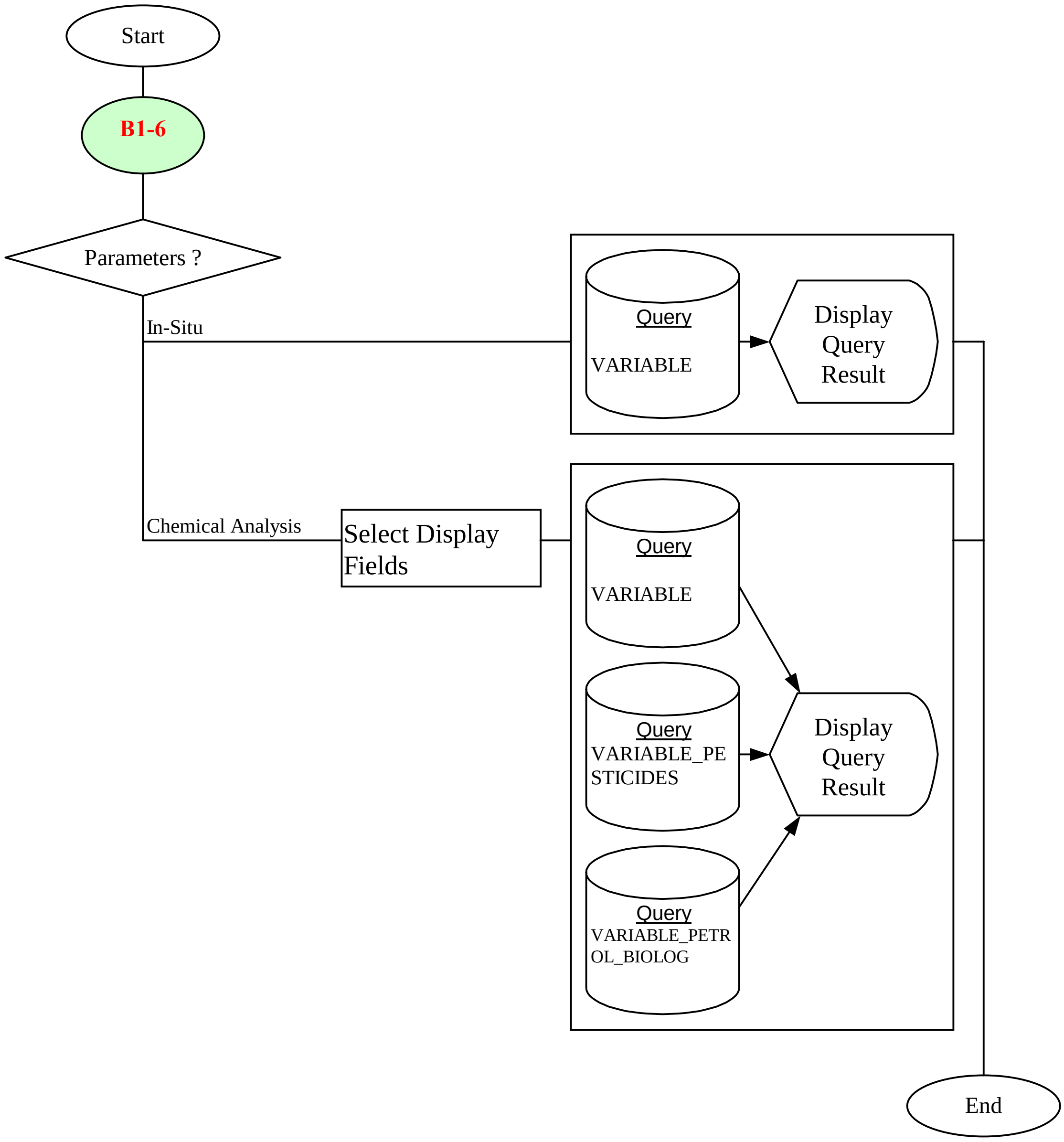
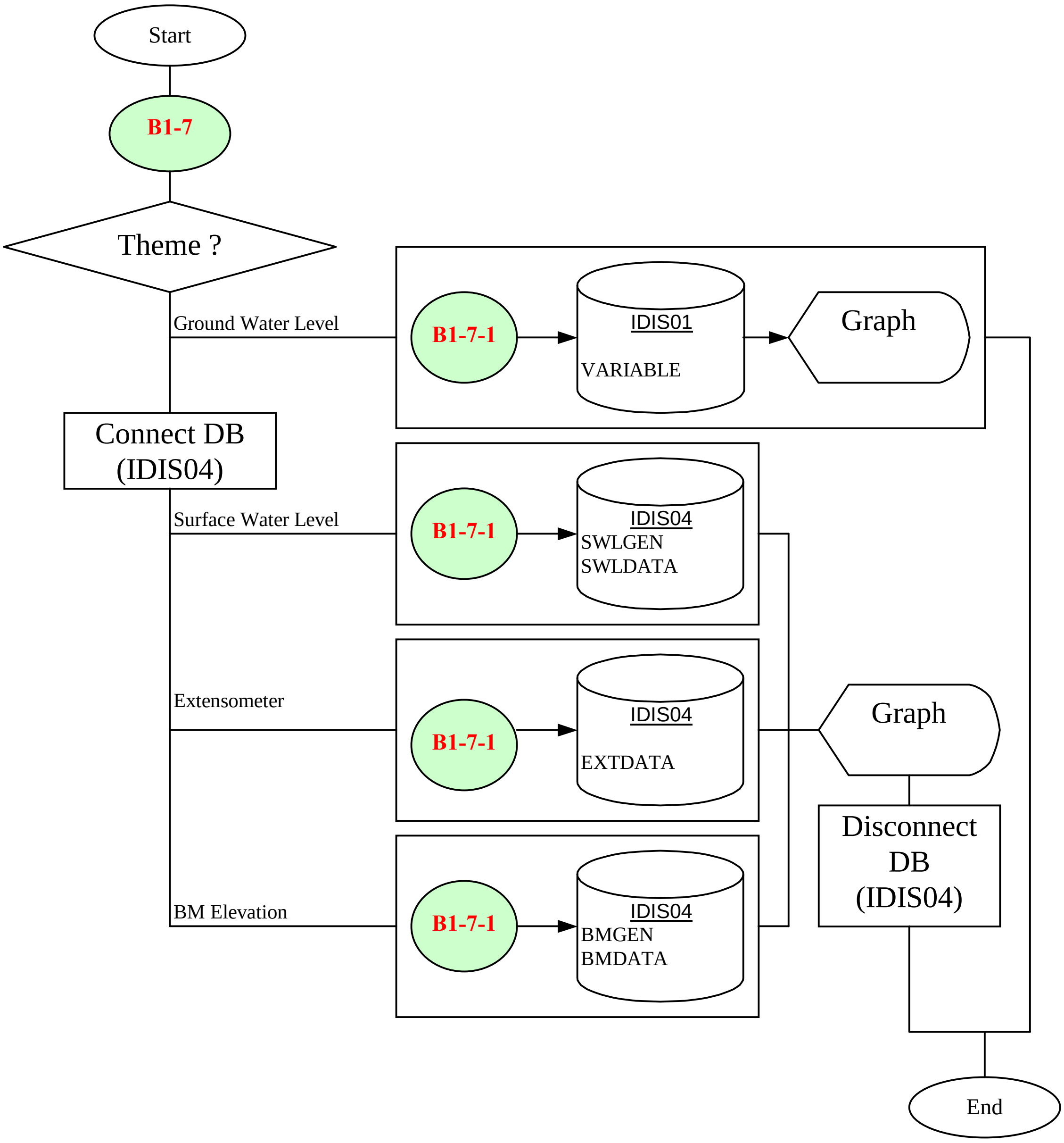


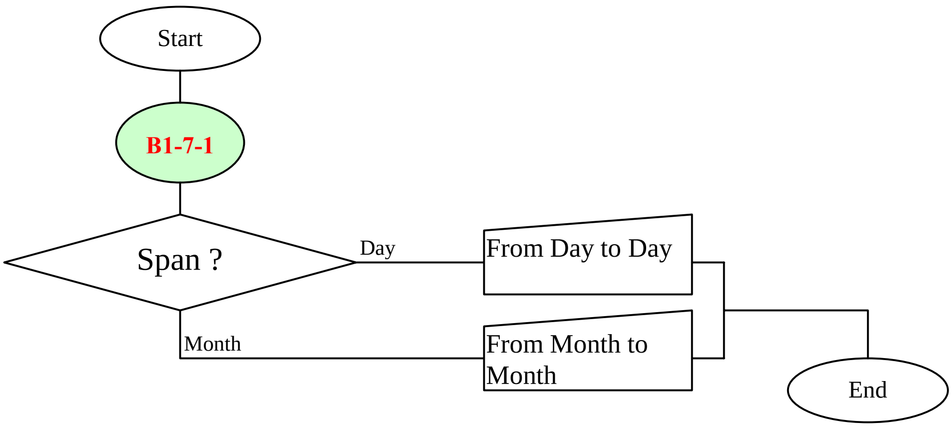
- **HIDROGEO::HYDAT:QUERY PROCESS – PARAMETERS (B1-6)**



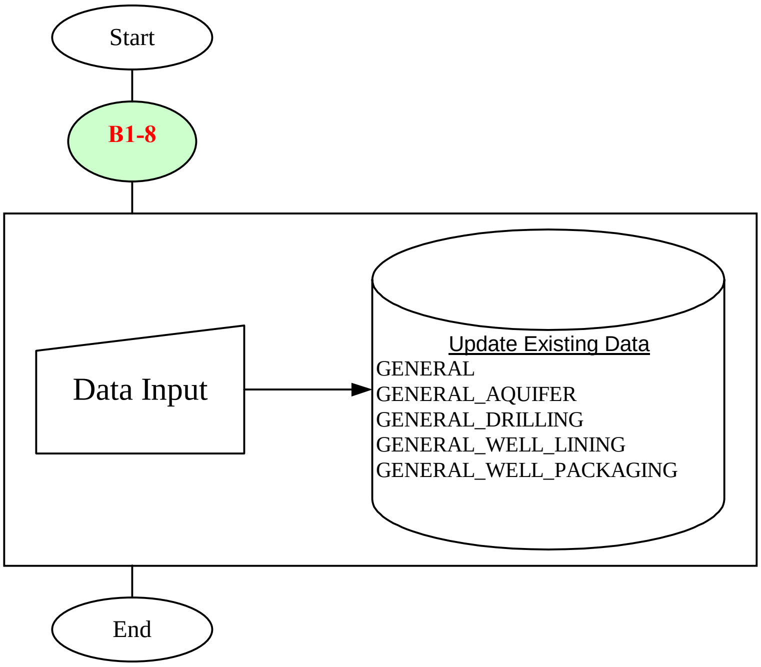
- **HIDROGEO::HYDAT:QUERY PROCESS – ANALYSIS (B1-7)**



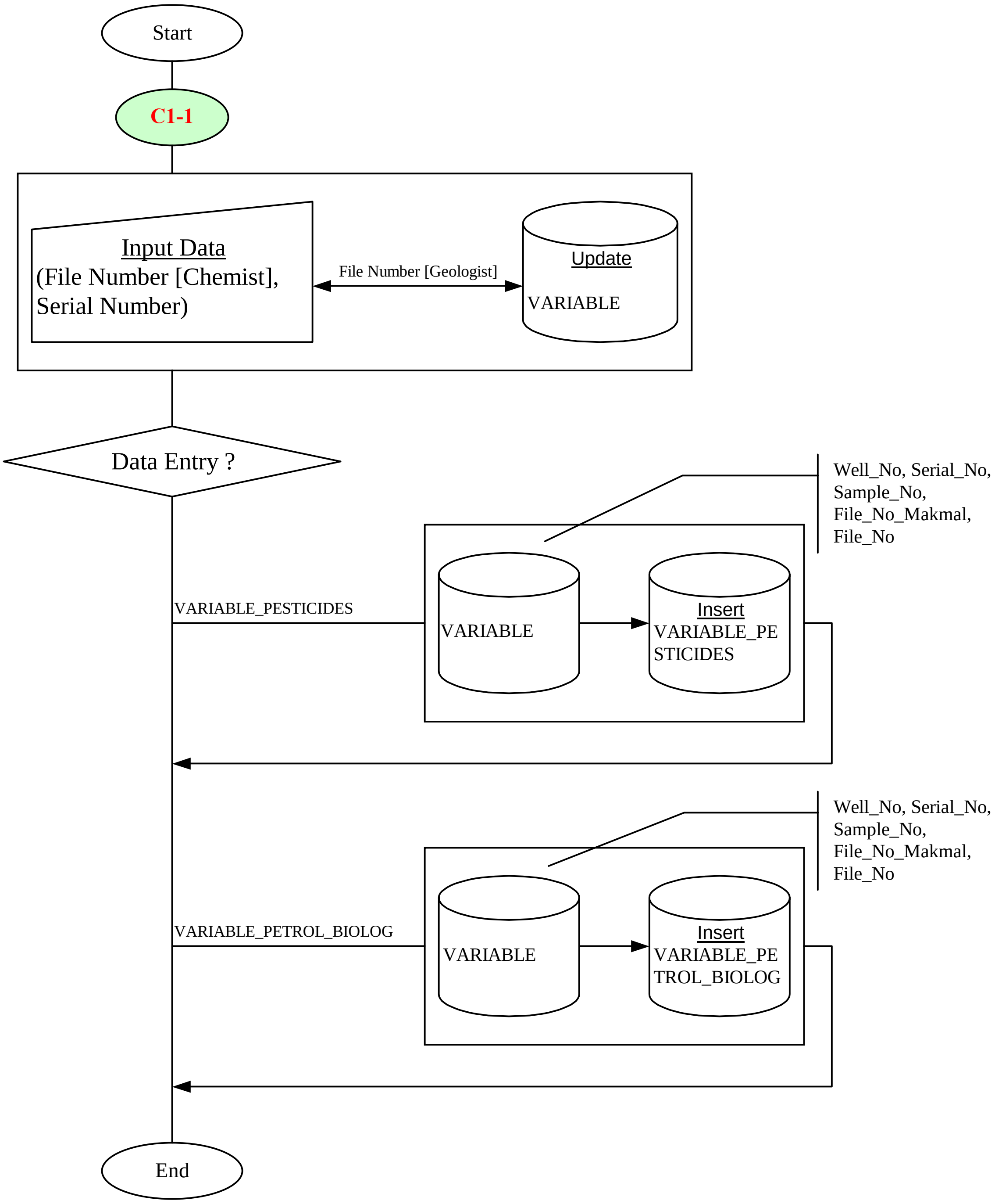
- **HIDROGEO::HYDAT:QUERY PROCESS – ANALYSIS (B1-7-1)**



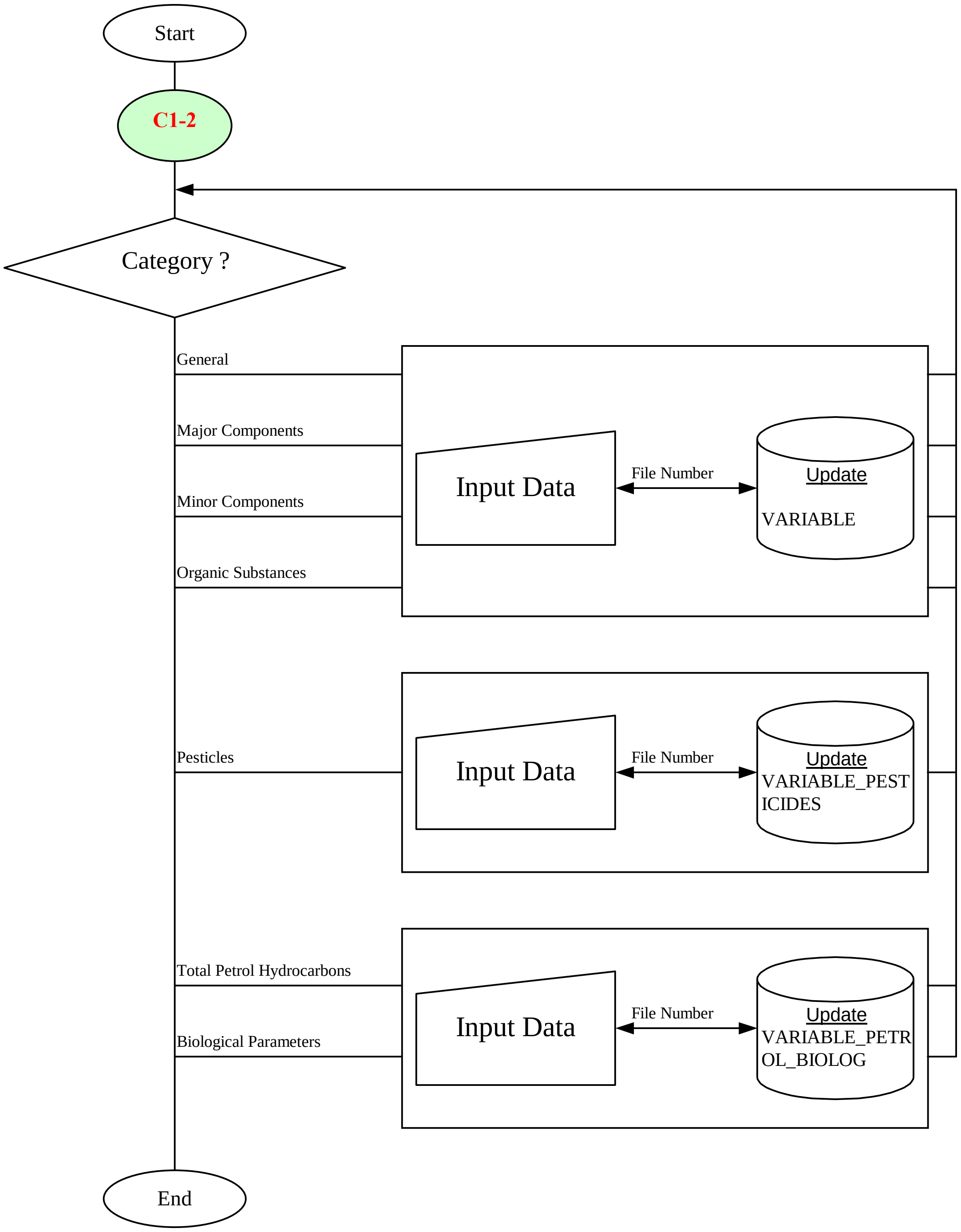
- **HIDROGEO::HYDAT:MODIFY PROCESS – GENERAL (B1-8)**



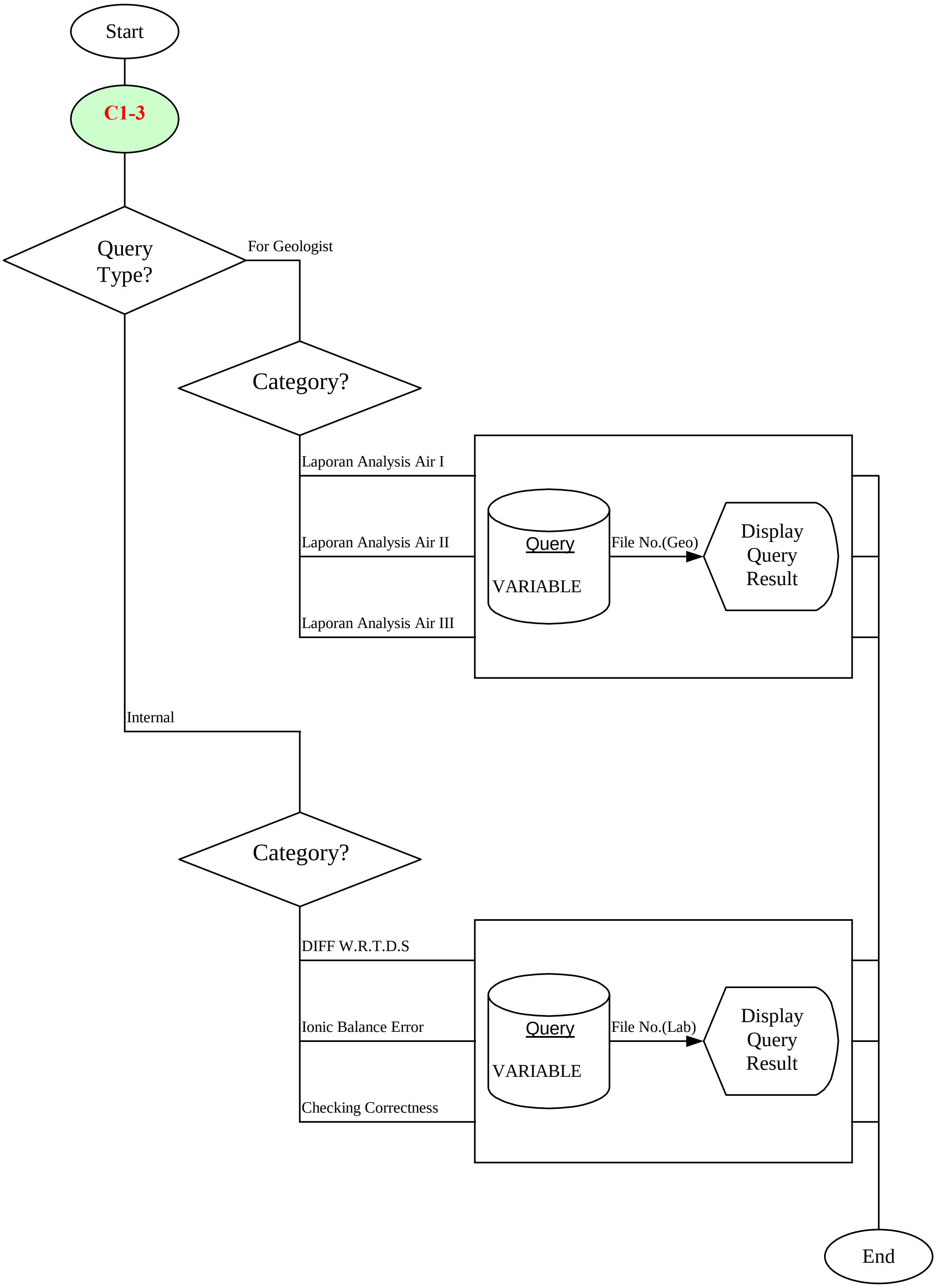
HIDROLAB::HYDAT:DATA ENTRY PROCESS – SERIAL NUMBER REGISTRATION (C1-1)



- **HIDROLAB::HYDAT:UPDATE PROCESS – CHEMICAL ANALYSIS (C1-2)**



- **HIDROLAB::HYDAT:QUERY PROCESS – WATER ANALYSIS (C1-3)**



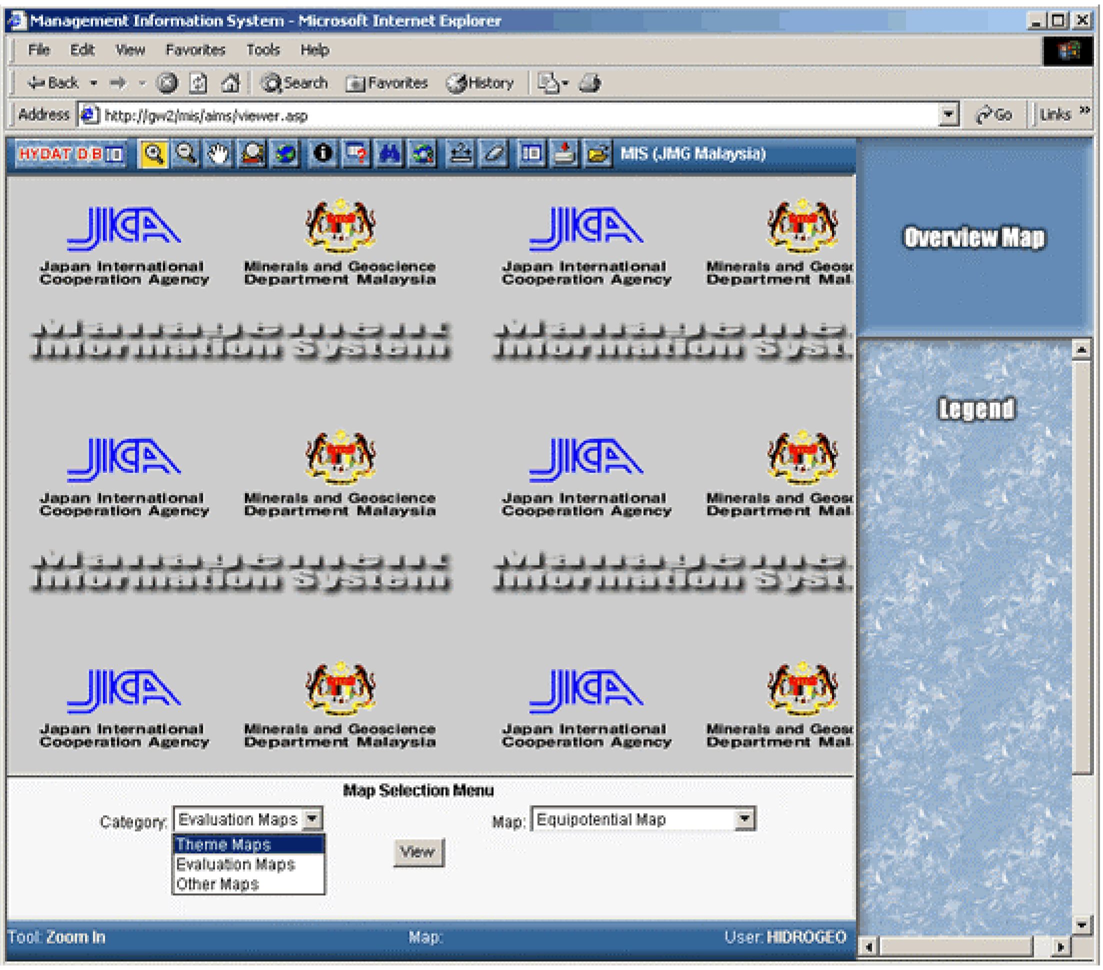
5. MAJOR OUTPUTS

5.1 System Interface

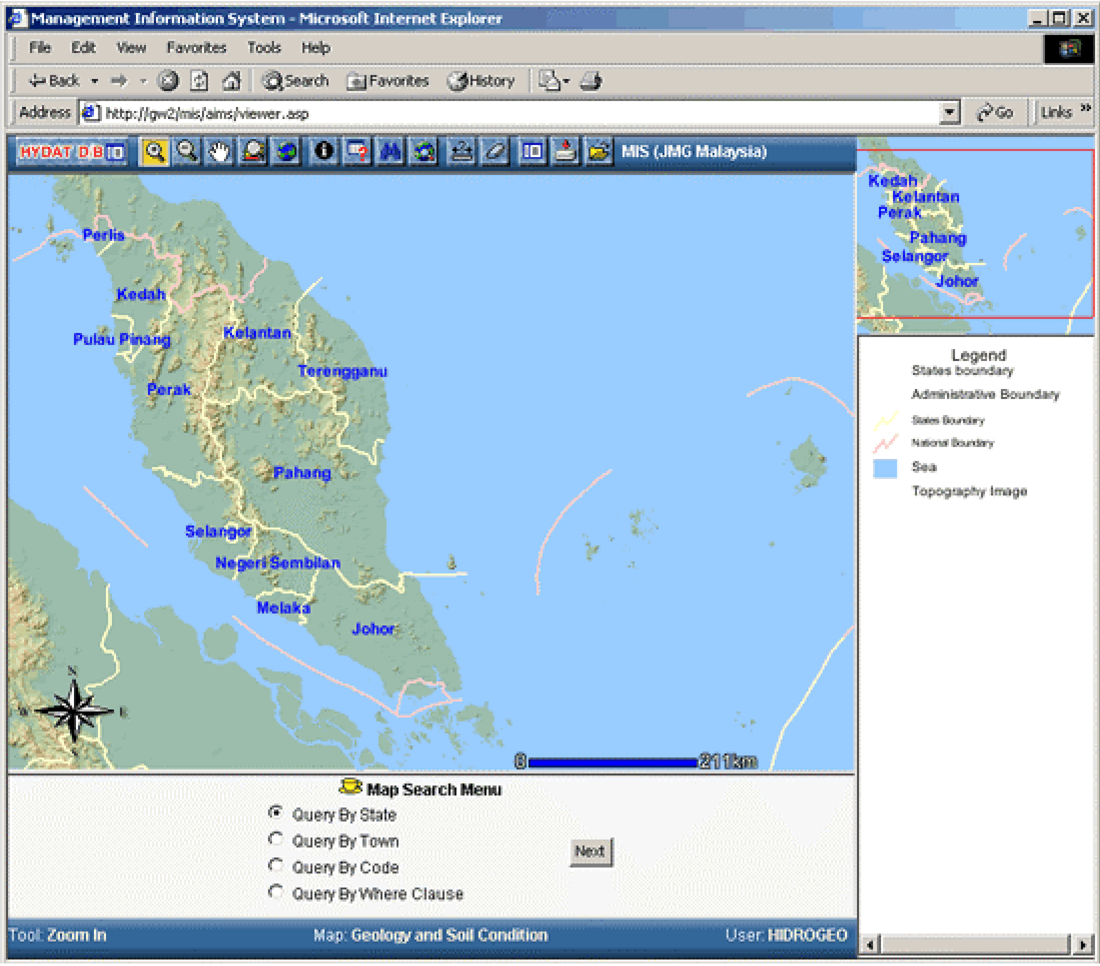
The major output illustrations in this MIS system are as follows:

Annex Figure I.2.7 Start up Process (MIS Title & Menu)

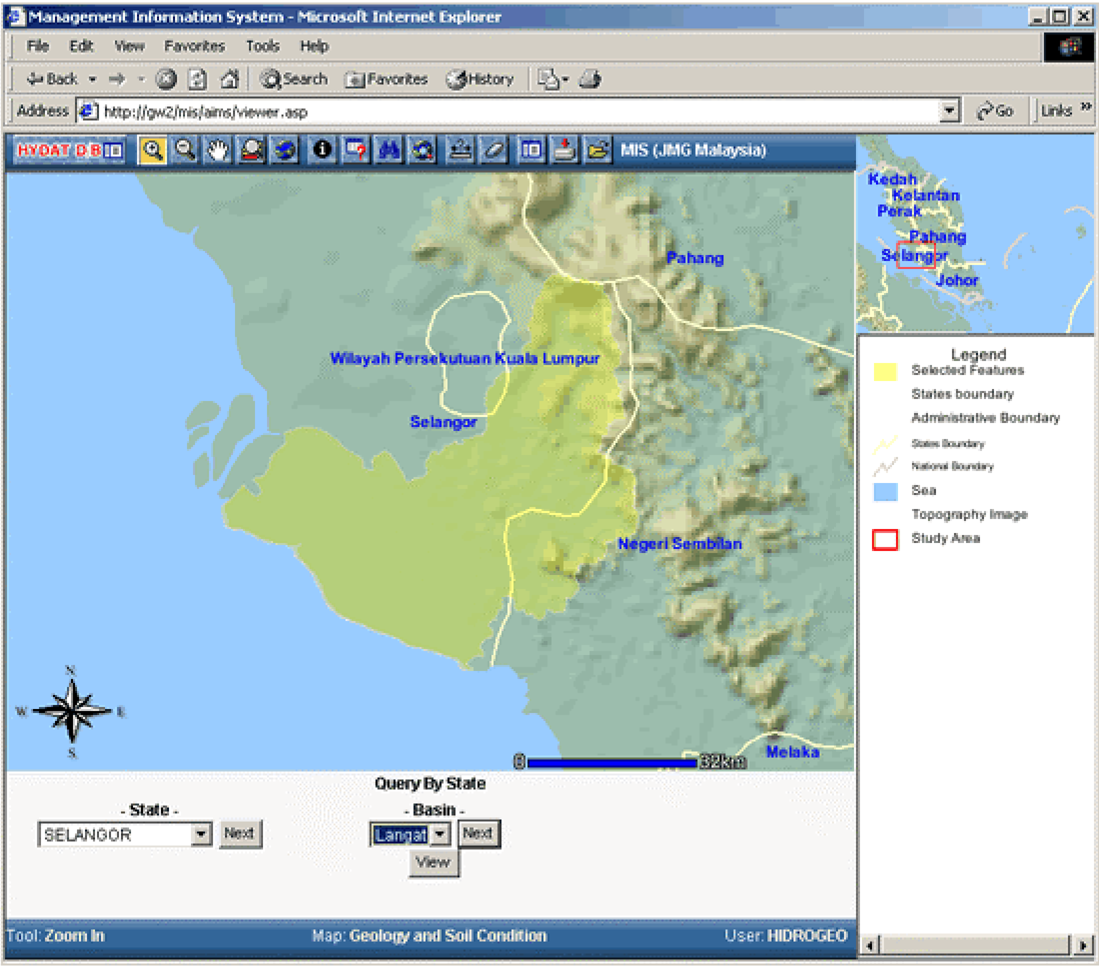
Annex Figure I.2.8 User Login Process



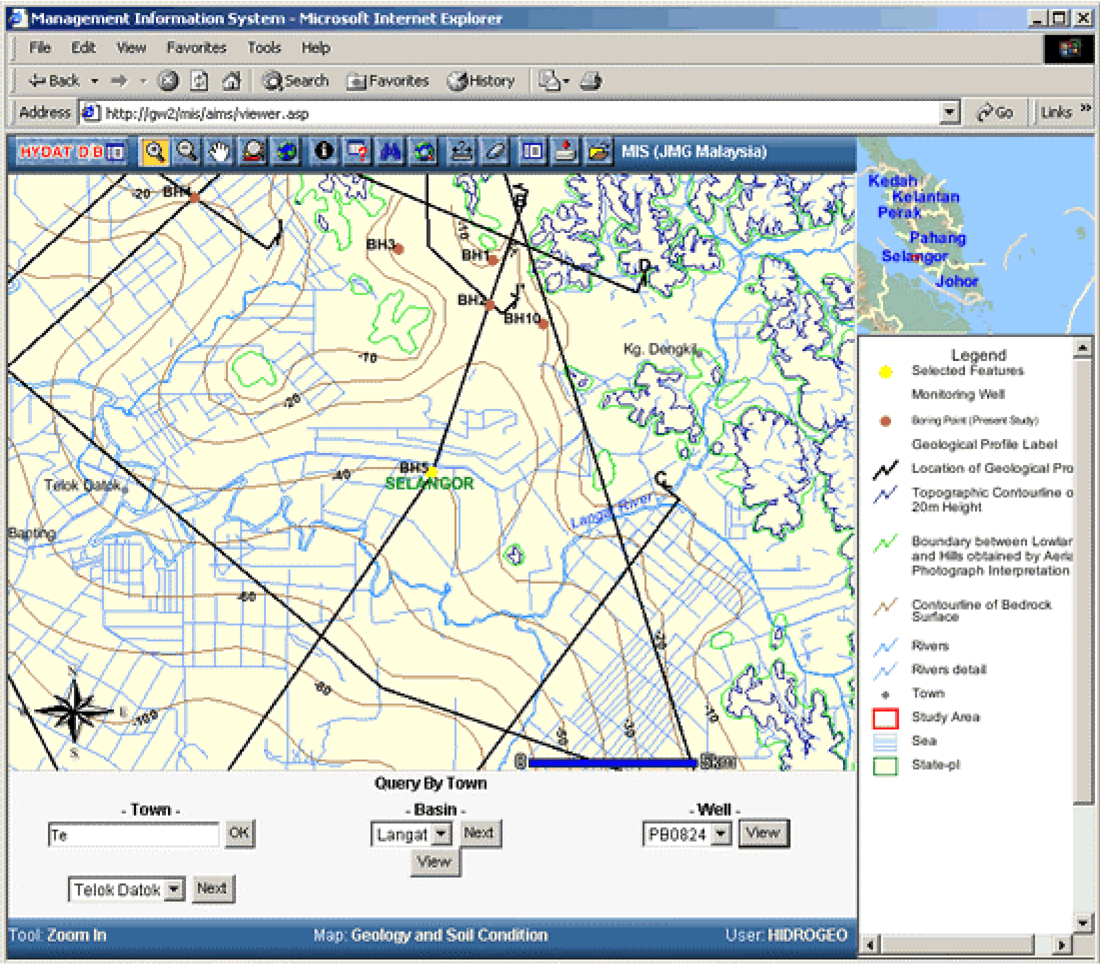
Annex Figure I.2.9 Map Selection Process



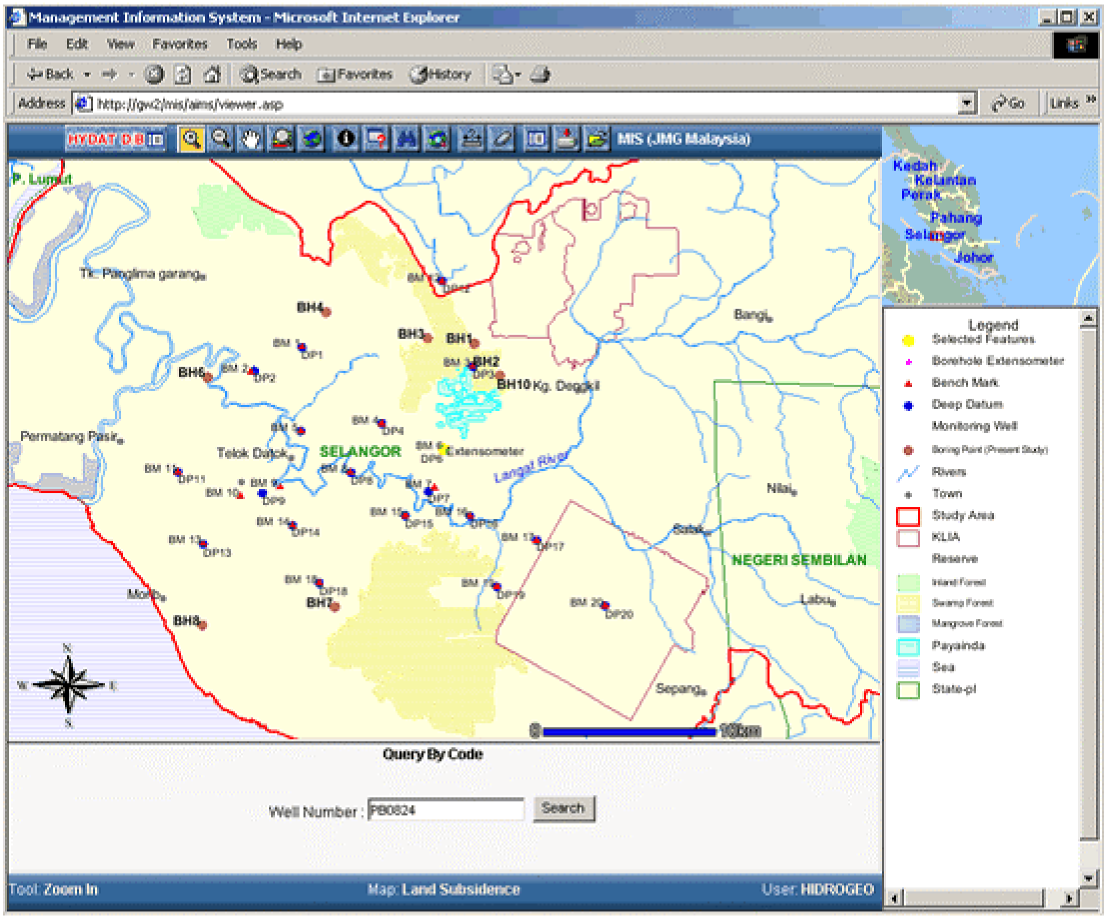
Annex Figure I.2.10 Map Search Process (Map Search Menu)



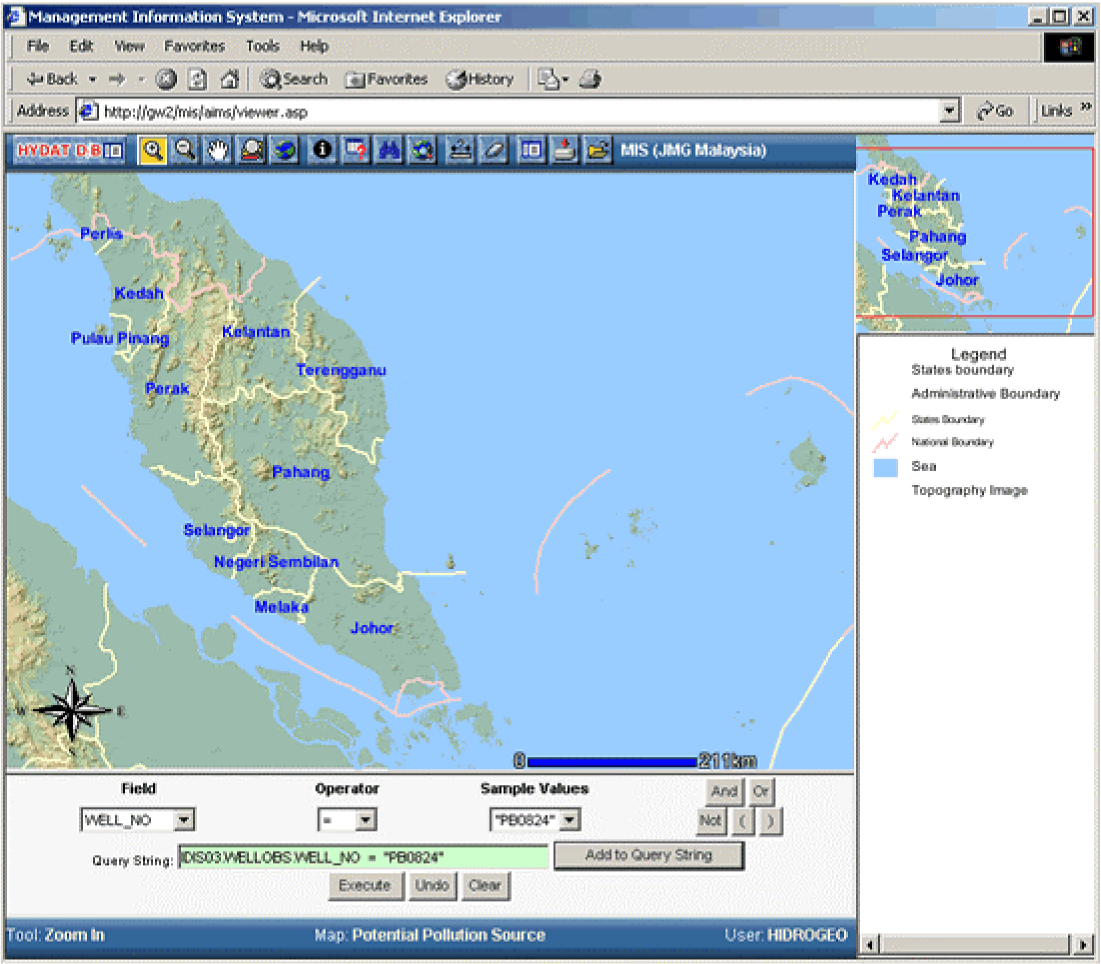
Annex Figure I.2.11 Map Search Process (Query by STATE)



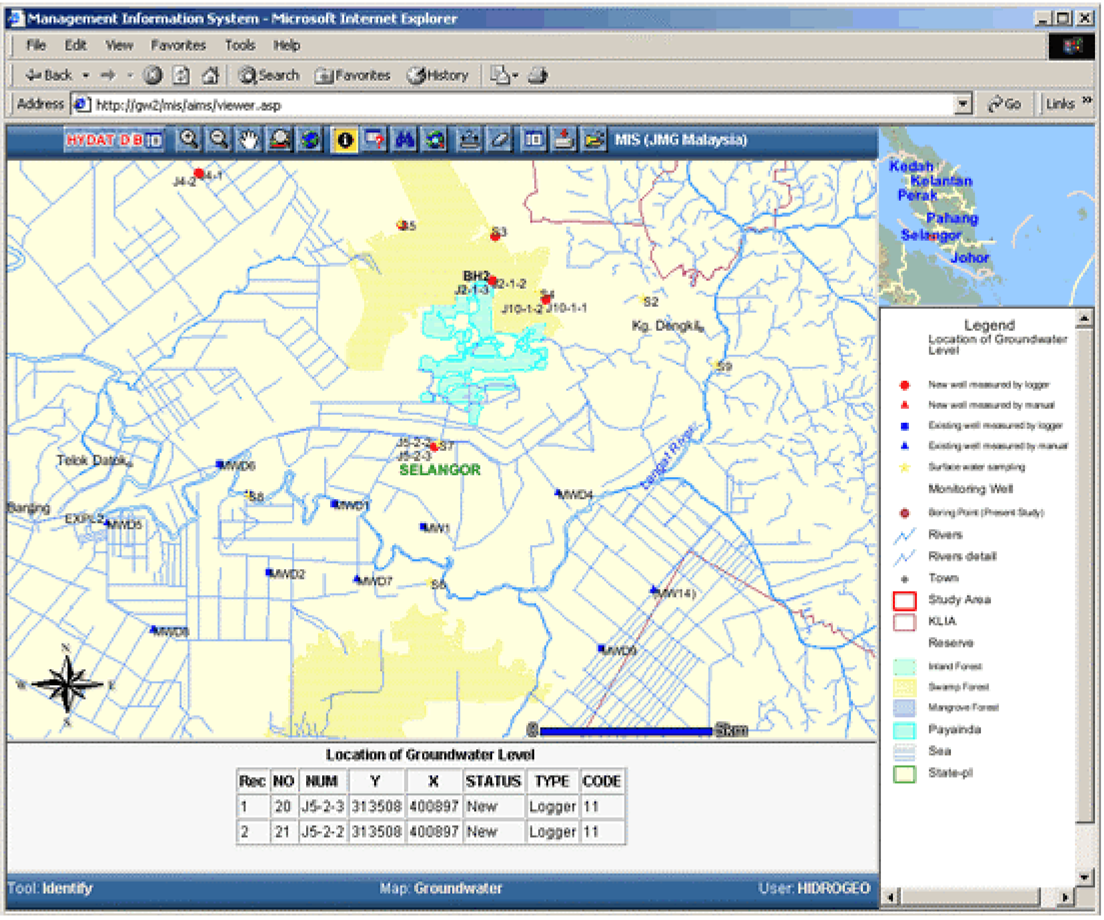
Annex Figure I.2.12 Map Search Process (Query by TOWN)



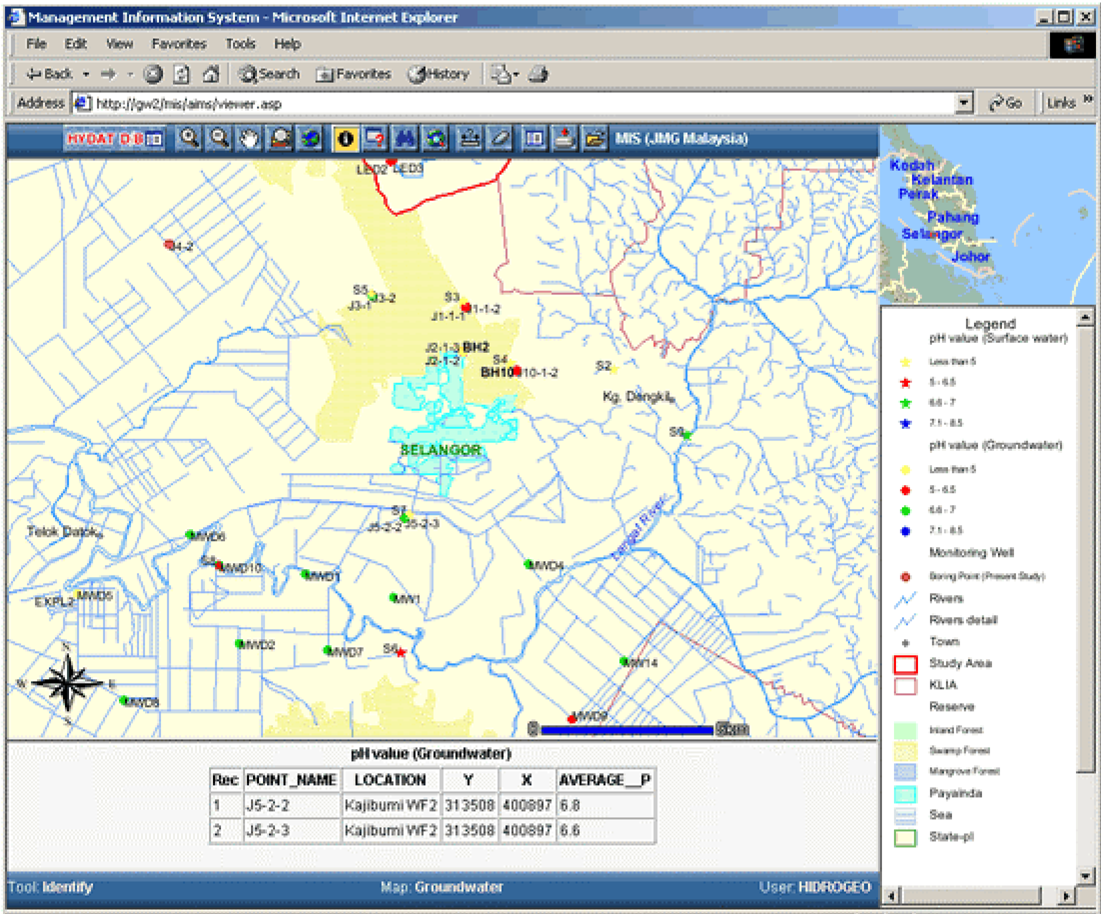
Annex Figure I.2.13 Map Search Process (Query by CODE)



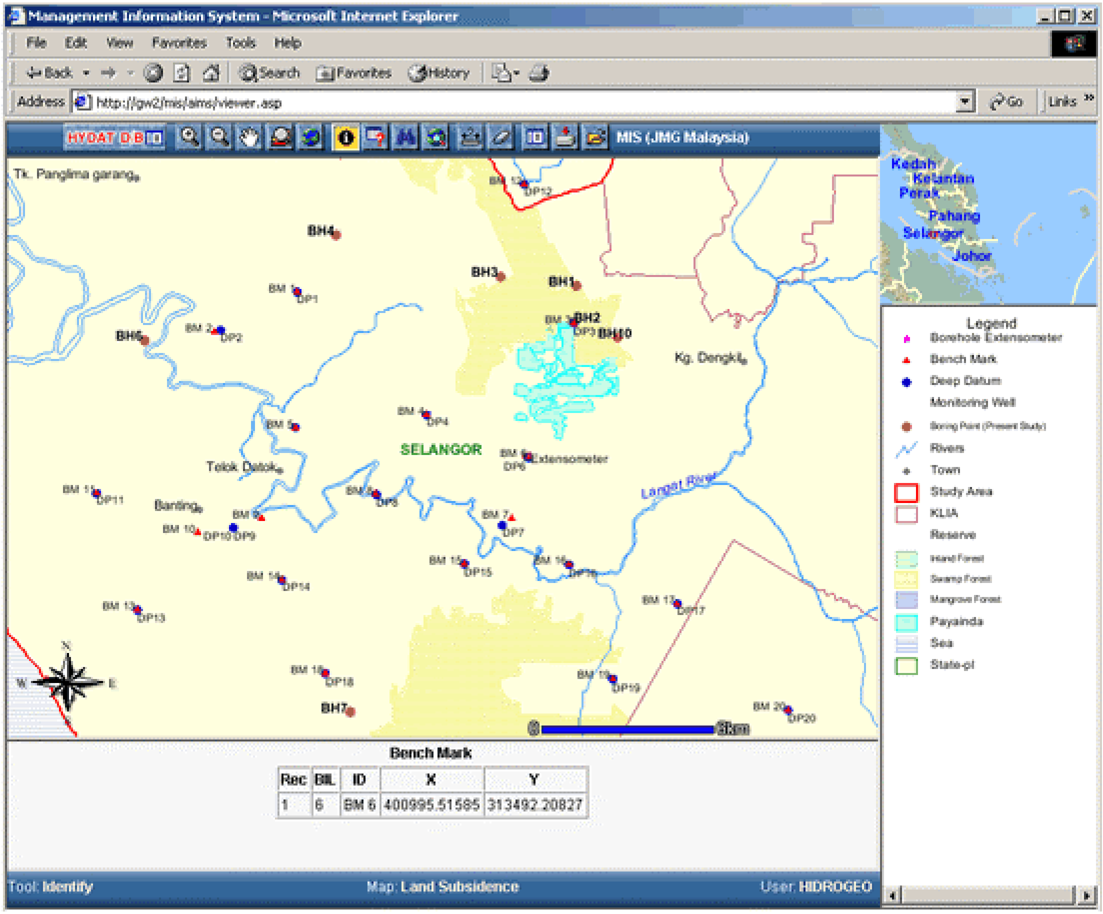
Annex Figure I.2.14 Map Search Process (Query by WHERE CLAUSE)



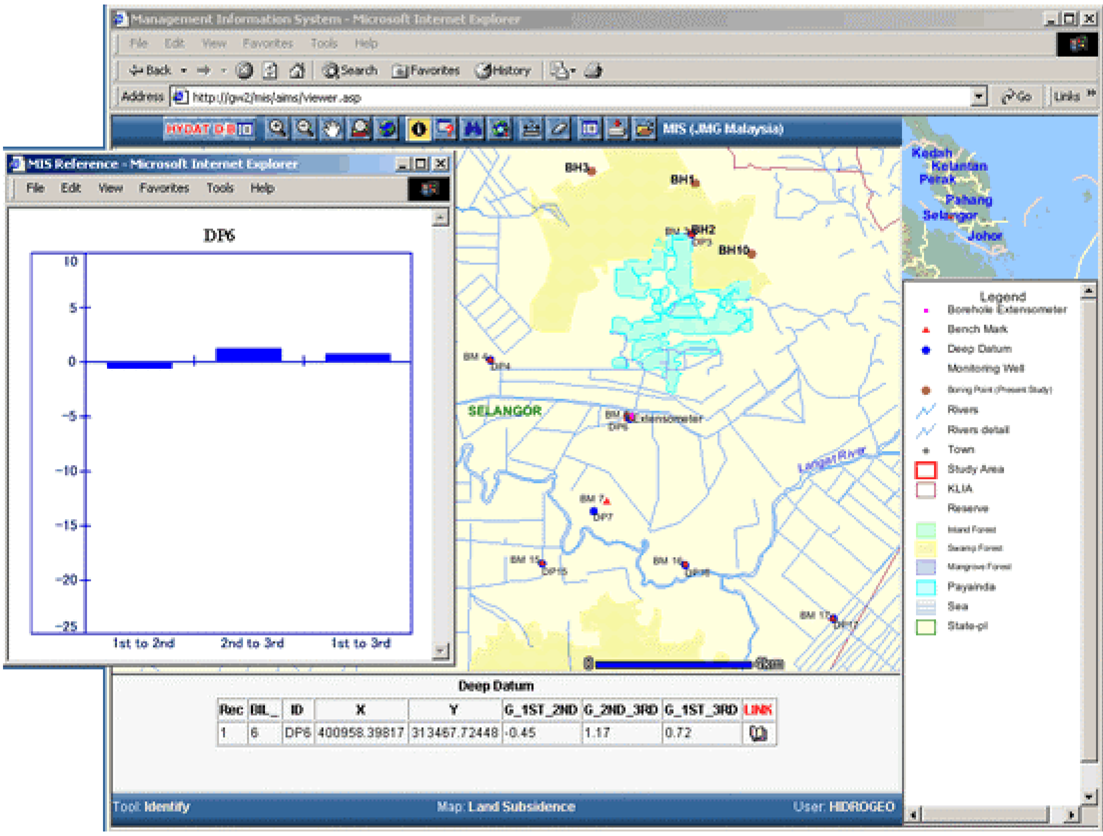
Annex Figure I.2.15 Theme Map Groundwater (1)
Location of Groundwater Level



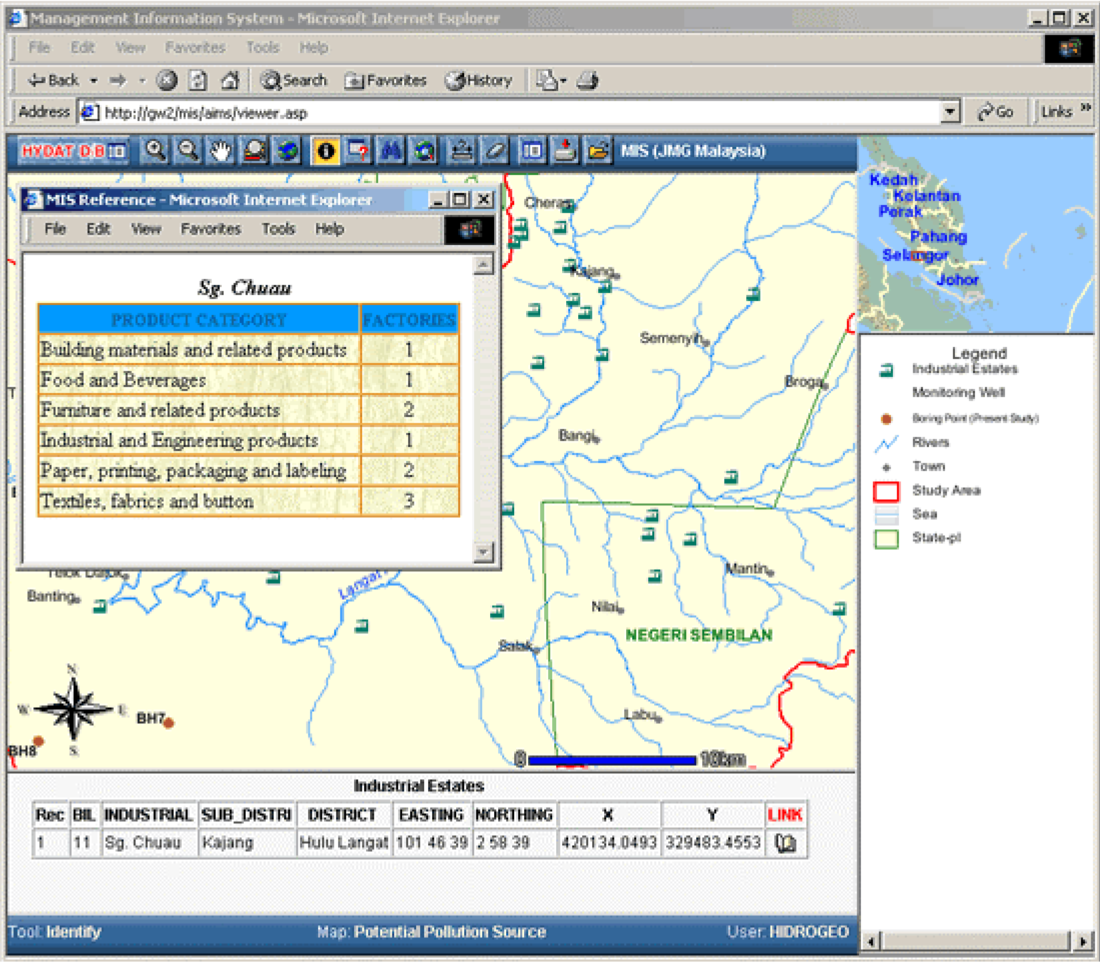
Annex Figure I.2.16 Theme Map Groundwater (2)
pH value (Surface water), pH value (Groundwater)



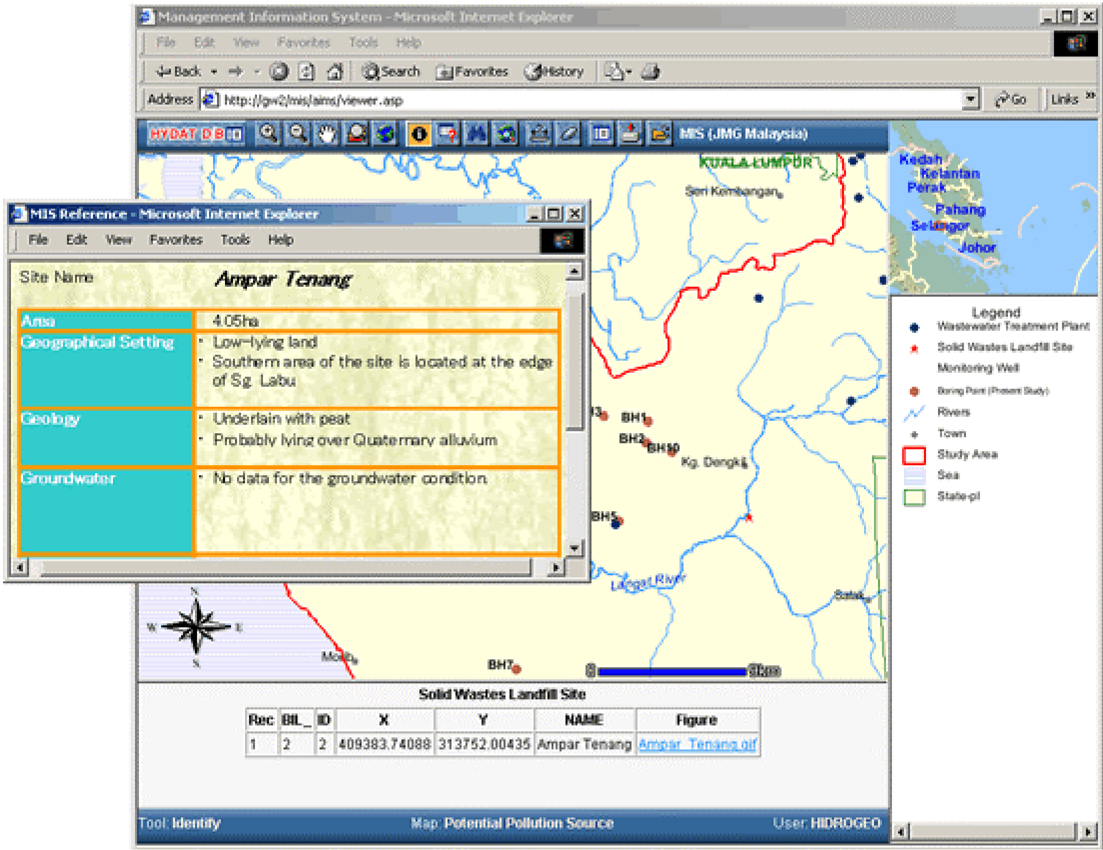
Annex Figure I.2.17 Theme Map Land Subsidence (1)



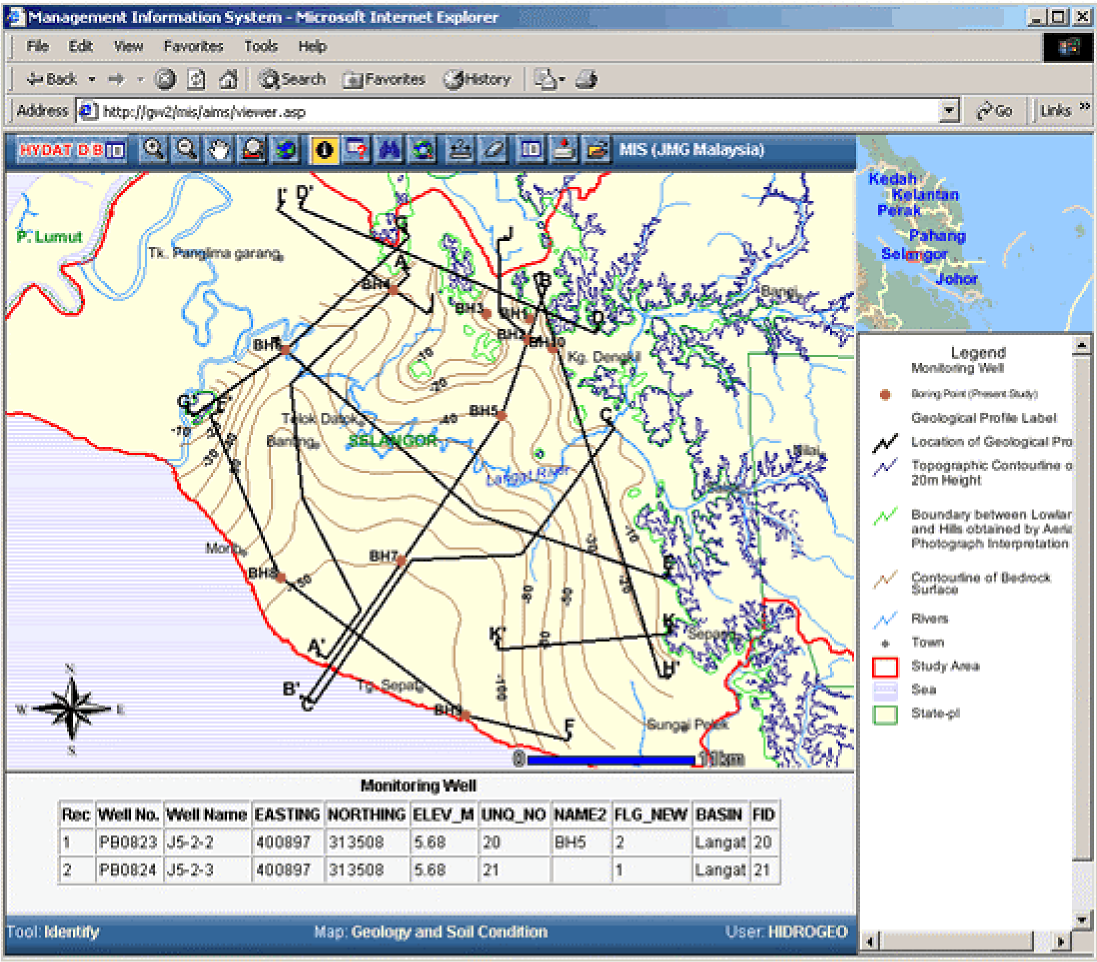
Annex Figure I.2.18 Theme Map Land Subsidence (2)



**Annex Figure I.2.19 Theme Map Potential Pollution Source (1)
Industrial Estates**

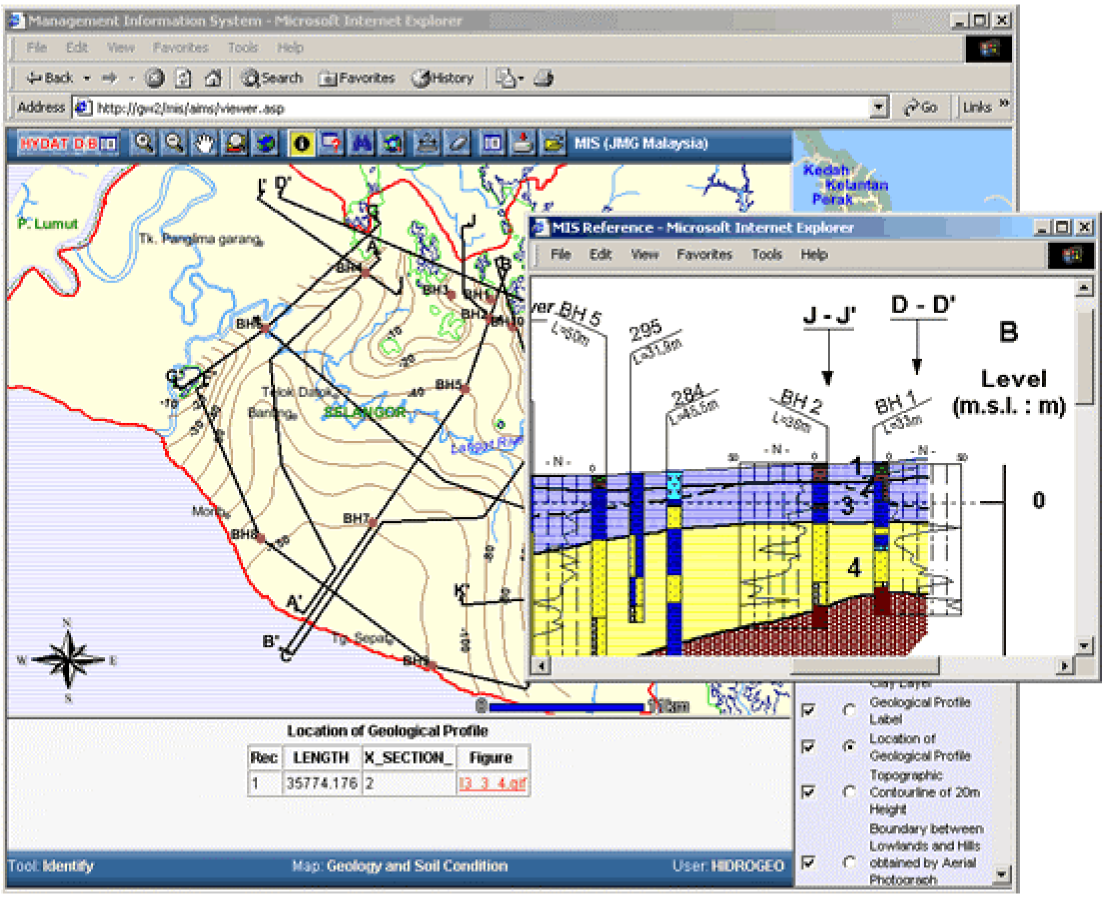


Annex Figure I.2.20 Theme Map Potential Pollution Source (2)
Solid waste and wastewater treatment



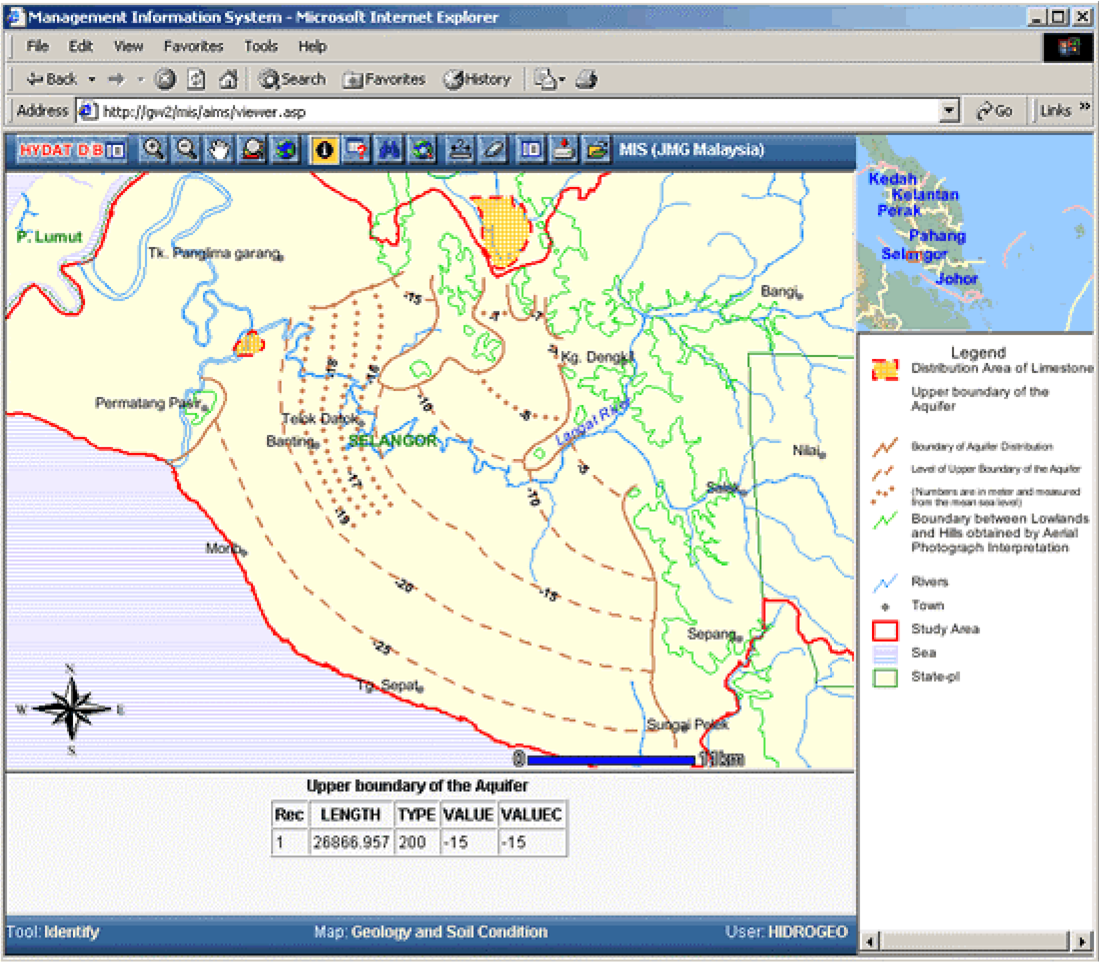
Annex Figure I.2.21 Theme Map Geology and Soil Condition (1)

Available geological profiles



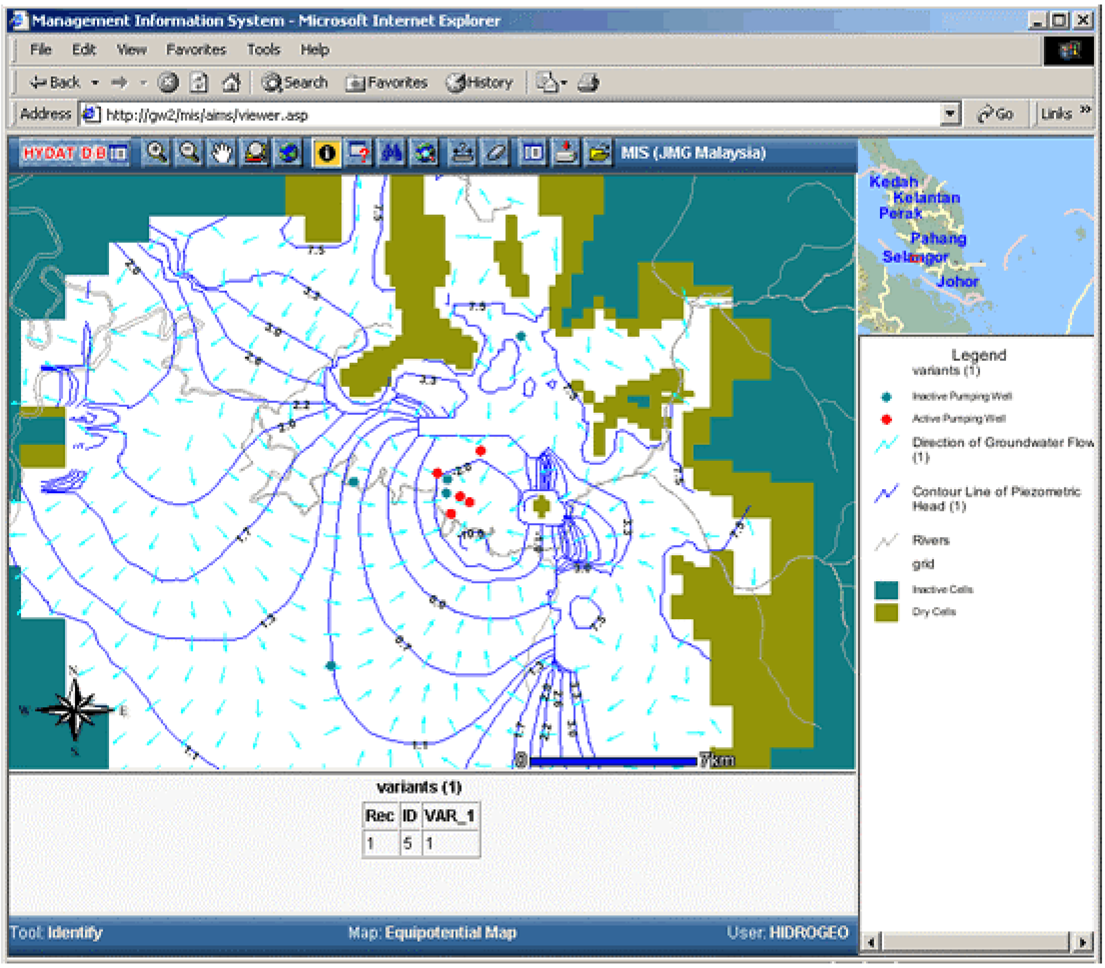
Annex Figure I.2.22 Theme Map Geology and Soil Condition (2)

Available geological profiles (with Figure)

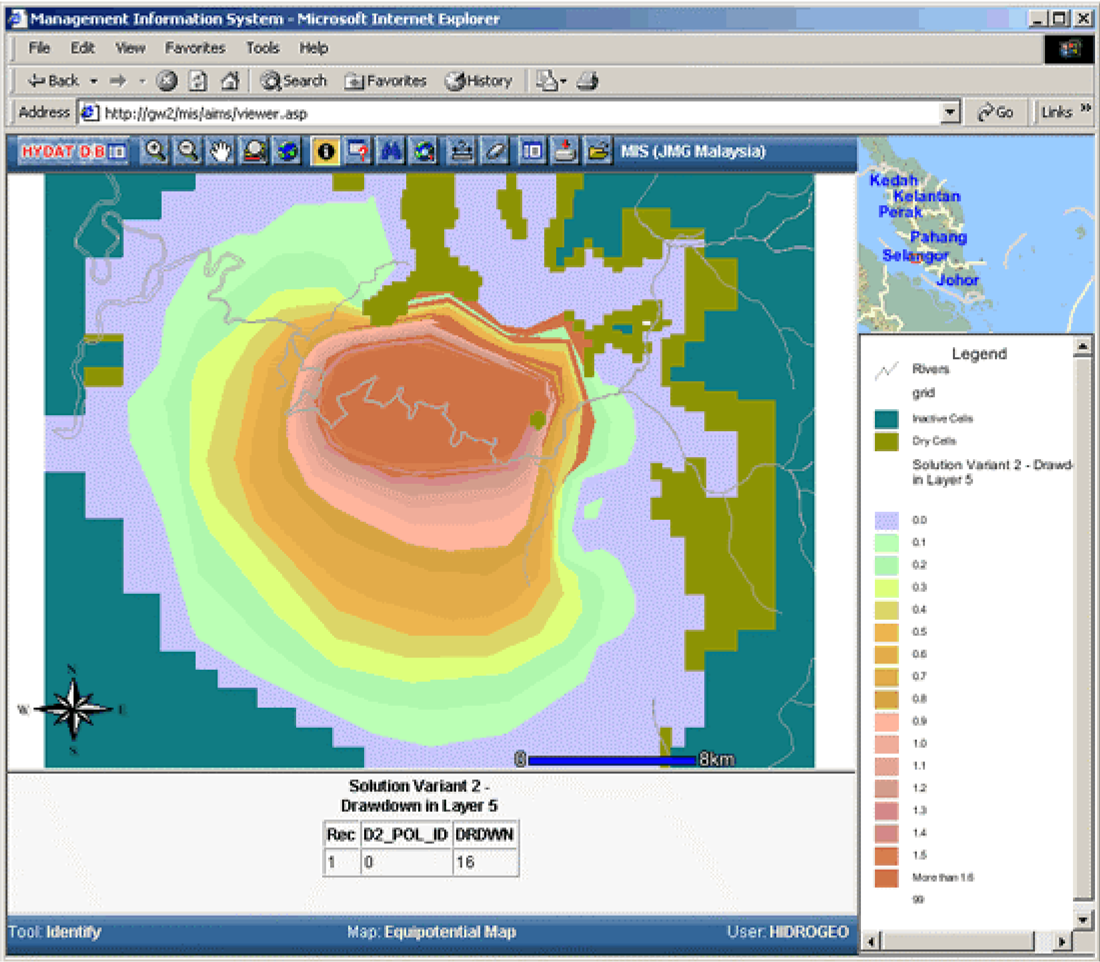


Annex Figure I.2.23 Theme Map Geology and Soil Condition (3)

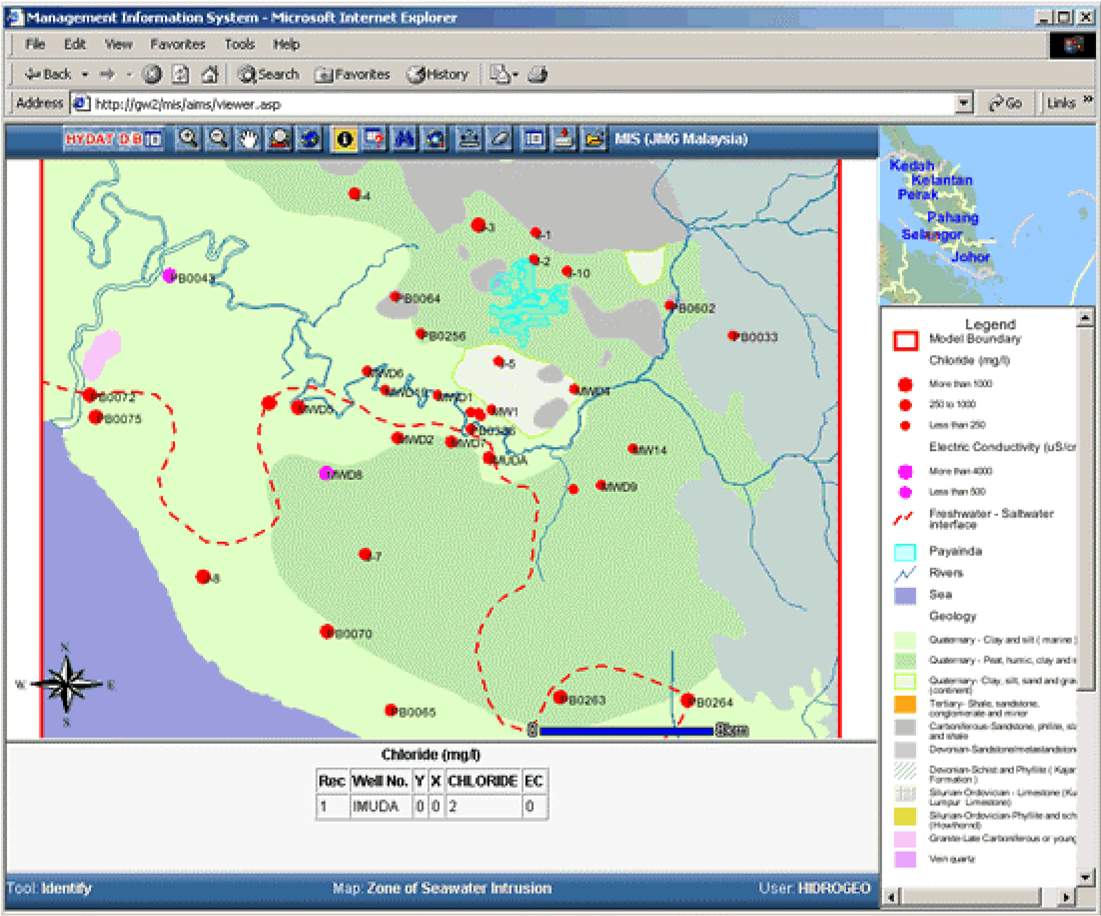
Upper boundary of the Aquifer



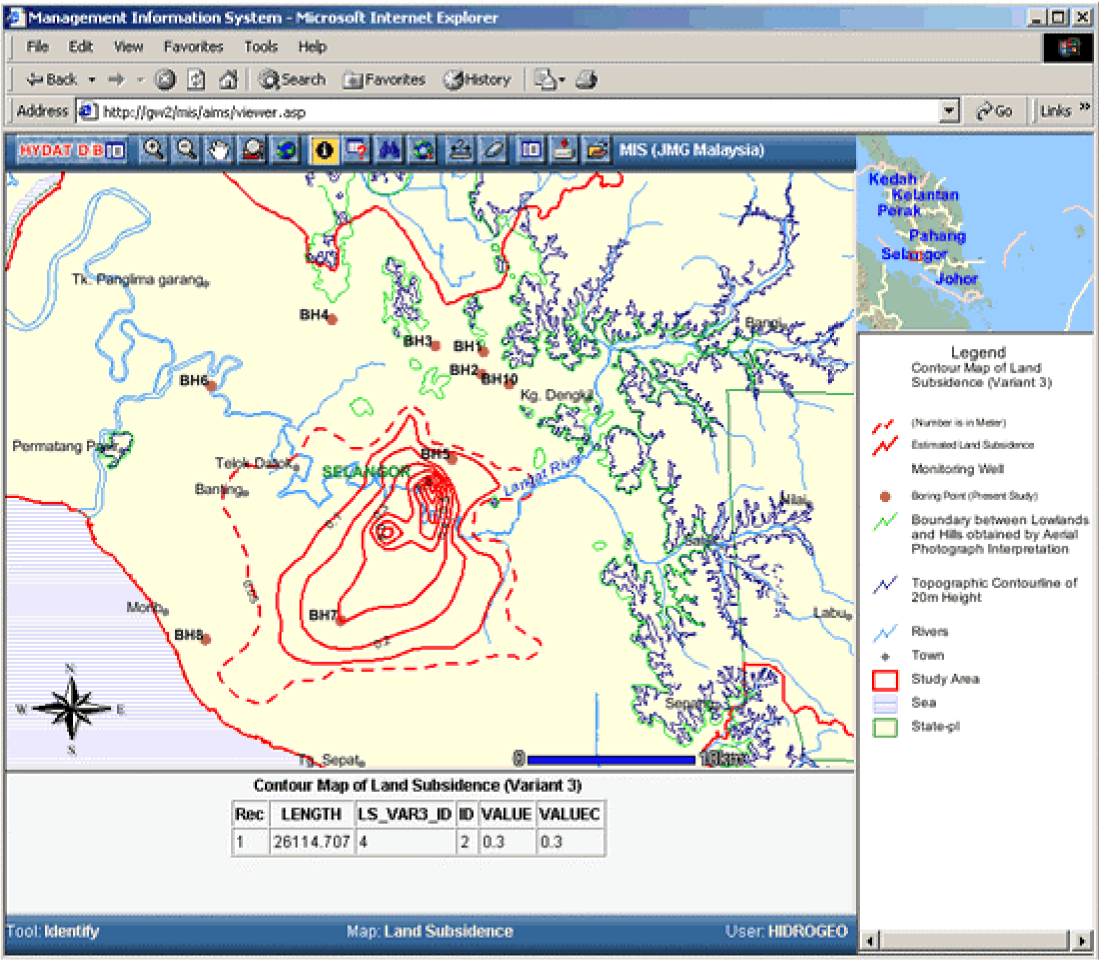
Annex Figure I.2.24 Evaluation Map Equipotential Map (1)



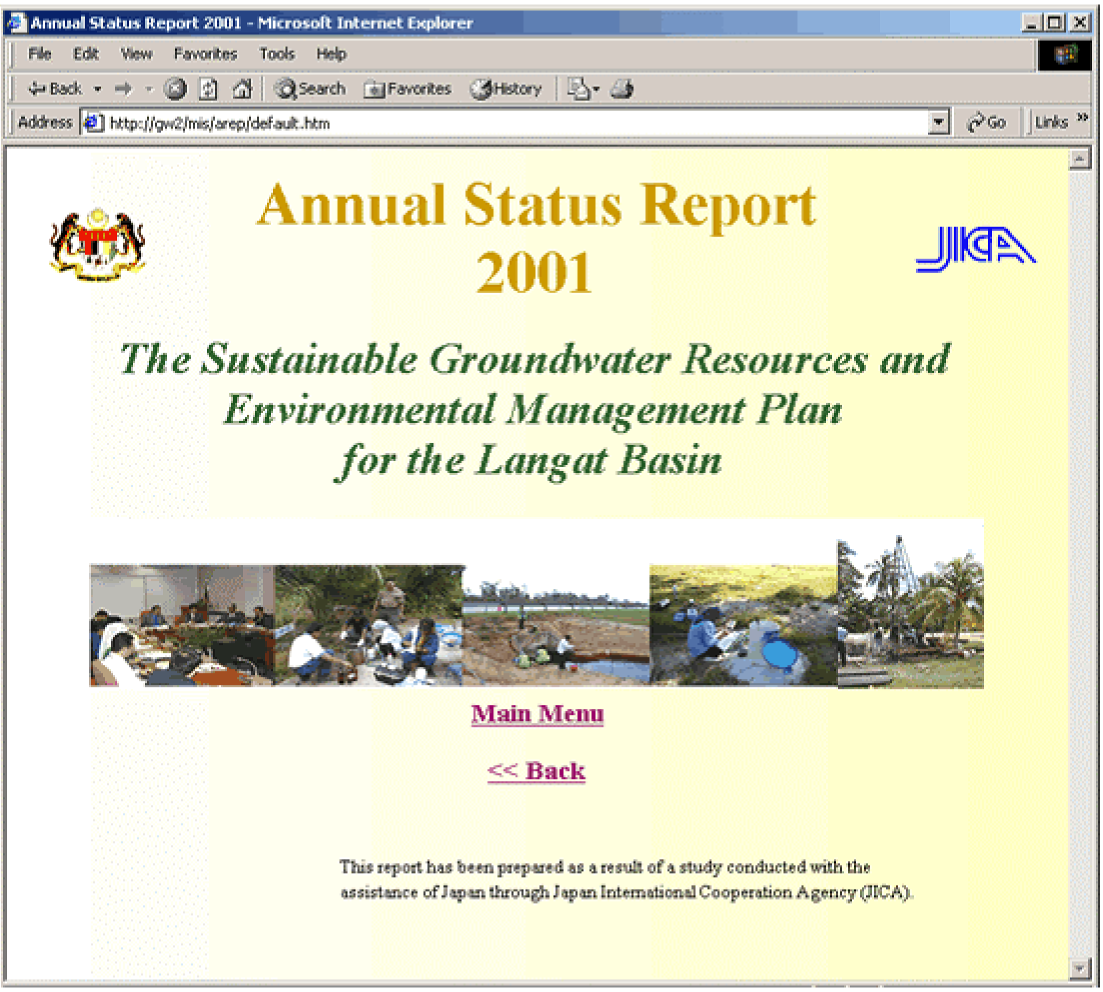
Annex Figure I.2.25 Evaluation Map Equipotential Map (2)



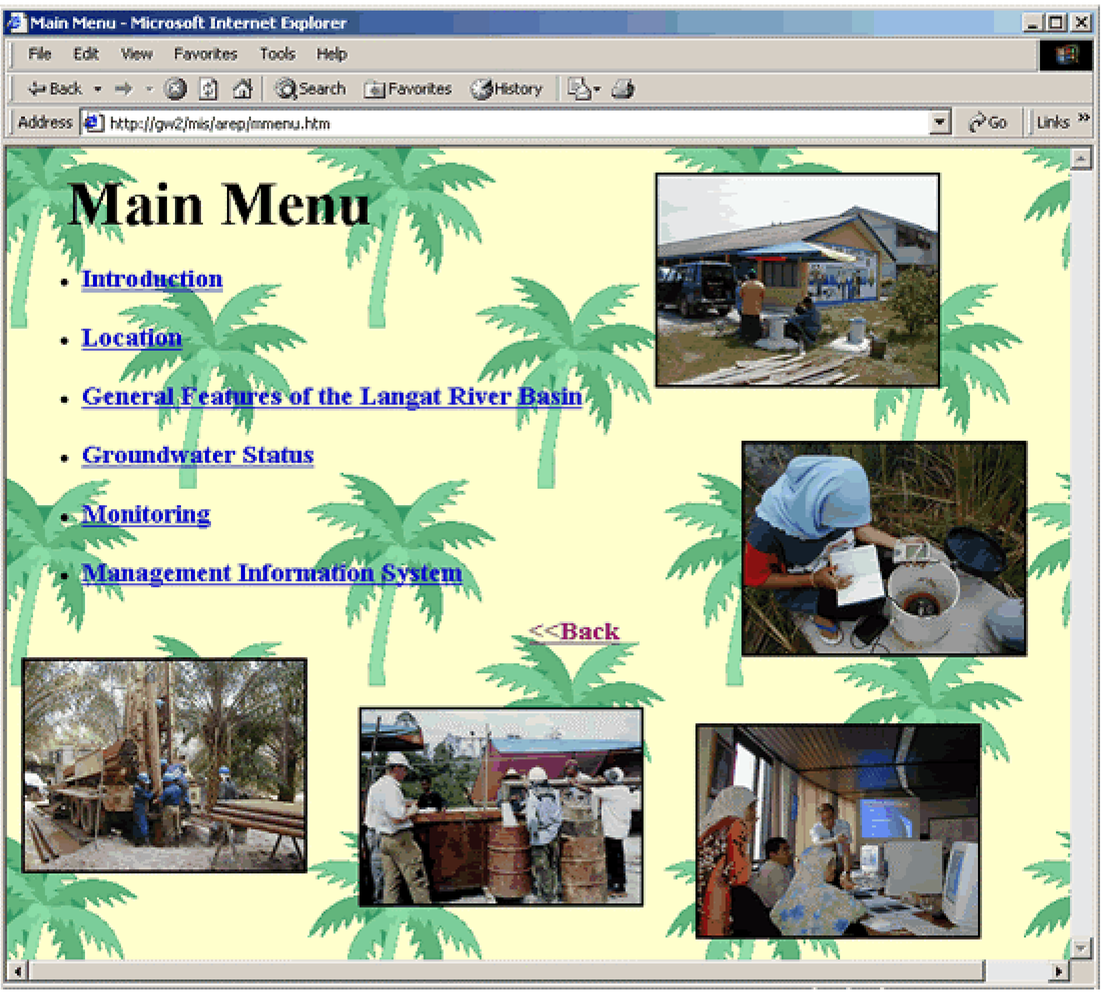
Annex Figure I.2.26 Evaluation Map Zone of Seawater Intrusion



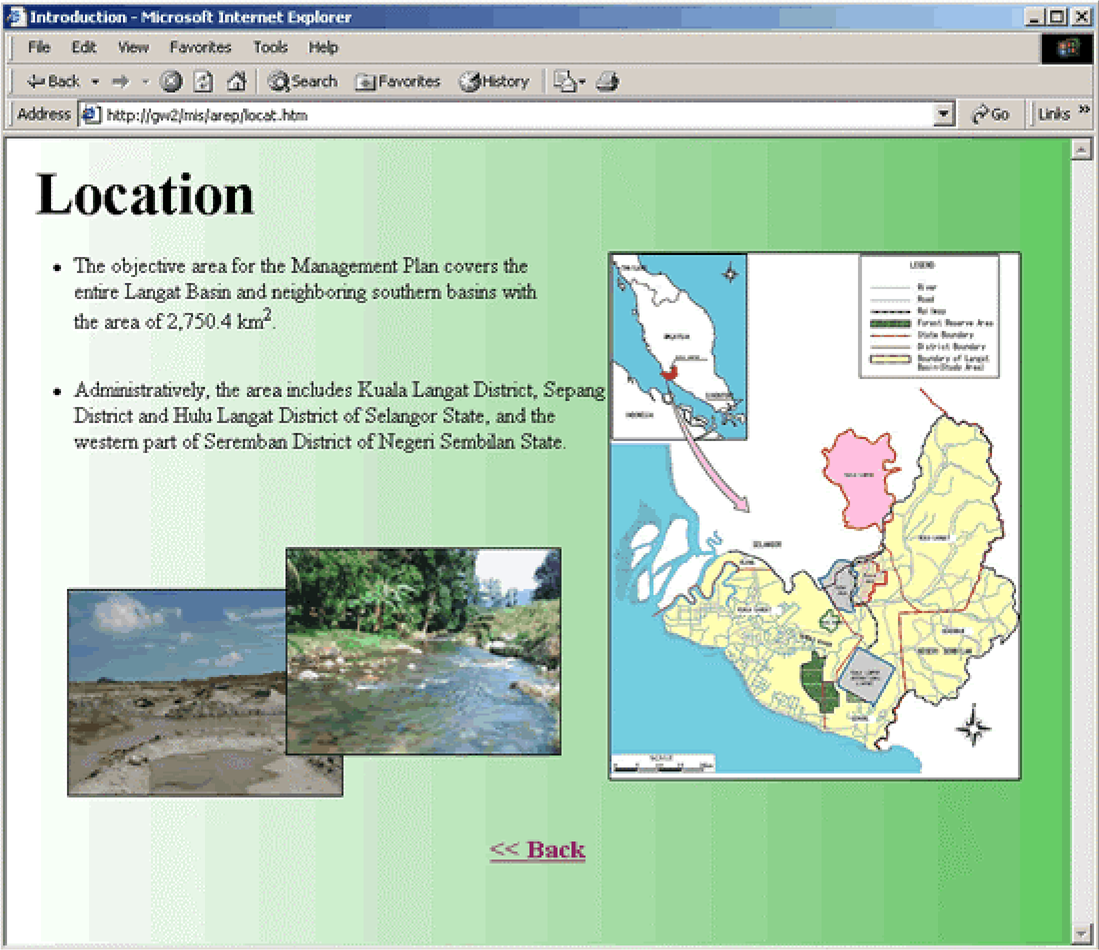
Annex Figure I.2.27 Evaluation Map Land Subsidence Map



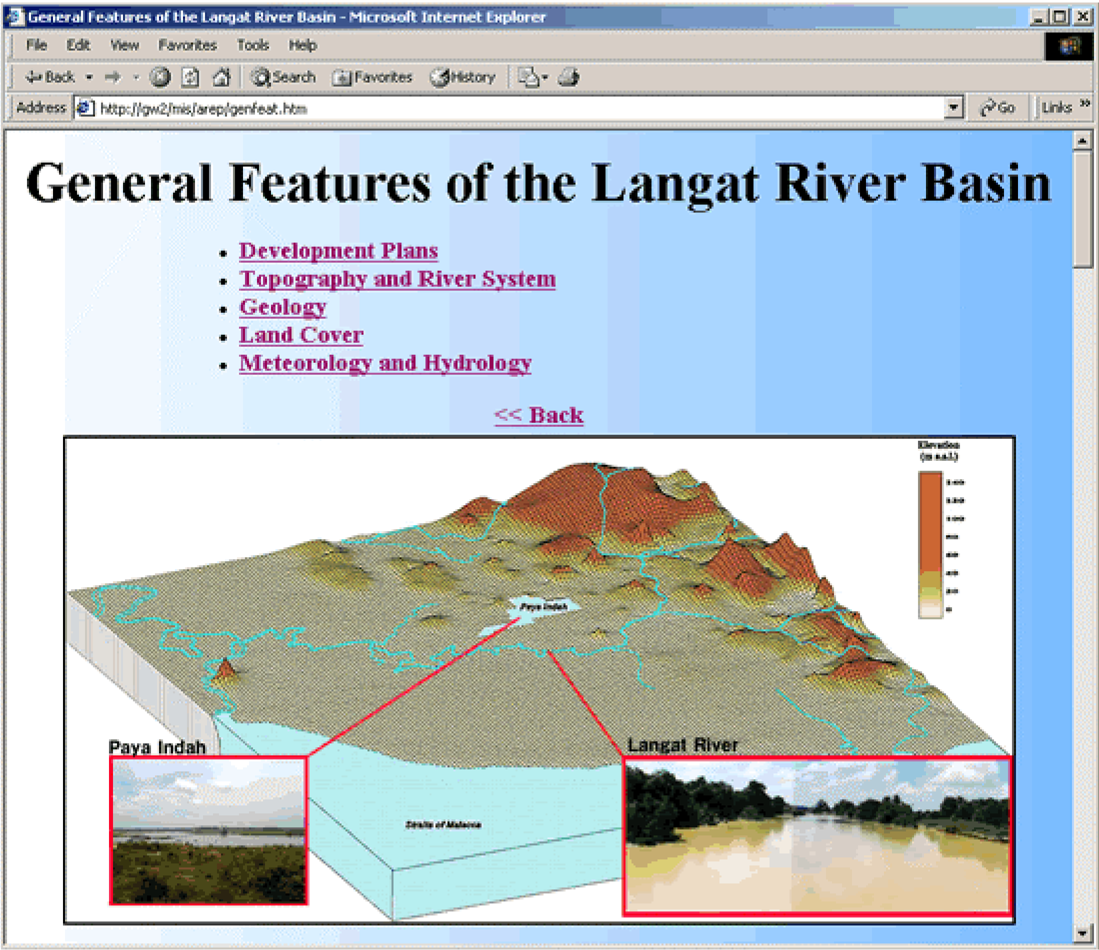
Annex Figure I.2.28 Annual Status Report (1)



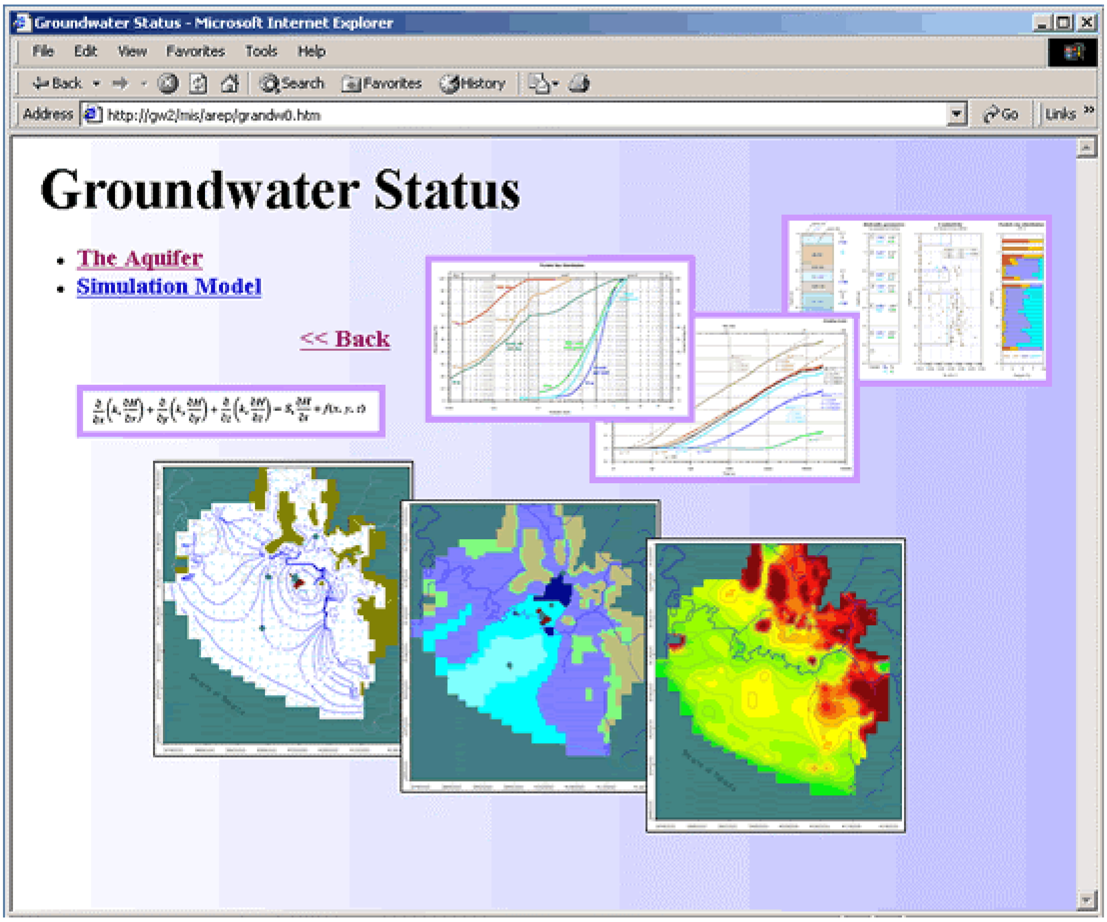
Annex Figure I.2.29 Annual Status Report (2)



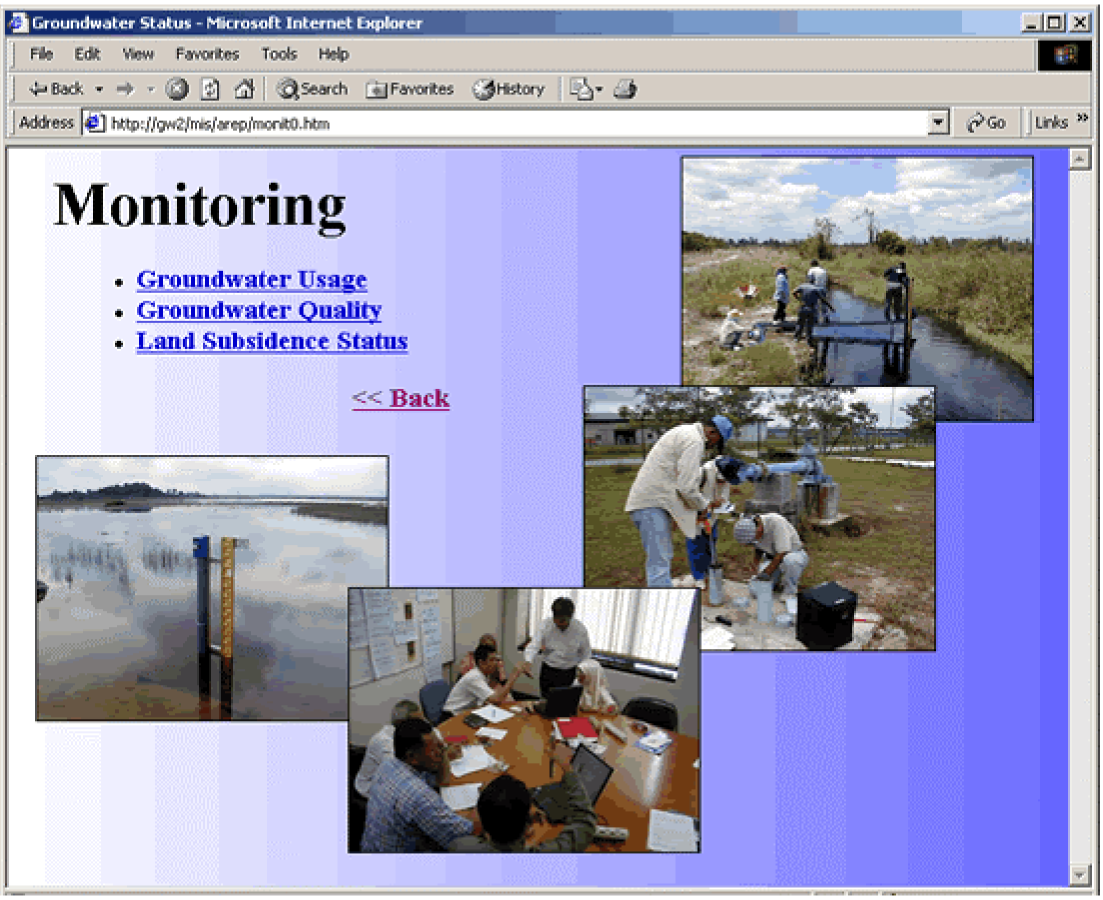
Annex Figure I.2.30 Annual Status Report (3)



Annex Figure I.2.31 Annual Status Report (4)



Annex Figure I.2.32 Annual Status Report (5)



Annex Figure I.2.33 Annual Status Report (6)

SECTOR J

INSTITUTIONAL ASPECTS OF GROUNDWATER MANAGEMENT

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

FINAL REPORT

SECTOR J

INSTITUTIONAL ASPECTS OF GROUNDWATER MANAGEMENT

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SECTOR J

INSTITUTIONAL ASPECTS OF GROUNDWATER MANAGEMENT

1. INTRODUCTION

The thrust of this section is mainly the formulation of a human and institutional resources development plan (IHRP) for groundwater management. The study in general involves the existing framework in the country with analysis more specifically directed to the needs of the Langat Basin.

The present status of the institutional aspects has been grasped first including the following:

(1) A review of the existing laws and regulations affecting groundwater management and use.

(2) Review of roles and functions of organisations responsible for groundwater development and management.

(3) Review of current practices and enforcement of groundwater extraction and management.

Based on the present situation, the study has been conducted for the overall objectives of the Study as specified in the Terms of Reference are as follows:

(1) To formulate the IHRP (Institutional and Human Resource Plan) to implement the Groundwater Resources and Management Plan (GRMP) for the Langat Basin;

(2) To propose an organisational framework to ensure coordination in the development and conservation of groundwater resources; and

(3) To establish the framework for public information and consultation.

2. 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, and some sections are summarised in **Annex J.2.1**.

2.1 Federal State Jurisdiction on Water

The Federal State's jurisdiction over water is governed by the Constitution. Matters concerning legislation are mentioned in the 9th Schedule under the category of Federal List, State List, or Concurrent List. The Constitution also clarifies the relation between the Federation and the State with respect to the following:

(1) Distribution of legislative power;

(2) Distribution of executive power; and

(3) Distribution of financial burden.

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 the states. This suggests that the State has legislative competence over rivers and water resource development within its boundaries. In fact, Article 78 of the Constitution further restricts any federal law relating to the use for navigation or irrigation of rivers wholly within the state unless approved by a resolution of the State Legislative Assembly. The Federal Government may however legislate on any matter on the State List (Art. 76) but only for purposes of promoting the uniformity of laws among the states or if so requested by the State Legislative Assembly. A Federal Act on a State item may be taken under Article 76(3) where the Act is then deemed as a State Law, or under Article 76(4). As examples of Federal Law, the Land Conservation Act of 1960 is taken under Article 76(3) while the National Land Code is taken under Article 76(4).

The Constitution also accords executive authority on the Federal Government on all matters. Parliament may enact laws subject to certain exceptions and to the State the executive authority with respect to matters on the State List. The Federal Government however has executive authority on matters given in the State List for purposes mentioned in Articles 93, 94 and 95 pertaining to inquiries, surveys and statistics, as well as conduct research, provide technical assistance, give advice and inspect a state department. This provision empowers the federal agencies to carry out a national census and geological survey in any state. Insofar as concurrent matters are concerned, executive authority is normally vested on the State unless otherwise provided by law [Art. 80(2)]. Hence, the Federal Government can exercise executive authority on matters under the Concurrent List if provided by law.

As to the distribution of financial burden, the Constitution is silent except for matters under the Concurrent List (Article 82). Financial burdens are usually distributed according to the executive authority. However, it is not uncommon for the Federal Government to fund projects that are within the purview of the State List, e.g., water supply projects, river improvement and conservancy works, urban drainage works, etc. This funding is usually allocated according to the 5-year Malaysia Plan, and projects pass through a bidding process evaluated by EPU (Economic Planning Unit) and the Treasury.

2.2 Ownership of Water Resources

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). The Waters Act provides that the entire ownership and control of a river is vested on the State. A river is defined to include tributaries, streams, gazetted canals and any natural watercourse. This is further strengthened by the National Land Code, which includes under the definition of land as the earth below the surface and all substances therein including vegetation and all natural products. This suggests that groundwater is an integral element of land, which is under the jurisdiction of the State Authority. The SWMAE 1999, under s44, states that the control of use and flow of water including subsurface water is under the jurisdiction of the State Authority. Hence, it can be safely concluded that ownership and use of water resources including groundwater is subject to the control of the State Authority (SA).

2.3 Water Resource Conservation

There are a number of legislations that empower the conservation of water resources. These include provisions in the Land Conservation Act (LCA), Forestry Act, Town and Country Planning Act (TCPA), SWMAE, Selangor Water Supply Enactment 1997 (SWSE). The LCA aims at consolidating the law relating to the conservation of hill land and the protection of soil from erosion and the inroad of silt. Selangor has adopted this Act by virtue of En.7/1960. Hill lands need to be gazetted and once this is done they are covered under prohibitions on short-term crops and land clearing without a permit. The Land Administrator is empowered to administer the provisions of the Act and may enforce the terms and conditions of the permit, which could include the laying of drains or watercourses to prevent erosion. However, it is doubtful if this Act is being effectively enforced because there are very few hill lands that have been gazetted and recent trends indicate that even forest reserves on hills have been revoked for development. There are also limitations on the monitoring and enforcement capacities due to constraints in personnel and resources at the Land Office. The Forestry Act is implemented by the State Forestry Department since forestlands come within the State List. The protection of forestland is important to ensure recharge of groundwater, supply of water in the rivers and reduce silt into the river courses. Under the Act the SA may constitute any land as a permanent reserve forest. These permanent forest reserves may be classified as timber production forest or protected forest that could be categorised as flood control forest, water catchment forest, soil protection forest, amenity forest, etc. Except for the peat and swamp forest, most of the other forest areas in the Study Area are found in the upstream areas and any attempt to convert these areas for urban use will bring about associated problems relating to erosion and increased runoff, and possible reduction in the recharge capacities of the aquifers. The issues pertaining to the effective implementation of this Act pertaining to water conservation are set out below:

(1) There are several tracts of forested areas including mangrove swamps, peat forest, wetlands and rainforest that are not gazetted as forest reserves;

(2) There have been instances of permanent forest reserves being degazetted for development purposes;

(3) Logging, if allowed in the upstream areas, may cause serious siltation because the enforcement of controlled logging is difficult due to lack of personnel and remoteness of the area; and

(4) Current environmental impact assessment (EIA) requirements only apply to conversion of forestland covering more than 50 ha and logging area covering more than 500 ha.

There are also a number of provisions in the SWMAE 1999 relating to water resource conservation, as follows:

(1) The State Authority (SA) may establish zones of protection such as river reserves or flood zones for safeguarding any water source or reservoir (s48). The gazette shall include the purpose for the declaration, the boundaries and the restrictions that apply within the zone. These restrictions may include restrictions on structures, storage of chemicals and fertilisers, grading of contours, construction of roads, the felling of trees, draining of wetlands and discharge of effluent or waste;

(2) The SA may declare as a Designated Area any river basin, catchment area, groundwater area, wetland or water body (s56). Thereupon the SWMA is required to prepare and implement an integrated management plan for the conservation and sustainable development of the water source. It may also control the management and operations of any dam, reservoir or impoundment, as well as make regulations on the control of any resource alteration activities; and

(3) Declaration of problem soil area (s73) where water table management is necessary in an area adjoining a water source. The SWMA is required to prepare a management plan, including facilities to be provided, schedules of abstraction and discharges.

The Selangor Water Supply Enactment 1997 also provides for the State Authority to declare any lake, river or waterway or its surroundings to be a catchment area (s23). However, Amendment Enactment No. 1 of 1999 had repealed this provision.

The Town and Country Planning Act (TCPA) also require the State Planning Committee (SPC) to promote in the State, the conservation, use and development of all lands in the state. Both the Structure and Local Plans have to incorporate policies on the use and development of land, as well as the protection and improvements to the physical environment. All designated areas, river reserves and flood zones have to be demarcated in these development plans.

2.4 Pollution Control

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 (s4) and confers the licencing authority under the Act on the Director General (s10). The Act also requires prescribed premises to be licenced (s18). Prescribed premises are established by a Ministerial Order and include rubber factories, scheduled waste treatment facilities, palm oil processing facilities. Discharges from these facilities are governed by conditions of the licence and regulations established under s51. An example of such a regulation is the environmental quality (Sewage and Industrial effluents) regulations of 1979. Discharge standards from sewerage treatment plants are governed by these regulations. The current list of environmental regulations is shown in **Annex J.2.2**.

Under the Act, the Minister may specify acceptable conditions for the emission, discharge or deposit of waste (s21). There are also restrictions on the pollution of soil, which includes refuse dump and sludge disposal sites that might interfere with underground water (s24). The Act also restricts the pollution of inland waters including rivers, streams and drains. There are currently no discharge standards from solid waste disposal sites and petrol stations, the two potential sources of groundwater pollution. Enforcement of these standards may also be difficult unless monitoring wells are located close to these premises. The Director General (DG) may by notice in writing require the occupier of any premise to install and operate control equipment (s31). Under s34A of the Act, the project proponent of a prescribed activity is required to submit an EIA to the DG before the relevant Authority grants approval for the project. Prescribed activities are established under Environmental Quality Order 1987. Groundwater development is a prescribed activity if its production exceeds 4,500 cu.m. per day.

Prohibition on pollution of watercourse is also found in a number of related legislations. These include the Waters Act 1920, SWMAE 1999, Local Governments Act 1976, Earthworks Bylaws, Mining Enactments and the Mineral Development Act 1994.

Under the Waters Act, there is a prohibition on the pollution of rivers, inland waters and subterranean water resources (s7A). The SWMAE 1999 also empowers the Authority in consultation with the DG of Environmental Quality to prescribe acceptable conditions for the discharge of waste into any designated groundwater area (s78). There are also prohibitions on the discharge of pollutants to any water source. This could include poisonous or noxious material, temperature, biological and chemical altering matter, material that causes discolouring effects, and oil (s79). The Director may also issue a Water Protection Order if there is any serious risk of pollution or serious threat to the environment (s122). Under the Local Government Act (LGA) 1976, the Local Authority (LA) has power to recover expenses to carry out work resulting from any person who commits a nuisance or deposits filth including garbage in any water course (s69, s70 and s71 LGA 1976).

The LA may also make bylaws to keep watercourses clean. Under the Earthworks Bylaws formulated under 70A Streets, Drainage and Building Act (SDBA), the LA is responsible for the control earthworks to prevent soil erosion, disturbance and pollution. Other causes of pollution of watercourses are mining activities. Sand mining operators are issued permits by the Land Office under the National Land Code. Uncontrolled riverine sand mining operations often cause increased sedimentation downstream of the rivers. In Selangor there is now a requirement that the SWMA is consulted before a permit is issued (s60 SWMAE). Under the Mining Enactment (Cap 147), there is also a need for a licence to divert and discharge water (s65). Similarly all water used in mining operations has to be free of hazardous chemicals and excessive solid matters before it is discharged to a river or natural watercourse (s74). A similar provision is also found in the Mineral Development Act 1994, which states that water before it leaves the mine has to comply to prescribed water quality standards and be reasonably free of solid matter and harmful chemicals (s18). There is also a duty on the mine operator to minimise erosion of land and prevent silt to be discharged to any river or drainage system (s19). The Inspector of Mines prior to any abstraction or discharge of any substance to any water source has also to obtain the advise of the SWMA (s61).

2.5 Water Quality

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 in the country. These guidelines were based on the WHO drinking water quality guidelines. Subsequently, a National Drinking Water Quality Surveillance programme (NDWQSP) was started in 1983, and yearly reports on water quality status were compiled and reported. A panel of representatives from the Public Works Department (PWD), Department of Chemistry, Department of Environment (DOE) and the MOH has vetted on these guidelines. According to the National Guideline for Drinking Water Quality (NGDWQ), drinking water must be clear, colourless, odourless, pleasant to drink, and free of harmful micro-organisms and chemical contaminants within the limits prescribed in the guidelines (See **Annex J.2.3**). The four groups of parameters analysed are Group 1 for physical and bacteriological properties, Group 2 for chemical properties, Group 3 for heavy metal limits, and Group 4 for pesticides and radiochemical elements. The respective State water supply authorities enforce these guidelines. To further ensure compliance, MOH is in the process of drafting the Safe Drinking Water Act to control the quality of drinking water supplied to the public. Under the Act, it will be an offence to supply drinking water that does not satisfy specific standards. There are currently no quality standards of water for industrial use and for irrigation purposes.

2.6 Water Supply

Water supply functions within the State are the responsibility of the State. The State Government is responsible for the development, operation and maintenance of water supply. In exercising this responsibility, the State relies either on the State PWD, the State Water Supply Department, the State Water Supply Board, or the State Water Supply Corporation or Company. The various types of water supply organisations in Malaysia are shown in **Table J.2.1** below.

Table J.2.1 Water Supply Organisations in Malaysia

No.	Type	Water Supply Area
1	State Public Works Department	Kedah, Perlis, Sarawak (except Kuching, Sibu, Miri, Bintulu and Limbang)
2	State Water Supply Department	Selangor (including KL), Negeri Sembilan, Sabah and Pahang
3	State Water Supply Board	Melaka, Perak, Kuching, Sibu
4	Corporatised Company	LAKU (Miri, Bintulu, Limbang in Sarawak), Pulau Pinang, Terengganu
5	Privatised Company	Kelantan and Johor
6	Federal PWD	Labuan

Source: PWD (Water Supply Branch)

The principal legislation affecting the supply of water in Selangor is the Water Supply Enactment of 1997 and the Water Supply (Amendment) Enactment of 1999. The supply authority under the Enactment is the Selangor Water Supply Department or any other statutory authority established by law to supply water in Selangor. The implementation of the Enactment is the responsibility of the Director of Water Supply who is appointed under s3. Under the privatisation agreement, a licencee or concessionaire may also supply water in the State (s5). Currently, the distribution aspects of water supply in Selangor are handled by JBA (Waterworks Department) while the production aspects are by privatised companies (See **Figure J.2.1**). No person other than the supply authority may operate a water supply system or abstract any water from any river without a licence (s10). It is still unclear if this licencing provision also extends to groundwater extraction or covered under the SWMAE. Any licence issued shall set out the water supply area, tariff payable, annual licence fee payable, rights and duties of licencee and minimum quality of water required [s10 (10)]. The licencee is also required to erect and maintain adequate fencing around treatment plants. The licencee may also enter into a separate agreement with the owner or occupier of any premise for private water supply; provided, the agreement is approved by the Director (s26 and s31).

The SA is also required to gazette the charges to be paid by any person to whom water is supplied (s35). When water supply is insufficient due to drought, the State may declare a water supply emergency and limit the quantity of water (s48) supplied.

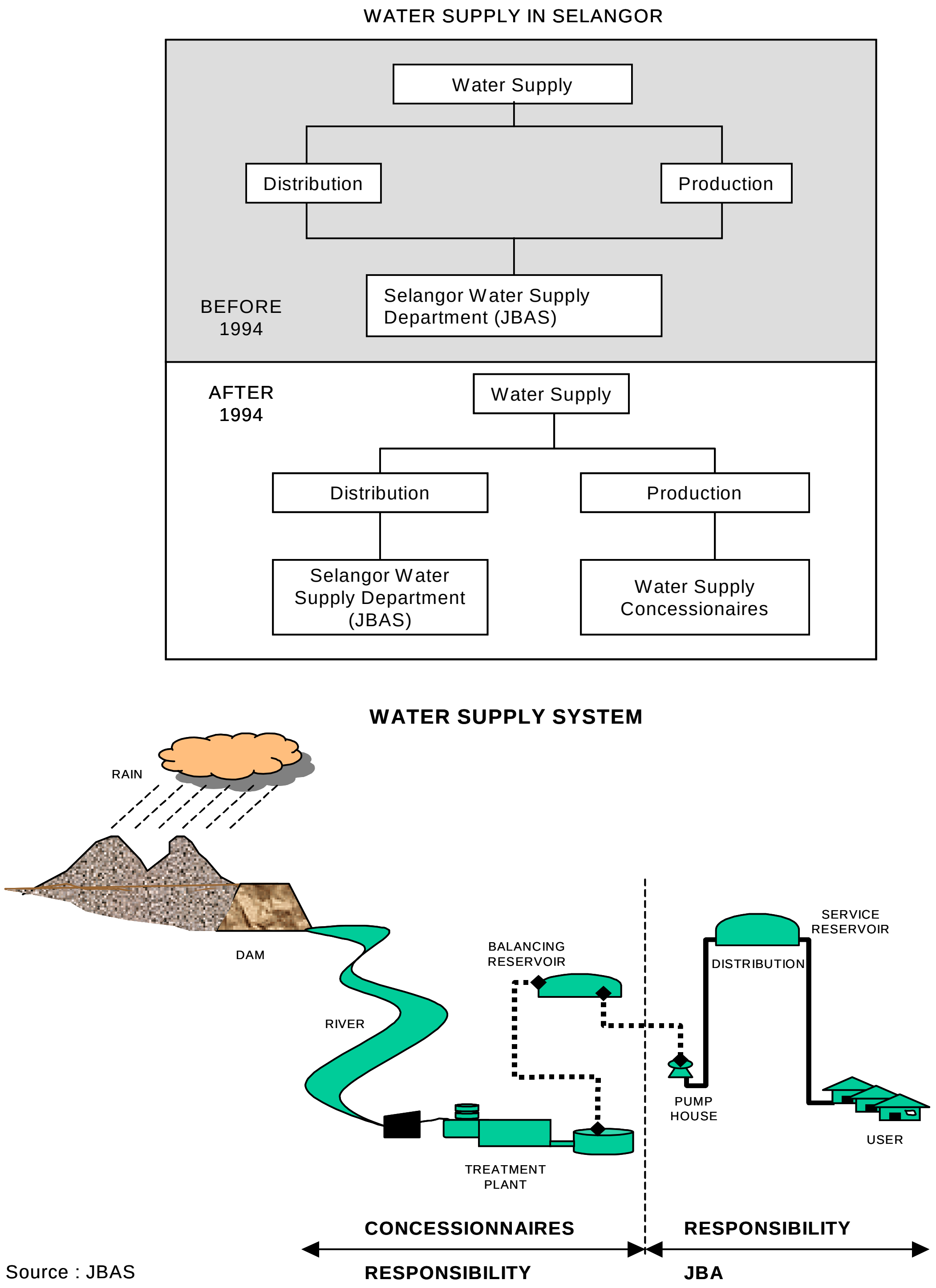

Figure J.2.1 Water Supply System in Malaysia

Under the Irrigation Areas Act, the State is also required to provide water for agricultural purposes especially in granary areas. The supply of water for irrigation purposes is carried out by the Drainage and Irrigation Department (DID).

2.7 Land-use Development

The two principal legislations that affect landuse development are the National Land Code (NLC) and the Town and Country Planning Act (TCPA). The NLC was promulgated under Article 76(4) for purposes of achieving uniformity of all laws pertaining to land and land tenure. Both land and rivers are defined in this Act (s5). The reservation of land is provided under s62 of the NLC. There are several states that have gazetted river and forest reserves using these provisions. Upon reservation there is a need to appoint a controlling officer for the reserve who shall be consulted if there is any development on the reserve. The SA may also lease reserve land for a period not exceeding 21 years. The NLC also contains provisions for land development. The most common method of urban land development is through a process of conversion and subdivision (s124, s124A and s135). Generally the subdivision plan has to conform to the Local Plan for the area and has to provide for sufficient river and drain reserves and other drainage facilities. The conversion stage or change of category of use is especially important as it determines if the land can be developed or not. The NLC provides for the following categories of landuse, i.e., agriculture, building, industry and nil category. Most urban lands fall under the building or industrial category. Further categorisation on landuse is contained in the express conditions that are imposed on the land title and the town and country planning requirements (land use zoning) that apply to the land. It is important that landuse conversions conform to the Development Plan for the area. This is usually achieved administratively as all applications are referred to the relevant technical departments including the Local Authority and the Town and Country Planning Department. However there is currently no legal provision in the NLC for conversion to conform to the approved development plan (Structure and Local Plan) for the area. This has sometimes resulted in conflicting planning decisions.

The enforcement of the conditions of landuse is vested with the Land Office, which is however constrained by lack of enforcement personnel. Hence, it is not uncommon to see several illegal industrial activities in the fringes of local authority areas. These industries are a potential source of pollution of watercourses.

The Town and Country Planning Act was enacted for the proper control and regulation of town and country planning in local authority areas. This Act was amended by Amendment Act (A933), which among others expanded on the contents of the Local Plan, introduced the Development Proposal Report (LCP), defined the Layout Plan and introduced the Tree Preservation Order. This Act provides for the establishment of the State Planning Committee (SPC) and for the preparation of the Structure and Local Plans, which are used for the purposes of guiding and controlling development in the area. Section 18 of the Act states that no person shall use any land or building unless it conforms to the Local Plan. Similarly, no person can commence development without planning permission from the Local Planning Authority (LPA). An application for planning permission has to be supported by a Layout Plan and a Development Proposal

Report (LCP), which among others has to provide a description of the land, topography, landscape, geology, contours, drainage, water bodies catchments and natural features. Other provisions of the Act include the Requisition Notice (s30) that can be issued by the Local Authority (LA) to the owner of any land to discontinue any use or impose new conditions for the continued use of the land. Any person aggrieved by this notice may file an appeal with the Appeals Board. The Selangor State has recently constituted an Appeals Board to hear appeals under the Act. The LA may impose a development charge (s32) on any land that has enhanced in value as a result of the Local Plan provisions. The converse situation is when the Local Plan designates any private land for public purpose that renders the land incapable of reasonable beneficial use. The landowner may then serve a Purchase Notice (s37) on the LA to purchase his land. This may arise if any private land is designated as groundwater area under the SWMAE. The Local Planning Authority (LPA) may also declare an Action Area as a Development Area (s38) and comprehensively develop the area. Once the area is gazetted, the LA has to acquire the land by purchase or compulsory acquisition.

Under s58 of the SWMAE, local authorities are required to obtain the advise of the SWMA in drawing up or amending any development plan including structure and local plans in any designated groundwater area. The LPA is also required to comply with any condition or requirement imposed by the Authority. This provision is necessary to ensure that water resource management activities are coordinated with landuse development plans.

2.8 Groundwater Management and Control

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 1987. Groundwater is defined in the SWMAE 1999 to mean subsurface water and includes wells and boreholes (s2 SWMAE). The control on the use and flow of water including subsurface water is under the jurisdiction of the SA (s41). The SWMA may also impose a charge for the abstraction of groundwater except for domestic and subsistence agricultural purposes and subject to the conditions of s45 (3), i.e.:

(1) It will not cause significant obstruction or diversion to the flow of water in the water course;

(2) Store more than one megalitre of water; or

(3) Abstract water at a flow rate exceeding 20 litres/sec.

This suggests that domestic shallow wells are exempted from payment of any charge. The Authority may also declare a groundwater area as a designated area under s56. The Authority has also powers to prepare privatisation plans (s82) and licence operators under s87. This suggests that the production aspects of groundwater development could be privatised to licenced operators under the Enactment while the distribution aspects will have to be carried out under the Water Supply Enactment (WSE). The Authority is also empowered to make rules on the management, regulation and control of groundwater and wetlands [s127(i)(j)].

Provisions relating to wells and groundwater extraction were also found in the Water Supply Enactment (WSE) of 1997. Section 52 and 53 of the Enactment relating to wells and the penalty for building wells without a licence were however repealed by Amendment Enactment No. 1 of 1999. This suggests that wells and groundwater management and control come within the purview of the SWMAE and not the WSE.

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:

(1) the well is less than 30 feet deep without reaching bedrock;

(2) yield is less than 500 gal of water/day; and

(3) 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 (s13a):

(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 (See **Annex J.2.4**). For both well drilling and groundwater abstraction, the rules require an application for a licence to be first obtained from the government agency responsible for the supply of water and water resource management in the state. However, it should be noted that the agency responsible for water supply and water resource management in Selangor are two different entities, i.e., JBA and SWMA. In view of the recent amendments to the WSE, it is more likely that the relevant Authority to issue the licence is the SWMA. These draft rules are expected to serve as a common set of rules that can be adopted by the respective States or Water Management Authorities of the States. It should be noted however that the Geological Department under the GSA is not a licencing department. In addition to the above, the Environmental Quality Order 1987 (Prescribed Activities) also requires the preparation of an EIA for groundwater development for industrial, agricultural or urban water supply that exceeds 4,500 m^3 per day.

2.9 Drainage and Flood Control

Fundamentally drainage is listed under the 9th Schedule of the Constitution under the Concurrent List. The enabling act on urban drainage is the Streets, Drainage, and Building Act of 1974 (Act 133) that empowers local authorities with the responsibility for drainage within their areas of jurisdiction. The LA is responsible for constructing and maintaining surface and storm water drains, culverts, gutters and watercourses (s50SDBA). Functionally, drainage functions are divided between DID and the LA as a result of the Cabinet Directive of 1996 whereby DID is responsible for all rivers while the latter is responsible for all drains in local authority areas. Outside local authority areas, drainage and flood mitigation works are carried out by DID. Under the Ministerial Functions Act 1969, DID is entrusted with both river conservancy and flood mitigation works. However, there appears to be no governing law supporting these functions. The Drainage Works Act also empowers the State to undertake drainage and flood mitigation works. The SA may also impose drainage rates within the Drainage Area to meet the cost of drainage works. The works undertaken under this Act is implemented by DID.

2.10 Conclusion

A summary of the main legislations and the implementing agencies responsible for the various legislations related to groundwater development and management is shown below.

Table J.2.2 Related Legislation and Implementing Agencies Pertaining to Groundwater Development and Management

Legislation	Implementing Agency / Authority
Federal – State jurisdiction and functional responsibility with respect to water resource management Federal Constitution Ministerial Functions Act 1969 (Ministers of the Federal Government Order) The Incorporation (State Legislatures Competency) Act 1962	Federal Government, State Government, State Authority, Federal Ministers and Departments
Ownership Of Water Resources Federal Constitution Waters Act 1920 National Land Code 1965 Mining Enactments SWMAE	State Authority (SA)

Table J.2.2 Related Legislation and Implementing Agencies Pertaining to Groundwater Development and Management (cont'd)

Legislation	Implementing Agency / Authority
Groundwater Management and Control	
SWMAE 1999	SWMA (LUAS)
Geological Survey Act 1974	JMG
Environmental Quality (Prescribed Activity) Orders 1987	DOE
Water Resource Conservation	
Land Conservation Act 1960	District Land Administrator
National Forestry Act 1984	State Forestry Department
SWMAE 1999	SWMA, Director of LUAS
TCPA 1976	Local Planning Authority (LPA), State Town and Country Planning Dept (STCPD)
Water Quality and Pollution Control	
Environmental Quality Act 1974 (EQA)	DOE
SWMAE 1999	SWMA
Waters Act 1920 (revised 1989)	District Office
LGA 1976	LA
Mining Enactments	State Director of Lands and Mines
Mineral Development Act 1984	Director of Mines
Earthworks By Laws	LA
Safe Drinking Water Act (proposed)	Ministry of Health (MOH)
Water Supply	
Water Supply Enactment 1997	JBAS
Irrigation Areas Act 1953	SA, DID
Drainage and Flood Mitigation	
Streets, Drainage Building Act 1974	LA
Drainage Works Act 1954	SA, DID
Local Government Act 1976	LA
Landuse Development	
National land Code 1965	SA, Director of Lands and Mines
Town and Country Planning Act 1976	State Planning Committee, State Dept. of Town Planning, Local Planning Authority

3. ORGANISATIONAL FRAMEWORK

Some of the key agencies involved in groundwater development and management in the country are as follows:

(1) Economic Planning Unit (EPU);

(2) Minerals and Geoscience Department (JMG);

(3) Public Works Department (Water Supply Branch);

(4) Selangor Water Supply Department (JBAS);

(5) Drainage and Irrigation Department (DID);

(6) Selangor Waters Management Authority (LUAS); and

(7) Department of Environment (DOE).

Departments with influence on landuse development that may affect groundwater regimes are the Lands and Mines Department, the Town and Country Planning Department, the Forestry Department and the local authorities. The national institution that has a bearing on groundwater programme and policy development is the National Water Resources Council. The Ministerial Functions Act of 1969 and the related Ministers empowered by the Federal Government Order issued under the Act also govern the functional responsibilities of the various departments. Under the Federal Government Order of 1995, the Geological Survey Department is responsible for geological survey while the Mines Department is responsible for the control of mining activities and mineral resources. Among other functions, Public Works Department (PWD) is assigned the responsibility for the development of water works and water resources. The State's power to incorporate statutory bodies is provided under the Incorporation (State Legislatures Competency) Act of 1962. Under the Act the States are empowered to incorporate a statutory body for 17 prescribed activities in the First Schedule including both water supply and water resources management. This for an example provided the enabling power to establish the SWMA (LUAS) for water resources management in the State. Using these powers the State may also incorporate a statutory body (Water Board) to be responsible for water supply in the State. A summary of the functions of the various departments is shown in **Annex J.3.1**.

3.1 Federal Level

3.1.1 Economic Planning Unit

This is a central planning agency that formulates policies, strategies and programmes for short and long-term economic development of the country. Its functions include the preparation of the national development policy and the country's 5-year development plans. It also determines the development budget allocation and assists the Treasury in the preparation of the annual development budget estimates. The EPU is divided into a number of divisions such as the Energy and the Infrastructure and Utilities Section, which are represented in the Steering Committee of this study.

3.1.2 Ministry of Primary Industries

The Ministry of Primary Industries is mainly concerned with the development of primary commodities such as rubber, timber, palm oil, tin, cocoa, tobacco and pineapple. Its involvement in water resources management is through the programmes initiated by the Department of Mines and Geoscience and the Forestry Department, which are under the jurisdiction of the Ministry. The Minister of Primary Industries is also a member of the National Water Resources Council.

3.1.3 Minerals and Geoscience Department (JMG)

The two departments under the Ministry of Primary Industries; namely, the Geological Survey Department and the Mines Department, will be merged as the Minerals and Geoscience Department. 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 geoscience. Other specific functions include the following:

(1) Undertake systematic geological mapping;

(2) Undertake exploration for minerals other than petroleum and gas;

(3) Undertake engineering geology investigations;

(4) Investigate and develop groundwater resources;

(5) Provide analytical services for minerals;

(6) Prepare thematic maps on geological, geochemical, hydrological, geophysical and mineral resource maps;

(7) Act as a national depository for information related to geology and mineral resources; and

(8) To execute Federal and State policies on geological activities and mineral industry.

The department is headed by a Director General and assisted by two deputy director generals. The Department has 10 state branches including Sabah and Sarawak. The main divisions in the department are as follows:

(1) Coordination, Operations and Implementation;

(2) Corporate and Mineral Economics;

(3) Technical Services; and

(4) Mineral Research Centre.

These divisions are further divided into operational units (See **Annex J.3.2**). 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:

(1) Systematic groundwater resource assessment;

(2) Exploration and development of groundwater as an alternative water resource in water stress areas;

(3) Develop a hydro-geological database; and

(4) Preparation of groundwater resource maps and other hydro-geological maps.

Some of the hydrogeology programmes of the department in the past years included the following topics:

(1) Investigation of groundwater study projects in Selangor. As a result of the water crisis, 55 existing wells were checked and reconfirmed for emergency water supply;

(2) Construction of several new wells both for production and monitoring purposes;

(3) Continuation of long-term groundwater quality and water level monitoring programme in Kelantan;

(4) Carrying out of field checks for commercial source certification and renewal of licences for mineral water together with the Ministry of Health (MOH);

(5) Participation in the National Committee of the International Hydrological Programme (IHP) with Pulau Tioman as the Study area;

(6) Carrying out of groundwater contamination study at the municipal waste disposal site at Gemencheh Negeri Sembilan;

(7) Compilation of hydro-geological data into a database system (HYDAT);

(8) Provision of hydro-geological advice and consultative services to government agencies; and

(9) Undertaking of a hydro-geological study to review the groundwater pattern in Cameron Highlands.

The total development budget for 1999 was RM8 million, while the operational budget for the same year was RM19.7 million. From the budget allocation, this department has been more of a service department than a development department.

3.1.4 Public Works Department (Water Supply Branch)

The Water Supply Branch of the Federal PWD provides consultation and technical advise to the State Water Authorities as well as a coordinating agency of all water supply projects funded by the Federal Government. The other functions include:

(1) Implementation of water supply schemes for Federal Land Development Authorities (Felda);

(2) Maintaining Engineering standards for water supply practise;

(3) Setting standards and criteria for design, operation and maintenance of water supply systems;

(4) Standardisation of water supply specifications for use by the State Water Authorities; and

(5) Development of Water Supply in the Federal Territory of Labuan.

The main operational sections in the Water Supply Branch are the Design, Planning, Special Projects, Control and information, Administration and Finance sections (See Organisation Chart in **Annex J.3.2**). These sections may be further divided into the following operational sections:

(1) The Design Section undertakes infrastructure design of water supply facilities and evaluates designs prepared by private consultants, prepares cost estimates and tender documentation.

(2) The Planning Section includes the Contracts Unit, Water Resources Planning Unit and the Water Supply Coordination Unit. The Contracts Unit administers government project contracts and provides quantity survey services for government water supply projects. The Water Resources Planning Unit prepares long term 20-year plans on national water needs. It reviews consultants' reports and coordinates water supply development programmes for the 5-year Malaysia plans. It also provides technical assistance to State Water Management Authorities. The water supply coordination unit assists in the coordination of

various government departments involved in the planning and management of water supply projects. It also provides technical advise to State Authorities on the management and development of water resources including water supply projects that transcend state boundaries.

(3) The Control and Information Section has a number of units including the Quality Control Unit, Non-Revenue Water Control unit (NRWC), Dam Safety Unit, Information and Records Unit, and Materials and Standards Unit. The Quality Control Unit is the Secretariat to the Taskforce for Drinking Water Quality. It compiles data on the drinking water quality throughout the country. The NRWC unit provides training and makes recommendations to the State Water Authorities on effective methods to reduce non-revenue water. The Dam Safety Unit undertakes programs on safety, maintenance and operations of dams to the respective operators. The Information and Records Unit keeps all records and prepares strategic data on water supply for the country in addition to preparing reports, while the Special Projects Section is currently involved in a major project to channel raw water from Pahang to Selangor.

Total staff strength of the Water Supply Branch is 86 although 123 posts have been approved. There are a total of 25 engineers with the Branch. The total development budget for the Water Supply Branch of PWD was RM320 million in 1999, while the operational budget was about RM2.4 million.

3.1.5 Department of Environment (DOE)

The DOE is a Federal Agency located within the Ministry of Science, Technology and Environment. The vision of the Department is to ensure that the uniqueness, diversity and quality of the environment are conserved. It is charged with the responsibility of preventing and controlling pollution while protecting and enhancing the quality of the environment. It does so by administering and enforcing the Environmental Quality Act of 1974 and the various regulations enacted under the Act, as well as the promotion of environmental education and awareness. Among the functions of the department are summarised as follows:

(1) Assess development projects of prescribed activities that are subject to EIA prior to project implementation.

(2) Evaluate site suitability and pollution control systems of non-prescribed activities.

(3) Provide environmental input to development planning such as structure and local plans, as well as inputs to planning guidelines of the Town and Country Planning Department.

(4) Carry out enforcement of pollution sources to ensure compliance with approval, licencing conditions, emission and discharge standards.

(5) Develop national networks for air, river, groundwater, marine water and noise monitoring systems to establish the state of the nations environment. Monitoring functions for air and rivers are also conducted by Alam Sekitar Malaysia Sdn. Bhd. (ASMA).

(6) Review and introduce new environmental regulations.

(7) Prepare environmental guidelines to assist project initiators to integrate environmental factors in project planning. This includes the EIA Guidelines on Groundwater and Surface Water Supply of 1995, land and industrial development guidelines, and waste management guidelines.

(8) Formulation of national environmental criteria and standards.

(9) Dissemination of environmental information to enhance environmental awareness and education.

The organisation chart of the Department is shown in **Annex J.3.2**. The main divisions in the Department are Administration, Information Technology, Control, Development Planning and Assessment. The department also has federal branches in all the States including Sabah and Sarawak. The total development budget for the Department in 1999 was RM6.8 million, while its operational budget was RM40.8 million. The Monitoring Unit of the Control Division currently undertakes groundwater functions. There are currently 81 monitoring wells in the country out of which 6 are in Selangor. The monitoring wells are located in sites representing various landuse categories such as agriculture areas, golf courses, industrial sites, and solid waste dump sites. In 1999 about 12 wells were developed to monitor the nipah virus near the hog burial sites as a result of the recent encephalitis epidemic. The objective was mainly to detect contamination of groundwater quality. The groundwater quality-monitoring unit comprises five (5) members (3 Environmental Officers and 2 Assistants) under the Director of the Control Division, while the groundwater quality monitoring unit at the Selangor office comprises only two persons (Assistant Control Officer and a Technician). For the period 2000-2001, the Department has requested an allocation of RM4.73 million for groundwater related activities. The budget is required to build monitoring wells in Sabah and Sarawak and undertake a study on the environmental impacts of extracting groundwater for aquaculture purposes and the impacts of brackish water ponds on the groundwater regime.

3.1.6 Drainage and Irrigation Department (DID)

The Drainage and Irrigation Department is both a Federal and State department. The Federal department is located within the Ministry of Agriculture. The DID is entrusted with various functions including the following:

(1) Irrigation works;

(2) Drainage Works;

(3) Flood mitigation works;

(4) Conservation and improvement of river flow and hydraulic efficiency;

(5) Collection and analysis of hydrological data for water resource development;

(6) Undertaking of research and execution of coastal erosion works; and

(7) Provision of engineering support services to other departments.

These works are carried out by six main divisions in the DID; namely, the River Engineering Division, the Hydrology Division, the Coastal Engineering Division, the Corporate Development Division, the Drainage Division, and the Irrigation Division.

The Irrigation Division is responsible for irrigation projects to support agricultural development in line with the national agricultural policy. The department also plans to develop 20 small reservoirs, 100 groundwater tube wells and 4 dams by the year 2010 so as to provide reliable irrigation supply to 6 granary areas and 74 secondary granary areas. A national policy on groundwater utilisation should also look into the prospects of groundwater use for irrigation purposes. However, in Selangor, the usage of groundwater for agricultural purposes is minimal where only 2 wells are documented in the Kuala Selangor district.

The Drainage Division of DID has recently been restructured with the establishment of a new Flood Mitigation Division. The functions of the Drainage Division have also been reassigned. The agricultural drainage function relating to the planning and design of drainage projects to support the development of tree crops has been reassigned to the Irrigation Division. The preventive aspects of flood management such as urban drainage master plan studies and storm water management have been reassigned to the Rivers Division, while the curative aspects of flooding relating to the implementation of urban drainage works such as river widening and deepening have been assigned to the Flood Mitigation Division.

The main functions of the Rivers Division are described as follows:

(1) To reduce flooding problems through the implementation of flood preventive programmes and non-structural measures;

(2) To implement river management works through river conservancy programmes, preparation of master plan for rivers, preparation of guidelines on riverfront development, implementation of “Love the River” campaign, rehabilitation of polluted rivers and the classification of river systems; and

(3) Storm water management.

The river regime has a direct bearing on groundwater resources and the effective management of the river basin is necessary for groundwater recharge purposes and ensure a sustainable development of groundwater resources. The total staff strength of the Rivers Division of DID (HQ) is 30 with 16 engineers.

3.1.7 Malaysian Wetlands Foundation (MWF)

The Malaysian Wetlands Foundation is a non-profit organisation set-up in 1997 with the objective of developing and managing the Paya Indah Wetland Sanctuary. The sanctuary covers an area of 3,200 ha and is accessed from the B18 that joins Dengkil-Banting. The main functions of the Foundation are as follows:

(1) To rehabilitate, conserve and sustainably maintain the diverse biological resources of Paya Indah Wetland Sanctuary;

(2) To study, identify, finance and administer projects on the conservation and sustainable use of wetlands resources;

(3) To promote wetland based research; and

(4) To support cooperation and partnership with other organisations to advance the course of protection and sustainable use of the sanctuary.

Its main sources of funds are the Federal Government grants and financial assistance from international funding agencies such as the DFID (Department for International Development), Royal Netherlands, JICA and Danced. It is also allowed to collect gate receipts once the sanctuary is opened to the public. The total staff strength is about 54 persons with 8 in the management and professional group. Its annual budget fluctuates depending on the funding arrangements but averaged about RM6.3 million in 1998 out of which RM4.2 million was for development projects. The foundation has a patron and managed by Trustees. At the operation level, the Foundation is headed by a chief executive officer (CEO) and operationally grouped into the following:

(1) Natural Resource Department;

(2) Education Department;

(3) Business Development Department;

(4) Marketing Department;

(5) Finance and Administration Department; and

(6) Project Management Secretariat.

The organisation chart is shown in **Annex J.3.2**. Some of the current and planned projects related to groundwater are as follows:

(1) Study on the hydrogeology of the Sanctuary;

(2) Study on the water balance of the Sanctuary; and

(3) Strategic Environmental Assessment for the Local Plan of the Sanctuary.

The wetlands sanctuary is not only important as a passive recreational area but also for the preservation of biodiversity and the regulation of surface water runoff, ensuring long-term groundwater recharge.

3.1.8 Water-Related Councils

Water resources come within the prerogative of the State. However, following the recent water crises especially in Selangor, there was greater urgency to establish a National Water Resources Council (NWRC) with adequate State and Federal representation. The other water related council is the National Coastal Protection Council, which is concerned with matters of coastal erosion. There have also been proposals to establish the National Rivers Council to serve as a coordinating body for river conservancy, river basin management and storm water management. The NWRC was set up to ensure that sufficient quantity and quality of water is made available to meet the needs of the nation. The key functions of the NWRC are as follows:

(1) Formulation of a National Water Policy;

(2) Preparation of a National and Regional Water Resources Master Plan and periodic updating of the plan;

(3) Allocation of water resources for various water users and deciding on priorities during emergencies such as drought;

(4) Advising states on conservation, protection and gazetting of water catchment areas;

(5) Implementation and management of interstate water transfer projects for water supply;

(6) Coordination of the implementation and management of other water resources projects; and

(7) Collection and collation of information on national water resources and water demand of all users in the country.

The NRWC will be chaired by the Prime Minister and will include representation of State Chief Ministers and Federal Government Ministers. It is expected that the NRWC will be formed by Charter or MOU whereby State governments will continue to retain their existing rights on water resources and water supply. The membership of the Council is composed of the following persons:

(1) Prime Minister (Chairman);

(2) Minister of Finance;

(3) Minister of Works;

(4) Minister of Agriculture;

(5) Minister of Science, Technology and Environment;

(6) Minister of Energy, Telecommunication and Posts;

(7) Minister of Lands and Cooperative Development;

(8) Minister of Housing and Local Government; and

(9) Minister of Primary Industries.

3.2 State Level

The main agencies involved in groundwater resources management and development in the State are the Selangor Waters Management Authority (LUAS), the State Water Supply Department (JBAS), the Minerals and Geoscience Department (Selangor / KL Office), and the Department of Environment (Selangor Branch). Other related agencies that may have an effect on groundwater utilisation and use are the State Economic Planning Unit, the Lands and Mines Department, the Town and Country Planning Department, the Forest Department, local authorities, and water supply concessionaires.

3.2.1 Selangor Waters Management Authority

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. There are wide ranging powers given to the Authority as shown below:

(1) Advise the State Authority on the declaration of designated areas (s56) (river basins, catchment areas, groundwater, wetlands and water bodies), protected areas (s48), and river reserves (s46), and formulate and implement development and management plans for such areas.

(2) Formulate policies, methods and measures to be adopted for sustainable development, use and conservation of water sources.

(3) There is a duty under the law to consult and obtain advise from the SWMA in preparing development plans (Structure and Local Plans) in designated and protected areas (s58 SWMAE). There is a also duty on the Local Authority to invite the Director to participate in the preparation of Structure and Local Plans

for the adoption of measures related to the management, conservation and development of water resources in such plans (s67).

(4) The Authority may develop and implement guidelines, standards, methods and procedures for sustainable development and management of water sources.

(5) Undertake research.

(6) Provide training and maintain training facilities.

(7) The Authority may also impose a charge for the abstraction of water or the discharge of wastewater into any water source.

(8) The Authority also has powers to issue licences for the extraction of resources from water, or any recreational activity that may adversely affect the hydraulics and quality of water source.

(9) Undertake flood defence programme and prescribe such measures for the proper management of flood defence.

(10) Complement the powers of DOE in requiring environmental impact assessments of projects within designated areas and in consultation with DOE prescribe acceptable standards for the emission, discharge or deposit of waste in any designated area (s78).

(11) The Authority has also powers of enforcement, power to compound offences, power to arrest and also powers to prosecute with the consent of the Public Prosecutor.

(12) Advise the State Authority on privatisation projects.

Menteri Besar acts as the Chairman of the Authority with the State Secretary as the Deputy Chairman. The Director General of Federal DID is also a permanent member of the Authority while the Director appointed by the Authority is the Secretary. Other members of the Authority are the State Legal Adviser, the State Financial officer, two members of the State Exco and five other members appointed by the State Authority. JMG however is not a permanent member of the Authority but may be appointed by the State Authority. The Authority is assisted by a Technical Committee, which is chaired by the State Secretary and represented by Directors of Technical Departments and Presidents of Local Authorities. The State Director of the Geological Department is a permanent member of this Committee. The functional linkages between SWMA and other agencies in the State are shown in **Annex J.3.3** while the proposed organisational structure is shown in **Annex Figure J.3.5 of Annex J.3.2**. At the operational level, a Director heads the SWMA with four (4) divisions at its headquarters:

(1) Planning Division;

(2) Development, Operations and Maintenance;

(3) Law and Enforcement; and

(4) Corporate Services.

In addition, there are four (4) regional offices; one each for the main river basin areas of Sg. Selangor, Sg. Bernam, Sg. Kelang and Sg.Langat. Wide ranging powers have been given to this Authority ranging from management powers, regulatory, development of water resources, pollution control, enforcement, research, training and imposition of tariffs. Despite its wide functions, both its technical and financial capacities are quite limited at the moment.

At manpower level, the staffing is expected to increase from the current 5 to about 200. The current Director of the SWMA is a seconded officer of DID. This Authority is expected to be the principal agency in the State to formulate policies and strategies on groundwater utilisation and management at the state level. It is also likely that other States will follow suit in establishing their own Waters Management Authority. The organisational structure of the head office for the next 5 years is shown in **Annex Figure J.3.6 of Annex J.3.2**. The total staff strength in the next 5 years is 77 personnel with 20 professionals. Of this total, however, only 24 posts have been agreed upon in principle by the Public Services Department.

The Authority is empowered to establish a fund, which will be administered and controlled by the Authority. Sources of finances include the following:

(1) State and Federal grants;

(2) State Government loans;

(3) Commercial loans;

(4) Moneys earned by the Authority from any project financed from the Fund;

(5) Moneys earned from any property or investments;

(6) Fees and charges prescribed and collected by the Authority; and

(7) All other moneys or property payable to the Authority.

The Authority has requested for a RM10 million grant from the Federal Government and another RM10 million from the State Government. However, this amount has yet to be disbursed. The total development budget requested under the 8th Malaysia Plan (5 years) is RM206 million with an annual development budget increasing from RM22 million in 2001 to RM51.5 million by 2005. Operational budget is expected to increase from RM1 million in 2001 to RM4.5 million by 2005 in tandem with staff increase. The main projects under the 8th Plan are taken under the following budget headings:

(1) Planning, Development, and Management of Catchment Areas;

(2) Cleansing and Rehabilitation;

(3) Water Pollution Control; and

(4) Public awareness and education.

The Authority has also proposed to impose a charge of 4 sen/m^3 for raw water abstraction from rivers. This could in effect sustain the Authority. A higher charge could also be imposed for groundwater abstraction in the future.

3.2.2 Minerals and Geoscience Department (Selangor and Kuala Lumpur Office)

This department is a branch of the Federal department. The department is headed by a Director and have the following functional units (See **Annex Figure J.3.7 of Annex J.3.2**):

(1) Mineral Resources;

(2) Geoscience;

(3) Mines and Quarry;

(4) Administration and Finance; and

(5) Data Management.

Groundwater development is part of the functions of the Geoscience Unit. There are two post for hydrogeologists 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. The current staff strength of the department is only 5 persons including a Director and two geologists.

3.2.3 Selangor Water Supply Department

This department is the water supply authority under the Selangor Water Supply Enactment of 1997. The duties of the Director of Water Supply are inter alia:

(1) Advise the State Authority on matters related to water supply;

(2) Promote efficiency in the supply of water at reasonable prices;

(3) Advise the State Authority on the issuance of licences; and

(4) Establish the quantity and quality of the treated water for supply purposes.

The department is mainly responsible for the distribution of treated water from the Treatment Plants and Balancing Reservoirs to the end user while the production of treated water in the State has been privatised to a number of water concessionaires. The

Department however is responsible for the operation and maintenance of all water supply dams in the state except the Sg. Buluh Dam. The State Water Authorities are also empowered to appoint and issue licences to plumbers who are then referred as registered plumbers. The main functional units in the Department are the Project Implementation Unit, Operations and Maintenance Unit and the Planning and Design Unit. In addition to the Headquarters, there are also district water supply engineers for all the districts of Selangor including Kuala Lumpur (See **Annex Figure J.3.8 of Annex J.3.2**). There are currently 21 engineers at HQ and another 9 at the district level. All the engineers in the Selangor JBA are seconded from the Federal PWD. The total development budget for 1999 was RM571 million while the operations and maintenance budget was RM314 million for the same year.

3.2.4 Other Related State Agencies

(1) State Economic Planning Unit

This unit is responsible for the socio-economic development programme in the State. It also finalises economic development plans and submits the state programme for inclusion in the Malaysia Plan. This unit coordinates the budgeting for state projects before funds are released.

(2) State Drainage and Irrigation Department

The main responsibility of this department is the design, construction and maintenance of irrigation channels and drains for agricultural purposes in rural areas and the implementation of flood mitigation projects. The department also collects hydrological data, which is necessary for water resource studies. The department also provides advisory service to local planning authorities and land offices on storm water management applications, water and river sand extraction and development along riverbanks. This is a State Department with officers seconded from the Federal Level. The state DID, however, is currently not directly involved in groundwater development.

(3) State Town and Country Planning Department

This department is the principal advisor to the State and local authorities on physical planning and development. It also serves as the Secretariat to the State Planning Committee (SPC). The department also provides technical advice to local authorities on the layout plans submitted by developers. It is at the layout plan stage that sufficient drainage and river reserves for the projects are secured. It is also necessary that designated areas for groundwater development are addressed in the Structure and Local Plans of the Local Authority to ensure compatible developments in these areas.

(4) State Planning Committee

This is probably the only committee within the framework of planning administration established through legislative provisions, i.e., Section 4(1), Town and Country Planning Act of 1976. This committee which is chaired by the Chief Minister comprises most of the senior government officials in the state including the State Secretary, State Legal Advisor, State Director of Lands and Mines, Director of State Planning Unit, State Director of Public Works, the State Financial Officer, the State Development Officer, the State Director of Environment and four other members appointed by the State Authority. The functions of this committee are inter alia:

(a) Promote within the framework of the national policy, the conservation, development and use of all lands in the state.

(b) Advise the State government on matters relating to the conservation, use and development of land in the state.

(c) Give direction to the Local Authority on matters pertaining to physical planning and development.

(d) To approve Draft structure plans with or without conditions. In practice the SPC also approves the Draft Local Plan before the Local Authority adopts it.

(e) Collection and publication of information and statistics on town and country planning.

The SPC should be used as an effective forum for the advancement of sustainable groundwater development in the State particularly in ensuring compatible landuse development in designated areas.

(5) Lands and Mines Department

The Lands and Mines Department is a state department that is responsible for implementing the provisions of the National Land Code, Land Conservation Act and the Mining Enactments. This department is responsible for land administration issues related to registration of land titles, land alienation, conversion and subdivision of land, enforcing the change of category of use (landuse conversion) and hill land development. The department also processes applications for Temporary Occupation licences and permits for sand mining operations. The Director of Lands and Mines is assisted by District Land Administrators who are responsible for land administration matters at the district level. The proper administration and management of land resources is important to ensure sustainable development of groundwater.

(6) State Forest Department

This department has control over development activities in gazetted forest reserves. Most of the mountainous areas in the upper reaches of the Langat River basin are gazetted forest reserves. These are also important water catchment areas for the Langat River. Under the Forestry Act, the State Director may classify permanent forest reserves into flood control forest or water catchment forest and thereby restrict development activities in these areas.

3.3 Local Level

3.3.1 Local Authority

Local Authorities are a state responsibility. The Federal government with the exception of Kuala Lumpur has no direct authority on local authorities. However, the Ministry of Housing and Local Government establishes guidelines and assists Local Authorities with specific grants. At a policy level the National Council of Local Government plays a coordinating role in ensuring that Federal policies and directives are conformed with. There is currently no elected council at the local authority level, and the State Authority appoints the councillors. The fiscal resources of local authorities are limited, relying on a combination of Federal grants, state grants and local collections from rates and licences. Local authorities may be classified as Municipal Councils or District Councils. The financial and technical strength of district councils is generally weak and they largely manage through committees comprising councillors, local government officials and representatives from various government agencies such as PWD and DID. Local Authorities administer three related Acts viz. the Local Government Act of 1976, Town and Country Planning Act of 1976, and the Streets, Drainage and Building Act (SDBA) of 1974. 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 LA may also use its powers under the Earthworks bylaws to control excessive sedimentation and silt from building sites. The local authorities within the study area are as follows:

(1) Kajang Municipal Council;

(2) Sepang District Council;

(3) Kuala Langat District Council;

(4) Seremban District Council;

(5) Parts of the Klang Municipal Council area; and

(6) Putrajaya.

Other important management bodies in the study area include Cyberjaya and the Kuala Lumpur International Airport.

3.3.2 Putrajaya

Putrajaya is the Federal administrative capital of the country. Putrajaya is administered by the Putrajaya Corporation, which was established under the Perbadanan Putrajaya Act of 1996. The Corporation is also the Local Authority for its area of jurisdiction and is empowered to administer the SDBA1974 and the TCPA 1976 through an enabling state legislation, Putrajaya (Performance of Functions) Enactment of 1995. The Putrajaya area has also been designated as a district and the State has appointed a land administrator under the National Land Code to undertake land administration functions in the district. Putrajaya is planned and developed as a garden city with a total area of 4,400 ha with a target population of 250,000. One of the key design features of the city is a man-made lake that will inundate an area of more than 600 ha, including 160 ha of constructed wetlands at the upstream of Sg. Chuau. The lake is also expected to serve as a storm water retention facility that will be able to accommodate increased flood peaks.

3.3.3 Cyberjaya

Cyberjaya is located to the west of Putrajaya and is planned as a leading edge multimedia development area. Cyberjaya is also a designated Multimedia Development site that enjoys tax and tariff incentives for multimedia enterprises. Cyberjaya covers an area of 7,000 ha. The hub of Cyberjaya is the Flagship zone, which occupies an area of 2,800 ha. Cyberjaya is currently not a local authority. Development functions for the area are undertaken by Setia Haruman Sdn Bhd, which is responsible for implementing the Flagship zone, while the functions relating to the promotion of multimedia enterprises is with the Multimedia Development Corporation. Local Authority functions for the area are carried out by the Sepang District Council while planning approval are administered by a one-stop agency chaired by the Director-General of Town Planning.

3.3.4 KLIA (Kuala Lumpur International Airport)

The KLIA is located about 70 km to the south of Kuala Lumpur and occupies an area of 10,000 ha out of which the airport site occupies 5,000 ha. It is designed to cater for 25 million passengers per annum and can be expanded up to 45 million ppa. The ownership and operation of the airport is under the Malaysian Airports Berhad. Aviation control is administered by the Department of Civil Aviation, while local authority functions for the area are administered by the Sepang District Council.

3.3.5 Water Supply Concessionaires and Private Sector Participation

The production aspects of water supply in Selangor have been privatised. Within the study area the main private sector companies are:

(1) Puncak Niaga Sdn. Bhd., which has an agreement with JBA to operate dams at Langat, Klang Gate, Meru/Subang and operate 26 water treatment plants including the Sg. Semenyih water treatment plant (WTP).

(2) Alam Sekitar Malaysia Sdn. Bhd. (ASMA), which undertakes air and surface water quality monitoring. This is under a privatised agreement with DOE.

(3) Indah Water Consortium is responsible for sewerage services. The function of this body is regulated by the Sewerage Services Department.

In addition to the private entities there are a number of NGO's that are actively involved in increasing public awareness, research and education. These include among others:

(1) ENSEARCH;

(2) Environmental Protection Society of Malaysia;

(3) Federal Organisation of Malaysia Consumers Association (FOMCA);

(4) Malaysian Business Council for Sustainable Development;

(5) Malaysian Nature Society;

(6) Malaysian Water Association;

(7) Malaysian Wetlands Foundation; and

(8) Sahabat Alam Malaysia.

3.4 Current Practices on Groundwater Extraction and Management

3.4.1 Sustainable Management of Water Resources

The government is committed towards a sustainable development of water resources in the country. The Earth Summit of 1992 defined sustainable development as the "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The 7th Malaysia Plan has 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. To this end the Government has updated the 1982 National Water Resources Study with the Kajian Sumber Air Negara (KSAN) 2000-2050, which is a comprehensive water resources study that includes state-wide water resource master plans, database on water resource management and the establishment of an institutional mechanism to resolve the legal, institutional and financial matters relating to water. The Government also 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. Some of the policy directions in the Mid-Term Review of the 7th Plan were presented as follows:

(1) Identify new sources of water.

(2) Protect and conserve water catchment areas and establish the criteria for landuse policy in these areas.

(3) Implement new water supply projects including the Sungai Selangor Phase II.

(4) Establish a monitoring and surveillance system that will provide an early warning response following the water crises in the Klang Valley.

(5) Interstate and inter-basin water transfer including the water supply project from Pahang to Selangor.

(6) Reduce the incidence of non-revenue water.

(7) Explore opportunities for the development of groundwater resources.

(8) Encourage the usage of recycled water especially for industrial use.

The National Economic Recovery Plan has also expressed strong recommendations on the conservation of water and the sustainable utilisation of groundwater. Some of the recommendations of the Plan are summarised as follows:

(1) Development in water catchment areas will not be permitted. The State shall not be allowed to revoke existing catchment area gazettes without the approval of the Federal Government.

(2) Adequate funds to be allocated to acquire the necessary infrastructure and facilities to develop groundwater resources.

(3) Existing pricing and charge rates for water use to be reviewed to reflect the actual cost of its production.

(4) To increase the enforcement capacity of the DOE to control waste discharge in water bodies.

(5) To undertake a feasibility study on the licencing and commercial development of groundwater resources.

(6) Conserve existing water resources.

(7) Recycling of water will be encouraged.

(8) River reserves to be enforced and specific guidelines to be drawn up on the activities allowed in the reserve.

3.4.2 Licences and Tariffs

Water is generally consumed largely for irrigation, domestic and industrial use and to a minor extent for aquaculture and mining. Most of the raw water is sourced from rivers (98%). Groundwater only accounts for 2% of raw water source (Water Industry Report 98/99) with most of it being used for industrial purposes. Groundwater for industrial use has been exploited by several industries in Petaling Jaya, Bukit Raja and Shah Alam. One of the major users of groundwater in the study area is the Megasteel Company. Puncak Niaga Sdn. Bhd. (private water company) also taps the groundwater source to supplement production for the treatment plant. At the Olak Lempit well field, JBA pumps about 22mld into the public water supply (KSAN Vol 12). As reported in the KSAN, the usage of groundwater for agricultural purposes is minimal and occurs in the Kuala Selangor district, which has a granary area. Currently there are no licencing procedures governing well drilling or groundwater extraction. For the State of Selangor, licencing procedures could be carried out under the SWMAE 1999. However, the supply of groundwater for domestic and industrial use utilising a supply system on a commercial basis may necessitate another licence under the Water Supply Enactment (WSE) unless JBA or the existing licencees and concessionaires undertake the supply. A feasibility study on the commercialisation of groundwater production should also be carried out to ascertain prospects for privatisation. Currently, raw water is abstracted from the rivers free of charge. The public is however charged for treated water, which varies with different states as shown in **Annex J.3.4**. The charge in Selangor for domestic consumption was 42 sen for the first 15m^3 of water. This has been increased effective on the 19th day of April 2001 to 57 sen/m^3 for the first 20m^3 and progressively increased to 91sen per m^3 for water consumption of 21-35m^3 and at RM1.70 per m^3 for consumption exceeding 35m^3. The SA first approves the tariffs before they are implemented. The SWMA is also looking into the prospects 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.

3.4.3 Development Budget

The development budget generally includes budgets for implementing projects and undertaking feasibility studies. Implementation agencies like PWD and JBAS had a larger development budget than service departments like DOE and JMG. Both DOE and JMG had higher operational budgets than development budgets. 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 has requested for a higher development budget for hydrogeological activities to about RM12.1 million under the 8th Plan (2001-2005). The DOE has also requested for an increased budget of about RM4.73 million for works related to groundwater including the construction of monitoring wells and feasibility studies. Similarly, LUAS (SWMA) has also requested for a large development budget of RM206 million under the 8th Plan. However, most of the budget is for feasibility studies, drainage and storm water management, river basin management and pollution control. No specific budget was requested for groundwater development. Both JBAS and PWD (Waters Branch) have also not requested specific budgetary allocations for groundwater development. This suggests that the major source of funding for groundwater development may have to be outsourced to private sector initiatives. The development budget of selected departments is shown below.

Table J.3.1 Development Budget of Selected Departments (RM million)

Departments	1995	1996	1997	1998	1999
PWD (Waters Branch)	393.00	305.00	510.00	771.00	320.00
JBAS	268.32	303.19	341.77	344.88	571.86
DOE (HQ)	12.95	6.23	6.89	6.78	n.a.
JMG (Geology Dept. HQ)	6.06	2.05	8.41	8.49	8.09
JMG (Hydrogeology)	n.a.	n.a.	1.02	1.78	1.37

Note: ‘n.a.’ means not applicable.
Source: Government agencies

3.4.4 Enforcement Capacity

Wide enforcement functions with respect to groundwater development and management are found in the SWMAE. Other related provisions are found in the NLC, Mining Enactments, Environmental Quality Act (EQA), etc. The related offences and enforcement authority are summarised below.

Table J.3.2 Offences and Enforcement Related to Groundwater Development and Management

Offences	Enabling Law	Enforcement Agency
Landuse Violation	NLC, TCPA	Land Administrator, LPA
Litter and unauthorised garbage disposal	LGA	LA
Erosion of Hill land	Land Conservation Act	District Land Administrator (DLA)
Control of Earthworks	Earthworks By Laws, ESCP (Erosion and sediment control plan)	LA DOE
Diversion and abstraction of water and damage to river banks	Waters Act, SWMAE	District Office, SWMA
Sand Mining Operation	NLC, SWMAE	DLA, SWMA
Mining Operations	Mining Enactments, Mineral Development Act (MDA)	Director of Lands and Mines (DLM) Inspector of Mines
Discharge of waste water	EQA, SWMAE, MDA, LGA	DOE, SWMA, LA, Director of Mines
Unlicenced Blockage and diversion	SDBA, WA, SWMAE	LA, District Office, SWMA,
Indiscriminate Development in Catchment Area	SWMAE, NFA	SWMA, State Forest Department
Enforcement of river and drain reserve	NLC, SWMAE	DID, SWMA, DLM
Unauthorised disruption or taking of water from any water source	SWMAE	SWMA
Pollution of water courses	LGA, WA, WSE, SWMAE, MDA,EQA	LA, District Office, SWMA, JBA, Director of Mines, DOE
Contamination of soils	EQA, SWMAE	DOE, SWMA

While the law provides for adequate powers of enforcement depending on the type of offence, the capacity of enforcement agencies is limited particularly in terms of manpower, technical capacity and the availability of adequate standards and regulations that can be enforced.

3.4.5 Privatisation

Both the Federal and State governments actively promote the policy on privatisation. Both the State Enactments on Water Supply and Water Resources Management have provisions for privatisation. Pursuant to s5 WSE, the State Government may enter into an agreement with any licencee or person to privatise the management, operation and distribution of water supply. Similarly, under the SWMAE, the Authority may privatise any of its undertakings subject to the approval of the SA (s83 SWMAE). Privatisation will also allow for greater private sector participation. In the context of the policy to downsize the government structure, it is likely in the long run that these departments, i.e., JBA and SWMA, will remain mainly as regulatory bodies while their implementation functions may be privatised.

3.4.6 Information Dissemination, Awareness and Research

The awareness of groundwater resources and its importance in sustaining the river basin is currently lacking. It has taken the recent water crisis for people concerned to realise that water resources are not infinite and have to be managed in a sustainable manner. There is a need therefore to educate the public as well as industrial users and the potential polluters of the impacts of their activities on groundwater resources, and JMG, SWMA, the National Water Resources Council and the NGOs may spearhead this effort. Similarly, research on hydrogeology and groundwater development and management should also be promoted, and JMG, NAHRIM (National Hydraulic Research Institute of Malaysia) and the universities could undertake this function.

3.5 Strategic Issues

This subsection of the report attempts to reiterate some of the salient issues raised in the preceding sections. A feedback from the Technical and Steering Committee on these issues provided a direction towards establishing an Institutional and Human Resources Plan as presented in the next **Chapter 4**.

(1) There is no coherent national policy on groundwater development although references on the importance of groundwater as an alternative water resource is contained in the Mid-Term review of the 7th Plan and the National Economic Recovery Plan. This is expected to be contained in the National Water Policy, which will be formulated by the National Water Resources Council.

(2) At present the various institutional aspects pertaining to groundwater development and management is somewhat fluid and there is a need for a clear demarcation of responsibility of the various government departments and agencies in respect of the following areas of groundwater development and management:

  (a) National groundwater policy;

  (b) Groundwater development programme;

  (c) Groundwater development master plan and feasibility studies;

  (d) Laws, regulations and guidelines, standards;

  (e) Research and development;

  (f) Public awareness and education;

(g) Technical assistance and capacity building;

(h) Groundwater production and distribution (planning, design, construction and management);

(i) Water quality monitoring;

(j) Emergency Response Management - Coping with possible groundwater accidents; and

(k) Pollution control and monitoring.

These are addressed in greater detail in **Chapter 4**.

(3) Groundwater regimes may sometimes transcend state boundaries. While water supply schemes, river works and canals that are constituted wholly within the State are within State control, the law is not explicit about groundwater regimes that transcend state boundaries. Under the Constitution, water supplies, rivers and canals not wholly within the State or regulated by an agreement between the states come under the Federal List. It is submitted that the same principle would apply to groundwater regimes. Since the National Water Resources Council will handle the task of resolving disputes and issues pertaining to interstate water supply, it is suggested that this forum should also be used to discuss issues pertaining to groundwater regimes that transcend state boundaries.

(4) The overall review of the various organisations suggest that JMG has the necessary technical capacity (both personnel and equipment) to be the main technical department for groundwater development in the country. The expression of this function should be included in the Ministers of the Federal Government Order under the MFA 1969. Additionally, there is a need to ensure representation of JMG in the SWMA or State Water Resources Councils or Committees as well as the NWRC or the technical committees established under it. Moreover, there is a need to increase the development budget of the Department to effectively carry out this function.

(5) While the States will retain the regulatory powers pertaining to licencing, control and privatisation, JMG will continue to be the main technical department to advice the state on groundwater development and management. In addition it should be the main repository of technical data on groundwater development in the country. In this respect there has to be proper inventory of all production and monitoring wells including private wells, JBA wells, JMG wells, DID wells and DOE wells). There has to be legal provisions in the State Enactments to ensure that JMG is consulted on matters pertaining to groundwater development in the state. JMG should continue to be the main centre to investigate, monitor and analyse groundwater resources in the country and assist the State in managing its groundwater resources.

(6) Water Quality standards for groundwater for domestic, industrial and irrigation purposes should also be established. The Ministry of Health in collaboration with PWD, the Department of Chemistry, and the DOE have developed water quality standards for safe drinking water. If groundwater is to be used for domestic purposes it has to satisfy the NGDWQ (National Guideline for Drinking Water Quality). A similar standard could also be established if water is to be used for industrial or irrigation purposes. JMG has also the equipment and personnel to carry out chemical analysis of raw groundwater and should be represented in any committee that establishes parameters or standards for water quality.

(7) There are currently no DOE standards/criteria for groundwater quality monitoring for pollution control purposes. Currently the information gathered by DOE is benchmarked against the MOH standards for raw water quality guidelines. Groundwater samples taken near solid waste dumpsites indicate that the level of some parameters exceeded these guidelines. Under the Environmental Quality Act (EQA), there are also restrictions on the pollution of the soil that may lead to pollution of groundwater. The enforcement of this is tied up with establishing standards and criteria for contaminated land. DOE will carry this out by as a programme under the 8th Plan. Unless adequate standards and regulations are in place it may be difficult to enforce pollution control. Both JMG and DOE currently carry out monitoring functions and it is necessary that their programmes are coordinated with each other. In the case of Selangor the SWMAE also empowers LUAS to prescribe acceptable discharge standards in designated areas. A framework of cooperation for monitoring purposes among the various agencies has to be established similar to the NDWQSP (National Drinking Water Quality Surveillance Programme).

(8) There is a need for comprehensive legislation on groundwater use and management for the country. The laws pertaining to groundwater management and development is currently fragmented and found in several related laws. Again most of the existing laws on water resources relate to surface water use and the control of rivers and streams and does not adequately cover groundwater. At the state level, most states have enactments covering water supply but not water resource management with the exception of Selangor. The SWMAE has some provisions covering groundwater use and management. Provisions on groundwater could also be incorporated into the Waters Act 1920. The scope of this Act is currently limited to the control of rivers and streams but could be expanded to include groundwater. This Act is currently applicable in the states of Negeri Sembilan, Pahang, Perak, Malacca, Penang and the Federal Territory. Perhaps the scope of this Act should be widened to cover concerns of water resources management for the purposes of ensuring uniform provisions in all the states. In the case of Selangor there is a need to adopt rules and regulations particularly pertaining to well drilling, groundwater abstraction and monitoring wells and strengthening the provisions on groundwater management and use in the SWMAE.

(9) Enhancing the Operational Capacity of SWMA (LUAS): While LUAS has been established under a state enactment with wide ranging powers in water resources management, it has constraints in terms of personnel and finances. The Director still operates with minimal staff although 24 new posts have been recently approved. In the long-term, however, it is likely that LUAS assumes a regulatory role whereby most of its implementation undertakings under the Act could be outsourced. In the interim period, sufficient funding and staffing have to be allocated to LUAS for it to function effectively. Additionally LUAS could make recommendations to the SA to impose a charge for abstracting raw water for both ground and surface water. This would provide a consistent source of income to the Authority.

(10) Privatisation of Groundwater Production: In line with the trend in Selangor whereby the production aspects of water supply has been privatised to concessionaires, there are also provisions in the SWMAE to allow for this. There may be a need to carry out a feasibility study to ascertain its viability. This recommendation is also contained in the National Economic Recovery Plan Document.

(11) Draft Rules, Standards and Guidelines: Being the technical department most adept with groundwater development, JMG has prepared draft rules on well drilling, groundwater abstraction and groundwater monitoring. These rules and guidelines have to be adopted by the respective states before they can be made operational. In the state of Selangor, they can be adopted as rules under the SWMAE. In the other states it may remain as guidelines. However, in order to get them adopted by all the states there may be a need to table them to the NWRC (National Water Resources Council), and applied administratively in all the states.

(12) Groundwater development and management should be viewed in the context of river basin planning. Practically it is difficult to separate sustainable groundwater development from river basin planning. The Rivers Division of DID currently undertake river basin planning for drainage and storm water management. There is obviously a need to coordinate both of these activities. Fortunately in Selangor the responsibility for both of these functions rests with the SWMA (LUAS). While DID is expected to advice LUAS on river basin management, JMG may have to provide advice on sustainable development of groundwater resources. Hence, it is important to coordinate the programmes of DID and JMG.

(13) Public awareness and education are important to reduce possible pollution risk to groundwater and reduce incidence of non-revenue water due to public apathy. Similar to the “Love the River” campaign by DID, similar public awareness programmes must be initiated by the relevant agencies, in particular, JMG, NWRC, DOE, NGOs and the SWMA. These agencies should set aside sufficient budget to undertake these activities.

(14) There should also be continued efforts to promote research and development in groundwater management and development. Research grants may be sourced both locally and internationally. JMG, NAHRIM (National Hydraulic Research Institute of Malaysia) and the universities could promote research related activities. The possibilities of establishing a research grant for groundwater development could also be investigated.

The various aspects of issues raised above are explored in greater detail in the next **Chapter 4**.

4. HUMAN RESOURCES AND INSTITUTIONAL DEVELOPMENT PLAN

4.1 Introduction

The Human Resources and Institutional Development Plan attempts to formulate an overall framework for the implementation of the Management Plan. For purposes of discussion, this chapter will look into the overall organisational framework for sustainable groundwater management and development in the Langat Basin and the roles played by the various agencies on different aspects of groundwater development and management. This will be followed by discussions on human resources development and the roles and functions of the three key agencies involved in groundwater development, i.e., LUAS, JMG and DOE, as well as suggestions on the improvements to the legal provisions.

4.2 Proposed Organisational Framework

The organisational framework for groundwater management and development in the Langat Basin has to take account of existing constitutional and legal provisions as well as national policies relating to groundwater resources.

As discussed earlier, the Federal Constitution and other legislations confer ownership of water resources on the State. This is further expressly provided in the SWMAE 1999 (s.41) that the control of use and flow of water including subsurface water is under the jurisdiction of the State. This would suggest that the State has executive authority over the use and management of its water resources. In tandem with these powers, the state of Selangor has established LUAS (Lembaga Urus Air Selangor) or SWMA (Selangor Waters Management Authority) for the management and protection of river basins, water bodies, groundwater, coastal waters and wetlands and for the sustainable development of these resources.

Although water resources is under the State List, the constitution enables Federal Government to legislate and make policies on such matters for purposes of uniformity and establish priorities for funding allocation. Recognising that fresh water is a finite and vulnerable resource, the 8th Malaysia Plan (2001- 2005) calls for the formulation of a National Water Policy to provide a framework for water conservation and management. Other key proposals in the 8th Plan are as follows:

(1) State Governments will be encouraged to establish water management bodies similar to LUAS to ensure proper planning, monitoring, enforcement and management of water resources on a river basin basis.

(2) Groundwater exploration will be conducted in the main river basins to identify potential aquifers and outline protection zones to conserve groundwater resources.

(3) Groundwater research will be intensified and better coordinated to provide a unified database.

Although more than 98% of raw water is currently sourced from rivers (KSAN 1998), the government has nevertheless given high priority for groundwater development as an alternative source of fresh water. This is also contained in the National Economic Recovery Plan (NERP), which states that:

(1) Adequate funds will be allocated to acquire the necessary infrastructure and facilities to develop groundwater resources.

(2) Feasibility studies will be prepared for the licencing and commercial development of groundwater resources.

There are several different agencies involved in different components of groundwater development and management. These include aspects related to groundwater policy, and programme and plans, infrastructure development both for production and distribution, regulatory aspects, groundwater monitoring, groundwater basin management. Other aspects of importance include aspects related to education, research, training and public awareness. The overall organisational framework for groundwater development and management in the Langat Basin is shown in **Figure J.4.1** while the roles of these agencies involved is summarised in **Table J.4.1**. These aspects are further elaborated below:

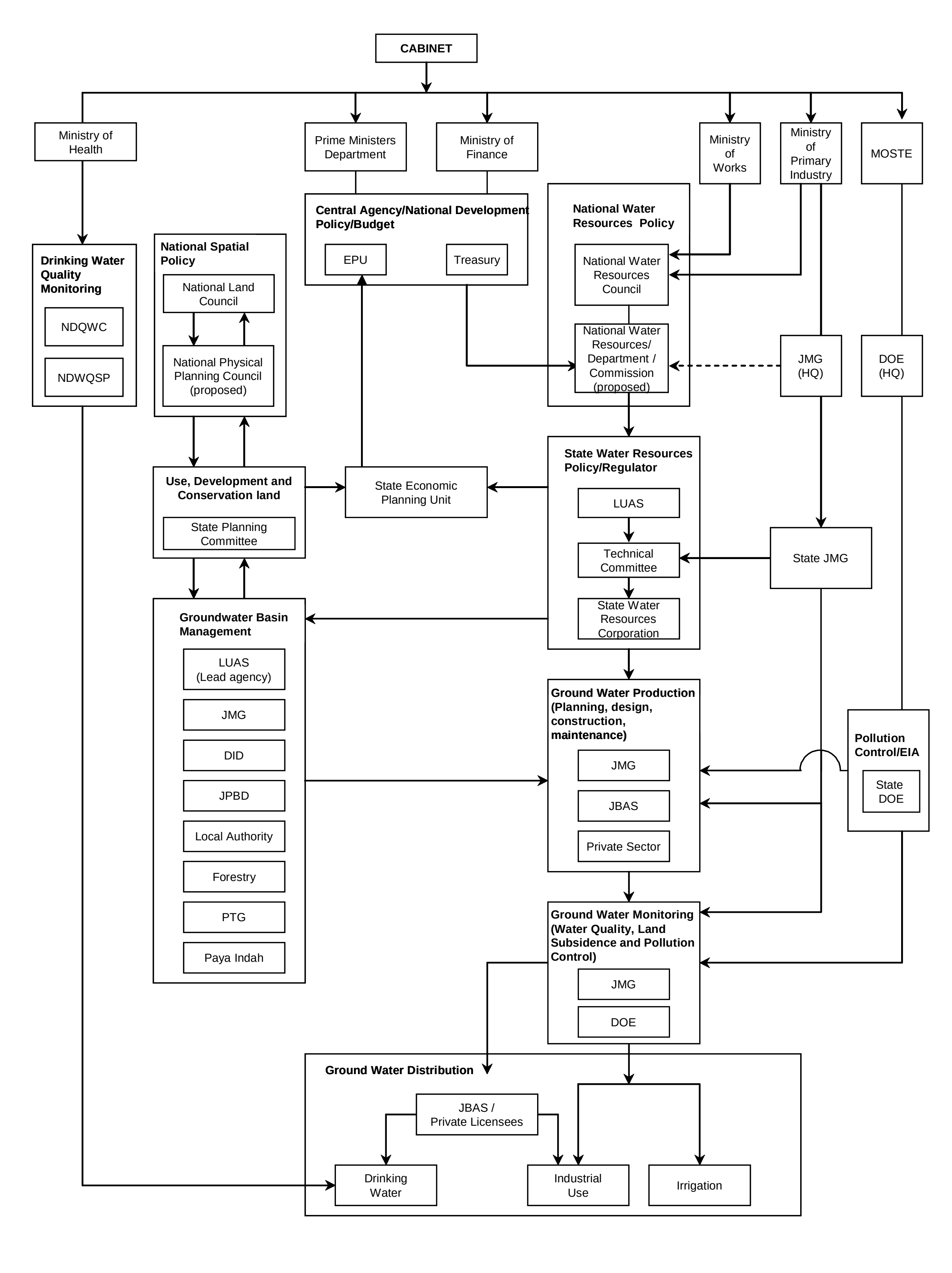

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Figure J.4.1

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

Table J.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 : Leading agencies are presented in bold letters.

4.2.1 Policy, Programme and Plans

This subsection reviews the main agencies involved in the policy formulation, development programme, master plan and feasibility studies, and the implementation of the Langat Basin Management Plan.

(1) National Groundwater Policy

The national groundwater policy should be a constituent component of the proposed National Water Resources Policy. This policy is expected to contain specific provisions on groundwater and lays out the broad principles for the periodic assessment and exploration of areas with groundwater potential, integration with surface water development and the avoidance of over-exploitation of the resources. The Policy will be administered by the National Water Resources Council (NWRC), which was established in June 1998 and supported by both the Federal and State Governments. The functions of this council were discussed in the preceding chapter. It is also suggested that this be the forum to discuss and resolve issues pertaining to groundwater regimes that transcend state boundaries. The Council will be supported by a Secretariat, which is currently with the PWD Water Supply Branch. It has been proposed recently that this Branch may be converted to a National Waters Commission. In complementing the policy, a National Water Resources Study (KSAN) has been formulated to cover a planning horizon up to year 2050. The study has also devoted a chapter on groundwater development and also made proposals for a National Water Resources Department to be established to administer the policy and programmes of the NWRC. JMG is currently represented in the Council via the Minister of Primary Industries that is one of the permanent members of the Council. The NWRC will be an important forum to deliberate on policy matters regarding groundwater and on issues relating to groundwater regimes that transcend state boundaries.

(2) Groundwater Development Programme

The development programmes of government departments and agencies are normally incorporated into the 5-year Malaysia Plans. These proposals are vetted by EPU and Treasury through a bidding process before funds are released. Request for funding by state agencies is coordinated by the State Economic Planning Unit (SEPU) before it is forwarded to EPU. The principal agencies that will be responsible in formulating an overall programme for groundwater development is expected to include NWRC, EPU, Treasury, JMG and LUAS.

(3) Groundwater Development Master Plan and Feasibility Studies

While a national water resources master plan is currently formulated, there may be a need to develop more specific master plans for areas with good groundwater potential such as the Langat Basin and in Kelantan. The master plan will have to be commissioned and vetted by a technical agency competent in groundwater development. It is suggested that JMG be entrusted to prepare this master plan 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. Funding for these studies may be sourced from Federal or State funds or Official Development Assistance (ODA). It is also possible that a private enterprise that wish to participate in groundwater development could also be encouraged to prepare feasibility studies under the privatisation policies of the government.

(4) Langat Groundwater Basin Management

The recharge capabilities of the Langat aquifer will very much depend on sustainable development and management policies for the river basin. 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 (s56 SWMAE), protected areas (s48 SWMAE) and river reserves (s46 SWMAE) and formulate and implement development and management plans for the area. LUAS will have to coordinate and liase with the State Planning Committee on matters pertaining to the use, development and conservation of land in the state. Designated and protected areas should also be incorporated into the Structure and Local Plans to ensure coordinated land use planning. Other important works related to groundwater management such as field data capture, modelling and data management will be carried out by the State JMG. Other key agencies involved in river basin development and management include the Drainage and Irrigation Department (DID), Town and Country Planning Department (JPBD), Local Authorities, Forestry Department, Land and Mines Department (PTG) and the Malaysian Wetlands Foundation (Paya Indah Wetland Sanctuary). The main local authorities included in the Langat Basin are the Kajang Municipal Council, Sepang District Council, Kuala Langat District Council, Seremban District Council, Putrajaya, Klang Municipal Council and management bodies such as Cyberjaya, KLIA, and the Paya Indah Wetlands Sanctuary. The groundwater management plan should also be integrated with the Langat River Basin Management Plan. It is expected that these agencies will play an important role in the development of an integrated basin development plan.

4.2.2 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. There would however be a number of production wells constructed by JMG and JBAS to complement the existing water supply sources in the State. 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. As it would be extremely costly to develop a separate reticulation supply system for groundwater, it is suggested that the existing JBAS system could be utilised for the distribution of potable groundwater. Most of the groundwater in the Langat Basin is expected for on site industrial use or as drinking water. Except for isolated instances in Kuala Selangor, groundwater is not extensively used for irrigation purposes.

4.2.3 Regulatory Aspects

Regulatory aspects on groundwater development will include issues related to powers to make laws and regulations, licencing, pollution control, and issuance of guidelines and standards.

(1) Laws and Regulations on Groundwater

The laws pertaining to groundwater are not consolidated into a single comprehensive legislation. Provisions on groundwater are found in the SWMAE, the Geological Survey Act and the Environmental Quality Act (EQA). In the case of Selangor, the principle law on groundwater is the SWMAE. The law defines groundwater and allows for the imposition of charges for abstraction and declaration of designated groundwater areas. The enactment also provides for the licencing of operators and the making of rules for the management, regulation and control of groundwater. Provisions relating to groundwater were repealed from the Selangor Water Supply Enactment. This would suggest that the principle authority for the making of laws and regulations on groundwater in Selangor is the State Authority and LUAS.

(2) Licencing for Well Drilling, Groundwater Abstraction and Monitoring

In the case of Selangor, the licencing powers with respect to the above are given to LUAS under the SWMAE. Licencing of wells should be the prelude to imposing charges to the abstraction of groundwater. 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 [s45(2) SWMAE].

(3) Pollution Control Enforcement

The main enforcement powers on pollution of watercourses are with DOE and LUAS. Both these agencies are empowered by the respective laws i.e., EQA and SWMAE respectively. For example, there are restrictions on the pollution of soil, which include refuse dumps and sludge disposal sites that might interfere with underground water (s24 EQA). The DOE may also enforce the conditions of approval of the EIA, which is required for groundwater development facility where production exceeds 4500 m^3 per day. LUAS is also empowered to complement DOE in requiring EIA's for projects in designated areas and prohibit the pollution of water sources (s79 SWMAE). Prohibition of pollution of watercourses is also found in a number of related legislations such as the

Waters Act, the Local Governments Act, Earthworks Bylaws, Mining Enactments and the Mineral Development Act.

(4) Guidelines and Standards

Uniform model regulations for well drilling, groundwater abstraction and monitoring wells have been formulated by JMG to be adopted by the respective state governments as rules under the respective State Water Resources Management Enactment or the State Water Supply Enactments. In the case of Selangor, the enabling law is the SWMAE. JMG being the principal technical department on groundwater may also prescribe uniform standards and guidelines on groundwater management. These could be first deliberated at the NWRC before it is subsequently adopted by the respective states.

4.2.4 Monitoring

Groundwater monitoring is an important component of groundwater development and management. Groundwater monitoring involves the taking of measurements related to groundwater level, TEM surveys, water quality, land subsidence measurement, etc. JMG and DOE currently manage the monitoring of wells. The other agency that may carry out monitoring functions is LUAS although at the moment it does not operate any well. The more comprehensive range of monitoring functions is carried out by JMG. It has also been suggested in the earlier chapter that JMG be the main central depository of information obtained from all monitoring wells. An overview of this monitoring plan is discussed in **Sector H**.

The DOE also carries out monitoring functions. In Selangor, about five (5) sites are used for monitoring purposes selected from different land uses. Most of the information collected relates to groundwater quality in line with its function as the main pollution control agency in the country. Potential pollution sources to groundwater include industrial activities, agricultural activities including livestock farms, mines, solid waste landfill sites, waste water treatment plants, and oil storage tanks. Discharge from these activities has to be monitored to prevent possible contamination to the groundwater resources.

Safe drinking water is an important public health concern. Since 1982, the Ministry of Health (MOH) has instituted a National Drinking Water Quality Surveillance Programme (NDWQSP). The main agencies involved in this programme are MOH, PWD (Water Division), Chemistry Department and DOE. Samples of raw and treated water are taken on a regular basis by the District Health Officials. These samples are analysed by the Chemistry Department to see if they conform to the National Drinking Water Quality Standards (NDWQS), which has been established for both raw water and treated water. Obviously, if groundwater is to be used for dinking purposes, then it has to satisfy the NDWQS. It is also proposed in this study that the JMG be made as a permanent member of the NDWQSP as well as the National Drinking Water Quality Committee. The proposed interagency organisation chart for the Drinking Water Quality

Surveillance Programme and the functions and responsibilities of the agencies involved are shown in **Figure J.4.2** and **Table J.4.2**.

4.2.5 Education and Research

Some of the main areas under education and research include public awareness and education, emergency response management (ERM), research and development and training. Aspects related to training will be discussed in the next section on Human Resources Development.

Public awareness and education on the groundwater resources and the need to protect these resources are an important component of a management plan. The recent water crisis in Selangor has clearly shown that water is not an infinite resource and has to be managed in a sustainable manner. Similar to the "Love the River" campaign of DID and the "Forest for Water and Water for Life" campaign by the WWF, similar campaigns may be organised for groundwater. This initiative could be spearheaded by JMG and LUAS with the support of Local Authorities particularly those in the Langat Basin, the Schools and NGO's such as the Malaysian Water Association and the Malaysian Wetland Foundation.

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. At the regional level, the main agencies involved should include JMG, LUAS, JBAS, the Local Authorities, DOE and the District Office. Contingency measures must be planned and implemented should such an eventuality take place.

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 JPS. Part of the research should also include an integrated water resources model involving both surface and groundwater resources development and management.

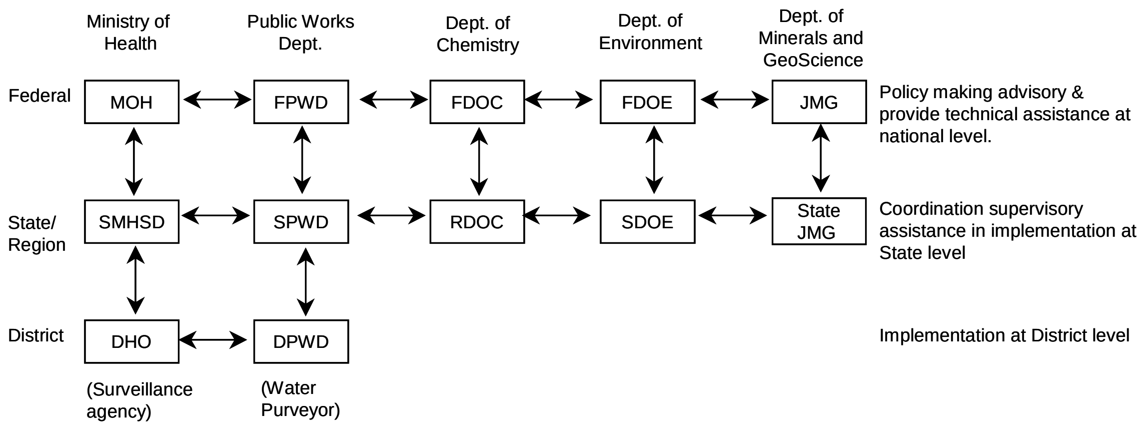

Figure J.4.2
Proposed Inter & Intra Agency Organisation Chart
(Drinking Water Quality Surveillance Programme)

Table J.4.2 Functions and Responsibilities of the Various Agencies for Drinking Water Quality

Agency	Function	Responsibility
(Surveillance) MOH - UDWQS (Unit of Drinking Water Quality Surveillance) SMHSD DHO	Surveillance of drinking water quality	To ensure that all drinking water quality in the country is free from health hazards; to find out what is wrong and assists in putting matters right.
(Water Surveyor) FPWD SPWD DPWD	Supplying of potable water	To provide water of sufficient quantity and quality to the population.
(Laboratory) FDOC RDOC	Testing of water	To provide laboratory services for analysis of water samples
(Environment Protection) FDOE SDOE	Controlling of pollution at source	To protect the raw water sources from being unduly polluted.
(Groundwater) FJMG SJMG	Monitoring groundwater including water quality testing	To monitor groundwater resources and identify sources suitable for drinking water

4.3 Proposed Human Resources Development Plan

The human resources development plan will look into improvements in manpower and the training needs for the key departments involved in implementing the management plan. This will also include recommendations on the proposed functions of the key departments such as JMG, LUAS and DOE that are involved in groundwater development and management.

4.3.1 Roles and Functions

(1) Minerals and Geoscience Department (HQ)

From the previous discussion on the organisation structure it is clear that JMG will be the main technical department for groundwater development and management. Except for laws and regulations, which 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/ hydro-geological 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 hydro-geological functions of the department. This will include functional sections under (i) Policy and Programme, and (ii) Groundwater Management (MIS). The Policy and Programme Section will administer all works related to policy, establishing programmes and feasibility studies including the groundwater master plan while the MIS Section will be the national depository for groundwater management information. This information will be sourced from the respective state JMG, private licencees and other agencies that carry out monitoring functions such as DOE. This unit will also be supported by the Information Management Unit, particularly, in the area of system administration.

The headquarters will be supported by the Technical Services Division in Ipoh. A new unit on groundwater is proposed to be established and headed by a hydrogeologist. The main function of this unit is to provide specialist groundwater expertise particularly researchers and modellers to State JMG’s 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 JMG’s.

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 labs. The proposed organisational structure for Headquarters is shown in **Figure J.4.3**.

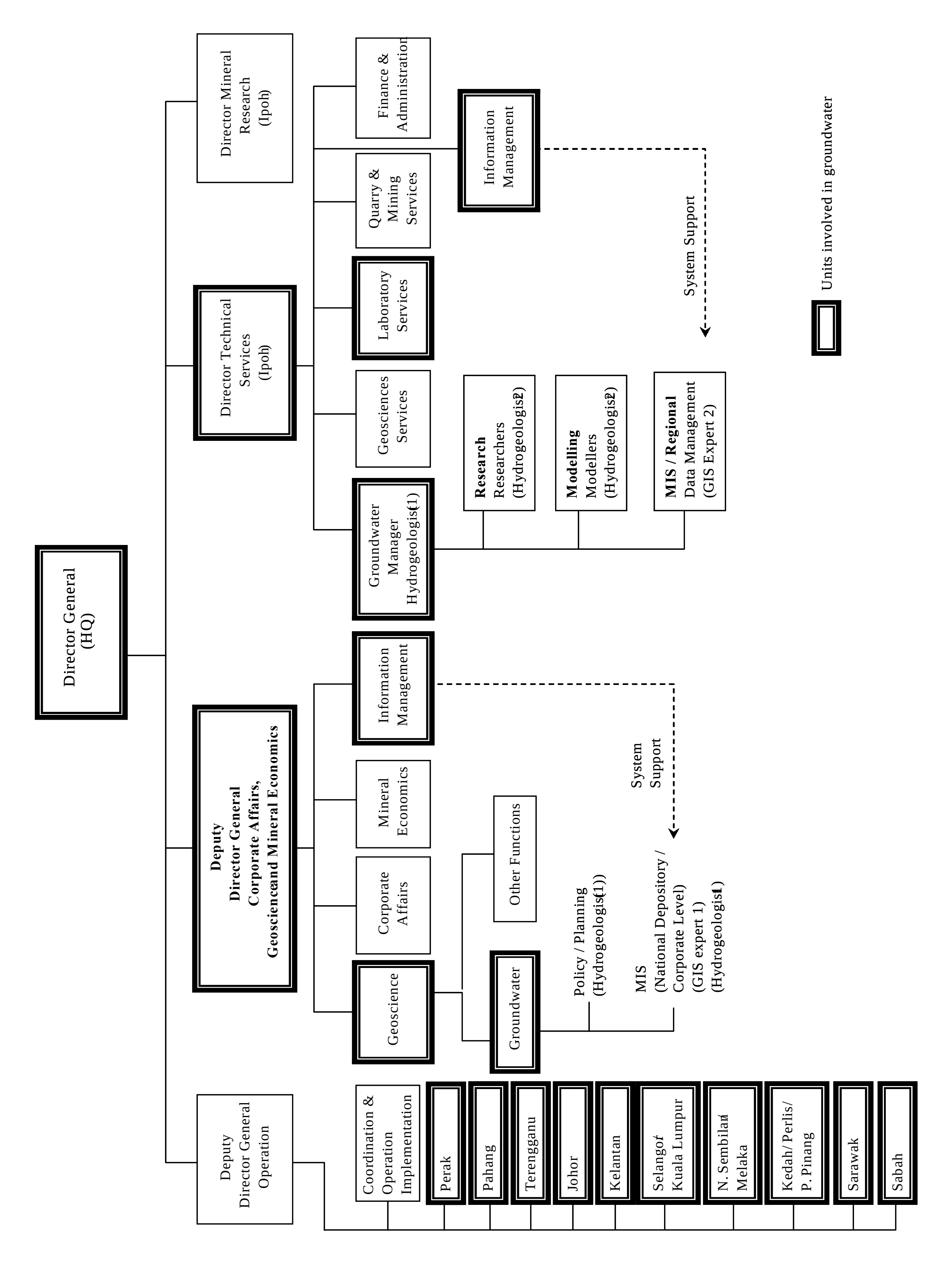

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Figure J.4.3

Proposed Organisation of Minerals and Geoscience Department for Groundwater Management

The functions of this Unit with respect to groundwater development are summarised below:

JMG (HQ) Geoscience Division (Groundwater functions)

(a) Assist the NWRC on matters relating to the policy framework on groundwater development and management.

(b) Formulate a long-term master plan for groundwater development in the country

(c) Establish a 5-year development programme and annual budgets on groundwater development and monitoring to be incorporated into the Malaysia Plans.

(d) Develop a hydro-geological database and be the national depository for information related to groundwater.

(e) Infrastructure development (including the planning, design, construction and maintenance of wells) for selected projects of national importance. In all other cases this function shall be delegated to the State JMG.

(f) Establish programmes/campaigns for greater public awareness of groundwater resources and its uses.

Technical Services Division (Ipoh) Groundwater Unit

(a) Undertake research and development on groundwater development and management.

(b) Provide specialist groundwater expertise especially modellers/simulation experts as required by State JMG’s and State Water Resources Agencies.

(c) Provide MIS/Data Management Services to State JMG’s and State Water Resources Agencies.

(d) Provide laboratory services especially for water quality analysis.

In addition to the above, in order to further emphasise this responsibility, it may be necessary to include Hydrogeology and Groundwater Development as one of the functions of JMG in the Ministers of the Federal Government Order under the Ministerial Functions Act 1969.

(2) 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 the state JMG is shown in **Figure J.4.4**. 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. Most of the work will be contracted out to consultants and contractors. This section will also evaluate technical reports and feasibility studies submitted by private concessionaires and licencees. Other aspects of development work relates to development programme 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.

A summary of the functions of the Selangor State JMG with respect to groundwater development and management is given below. This model could be replicated in other states that have good groundwater potential such as Kelantan.

(a) Establish a development programme for groundwater development in the State.

(b) Evaluate technical reports and feasibility studies carried out by private concessionaires/licencees.

(c) Provide technical advice to LUAS on matters pertaining to groundwater development and management.

(d) Advise the state on any licencing matter with regard to well drilling, groundwater abstraction and monitoring.

(e) Undertake infrastructure development (planning, design, construction and maintenance) of wells funded by the Government.

(f) Undertake comprehensive monitoring including water levels, water quality, land subsidence, etc.), for purposes of groundwater management.

(g) Undertake GIS and Data Management functions of groundwater in the State.

(h) The Director of JMG is a Member of the Technical Committee of LUAS.

(i) Assist the State / LUAS in implementing the Management Plan for the Langat Basin.

(j) Participate in the Drinking Water Surveillance Programme if groundwater is to be used as potable water.

(k) Assist LUAS in carrying out public awareness campaigns on groundwater resources and its usage.

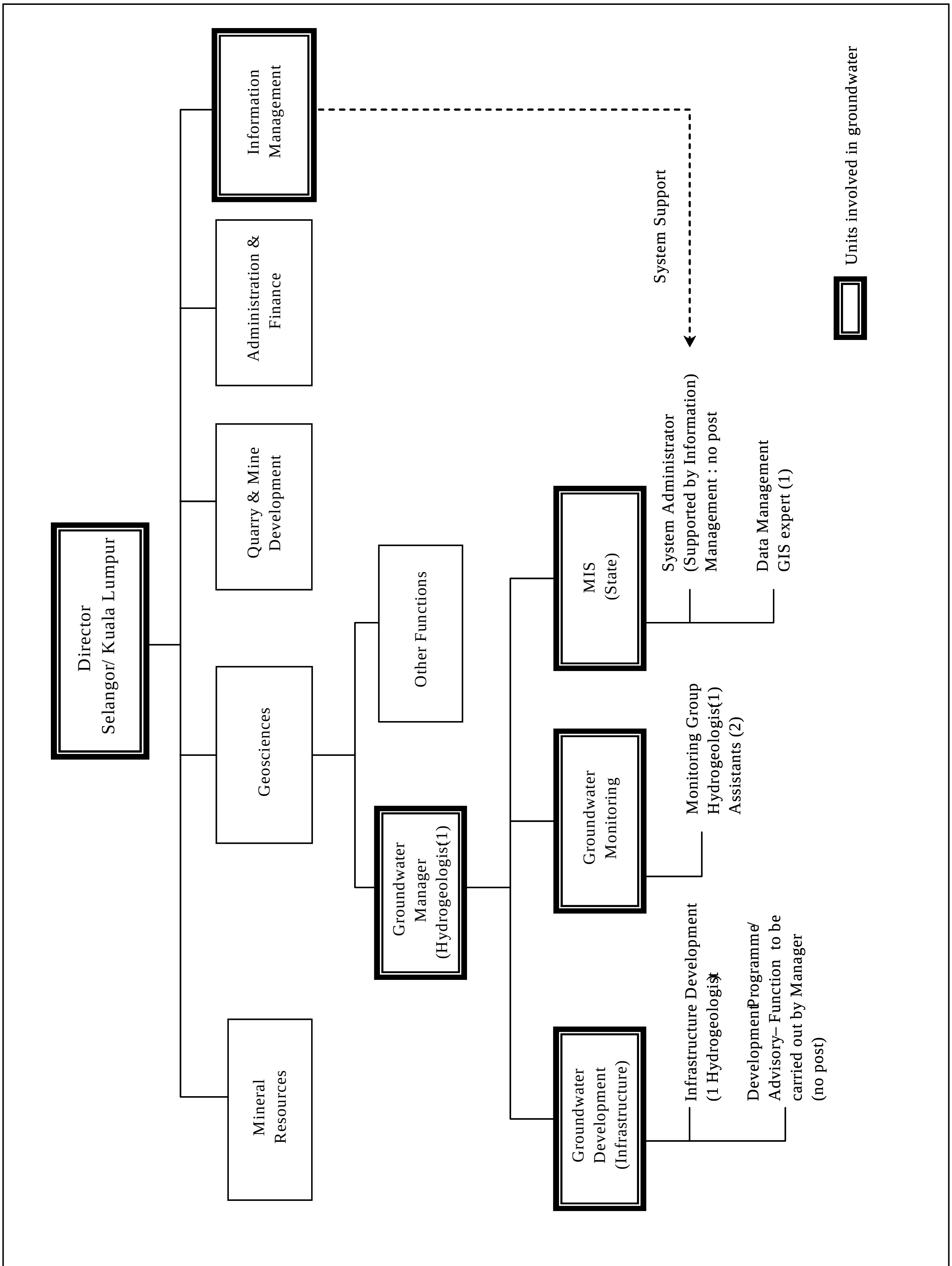

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Figure J.4.4

Proposed Organisation of Selangor Mineral and Geoscience Department for Groundwater Management

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(3) 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. DOE has also requested a development budget (RM 4.73 million) to build monitoring wells. However this budget does not include any new wells in the Langat Basin. The groundwater monitoring programme is currently carried out by HQ with assistance from the State DOE. The construction of wells is administered and supervised by HQ, while water samples are collected by staff from the state office. The samples are sent to the Chemistry Department for laboratory analysis and benchmarked against the National Drinking Water Quality Standards for raw water. The DOE is again constrained by manpower with only three (3) staff members under the Director of Control Division involved in the programme. Part of the functions of DOE with respect to groundwater should include the following:

(a) Formulate national standards on groundwater quality.

(b) Carry out enforcement of pollution sources to ensure compliance with approval conditions, licencing conditions, emission and discharge standards.

(c) Carry out a national network of groundwater monitoring. This function has to be coordinated with the programme of JMG.

(d) Assess development projects that require an EIA. This includes groundwater projects that have a production capacity exceeding 4500 m^3 per day and development projects in designated areas.

(e) Prepare environmental guidelines for project planning. This includes the EIA guidelines on groundwater and surface water supply 1995, Land and industrial development guidelines and waste management guidelines.

(f) Dissemination of environmental information.

(g) Assist LUAS in discharging its functions on pollution control as required under the SWMAE.

(h) Assist LUAS/ JMG in implementing the Langat Basin Management Plan.

As a principle pollution control agency in the country, it is important that groundwater standards are established under the EQA before they can be enforced. The DOE is currently in the process of preparing these standards. In the area of groundwater monitoring it would be better if the programmes of both

JMG and DOE are coordinated. It is suggested in this study that the central depository of information on groundwater be based in the JMG. This would suggest that there should be better exchange of information between the two agencies so as to optimise resources. Again, there is a need to increase the manpower resources in DOE to fully carry out the functions described above.

(4) Selangor Waters Management Authority (SWMA or 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. As mentioned in the Progress Report, LUAS is given wide powers under the enactment. This includes formulation of policies, regulatory function, prepare development and management plans for designated areas such as river basins and groundwater areas, develop and implement guidelines and standards, powers of enforcement, provide training, undertake research, ERM, imposing charges, issue licences, pollution control and advise the State on privatisation projects. 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 be increased to 200. The main proposed divisions of the Department are as follows:

(a) Planning Division;

(b) Development, Operations and Maintenance;

(c) Law and Enforcement;

(d) Corporate services; and

(e) Four regional offices at Sg. Selangor, Sg. Bernam, Sg. Kelang and Sg. Langat.

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. The main priority functions with respect to groundwater development are suggested as follows:

(a) Establish an overall groundwater development programme within the State in collaboration with JMG.

(b) Formulate rules under the SWMAE pertaining to well drilling, groundwater abstraction and monitoring.

(c) Licencing of wells as provided under the Enactment.

(d) Determine tariffs and impose charges for the abstraction of groundwater as provided under the enactment.

(e) In collaboration with DOE determine pollution control standards for groundwater.

(f) Public awareness campaign on the importance and usage of groundwater.

(g) Lead agency to implement the Langat Basin Management Plan with assistance from JMG.

Adequate financial and staff resources have to be allotted to LUAS before it can effectively carry out its functions. The staffing and budget requirements of the agency have already been submitted to the relevant authorities for consideration.

4.3.2 Training

Training is an important component of human resource development. Training and development are part of the functions of a number of agencies including JMG; this function could be further developed at the Ipoh Branch. Other relevant agencies include NAHRIM (National Hydraulic Research Institute of Malaysia), 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.

4.4 Improvements to the Legal Framework

The laws pertaining to groundwater development and management is currently fragmented and found in several related laws. The main legislations that make specific references to groundwater include the Geological Survey Act 1974, the Environmental Quality Act and the Selangor Waters Management Authority Enactment 1999.

4.4.1 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.

4.4.2 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 the following amendments:

(1) 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.

(2) A well is defined as one with an abstraction rate exceeding 2500 l/d regardless of the purpose the water is used.

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

It should be noted that under the Act, JMG is not an approving or licencing authority. The approval for a project will have to be obtained from the relevant state authorised agency, i.e., LUAS. Notwithstanding this, there is a need to consult the Director General of JMG before an approval is given by the relevant State Authority. This provision could be included in the proposed amendments of the GSA.

4.4.3 Environmental Quality Act

There are a number of provisions in the Act that could be used for pollution control of groundwater resources, namely:

(1) Under the Act, the Minister may specify acceptable conditions for the emission, discharge and deposit of waste (s21).

(2) There are restrictions on the pollution of soil including refuse dumps and sludge disposal sites that might interfere with underground water (s24).

(3) The DG may by notice in writing require the occupier of any premise to install and operate control equipment (s31).

(4) Under s34(A) and the Environmental Quality Order 1987, groundwater development that exceeds production of 4500 m^3 per day is subject to an EIA. Under this provision, the EIA must be submitted and approved by DOE before the commencement of the project. The DOE is also empowered to ensure that the conditions of approval are complied with.

With respect to (i) and (ii), DOE is currently preparing comprehensive standards for groundwater quality control. Wide powers are also given to DOE to require occupiers of any premises that is likely to emit or discharge pollutants to install control equipment. This would suggest that control equipment could be enforced on any premises that are potential sources of groundwater pollution. Under the EQA, it is mandatory that the EIA report is first approved by DOE before the project proponent may commence with the project.

4.4.4 Selangor Waters Management Authority Enactment

There are a number of provisions in the SWMAE that relate to groundwater. These are shown in **Table J.4.3** below:

Table J.4.3 Provisions Related to Groundwater in the SWMAE 1999

Provisions	Contents
S2	Groundwater defined to mean subsurface water and includes wells and boreholes.
S4(1)(g)	JMG is not a permanent member of the Authority but may be appointed under this section.
S26(2)(l)	The State Director of Geological survey is a member of the Technical Committee.
S41	Control on the use and flow of water including subsurface water is under the jurisdiction of the Authority.
S44	The Authority may impose a charge for the abstraction of groundwater except for domestic and subsistence agriculture purpose subject to conditions of s45(3). • It will not cause significant obstruction or diversion to the flow of water. • Store more than 1 megalitre of water. • Abstract water at a flow rate exceeding 20 litres/sec.
S48	Power to establish zones of protection to safeguard any water source.
S56	Declaration of any wetlands and groundwater areas as designated areas.
S73	Where water table management is required the Authority to declare the area as problem soil area and develop a management plan.
S78	The Authority may in consultation with DG of Environmental Quality prescribe acceptable conditions for discharge of waste in any designated area.
S79	Prohibition of pollution of a water source from poisonous matter, due to biological and chemical content, discolouring effect and oil.
S82	The Authority may prepare privatisation plan.
S87	The power to licence operators.
S122	Director to issue water protection order where there is an immediate threat to the quantity and quality of water.
S127(i)	The Authority may make rules on the management, regulation and control of groundwater.

There are a wide range of functions and powers related to groundwater management and licencing of activities related to groundwater activities. There is obviously a need to administer and implement these provisions. There is also a need to provide for a set of rules for the management, regulation and control of groundwater [s127 (i)]. These rules should also be consistent with the draft regulations proposed by JMG with respect to well drilling, monitoring and abstraction of water. In this context, a common definition for a well for purposes of imposing charges may be necessary. The JMG's proposed definition of a well as being one "with an abstraction rate exceeding 2500 l/d regardless of the purpose the water is used" could be used as a common platform.

4.4.5 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, the Town and Country Planning Act, the Environmental Quality Act, the Local Government Act and the Mining Enactments. (see **Table J.4.4**). These laws cover aspects pertaining to land-use planning, forest and land resources conservation and pollution control. 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. However it should be noted that while there are adequate powers for enforcement what may be lacking is the limited manpower, lack of financial resources, lack of technical skills and the availability of adequate standards and regulations for enforcement purposes.

Table J.4.4 Enforcement Provisions Related to Groundwater Development and Management

Offenses / Aspects	Enabling Law	Enforcement Agency
Land Use Violation	NLC, TCPA	Land Administrator, LPA
Litter and unauthorised garbage disposal	LGA	LA
Conservation of Wildlife and Biodiversity	Protection of Wildlife Act	Wildlife Department
Erosion of Hill Land	Land Conservation Act	District Land Administrator (DLA)
Conservation of Forest Reserves	National Forestry Act	State Forest Department
Control of Earthworks	Earthwork by laws ESCP (Erosion and Sediment Control Plan)	LA DOE
Diversion and abstraction of water and damage to river banks	Waters Act, SWMAE	District Office, SWMA
Sand Mining Operation	NLC, SWMAE	DLA, SWMA
Mining Operations	Mining Enactments, Mineral Development Act (MDA)	Director of Land and Mines (DLM), Inspector of Mines
Discharge of wastewater	EQA, SWMAE, MDA, LGA	DOE, SWMA, LA, Director of Mines
Unlicenced blockage and diversion	SDBA, WA, SWMAE	LA, District Office, SWMA
Indiscriminate Development in Catchment Area	SWMAE, NFA	SWMA, State Forest Department
Enforcement of river and drain reserve	NLC, SWMAE	SWMA, DLM
Unauthorised disruption or taking of water from any water source	SWMAE	SWMA
Pollution of water courses	LGA, WA, WSE, SWMAE, MDA, EQA	LA, District Office, SWMA, JBA, Director of Mines, DOE
Contamination of soils	EQA, SWMAE	DOE, SWMA

4.4.6 The Proposed 'Safe Drinking Water Act'

At present the quality of treated water is based on the NDWQS, which is bench marked on the WHO standards. The 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. The passage of this Act is however fraught by difficulties on the constitutional issues pertaining to Federal and State rights. Notwithstanding this however, it may still be possible to codify these standards and guidelines under the respective State Water Supply or Water Resources Enactment. If groundwater is to be used for drinking purposes, it would additionally have to comply to these standards.

4.5 Establishing a Levy for Groundwater

4.5.1 Introduction

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 with the biggest users being Megasteel and Imuda Tin Mine.

4.5.2 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. However this is subject to a private right to take and use water for domestic and subsistence agriculture purposes where the land has a river frontage or where there occurs groundwater under the land; provided:

(1) It does not cause significant obstruction or diversion to the flow of water

(2) Do not store more than 1 megalitre of water.

(3) Do not take water at a flow rate exceeding 20 litres per second.

This would suggest that domestic wells and use of river water for subsistence agriculture, which are not subject to the above provisions, are not subject to a levy or a licence (s45(4)). 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". The charge wherever possible should reflect the economic cost of the resource.

4.5.3 Comparative Studies

Studies in Australia indicate that the income collected from levies is small compared to the issues that need to be addressed and the programmes that need to be carried out for the effective management of a water resource. Historically, no water based levy is charged on stock and domestic water users. The levy charged is also differentiated by users, for example, raw water sold to the Adelaide Water Supply Company is charged at AUS$10.00 (US$5.18) per megalitre compared to AUS$3.50 (US$1.81) per megalitre for agriculture users. This essentially depends on what the market is willing to pay for the commodity. Wine growers in the McClaren valley are willing to pay higher for good quality ground water compared to potato and wheat farmers in the Murray Basin.

Some of the programmes that are financed by the levy include:

(1) Survey of wells and the establishment of a compensation (cost sharing) fund. The cost-sharing fund is established to compensate for stock and domestic wells affected by the draw down.

(2) Assess reports on water use

(3) Community information and education programme

(4) Monitoring and Modelling

(5) Undertake research into key issues such as groundwater dependent ecosystems, impacts of saltwater intrusion resulting from groundwater abstraction, etc. Research and monitoring for saltwater intrusion is particularly important, since the cost for rectification works can be prohibitive.

(6) Develop and implement water allocation plans as well as evaluation programmes.

The proposed annual budget for the Mallee PWA is shown in **Table J.4.5**. The Mallee PWA is 150km east of Adelaide and has a permissible annual volume of 52,800 megalitres. The levy charged in the PWA is used to finance the programme. However it is noted that the current levy at AUS $3/Megalitre is insufficient to meet the expected expenditure. A significant part of the budget is for monitoring and modelling (13.9%), implementing WAP programme and its evaluation (9.9%), staff cost and programme administration cost (42.6%), while the budget for developing and implementing cost-sharing arrangement is 20.8%. (See **Table J.4.5**)

Table J.4.5 Plan for Implementing Groundwater Management Programmes in the Mallee Prescribed Wells Area

Item	Action	Budget 2001 $AUSD	%
1	Develop and implement cost sharing arrangement	42	20.8
2	Assess reports on water use	5	2.5
3	Inform and educate	9	4.4
4	Monitor and model	28	13.9
5	Undertake research on key issues	12	5.9
6	Develop and Implement WAP evaluation programme	20	9.9
7	Staff cost	57	28.2
8	Programme administration cost	29	14.4
	Total yearly budget	202	100.0

Source: River Murray Catchment Water Management Plan 2001

4.5.4 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. The charges imposed in South Australia are much lower at 0.35 sen/m^3 (Angus Bremer Prescribed Wells Area) and 0.30 sen/m^3 (Mallee PWA). The yields in these PWAs are much higher and most of the groundwater is used for irrigation. There is also no significant differentiation in the levy for surface water and groundwater in the Australian example. The rates used in Australia are historically applied and do not reflect the economic cost of the commodity.

Table J.4.6 Existing Charge Rates

Angus Bremer PWA (South Australia)	Mallee PWA (Murray Water Catchment Area)	Johore (proposed)
0.35 sen/m^3	0.30 sen/m^3	6.7 sen/m^3

4.5.5 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:

(1) The charge should take into account the economic cost of the resource.

(2) 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.

(3) 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.

(4) There are generally no charges imposed for the use of water for domestic use and subsistence agriculture as provided under the Enactment.

(5) 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.

(6) The indicator of value of water is the price the user is willing to pay for it. The charge should not significantly burden the user and should reflect the propensity of the market to pay for it. A social impact study is normally carried out before the Authorities decide on the charge rate.

4.5.6 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 65,7000 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:

(1) The revenue generated should at least meet cost of groundwater management in the Langat Basin.

(2) Infrastructure development cost of drilling and maintaining the wells will be met by private concessionaires and licenced operators.

(3) 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. (See **Table J.4.7**)

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. As in the Australian case, 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.

Since the cost for groundwater management in the Langat Basin may have to borne by both LUAS and JMG, it is appropriate that a cost sharing mechanism be worked out and a portion of the revenue collected by LUAS be allocated to support the groundwater programmes of JMG in the Langat Basin.

Table J.4.7 Financing the Groundwater Management Programme in the Langat Basin

No	Item	Unit	Unit rate	Annual Amount (RM)	%
	Revenue				
1.0	Annual sustainable yield	45000m^3/day x 365 days	RM0.04/m^3	657,000	
2.0	Annual sustainable yield	45000m^3/day x 365 days	RM0.06/m^3	985,500	
	Expenditure				
1.0	Monitoring/retrieval of data	40 wells x 2times /year	RM500/well	40,000	
2.0	Analysis of water quality	Est (see monitoring plan)		134,000	
3.0	Land subsidence measurement	Est (see monitoring plan)		16,000	
			Subtotal	**190,000**	35.2
4.0	Staff cost	Senior Hydrogeologist (1)	60000/yr	60,000	
		Hydrogeologist (2)	42000/yr	84,000	
		GIS expert (1)	36000/yr	36,000	
		Assistants (2)	25000/yr	50,000	
			Subtotal	**230,000**	42.6
5.0	Research	Provisional sum (Ps)		50,000	
6.0	Information and Education	Ps		20,000	
7.0	Assess reports on water use	Ps		10,000	
8.0	Evaluation of Water allocation plan (WAP)	Ps		40,000	
			Subtotal	**120,000**	22.2
			Total	**540,000**	100.0

4.6 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 J.4.8**. 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 J.4.8 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.

ANNEX J.2.1

LIST OF LEGISLATION RELATED TO GROUNDWATER DEVELOPMENT

Annex Table J.2.1
List of Legislation Related to Groundwater Development

List of Legislation Relevant to Groundwater Resources and Management (1/7)		
Federal Constitution	9th Schedule Legislative List Federal List Item 11	Federal works and power related to water supply, rivers and canals except those wholly within one state or regulated by agreement between the States concerned including production, distribution and supply of water power (hydro power)
	9th Schedule, State List Item 6	State to legislate on water (including water supplies, rivers, canals) control of silt, riparian rights
	Article 78	Restriction on any law made by Parliament in relation to any rivers wholly within a State.
	Article 76	Parliament may make laws on matters enumerated in the State Lists only for the purpose of implementing a treaty, uniformity of laws or if requested by the State Legislative. Except for the items under Article 76(4), all other Federal laws under the State list shall not come into operation until it is adopted by the State legislature.
	Article 75	In the event of inconsistency between Federal and State law , Federal law will prevail
	Article 93, 94 and 95	Federal Government to have executive authority in the following matters under the State List: i) inquiries, surveys and publication of statistics ii) conduct research and give advice and technical assistance iii) Inspect any department or work not within the exclusive legislative authority of the State.
Ministerial Functions Act 1969	Ministers of the Federal Government Order	
	EPU	National Economic Planning Development Budgeting Programme Development Aid
	Ministry of Finance , Budget Division	Preparation of expenditure budget and control of expenditure
	Public Works Department (JKR)	Development of roads, bridges, buildings and airports Development of Waterworks and water resources
	Mines department	Control of mining activities and Mineral resources
	Geological Survey department	Geological Survey
	Drainage and Irrigation	Flood mitigation Agricultural Drainage Irrigation River Conservancy Hydrology Coastal Engineering
	Department of Environment	Environmental Quality Council Prevention and Control of Environmental Pollution Protection and enhancement of the Quality of the Environment
	Town and Country Planning Department	Development and enhancement of physical, social, economic and environment system Town and Country Planning Act 1976
	Sewerage Services Department	Sewerage Services

List of Legislation Relevant to Groundwater Resources and Management (2/7)		
National Land Code 1965	S5	Land includes land covered by water and all things attached to the earth whether on or below the surface. River means any river, streams, creek or other natural water course or artificial deviation thereof
	S49	Encroachment of alienated land by river will render the land State land
	S62	SA to reserve land by notification in the Gazette
	S63	SA may lease reserve land for a period not more than 21 years
	S124, 124A and s135	Conversion and subdivision of land • Subdivision plan to conform to Local Plan for the area • Sufficient river and drain reserves to be met
	S70,72 & 74	Land Administrator to issue permit for extraction, removal and transportation of rock material and sand
Waters Act 1920 (revised 1989)	S2	Rivers to include tributary of river or any canal that is gazetted
	S3	Entire property and control of river in the State is vested solely in the Ruler of the State except for reserve land
	S4	SA to direct any person who interferes with river banks to restore the same
	S5	Prohibits acts affecting the River including the felling of trees into rivers, obstruct or interfere with any river, build any bridge or jetty except under license
	S7	Prohibition of diversion of any river except with license
	S 7A	Prohibits the pollution of rivers, inland waters and **subterranean water resources**
	S14	No building or structures within 50 feet from any bank or flood channel
SWMAE 1999	S2	Groundwater defined to mean subsurface water and includes wells and boreholes
	S41	Control on the use and flow of water including subsurface water is under the jurisdiction of the SA
	S44	The Authority may impose a charge for the abstraction of groundwater except for domestic and subsistence agriculture purpose subject to conditions of s45(3) • It will not cause significant obstruction or diversion to the flow of water • Store more than 1 megalitre of water • Abstract water at a flow rate exceeding 20 litres/sec
	S48	Power to establish zones of protection to safeguard any water source
	S56	Declaration of any wetlands and groundwater areas as designated areas
	S73	Where water table management is required the Authority to declare the area as problem soil area and develop a management plan
	S87	The power to license operators
	S78	The Authority may in consultation with DG of Environmental Quality prescribe acceptable conditions for discharge of waste in any designated area
	S79	Prohibition of pollution of a water source from poisonous matter, due to biological and chemical content, discolouring effect and oil

List of Legislation Relevant to Groundwater Resources and Management (3/7)		
SWMAE 1999	S122	Director to issue water protection order where there is an immediate threat to the quantity and quality of water
	S127(i)(j)	The Authority may make rules on the management, regulation and control of groundwater and wetlands
	S4(1)(g)	JMG is not a permanent member of the Authority but may be appointed under this section
	S26(2)(l)	The State Director of Geological survey is a member of the Technical Committee
Water Supply Enactment 1997	S2	Supply authority means Jabatan Bekalan Air Selangor or any authority established by law to supply water in Selangor Water supply area means an area within which a licensee is authorized to supply water.
	S4	SA may gazette any area as a water supply area
	S5	State Government may enter into a privatization agreement with any person to privatize the management, operation, distribution of water supply in any water supply area.
	S6	Duties of Director of Water Supply inter alia: • Advise the SA on issuance of license • Promote efficiency in the supply of water at reasonable prices • Advise the SA on matters related to water supply
	S10	Unless exempted no person other than the supply authority may operate a water supply system or services or abstract any water from any river without a license. License may be issued by the Director with the approval of the State
	10(10)	Any license issued shall set out • The water supply area • Tariff payable • Annual license fee payable • Rights and duties of licensee • Minimum quality of water required
	S22	A licensee to erect and maintain adequate fencing around treatment plants
	S23 (repealed)	SA may declare any lake, river or waterway or its surroundings to be a catchment area. The order shall define the boundaries and specify activities which are prohibited in the area
	S24 (repealed)	SA may make regulations to prohibit or regulate activities within the area
	S26 and 31	Licensee may enter to a separate agreement with the owner or occupier of any premise for private water supply provided the agreement is approved by the Director
	S35	SA by notification in the gazette prescribe the charges to be paid by any person to whom water is supplied
	S48	When water supply is insufficient due to drought the State may declare a water supply emergency and limit the quantity of water
	S52 (1) (repealed)	The SA may declare in the gazette the location of wells built by the Director or the licensee for the supply of water
	S52 (2) (repealed)	Any persons to intends to sink a well within ½ km of a **gazetted well** requires a license to do so. The well does not include one that yields less than 2500litres/day and is used for domestic purposes.

List of Legislation Relevant to Groundwater Resources and Management (4/7)		
Water Supply Enactment 1997	S53 (repealed)	The penalty for building a well without a license or contravening the conditions of the license is a fine not exceeding RM50000 or imprisonment up to 2 years or both.
Local Governments Act	S69,70 and 71	LA has power to recover any expenses to carry out work resulting from any person who commits a nuisance or deposits any filth in any watercourse.
	S73 (a)(ii) and (b)(i)	LA may make bylaws to keep water courses clean. By laws to have effect upon approval by State Authority
	S101(ee)	Power to divert or canalize any watercourse subject to consent from appropriate authorities
Streets Drainage Building Act	S50	LA to construct/ cause to be constructed and maintain surface and storm water drains, culverts and gutters and watercourses. SA may acquire land for such purpose
	S53	LA to maintain, repair, alter discontinue or close any surface or storm water drain
	S70A	No person to commence earthworks without first submitting and obtaining approval from LA
Irrigation Areas Act (revised 1989)		Act to enable provision of water for agricultural purposes SA empowered to declare irrigation areas in the gazette Prohibition on interference of irrigation works
Drainage Works Ordinance 1954	S2	Drainage works includes the construction and maintenance of drains, water courses, embankments, culverts, water gate, access path in drainage reserves
	S3	SA to declare any area in the State as Drainage Area and specify the boundary
	S4	SA to appoint a Drainage Board in respect of every drainage area
	S8	SA to impose drainage rates to meet cost of drainage works. No rate to be collected unless drainage work is completed
	S10	Mode of collection similar to that for land revenue
Earthwork By Laws	These by laws are formulated under the provisions of s70A SDBA	LA to control earthworks to prevent soil erosion, disturbance and pollution. LA may impose conditions e.g. • Drainage provision of adequate bunds and culverts • Silt traps • Retaining structures • Slopes protected against erosion • Surface roads to be sealed • Fills are compacted
Town and Country Planning Act	S4	Establishment of the State Planning Committee
	S8	LA to prepare Structure Plans
	S12	LA to prepare Local Plans
	S18	No person shall use land or building unless it conforms to the Local Plan
	S19	No person to commence development without planning permission
	S21A	An application for planning permission to be supported by the Development Proposal Report (LCP) and a Layout Plan
	S30	LA to issue requisition notice to land owner to discontinue any use or impose new conditions for the continued use
	S32	LA may impose development charge where Local Plan effects a change of use or density to enhance the value

List of Legislation Relevant to Groundwater Resources and Management (5/7)		
Town and Country Planning Act	S37	Landowner to serve Purchase Notice on LA if his land is to be used for public purpose
	S38	Declaration of Development Area. LA to acquire the land by purchase or compulsory acquisition.
Environmental Quality Act 1974	S4	Establishment of the Environmental Quality Council
	S10	Director General shall be the licensing Authority
	S18	Prescribed Premises to be licensed
	S21	Minister to specify acceptable conditions for emission, discharge or deposit of waste
	S24	Restrictions on the pollution of the soil and includes refuse dump, sludge disposal site that might interfere with underground water.
	S25	Restriction on pollution of inland waters. Prohibits the discharge of waste in any inland water including rivers, streams, drains
	S31	DG may by notice in writing require the occupier of any premise to install and operate control equipment
	S34A	The project proponent of a prescribed activity is required to submit an EIA to the DG before an approval for the project is granted by the relevant Authority.
	S51	Minister may make regulations prescribing standards and criteria
Environmental Quality Order 1987 (prescribed Activities)	Drainage and Irrigation	• Construction of dams with surface area more than 200ha • Drainage of wetlands covering more than 100ha • Irrigation Schemes more than 5000ha
	Forestry	• Conversion of hill forest land more than 50ha • Conversion of mangrove swamps more than 50ha.
	Housing	• Area more than 50ha
	Industrial Estate	• Area more than 50ha
	Mining	• Sand dredging (more than 50ha)
	Water Supply	• **Groundwater Development for industrial, agricultural or urban water supply greater than 4500 cu.m per day**
Land Conservation Act 1960	S1	The Act has to be adopted by the States before it comes into operation. Selangor has adopted it by virtue of En.7/1960
	S3	Hill area has to be gazetted
	S5	Prohibits short term crop except with permit
	S6	Prohibits land clearing except with permit
	S10	Land Administrator to enforce the terms and conditions of the permit and the cost can be recovered from the owner
	S11	Power to control sources of soil erosion
Mining Enactment 1936 (FMS Cap 147)	S61	Entire property and control of waters of all rivers, streams and water course shall be in the Ruler of the State
	S62	The occupier of any mining land shall may not alter the water supply of any lands without the sanction of the Inspector
	S64	No interferences with the river banks unless permitted
	S65	Need for a license to divert, make use of and discharge water

List of Legislation Relevant to Groundwater Resources and Management (6/7)		
Mining Enactment 1936 (FMS Cap 147)	S69	Ruler in council may set conditions for water use and allow the construction of pipes, pumps, drains dams for effective mining purposes.
	S74	All water used in mining operations be free of hazardous chemicals and excessive solid matters before it is discharged to a river or natural water course.
	S84	A license is required to commence any underground workings
Mineral Development Act 1994		An act for the inspection and regulation of the exploration and mining of minerals.
	S3	Mineral is any substance in solid, liquid or gas formed by a geological process but excludes water, rock material and petroleum
	S4	Minister to appoint Director General of Mines, Deputy DG and Directors of Mines
	S5	DG to exercise supervision and control on the safety aspects relating to mines, movement, storage and processing of mineral ores Obtain information and keep records
	S10	Proprietor to submit to Director of Mines an operational mining scheme including the date of commencement, annual raw ore production, plans of the workings of the mine. Failing to submit an OMS is liable to a fine of not more than RM 100000 Director to approve the mining scheme
	S11	Prospecting licence and exploration licence holders to sent a written notice to DG of Geological Survey
	S13	Fossicking, panning, exploration, mining and mineral processing to comply to environmental standards
	S18	Water before it leaves the mine to comply to prescribed water quality standards and be reasonably free of solid matter and harmful chemicals. The Asst. Director to enforce this provision
	S19	There is a duty on the mine operator to minimize erosion of land and prevent silt to be discharged to any river or drainage system
National Forestry Act 1984	S7	The SA to constitute any land as permanent forest reserve
	S10	Director to classify permanent forest reserve (11classes) such as timber production forest, soil protection forest, flood control forest, water catchment forest etc.
	S15	Prohibition of taking forest produce without a license
	S20	Licensee to prepare forest harvesting plan and a reforestation plan
	S56	The SA to establish a Forest Development Fund
Incorporation (State Legislatures Competency) Act 1962	S3	State Legislature may incorporate any person or body in relation to matters in the 1st Schedule (17 items) including water supply and water resources management
	S3A	Special provisions of the 2nd Schedule to apply in respect of incorporation for purposes of agricultural development, housing development or the development of urban and rural areas.
Geological Survey Act 1974	S6	Minister with the concurrence of the SA by notification in the gazette designate the area to be surveyed

List of Legislation Relevant to Groundwater Resources and Management (7/7)		
Geological Survey Act 1974	S7	Authorized person may enter any land in designated area after serving notice for purpose of geological survey
	S13	The DG to be notified if any person sinks a well to extract water. Exempted from notification • if well is less than 30feet deep without reaching bedrock • yield less than 500 gal of water used only for domestic purposes
Proposed Amendments to Geological Survey Act 1974	S5A	The DG may authorize any Geological survey officer to undertake research and development
	S13	i) Any person who intends to sink a well, enlarge, deepen or close a well shall refer to the DG before commencing work. ii) A well has an abstraction rate exceeding 2500 litres per day. iii) Person sinking the well shall keep records of all works and test and send a copy to DG in the prescribed manner.
Draft Regulations for well drilling	See Draft Rules	Any person who intends to develop a well for purposes of abstracting ground water shall apply to the Authority for a license. The Authority is the Government agency responsible for the supply of water and water resource management in the state.
Draft regulations for groundwater abstraction	See Draft Rules	Any person who intends to pump or abstract groundwater from a well shall apply for a license from the Authority.
Draft Regulations for groundwater monitoring	See Draft rules	A licensee shall establish, equip and maintain monitoring wells.
		Monitoring wells are required for every licensed production well.
		The licensee shall submit the monitoring data to the Authority with a copy to the State dept of Minerals and Geoscience. The type of information to be submitted to include ground water level and ground water quality.

ANNEX J.2.2

REGULATIONS AND ORDERS MADE UNDER THE ENVIRONMENTAL QUALITY ACT, 1974

Annex Table J.2.2
Regulations and Orders Made Under the Environmental Quality Act, 1974

1.	Environmental Quality Act, 1974 Amendment 1975, 1985, 1996, 1998
2.	Environmental Quality (Prescribed Premises) (Crude Palm Oil) Order 1977 Amendment, 1982
3.	Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulations 1977
4.	Environmental Quality (Licensing) (Crude Palm Oil) Regulations 1977
5.	Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations 1978 Amendment, 1980
6.	Environmental Quality (Clean Air) Regulations 1978
7.	Environmental Quality (Compounding of Offences) Rules 1978
8.	Environmental Quality (Sewage and Industrial Effluents) Regulations 1979 Amendment, 1997
9.	Environmental Quality (Control of Lead Concentration in Motor Gasoline) Regulations 1985
10.	Environmental Quality (Motor Vehicles Noise) Regulations 1987
11.	Environmental Quality (Prescribed Activities) (Environment Impact Assessment) Order 1987 Amendment, 1995
12.	Environmental Quality (Scheduled Wastes) Regulations 1989
13.	Environmental Quality (Prescribed Premises) (Scheduled Wastes Treatment and Disposal Facilities) Order 1989
14.	Environmental Quality (Prescribed Premises) (Scheduled Wastes Treatment and Disposal Facilities) Regulations 1989
15.	Environmental Quality (Delegation of Powers on Marine Pollution Control) Order 1993 Amendment, 1994
16.	Environmental Quality (Prohibition on the Use of Chloroflurocarbons and Other Gases as Propellants and Blowing Agents) Order 1993
17.	Environmental Quality (Prohibition on the Use of Substance in Soap, Synthetic Detergent and Other Cleaning Agents) Order 1995
18.	Environmental Quality (Control of Emission from Diesel Engines) Regulations 1996
19.	Environmental Quality (Control of Emission from Petrol Engines) Regulations 1996
20.	Environmental Quality (Refrigerant Management) Regulation 1999
21.	Environmental Quality (Halon Management) Regulation 1999
Other Associated Regulations	
22.	Custom Duties (Amendment) (No 35) Order, 1989 (made under the Customs Act 1967)
23.	Promotion of Investment (Promoted Activities and Products) (Amendment) (No 10) Order, 1990 (made under the Promotion of investment Act 1986)
24.	Customs (Prohibition if Import) (Amendment) (No. 2) Order 1993
25.	Customs (prohibition of Export) (Amendment) (No. 3) Order 1993
26.	Sarawak Natural Resources and Environment (Prescribed Activities) Order 1994

ANNEX J.2.3

WATER QUALITY STANDARDS AND FREQUENCY OF MONITORING

Annex Table J.2.3
Water Quality Standards and Frequency of Monitoring

PARAMETERS	RAW WATER		STANDARD	DRINKING WATER		
				FREQUENCY OF MONITORING		
	Recommended Acceptable Value	Frequency of Monitoring		Treatment Plant Outlet	Service Reservoir Outlet	Distribution System
MICROBIOLOGICAL: TOTAL COLIFORM	5000	w	MPN Method • Should not exceed 10 MPN/100ml • Should not be detectable in 2 consecutive samples • Throughout a year coliform in 100ml should not be detected in 95% of samples **MEMBRANCE FILTER Method:** • Arithmetic mean of all monthly samples is 3 colonies/100ml • Not more than 4 colonies/100ml in 2 consecutive samples	W	W	W
FAECAL COLIFORM	-	-	Absent in 100ml sample	WN	W	M
FAECAL STREPTOCCOCI CLORSTRIDIUM PERFRINGES VIRUSES PROTOZOA HELMINTHS	-	-	Absent	WN	WN	WN
PHYSICAL-GROUP I:						
TURBIDITY	1000	W	5	w	w	M
COLOUR	300	W	15	w	w	M
pH	5.5-9.0	W	6.5-9.0	w	w	M
FREE RESIDUAL CHLORINE	-	-	Not less than 0.2	w	w	M
COMBINED RESIDUAL CHLORINE	-	-	Not less than 10	w	w	M
INORGANIC-GROUP II:						
TOTAL DISSOLVED SOLIDS	1500	M	1000	M	M	Y/2
CCE	0.5	M	0.5	M	M	Y/2
BIOCHEMICAL OXYGEN DEMAND	6	M	-	-	-	-
CHEMICAL OXYGEN DEMAND	10	M	-	-	-	-
CHLORIDE	250	M	250	M	M	Y/2
ANIONIC DETERGENT MBAS	1.0	M	1.0	M	M	Y/2
AMMONIA (As N)	0.5	M	0.5	M	M	Y/2
NITRATE (As N)	10	M	10	M	M	Y/2
TOTAL NITROGEN as N (excluding NO_3)	1.0	M	-	-	-	-
IRON	1.0	M	0.3	M	M	Y/2
FLOURIDE	1.5	M	0.9	M	M	Y/2
HARDNESS	500	M	500	M	M	Y/2
ALUMINIUM	-	-	0.2	M	M	Y/2
MANGANESE	-	-	0.1	M	M	Y/2
GROUP III:						
MERCURY	0.001	Y/4	0.001	Y/4	M	Y/2
CADMIUM	0.005	Y/4	0.005	Y/4	M	Y/2
SELENIUM	0.01	Y/4	0.01	Y/4	M	Y/2
ARSENIC	0.05	Y/4	0.05	Y/4		
CYANIDE	0.1	Y/4	0.1	Y/4		
LEAD	0.1	Y/4	0.05	Y/4	Y/2	Y
CHROMIUM	0.05	Y/4	0.05	Y/4	Y/2	Y
SILVER	0.05	Y/4	0.05	Y/4	Y/2	Y
COPPER	1.0	Y/4	1.0	Y/4	Y/2	Y
MAGNESIUM	150	Y/4	150	Y/4	Y/2	Y
MANGANESE	0.2	Y/4	0.1	-	Y/2	Y
ZINC	1.5	Y/4	1.5	Y/4	Y/2	Y
SODIUM	200	Y/4	200	Y/4	Y/2	Y
SULPHATE	400	Y/4	400	Y/4	Y/2	Y
MINERAL OIL	0.3	Y/4	0.3	Y/4	Y/2	Y
PHENOL	0.002	Y/4	0.002	Y/4	-	-
CHLOROFOAM	-	-	0.03	Y/4	Y/2	Y
GROUP IV:						
TOTAL ORGANOCHLORINE PESTICIDES	0.1	Y/4	0.1	Y/4	WN	WN
ALDRIN/DIELDRIN	0.00003	Y/4	0.00003	Y/4	WN	WN
CHLORDANE	0.003		0.0003			
DDT	0.001	Y/4	0.001	Y/4	WN	WN
HEPTACHLOR&HEPTACHLOR EPOXIDE	0.0001	Y/4	0.0001	Y/4	WN	WN
HEXACHLOROBENZENE	0.00001	Y/4	0.00001	Y/4	WN	WN
LINDANE	0.003	Y/4	0.003	Y/4	WN	WN
METHOXYCHLOR	0.03	Y/4	0.03	Y/4	WN	WN
HERBICIDES :2, 4-D	0.1	Y/4	0.1	Y/4	WN	WN
RADIOACTIVITY						
GROSS α	0.1	Y	0.1	Y	WN	WN
GROSS β	1.0	Y	1.0	Y	WN	WN

Source : Ministry of Health

W indicates parameters to be monitored at least once a week
M indicates parameters to be monitored at least once a month
Y/4 indicates parameters to be monitored at least once in 3 months
Y/2 indicates parameters to be monitored at least once in 6 months
Y indicates parameters to be monitored at least once a year
WN indicates parameters to be monitored when necessary

Note :

Collection of samples of both raw water and treated water examination for toxic substances should be carried out more frequently if values above the acceptable values are known to be present in the source of supply, or where such potential pollution exists.

ANNEX J.2.4

DRAFT REGULATIONS FOR WELL DRILLING, GROUNDWATER ABSTRACTION AND GROUNDWATER MONITORING

Annex Table J.2.4
Proposed Regulations for Well Drilling
– Jabatan Minerals dan Geosains

1. Any person who intends to bore, dig, drill or construct a well for the purpose of pumping or abstracting groundwater or recharging groundwater shall apply to the authority for a licence to do so.

2. Any person who intends to deepen, enlarge or alter an existing well shall apply to the authority for a licence to do so.

3. Drilling and well construction shall be carried out only by registered drillers.

4. A licence for the drilling of a well shall not include the right to inject any hazardous material into the ground.

5. Application for a well drilling licence shall be made in a prescribed form (Schedule 2 – FORM GWR-1) and shall be accompanied by a written consent of the owner of the property on which the well is to sited.

6. The authority shall prescribe the fees (Schedule 3) payable in respect of a licence, transfer or renewal thereof.

7. No work shall commence until a written approval has been obtained from the authority.

8. Any licence issued shall remain valid for a period of 12 calendar months. The licence may be extended or renewed upon application.

9. The licencee shall prepare and submit a report in a prescribed form (Schedule 4 – FORM GWR-2) to the authority, with a copy to the State Department of Minerals and Geoscience within 3 calendar months of completion of the works. The licencee shall also provide any other information that may be required from time to time.

10. The authority shall be notified of any intention to abandon any borehole/well. Such abandonment shall be carried out in a manner that will not contaminate the aquifer in the area. The well record form (Schedule 4 – FORM GWR-2) shall be submitted and filled with relevant information within 3 calendar months of completion of the works.

11. The authority may direct the licencee to take any measures, as it deems necessary to ensure that the groundwater resources are protected.

12. The licencee shall retain representative samples of earth, rock materials or cuttings, or any liquid encountered during the drilling operations for inspection by the authority for 1 calendar month after submission of the report of works.

13. The authority may impose other conditions as deemed necessary.

14. Any person, who fails to obtain a licence prior to the boring, digging, drilling and of a well, or who contravenes any conditions imposed in such a licence shall be guilty of an offence.

Proposed Regulations for Groundwater Abstraction and Monitoring
- Jabatan Minerals dan Geosains

A. Regulations for Groundwater Abstraction

1. Any person who intends to pump or abstract groundwater from a well shall apply for a licence from the authority.

2. A maximum quantity of pumping shall be prescribed by the authority for each well or a group of wells on a daily/monthly/yearly basis. The pumping rate may be reviewed by the authority as deemed necessary from time to time.

3. The authority shall prescribe the fees payable in respect of the issuance, transfer or renewal of a licence thereof (Schedule 6).

4. Application for a groundwater abstraction licence shall be in a prescribed form (FORM GWR-3).

5. The licence granted for the groundwater abstraction shall be valid for 12 calendar months or such period the authority may approve after which the licence may be renewed upon application.

6. The authority may issue a licence subject to further conditions as deemed necessary.

7. The authority may suspend or revoke a licence that has been issued.

8. Any person who fails to obtain a licence from the authority prior to the abstraction of groundwater, or who contravenes any conditions imposed in such a licence shall be guilty of an offence.

B. Regulations for Groundwater Monitoring

1. Any person who holds a licence to abstract groundwater shall establish, equip and maintain monitoring wells (Schedule 4) for the purpose of monitoring the quantity and water level of the groundwater in his property (Schedule 5).

2. Regardless of the amount of groundwater abstracted, monitoring wells are required for every licenced production well. The layout plan and the design of the monitoring wells shall be provided by the licencee.

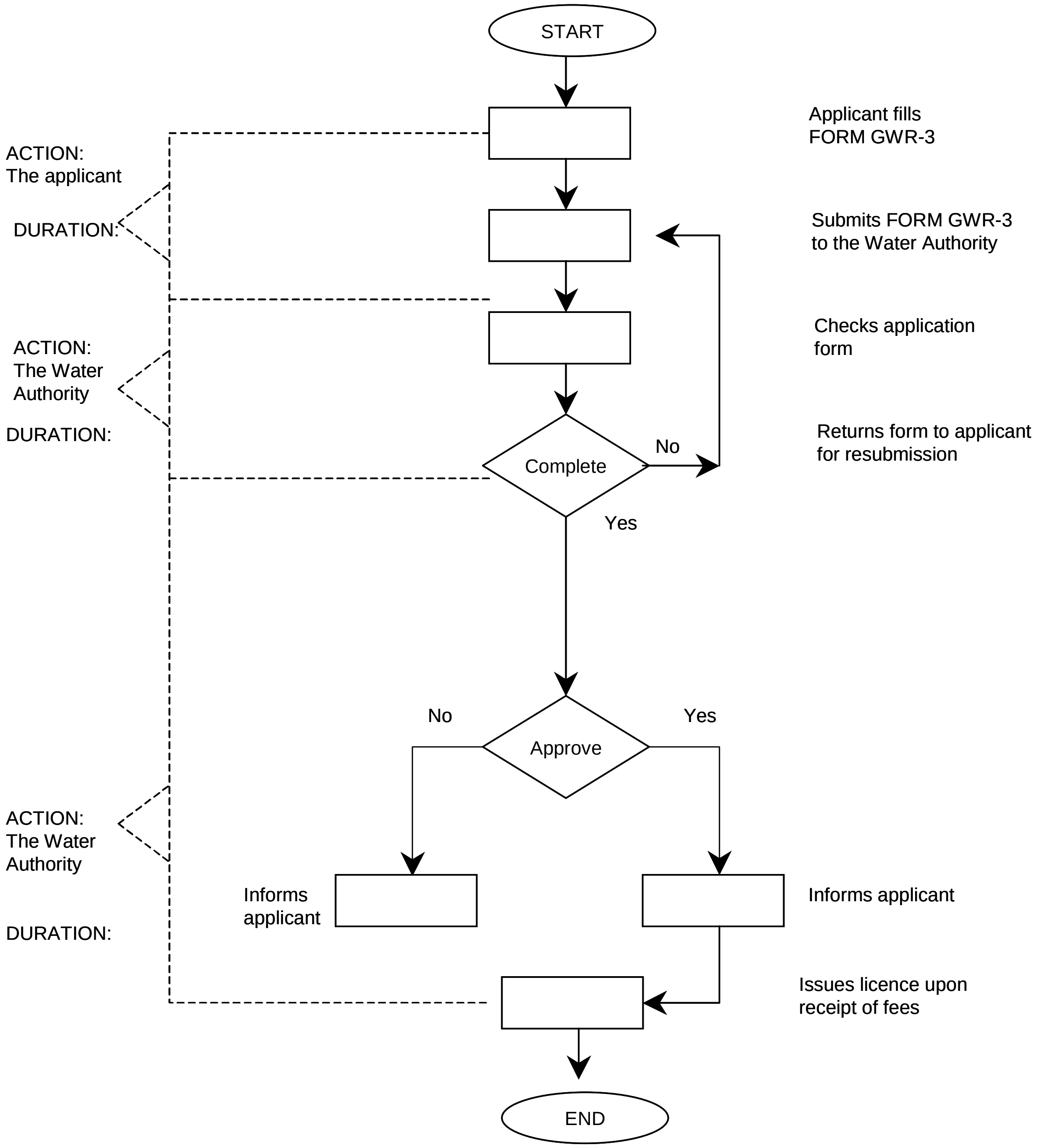
3. No abstraction shall be allowed to commence until the authority is satisfied that the monitoring wells are in place and operational.

4. The authority may at any time direct the licencee to construct new monitoring wells and to equip and maintain wells.

5. The licencee shall submit the monitoring data (FORM GWR-4) to the authority with a copy to the State Department of Minerals and Geoscience.

6. The authority shall, at all times, be allowed access into the property or premise of the licencee to carry out monitoring checks.

REGULATION FOR GROUNDWATER ABSTRACTION & MONITORING
FLOW CHART



Source : JMG

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

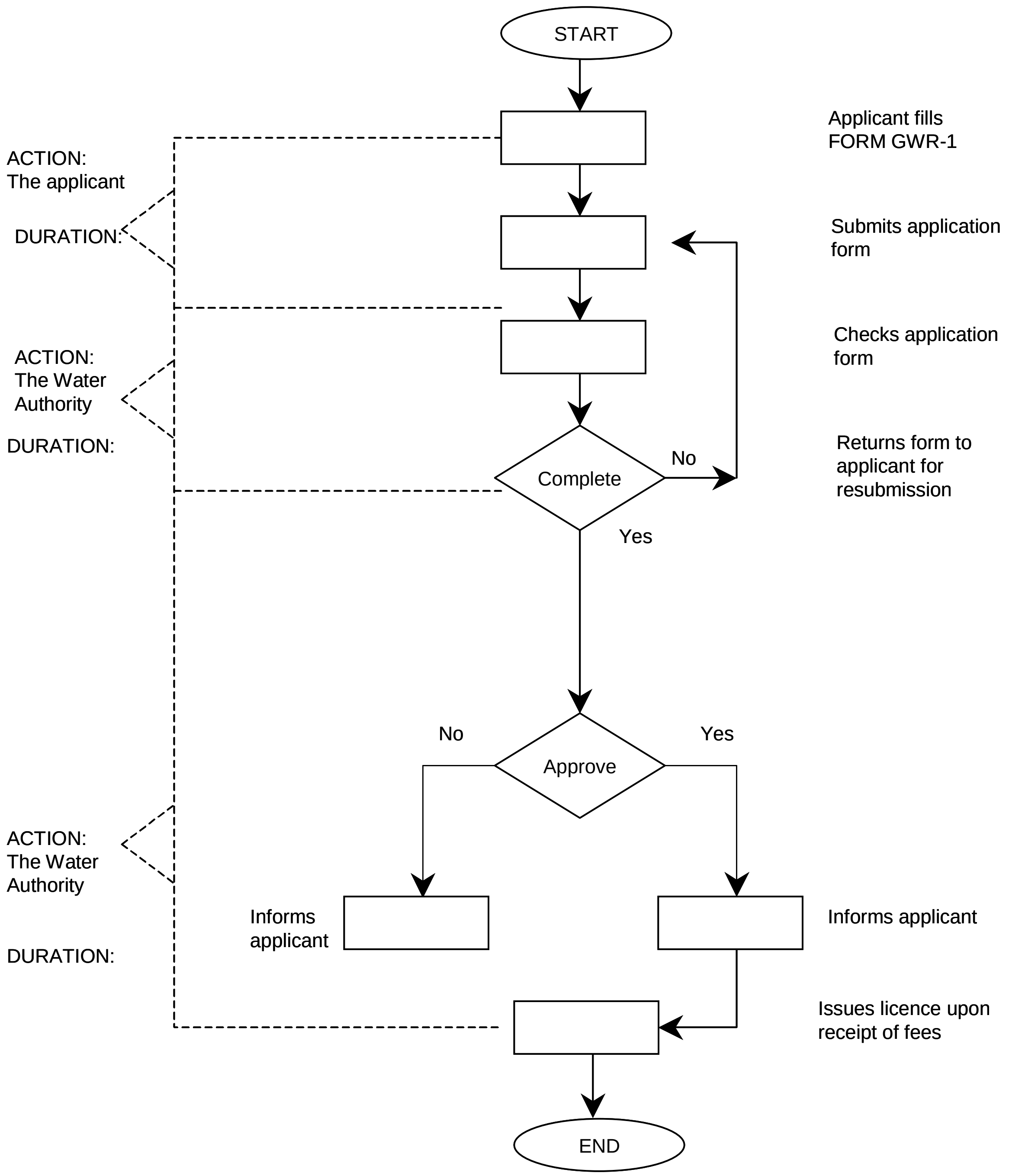
THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

CTI Engineering International Co., Ltd. OYO CORPORATION

Annex Figure J.2.1

Obtaining a Licence for Groundwater Abstraction

REGULATION FOR WELL DRILLING
FLOW CHART



Source : JMG

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Minerals and Geoscience Department Malaysia

Annex Figure J.2.2

Obtaining a Licence for Well Drilling

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ANNEX J.3.1

FUNCTIONAL RESPONSIBILITIES OF KEY AGENCIES INVOLVED IN GROUNDWATER DEVELOPMENT

Annex Table J.3.1
Functional Responsibilities of Key Agencies Involved in Groundwater Development

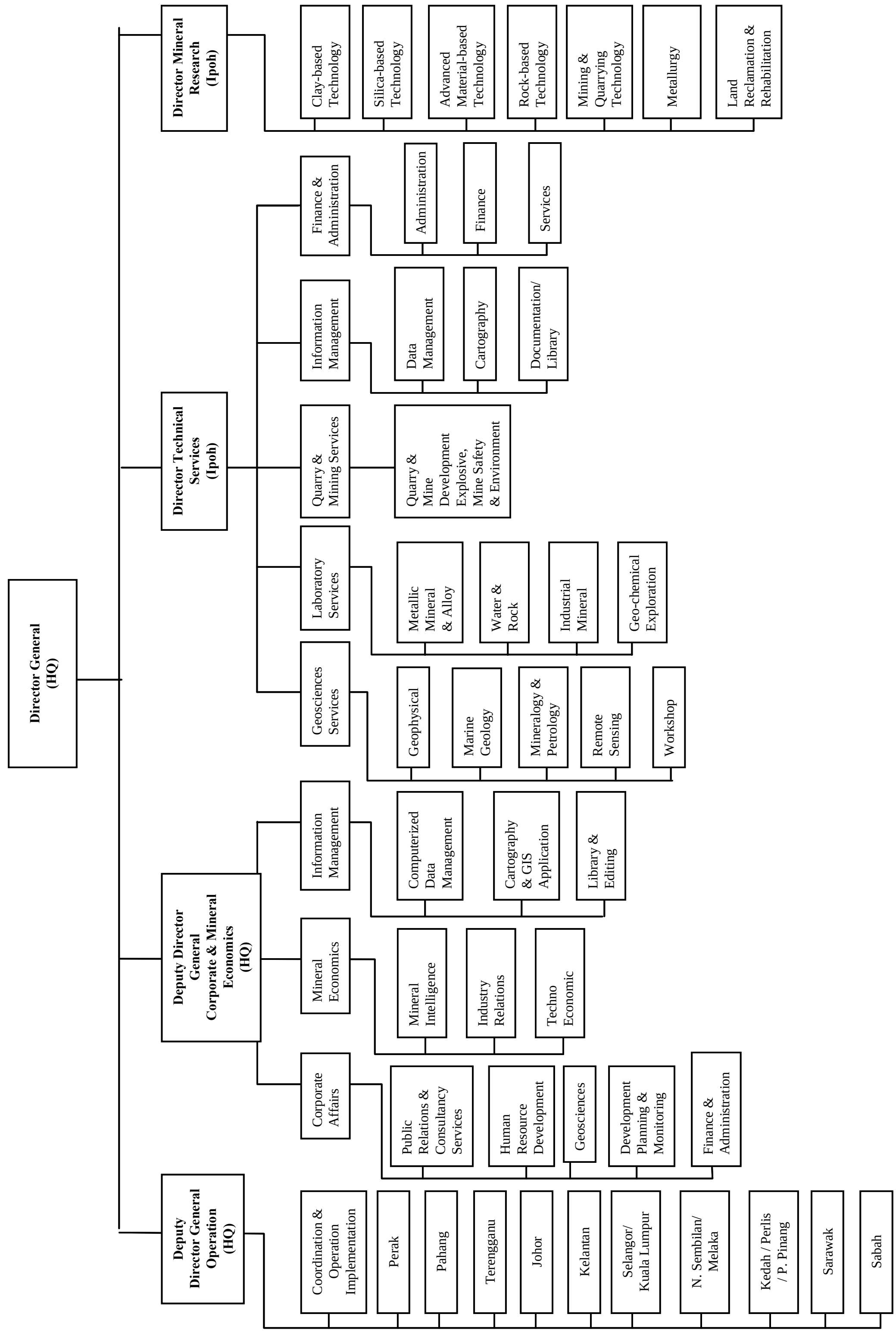
Agency	Functions	Notes
EPU	National development policy, development budgets	
National Water Resources Council	• Formulation of a National Water Policy • Resolution of water resources disputes between states • Coordination of river basin development to facilitate interbasin and inter state water transfer • Ensure long term sustainability of water supply • Establish tariff formula and quality standards for raw water • Ground water use and development • Recycling of water especially for industrial use	
State Planning Committee	• Promote the conservation ,development and use of all lands in the state • Give directions to Local Authority on matters related to town planning • Approve Draft Structure Plans • Collection and publication of information and statistics on town planning	Town and Country Planning Act 1976
JMG	Technical Department for Ground water development including hydrogeology, data inventory and mapping functions i.e • Systematic ground water resource assessment • Exploration and development of groundwater as an alternative water resource in water stress areas • Develop a hydro-geological database • Preparation of	Functions to be incorporated under the MFA Geological Survey Act 1974

Agency	Functions	Notes
	groundwater resource maps and other hydro-geological maps	
Public Works Department (Waters Branch)	• Provides consultation and technical advise to the State Water Authorities • coordinates all water supply projects funded by the Federal Government. • Implementation of water supply schemes for Federal Land Development Authorities (Felda) • Maintaining Engineering standards for water supply practise • Setting standards and criteria for design, operation and maintenance of water supply systems • Standardization of water supply specifications for use by the State Water Authorities • Development of Water Supply in the Federal Territory of Labuan	
JBA	• Water Supply Authority • Responsible for the distribution of treated water in the State • Establishes standards for the quantity and quality of treated water • Advise the State on the issuance of license to persons to operate water supply system or services or abstract any water from a river.	Water Supply Enactment 1997
SWMA	• The management, regulation and control of groundwater. • Declaration of designated areas or problem soil area • Imposition of charges for groundwater abstraction • Power to issue licenses to operators	Selangor Waters Management Authority Enactment 1999

Agency	Functions	Notes
	• Director may issue water protection order if there is a serious threat or risk of pollution • The Authority in consultation with DOE prescribe acceptable conditions for the emission or discharge of waste into any designated area	
DID	• Flood Mitigation • Agricultural Drainage • Irrigation • River Conservancy • Hydrology • Coastal Engineering	MFA 1969. Irrigation Areas Act 1953 Drainage Works Act 1954
Malaysian Wetlands Foundation	• Management of Paya Indah Wetlands • Rehabilitate, conserve and sustainable development of wetlands • Promote research	
DOE	• Prevention and Control of environmental pollution • Protection and enhancement of the quality of the environment • Implementation of EIA/ EMP requirements for prescribed projects	Environment Quality Act 1974

ANNEX J.3.2

ORGANISATIONAL CHART OF RELEVANT AGENCIES TO GROUNDWATER DEVELOPMENT



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Annex Figure J.3.1

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

Organisational Chart of Mineral and Geoscience Department (HQ)

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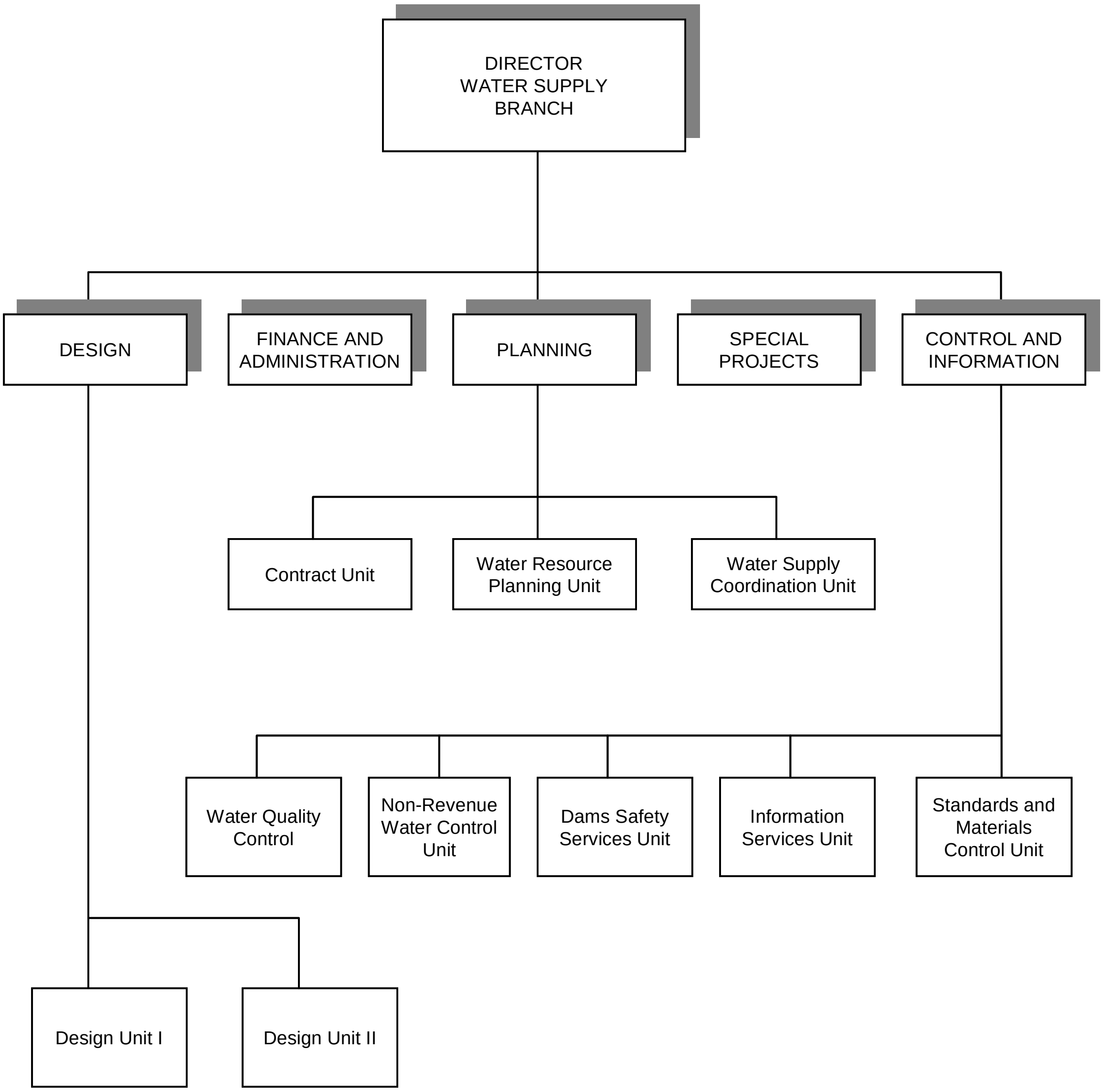

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THE STUDY ON THE SUSTAINABLE GROUNDWATER RESOURCES AND ENVIRONMENTAL MANAGEMENT FOR THE LANGAT BASIN IN MALAYSIA

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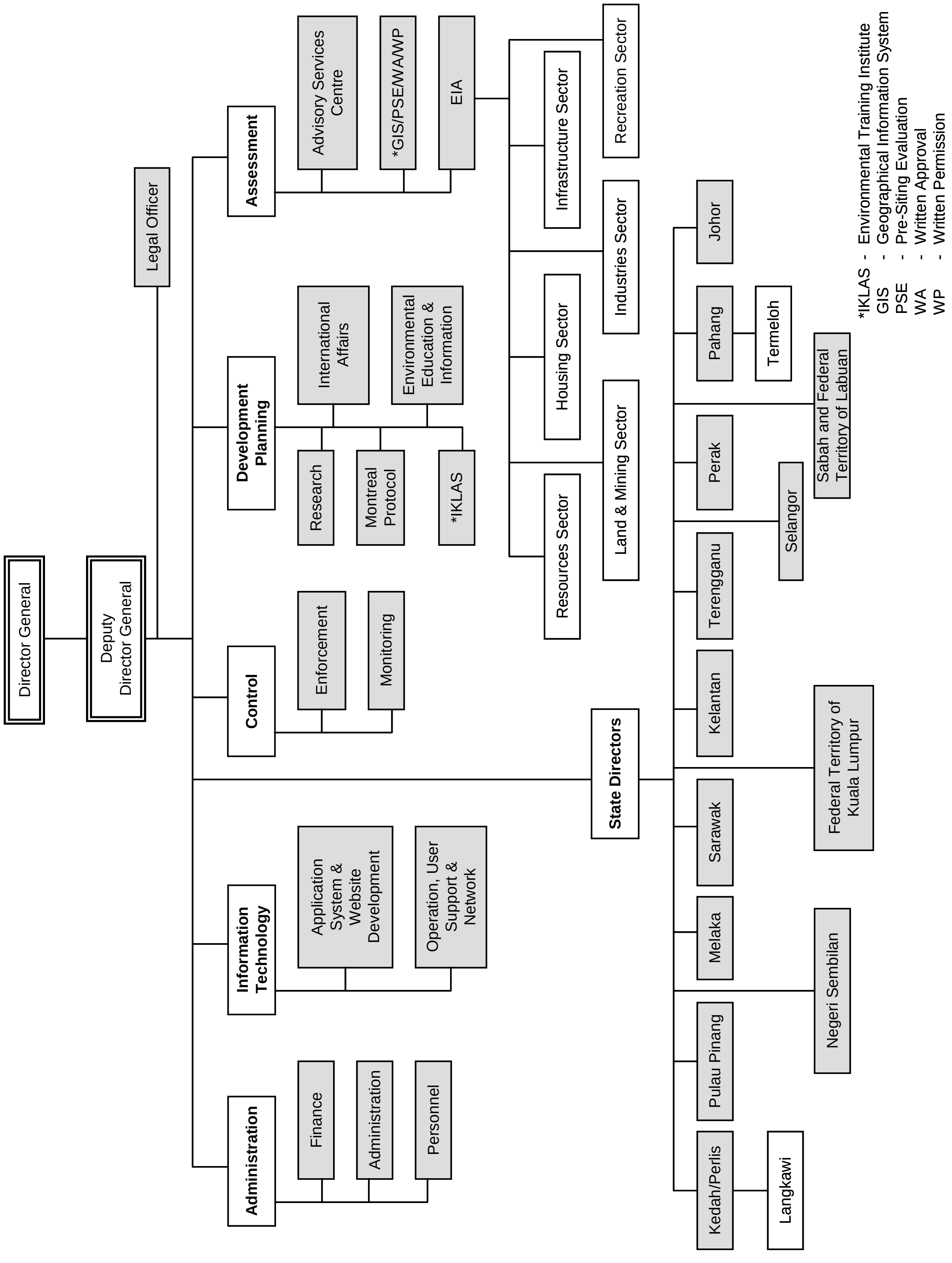
Annex Figure J.3.2

Organisational Chart of the Public Works Department (Water Supply Branch)



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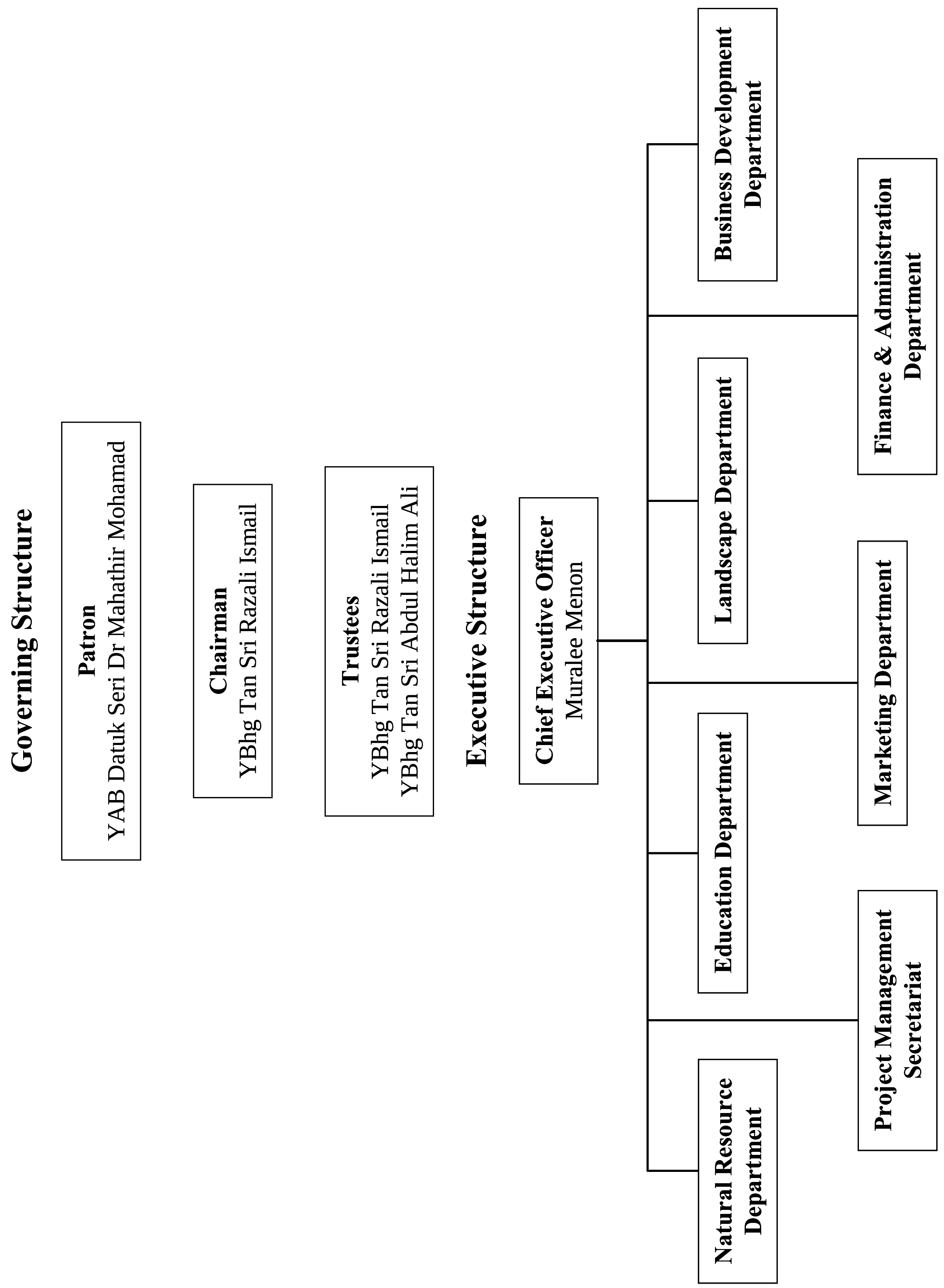
Annex Figure J.3.3

Organisational Chart of Department of Environment



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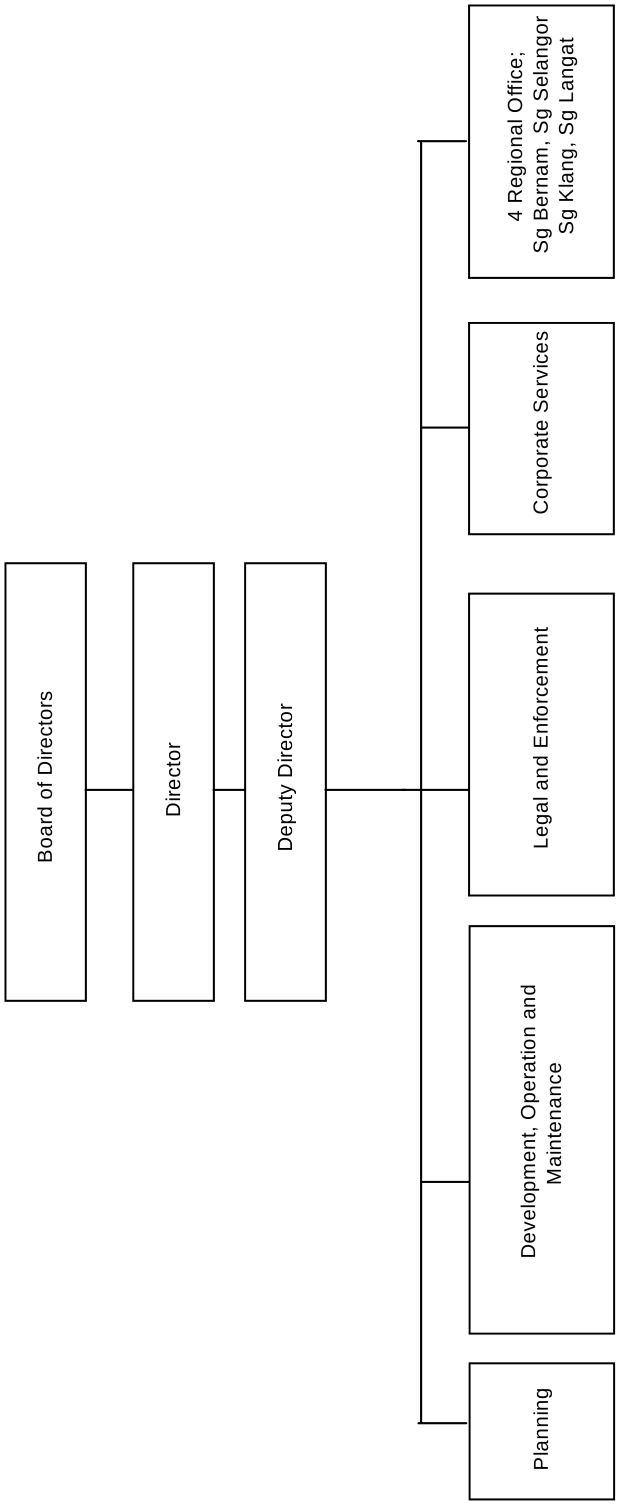
Annex Figure J.3.4

Organisational Chart of Malaysian Wetlands Foundation



Source: Selangor Waters Management Authority

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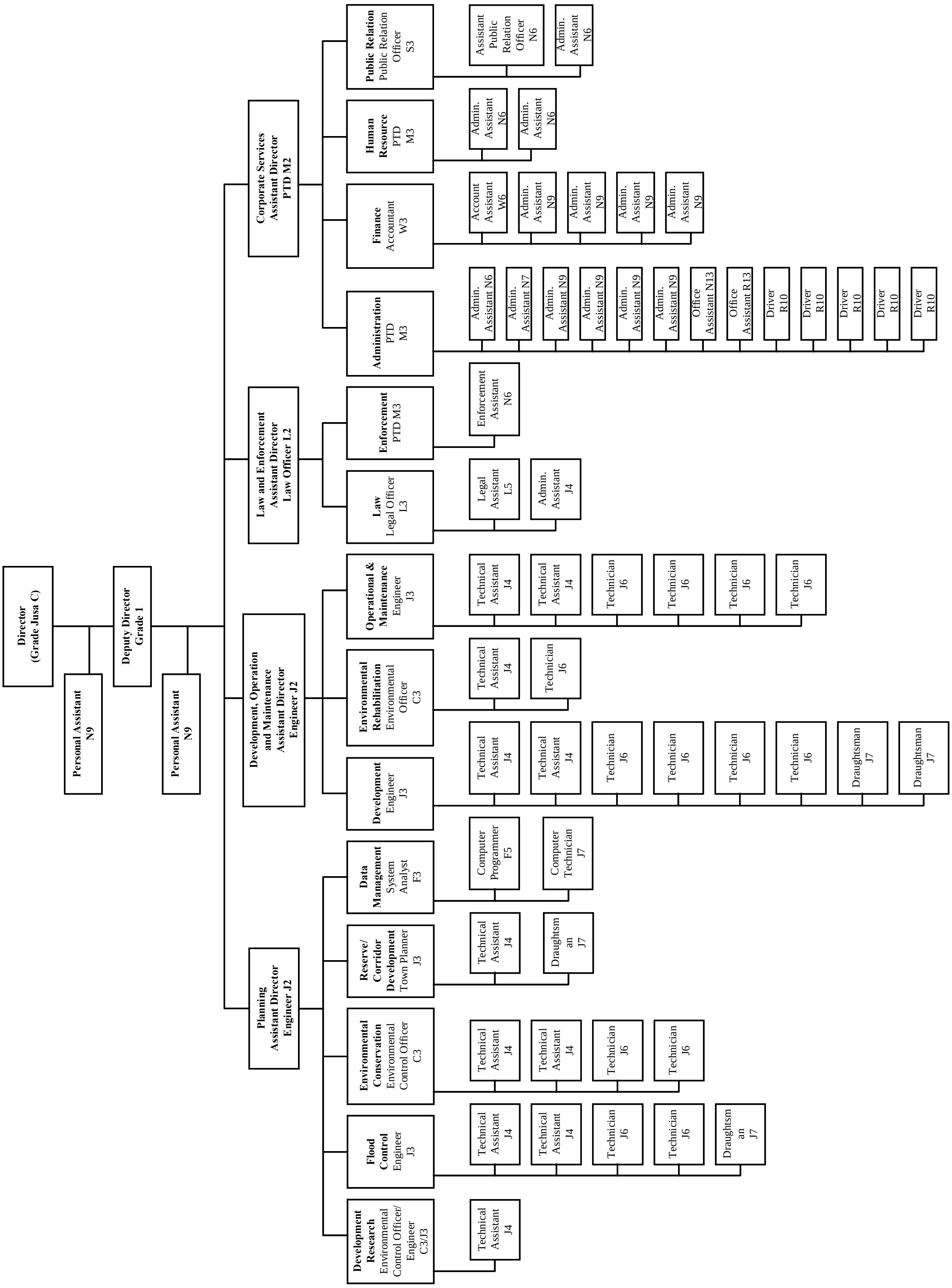
Annex Figure J.3.5

Organisational Chart of the Selangor Water Management Authority



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

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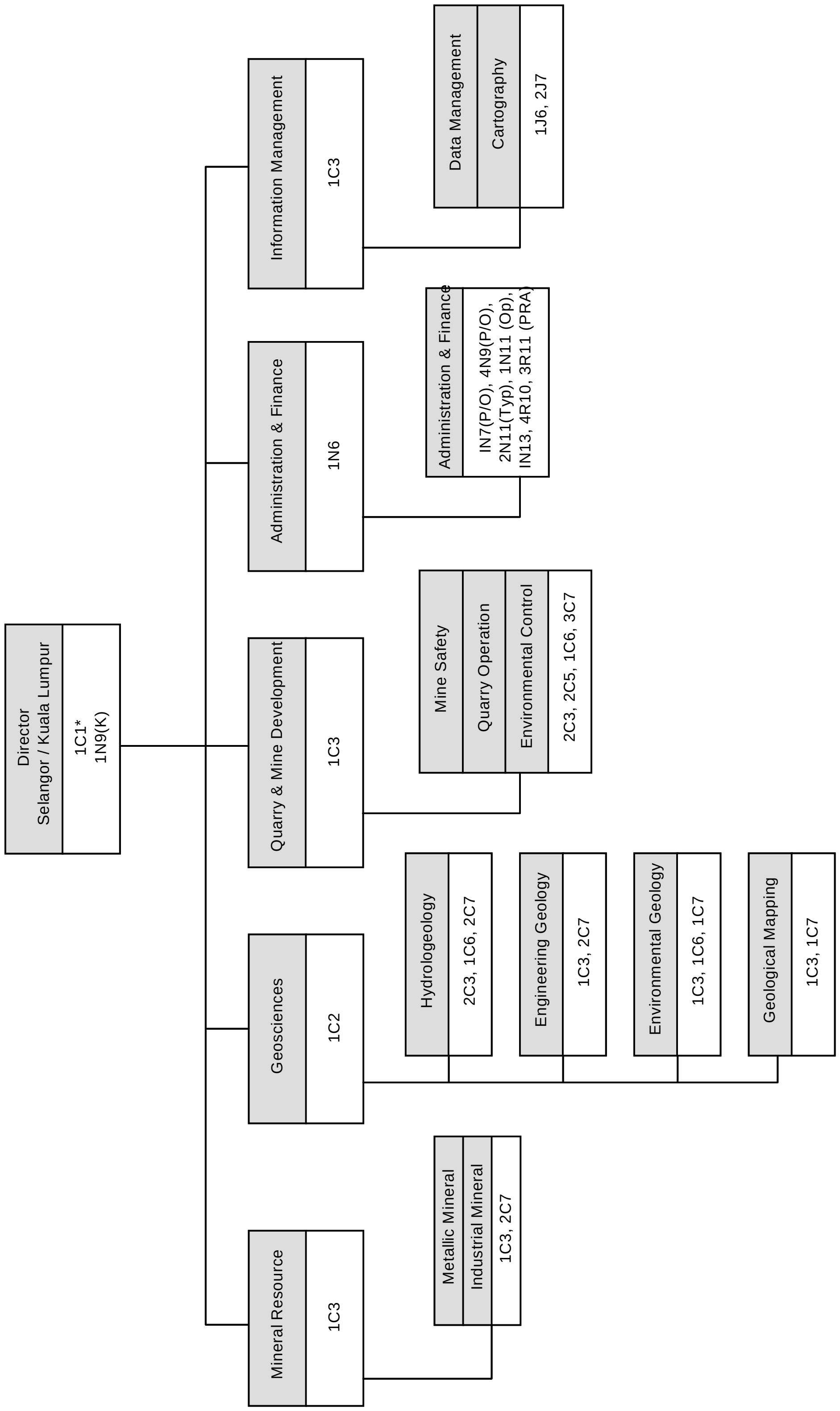
Annex Figure J.3.6

Proposed Organisational Chart (5 years) of the Lembaga Urus Air Selangor (LUAS)



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

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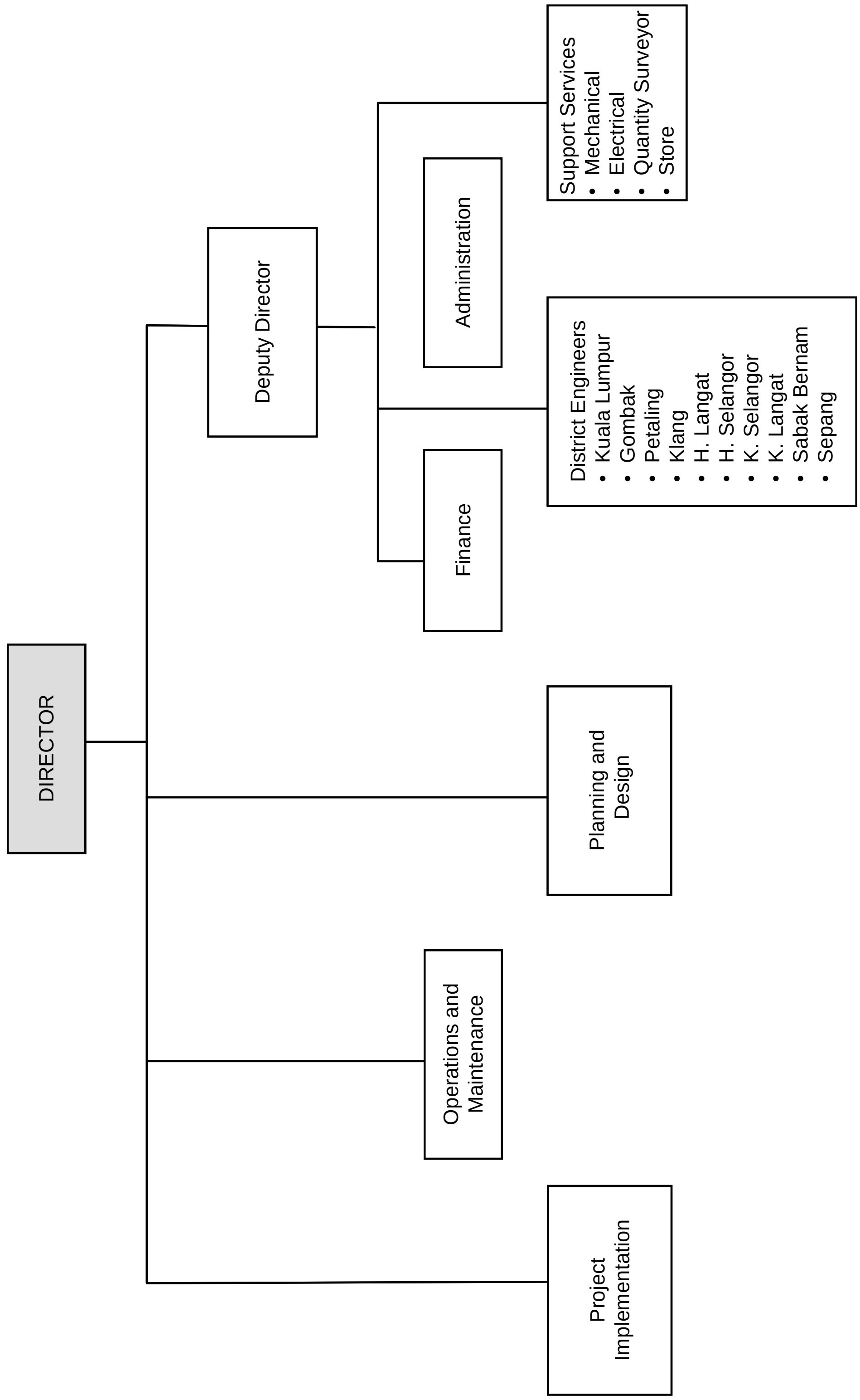
Annex Figure J.3.7

Proposed Organisational Chart for the Mineral and Geoscience Department, Selangor /Kuala Lumpur



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

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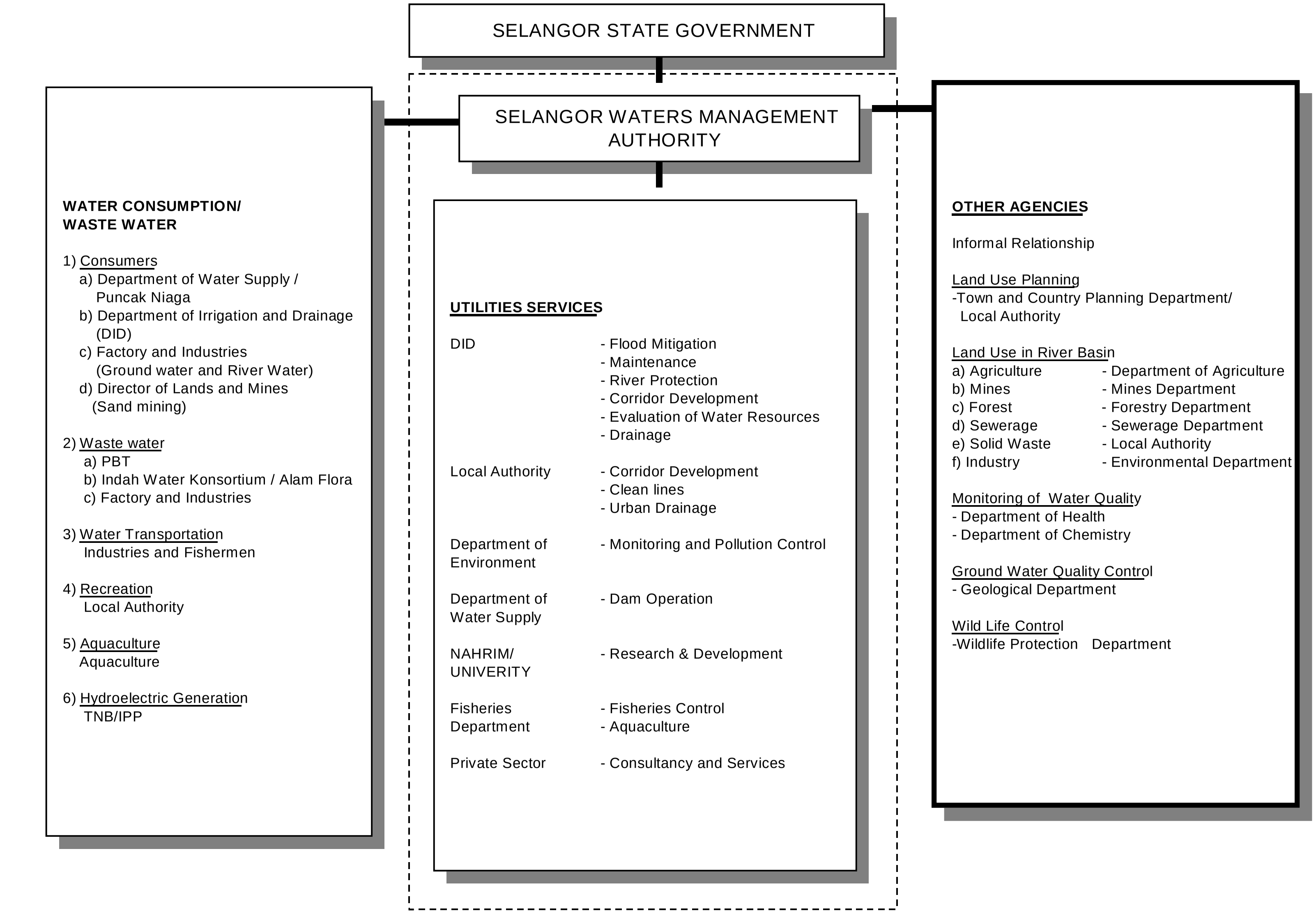
Annex Figure J.3.8

Organisational Chart of the Selangor Water Supply Department (JBAS)

ANNEX J.3.3

FUNCTIONAL LINKAGES BETWEEN SWMA AND OTHER AGENCIES IN THE STATE



Source : Selangor Waters Management Authority

Annex Figure J.3.9

Hierarchy of Relationship Between Selangor Water Management Authority and Service Providers and Supporting Agency at State Level

ANNEX J.3.4

WATER RATES IN MALAYSIA

Annex Table J.3.2 Water Rates in Malaysia
(As of 1st April 1998)

NO.	TYPE OF CHARGE	JOHOR	NEGERI SEMBILAN	SELANGOR AND FEDERAL TERRITORY OF KUALA LUMPUR	PULAU PINANG	KEDAH	PAHANG
	DOMESTIC SUPPLIES						
1.	Residential	0-15m³ @ RM 0.30/m³ 16-30m³ @ RM 0.70/m³ 31-45m³ @ RM 0.95/m³ >45m³ @ RM 1.15/m³	0-9 m³ @ RM 0.40/ m³ 10-20 m³ @ RM 0.55/ m³ >20 m³ @ RM 0.65/ m³	0-20 m³ @ RM 0.57/ m³ 21-35 m³@ RM 0.91/ m³ >35 m³ @ RM 1.70/ m³	0-20 m³ @ RM 0.22/ m³ 0-60 m³ @ RM 0.42/ m³ >60 m³ @ RM 0.70/ m³ Bulk Supply 0-90 m³ @ RM 26.00/month >90 m³ @ RM 0.35/ m³	0-20m³ @ RM 0.40/ m³ 21-40m³ @ RM 0.70/ m³ 41-60m³ @ RM 0.90/ m³ >60m³ @ RM 1.10/ m³	0-18 @ RM 0.37/ 18-45 m³ @ RM1.79/m³ >45 @ RM 0.99/ m³ Military Camp RM0.55/m³
2.	Religious Institutions	- do -	In excess of free supply RM0.20/ m³	RM0.40/ m³ Min. charge – RM 5.00	- do -	- do -	RM0.44/m³
3.	Charitable Organisations	- do -	In excess of free supply RM0.20/ m³	RM0.50/ m³ Min. charge – RM 19.00	- do -	- do -	- do -
4.	Government Buildings and Statutory Bodies	RM1.15/m³ Min. charge – RM5.00	RM0.05/ m³ Min. charge – RM5.00	RM1.40/ m³ Min. charge – RM15.00	As for industrial	- do -	- do
	Min. charge per month	RM3.00	RM3.00	RM 3.00	RM 2.50	RM3.00	RM3.00
	COMMERCIAL SUPPLIES						
5.	Industrial/commercial	0-20 m³ @ RM 1.20/ m³ >20 m³ @ RM 1.60/ m³ min. charge – RM 10.00	0-100 m³ @ RM 1.00/ m³ 100-500 m³ @ RM 0.90/ m³ >500 m³ @ RM 0.85/ m³ min. charge – RM 10.00	Min. charge – RM30.00 (inc. private swimming pool) 0 - 35 m³ @ RM 1.80/ m³ > 35 m³ @ RM 1.92/ m³	0-20m³ @ RM 0.52/m³ >20m³ @ RM 0.70/m³ min. charge – RM 6.00	0-10000 m³ @ RM 1.20/m³ 10001-50000 m³ @ RM 1.40/m³ >50000 m³ @ RM 1.80/m³ min. charge – RM 10.00	Gazzeted Area 0-227m³ @ RM0.92/m³ >227m³ @ RM0.84/m³ min. charge – RM 30.00 Trade @ RM 1.45/m³ min. charge – RM 20.00 Part Trade @ RM 0.99/m³ min. charge – RM 10.00
6.	Construction	- do -	- do -	- do -	@ RM 0.90/m³ min. charge – RM 10.00	- do -	As for trade
7.	Swimming Pool	- do -	@ RM 1.00/m³ min. charge – RM 5.00	- do -	As for industrial	- do -	@ RM 1.32/m³ min. charge – RM 15.00
	SPECIAL RATE						
		Shipping @ RM3.70/m³	Shipping @ RM1.00/m³	Shipping @ RM2.10/m³	Shipping @ RM1.50/m³		Commercial Shipping @ RM4.00/m³ min. charge – RM 30.00 Fishing Boat @ RM4.00/m³ min. charge – RM 30.00
8.	Bulk Supply Educational Institute/ Army Camp/ Estate		Ladang Estate @ RM0.70/m³ min. charge – RM 5.00	@ RM0.65/m³ min. charge – RM 100.00			Bulk rate (untreated) @ RM0.52/m³ min. charge – RM 30.00
9.	Pig Rearing Areas in Mukim Bt. Pelandok Port Dickson		0-70 m³ @ RM 0.90/ m³ >70 m³ @ RM 0.80/ m³ min. charge – RM 5.00				
10.	Condominium			@ RM 1.20/ m³ min. charge – RM150.00			
11.	Residential Flats (Government/ Semi Government)			@ RM 0.70/ m³ min. charge – RM30.00			
	Current rate w.e.f.	**1/4/1991**	**1/2/1993**	**1/1/1991**	**1/5/1993**	**1/3/1993**	1/1/1983

w.e.f. – with effective from

Annex Table J.3.2 Water Rates in Malaysia (cont'd)
(As of 1st April 1998)

NO.	TYPE OF CHARGE	KELANTAN	SABAH/1	FEDERAL TERRITORY OF LABUAN	KUCHING	SIBU	SRI AMAN, MIRI, LIMBANG, SARIKEI, KAPIT
	DOMESTIC SUPPLIES						
1.	Residential	0-20m³ @ RM 0.25/m³ 21-50m³ @ RM 0.40/m³ >51m³ @ RM 0.60/m³	@ RM 0.90/ m³	@ RM 0.90/ m³	1-15m³ @ RM 0.48/ m³ 15-50 m³ @ RM 0.72/ m³ >50 m³ @ RM 0.76/ m³	1-15m³ @ RM 0.48/ m³ 15-50m³ @ RM 0.72/ m³ >50m³ @ RM 0.76/ m³	1-15 m³ @ RM 0.48/ m³ 15-50 m³ @ RM 0.72/ m³ >50 m³ @ RM 0.76/ m³
2.	Religious Institutions	- do -	Free	Free	- do -	- do -	- do -
	(Mosque and Surau)	Free for the 1st 35m³					
3.	Charitable Organisations	- do -	@ RM0.90/ m³	@ RM0.90/ m³	- do -	- do -	- do -
4.	Government Buildings and Statutory Bodies	- do -	- do -	@ RM0.90/ m³	As for commercial	As for commercial	- do -
	Schools	- do -	@ RM0.45/ m³	@ RM0.45/ m³	As for commercial	As for commercial	@ RM0.66/m³
	Min. charge per month	RM2.50	RM4.00	RM 4.00	RM 4.40	RM4.40	RM4.40
	COMMERCIAL SUPPLIES						
5.	Industrial/commercial	RM0.70/ m³ min. charge – RM 7.00	Commercial @ RM 0.90/ m³ min. charge – RM4.00	RM0.90/m³ min. charge – RM4.00	Commercial min. charge – RM 22.00 1-25m³ @ RM 0.97/m³ >25m³ @ RM1.06/m³ Domestic/Commercial min. charge – RM 18.70 1-25m³ @ RM 0.83/m³ >25m³ @ RM0.95/m³	Commercial min. charge – RM 22.00 1-25m³ @ RM 0.97/m³ >25m³ @ RM1.06/m³ Domestic/Commercial min. charge – RM 18.70 1-25m³ @ RM 0.83/m³ >25m³ @ RM0.95/m³	Commercial min. charge – RM 22.00 1-25m³ @ RM 0.97/m³ >25m³ @ RM1.06/m³ Domestic/Commercial min. charge – RM 18.70 1-25m³ @ RM 0.83/m³ >25m³ @ RM0.95/m³ Industrial min. charge – RM 24.20 1-25m³ @ RM 1.21/m³ >25m³ @ RM1.33/m³
6.	Construction	- do -	- do -	- do -	As for commercial Special Commercial Rate for water processed for sale min. charge – RM27.50 1-25m³ @ RM 1.21/m³ >25m³ @ RM1.33/m³	As for commercial Special Commercial Rate for water processed for sale min. charge – RM27.50 1-25m³ @ RM 1.21/m³ >25m³ @ RM1.33/m³	As for commercial Special Commercial Rate min. charge – RM27.50 1-25m³ @ RM 1.21/m³ >25m³ @ RM1.33/m³
7.	Swimming Pool	- do -	As for industrial/ residential/2	- do -	As for commercial	As for commercial	As for commercial
8.	Bulk supply	- do -			@ Rm0.43/m		
9.	Public Standpipes	- do -			@ Rm0.43/m	@ Rm0.43/m	@ Rm0.43/m
	SPECIAL RATE						
		Shipping @ RM2.00/m³ min. charge – RM20.00	Shipping @ RM2.70/m³	Shipping @ RM2.70/m³	Shipping @ RM1.70/m³	Shipping @ RM1.70/m³	Shipping @ RM1.70/m³
	Current rate w.e.f.	**1/7/1983**	**1/1/1982**	**1/1/1982**	**1/1/1992**	**17/8/1995**	**17/8/1995**

/1 – except for Kota Belud District where rates are half of those shown for Sabah
/2 – industrial rate for hotel pools and residential rate for domestic pools.

SECTOR K

INITIAL ENVIRONMENTAL ASSESSMENT (IEA)

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

FINAL REPORT

SECTOR K

INITIAL ENVIRONMENTAL ASSESSMENT (IEA)

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SECTOR K

INITIAL ENVIRONMENTAL ASSESSMENT (IEA)

1. GENERAL ENVIRONMENTAL CONDITION OF THE BASIN

1.1 Air Quality

Air pollution occurs through the burning of fossil fuel for transportation, burning of forest for land clearance, oil palm processing and construction activities. In order to determine the extent of air pollution, some surveys were carried out at Kuala Lumpur (KL), the surrounding areas of Kuala Lumpur International Airport (KLIA), and Kuala Langat.[1), 2)] The surveys show that air quality in these areas were generally good and almost all the parameters were below the limits specified in the Malaysian Guidelines. However, the level of carbon monoxide (CO) at Banting was over the limit, i.e., 18 ppm, because of heavy traffic. The level of total suspended particulate (TSP) at Puchong recorded as high as 170 µg/m^3 because of mining activity and heavy traffic while it was recorded below the Guideline in Telok Panglima Garang industrial area.[3)]

Table K.1.1 shows the average levels of air pollutants in Kuala Lumpur and around KLIA.

Table K.1.1 Air Pollutant Levels in KL (1995-1997) and Surrounding Areas of KLIA

Parameters	KL	Surrounding Areas of KLIA		Malaysian Guidelines
		Labu Lanjut	Sepang	
TSP (µg/m^3)	89	-	14-149	Less than 260µg/m^3 (24hr)
CO (ppm)	3.08	0.1-1.3	0.3-1.1	Less than 9ppm (8hr)
SO_2 (ppb)	5.61	0.67-17.8	1-24	Less than 40ppb (24hr)
NO_2 (ppb)	46.86	3-8	5-11	Less than 60ppb (24hr)
PM_{10} (µg/m^3)	114	40-70		Less than 150µg/m^3

Note: TSP: Total suspended particulate, CO: Carbon monoxide, SO_2: Sulfur dioxide, NO_2: Nitrogen dioxide, PM_{10}: Particulate matter 10 micron diameter.
Source: DOE, Compendium of Environment Statistics, October 1998.
Kuala Lumpur International Airport, Environmental Impact Assessment Study, March 1993.

1.2 Noise

Noise pollution in residential area occurs mainly from traffic activity. Noise level surveys were carried out in Kuala Langat, KLIA and its surrounding areas such as Sepang. The survey in KLIA was conducted before construction of KLIA, and recorded typically low noise levels, particularly in villages and estate areas away from the main road network of these areas. All records at monitoring stations located within 10 km west of KLIA showed that the noise level was under 55 decibel (dB) regulated by the Noise Exposure Limit of the World Health Organisation (WHO) for community or urban areas.[2)]

In Kuala Langat, the minimum level was 63.0dB and maximum was 83.0dB while in Sepang, the minimum was 67.0dB and maximum was 79.0dB.[3)] The noise level in industrial area was sometimes over the Noise Level Guidelines in Malaysia (75dB at daytime), but noisy areas concentrated on the town or along main roads.

1.3 Terrestrial Flora and Fauna

1.3.1 Flora

There are 52 Permanent Forest Reserves and 8 Virgin Jungle Reserves in Selangor.[1)] In the Langat Basin, types of the forest reserve are dipterocarp forests or inland forests, peat swamp forests, such as Kuala Langat North and South, and mangrove forests like Sepang Kecil and other coastal forests. The total area of the Basin is 231,521.65 hectares. Of the total forest area, the inland forests constitute about 88.8%, peat swamp about 9.4%, and mangrove forests 1.8%. The Hulu Langat and Sg. Lalang Forest Reserves cover approximately 42% of the total forested areas in the Basin.[5)]

The most common species found in mangroves and swamp forests areas are mainly *Rhizophora* spp., *Avicennia* spp., *Bruguiera* spp., *Sonneratia* spp., and *Xylocarpus* spp. The cultivation of fast growing species such as *Acacia mangium* and *Pinus caribaea* are also emphasized in the forest plantation area.[4), 5), 6)]

1.3.2 Mammal

There are some studies that examined mammals in the Langat Basin. A total of 143 species of mammals ranging from 28 families and 11 orders has been reported in five decades, i.e., 1950s to 1990s.[7)] Among these, about 10% were big mammals such as monkeys, leopards and deers, and about 90% were small ones such as squirrels, rats and bats. Most of them live in forest area, namely primary and tall secondary forests. Hulu Langat and Sg. Lalang Forest Reserves have the highest diversity of mammalian species while the urban area has few.

Based on the threatened species classified by the International Union for Conservation of Nature and Natural Resources (IUCN) Red List in 1994, 16 species are listed as threatened. **Table K.1.2** shows the list of endangered species.

Table K.1.2 List of Endangered Species (Mammals)

No.	Species	Common Name	Classification*
1	*Elephus maximus*	-	EN
2	*Panthera Tigris*	Tiger	EN
3	*Macaca nemestrina*	Pig-tailed macaque	VU
4	*Hystrix brachyura*	Malayan porcupine	VU
5	*Neofelis Nebulosa*	Clouded Leopard	VU
6	*Prionailurus planiceps*	Flat-headed cat	VU
7	*Capricornis Sumatrensis*	Serow	VU
8	*Tapirus Indicus*	Tapir	VU
9	*Hipposideros ridleyi*	Singapore roundleaf horseshoe bat	VU
10	*Lutra Perspicillata*	Smooth Otter	VU
11	*Presbytis melalophos*	Banded-leaf monkey	LR
12	*Macaca fascicularis*	Long-tailed macaque	LR
13	*Hylobates lar*	White-handed gibbon	LR
14	*Manis javanicus*	Scaly anteater/pangolin	LR
15	*Myotis montivagus*	Burmese whiskered bat	LR
16	*Cheiromeles torquatus*	Hairless bat	LR

Note: * EN: A taxon is *Endangered* when it is not Critically Endangered but is facing a very high risk of extinction in the wild in the near future.
VU: A taxon is *Vulnerable* when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future.
LR: A taxon is *Lower Risk* when it was evaluated, but does not satisfy the criteria for any of the categories; Critically Endangered, Endangered or Vulnerable.

Source: Saiful Arif Abdullah, Changes of Forested Areas and Wildlife Diversity in the Langat Basin, "Penyelidikan Ekosistem Lembangan Langat", *Langat Basin Ecosystem Research*, 5-6 June 1999.
Laporan Invenrtori Hidupan Liar Di Kawasan Daerah Kuala Langat Hutan Simpan, Selangor, Department of Wildlife and Natural Parks.

1.3.3 Birds

A total of 295 species from 44 families of birds have been recorded existing in the Langat Basin (Zakaria et al., 1999; Department of Wildlife and National Park (DWNP), 1998; Jasmi, 1997).

Of the 295 species 19% are from the family of Muscicapidae such as species of robin, sharma, flycatcher and warbler, followed by Cucclidae, 7% (cuckoo, malkoha and coucal) and Picidae, 6% (woodpecker and goldenback).[6)]

In a study conducted in Hulu Langat and Sg. Lalang Forest Reserve, a total of 126 species has been caught (DWNP, 1997; 1998; Jasmi, 1997) while 83 species has been found around KLIA.[2), 8), 9)] In another survey which was carried out by DWNP between 1992 and 1995, 29 species have been found in the Langat Basin, specifically in areas of Kuala Langat, Sepang, Banting, Dengkil, Hulu Langat and Kajang.

In plantation areas, pigeons, quails and the crow pheasant, swallows, swifts, and few Black Shouldered Kites and the Osprey may be found. In secondary forests, spiderhunters, flycatchers can be found, and bulbuls can be found. In peat swamp forest, *Alcedo atthis* (kingfisher), *Acridotheres* sp. (myna), *Pycnonotus*.sp (bulbul), *Caprimulgus macrurus* (large tail mnghtjar), *Amourornis* sp. (waterhen) and *Dicruvus* sp. (drongo) can also be found. Swamp forests or mangrove and peat forests are being used by migratory birds from northern hemisphere during the northern winter such as *Xenus cinereus* (terek sandpiper), *Arenaria interpres* (ruddy turnstone), *Tringa totanus* (common redshank).[6)]

Based on the threatened species classification by IUCN Red List published in 1994 and standard by State, 7 species are defined as threatened by the Red List, and 9 species should be saved in the Langat Basin as shown in **Table K.1.3**.

Table K.1.3 List of Endangered Species (Birds)

No.	Species	Common Name	Classification
1	*Rhinomyias brunneata*	Brown-chested Flycatcher	VU
2	*Pycnonotus Zeylanicus*	Straw-Headed Bulbul	VU
3	*Terpsiphone atrocaudata*	Japanese Paradise Flycatcher	LR
4	*Trichastoma bicolor*	Ferruginous Babbler	LR
5	*Megalaima rafflesii*	Red-crowned Barbet	LR
6	*Platysmurus leucopterus*	Black Magpie	LR
7	*Centropus Rectunguis*	Short-Toed Coucal	LR
8	*Tringa nebularia*	Common Greenshank	-
9	*Gallinago gallinago*	Common Snipe	-
10	*Accipiter gularis*	Japanese Sparrowhawk	-
11	*Treron vernans*	Pink-Necked Pigon	-
12	*Psittacula cyanurus*	Blue-rumped Parrot	-
13	*Loriculus galgulus*	Blue-crowned Hanging Parrot	-
14	*Copsychus malabaricus*	White-rumped Shama	-
15	*Gracula religiosa*	Hill myna	-
16	*Zosterops palpebrosa*	Oriental White-eye	-

Note: Refer to Table K.1.2 about classification.
Source: References No .8 and 15.

1.3.4 Reptiles

According to the survey carried out by DWNP in 1992/95, water monitor lizard, hamadryad/king cobra, and python were found in the basin. In another survey, clouded monitor lizard and Malayan box turtle were noted. *Xenelaphis hexagonotus* (common snake), and *Enhydris* sp. (water snake) are expected to live in the Basin, too. Lizards included *Mabuya multifasciata* (slink) and *Catotes versicolor* (long tailed agamid).[2)] The other survey in Paya Indah found 18 species.

There are two endangered species found in these surveys, as shown in **Table K.1.4**.

Table K.1.4 List of Endangered Species (Reptiles)

No.	Species	Common Name	Classification
1	Heosemys spinosa	Spiny Hill Turtle	VU
2	Cuora amboinenis	Malayan Box Turtle (South Asian Box Turtle)	LR

Note: Refer to Table 2.3.2 about classification.
Source: References No. 2 and 9.

1.3.5 Amphibians

There are some amphibians found named *Bufo melanostictus* (common toad), *Polypedates leucomystax* (common bush frog) and steam dwelling species such as *Rana blythi* and *Rana limnocharis*.[2)] In another survey in Paya Indah, 7 species were found.[10)]

There is no endangered species in the Study Area.

1.3.6 Insects

According to the KLIA EIA Study, butterflies were surveyed and found to be relatively poor. Nine families are represented, mostly from open areas of the forest and fringe vegetation where species of the geni *Mycalesis Ypthima*, *Precis, Appias, Eurema, Leptosia, Catopsilia, Chilades*, and *Aiaina* were noted.[2)]

Another survey was carried out to estimate richness and diversity of soil dwelling insects in Sungai Lalang Forest Reserve. The result of this survey shows that 10-year old logged forest was more diverse than primary forest.[11)]

In the survey in Paya Indah, 36 butterflies were found and one of them is to be saved by the State. Its name is *Idea lynceus lynceus* (tree nymph).

1.4 Aquatic Flora and Fauna

1.4.1 Flora

The presence of aquatic flora in the freshwater habitat varies depending on the river flow, illumination condition and nutrient levels in the water. The most dominant group in the upstream region is the (*Bacillariophytes*) (diatoms) while along the mid-stream *Cyanophyta* (blue green algae) is usually abundant, indicating an increase in organic loading within the river system. From downstream to river mouth and coastal region, the population of diatoms once again predominate.[12)]

Wetlands consist of many kinds of habitats, such as pond, deep marsh, shallow marsh, fringing marsh, and swamp forest. Vegetation changes depending on them and also water quality. The Kuala Langat north peat swamp forest and adjacent wetland areas have about 100 species and half of those are trees/shrubs. Alstonia pneumatophora and Myristica sp. are found as tall trees while *Nelumbo nucifera* (lotus) and *Salvinia molesta* (floating fern) can be seen in swamps as aquatic flora.[13)]

1.4.2 Freshwater Fish

A total of 40 species were recorded in the Langat River and most of them were also found occupying its tributaries. A typical species in the Langat Basin is Cyprinidae such as *Acrossochilus deauratus, Barbodes schwanenfeldii* and *Osteochilus hasselti* followed by Belontidae such as *Trichogaster trichopterus* and *Beta fusca,* and other groups (*Pangasius* sp., *Mystus* spp., *Notopterus* spp.).[14)]

The other survey carried out around Paya Indah found 18 species there such as catfish, tilapia, and glassfish. The richness of species of fish in the Langat River slightly decreases as the river order increases. What is worse is that the increasing exotic species disturb the native species' habitat.[14)] Except fish, crab, prawn, jellyfish and snail can be found in the Langat Basin.[3)] There is no endangered species in the Study Area.

2. INTRODUCTION OF THE INITIAL ENVIRONMENTAL ASSESSMENT

2.1 Requirement for the EIA

Environmental Impact Assessment (hereinafter referred to as "EIA") is a study to identify, predict, evaluate and communicate information about the impacts on the environment of a proposed project. It is necessary to preliminarily examine the potential environmental impact from the project construction and operation during this planning stage. Thus, the appropriate corrective measures can be taken during the early phase of this study.

Activities subject to EIA are prescribed under the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 1987. According to this, the following activity is "prescribed" under the Groundwater Supply sector:

Groundwater development for industrial, agricultural or urban water supply of greater than 4,500 cubic meters (m^3) per day

It is not necessary to achieve an EIA on this project, because the project is not a development plan but only a short-term investigation for groundwater management. This is an IEA (Initial Environmental Assessment), which is a simple assessment and evaluation of the impact by the proposed project and suggests some mitigation to make some impacts on the environment minimum. When the assessment was carried out, the "Environmental Impact Assessment Guidelines for Groundwater and/or Surface Water Supply Project (published by Department of Environment, Malaysia, 1995)" was made as reference.

2.2 Step for IEA

IEA is a simple and easy way of EIA, but the procedure is almost the same. To successfully undertake an EIA, it is necessary to:

(1) describe the project activities which could potentially adversely affect the environment;

(2) clearly identify just what the issues are;

(3) predict who or what could be affected and how; and

(4) evaluate the significance of the effect.

In addition, if significant adverse impacts are predicted, mitigation measures should be taken.

3. PROJECT DESCRIPTION

3.1 Project Proponent

This project is proposed by:

JABATAN MINERALS DAN GEOSAINS MALAYSIA (Department of Minerals and Geoscience Malaysia)

Address: Tingkat 19-23, Bangunan Tabung Haji, Jalan Tun Razak, Peti Surat 11110, 50736, Kuala Lumpur, Malaysia

Tel. No.: +603-2161-1033/1034 Fax No.: +603-2161-1036

3.2 Need for the Project

In this project, the following studies will be proposed:

- Soil investigation at 9 locations;
- Pumping test at 3 locations;
- Observation around pumping well at 14 locations; and
- Long-term groundwater monitoring at 10 locations.

Among them, pumping test is predicted to bring a relatively big impact on the environment while the other studies are predicted to give quite a little impact.

There are some objects at each study. The objective of pumping test is the investigation of the following matters:

- Yields of well;
- Basic aquifer parameters (horizontal hydraulic conductivity);
- Sustainable yield or allowable draw-down of groundwater level of an aquifer;
- Groundwater recharge;
- Aquifer boundaries;
- Groundwater flow between the surface and an aquifer;
- Piezometric changes in an aquifer and groundwater changes and their impact on ecological conditions; and
- Groundwater flow direction and its changes for computation of groundwater pollution flow, forecasting, monitoring and control.

Three (3) sites were chosen for pumping test: Paya Indah, Kajibumi Well Field 2, and Kanchong Darat. Specific objectives of pumping tests are shown in **Table K.3.1**.

Table K.3.1 Specific Objectives of Pumping Tests

Objectives	Location		
	Paya Indah	Kajibumi WF2*	Kanchong Darat
Aquifer properties	O	O (coarser)	O (finer)
Sustainable yield	O	O (coarser)	O (finer)
Groundwater recharge	O	O (river)	O (vertical)
Boundary conditions	O	O	O (free)
Groundwater flow between the surface and aquifer	O (horizontal)	O	O
Impact on ecology due to groundwater level change	O (horizontal)	Δ	Δ
Groundwater pollution flow	O	Δ	O
Impact from mines	O	–	–

Note: O: main object Δ: sub-object –: unconcerned
* Kajibumi Well Field 2

3.3 Project Description

As mentioned before, pumping test would give the biggest impact among the studies for this project. Therefore, this IEA focuses on this pumping test including other studies carried out around pumping well.

3.3.1 Location

Proposed three pumping test locations are shown in **Figure K.3.1**. Cyberjaya and Putrajaya bound these areas on the north, and KLIA (Kuala Lumpur International Airport) on the east.

One of the pumping test wells is on the borderline at the north of Paya Indah, another is near the Megasteel at Olak Lempit named ‘Kajibumi Well Field 2’, the other is in a palm oil estate in Kuala Langat named ‘Kanchong Darat’.

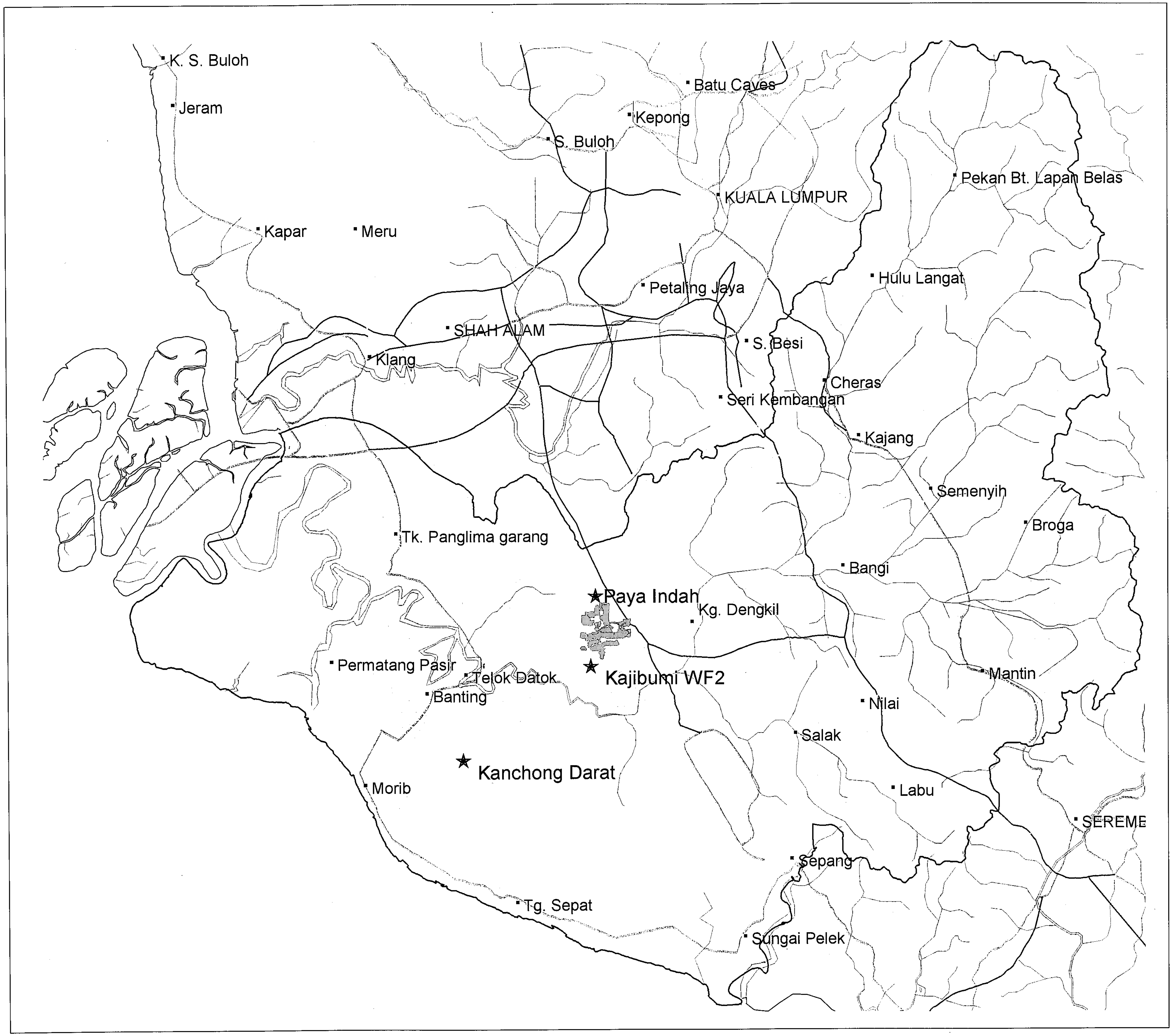
<u>Paya Indah</u>: this site is located at the northeast of Main Lake which is northernmost of Paya Indah approximately 30km southwest of Kuala Lumpur. The existing condition is shown in **Photographs K.3.1 and K.3.2**.

<u>Kajibumi Well Field 2</u>: this site is located near the Megasteel at Olak Lempit surrounded many industries. The existing condition is shown in **Photographs K.3.3 and K.3.4**.

<u>Kanchong Darat</u>: this site is located inside the palm oil, banana, and corn plantation area in Kuala Langat district. The existing condition is shown in **Photographs K.3.5 and K.3.6**.

Figure K.3.1

Location of Proposed Pumping Wells



LEGEND

- Langat Basin
- ★ Pumping Well Site
- Paya Indah Wetland
- ▪ Town
- Coastal line
- River

Road

- Federal
- State
- Highway

3000 0 3000 6000 Meters

N E S W

Japan International Cooperation Agency

Minerals and Geoscience Department Malaysia

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

CTI Engineering International Co., Ltd.

OYO CORPORATION

Photograph K.3.1 Paya Indah (1)
(Taken from the edge of Main Lake toward south direction)

Photograph K.3.2 Paya Indah (2)
(Pumping well will be set on this path.)

Photograph K.3.3 Kajibumi Well Field 2 (1)
(Existing well can be seen, which will be used for the pumping well.)

Photograph K.3.4 Kajibumi Well Field 2 (2)
(Another existing well)

Photograph K.3.5 Kanchong Darat (1)
(Taken from pumping well site toward north-east direction.
Right: corn estate, Left: palm oil estate)

Photograph K.3.6 Kanchong Darat (2)
(Taken from pumping well site toward north-west direction.
A big canal and only a residence can be seen.)

3.3.2 Construction Techniques and Programme

(1) Project Operation

Construction techniques that are so far decided may be changed depending on the result of the soil investigation carried out in Phase II and the surrounding environment. The result of the investigation will be utilised to plan the groundwater observation well (depth of pressure measurement and sample collection) and the pumping test (design of pumping well, length and location of screen, testing conditions and others). Specifications of pumping tests are shown in **Table K.3.2**.

At three locations, the pumping test will be carried out for 1 month. After pumping, recovery test will be done for 1 month. Other 14 wells for groundwater observation will be set around these pumping wells, the locations of which are shown in **Figure K.3.3**. They will be used as observation wells during pumping test. Some of them will be utilised as long term monitoring wells after pumping test, but the rest will be closed. The purposes of monitoring are to investigate inflow and pollution at Paya Indah, and seawater intrusion at Kanchong Darat. Kajibumi Well Field 2 is set as a standard monitoring point.

Table K.3.2 Specifications of Pumping Test and Other Surrounding Boreholes

Location	Pumping Rate (l/sec.)	Expected Depth (m)	Observation Well (Long Term Monitoring Well)	Borehole for Soil Investigation
Paya Indah	50	35-40	8 (3)	1
Kajibumi Well Field 2	100	50-55	3 (1)	1
Kanchong Darat	100	80-85	3 (1)	1

(2) Secondary Product

Since this project is not a development plan but only a test, the pumped water is not to be used for another purpose. It should be put into suitable places where no effect on this test and on the environment can be found.

Paya Indah: There are two alternative places to dispose the pumped water. One is the lake within 700 m west of the pumping well whose name is Driftwood Lake next to Main Lake. The reclamation road 20 m wide separates each lake. The other option is to discharge the water into the nearest small canal, which is situated at approximately 200 m from the pumping well. There is no water in dry season but it flows in rainy season. At present, the canal is covered with some garbage.

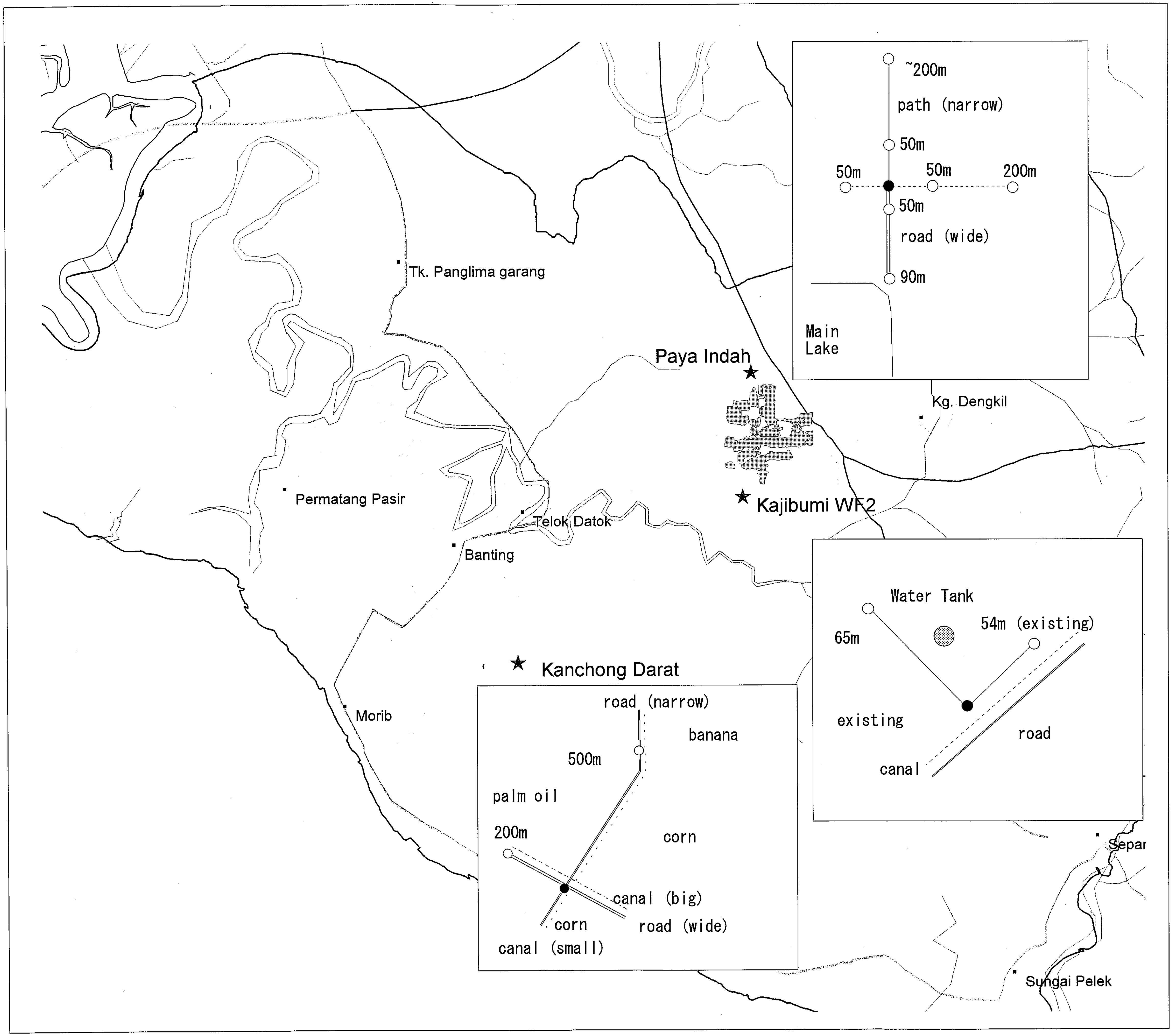


Figure K.3.2

Location of Proposed Observation Wells around Pumping Wells

LEGEND

- Langat Basin
- Pumping Well Site
- Paya Indah Wetland
- Town
- Coastal line
- River
- Road
  - Federal
  - State
  - Highway
- Pumping Well
- Observation Well

2000 0 2000 4000 Meters

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Kajibumi Well Field 2: Used water is to be discharged into the drainage canal beside the site linking with Langat River. The width and depth of this canal are about 1 m and 0.7 m respectively. At present, quite a little water flows in this canal.

Kanchong Darat: Used water is to be drained into the canal along the estate. The width and depth of this canal are about 3 m and 1 m respectively. At present, water does not flow but stagnate and many algae are growing inside the canal.

(3) Project Schedule

Project schedule has not been decided yet. Details of this project will be finally decided after the soil investigation in Phase II (from the middle of September 2000 to the end of March 2001).

Pumping much water and draining it into the surface water in rainy season will make the rivers overflow. Pumping test during the heavy rainy season, especially November through January, should be avoided if possible.

3.3.3 Access

The major access roads linking with the three sites are the Airport Highway that runs from Kuala Lumpur through KLIA and the state road (Dengkil-Banting Road: B18) that runs from west to east connecting major towns like Dengkil, Telok Datok and Banting. Paya Indah and Kajibumi Well Field 2 are around this road. Not only this road but also a lateral small access road from the highway connects with the Main Lake in the northernmost part of Paya Indah.

The nearest federal road is situated on the west, linking towns like Banting and Morib. After passing Banting, Jl. Durian links with Kanchong Darat.

It takes about 1 hour by road transportation to Paya Indah and Kajibumi Well Field 2, and about 1.5 hours to Kanchong Darat from Kuala Lumpur.

4. ACTIVITIES AND POTENTIAL IMPACTS

4.1 General

Environmental impacts result from activities associated with planning, well drilling, operating and after testing. The project activities may generate significant environmental changes that may cause serious impacts on the environment. These impacts can be grouped into issues requiring urgent consideration.

The predicted impacts are described at each project activity in three phases: pre-construction stage, construction stage and post-construction stage. Planned activities of the pumping test are summarised in **Table K.4.1**.

Table K.4.1 Planned Activities of the Project

	ACTIVITY	SUB-ACTIVITY	PLAN
PRE-CONSTRUCTION ACTIVITY	INVESTIGATION	Resettlement	There is only one resident inside the study area at Kanchong Darat but it is not necessary to resettle.
		Establishing Base Camps	Only one (1) tent will be established at each site.
		Putting In Temporary Access Ne Roads	A new access road will be put with gravel and sand in Paya Indah.
		Establishing Place For Materials	Some space for putting materials is needed around pumping well.
	LAND ACQUISITION	Acquire Land	Sites at Paya Indah, Kajibumi Well Field 2 and Kanchong Darat belongs to Malaysia Wetlands Foundation, JBA and Felcra Berhad respectively.
		Cutting Some Trees	Not cutting tall trees or crops but some insignificant weeds and bush will be cut to make space for putting materials.
CONSTRUCTION ACTIVITY	TEMPORARY OCCUPATION	Construction of Temporary Buildings	Temporary building around the sites may be needed if necessary.
	WELL CONSTRUCTION	Water Supply	Much water should be needed in drilling wells. Surface water may be taken.
		Drilling Wells	2 pumping wells at Paya Indah and Kanchong Darat and 14 observation wells will be drilled. Much bentonite will be used.
		Washing Wells	Much bentonite will be used in washing well.
		Operating Equipment	The equipment for drilling wells, tracks for carrying materials will be used
	ABANDONMENT	Solid Waste	No solid waste will be come out because base camps and some equipment should be brought back.
POST-CONSTRUCTION	GROUNDWATER ABSTRACTION	Water Abstraction	Maximum volume of water supply is 50litre/sec at Paya Indah while 100litre/sec at Kajibumi WF2 and Kanchong Darat for 1month.
		Pumped Water Discharge	Pumped water should be throw away. It will be put into Driftwood Lake or canal about 200m away from the pumping site in Paya Indah, the canal beside the road in Kajibumi WF2, and the canal beside palm oil estate in Kanchong Darat.
	MAINTENANCE	Well Screen, Pump, Treatment System	Specific method of maintenance would not be needed, just using some water.

4.2 Pre-Construction Stage

4.2.1 Land Acquisition

Negotiation with landowners and getting permission for setting the pump wells and observation wells and for establishing base camps, new road and material storage place are needed. The size of this area is approximately 25 m by 25 m, but it will change depending on the sites and specification of wells.

- Predicted Impact: Loss of income and reduced asset

4.2.2 New Access Road and Place for Material

New access roads for construction cars and trucks will not be needed in Kajibumi Well Field 2 and Kanchong Darat. The existing road at those two sites could be used. At Paya Indah, a new carrying road will be put around the proposed wells with some boards or sand.

An area for storing materials will be needed at all sites. However, no tall tree will be cut for it.

- Predicted Impact: Temporary removal of vegetation and loss of terrestrial habitat

4.2.3 Base Camps

Base camps are not for workers but for guards to watch the wells during pumping test. One tent at each site of pumping well will be established. Besides the base camp, buildings needed for boring work may be built depending on the situation.

- Predicted Impact: Impact on health and safety of guards

4.3 Construction Stage

4.3.1 Water Supply

Abundant water would be needed for drilling wells, from the nearest river or by water tankers.

- Predicted Impact: Reduced stream flow will affect downstream users. It will be a slight impact considering the term of taking water.

4.3.2 Well Drilling

Two pumping wells at Paya Indah and Kanchong Darat, and 14 observation wells around them will be drilled. The existing well at Kajibumi Well Field 2 will be used as a pumping well. Large amounts of bentonite will be used in drilling.

- Predicted Impact: Groundwater contamination by the drilling fluid and loss of terrestrial habitat

4.3.3 Washing Wells

At Paya Indah and Kanchong Darat, washing inside the well would be needed before pumping. Much water will be used and abundant muddy water will be generated because of much bentonite. The washing water is going to be drained into the surface water. Washing by water will not be needed at Kajibumi Well Field 2. The existing well is going to be washed by air.

- Predicted Impact: Reduction in surface water quality

4.3.4 Operating Equipment

Equipment for drilling wells and trucks for carrying materials will be used.

- Predicted Impact: Noise, spills and leaks will be generated.

4.3.5 Solid Waste

No solid waste will be generated, because base camps and some equipment would be moved out of sites.

- Predicted Impact: Negligible impact of solid waste

4.4 Post-Construction Stage

4.4.1 Water Abstraction

This may be one of the most important issues on this project. At maximum, 50 litre per second (l/s) water at Paya Indah and 100 l/s water at Kajibumi Well Field 2 and Kanchong Darat will be taken continuously for 30 days.

- Predicted Impact: Over-abstraction will disrupt water supply to existing users, cause groundwater drawdown, land subsidence, saltwater intrusion, and cause destruction of swamps around Paya Indah.

4.4.2 Pumped Water Discharge

Once water is pumped out, it has to be put somewhere after chemical analysis. The place for putting this water is given in the previous section. (See "**Subsection 3.3.2**, Construction Techniques and Programme (2) Secondary Product").

- Predicted Impact: Change of water quality, surface water hydrology, water level, and aquatic habitat, especially in Paya Indah

4.4.3 Maintenance

After testing the pumping wells for 30 days, pumping should be stopped and those wells will be used as monitoring wells. Specific method of maintenance would not be needed, just using some water.

- Predicted Impact: Negligible

5. EXISTING ENVIRONMENT

5.1 Introduction

The predictions would depend on understanding cause-effect relationships. That is, "cause" means project activity and "effect" means change in the physical, biological and social characteristics of the environment.

In this section, baseline studies are undertaken on those components of the environment that are significant and are going to be substantially affected by the project activities. **Annex Table K.5.1** gives the matrix that shows the physical, biological and social components at each of the three sites. Details of activities in each project phase are described in the previous section, and the symbols written in the matrix show the level of effect on the environment.

After consideration, the following components, which are significant or substantially affected by the activities at any phase, are selected.

Table K.5.1 Significant Environmental Components of the Pumping Tests

Environmental Component		Site Name		
		Paya Indah	Kajibumi WF2*[2]	Kanchong Darat
Physical	Land subsidence*[1]	O	O	O
	Surface water	O	O	O
	Groundwater	O	O	O
Biological	Species	O	–	–
	Habitat	O	–	–
Social	Settlement	O	O	O
	Landscape	O	–	–
Environmental condition		Wetland area	Industrial area	Plantation area

Note: O: considered to be significant for environment
*[1] In the following description, land subsidence is included in 'groundwater' component because it is considered to result from groundwater abstraction.
*[2] Kajibumi Well Field 2

The object of this project is to get some data about groundwater properties. There is so far little information about existing groundwater condition.

5.2 Study Area

The pumping wells, as well as the observation wells, are to be set in the three sites selected; namely, Paya Indah, Kajibumi Well Field 2 and Kanchong Darat. The study area should include the area where effect by project activities is expected. That is, it should include not only wells and surrounding areas but also the roads where the construction cars will often pass through, the material places, and base camps. **Figure K.5.1** shows the study area for this IEA.

5.3 Physical

5.3.1 Surface Water Quality

(1) Langat River

Development of the upper reaches of the river and its tributaries has lead to the discharge of a large volume of sediment into the main Langat River, causing considerable sedimentation on the river bed.[21)]

The water of Langat River is slightly acidic to neutral and very heavily coloured. Concentration of manganese and iron are also high, probably due to high content of suspended solids. COD and NH_4 values are high, indicating probable contaminant effluent from palm oil processing plants.21) The water quality of the river is as shown in **Table K.5.2**.

Table K.5.2 Water Quality of the Langat River

Parameter (unit)	pH -	Turbidity (NTU)	Colour (Hazen)	TDS (ppm)	COD (ppm)	Cl (ppm)	Detergent (ppm)	NH_4 (ppm)
Average	6.51	**208**	**254**	111	**43**	12.0	0.08	**1.04**
Standard	6.5-9.0	50	150(TUC)	1,000	25	200	-	0.3

Parameter (unit)	NO_3^- (ppm)	SO_4 (ppm)	F (ppm)	$CaCO_3$ (ppm)	SS (ppm)	Pb (ppm)	Mn (ppm)	Fe (ppm)
Average	0.41	29.9	0.15	16	**346**	0.03	**0.15**	**5.77**
Standard	7/3(NO_3/NO_2)	200	1	100	50	0.05	0.05	0.3

Source: Pakatan Runding Yusoff Sdn. Bhd, 1995 (EIA report for Megasteel/Amsteel)
Note: The standard is Class IIA (conventional treatment required).

(2) Wetland (Paya Indah)

There are altogether 14 lakes in Paya Indah (see **Figure K.5.2**). The pH value is different from north to south, i.e., 3.5-4.5 in the north, 4.5-5.0 in the mid-section, and probably mild in the south. This acidity is expected to come from at least 3 ways. The most dominant cause would come from the adjacent peat swamps. The swamp water is tea-coloured and contains tannins and organic acids. Another reason would be the oxidation of pyrite sediment brought up from the sub-surface level to the land surface by the dredging operation, and the other would be acid rain.[24)]

Pumping well and some observation wells are located at the northernmost part of Paya Indah. Driftwood Lake where pumped water may be discharged is connected to Timah Lake at the west and Main Lake at the east with underground culverts.

The waters of Main Lake and Timah Lake (there is no data about Driftwood Lake) against the National Water Quality Standard Class IIA are both "Slightly Polluted" in 1996. The values of pH, turbidity, COD, Fe, Pb, and NH_3-N exceed the standard in Main Lake while pH, conductivity, COD, Fe, Pb, Mn and NH_3-N exceed it in Timah Lake as shown in **Table K.5.3**. On the other hand, New Lake and Blue Lagoon located in the south are "Clean".[16)]

Table K.5.3 Water Quality in Main Lake and Timah Lake (1996)

Parameter	Main Lake	Timah Lake	Class IIA Guideline
pH	**4.33-4.58**	**3.37-3.65**	6.5-9.0
DO (mg/l)	Above 5	Above 5	5-7 mg/l
Conductivity (μS/cm)	41(min.)-49(max.)	**60(min.)-331(max.)**	Below 100μS/cm
Turbidity (NTU)	**71.0-82.0**	Below 50	Below 50 NTU
E-coil (organisims/100ml)	Below 100	Below 100	Below 100 orgs./100ml
BOD (mg/l)	Below 2	Below 2	Below 3 mg/l
COD (mg/l)	**42(min.)-50(max.)**	**<6(min.)-48(max.)**	Below 25 mg/l
SS (mg/l)	Below 50	Below 50	Below 50 mg/l
TS (mg/l)	91-200	91-200	Below 1,000 mg/l
Total Hardness (mg/l)	3-45	3-45	Below 250 mg/l
Trace Metals (Ca,Mg,K,Zn,Mn,Sn…)	**Fe: 2.9-3.1** **Pb: <0.2-0.42**	**Fe: 0.2-2.7,** **Pb: <0.2-1.2** **Mn: 0.03-0.21**	Fe: below 0.3 mg/l Pb: below 0.05 mg/l Mn: below0.1 mg/l
Chloride (mg/l)	2.1-19	2.1-19	Below 200 mg/l
Sulphate (mg/l)	6.1-99	6.1-99	Below 250 mg/l
Nitrate Nitrogen (mg/l)	<0.01-1.3	<0.01-1.3	Below 7 mg/l
Ammoniacal Nitrogen (mg/l)	**<0.05(min.)-26(max.)**	**0.03(min.)-26(max.)**	Below 0.3 mg/l
Phosphate (mg/l)	<0.05	<0.05	Below: 0.2 mg/l as P

Source: Wetlands International Asia Pacific, Preliminary Hydrological and Water Quality Assessment for the Malaysian Wetland Sanctuary, Appendix B pp.9-13, Selangor, Dec. 1996.
Note: Class IIA means water available for 'Water Supply II (conventional treatment required)' of National Water Quality Standard for Malaysia

Figure K.5.1

Study Area for the Initial Environmental Assessment

LEGEND

- Langat Basin
- Pumping Well Site
- Study Area for the Initial Environmental Assessment
- Paya Indah Wetland
- Town
- Coastal line
- River

Road

- Federal
- State
- Highway

1000 0 1000 2000 Meters

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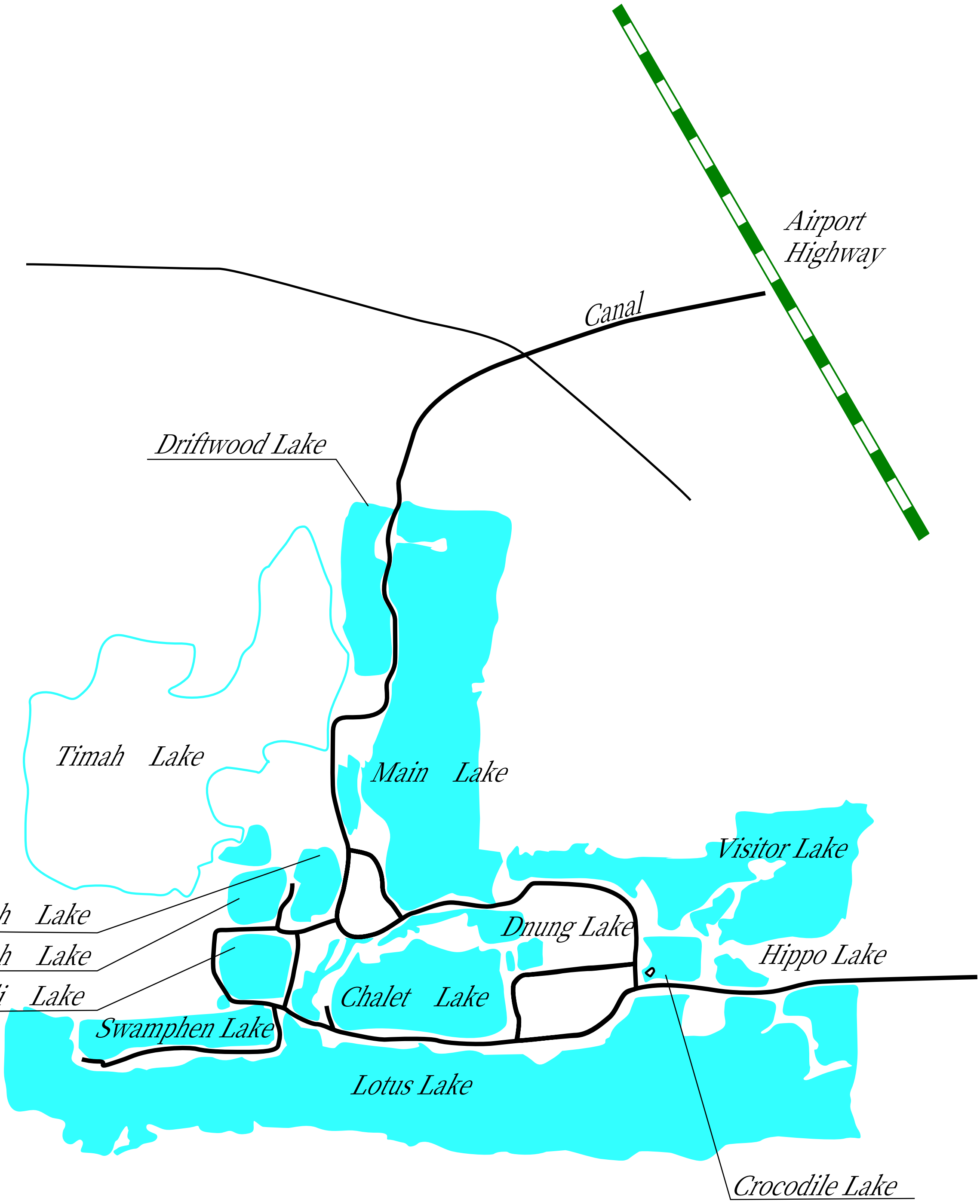

Timah Lake is not included in Paya Indah until 2004.

Not to scale

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Figure K.5.2

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

Shape of Paya Indah

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5.3.2 Surface Water Hydrology

(1) Langat River

Langat River flows via Dengkil, turns south and west after flowing through Bt. Changgang, Telok Datok and lastly meandering its way to the Strait of Malacca. Tributaries of Langat River adjacent to Olak Lempit consist of Sg. Semenyih, Sg. Chuah, Sg. Labu and Sg. Kelembau.[21)] All of them join Langat River before it reaches the Kajibumi Well Field 2.

Other drainage systems are formed mainly of agricultural ditches dug by the estates or plantations for oil palm. All drainage systems discharge into the Langat River or its tributaries.[21)] There are some drains around Kanchong Darat but they are far from the main Langat River.

(2) Wetland (Paya Indah)

The water coming into Paya Indah ultimately drains into Langat River. Apart from rainfall, this area receives water from the peat swamps east of the Airport Highway via two small culverts that run under the highway.[25)]

In Paya Indah, the water level in the drainage canal flowing through or bordering the peat swamp forest is controlled with regulators in order to protect this area from fire and flood.

The water inside Paya Indah is basically flowing from north to south with the fall of altitude. The water level of Main Lake is 5.4 m on the average. It is said to be necessary to keep it to a maximum of 6.8 m to avoid bank erosion. The water levels of the lakes differ from each other. Visitor Lake overflows into Main Lake and Main Lake drains into Lotus Lake via a long canal. An outlet structure and channel were constructed between Driftwood Lake and Timah Lake to prevent overflow, and two culverts were also installed between Main Lake and Driftwood Lake to prevent algae from overgrowing. The channel was designed to regulate the water level within +4.8 m to +6.6 m. It is also said that the water level should be maintained within 300 mm to 600 mm below ground level to regulate peat subsidence and mitigate peat fires.[20)] Proposed water level of each lake and northern canal are shown in **Table K.5.4**.

During wet season, especially October, November, December and January, the gates in the peat swamp forest should be fully opened while all the gates should be closed to maintain water levels during dry season.[20)] Besides, there are some gates and culverts to control the water level.

Table K.5.4 Proposed Water Levels of Lakes and Canal

Name of Place	Min.(m)	Max.(m)
Main Lake	5.0	6.8
Driftwood Lake	4.8	6.6
Timah Lake	4.6	6.3
Northern canal going through Kuala Langat Forest Reserve(U)	Before meeting other canal: 6.5-6.0 After meeting other canal : 7.2-6.8	

Source: Water Management Plan for Malaysian Wetland Sanctuary at Selangor, Malaysian Wetlands Foundation, May 1998

Water balance has been figured out using net storage of current month and previous month, rainfall, total evapotranspiration, and seepage loss during the dry season. The result shows the seepage loss rate representing a water loss of 45,000 m^3/day, and a seepage loss of 40 mm/day has a negligible effect on water availability for the lakes. However, this result seems to be unlikely and have to be checked on site.[19)]

5.3.3 Groundwater Quality

Table K.5.5 shows the result of groundwater quality test. Characteristics of the groundwater quality for each pumping site are summarised as follows:

(1) Paya Indah

The lakes are situated in a former tin mine. Thick layers (sometimes up to 5m) of peat, followed by clay and sand were excavated and these pits then filled up with groundwater and rainwater.

No sampling test has been found in this area. The result of the nearby sampling point is made as reference. The point is located more than 10 km west of Paya Indah. The value of pH and turbidity exceed the standards for drinking water in Malaysia.

(2) Kajibumi Well Field 2

The Geological Survey Department Malaysia has been carrying out evaluation of the groundwater resource at the very point of existing Kajibumi Well Field 2 since 1998. All parameters except As, Fe and turbidity were within the standard and the result shows absence of saline water encroachment at Megasteel.[23)]

The groundwater is generally brownish to dark brown to black caused by the breakdown of organic matters from the peat.[21)]

(3) Kanchong Darat

No sampling test has been found in this area. The result of the nearby sampling point is made as reference. The point is located about 5 km southwest of Kanchong Darat. One of the significant characteristics of this quality is high salinity coming from the sea. Groundwater in Kanchong Darat also must be saline.

Table K.5.5 Groundwater Quality at the Pumping Test Sites

Parameter Unit	Depth m	Mg mg/l	Na mg/l	Cl mg/l	SO_4 mg/l	F mg/l	As mg/l
Nearby Paya Indah	13.8	1.6	12.5	10	67	-	<0.005
Kajibumi Well Field 2	48	6.3	35	31	<3	<0.5	**0.2**
Nearby Kanchong Darat	74.5	**181**	**1880**	**2340**	<3	-	<0.005
Standards*	-	150	200	250	400	1.5	0.05

Parameter Unit	Al mg/l	NH_4 mg/l	Fe mg/l	Mn mg/l	Zn mg/l	Cd mg/l	Cr mg/l
Nearby Paya Indah	-	-	0.9	0.01	-	-	-
Kajibumi Well Field 2	0.1	<0.50	**7.3**	0.1	<0.1	<0.01	<0.01
Nearby Kanchong Darat	<0.1	-	0.3	**1.7**	<0.1	<0.01	<0.01
Standards	0.2	0.5	0.3	0.1	5	0.005	0.05

Parameter Unit	Colour Hazen	Tur. NTU	DS mg/l	Hg mg/l	Cu mg/l	Pb mg/l	pH -
Nearby Paya Indah	10	**84**	-	-	-	-	**5.4**
Kajibumi Well Field 2	5	**55**	154	<0.2	<0.1	<0.01	6.5
Nearby Kanchong Darat	**100**	**14.5**	-	-	<0.1	<0.01	8.2
Standards	15	5	1000	0.001	1	0.05	6.5-8.5

Source: Geological Survey Department Malaysia, Pemantauan Sumber Dan Pemodelan Aliran Air Tanah Kawasan Telok Datuk-Olak Lempit, Kuala Langat, Selangor, pp. 20-21, February 1999.
Note: * Drinking Water Quality Standards (1983).

5.3.4 Groundwater Hydrology

Groundwater bodies comprise two types: unconfined aquifer and confined aquifer. Unconfined aquifer in general comprise water found in the upper peat layer bounded by the water table while the confined aquifer is found in the Simpang Formation and Kenny Hill Formation.[21)]

Existing monitoring wells concentrate south of the Dengkil-Banting road and around Tg. Sepat located in the south coastal area. The aquifer of the area including three study areas is alluvial sediment. The alluvium in the Kuala Langat area is in the range of 20 m to 80 m in thickness and overlies mudstone and quartzite bedrock. The thickness decreases from northwest to southeast.[21)]

Groundwater hydrology in the study area has not been confirmed yet although the following describes existing conditions observed at the site or reviewed by literature. That is why this project was proposed.

(1) Paya Indah

Paya Indah represents an ex-mining area that is being rehabilitated and conserved as a wetland. This area is projected to receive subterranean recharge flow from Bt. Cheeding to the north, and the Putrajaya/Cyberjaya area to the east.[21)]

The groundwater flow from Paya Indah is expected to move in the southwest direction through Olak Lempit, the Brooklands estate and towards the depression cone south of the Megasteel/Amsteel II area and south towards the coast.[21)]

(2) Kajibumi Well Field 2

When there was no groundwater abstraction yet, the groundwater was supposed to flow from Paya Indah southwards to the coast. However, after the well field operations was started, the groundwater began to flow to the well field.[21)]

According to the EIA study for Megasteel/Amsteel II, the water table occurs at an average depth of 2 m. The peat swamps in most of the area act as an unconfined aquifer.[21)]

(3) Kanchong Darat

Investigation about groundwater hydrology has not been done around this area but south of Megasteel/Amesteel II across the Langat River, and this centered at the sand mining pit within an ex-mining area. Kanchong Darat is located 5 km to the west.

Flow direction of groundwater is centered on the sand mining pit and is brought about by dewatering at the sand mining pit where a lowering of the water table down to the bedrock has taken place.[21)]

5.3.5 Geological Structure

Kenny Hill Formation (KHF) and the Beruas Formation (BF) comprise the surface geology, while the Gula Formation (GF), Kempadang Formation (KF) and Simpang Formation (SF) are included in the subsurface geology. The sediment composition in each formation is shown in **Table K.5.6** and is summarised as follows.

Table K.5.6 Soil Types of Each Formation

Part	Formation	Soil Type
Surface	Kenny Hill Formation (KHF)	Meta-sandstone, quartzite, phyllite, schist
	Beruas Formation (BF)	Peat, clayey peat
Subsurface	Gula Formation (GF)	Clay, silt, sand, minor gravelly clay
	Kempadang Formation (KF)	Clay with minor fine sand
	Simpang Formation (SF)	Sand, gravel with minor clay

Source: EIA Report for proposed groundwater abstraction on lots 1632, 2319, 2320, 2321 & 2323, p.8-5, Megasteel/Amsteel, September 1998.

(1) Paya Indah

BF, KF, SF and KHF line up in order from top. The top formation of the area that is situated on the north of Paya Indah is BF instead of GF. The boundary of this is just the Langat River. GF widely spreads south of the river.

(2) Kajibumi Well Field 2

This area is located near the borderline between GF and KF as the top surface formation. The thickness of the GF is more than 30 m here. SF whose thickness is about 40 m is covered under GF.

(3) Kanchong Darat

GF as the top formation and SF as the second formation are found around this area. The thickness of GF is almost the same (about 40 m) with the cross section around here.

5.3.6 Land Subsidence

According to Zakaria and Nor (1989), subsidence in the range of 2.5 to 3.6 cm per year (measured over 21 years) is usual in Peninsular Malaysian peat soils.[25)]

In Paya Indah, over-drainage has already led to some peat shrinkage and oxidation. Drained domes initially show strong subsidence, often in the range of 10-30 cm per year.[25)]

5.4 Biological

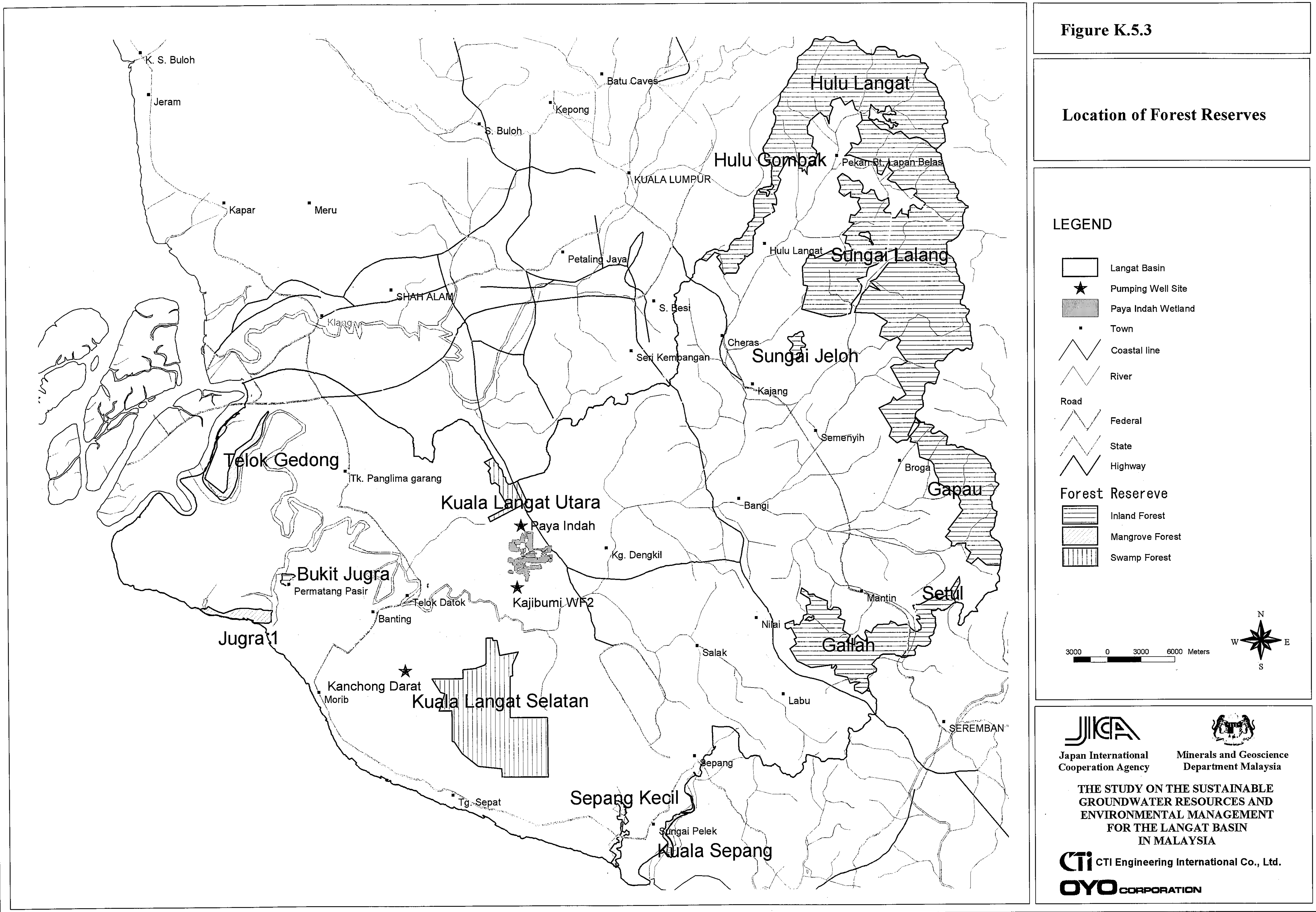
5.4.1 Preservation Area

There is no legal conservation area inside the study area such as National Park, Forest Reserve and Wildlife Reserve, but Paya Indah itself is the Wetland Reserve that does not have any legal regulation. **Figure K.5.3** shows the location of Forest Reserves. The Kuala Langat North Forest Reserve is located 3 km north of Paya Indah. Kuala Langat South Forest Reserve and Kanchong Darat adjoin.

The lakes provide habitat and food for the various species of fish, birds, reptiles, amphibians, mammals and insects. The lakes also act as a dam during periods of heavy rain. They can help recharge the groundwater. That is why Paya Indah is important.

Figure K.5.3

Location of Forest Reserves



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5.4.2 Habitat (Fauna & Flora)

(1) Paya Indah

Paya Indah has many kinds of habitats such as undisturbed secondary forest, degraded (recently logged-over/burnt) forest, open water, shallow marsh, scrubland and sand ridge. The habitat of the study area is scrubland. This area was burnt over in 1998. Burnt peat swamps are areas that were formerly peat swamp forests, but have been burnt after logging operations. Woody species have disappeared except for the ubiquitous shrublet *Melastoma malabathricum*, and the area is dominated by Alang-alang (*Imperata cylindrica*), a very persistent fire-tolerant species that is very difficult to control. Floristically these areas are very poor and only seven plant species were recorded at the northwest of Main Lake. The current conservation value of these burnt areas is very low.[24, 25)]

According to MWF, 210 species of birds, 18 species of fishes, 34 species of mammals, 18 species of reptiles, 7 species of amphibian and 36 species of insects (only butterflies) have been found. In another survey, 55 species of birds were recorded in scrubland and extensive areas such as pink-necked Pigeons (*Treron vernans*) and Thick-billed Pigeons (*Treron curvirostra*). Other species in this habitat including Barred Buttonquail (*Turnix suscitator*), Richard's Pipit (*Anthus novaeseelandiae*), Yellow-bellied Prinia (*Prinia flaviventris*) and Zitting Cisticola (*Cisticola juncidis*) also were recorded.

Annex K.5.2 shows a list of the significant species of flora and fauna that were recorded in Paya Indah and the extensive northern area including the Kuala Langat North Forest Reserve. However, there seems to be no significant terrestrial species in the study area because it is a burnt area and habitat value is low for scrubland.

Aquatic fauna and flora can survive in Main Lake even if the water is highly acidic. The most important thing for aquatic fauna is the value of DO. Below 5 mg/l may adversely affect the functioning and survival of biological communities, and below 2 mg/l may lead to the death of most fishes. The value of DO in Main Lake is above 5 mg/l.

(2) Kajibumi Well Field 2

The diversity of habitat is little because this area is an industrial zone. Only weeds can be found in the study area surrounded by the fence. Therefore, there will be no threatened fauna and flora there.

(3) Kanchong Darat

There seems to be no detail survey conducted in this area because it is a plantation area with no natural forest or wetland. It is to have little diversity of habitat and the number of species must be few because fertilisers and other toxic chemicals could make their habitation area diminish.

5.5 Social

5.5.1 Land Use and Ownership

(1) Paya Indah

Paya Indah is the Wetland Reserve area compromising tin mining lakes and peat swamp forests belonging to the Malaysian Wetlands Foundation (MWF). However, Petaling Tin Sdn. Bhd. had occupied Timah Lake (the west of Driftwood Lake) since 2004.

An area between the logged peat swamp forest and the Driftwood Lake was burnt over in 1998 and formed scrub. The pathway where the monitoring wells will be set was made during the fire fighting activity.

Wetlands International Asia Pacific has been proposing a large development plan that includes Paya Indah. Its plan is the establishment of a "Malaysia International Wetland Sanctuary, Selangor". In this plan, Wetland Visitor's Centre, sanctuary areas, a complex of nature trails, peat swamp forest regeneration areas and Environmental Science and Technology Business Park will be included.[10)] It has proposed construction of the Malaysia International Wetland Centre in Paya Indah. The development of this area is planned to start in early next year, i.e., 2001.

(2) Kajibumi Well Field 2

Kajibumi Well Field 2 is surrounded by many kinds of industries located near the Dengkil-Banting road at Olak Lempit. It lies midway between Dengkil and Telok Datok, about 10 km far from each other. This industrial area includes a group of the steel factory named Megasteel/ Amsteel II (subsidiaries of Lion Group of Companies). They are situated in the Brooklands estate and within 2km southwest of Kajibumi Well Field 2.

The study area belongs to Jabatan Bekalan Air Selangor. There are two pumping wells and one water tank inside the area.

(3) Kanchong Darat

This area is an agricultural area planted with oil palm, banana, and corn. It belongs to Felcra Berhad. The pumping well will be put around the crossroad near the bridge on Jl. Durian. One road going from southwest to northeast does not have enough width for two cars to pass through. There are some canals around there. One canal along the palm oil estate on Jalan Durian is relatively large; the width and depth are about 3 m and 1 m, respectively. Another small canal whose width is 1-2 m is located along the road next to corn or banana estates. Since water in both canals does not flow but stagnate, algae grow.

Residences and villages are located mainly along the Dengkil-Banting main road. The nearest town is Kanchong about 10 km away at the northwest. However, there is only one house found inside the study area. The worker of the plantation seems to live there.

5.5.2 Water Use

Figure K.5.4 shows the location of production wells, and the existing water use for each pumping site is summarised below.

(1) Paya Indah

No production well could be found in the study area and the adjacent area. According to MWF, surface water of lakes is sometimes drawn with pump and put into another lake when shortage of water in the southern lake occurs and some water is given for terrestrial flora when the water is much in lakes.

(2) Kajibumi Well Field 2

This area, Olak Lempit, is known to have many production wells. The existing wells and the volume of abstraction near the study area are shown below.[18)]

- Megasteel, 10,500 m^3/day
- Kajibumi Well Field 1&2, 16,600 m^3/day
- Sand mining, 23,600 m^3/day
- JBA (Jabatan Bekalan Air Selangor), about 3,000 m^3/day

The total amount of water used by Megasteel and the sand mining is expected to increase at most to 40,900 m^3 by 2005.[21)] JBA also take groundwater at 3,000 m^3 per day. This water is not used as usual living water but used during shortage of water.

In the EIA report for Megasteel/Amsteel II, the interviews about water supply, occupation, ownership, etc. were held with the residents living in Labohan Dagang, Bt. Changgang and Olak Lempit selected at random in 1996. The result showed there were a number of domestic wells in the area, but almost all were beyond 5 km away. Their depths are generally between 5-7 m. These wells except one, however, are not now being used because the whole region has been receiving piped water supply. Hence, there is very little dependence on well water in the area.[6)]

(3) Kanchong Darat

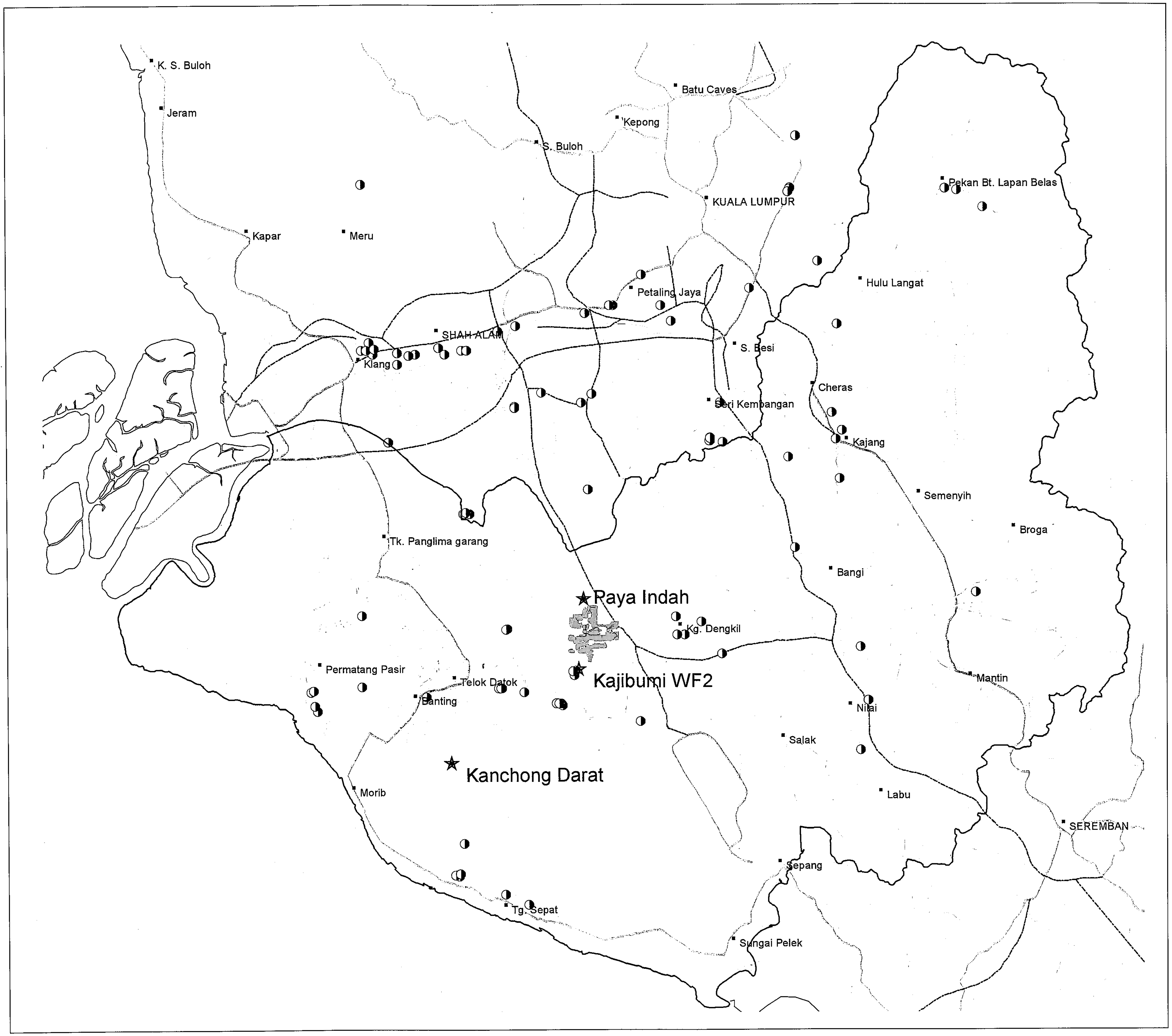
There is no well around this site. The groundwater nearby this area is quite saline since Na and Cl value indicate more than 9 times as high as the standard for drinking water.

5.5.3 Landscape

Mining swamp (Paya Indah) can be the only landscape in the whole study area. The area including Paya Indah and Kuala Langat North Forest Reserve is being developed and Malaysia International Wetland Sanctuary, Selangor has been established. (See **Subsection 5.5.1**, Land Use and Ownership)

Figure K.5.4

Location of Production Wells



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6. EFFECTS AND MITIGATION

Table K.6.1 shows the level of effect to the environmental component. Predicted significant effects are described below.

6.1 Physical

6.1.1 Surface Water Quality

The change of surface water quality would result from putting the pumped water into surface water as well as putting water with much bentonite used in washing and drilling wells in the construction stage.

(1) Paya Indah

It is planned to put the pumped water into Driftwood Lake or the small canal nearest Main Lake and the water mixed with much bentonite into Main Lake.

When comparing surface water quality in Main Lake and groundwater quality nearby Paya Indah, pH, Fe and Pb values were found to be lower in groundwater while turbidity was a little bit higher. The pH value in groundwater exceeded the standard for drinking water, but if the pumped water will be put into Driftwood Lake (next to Main Lake), the pH value is supposed to rise a little. Trace metal and salinity will not increase because not many metal and salinity elements (Na and Cl) were recorded in the groundwater quality analysis.

Significant impact is considered to increase the level of turbidity by putting much bentonite. Turbidity in Main Lake has already exceeded the Class IIA Guideline (conventional treatment required). The increase of turbidity may have influence on aquatic fauna and flora. According to the existing information, there are some significant species found in Paya Indah and Kuala Langat North Peat Swamp, but it is unknown whether they survive in Main Lake or not. In any case, it is better to try to diminish the turbidity from muddy water.

(2) Kajibumi Well Field 2

It is planned to put the pumped water into the canal along the road linking to Langat River. There is no plan to install a pumping well here; hence, bentonite will not be used.

When comparing surface water quality in Langat River and groundwater quality in Kajibumi Well Field 2, groundwater quality was relatively better than surface water except Fe and As. Turbidity in Langat River was already about 4 times as much as the standard. The surface water quality would become better although it is not still drinkable. After pumping, the quality would go back to the former condition.

(3) Kanchong Darat

It is planned to put the pumped water and the water mixed with much bentonite into the canal along the estate. The pumped up water might be saline and much bentonite could make the level of turbidity higher.

It is predicted that saline water accumulates on the surface of the ground by groundwater over-abstraction. This may have an adverse effect on crops.

Mitigation

To decrease the turbidity especially in Paya Indah, it is better:

- not to use bentonite more than necessary;
- to reuse bentonite;
- to segregate muddy water from surface water and sediment and only surface water (low turbidity) can be put into the lake or canal; while sediment should be buried in the ground or disposal place; and
- if adverse impact on surface water is found during pumping test, to inform the landowner and take more treatment or reconsider the plan.

6.1.2 Surface Water Hydrology

Hydrological changes on surface water by abstraction from groundwater and putting pumped water into canal or lake during pumping test (for 1 month) are considered. Pumping rates are 50 l/sec (4.32Mld) at Paya Indah, and 100 l/sec (8.64Mld) at Kajibumi Well Field 2 and Kanchong Darat. (Mld = million litres per day)

(1) Paya Indah

If the pumped water is put into Driftwood Lake, the water level will rise. The water level rise rate will be about 10 cm when the same volume of water is put into Main Lake for 30 days supposing there is no outflow to another lake or evaporation. Since Main Lake is much bigger than Driftwood Lake, the rise of water level in Driftwood Lake will be more than 10 cm. At present, however, Driftwood Lake is connected to Main Lake and Timah Lake with underground culverts. If some water will go into the Main Lake or the Timah Lake, the water level will not rise so much. Besides, the water level of each lake is being controlled. It is proposed that water level must be below 6.6 m in Driftwood Lake.

Another problem is the movement of water after discharging it into Driftwood Lake. It is not certain whether or not the water in Driftwood Lake will spread into the Main Lake through the underground culvert at the pumping rate because the water level is higher in Main Lake. Naturally, the water is considered to flow from Main Lake to Driftwood Lake. It is however predicted that if the amount of water becomes enough to cause overflow the water will flow into the Main Lake. If so, the water could seep underground near the pumping well and probably taken by the pump again. If such circulation were formed, correct measurement would become impossible. On the other hand, if the water mainly goes into the Timah Lake or even if it could go to the Main Lake and seepage rate is very slow, there will be little influence of pumping.

Taking the above situations into consideration, it may be better to drain the pumped water into the nearest canal. The water in the canal does not flow in dry season, but if water exists, it flows from north to south. This canal is now filled up with garbage. The garbage should therefore be removed at first if this canal is selected as the place where pumped water would be drained.

(2) Kajibumi Well Field 2

The canal is about 1m in width and 0.7 m in depth. There is little water existing at present but it does not flow. If pumped water is put here, the water would flow, but there is a possibility of overflow in the canal depending on the pumping rate. No calculation has been done on whether water will overflow or not.

Almost the same test was done in the EIA study for Megasteel/Amsteel II project. No comment was made about this matter. If Megasteel/Amsteel II could put much more water than the pumping rate proposed in this present study into the surface without any problem, the method should be made as reference.

(3) Kanchong Darat

The canal is about 3 m in width and 1 m in depth. There is much water inside it but does not flow and a lot of algae are growing. If the pumped water is put into the canal, it could probably overflow. If so, crops would get some damage because of the saline water.

<u>Mitigation</u>

- Accurate calculation should be done on whether or not pumped water can flow within the canal and lake before pumping.
- In Paya Indah, the water should be moved to another lake using a pump or other means in case of significant rise of water level.
- Pumping test should be avoided in rainy season if possible because flooding easily occurs in this season.
- When any adverse impact is found, the plan should be reconsidered.

6.1.3 Groundwater Quality

The change of groundwater quality due to saline intrusion by abstraction is expected especially in Kanchong Darat.

Saline intrusion will be the biggest impact in this area. It reaches the Langat River downstream at Telok Datok.[21)] Banting town is the point transition between brackish and fresh water according to Nasiman and Mohamad (1997).[21)] The value of sodium and chloride in the groundwater at the nearest existing well from Kanchong Darat (approximately 5km northeast from Kanchong Darat) were 1,880 mg/l and 2,340 mg/l, respectively, in 1994. (cf. the standard is 200 mg/l for sodium and 250 mg/l for chloride for drinking water, DWQS, 1983)

The EIA report for Megasteel/Amsteel II show that indication of the transition might only reflect salinity in the upper aquifer, and the position of the interface in the lower aquifer could not be predicted with certainty because of the influence of bedrock topography, groundwater flow rates and water levels.[21)]

Thus, if the groundwater level would get lower by over-abstraction, the interface between fresh and saltwater could gradually move inland. Not only the movement of the interface, but baneful influence on the crops is predicted.

Mitigation

- If saline water intrusion should be found during pumping test, the plan should be reconsidered such as stopping of pumping or reducing the pumping rate.
- More treatment will be needed in Kajibumi Well Field 2 if the groundwater is used as drinking water because turbidity values of As and Fe are over the Drinking Water Quality Standards.

6.1.4 Groundwater Hydrology

When groundwater is abstracted, drawdown occurs. Although drawdowns of each site are little enough to consider, the final range of drawdowns is unknown when groundwater at each site is taken at a time. This is also a problem to be found in this project.

(1) Paya Indah

Any change in the flow is not expected to affect Paya Indah since MWF controls the water level manually. It is said that the water table should not be allowed to drop below 30 cm in order to protect the peat structure (FRIM, 1996).[16)]

(2) Kajibumi Well Field 2

A production bore at Megasteel/Amsteel II was test-pumped for 30 days at 15,000 m^3/day in the EIA of Megasteel/Amsteel in 1997 and this pumping rate is more than that of this project. Drawdowns were measured in the pumped bore and 3 observation bores located 10 m, 55.5 m and 210 m away from the pumped bore.

As a result, drawdowns of each point after 30 days are approximately 8 m, 6-7 m, 5-6 m and 4.5-5 m. Since the proposed pumping rate of this project is less than the above, drawdowns are expected to be lower.

According to the report, Megasteel factory and the sandpit were abstracting groundwater at about 34,100 m^3 daily at that time. The result of computer - simulated model shows that this amount of groundwater has not adversely affected the regional groundwater level, the drawdown from both the top and bottom aquifers averaging 0.13 m. Even if 74,500 m^3/day groundwater is abstracted, it is anticipated that there will be a sharp groundwater level drawdown only around the immediate vicinity of well field and sandpit. [18)]

The following description refers to the studies for groundwater abstraction at Megasteel/Amsteel II.

The drawdown of water level in the wetland (Paya Indah) and adjacent shallow aquifer are less than 0.1 m within the main area and up to 0.3 m near its southwestern boundary even for pumping rates after 5 years at 50Mld.[21)]

At a radius of about 3 km oft he well field including Olak Lempit, the drawdown is less than 0.3 m even for pumping rate of about 50Mld.

There would be no reduction in the stream flow of Langat River on account of groundwater abstraction because an impermeable layer separates it. Pumping test showed that the river does not act as a recharge boundary otherwise steady state conditions would have been reached instantaneously due to the close proximity.[23)]

(3) Kanchong Darat

In the sand mining pit area to the south of Megasteel/Amsteel II, groundwater flows to the sand mining pit because of dewatering. This is likely to have significant effects on the aquifer and possibly land subsidence in the near vicinity.[21)] This area is more than 5 km away from the sand mining pit, so that effect by dewatering would be little.

Mitigation

- Long term monitoring is recommended.
- The natural recharge zones of the aquifer should be protected and maintained as water bodies rather than be reclaimed with the dewatering of sand mining areas.

6.1.5 Land Subsidence

Land subsidence is not likely to occur immediately after starting of abstraction. It is likely to be a process that may take several years to develop due to the presence of a thick clay aquitard of low permeability.[21)]

Over-abstraction of groundwater will affect land subsidence. The lowering of water table as a result of abstraction has potential to increase density brought about by water table lowering and changes in reservoir pressures with loss of fluids.[21)]

Fine sediments especially clay and silt are the main components subjected to compaction.[21)] The formation under Kajibumi Well Field 2 and Kanchong Darat is not Kenny Hill Formation and it is expected to be more seriously affected.

There was only a modelling study for Megasteel/Amsteel II. According to the modelling study, if the pumping rate is between 27 to 50Mld, drawdown of the upper aquifer is low and generally does not exceed 0.4 m. Waterhead drop for the lower aquifer of between 20-36 m has been estimated in the vicinity of the well field but this declines to about 8-24 m in the near vicinity (including Olak Lempit) and 3-4 m near Paya Indah.

If pumping rate is about 27Mld, 0.5-1.8 m will be sunk and if pumping rate is about 50Mld, 0.9-3.24 m will be sunk. However, this is far less (between 0.1-0.36 m) at locations that are further away from the well field. (Domenico & Schwartz)

Pumping rate of this project is less than that of the modelling test: 4.32Mld at Paya Indah, 8.64Mld at Kajibumi Well Field 2 and Kanchong Darat. It is estimated that subsidence would be also much lower than above. However, when groundwater is taken at three points at a time, significant subsidence could occur somewhere.

Monitoring of water head at selected areas and establishment of benchmark for monitoring of ground elevation are planned for long-term monitoring. The results of monitoring could find a solution to prevent the land from lowering.

Mitigation

- All demands for groundwater within the same aquifer should pass the approval of the relevant authority. Records of total demand from the aquifer should be maintained by some authority.[21)]
- Land subsidence can be minimised with effective management of groundwater. Therefore long term monitoring will be needed.

In the monitoring, safe yield is maintained by the following parameters:[23)]

- Discharging by pumping should not be more than the groundwater recharge to the aquifer.
- Piezometric levels are to be maintained above aquifer zone (i.e., no dewatering of aquifer).
- Lowering of piezometric levels in surrounding areas is to be minimal as much as possible.

6.2 Biological

The change of habitat and significant species would result from land occupation by drilling wells, establishing new roads and base camps and so on. Although biological impact in Paya Indah is the biggest among three sites for having many kinds of habitat and significant species, the restricted study area in Paya Indah is not worth protecting because it has been burnt over recently. Thus, the activities of this project would make little impression on biological environment. However, secondary effect such as the change of habitat influenced by change of water quality or water level is predicted.

Mitigation

- Cutting plants should be at a minimum even if they are not significant species.

6.3 Social

6.3.1 Landuse and Ownership

The MWF, which manages Paya Indah, says that it will support this project because it also wants to know the groundwater and surface water hydrology in order to control the water level.

Negotiations with the owner of Kajibumi Well Field 2 and Kanchong Darat estate have not been done yet. Crops will not be cut and will not be damaged in this plan. Since the area to be changed is small and pumping term is only 1 month, there will be a little impact such as loss of income and reduced assets.

A little effect on residents inside the study area in Kanchong Darat is predicted. Since there is no plan to occupy their house and no plan to construct at night, the impact will be quite little.

Mitigation

- If adverse effect is found such as pumping of highly saline water and water contamination, inform the landowner and reconsider the plan as soon as possible.
- Before starting construction, inform the residents about the project through the estate owner.

6.3.2 Water Use

Since there is no well water use for household found around Paya Indah and Kanchong Darat, the impact would be quite slight. In Paya Indah, households control the water level by opening and shutting the gate. Therefore, they would be able to change the water balance seeing the water level condition. Oil palm and banana trees do not depend on irrigation for their growth.[6)]

Around the Kajibumi Well Field 2, there are some wells but not used for drinking according to the result of interview in the EIA study of Megasteel/Amsteel II. Households obtain their water from the JBA public water supply. There will be an impact, but not on residents but on factories taking water from groundwater.

Mitigation

- If significant shortage of water supply takes place, the pumping rate should be changed or pumped water should be given if possible.

6.3.3 Landscape

Paya Indah will be developed as a wetland sanctuary. Some buildings are now under construction and the sanctuary will open in early 2001 as planned.

There will be a slight effect as long as the pumping test finishes before opening. Some measures should be made after pumping test, considering that the general public comes to this area.

Mitigation

- Pumping test should be finished before the wetland sanctuary opens. However, January and February fall in the rainy season, so it is better to finish the pumping test by the end of this year 2000.
- After the pumping test, the wells should not be trampled upon by walkers or touched by the general public. Some kind of protection to the wells may be necessary.

6.3.4 Others

The effect on health and safety of the guards who will watch the wells during pumping test all day long for 30 days will be quite little because all of the study areas are near towns and it takes within 30 min. to get to the nearest town.

Basically, workers will work from morning to evening and not stay at the site.

Mitigation

- In case of emergency, it is better to let the guards and workers have some medicine and cellular phones and to confirm the contact system.

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ANNEX K.5.1

EVALUATION OF ENVIRONMENTAL COMPONENTS

FOR

THE PUMPING TEST SITES

Annex Table K.5.1 Evaluation of Environmental Components for the Pumping Test Sites

ENVIRONMENTAL COMPONENT			PAYA INDAH	KAJIBUMI WF2	KANCHONG DARAT	REMARKS(REASON)
PHYSICAL	LAND	Landform	E	E	E	No large scale of drilling will be done.
		Soil Profile	E	E	E	Much soil will not be changed.
		Soil Composition	E	E	E	Much soil will not be changed.
		Slope Stability	E	E	E	Much soil will not be changed.
		Subsidence and Compaction	D	D	D	Groundwater will be taken for 1month.
		Seismically	E	E	E	No large scale of drilling will be done.
		Flood Plains/Swamps	D	E	E	Groundwater will be taken near Paya Indah wetland.
		Land Use	D	D	D	No large land will be acquired.
		Engineering and Mineral Resources	E	E	E	There is no mining land around the study area.
		Buffer Zones	E	E	E	There is no legal conservation area inside the study area.
	SURFACE WATER	Shore Line	E	E	E	No drilling will be done near shore.
		Bottom Interface	E	E	E	No large scale of abstraction will be done.
		Flow Variation	D	B	B	Pumped water will be put into the surface water for 1month. Water level is controlled in Paya Indah.
		Water Quality	B	B	B	Muddy water including much bentonite and groundwater will be put into.
		Drainage Pattern	D	B	B	Pumped water will be put into the surface water for 1month. Water level is controlled in Paya Indah.
		Water Balance	D	B	B	Pumped water will be put into the surface water for 1month. Water level is controlled in Paya Indah.
		Flooding	D	B	B	Pumped water will be put into the surface water for 1month. Water level is controlled in Paya Indah.
		Existing Use	E	E	E	Much surface water will not be needed.
	GROUNDWATER	Water Table	C	B	C	Groundwater will be taken for 1month.
		Flow Regime	C	B	C	Groundwater will be taken for 1month.
		Water Quality	C	B	C	Groundwater will be taken for 1month.
		Recharge	C	B	C	Groundwater will be taken for 1month.
		Aquifer Characteristics	C	B	C	Groundwater will be taken for 1month.
		Existing Use	E	B	E	Well water for household is scarcely used but industries take much
	ATMOSPHERE	Air Quality	E	E	E	No large scale of drilling will be done.
		Air Flow	E	E	E	No large scale of drilling will be done.
		Climatic Changes	E	E	E	No large scale of drilling will be done.
		Visibility	E	E	E	No large scale of drilling will be done.
	NOISE	Intensity	E	E	E	No large scale of drilling will be done.
		Duration	E	E	E	Construction will be done during day time.
		Frequency	E	E	E	No large scale of drilling will be done.
BIOLOGICAL	SPECIES / POPULATIONS	Terrestrial Vegetation	D	E	E	Paya Indah has many kinds of habitat. No significant vegetation found in the study area.
		Terrestrial Wildlife	D	E	E	Paya Indah has many kinds of habitat and significant species. The study area is scrubland. It means low diversity.
		Other Terrestrial Fauna	D	E	E	Paya Indah has many kinds of habitat and significant species. The study area is scrubland. It means low diversity.
		Aquatic/Marine Flora	C	E	E	Aquatic flora in each lake in Paya Indah is unknown.
		Fish	D	E	E	Paya Indah has many kinds of habitat but significant species are not found.
		Other Aquatic/Marine Fauna	C	E	E	Other aquatic fauna is unknown.
	HABITATS / COMMUNITIES	Terrestrial Habitats	D	E	E	Paya Indah has many kinds of habitat. The study area is scrubland. It means low diversity.
		Terrestrial Communities	D	E	E	Paya Indah has many kinds of habitat. The study area is scrubland. It means low diversity.
		Aquatic Habitats	D	E	E	Main Lake is already slightly polluted. It means low diversity.
		Aquatic Communities	E	E	E	Main Lake is already slightly polluted. It means low diversity.
		Estuarine Habitats	E	E	E	There is no estuary near the study area.
		Estuarine Communities	E	E	E	There is no estuary near the study area.
		Marine Habitats	E	E	E	There is no sea near the study area.
		Marine Communities	E	E	E	There is no sea near the study area.
SOCIAL	HEALTH / SAFETY	Physical Safety	D	D	D	Guards should be watch wells during pumping test all day long.
		Psychological well-being	E	E	E	There are towns within 30minutes drive from pumping well.
		Parasitic Disease	E	E	E	There are towns within 30minutes drive from pumping well.
		Communicable Disease	E	E	E	There are towns within 30minutes drive from pumping well.
		Physiological Disease	E	E	E	There are towns within 30minutes drive from pumping well.
	SOCIAL / ECONOMIC	Employment	E	E	B	Saline water will have adverse impact on crops.
		Housing	E	E	D	There is only one house inside the study area are in Kanchong Darat.
		Education	E	E	E	The project will not disturb an education.
		Utilities	E	E	E	The project will not disturb utilities.
		Amenities	D	E	E	Paya Indah will be developed as a wetland sanctuary early in 2001.
		Property & Settlement	E	E	C	No resettlement will be needed.
	AESTHETIC AND CULTURAL	Landform	E	E	E	No large scale of drilling will be done.
		Biota	B	E	E	The change of water properties may change the ecosystem.
		Wilderness	E	E	E	Paya Indah has many kinds of habitat. The study area is scrubland. It means low diversity.
		Water Quality	E	E	E	Muddy water including much bentonite and groundwater will be put into.
		Atmosphere Quality	E	E	E	No large scale of drilling will be done.
		Climate	E	E	E	No large scale of drilling will be done.
		Tranquility	E	E	E	No large scale of drilling will be done.
		Sense of Community	E	E	E	No large scale of drilling will be done.
		Community Structure	E	E	E	No large scale of drilling will be done.
		Man-Made Objects	D	E	E	Paya Indah will be developed as a wetland sanctuary early in 2001.
		Historic Places or Structure	E	E	E	There is no historic place around the study area.
		Religious Place or Structure	E	E	E	There is no religious place around the study area.
		Landscape	D	E	E	No large scale of drilling will be done.

Legend

A Serious impact is expected.
B Some impact is expected.
C Lack of information
D Little impact is expected.
E No impact is expected. IEA is not necessary.

ANNEX K.5.2

LIST OF THREATENED SPECIES IN PAYA INDAH

AND

KUALA LANGAT NORTH PEAT SWAMP

Annex Table K.5.2
List of Threatened Species in Paya Indah and Kuala Langat North Peat Swamp

	scientific name	common name	legal status	IUCN	Others
PLANTS	*Shorea Rugosa Var. Uliginosa*	Meranti Batu			Selangor endemic
	Shorea Teysmanniana	Meranti Punai			Selangor endemic
	Pinanga Riparia	Legung		R	Malaysian endemic
	Philydrum Lanuginosum	-			rare in Malaysia
BIRDS	*Ichthyophaga Inchthyaetus*	Grey-Headed Fish-Eagle		LR	
	Psittinus Cyanurus	Blue-Rumped Parrot		LR	
	Anthracoceros Malayanus	Black Hornbill		LR	
	Megalaima Rafflesii	Red-Crowned Barbet		LR	
	Trichastoma Bicolor	Terruginosus Babbler		LR	
	Platysmurus Leucopterus	Black Magpie		LR	
MAMMALS	*Echinosorex Gvmnurus*	Moonrat			
	Hylobates Lar	White-Handed Gibbon	TP	LR	
	Hystrix Brachyura	Malayan Porcupine	TP	VU	
	Ursus Malayanus	Malayan Sun Bear		VU	
	Panthera Pardus	Leopard/Panther			Threatened
	Neofelis Nebulosa	Clouded Leopard		VU	
	Tapirus Indicus	Malayan Tapir		VU	
	Presbytis Femoralis / Melaloophos	Banded-Leaf Monkey		LR	
	Macaca Fascicularis	Long-Tailed Macaque		LR	
	Macaca Nemestrina	Pig-Tailed Macaque		VU	
	Manis Javanica	Malay Pangolin		LR	
REPTILES	*Python Reticulatus*	Reticulated Python	TP		
	Ophiophagus Hannah	King Cobra	TP		
	Heosemys Spinosa	Spiny Hill Turtle		VU	
	Cuora Amboinenis	Malayan Box Turtle		LR	

sorce: A Preliminary Ecological Assessment Of The Malaysia Wetland Sanctuary, Selangor (Kuala Langat North Peat Swamp),Wetlands International Asia Pacific, July 1996
Malaysia Wetlands Foundation

legend: leagal status: Protection of Wildlife Act of 1972 (amended 1976 and 1988)
・TP: totally protect
IUCN: IUCN 1994 Red List of Threatened Animals
・LR(LOWER RISK): A taxon is Lower Risk when it has been evaluated, but does not satisfy the criteria for any of the categories Critically Endangered, Endangered or Vulnerable.
・VU(VULNERABLE): A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future
・R(RARE): taxa with small world populations that are not at present Endangered or Vulnerable but are at risk.