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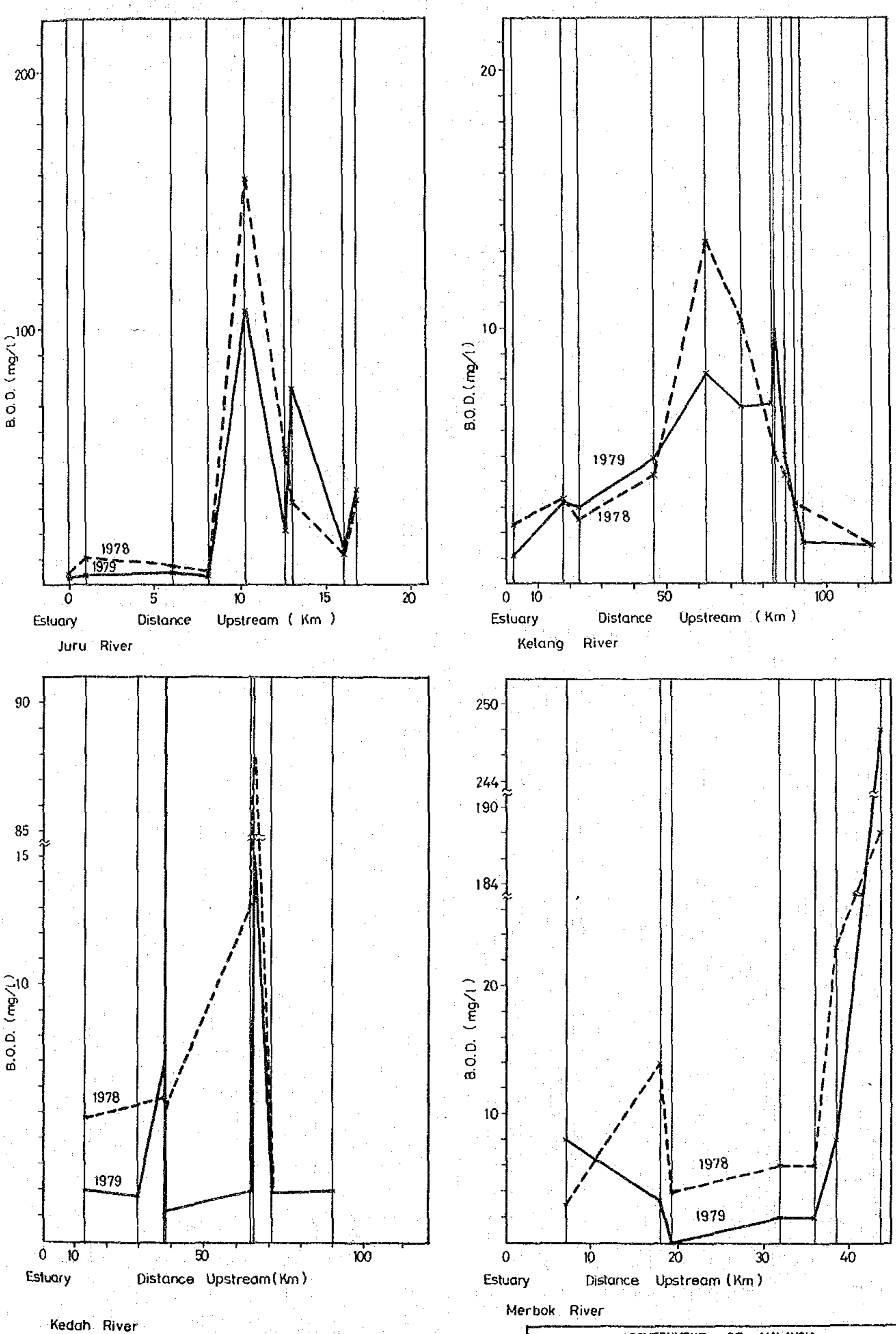

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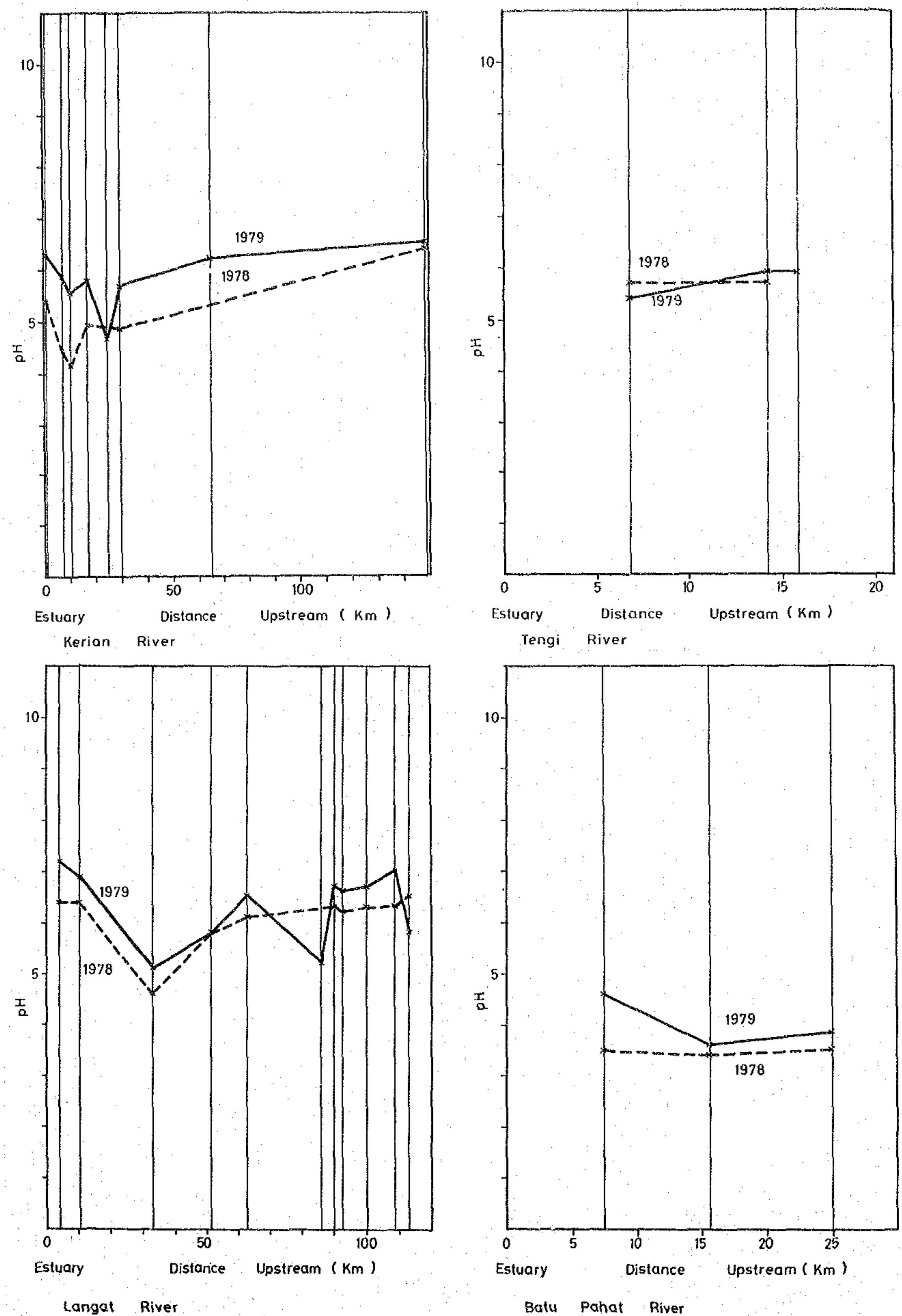

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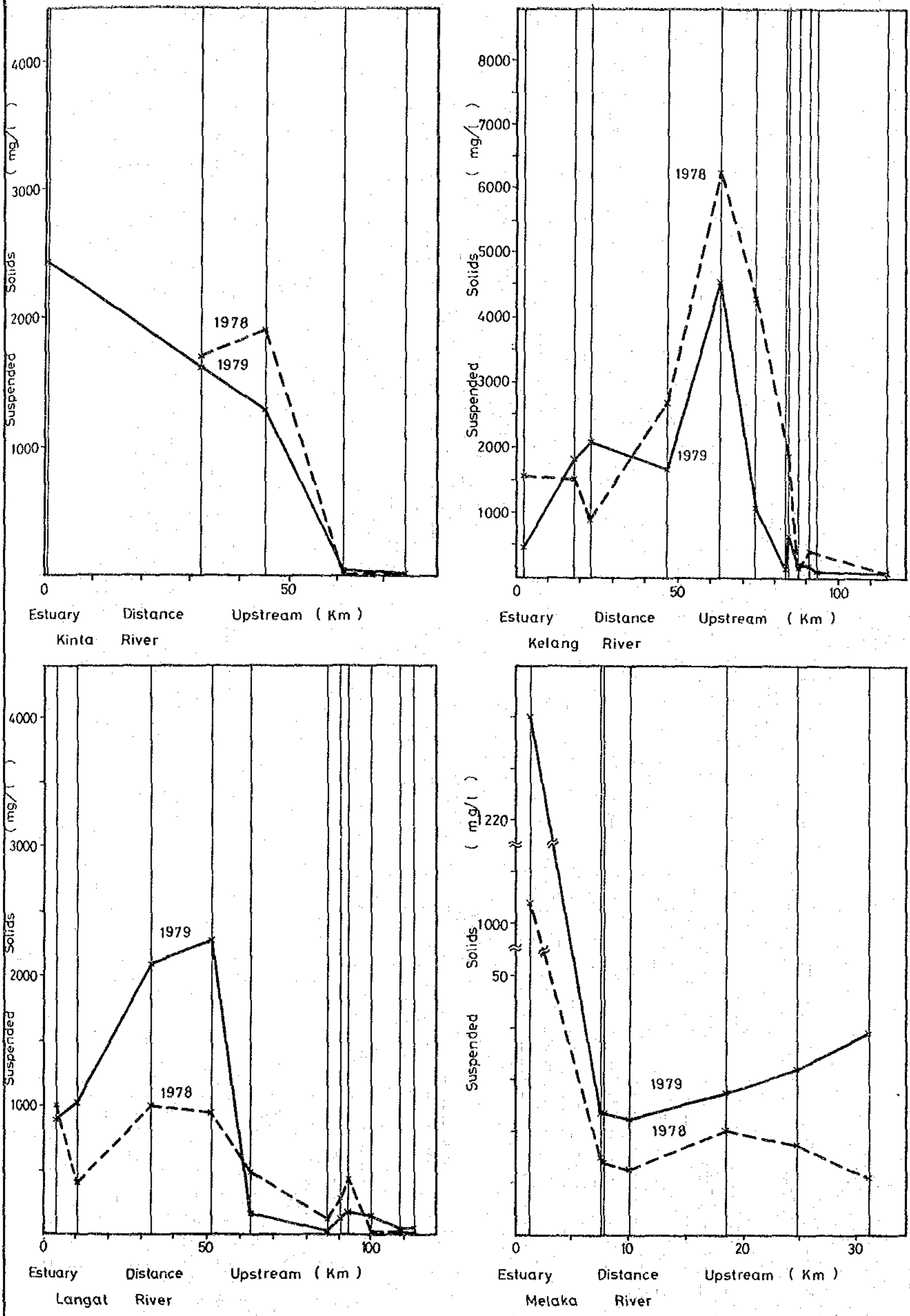

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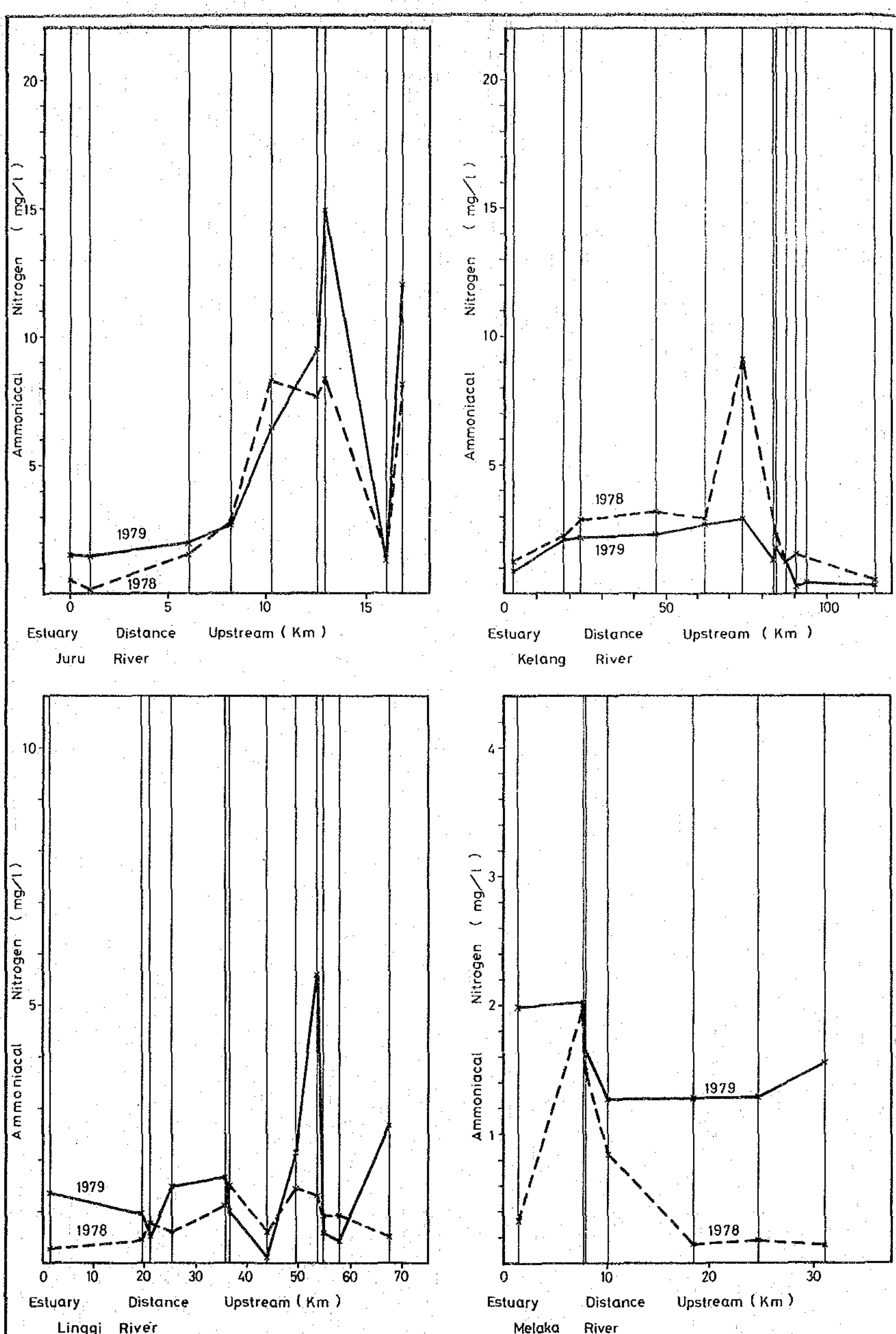

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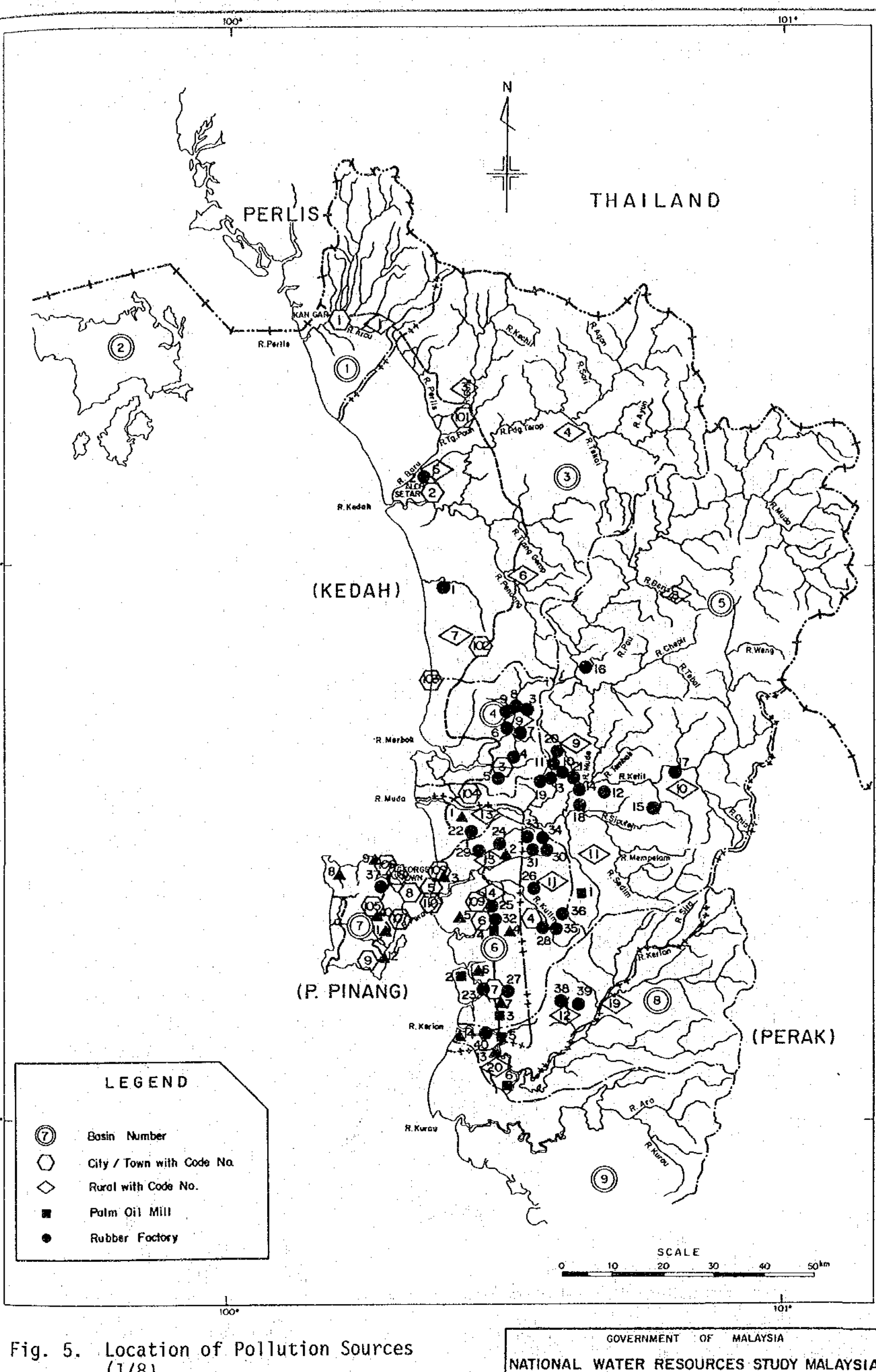

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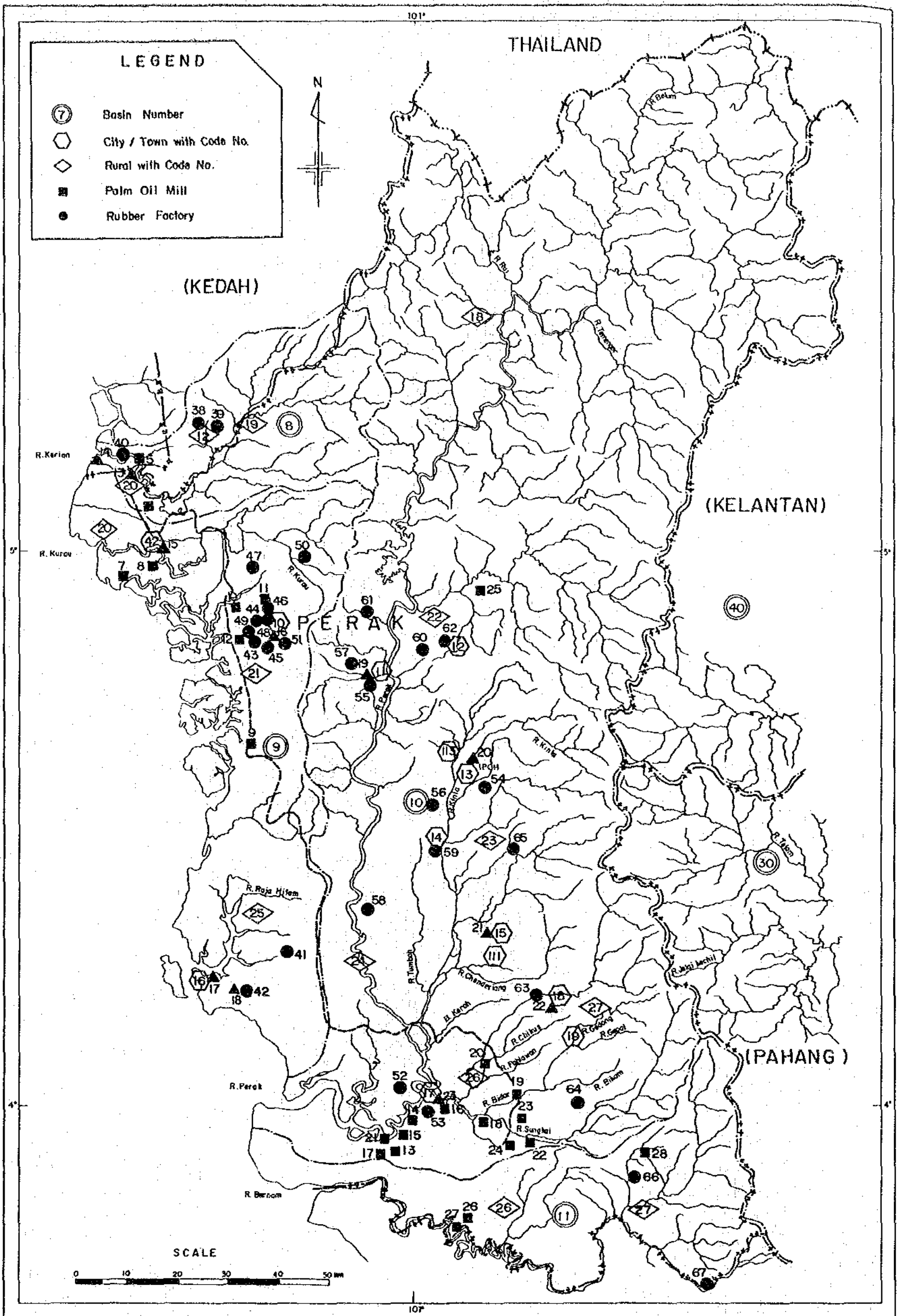

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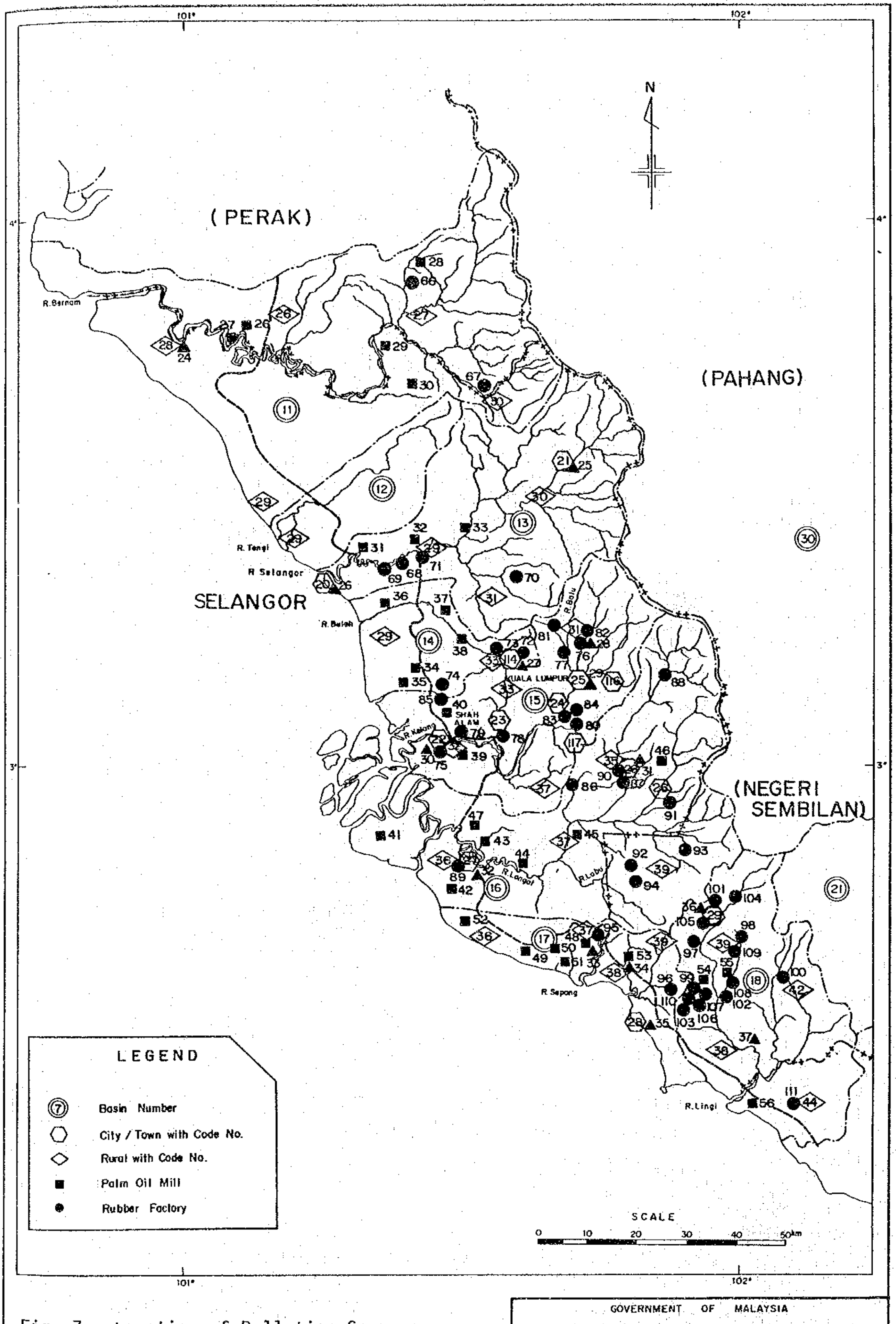

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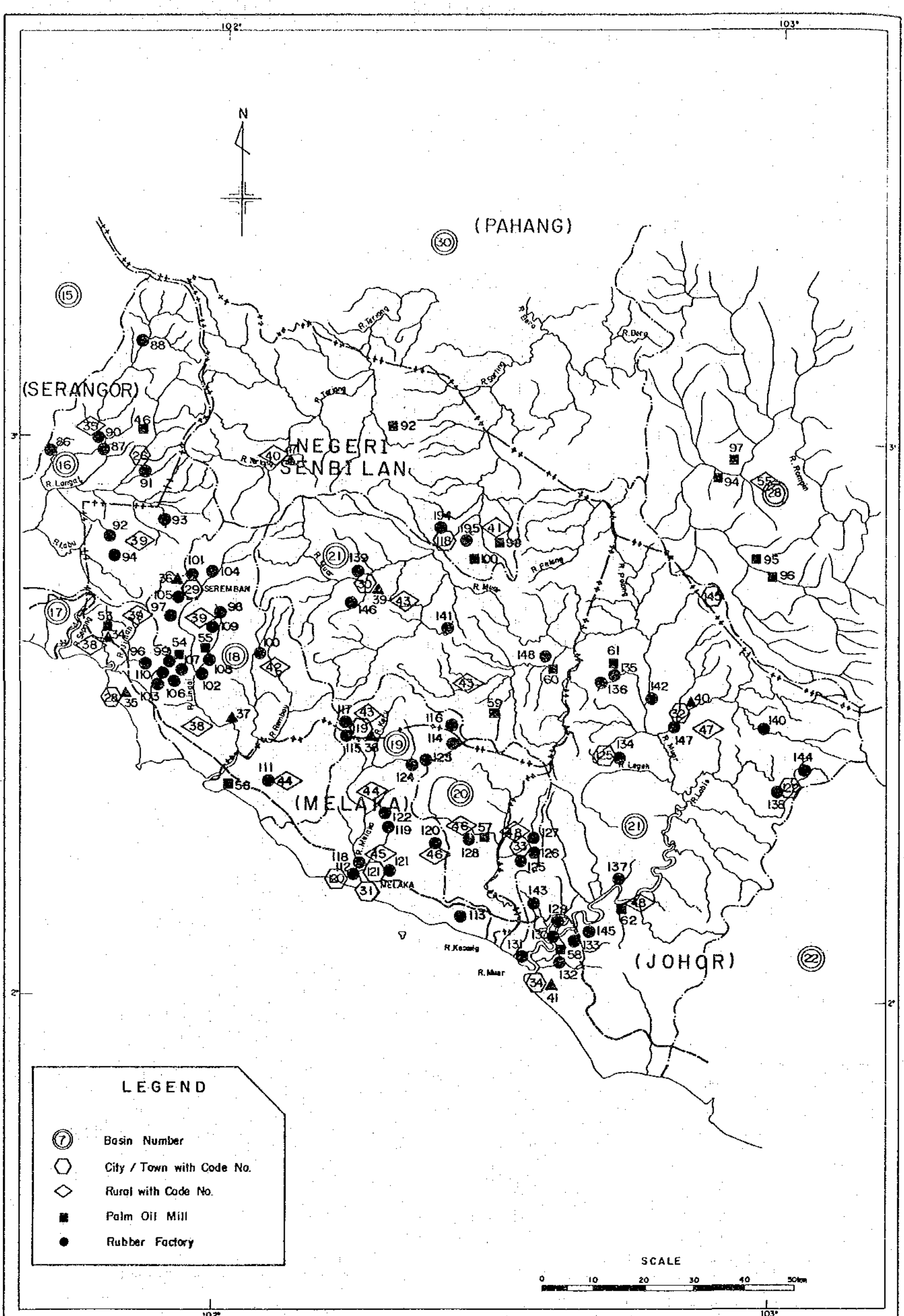

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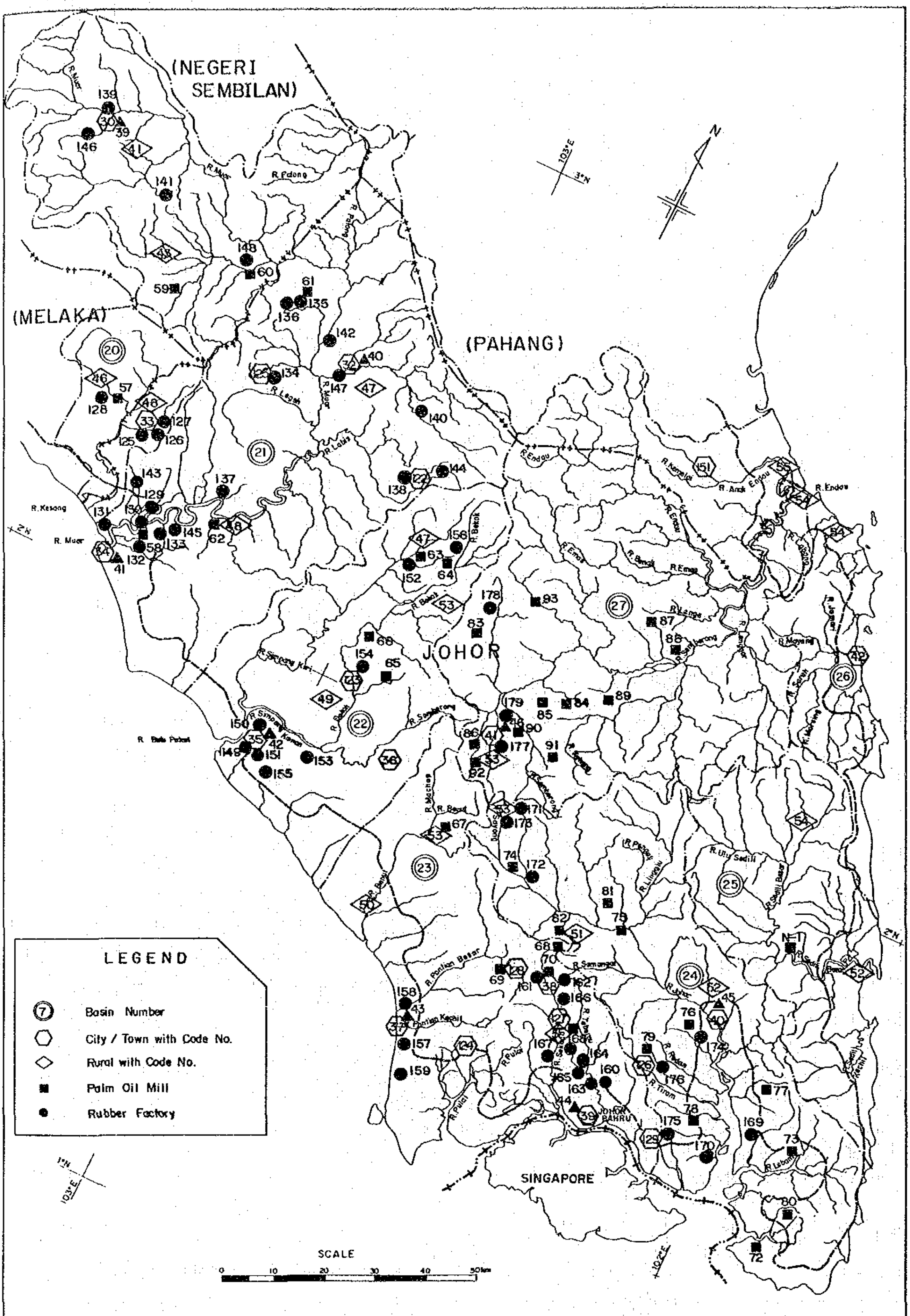

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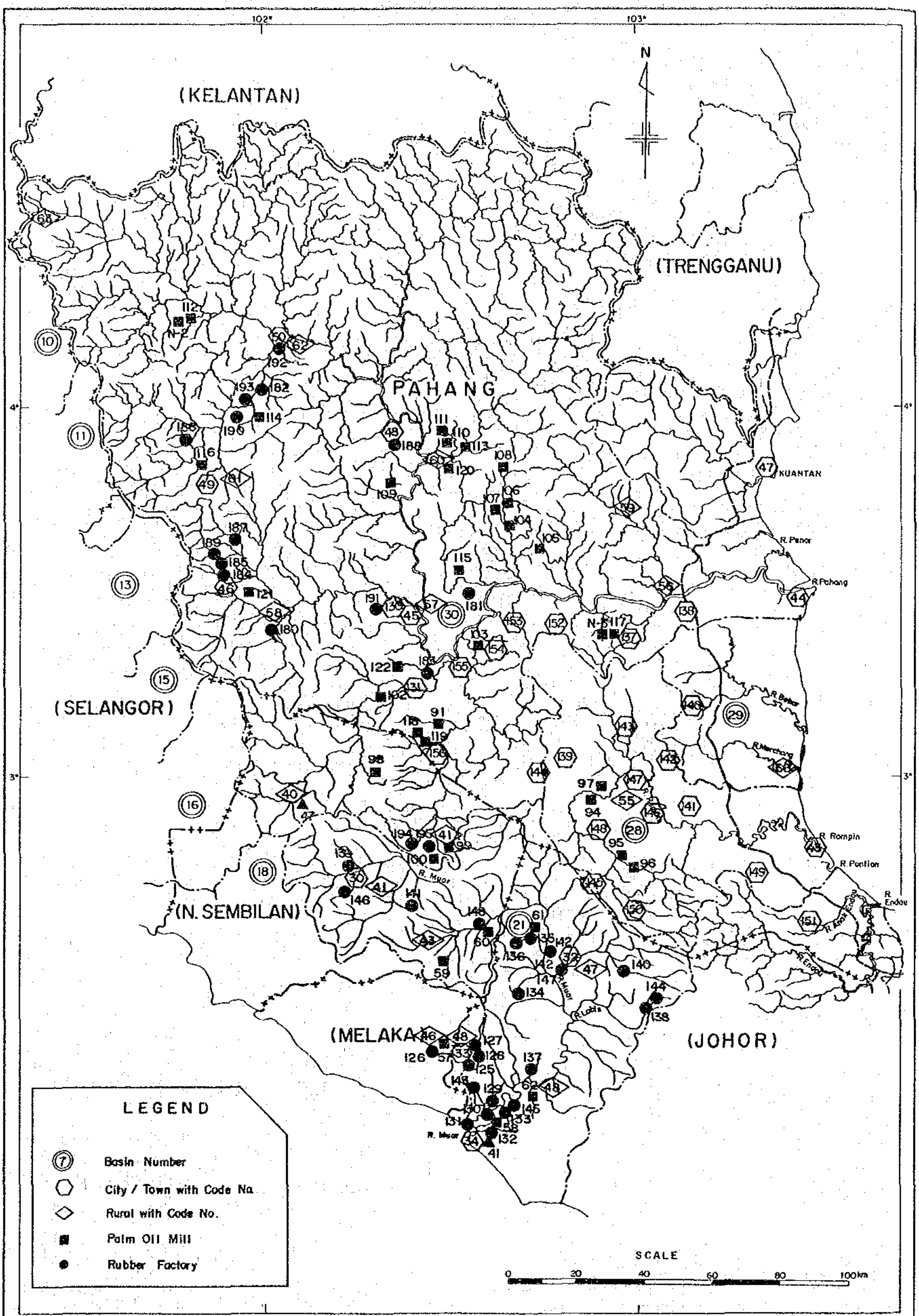

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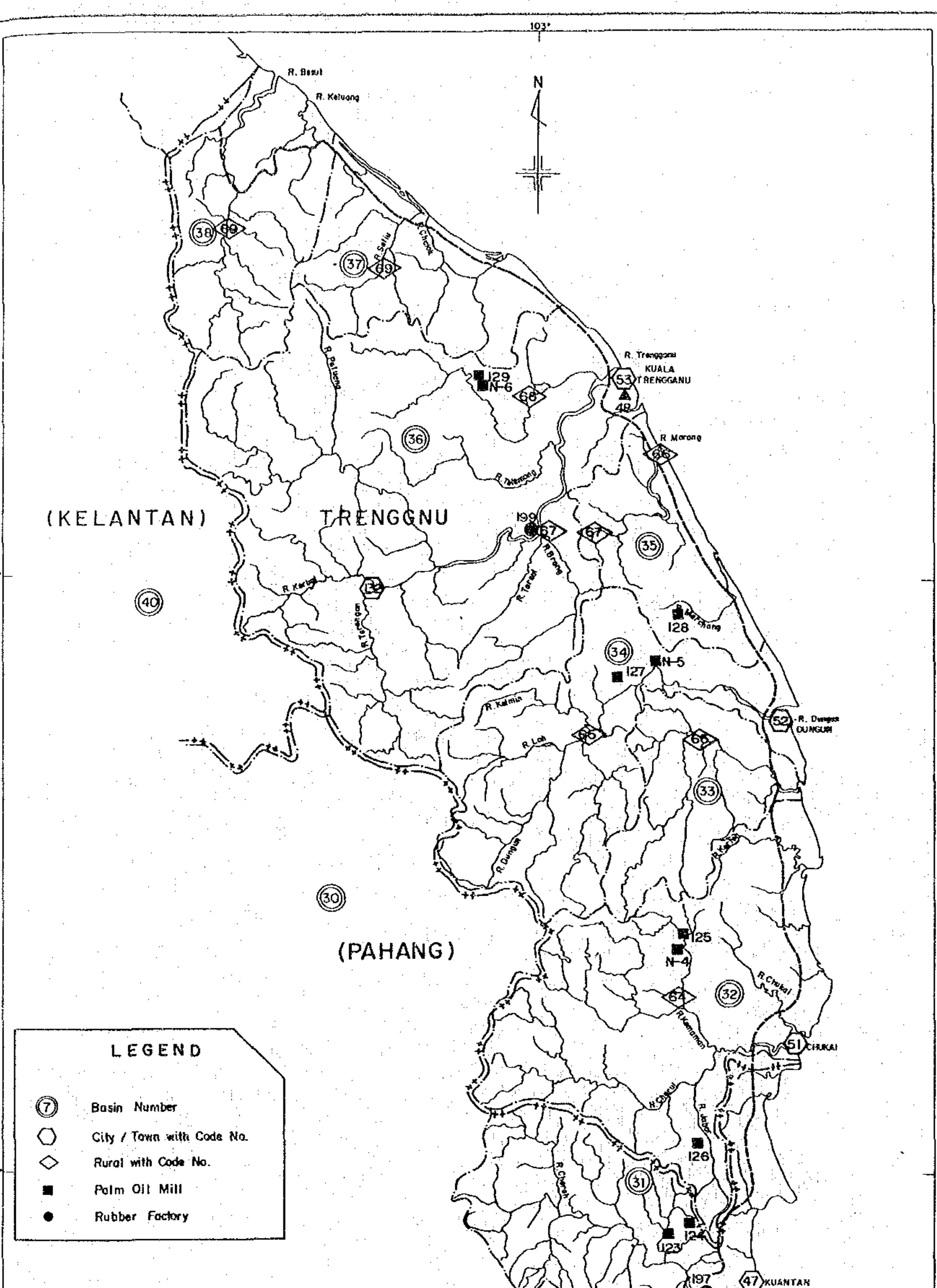

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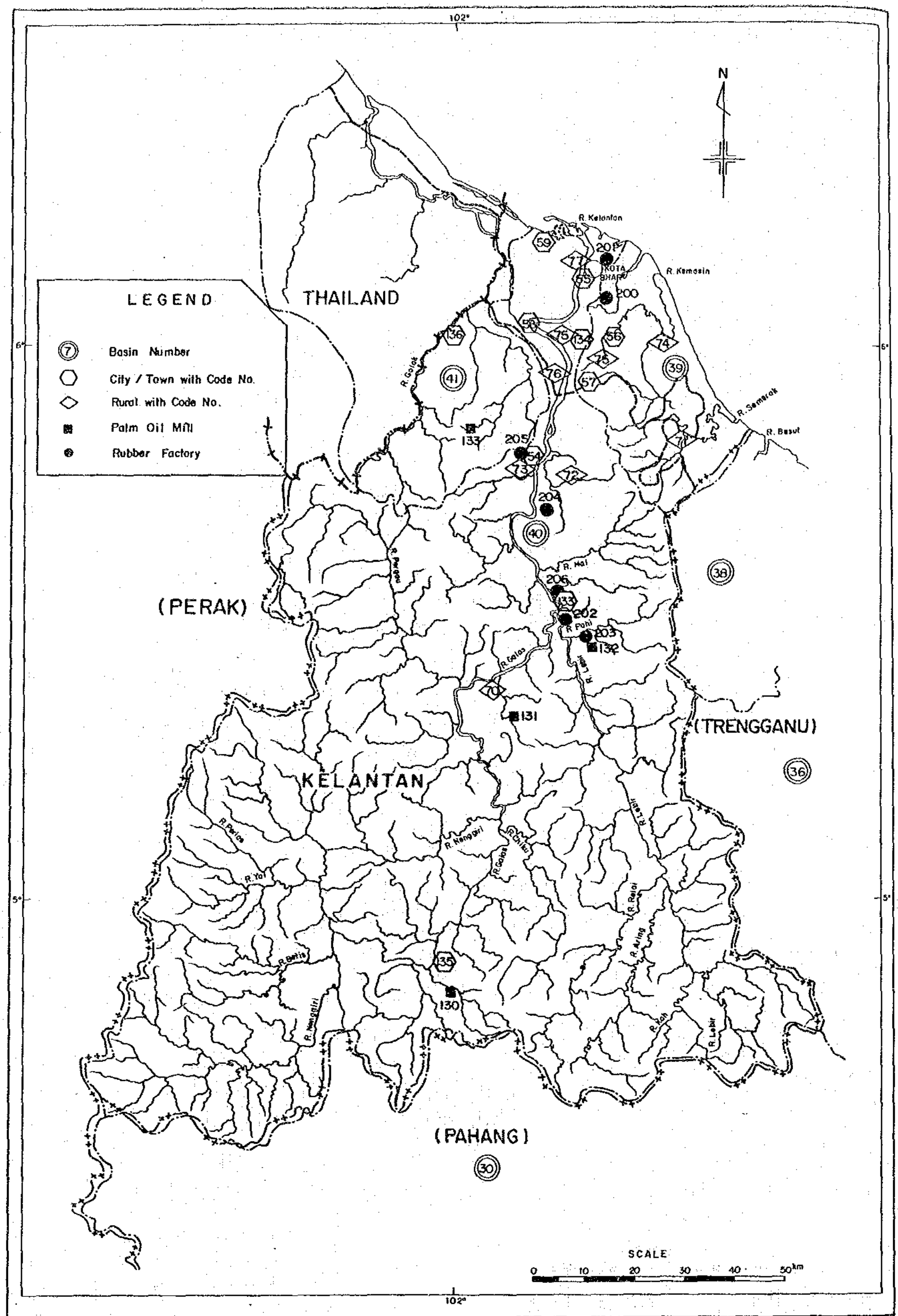

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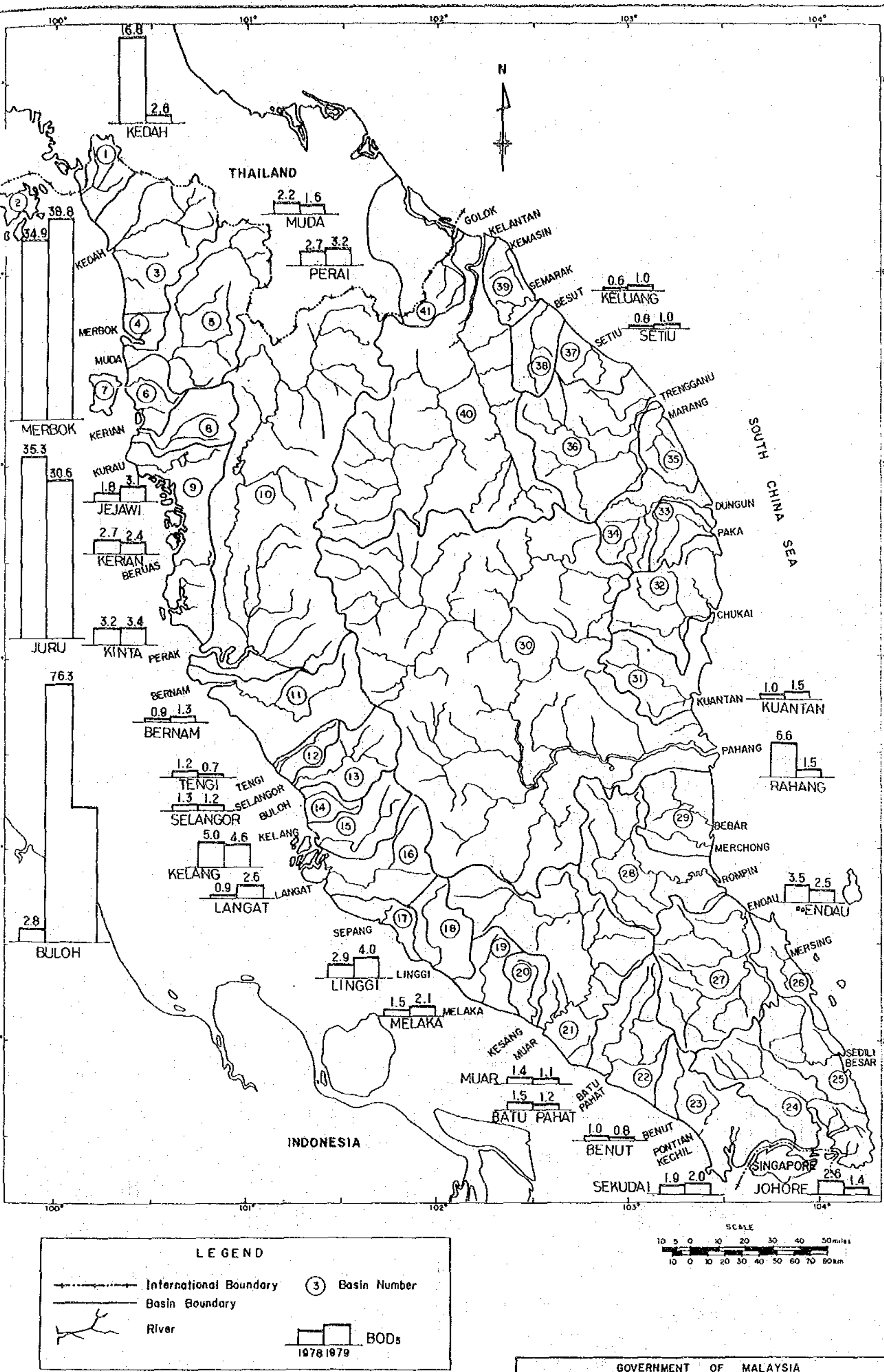

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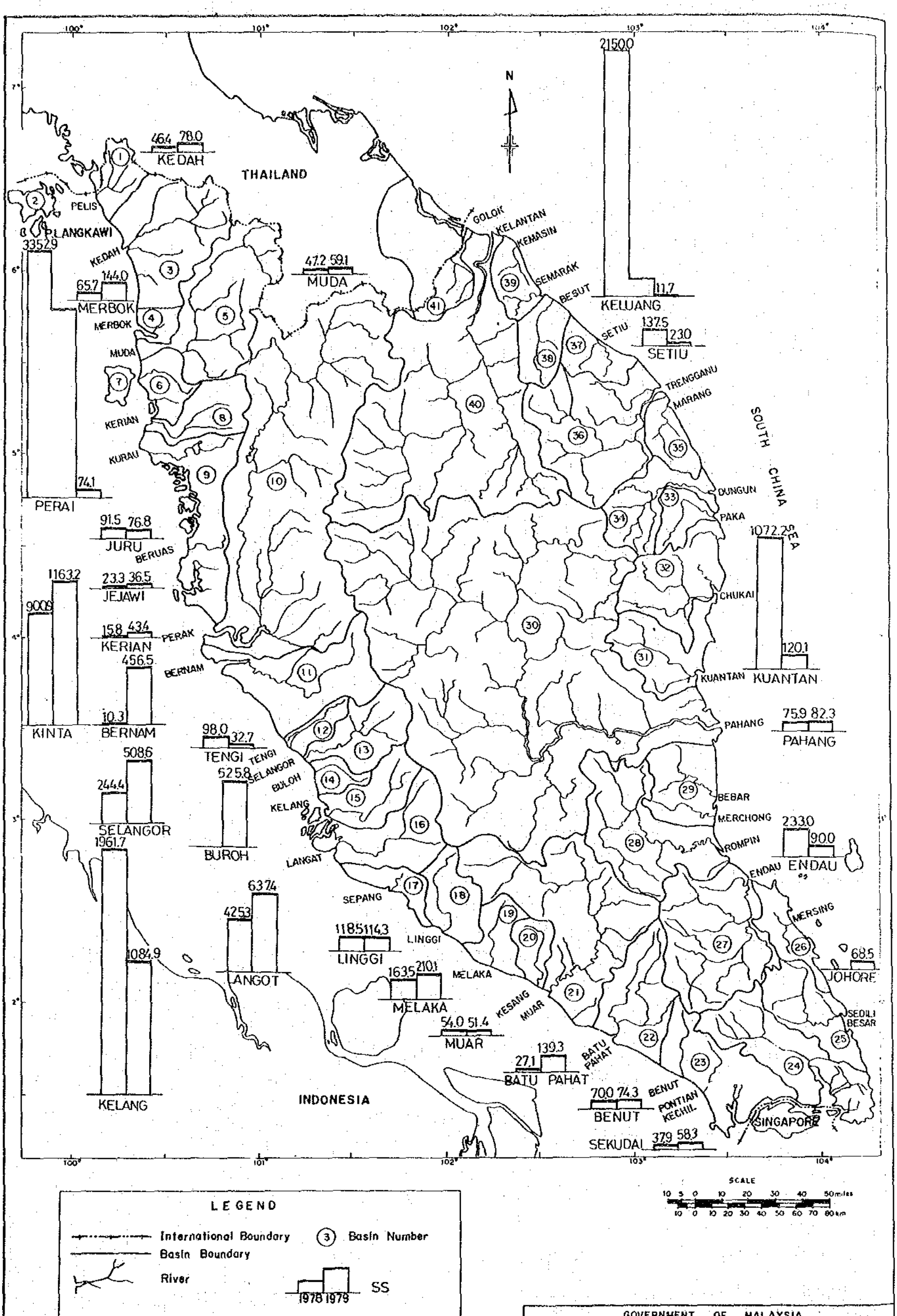

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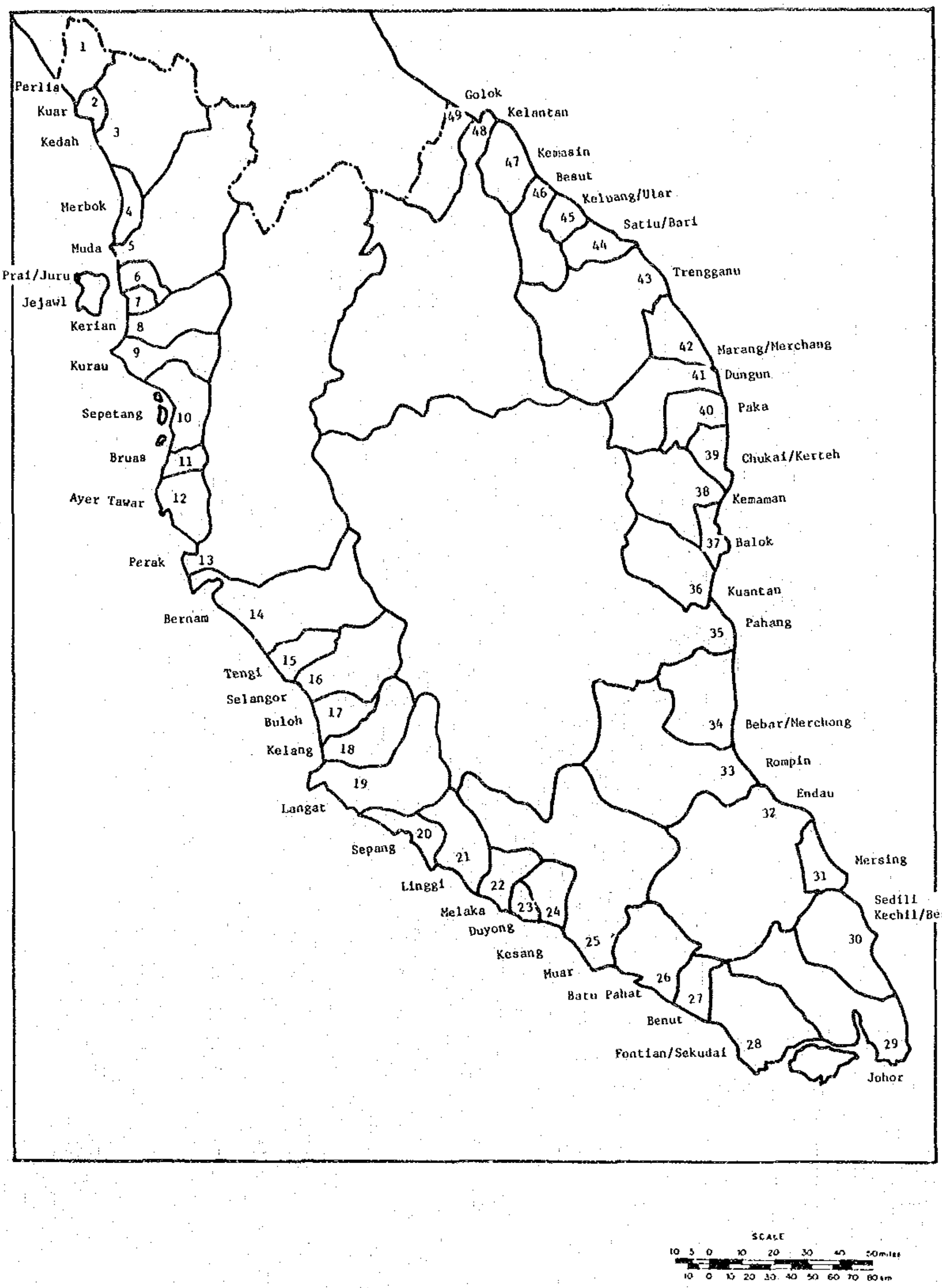

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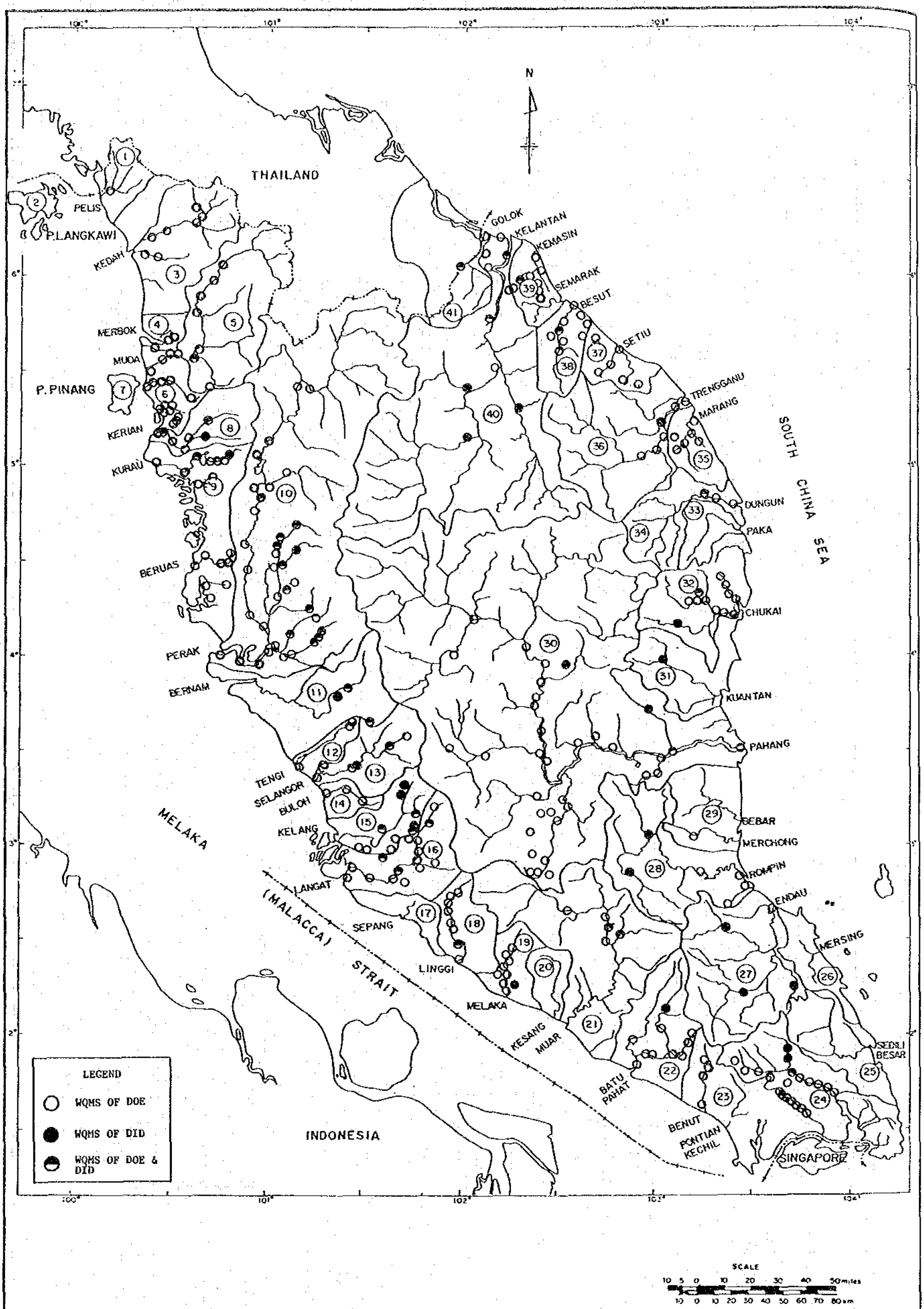

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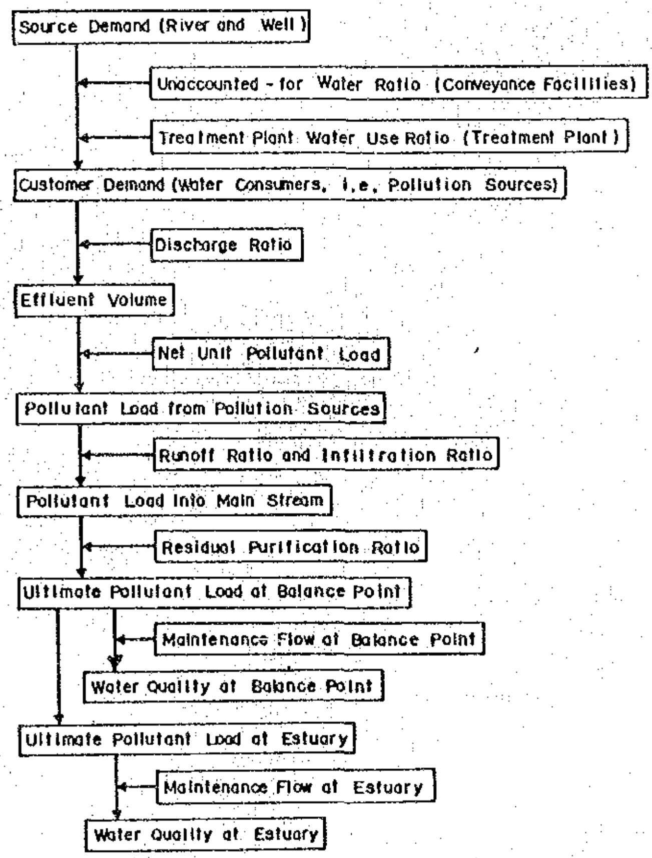

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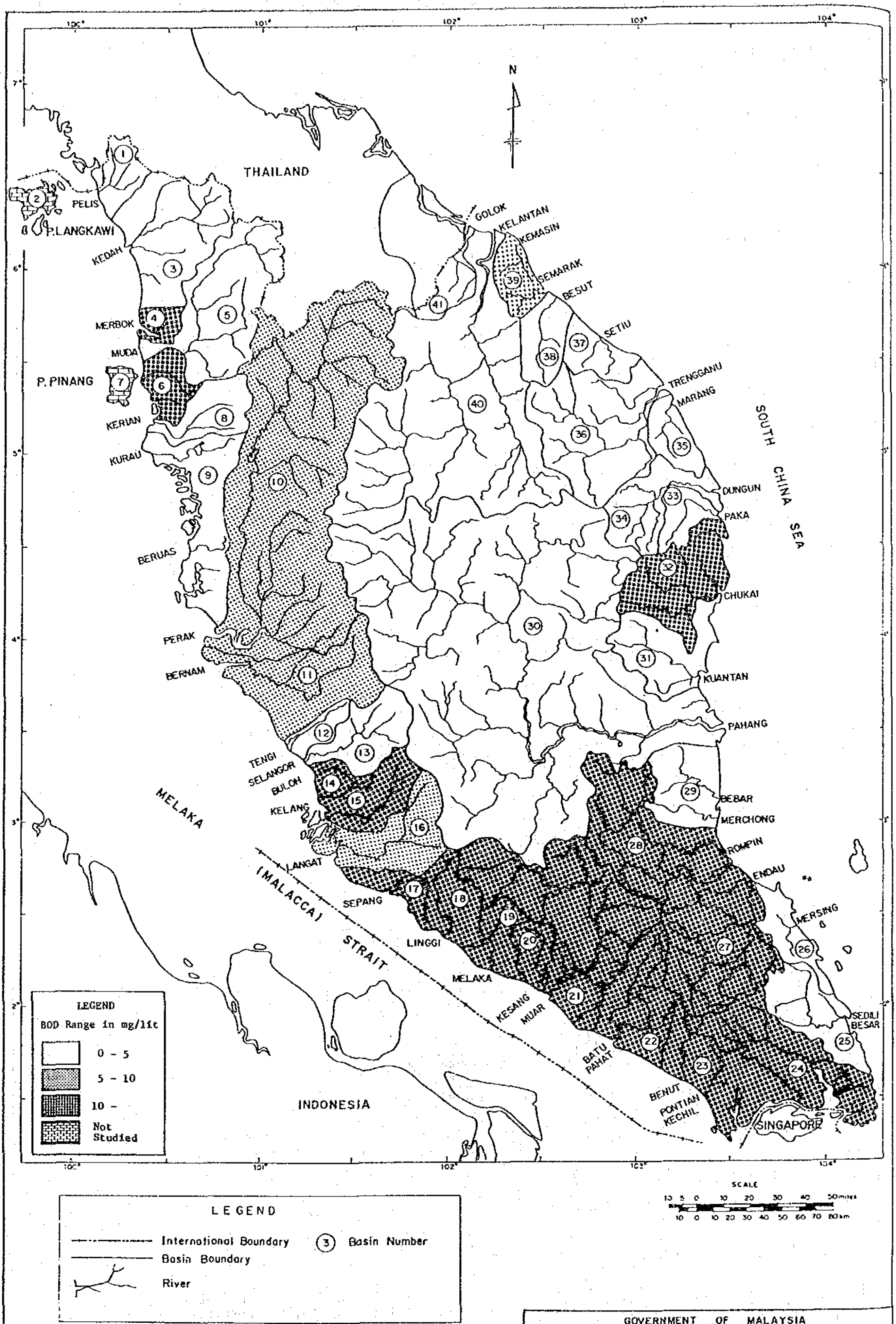

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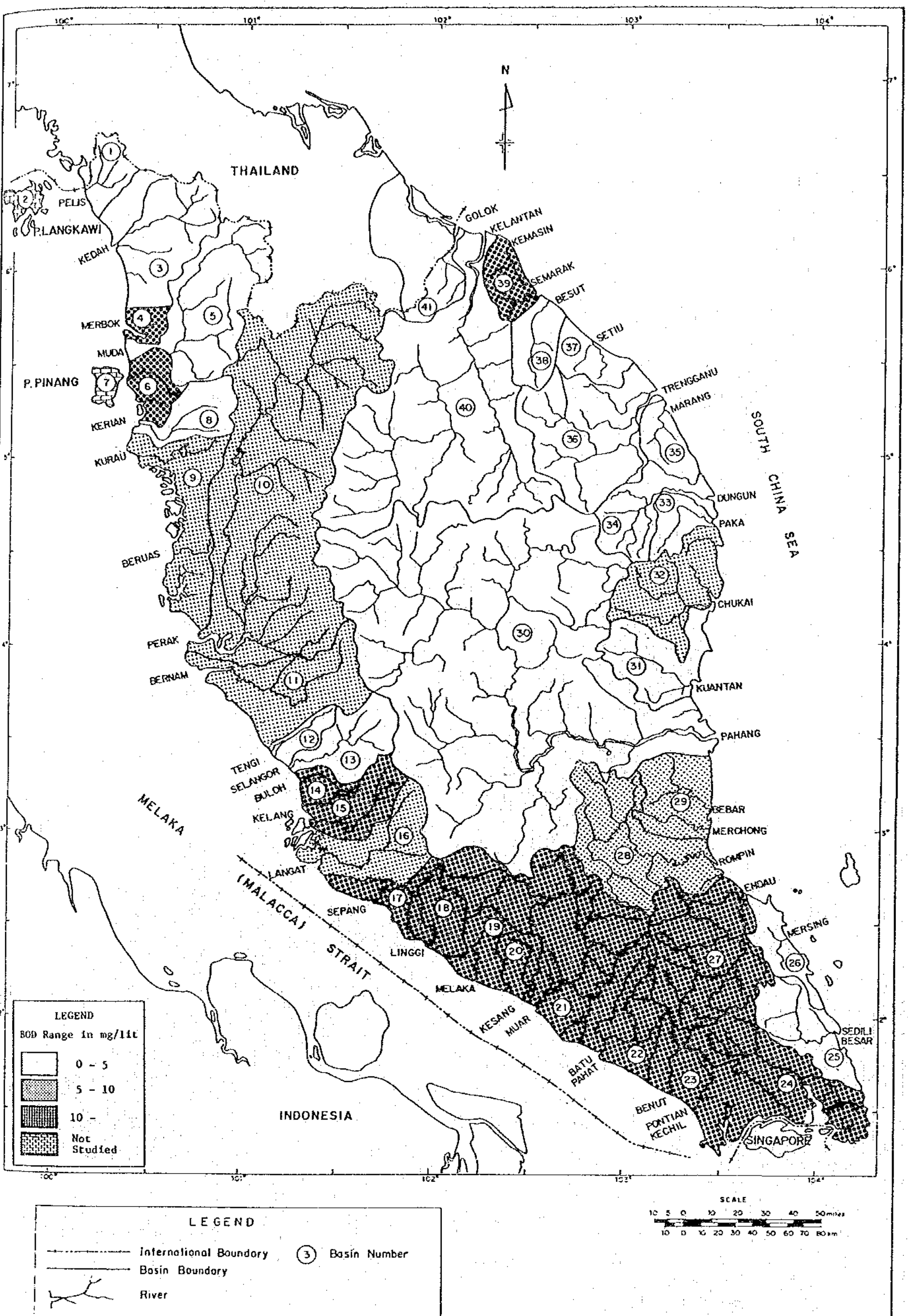

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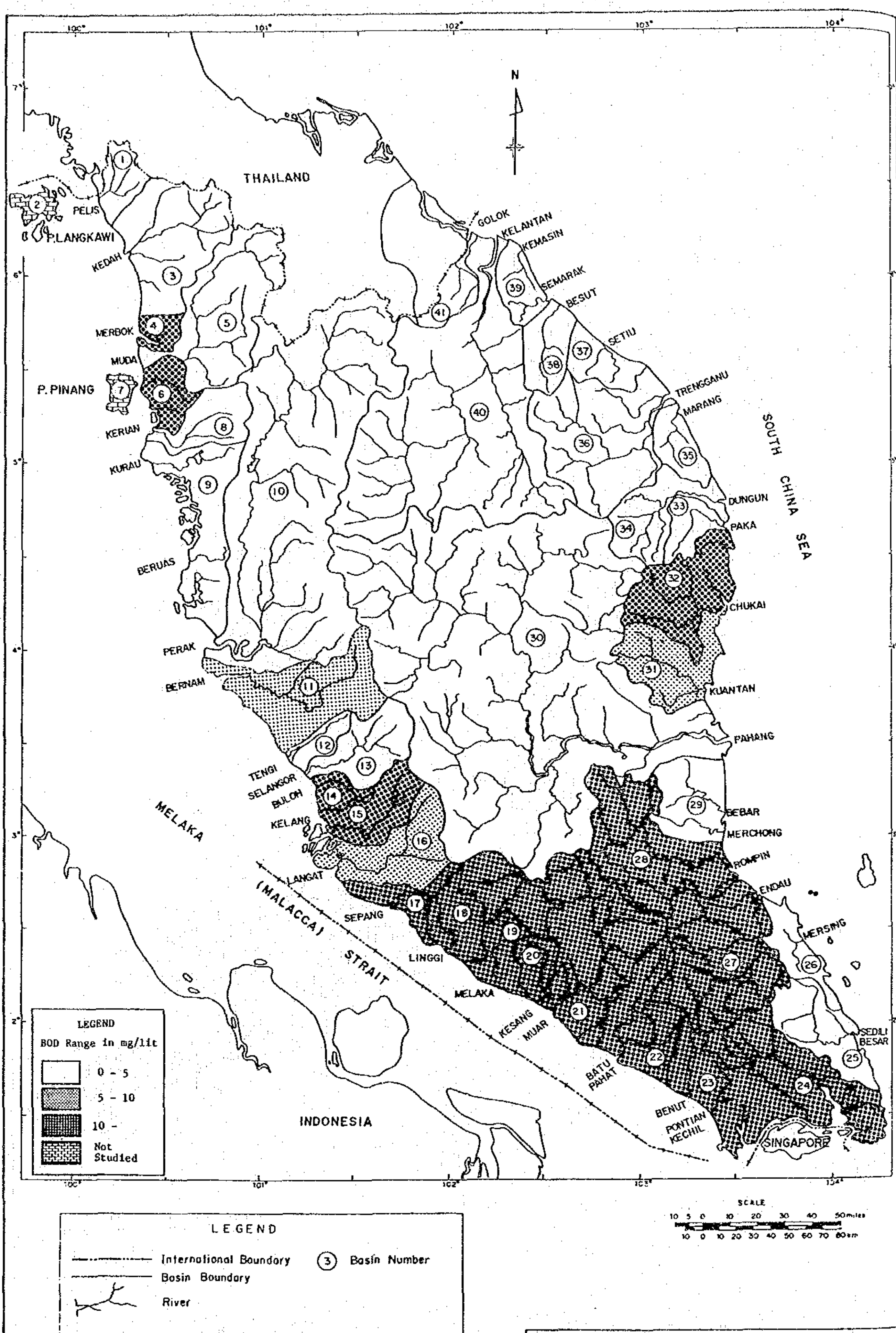

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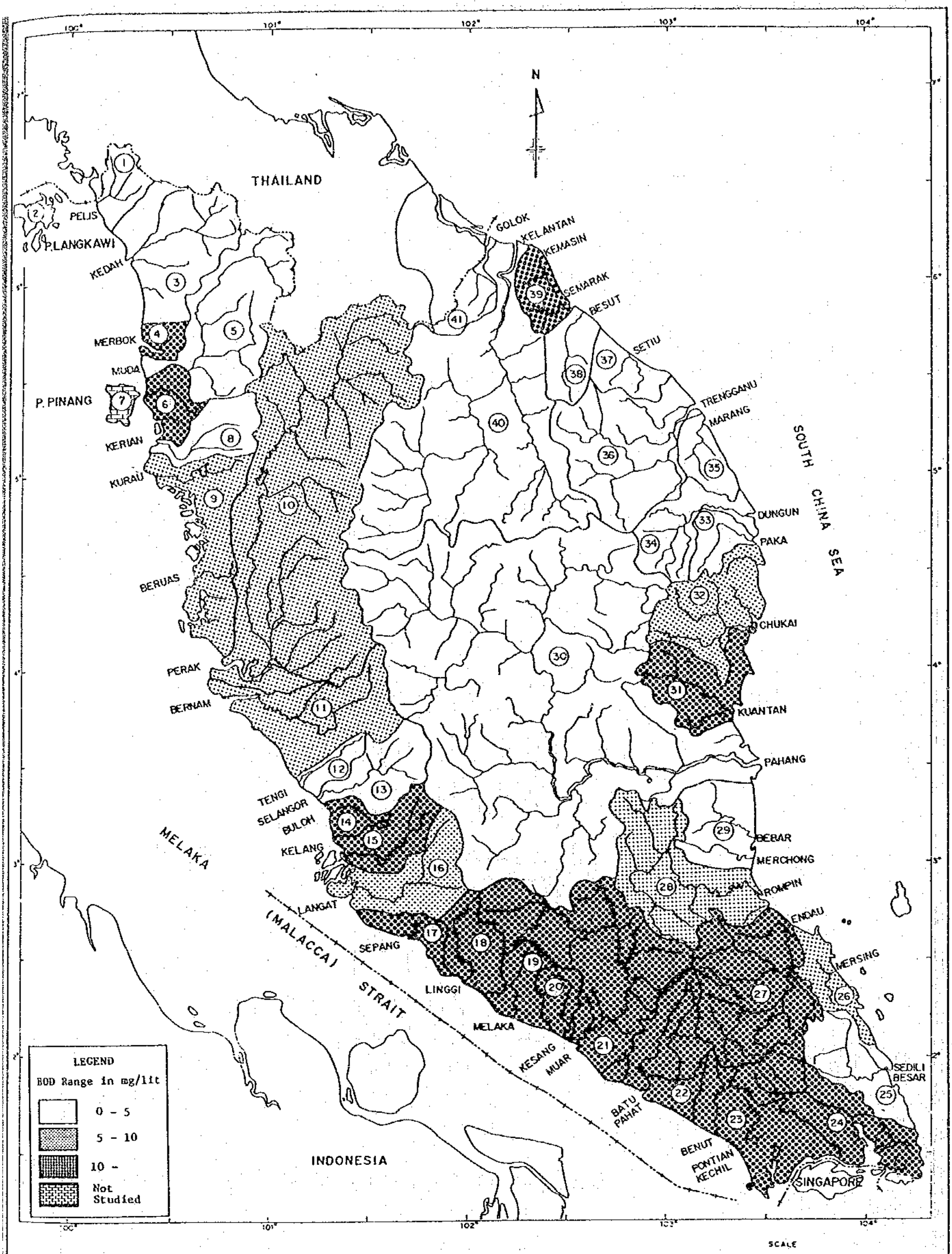

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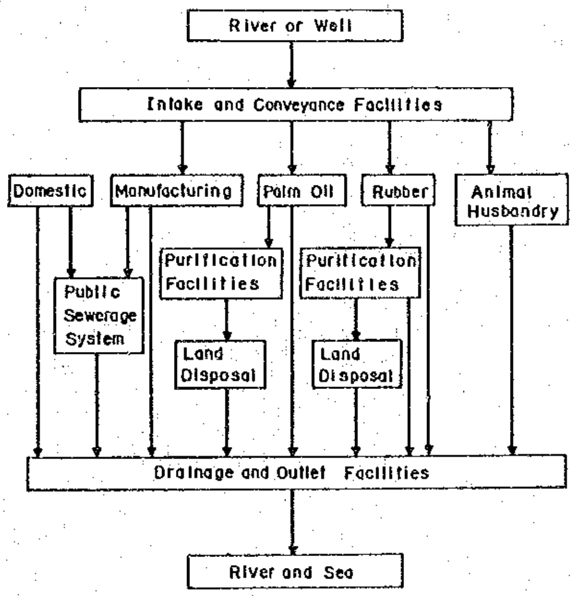

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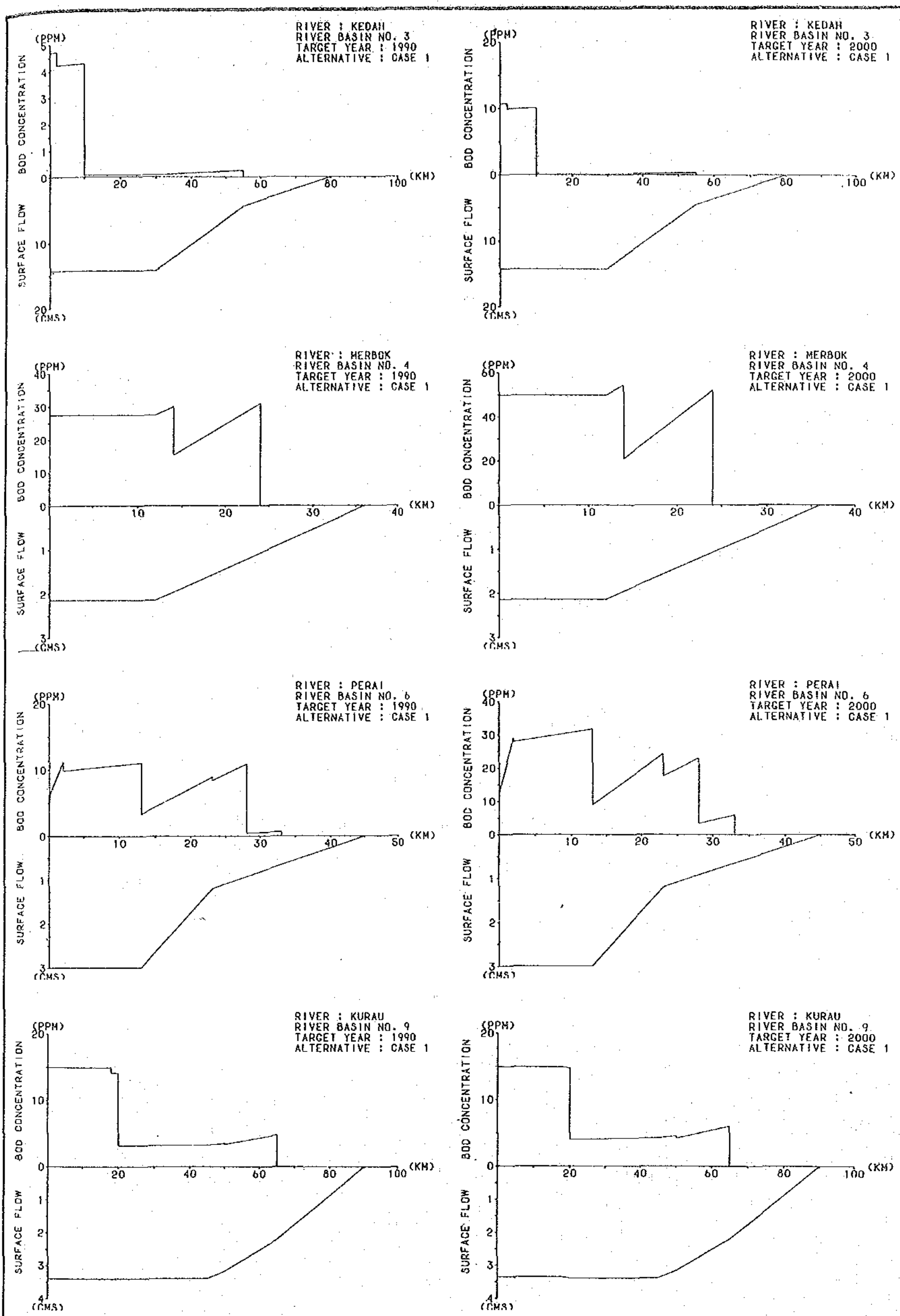

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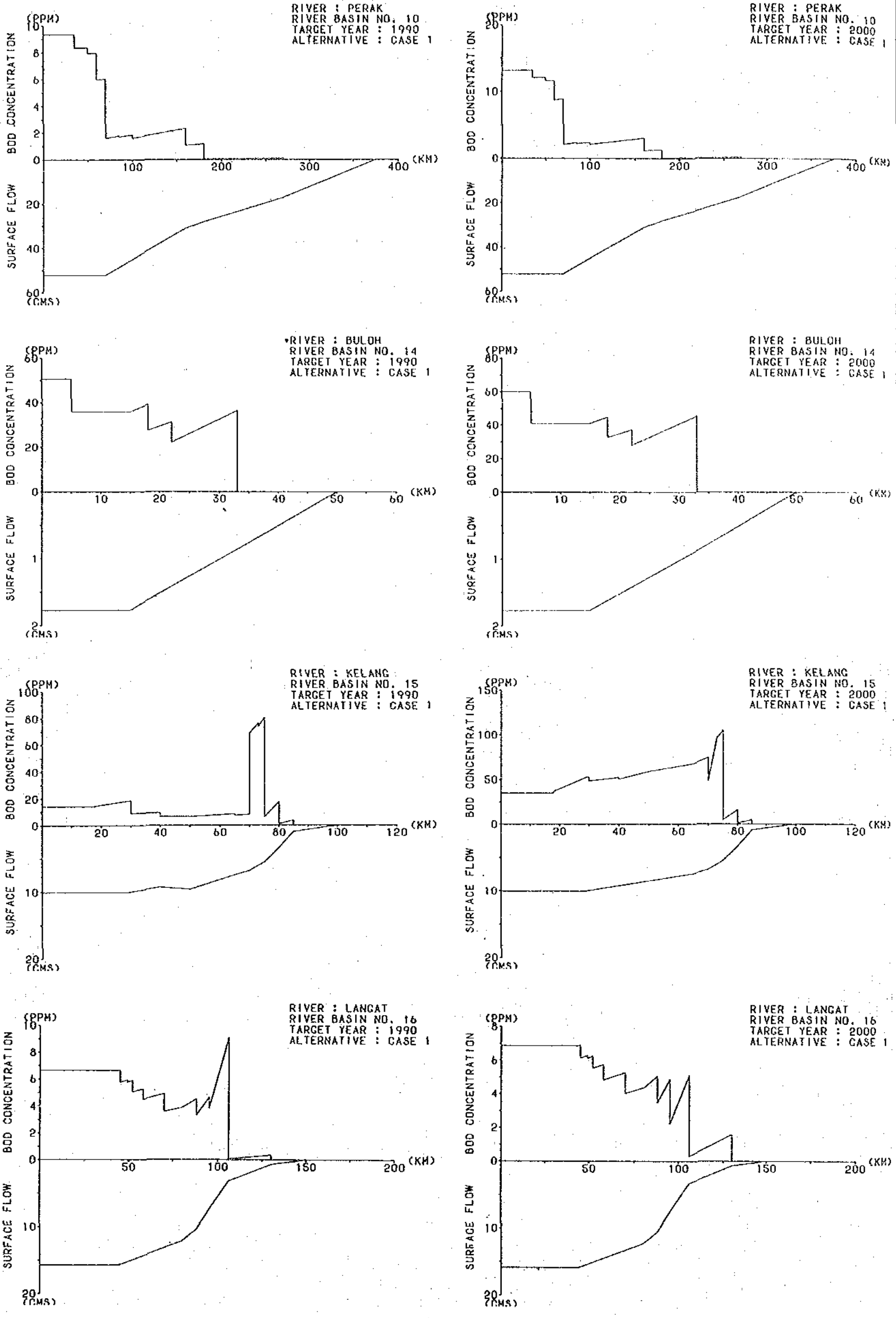

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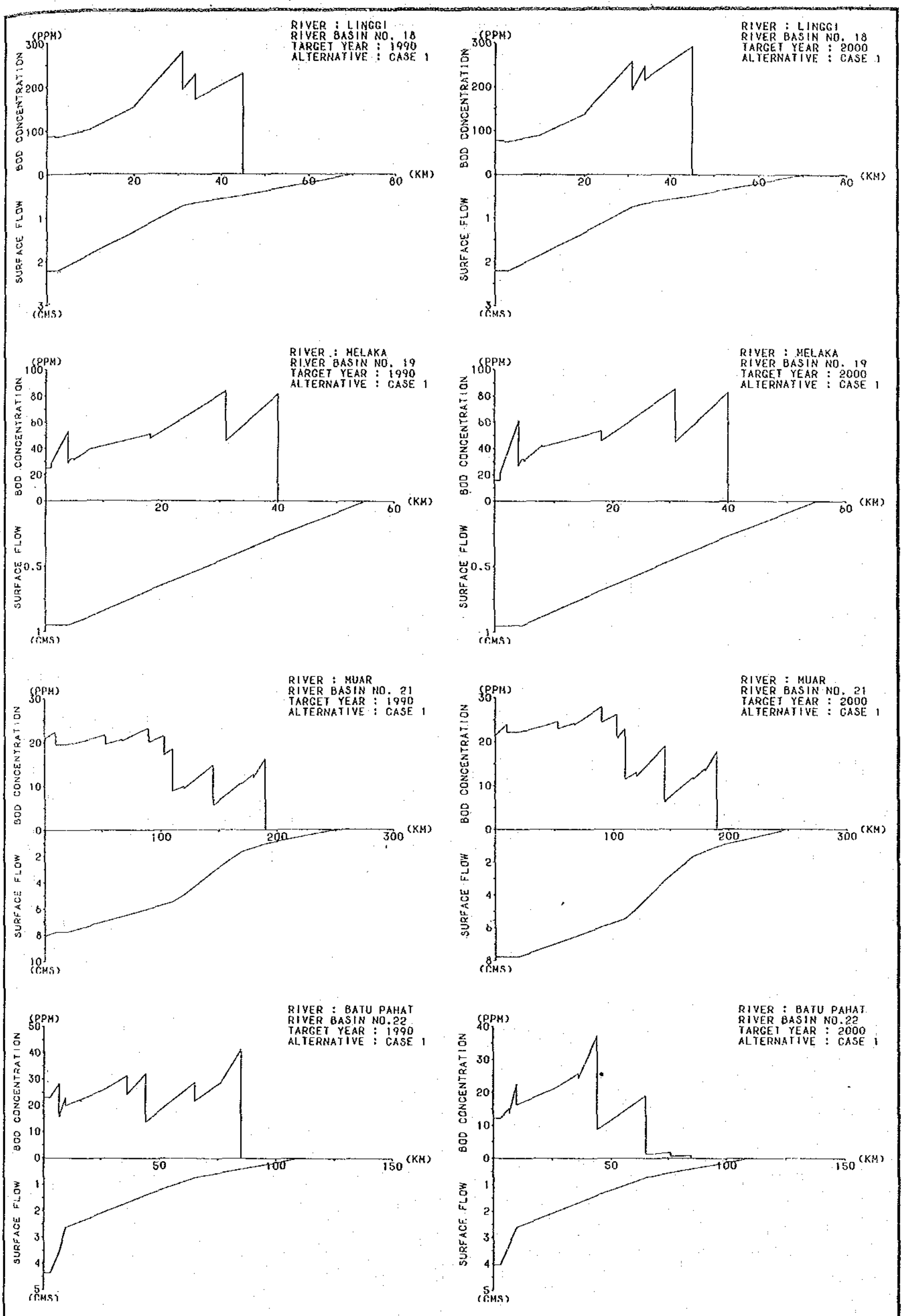

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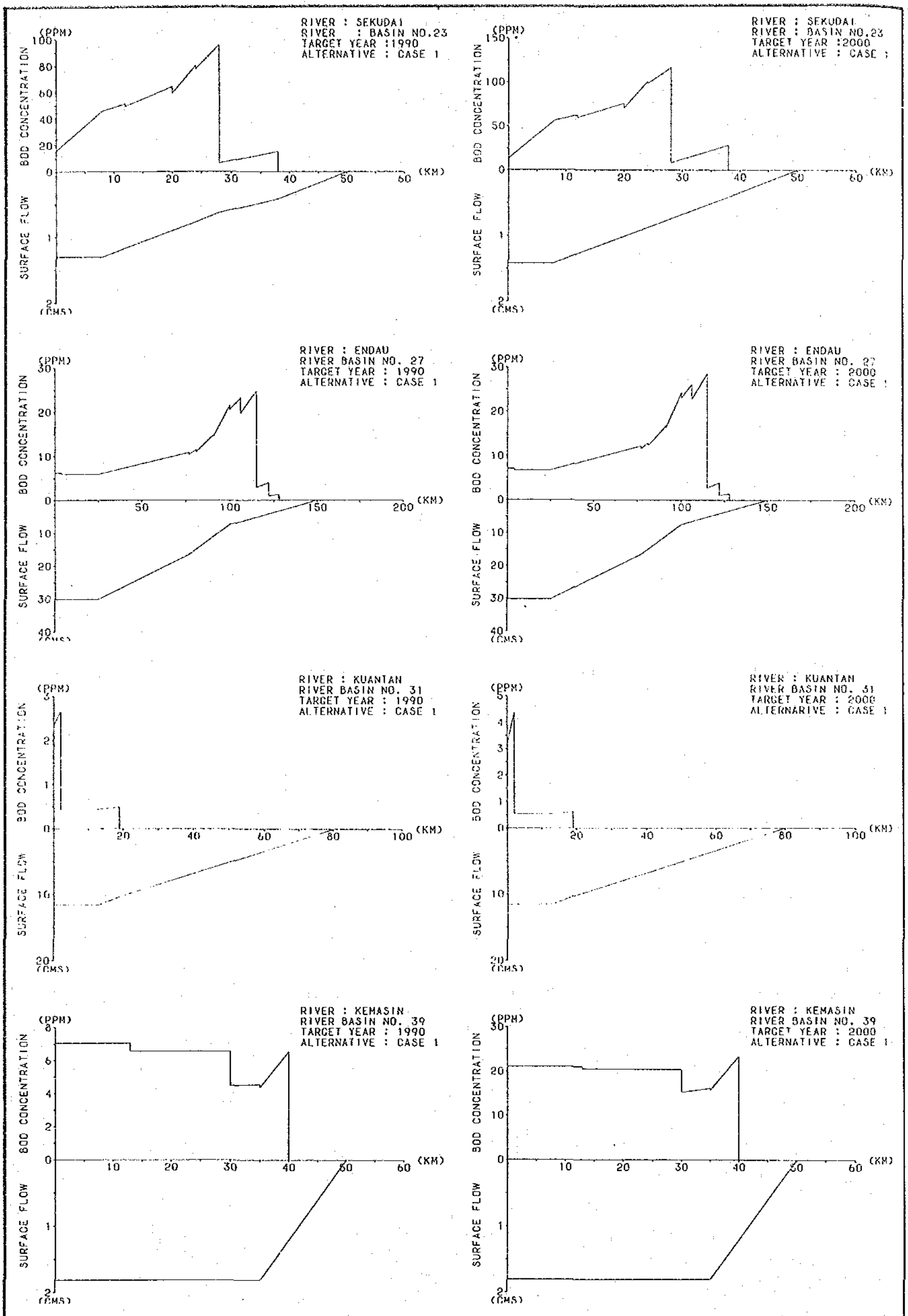

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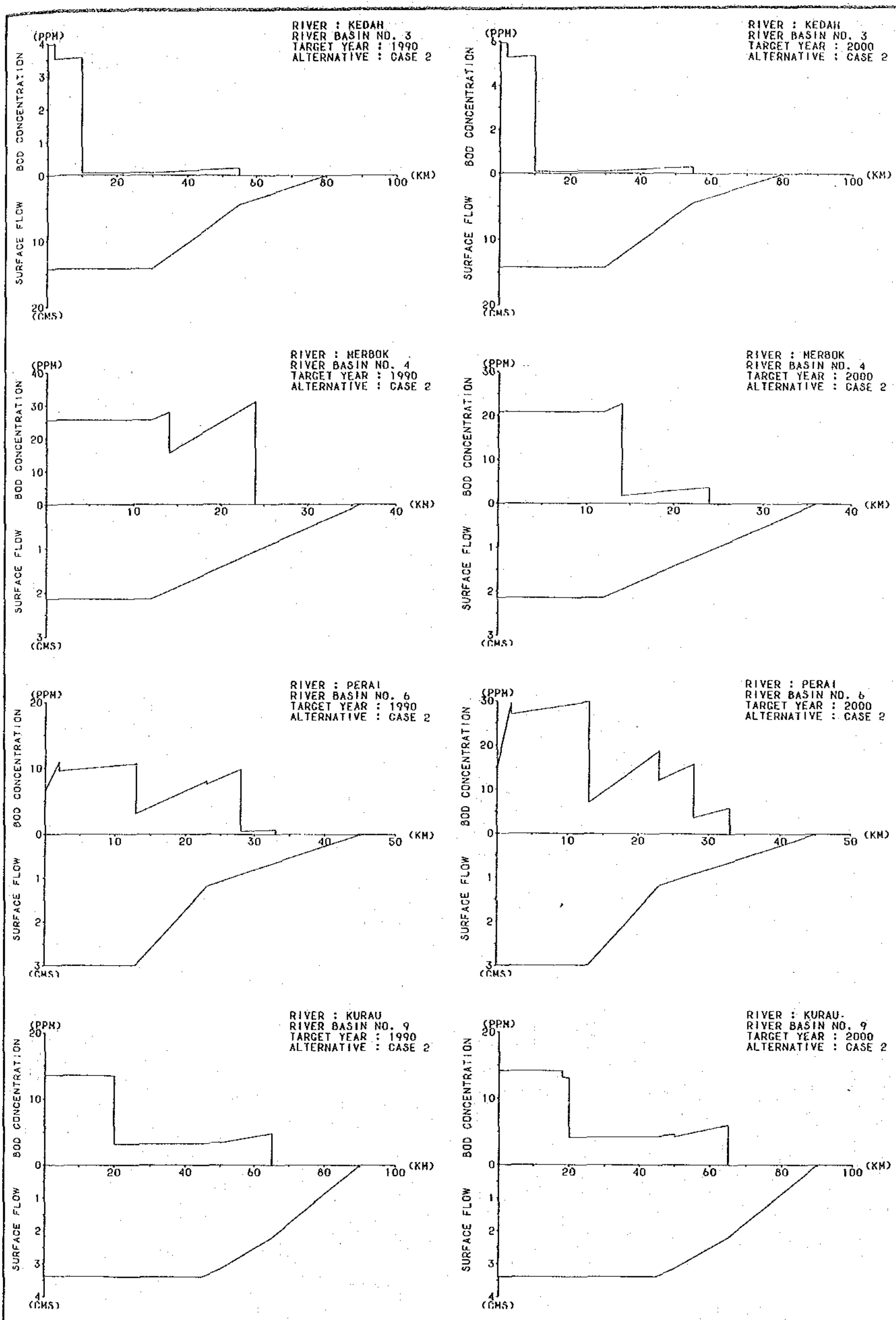

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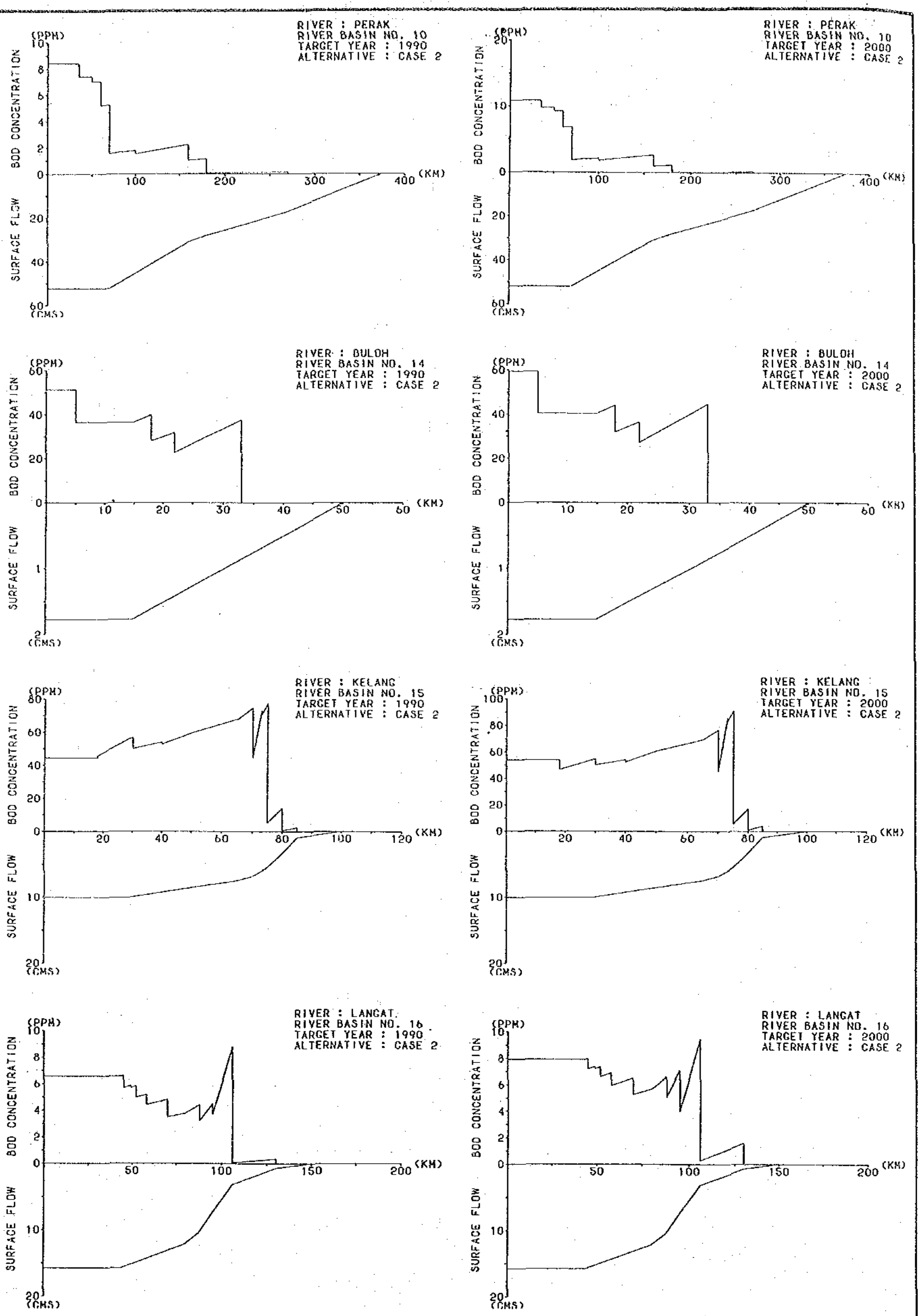

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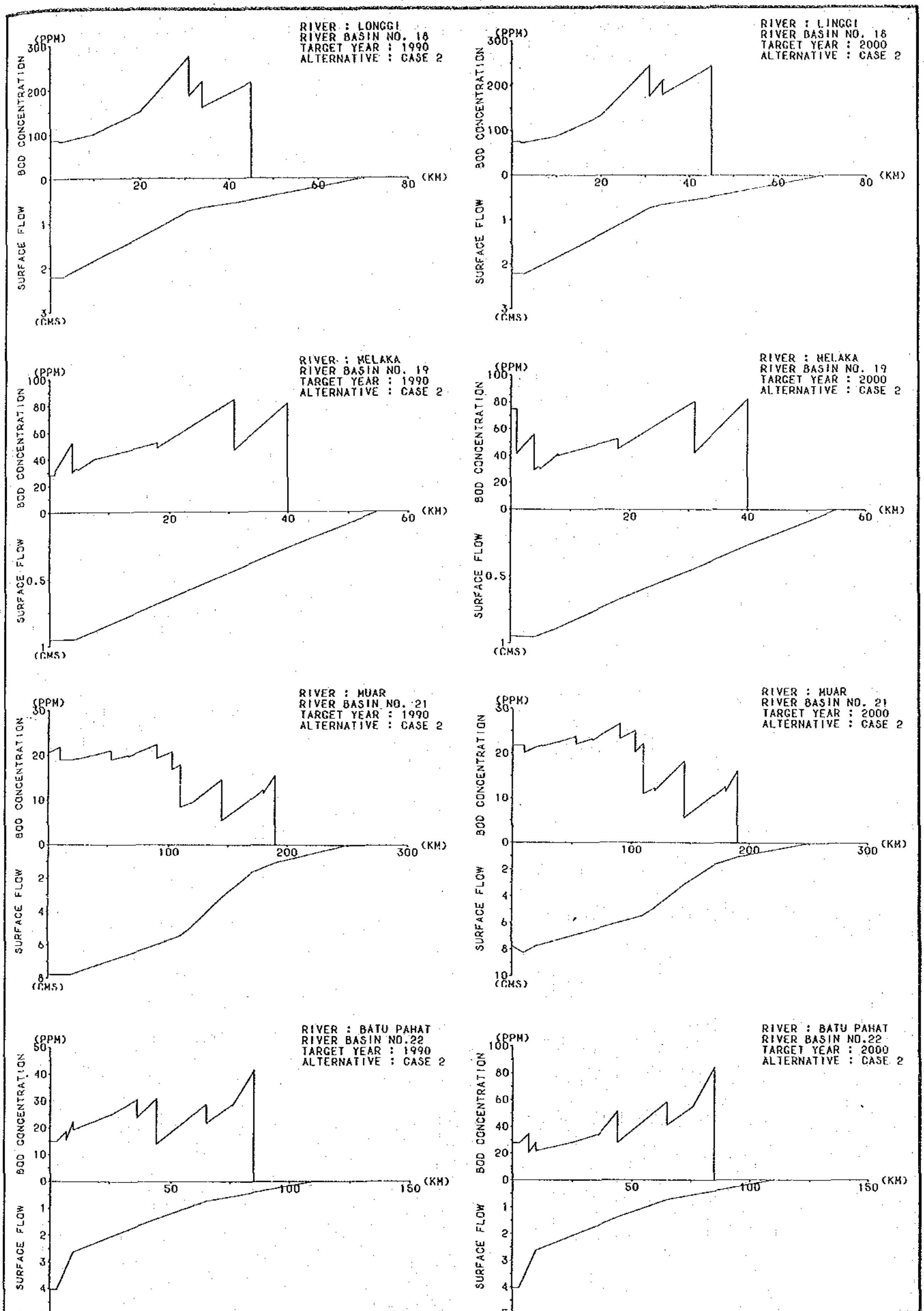

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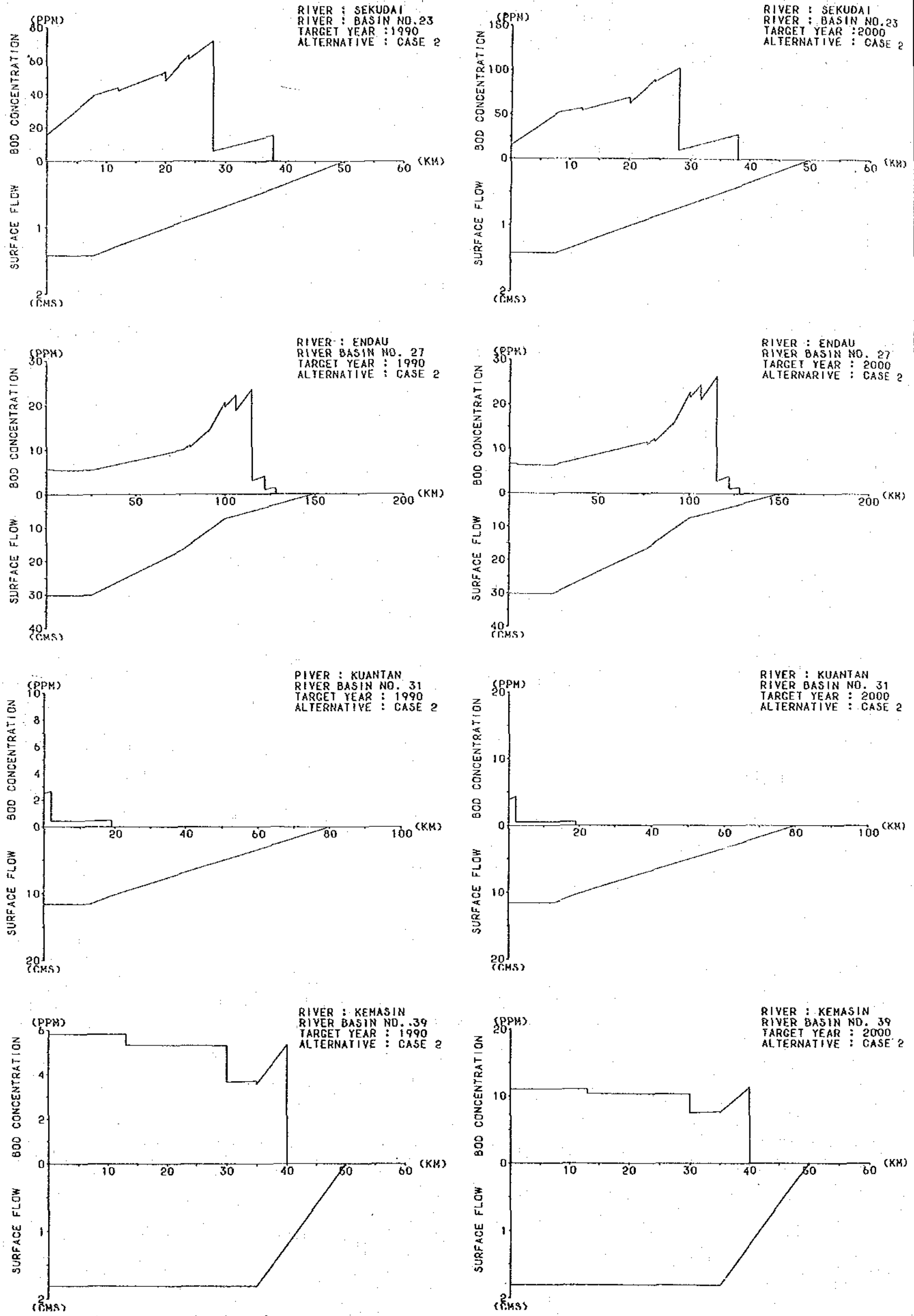

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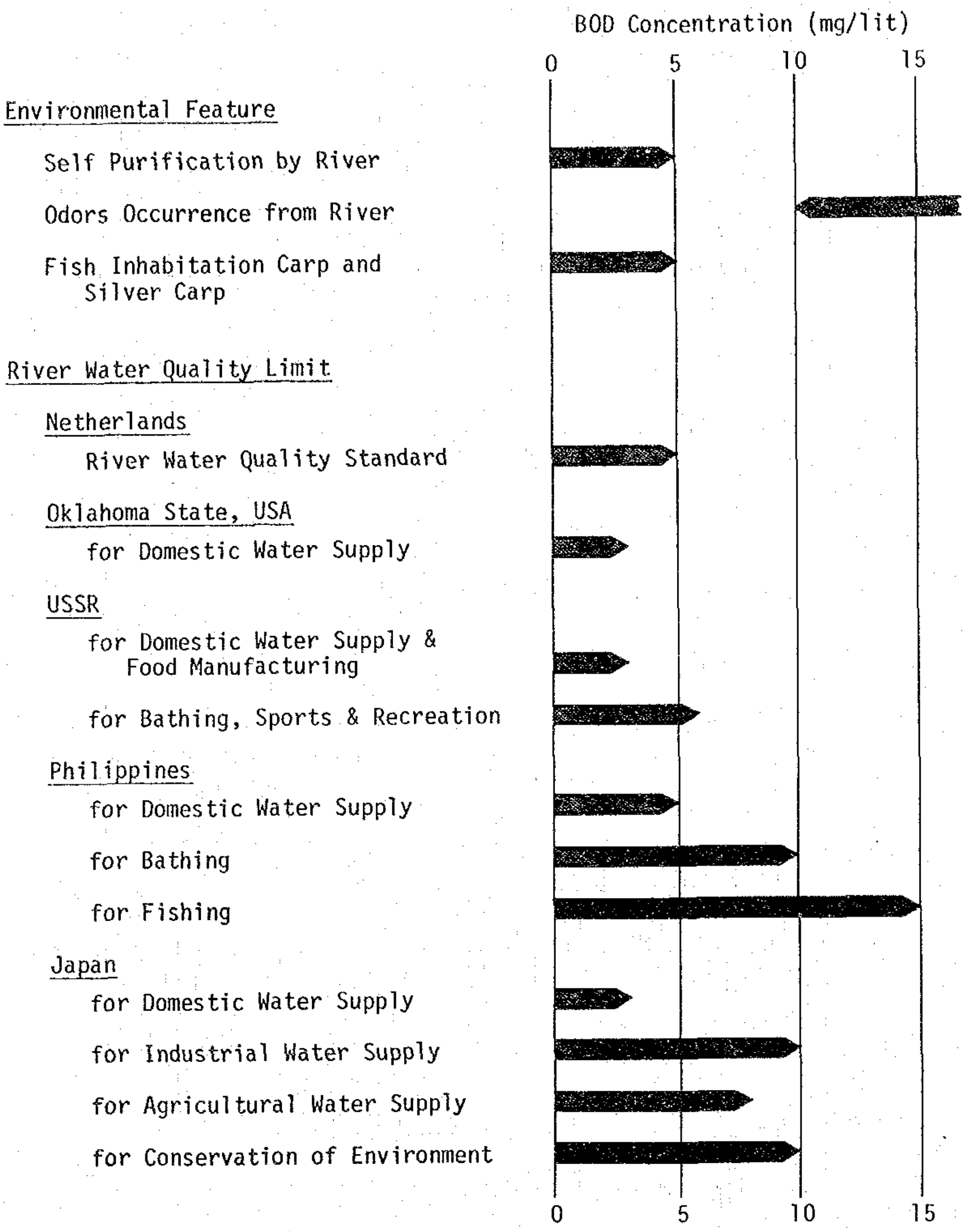

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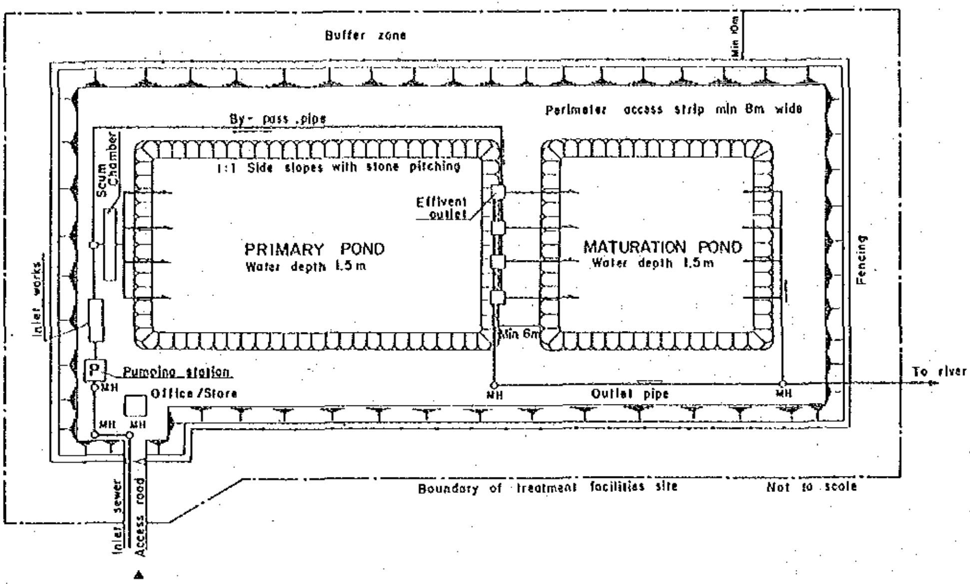

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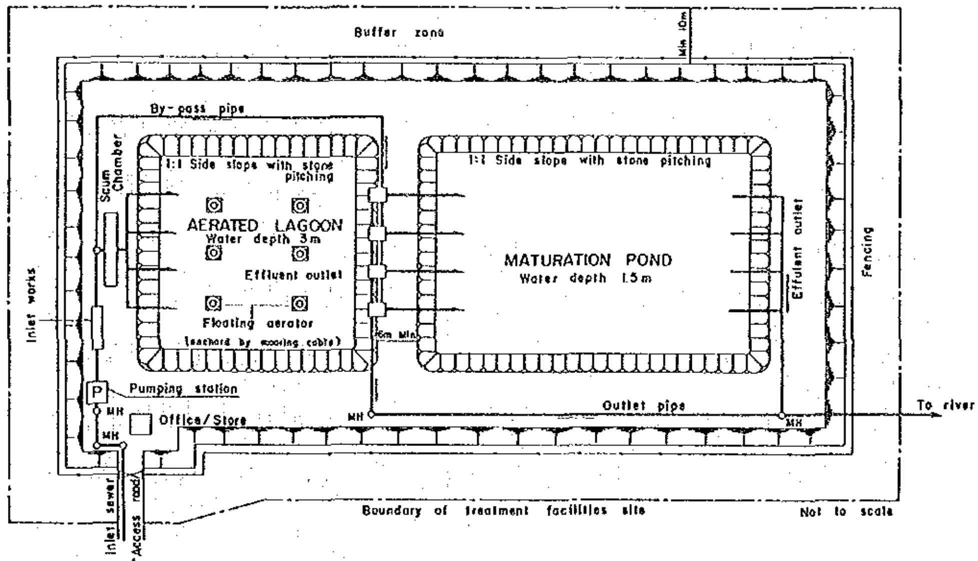

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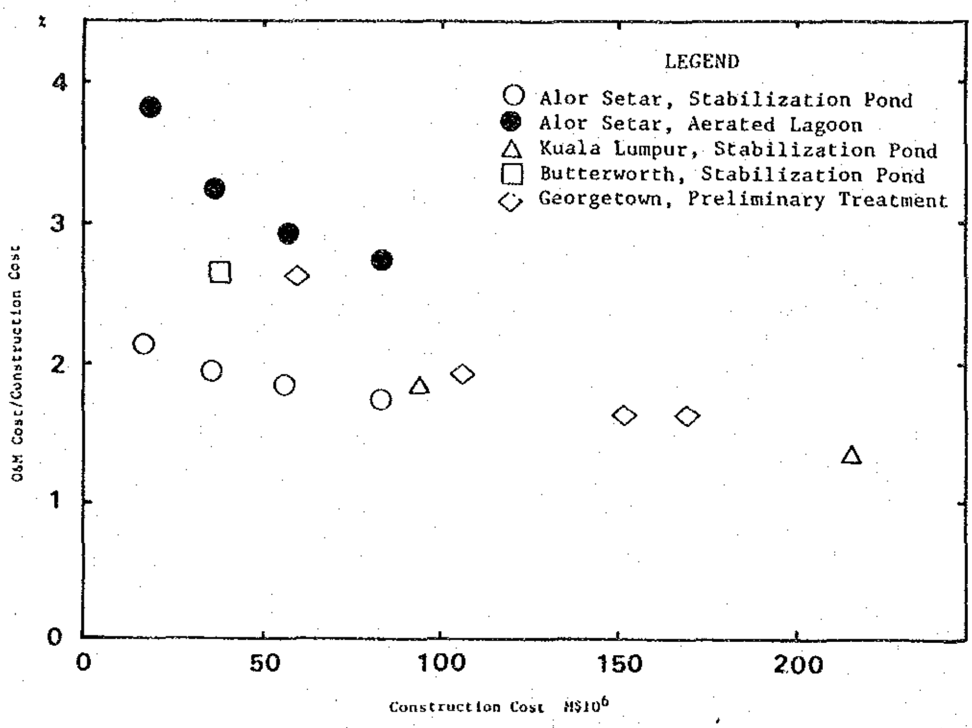

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PART 2

SABAH AND SARAWAK

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1. INTRODUCTION

This Report presents the results of water quality study including the condition of pollution sources, existing facilities of water pollution abatement, present monitoring systems for river water quality, present condition of river water quality, development plans for water pollution abatement, projection of water quality, water pollution abatement plans, planning materials, economic benefit and cost and manpower requirement, basing on the numerous data and studies available in 1981 in Sabah and Sarawak States.

The study on the present water quality in the rivers were carried out for 27 rivers which were selected based on the water quality in 1978, 1979, 1980 and 1981 and the water quality in 1990 and 2000 were projected for all basins. Water pollution abatement plans were drawn up for the basins where BOD concentration is higher than the target values. Public sewerage system in urban area and purification facilities in plam oil mills and rubber factories were proposed for water pollution abatement plans in the Study. To carry out the water pollution abatement plans will be expected to dicrease the pollutant load into rivers and keep the water quality clean.

2. MAJOR POLLUTION SOURCES AND THEIR EXISTING FACILITIES OF WATER POLLUTION ABATEMENT

In general, domestic sewage, industrial effluent and animal husbandry effluent can be considered as the main pollution sources to river water quality. Effluent from mines also cause pollution in form of suspended solids (SS) due to its large contents of particles.

2.1 Purification System for Domestic Sewage

The denseley populated town is one of the main pollution sources because of its large amount of domestic sewage, but, on the other hand, domestic sewage in rural areas does not affect river water quality even though it has the possibility to cause the local pollution. This is because the population density is still low and the domestic sewage is not being discharged concentratedly into any particular water course in rural areas. It is being noted that most major towns are located on the coastal region, as can be seen from the location map of towns as illustrated in Figs. 1 & 2.

Kota Kinabalu, Sandakan, Tawau, Lahad Datu, Labuan, Kudat and other minor towns such as Semporna, Ranau, Kundasang in Sabah have sewerage system in the town centre area and most of sewage collected in big cities is being discharged into the sea; not to inland water course. Therefore, it is considered that disposal of domestic sewage in Sabah and Sarawak is concentrated in the estuaries and the sea. But sewage from Runau and Kundasang is being discharged to inland water course.

2.1.1 Sewerage system

In Sabah, the sewerage system is installed in major towns; Kota Kinabalu, Sandakan, Tawau, Lahad Datu, Labuan, Kudat and other minor towns.

In Keningau and Tuaran, the sewerage systems are now under construction. In Sarawak, no town is equipped with Sewerage system except a few army camps where the package treatment systems are installed. The responsibility for providing sewerage services in Sabah rests with the Local Authorities, but, in practice, these obligations are carried out largely by the PWD on behalf of the Local Authorities. The PWD also undertakes the maintenance and operation of the sewerage facilities. The summary of each sewerage system in Sabah is as shown in Table 1 and summarized as follows.

(1) Sewerage system in Kota Kinabalu

The existing sewerage system in Kota Kinabalu serves about 27,000 people in urban areas. There are two sewerage systems. One system serves about 19,000 people and covers the coastal belt from Tanjong Aru to Tanjong Lipat in the town centre. The sewage is conveyed through a number of pumping stations to a cast iron outfall at Lipat Point, from which the sewage is discharged without treatment to the sea. It is reported that the degree of dilution and dispersion is reasonable and sewage contamination of the shoreline is not evident (Ref. 1).

The second system serves about 8,000 people in the eastern part of the urban areas. The sewage is conveyed to the treatment plants which comprise two stabilization lagoons which are in series, and discharged to the surface water drain along the Penampang Road after treatment. The degree of purification of this plant is satisfactory, and it can achieve the average BOD removal by the order of 80%. Additional lagoon capacity is being added to the system (Ref. 1).

(2) Sewerage system in Sandakan

The existing sewerage system in Sandakan serves about 22,000 people in the urban areas. The sewage from twon centre is discharged without treatment at the harbour shore near the central market. The other two smaller sewerage networks are located in the south along Leila Road, serving the Tun Razak Community Centre and Ramai Ramai Estates; and in both cases the sewage is discharged at the shoreline without treatment (Ref. 2).

(3) Sewerage system in Tawau

The existing sewerage system in Tawau serves about 12,000 people in the urban areas. There are two sewerage networks. One serves about 8,000 to 9,000 people in the town centre area, from which sewage is being discharged without treatment to the sea through a cast iron outfall. Another network serves about 3,000 to 4,000 people in the eastern town area. The sewage is also being discharged without treatment to the sea through a marine outfall (Ref. 3).

(4) Sewerage system in other towns

The sewerage systems in the towns such as Lahad Datu, Labuan and Kudat cover the town centre area, and the sewage is being discharged to the sea without treatment (Ref. 4).

2.1.2 Unsewered area

A significant proportion of the population in the existing urban area is not provided with sewerage system. In unsewered urban area, package treatment plant and septic tank are used as purification facilities for domestic sewage. Package treatment plants are used in housing estates and public organizations. This ranges from communal septic tanks and Imkoff tanks to the biological filter systems. The treated effluent is discharged into nearby watercourse and to the sea.

In other urban area, the installation of septic tank is compulsory by regulation, and thus the septic tank is considered as the most widespread purification system for domestic sewage in urban areas. It is common practice to discharge toilet wastes and usually kitchen wastes to the septic tank; and the remaining domestic sewage is discharged directly to the surface drains. A sepctic tank can achieve high purification ratio, if the septic condition is being kept satisfactory under proper maintenance. The Medical Department in Sarawak studied the purification rate of the septic tank by selecting 20 tanks which receive only the toilet wastes from houses, and it was found that the BOD removal was about 90% and the BOD of final effluent was only around 50 mg/lit. Though the responsibility for emptying septic tank is with the Local Authoritity, the maintenance of septic tank has not been carried out satisfactory due to the insufficient facilities and funds, and as the result the actual purification rate must be lower than the result obtained by the Medical Department in Sarawak. Even it is well-maintained and regularly desludged, a septic tank has a potential public health risk due to the final effluent which still contain a number of fecal coliforms.

In rural areas, pit privies are used in many houses for excreta disposal, and the remaining household wastes are directly being discharged into nearby watercourse or onto land without treatment.

2.2 Purification System for Industrial Effluent

In Sabah and Sarawak, there are many wood based factories such as saw mills. Though saw mills have little water usage in production process, sawdust from production process has been discharged into the rivers, and is causing water pollution and sedimentation in Sarawak. The effect caused by sawdust is most serious in the Rajang river, according to the interview to DOE. While in Sabah, sawdust being produced in saw mills are not allowed to be discharged into rivers and therefore they are burned.

There are some industrial establishments such as oil refinery, fish meal and soft drink. Those are said to be affecting the river water quality. Nevertheless, there are few information about the industrial effluent such as quantity of effluent quality of waste water and purification system in each factory. The actual extent and severity of water pollution caused by industrial effluent are yet to be studied by DOE. Rubber factory and palm oil mill are the main industries in Malaysia and also the major pollution sources due to the high content of organic matters in their effluents. There are three rubber factories each in Sabah and Sarawak, and 13 palm oil mills in Sabah and four in Sarawak. Though almost all the rubber factories and palm oil mills are located on the coastal region, one rubber factory and three palm oil mills in Sabah are discharging their effluent directly into the river.

The effluent from rubber factory and palm oil mill has a high value for organic matter content and thus can be major pollution sources to river water quality. The effluent from rubber factory and palm oil mill are controlled by DOE under "Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulation 1978" and "Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulation 1977" (Refs. 6 & 7).

In Malaysia, three types of rubber products are being produced, i.e., Conventional Grade, Black (Standard Malaysian Rubber; SMR) and Latex Concentrate. According to the study conducted by the DOE, the raw effluent from Latex Concentrate shows higher content of organic matters than that from Conventional Grade and SMR as shown in Table 2.

In Sabah and Sarawak, the rubber factories are mostly producing SMR as shown in Table 2. As the effluent from rubber factories in controlled according to the parmeter limit of the effluent, the effluent is treated in the biological treatment plants, which comprise usually anaerobic pond and facultative pond as shown in Table 3. In Sabah and Sarawak, two factories are installed with treatment plants comprising anaerobic pond and facultative pond to purify the raw effluent less than 30 mg/lit in BOD_3 and less than 200 mg/lit in SS. BOD_3 means Biochemical Oxygen Demand for three days in 30°C. One factory in Sarawak has a treatment plant using recycle process in which it uses the treated water on production process. The remaining three factories have no purification systems and they discharge untreated effluent into nearby watercourse and to the sea as summarized in Table 4.

There are 13 palm oil mills in Sabah, and four in Sarawak. The raw effluent from palm oil mill contains more organic matters than that from rubber factory. According to the study by D.A.M. Whiting, BOD_3 of the raw effluent was found to be around 20,000 mg/lit as shown in Table 5. The effluent from palm oil mills in controlled according to the effluent standard as shown in Table 6.

The treatment method of palm oil mill is generally the same as rubber factory. The effluent is treated with biological treatment plants, which comprise anaerobic pond and facultative pond. In Sabah and Sarawak, 10 out of 17 palm oil mills are applying biological treatment plant, four out of these 10 mills are carrying out land disposal as shown in Table 7. The water quality of treated effluent from six palm oil mills discharging effluent into nearby watercourse ranges from less than 100 to 800 mg/lit in BOD_3 and from 204 to 2,488 mg/lit in SS. Another four mills have to treatment plants at present, and they discharge raw effluent into the rivers and the sea without treatment. The water quality of raw effluent of these four mills ranges from 284.5 to 22,800 mg/lit in BOD_3 and from 31,600 to 35,400 mg/lit in SS. The treatment plants are now under construction in another three mills.

2.3 Purification System for Pig Farming Effluent

In Sabah and Sarawak, the major pollution source of animal husbandry effluent is from pig farming like Peninsular Malaysia. In Sabah, there are many pig farms around Kota Kinabalu, Kudat, Sandakan, Tawau and Tuaran. The major pig farms are located around Sandakan. In Sarawak, large-scale pig farms are found in the suburbs of Kuching, Sibu and Miri, while many small-scale pig farms are found in the villages of indigenous people.

In Sabah and Sarawak, there is no pig farm equipped with treatment plant, and thus the effluent from pig farms is being discharged directly into nearby watercourse without treatment. The effluent from pig farms has high content of organic matters, comparable to that from rubber factory and palm oil mill. For example, the BOD_3 ranges from 1,900 to 21,600 mg/lit in Malacca according to a study by DOE as shown in Table 8. Wide range of BOD_3 can be explained by the different amounts of water used. Therefore, the effluent from pig farms having a number of pigs can affect the river water quality.

2.4 Purification System for Mamut Copper Mine Effluent

Mamut Copper Mine is the sole large-scale mine in Sabah and Sarawak. It is located in the south-eastern slope of Mt. Kinabalu about 15 km north of Ranau town. The mine area is surrounded by mountainous tropical rainforests within the periphery of Kinabalu National Park. The ore-lot is concentrated within an area of 1.2 km^2.

The total ore-reserve in Mamut Copper Mine is estimated at about 830×10^6 tons with a copper-content averaging about 0.57%. Mamut Copper Mine started its operation in 1975. Up to date 470×10^3 tons of crude-ore have been mined, and about 10×10^3 tons of 25% copper concentrate are produced every month at present. In Mamut Copper Mine, the open-pit method is used for mining. The first step in the mining operation involves removing overburden materials and dumping them in the dumping site. At present two dump sites, i.e., Nasapang Waste Dump Site and Lohan Waste Dumping Site, are used for dumping. The chemical flotation method is used to separate copper-ore from the waste-materials and tailing in the copper-ore processing plant. Prior to the flotation process, certain chemicals such as calcium hydroxide and sodium-carboxy-methyl-cellulose are added to initiate the separation of the copper-ore. The effluent from the chemical flotation is partially recycled for use in the copper-ore processing plant. Remaining effluent are being discharged into the Langanan river without treatment. The waste-materials and tailing are surveyed by a drop-tank gravity flow system to the Lohan Tailing Dam, which is of 16 km distant from the copper-ore processing plant. The Lohan Tailing Dam serves as a sedimentation pond, and, after sedimentation of solids in the dam, the waste water are discharged into the Mirali river by overflowing (Ref. 10). The water used in Mamut Copper Mine is being taken from the Mamut and Banbangan rivers at a rate of 18 m^3/min. The source of water pollution and sedimentation in Mamut Copper Mine is mainly silt load from the copper-ore processing plant and Lohan Tailing Dam. However, in rainy season, silt load flows out from the waste dump sites through runoff and this can also be a major pollution source of water quality and sedimentation in Mamut Copper Mine of which annual rainfall is about 4,000 mm. In fact, in 1977, large quantities of silt were flowed out into paddy fields and as a result the paddy fields were damaged with much rain. The effluent from Mamut Copper Mine also gives rise to the risk of water pollution by heavy metals contamination. Therefore, since 1977, the water quality of the concerned rivers has been monitored once a month by the Environmental Unit of State Government and mining company independently, and the dredging of the rivers has been carried out by mining company. The monitoring results of river water quality by State Government and mining company in 1980 are as summarized in Table 9 to 11.

As new purification systems, making a siltation or sedimentation lake in the Mountain is considered. The effluent from the mine will be directed to this lake, the water will be filtered to a series of filter until the water is discharged to the lowland for irrigation.

3. PRESENT MONITORING SYSTEMS FOR RIVER WATER QUALITY

3.1 Monitoring System of DOE

In Malaysia, DOE was established under the Ministry of Science, Technology and Environment with the enactment of the Environmental Quality Act in 1974, and since then DOE has been in charge of the environmental problems. To enchance and protect national water quality for tangible and intangible uses, DOE has initiated to carry out "National Water Quality Monitoring Programme" (Ref. 11).

The objective of monitoring system is to systematically collect water quality data, to study the trend of the national water quality, to assess suitability of the water for all beneficial uses, to assess the performance of compliance to various pollution abatement regulation, and to evaluate the impact of the development activities on the national water quality.

The water quality control of DOE is managed at respective river basin controlled region, and 29 river basin control regions are established in Sabah and seven in Sarawak. Monitoring is being carried out at the stations allocated in each river basin control region. The location of monitoring stations are as shown in Figs. 3 to 5.

Monitoring frequency is established on the basis of river priority. Minimum sampling frequency is at twice a year and several occasions for the more important rivers; the frequencies are at every alternate months/ every month.

Water quality parameters are arranged to be selected according to the water use of the rivers such as drinking, irrigation, fishery and industrial processes. Water quality parameters used in Sabah and Sarawak are as follows:

- Temperature
- Dissolved Oxygen (DO)
- Ammonical Nitrogen (NH_4-N)
- Electric Conductivity
- Alkalinity
- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Suspended Solids (SS)
- Total Solidis
- pH
- Total Nitrogen
- Phosphate
- Chloride
- Iron

The analysis of the water sample is being made at the laboratories of the Chemistry Departments in Kota Kinabalu and Kuching.

3.2 Monitoring System of DID

DID has monitored the river water quality with the objective of assessing the suitability for irrigation purposes for several times a year since 1977 in Sabah. While, in Sarawak, the monitoring has been limited only for sedimentation and electric conductivity which may affect the water quality.

The monitoring of the river water quality by DID in Sabah are being carried out several times a year at about 20 monitoring stations in 11 rivers. The locations of the monitoring stations are as shown in Fig. 10. Monitoring frequency is at several times a year. Water quality parameters used in Sabah DID's monitoring system are as follows.

- Temperature
- Colour
- Turbidity
- Electric Conductivity
- Hardness
- Total Solids
- Suspended Solids
- Dissolved Solids
- pH
- Alkalinity
- Dissolved Oxygen
- Calcium (Ca)
- Chloride (Cl)
- Potassium (k)
- Magnesium (Mg)
- Sodium (Na)
- Sulphate
- Chemical Oxygen Demand
- Nitrate
- Ammoniacal Nitrogen
- Iron (Fe)
- Manganese (Mn)

The analysis of the water sample is being made at the laboratories of the Chemistry Department in Kota Kinabalu.

3.3 Monitoring Systems of PWD and Water Boards

PWDs in both the States and Water Boards in Sarawak, which are in charge of water supply, have monitored the water quality of the river water and other sources of water supply at the intake and the outlet of the treatment plant.

The monitoring frequency is dependant on the treatment plant and the monitoring parameters, from once a month to once a week. The water quality parameters adopted are Colour, Turbidity, Iron, Chlorides, pH, Nitrites, Coliform-count and others that may affect water for drinking. The analysis of the water sample is being made at the PWD Water Laboratory in Kota Kinabalu and the laboratory of the Chemistry Department in Kuching. The results are evaluated according to the standards for drinking water of the World Health Organization as shown in Table 12.

4. PRESENT CONDITION OF RIVER WATER QUALITY

4.1 Water Quality

Since the monitoring system of DOE has started only in 1981 for Sabah and Sarawak, the accumulation of data on water quality is insufficient, especially in Sabah. In Sabah, however, DID has been monitoring the river water quality, and the data have already compiled for some years.

In Sarawak, information has been limited apart from sedimentation and electric conductivity. Therefore, on studying the present condition of river water quality in Sabah and Sarawak, DID's data are being used for Sabah and DOE's data for Sarawak. The mean, maximum and minimum values of the five parameters, i.e., pH, BOD_5, COD, SS and Ammoniacal Nitrogen, are considered as the main parameters in relation to man-made water pollution as shown in Tables 13 to 16.

4.1.1 BOD_5 and COD

Biochemical Oxygen Demand for 5 days in 20°C (BOD) is defined as the amount of oxygen utilized by micro-organisms in the stabilization of waste water for five days at 20°C, and is commonly used as the indicator for organic pollution in rivers. It is also useful to classify the stretches of a river with respect to its BOD_5 range. The relation between BOD_5 range and pollution level is shown as below (Ref. 12);

BOD_5	Classification
0 - 4 mg/lit	Clean
4 - 8 mg/lit	Mildy Polluted
8 -12 mg/lit	Moderately Polluted
More than 12 mg/lit	Grossly Polluted

BOD_5 level in Sarawak is mostly less than 3 mg/lit except an extremely high value of 26 mg/lit observed in the Samarahan river. This fact means that the rivers in Sarawak are clean as a whole with respect to organic pollution. The high BOD_5 in the Samarahan river was due to the effluent discharge from pig farms which are presently located above the monitoring station. Chemical Oxygen Demand (COD) is defined as the amount of oxygen that is utilized in decomposing chemically the oxidizable materials by oxidizing chemicals. As the oxidizable materials are mainly composed of organic matters, COD is also commonly used as the indicator of organic pollution supplementary to BOD_5. In Sabah and Sarawak, most rivers have shown low COD level of less than 50 mg/lit except for high COD level occasionally observed in the Kinabatangan, Labuk, Lupar and Samarahan rivers. Therefore, it can be concluded that organic pollution level of rivers in Sabah and Sarawak is very low as a whole based on the analyzing results of BOD_5 and COD.

4.1.2 Suspended Solids

Suspended Solids (SS) contained in river water is one of the major pollutants in rivers. This is because SS is the source of sedimentation which brings changes to river conditions and also affects the treatment system of the water supply. The major pollutant sources in SS are attributed to that of soil erosion with rainfall, mining effluent, domestic sewage and industrial effluent.

SS can be divided into two kinds of SS. One is organic and the other inorganic in origin. Inorganic SS is mainly contained in runoff water and mining effluent. Organic SS can be found in domestic sewage and industrial effluent, especially in the effluent of rubber factory and palm oil mill. With respect to SS, these classification based on SS level can be established (Ref. 12).

Classification	SS
Class A	0 - 50 mg/lit
Class B	50 - 250 mg/lit
Class C	250 - 500 mg/lit
Class D	500 - 1,000 mg/lit
Class E	more than 1,000 mg/lit

According to this classification, the Kadamaian, Tuaran, Putatan, and Lakutan rivers in Sabah have the SS level of class A and/or class B for the past three years, and thus it can be considered that the pollution level in SS is low in these four rivers. The Segama, Kinabatangan and Lubuk rivers in Sabah sometimes show the SS level of class D and they are a little bit polluted in SS. No river in Sabah has been found to have the SS level at more than 1,000 mg/lit for the past three years.

In Sarawak, all rivers except the Lupar and Sarawak rivers can be classified between class A and class B, and hence can be considered that almost all rivers in Sarawak are clean. However, in the Lupar and Samarahan rivers, high SS values of more than 1,000 mg/lit have been observed at times. High SS values in the Lupar and Samarahan rivers are due to the effluent discharge from the town and pig farm, respectively.

4.1.3 Other parameters

Parameters of pH and Ammoniacal Nitrogen are important in order to study river water pollution. The value of pH in clean river water is usually almost nuetrality. The optimum permissible range of pH recommended for drinking by WHO is from 6.5 to 9.2 as shown in Table 12.

Low pH values of lower than 6.5 were observed in many rivers such as the Kinabatangan, Labuk, Papar, Tatau, and Lupar rivers in Sabah and the Miri, Kamena, Sebelak, Sadong, Kayan, Serayan, Sematan and Sebko rivers in Sarawak. Low pH would be often caused by the industrial effluent.

However, there are a few industries located along those rivers, and thus it is supposed that inorganic matters having cation should be the main source of low $_{p}H$ in Sabah and Sarawak.

In Sabah and Sarawak, the level of Ammoniacal Nitrogen is less than o.1 mg/lit in all rivers, thus indicating that most of the rivers in Sabah and Sarawak are not polluted with organic matters as being supported from the values of BOD_5 and COD obtained.

4.2 Sea Water Intrusion

The rise of salinity with sea water intrusion is one of the important parameters to study the river water quality. This is because the high salinity affects the usage of water supply and irrigation. The extent of sea water intrusion differs according to rivers, as it depends on shape and flow of the river. In some rivers in Sarawak, State DID has surveyed the extent of sea water intrusion by estimating Electric Conductivity at the stations located along the river. The distribution of Electric Conductivity estimated in some rivers are as shown in Figs. 6 and 7, According to the standards of WHO, 200 mg/lit in Chloride concentration is the highest desirable level of drinking. The Electric Conductivity equivalent to 200 mg/lit in Chloride concentration is 650 μmho/cm, and thus 650 μmho/cm in Electric Conductivity can be considered as the limit of sea water intrusion. It is found that the extent of sea water intrusion is about 20 km from the estuary of the Krian, Sebelak and Ensengei rivers, 50 km to 100 km for the Lupar and Tuang rivers, and more than 100 km for the Sadong, Krang and Samarahan rivers. Moreover, it was found that during the field survey the sea water intrusion has caused trouble at the water supply intake at Sarikei, Binatang and other places. The distance from the estuary is 70 km at Sarikei and 80 km at Binatang. While, in Sabah, it is said that the Lahad Datu intake is located at about 1 km from the estuary and is often affected by sea water intrusion. However, sea water cannot intrude more than 10 km from the estuary for most rivers, even if sometimes during the drought period it intrudes into some rivers such as the Papar river. Therefore, the extent of sea water intrusion is found to be shorter in rivers in Sabah than in Sarawak.

5. DEVELOPMENT PLANS FOR WATER POLLUTION ABATEMENT

5.1 Sewerage Development Plans

There are several cities having projects with master plan under 4MP for their sewerage systems. The study on the installation of sewerage system has been completed for Kota Kinabalu, Sandakan, Tawau and Lahad Datu in Sabah and for Bintulu in Sarawak. In Labuan in Sabah, the study on sewerage system is now undergoing. The summary of each master plan for sewerage systems will be described below:

5.1.1 Sewerage system plan for Kota Kinabalu

The proposed plan for sewerage systems in Kota Kinabalu is as follows (Ref. 1):

(1) The designed population is 271,000 people by the year 2010;

(2) The designed area covers the whole urban area and consists of three sewerage network systems: the northern system, the southern system and the Penampang system;

(3) The northern system will collect the domestic sewage from a population of 110,000 in the northern area including the existing town centre and will discharge the sewage to the Inanam river after being treated at Inanam treatment plant. Inanam treatment system will comprise five Screening, anaerobic lagoon, facultative lagoon and maturation lagoon. The existing outfall at Lipat Point will be abandoned;

(4) The southern system will collect the domestic sewage from a population of 130,000 in the southern area including the airport and the Kapayan Police Headquarters Complex. The sewage will be treated at Kapayan treatment plant and discharge to adjacent water course. Kapayan treatment plant will comprise of the same treatment processes as at Inanam treatment plant. The existing Luyang lagoons will be extended as planned and eventually decommissioned upon completion of the Kapayan treatment plant;

(5) The Penampang system will collect the domestic sewage from a population of 16,000 in Penampang area, treat at the stabilization lagoon and discharge treated waste water to adjacent watercourse;

(6) The treated sewage from all the three treatment plants will have a fecal coliform level of less than 1,000/0.1 lit in more than 80% of the samples, BOD_5 of 10 to 20 mg/lit and SS level of around 50 mg/lit and

(7) The estimated capital cost of the major elements, in 1981 prices, by the master plan is as shown in Table 17, including engineering and physical contingencies but excluding local sewers, house-connections and a septic tank conversions.

5.1.2 Sewerage system plan for Sandakan

The proposed plan for sewerage systems for Sandakan is as follows (Ref. 2):

(1) The designed population is 176,000 people by the 2010;

(2) The designed area covers the whole urban area and consists of three sewerage network systems: the northwestern system, the north system and the southern system;

(3) The northwestern system will collect the domestic sewage from a population of 43,000 in the new Government Centre, the airport and other developments in the Labuk and adjacent North Road areas, treat the sewage at Sibuga treatment plant and discharge to the adjacent storm water channels. Sibuga treatment plant will comprise five screening, anaerobic lagoon, facultative lagoon and maturation lagoon;

(4) The north system will collect the domestic sewage from a population of 75,000 in the north, treat the sewage at Kabun China treatment plant and discharge the treated sewage to the adjacent storm water channels. Kabun China treatment plant will comprise the same treatment processes at Sibuga treatment plant;

(5) The southern system in the south will collect the domestic sewage from a population of 58,000 in the south and discharge the sewage into Sandakan harbour through a marine outfall after pretreated by five screening;

(6) The treated sewage from both Sibuga and Kabun China treatment plants will have a fecal coliform level of less than 1,000/0.1 lit in more than 80% of the samples, BOD_5 of 10 to 20 mg/lit and SS level of around 50 mg/lit. The outfall system is designed to ensure that the fecal coliform level at the shore will not exceed 1,000/0.1 lit in more than 20% of samples; and

(7) The estimated capital cost of the major elements, in 1981 prices, by the master plan is as shown in Table 17, including engineering and physical contingencies but excluding local sewers, house connections and septic tank conversions.

5.1.3 Sewerage system plan for Tawau

The proposed plan for sewerage systems for Tawau is as follows (Ref. 3):

(1) The designed population is 184,000 people by the year 2010;

(2) The designed area covers the whole urban area;

(3) The sewerage system will collect the sewage from the designed area, treat the sewage at the Anas Laut treatment plant and discharge to the sea at the shore adjacent to the treatment plant. The existing outfalls will be abandoned. The treatment plant will comprise of five processes screening, anaerobic, facultative and maturation lagoon;

(4) The treated sewage will have a fecal coliform level of less than 1,000/0.1 lit in more than 80% of the samples, BOD_5 of 10 to 20 mg/lit and SS level of around 50 mg/lit; and

(5) The estimated capital cost of the major elements, in 1981 prices, by the master plan is as shown in Table 17, including engineering and physical contingencies but excluding level sewers, house connections and septic tank conversion.

5.1.4 Sewerage system plan for Lahad Datu

The proposed plans of sewage system for Lahad Datu is as follows (Ref. 4):

(1) The designed population is 53,300 by the year 2000;

(2) The designed area covers the whole urban area;

(3) The sewerage system will collect the sewage from the urban area, treat at the treatment plant to be constructed at the west of the airport and discharge the treated sewage into the Tabanac river. The treatment plant will comprise aerated lagoon, facultative pond and maturation pond; and

(4) The treated sewage will contain BOD_5 of less than 30 mg/lit with SS level of less than 50 mg/lit.

5.1.5 Sewerage system plan for Bintulu

The proposed plans for sewerage system for Bintulu is as follows (Refs. 13 & 14):

(1) The designed area covers all new residential area and the majority of the existing residential, commercial and industrial areas. The proposed plan consists of three sewerage network systems: the Bintulu sewerage system, the University Pertanian Malaysia sewerage system and the Kidurong industrial area system;

(2) The sewage to be collected is domestic sewage from private dwellings, commercial centres and minor industries, but not from Major Employment Generator which would be expected to discharge fully treated effluent of acceptable quality directly into the watercourses or into the sea;

(3) The Bintulu sewerage system will collect the sewage in the Bintulu urban development area and discharge it to the Kemena or Sibu river after treatment. The treatment plant will comprise the facultative and aerobic lagoons;

(4) The UPM sewage system will collect the sewage from the UMP campus and the associated UPM residential area and discharge it into the Sibiu river after treatment. The treatment plant will comprise the facultative and serobic lagoons;

(5) The Kidurong sewerage system will collect the sewage in the Kidurong industrial area and will be discharged into the Sebatang river after treated. The treatment plant will comprise the facultative and aerobic lagoons; and

(6) The treated sewage will contain BOD_5 of less than 30 mg/lit with SS level of less than 90 mg/lit. Chlorination facilities should be provided at all treatment plants.

5.2 Innovation of Purification Technology

The plans for sewerage system has been promoted to purify the domestic sewage in urban areas. But, at present, in the rural areas where the population density is still low, the pour-flush latrine is considered as the most appropriate method for disposal of excreta in "Rural Environmental Sanitation Programme". The Kitchens waste is recommended to be discharged into soakaway pits leading into the sullage waters and into the ground. After that, solid wastes are to be disposed off by burning or by burial (Ref. 14).

Though the present and future plans of the purification system of industrial effluent except rubber factory and palm oil mill are yet unknown, the industrial effluent is controlled under "Environmental Quality (Sewage and Industrial Effluents) Regulation 1979. The industrial effluent is requested to be treated below the parameter limit of effluent as shown in Table 18. Besides, the sewage discharged into inland watercourse is also controlled under the same regulation as the industrial effluent (Ref. 15).

The effluent from rubber factory and palm oil mill is controlled under the governmental regulations. The effluent from rubber factory is controlled under "Environmental Quality (Prescribed Premises) (Raw Natural Rubber) (Amendment) Regulation in 1980" and the factory is requested to treat the effluent to below 300 mg/lit in BOD_3 at present, below 200 mg/lit after April, 1983 and below 100 mg/lit in the maximum and 50 mg/lit in average after April, 1983 in the case of the production of Concentrated Latex or its associated products, and below 100 mg/lit in the maximum and 50 mg/lit in average at present and thereafter in the case of the production of products other than Concentrated Latex or its associated products as shown in Table 3. The effluent from palm oil mill is controlled under the "Environmental Quality (Prescribed Premises) (Crude Palm Oil) Regulation in 1977" and the factory is requested to treat the effluent below 500 mg/lit in BOD_3 at present, below 250 mg/lit after July, 1982 and 100 mg/lit in maxim and 50 mg/lit in average after January, 1984 as shown in Table 6. Therefore, there is need for the innovation of purification technology to achieve such parameter limits, and so Rubber Research Institute of Malaysia (RRIM) has studied the use of mechanical aeration and the applicability of the anaerobic filter bed, containing bio-disc and aerated lagoons for purification of rubber factory effluent (Ref. 6). For the purification of palm oil mill effluent, the Palm Oil Research Institute of Malaysia (PORIM) has studied the efficiency of the existing treatment systems, the effective utilization of the effluent further treatment, the recovery of methane gas from effluent and the modification of the production process (Refs. 17 & 18).

The pig farming effluent is being discharged without treatment and has become one of the major pollution sources in Peninsular Malaysia as well. At present, a study has been carried out about the present condition of pig farming effluent, and from the finding of this study the pilot projects is proposed to establish the purification systems for pig farming effluent in Melaka, Selangor and other states where the problems are serious (Ref. 9). The pilot project is a system involving the channel of all piggery wastes to a settling tank where the overflow is directed to an aerobic-algal lagoon into which aquaculture can be introduced. The settled solids from the settling tank will be pumped to a biogas system for treatment and the generation of biogas for purposes of heating and lighting. If sufficient biogas is generated, steps will be taken to acquire a "Total Energy Module (TOTEM)" for the conversion of the gas to electricity (Ref. 19).

6. PROBLEMS AND NEEDS

In Sabah and Sarawak, the main problems concerning the river water pollution are muddiness and sedimentation mainly consisting of inorganic matters at presnet. The major source of muddiness and sedimentation is the soil erosion, which is mainly dependent or rainfall, flora, the nature of the soil and the utilization of land. In Sabah and Sarawak, soil erosion resulted from clearance of logging area has affected the river water quality, extremely, and this problem is very serious in Sabah and Sarawak, where forestry is very active. Besides, there are water pollution problems caused by sediment load from Mamut Copper Mine in Sabah and sawdust discharge from sawmills in Sarawak; even though they seems to be a localised problem. The affect caused by sawdust is most serious in the Rajang river, while, in Sabah, there is no problem caused by the sawdust. This is because the sawdust are not allowed to be discharged into the river by regulation and therefore they are burned. In Mamut Copper Mine, large quantities of silt flowed out and damaged 800 ha of paddy fields in seven Kampongs. For the damage, the mining company paid about M$200 x 10^6 for compensation. Since then, the water quality of the rivers concerned has been monitored and the dredging of the rivers has been carried out. However, the risk of outflow of silt and water pollution still remains, and so the project resettles the affected inhabitants to Penawantai and its environs are being promoted at present. The bank erosion caused by the wake waves of the navigating boats also constitutes another cause of muddiness and sedimentation. The effect to the bank erosion is most serious in the Rajang river.

The organic pollution level in Sabah and Sarawak is low at present. This is because the pollutant load discharged into rivers is insignificant. This is due to the facts that the pollution sources are comparatively few and that many of the towns and factories identified as major pollution sources are located in coastal areas. Consequently, the river water quality is satisfactory as a whole, even if the local problems of water pollution have been arisen at the places close to pollution sources. The pollution source, being located above the water intake such as the effluents from the large-scale pig farms in Sandakan and the industrial estates in Sibu, has affected the water quality and obstructed the usage of water supply. Besides in Sarawak, some pig farming effluents would often affect the water quality, and the quite high BOD_5 value of the Samarahan river is due to the effluent from the pig farm located near the monitoring station.

In rural areas, domestic sewage from the houses near rivers are being discharged directly into the river without treatment, and especially excreta disposal has the risk of not only water pollution but also public health.

In certain rivers in Sarawak, the river water is polluted by sodium pentachlorophenate which is coated on the logs for the purpose of preservation when they are conveyed downstream through water course from the logging areas to the sawmills.

As the river water monitoring programme by DOE has just started since November, 1981 in Sabah and April, 1981 in Sarawak, the information on river water quality is not sufficient. Moreover, the present condition of industrial effluent, except rubber factory and palm oil mill, and the animal husbandry effluent is still under study.

Therefore, it is important that the present condition of water quality and pollution sources in Sabah and Sarawak depends a great deal upon further study. However, the number of the staff in charge of water pollution control is small both in Sabah and in Sarawak, and so the consolidation of manpower is being desired. In Sabah, though there are some sewerage plans in major towns, the budget for the implementation of the plans is insufficient. The septic tank that is the most wide-spread purification system in urban areas in Sabah and Sarawak is not being maintained satisfactory due to the lack of budget for equiping the maintenance facilities and consolidating man power. As a result, the purification rate of septic tank is degraded in most towns, and so there is need for consolidation of budget for the equipment, operation and maintenance of water pollution abatement facilities at present.

7. PROJECTION OF WATER QUALITY

7.1 General

Pollutant load and water quality of rivers by Basin were projected based on projection of D&I water demand. Major pollution sources are composed of 19 cities, 48 districts, 27 palm oil mills, 10 rubber factories and animal husbandry in Sabah and Sarawak. These sources are grouped into nine categories; i.e., (1) Urban domestic sewerage, (2) Urban domestic non-sewerage, (3) Rural domestic, (4) Urban manufacturing sewerage, (5) Urban manufacturing non sewerage, (6) Rural manufacturing, (7) Palm oil processing, (8) Rubber processing and (9) Animal husbandry. Each category has different figures respectively for net unit pollutant load, discharge ratio, runoff ratio and infiltration ratio. Composition of the above pollution sources is illustrated in Fig. 9.

In order to know the degree of organic water pollution of river, BOD was selected among five parameters for living environment such as BOD, SS, DO, pH and NH_4-N.

Porjected pollutant load and water quality by Basin are shown in Tables 19 to 34.

7.2 Source of Pollution

As major pollutant sources, 19 cities, 48 districts, 27 palm oil mills, 10 rubber factories and 32 pig farms are selected in the Study.

There are 17 palm oil mills in Sabah and Sarawak in 1980. Number of palm oil mill will increase to 23 in 1990 and 26 in 2000. Water demand of these palm oil mills is as shown in Table 35.

There are eight rubber factories in Sabah and Sarawak in 1980. And number of rubber factory will be 8 in 1990 and increase by 1 in 2000. Water demand of these rubber factories is as shown in Table 36.

There are numerous small-holder pig farms in Sabah and Sarawak. The number is 145 in Sabah and 83 in Sarawak. These 228 pig farms were grouped into 32 pig farms, being estimated production more than 1,000 heads of pigs in 2000. The pig production will grow rapidly with the annual average rate of 10.6% during the period from 1980 to 1990 and 3.0% from 1990 to 2000 (Ref. 23). Projected pig production of 32 pig farms is as shown in Table 37.

7.3 Water Quality Projection

7.3.1 Methodology

Water quality of river was projected for all Basins in Sabah and

Sarawak.

Water quality was calculated as the following order:

(1) Pollutant load from pollution source (PLS)
= Customer demand (C.D.) x Discharge ration (D-ratio)
x Net unit pollutant load (NUPL)

(2) Pollutant load inflow to river (PLR)
= PLS x Runoff ratio (R-ratio) x (1 + Infiltration ratio (I-ratio))

(3) Pollutant load at balance point (PLBP)
= PLR x Residual purification ratio (RP-ratio)

(4) Water quality at balance point (WQBP)
= PLBP/Maintenance flow at balance point (MFBP)

(5) Water quality at some point (W.Q.)
= CD x D-ratio x NUPL x R-ratio x (1 + I-ratio)
x RP-ratio/Maintenance flow at Some Point

Water quality was calculated by outlet of polluted wastewater in a Basin.

Water quality projection flow-chart is given in Fig. 10.

Calculation of water quality was carfied out on the following assumptions;

(1) Maintenance flow used for water quality projection is 97% probability Basin discharge and kept at every outlet point,

(2) When the river water is abstracted at intake, pollutant load of the river is decreased. The decreased load is expressed as (Abstracted volume x Water quality),

(3) Urban domestic and manufacturing wastewater in coastal area is discharged not to river, but to sea directly after treating,

(4) A part of abstracted water from river is reduced to river. The reduced volume is equal to (SD - CD)/2,

(5) Intake point of abstruction of surface water is the same point of outlet of effluent from pollution source, and

(6) I-ratio of groundwater into sewer pipe in city having public sewerage system is 20% of the average daily treatment capacity.

7.3.2 Net unit pollutant load

In order to know the degree of water pollution of river, five parameters such as pH, BOD, SS, DO and NH_4-N will be used. Of these parameters, BOD is the most suitable parameter to know the organic pollution of river water. The reason is described hereunder.

The river water is generally polluted organically in the beginning period because of the direct discharge of domestic wastewater and night soil. And then industrial effluent with heavy metal and chemical materials pollutes the river water chemically but industrial effluent with heavy metal should not be discharged to water body without treated. Therefore, heavy metals are not suitable parameters to know organic pollution of river water. River has the self purification phenomena to purity the organic pollution under flowing down. This phenomenon is that aerobic bacteria in river water transforms organic matters to in-organic matters using dissolved oxygen. Then volume of dissolved oxygen used by aerobic bacteria is BOD. For the above reason, BOD load was used in the Study as pollutant load.

NUPL was estimated based on several reports (Refs. 24 to 27), assuming that the purification measures remain at the present level of BOD concentration in 1990 and 2000. NUPL of non-sewerage-urban-domestic was estimated based on assumed development of septic tank in urban area as shown in Tabled 38 and 39. Estimated NUPL is given in Table 42.

Data for NUPL of sewerage, urban, rural, manufacturing, palm oil processing, rubber processing and animal husbandry were available in Malaysia (Ref. 27).

7.3.3 Discharge ratio

Pollution sources are equal to water consumers. They use clean water and then discharge polluted water to drainage, river or sea directly. D-ratio is the ratio of consumer demand water and discharged water. D-ratio of domestic consumer was determined based on the Malaysia data. D-ratio by pollution source is as shown in Table 42.

In manufacturing D-ratio was determined with consideration of the recyclic water use development. In palm oil mills and rubber factories the land disposal system is progressively applied as shown in Table 40. D-ratio of palm oil mills and rubber factories was determined with consideration of land disposal development and outflow of 10% of pollutant load from land disposal area as shown in Table 41. In animal husbandry no water is used.

7.3.4 Runoff ratio

The ratio of the reduction of discharged pollutant loads, which is the ratio before and after discharged pollutant reaches a river, is called the runoff ratio.

R-ratio is about 0.1 in rural areas but increases with the progress of urbanization. For a drainage channel made of concrete, R-ratio rises to nearly 1.0. R-ratio by pollution source is as shown in Table 42.

7.3.5 Infiltration ratio

The infiltration ratio in the existing sewerage systems in Sabah is equivalent to about 25% to 30% of the average flow. Since existing systems are constructed with rigid cement joints, it is to be expected that, with the provision of flexible, water tight joints in the future, the infiltration ratio should fall to about 20% of the average daily flow (ref. 1 to 3). I-ratio is assumed to be 20% in the Study.

7.3.6 Residual purification ratio

Pollutant load in river is decreased by deposition, adsorption, biological decomposition and so on. A concept which describes these phenomena totally is called residual purification ratio. In other words, RP-ratio is the ratio of pollutant load of upper stream and down stream. RP-ratio has a figure in the range of 0 to 1 by conditions of water quality, water velocity, water discharge, water depth, and riverbed of the river basin. The relationships between RP-ratio and water quality is close. RP-ratio is about 0.7 in a river with clean water and RP-ratio rises to nearly 1.0 in a river with polluted water. In the Study, RP-ratio of all basins in Sabah and Sarawak is assumed to be 0.7 with consideration of the river water quality in 1980 and 1981.

7.3.7 Maintenance flow

Maintenance flow used for water quality projection is 97% probability Basin discharge.

Based on the net unit Basin discharge by Basin, maintenance flow was calculated. Maintenance flow of effective catchment area of main river for water quality at balance point by Basin is as shown in Table 43.

7.3.8 Projection of water quality

Major pollution sources assumed are domestic and industrial water consumers comprising 19 cities, 27 palm oil mills, 10 rubber factories, animal husbandry and rural areas.

Water quality of 47 Basins in 1990 and 2000 was projected for two cases. Projected BOD load and BOD concentration by Basin in 1990 and 2000 are as shown in Tables 19 to 26 for Case 1 and Tables 27 to 34 for Case 2. Total BOD load from pollution sources in Sabah and Sarawak will be 130 ton/d for Case 1 and 116 ton/d for Case 2 in 1990, and 330 ton/d for Case 1 and 216 ton/d for Case 2 in 2000, respectively.

It is assumed that wastewater from nine cities mentioned hereunder out of 19 cities is discharged to sea directly because these nine cities are located near sea coast. These nine cities are Tawau, Semporna, Lahad Datu, Sandakan, Kudat, Kota Kinabalu, Labuan, Miri and Bintulu.

BOD load from these nine cities will be 52 ton/d for Case 1 and 39 ton/d for Case 2 in 1990 and 197 ton/d for Case 1 and 89 ton/d for Case 2 in 2000, respectively.

And BOD load into main stream will be 82 ton/d for Case 1 and 80 ton/d for Case 2 in 1990 and 144 ton/d for Case 1 and 132 ton/d for Case 2 in 2000, respectively.

In terms of BOD load from pollution source, Basin 236 will have the biggest BOD load because of the existence of big city, Bintulu. It will be 27 ton/d in 1990 and 120 ton/d in 2000 for Case 1 and 19 ton/d in 1990 and 53 ton/d in 2000 for Case 2.

In terms of BOD load into river, the Basin with the biggest BOD load in Case 1 and Case 2 will be Basin 246 in 1990 and Basin 241 in 2000. It will be 6 ton/d in 1990 and 13 ton/d in 2000 for Case 1 and 6 ton/d in 1990 and 10 ton/d in 2000 for Case 2.

Composition of BOD load into river is as shown in Tables 20 and 28. In Case 1, in 1990, palm oil mills and rubber factories will be the biggest pollution sources and those BOD load will be 14 ton/d being equivalent to 50% of the total BOD load of 28 ton/d. In 2000, the biggest pollution source will be urban domestic and urban industry followed by palm oil mills and rubber factories. BOD load of urban domestic and urban industry into river will be 24 ton/d being equivalent to 45% of the total BOD load of 53 ton/d. That of palm oil mills and rubber factories will be 23 ton/d being equivalent to 43% of the total. In Case 2, in 1990, palm oil mills and rubber factories will be the biggest pollution sources and its BOD load will be 14 ton/d being equivalent to 52% of the total BOD load of 27 ton/d. In 2000, they will be also the biggest pollution sources having the BOD load of 23 ton/d being equivalent to 50% of the total BOD load of 46 ton/d.

The projection of BOD concentration was conducted in consideration of the river maintenance flow. Projected maximum and minimum BOD concentration by Basin are as shown in Tables 19 and 27.

In Case 1, the highest BOD concentration, 9 mg/lit, was projected for Basins 217 and 234 in 1990 because of the non-treated effluent from the palm oil mills in Basins 217 and 234. In 2000, Basin 209 shows the highest BOD concentration of 7 mg/lit because of the non-treated effluent from two palm oil mills. In Case 2, the highest BOD concentration in 1990 and 2000 is as same as that in Case 1. Distribution of BOD concentration along river of the Basin with City/Town is illustrated in Figs. 11 to 14 for Case 1 and Figs. 15 to 18 for Case 2.

These are 16 Basins, i.e. Tawau Basin with C201, Tawau, Kalumpuang Basin with C202, Semporna, Silabukan Basin with C203, Lahad Datu, Labuk

Basin with C205, Ranau, Bongan Basin with C206, Kudat, Kadamatan Basin with C207, Kota Belud, Putatan Basin with C208, Kota Kinabalu, Papar Basin with C209, Papar, Padas Basin with C210, Keningau, Limbang Basin with C212, Limbang, Baram Basin with C213, Marudi, Miri Basin with C214, Miri, Kemana Basin with C215, Bintulu, Rajan Basin with C216, Sibu and C217, Sarikei, Sadong Basin with C218, Serian, and Sarawak Basin with C219, Kuching.

Since the wastewater from City/Town is discharged to the sea directly after treating, these figures show low BOD concentration in spite of existing of large City/Town in these 16 Basins. BOD concentration of most rivers in Sabah and Sarawak will not be more than 5 mg/lit in 1990 and 2000 for Cases 1 and 2, except for Silibukan, Bongan and Suai Basins. In Sabah and Sarawak, most rivers are little polluted presently and will be still clean in 1990 and 2000.