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AVERAGE ANNUAL SURFACE WATER RESOURCES OF PENINSULAR MALAYSIA

1976

JABATAN PENGAIRAN DAN SALIRAN
KEMENTERIAN PERTANIAN MALAYSIA

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1976

Bahagian Parit dan Taliair
Kementerian Pertanian
Malaysia

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AVERAGE ANNUAL SURFACE WATER RESOURCES OF PENINSULAR MALAYSIA

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Kementerian Pertanian

Bahagian Parit dan Taliair

TABLE OF CONTENTS

SUMMARY

This study, based on the Thornthwaite and Mather (1955) water balance model, aims at improving previous estimation of water resources from ungauged rivers.

By computing the daily water balance from rainfall records, summaries of annual precipitation, actual evapotranspiration, water deficit and runoff were obtained for some 600 rainfall stations. A surface water resources map for Peninsular Malaysia was produced by plotting the runoff data and mapping the isohyds (lines of equal runoff).

Estimated average annual runoffs obtained by integration of the water resources map compare favourably with observed averages obtained from water level recording and stage-discharge rating tables. The accuracy of the estimation procedure is to within approximately ± 15% of the true average annual discharge.

The annual surface water resources for each state of Peninsular Malaysia were computed and the average annual runoff for the whole of Peninsular Malaysia was estimated to be 1185 mm, equivalent to 5050 m^3/sec.

1. INTRODUCTION

1.1 The Problem

With the rapid development of water resources projects throughout Peninsular Malaysia there is a growing demand for information on average annual discharge for rivers which have never been gauged or instrumented with a flow recorder. The future allocation of water resources for irrigation, industrial, and domestic water supplies requires basic information on the spatial variability of available resources.

1.2 Study Objective

Goh (1974) estimated the surface water resources of Peninsular Malaysia using a precipitation (P) minus potential evapotranspiration (PE) approach. For catchments with streamflow records exceeding 10 years, he compare the observed average annual runoff with the estimated runoff obtained from the P-PE map. He concluded that the P-PE approach underestimated the observed water resources and attributed this to a number of factors including; an over-estimation of potential evapotranspiration obtained by the Thornthwaite (1947) procedure, the use of potential evapotranspiration in place of actual evapotranspiration and the inadequate coverage in the existing network of rainfall stations.

This study, based on the Thornthwaite and Mather water balance technique, aims at improving previous estimates obtained by Goh.

2. ANALYSES

2.1 Evapotranspiration and Soil Moisture Depletion Processes

Evapotranspiration from land surfaces is controlled by complex interactions between climatic variables, the vegetation and the soil.

Where soil moisture is not a limiting factor evapotranspiration will continue at a potential evapotranspiration rate depending on local climatic conditions and the vegetation type. However, once drying out of the soil profile commences due to limiting rainfall, the evapotranspiration process becomes more complex and the decrease of the actual evapotranspiration (AE) below the potential rate then depends on the available moisture in the soil, the water holding capacity (WHC) of the soil, and the rooting depth and root density of the vegetation.

When the moisture content of the soil is at, or above field capacity, surplus water or water added by precipitation is lost directly to gravitational drainage. Such gravitational water is only detained briefly, the period depending on the depth and permeability of the soil. This in computing the rate of drying of a soil from an initial value above field capacity it is necessary to determine separately the loss of water by evapotranspiration and by gravitational flow.

As soil moisture depletes it becomes increasingly difficult for plant roots to extract water from the soil, until eventually evapotranspiration ceases and the plant dies. The soil moisture content at this level is defined as the wilting point and the water holding capacity is the difference between field capacity and the wilting point.

The water holding capacity of a soil depends in turn on the type, structure and depth of the soil and can vary from a few millimetres for a shallow sand to more than 400 mm for a deep silt loam.

The rooting depth of plants somewhat compensates for the variable nature of the soil for, on sandy loams plants have deep-rooted systems while on clay soils plants tend to be more shallow rooted. Thus, the actual depth of water available to plants in the form of soil moisture is not as variable as might be expected.

2.2 Thornthwaite and Mather water balance model

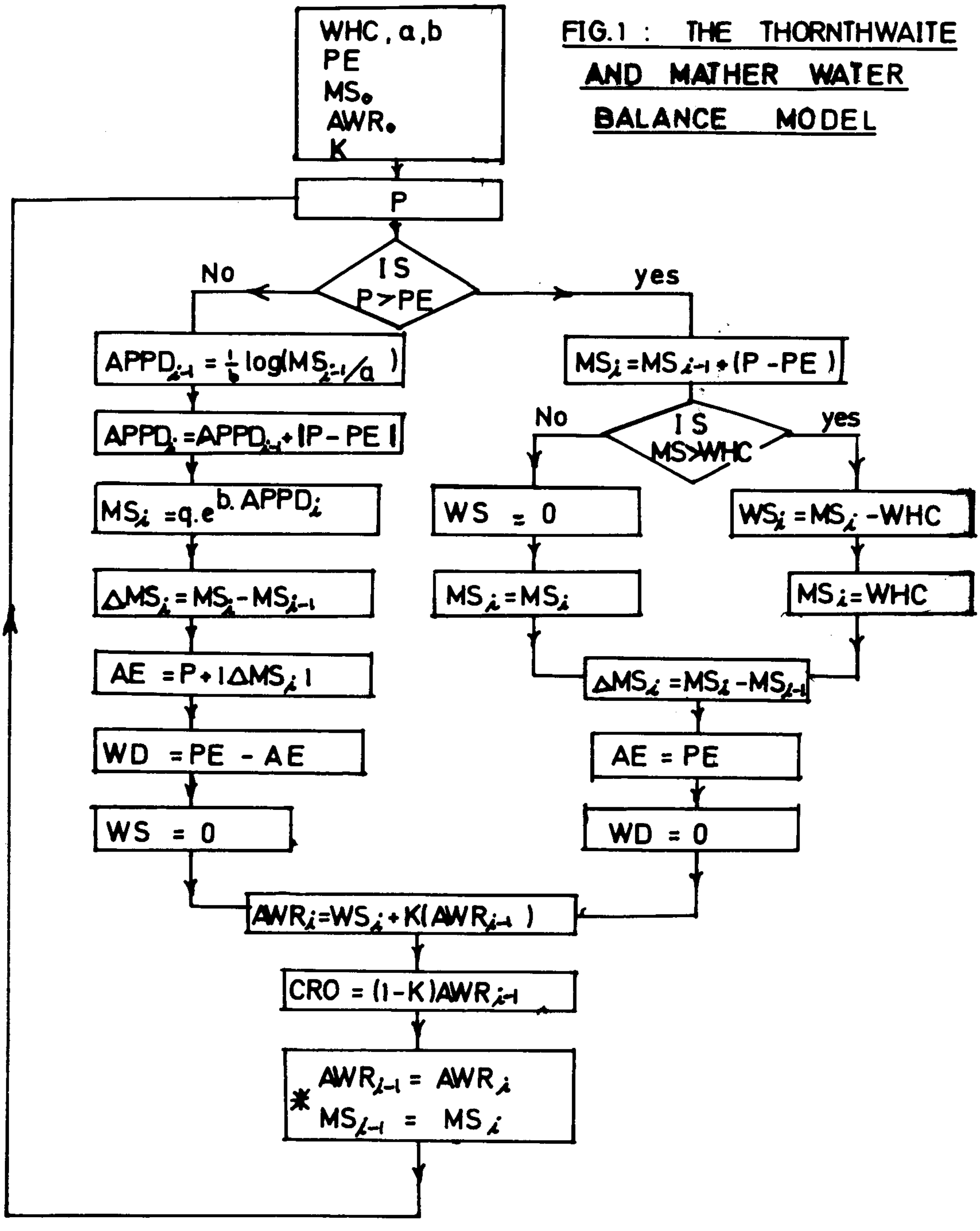
Thornthwaite and Mather (1955) constructed a single store conceptual model to simulate mathematically the processes described in 2.1. The model is outlined diagrammatically in Fig. 1.

Daily rainfall (P) in excess of potential evapotranspiration (PE) is added directly to the soil moisture store (MS). If the soil moisture exceeds the water holding capacity of the soil a water surplus (WS) occurs, the actual evapotranspiration (AE) for that day is equivalent to the potential rate, and there is no water deficit.

If rainfall is less than PE, the soil moisture store is adjusted according to a variable functions dependant on the soil moisture status at the end of the previous day. Actual evapotranspiration is equated to any precipitation (less than PE) plus the difference in soil moisture between this and the previous day (ΔMS). Water deficit (WD) is the difference between PE and AE.

Following adjustments to the soil moisture store any water surplus is added to previous gravitational water (AWR) available to runoff, which is recessed by a factor K to compute the daily runoff.

FIG.1 : THE THORNTHWAITE AND MATHER WATER BALANCE MODEL



Abbreviations:

P - Precipitation.
PE - Potential evaporation
AE - Actual evapotranspiration
MS - Soil moisture
ΔMS - Change of soil moisture
AWR - Available water for runoff
WHC - Water holding capacity.
WD - Water deficit
WS - Water surplus
APPD - Accumulated potential precipitation deficit.
CRO - Computed runoff
K - Recession Constant
a, b - Soil moisture retention constants

2.3 Processing System

Daily rainfall data observed at approximately 600 stations having 4 years or more of records were processed using a NOVA 1220 computer and the system described in Fig. 2. For long-term rainfall station records only 11 years of records (Jan. 1959 – June 1970) were analysed, with the first six months (Jan. – June 1959) being used to establish the initial storage conditions at commencement of the systemised analyses from 1 July 1959.

Computer programme EBAS, WRSTAPE, SELECT1 and WRSCARD are programmes designed to reorganise the rainfall data in various forms and from various sources onto a working disc file. Programme THORN2 computes the daily water balance and outputs a summary of annual precipitation, actual evapotranspiration, water deficit and runoff, together with the mean annual and standard deviation for the period of record. (Appendix 1).

All programmes are capable of handling up to 50 years of rainfall data. Execution time through THORN2 for a 11 year record takes about 2½ minutes.

2.3.1. Potential Evapotranspiration

Monthly potential evapotranspiration occurring at each rainfall station were estimated using the summaries and maps presented by Scarf (1976). For highland rainfall stations, monthly evapotranspirations from the nearest evaporation station were corrected for altitude difference between the evaporation and rainfall station. The evaporation – elevation relationships used were those presented by Scarf (1976).

For this particular study the evapotranspiring surface was assumed to be forest and grouped with rubber and oil palm is the dominant land used in Peninsular Malaysia. Differences in albedo between forest, rubber and oil palm were considered negligible. For those coastal rice growing areas at Kedah, Melaka and Kelantan the available water resources are probably slightly overestimated; rice evapotranspirating about 10% more water than forest.

2.3.2 Water holding capacity

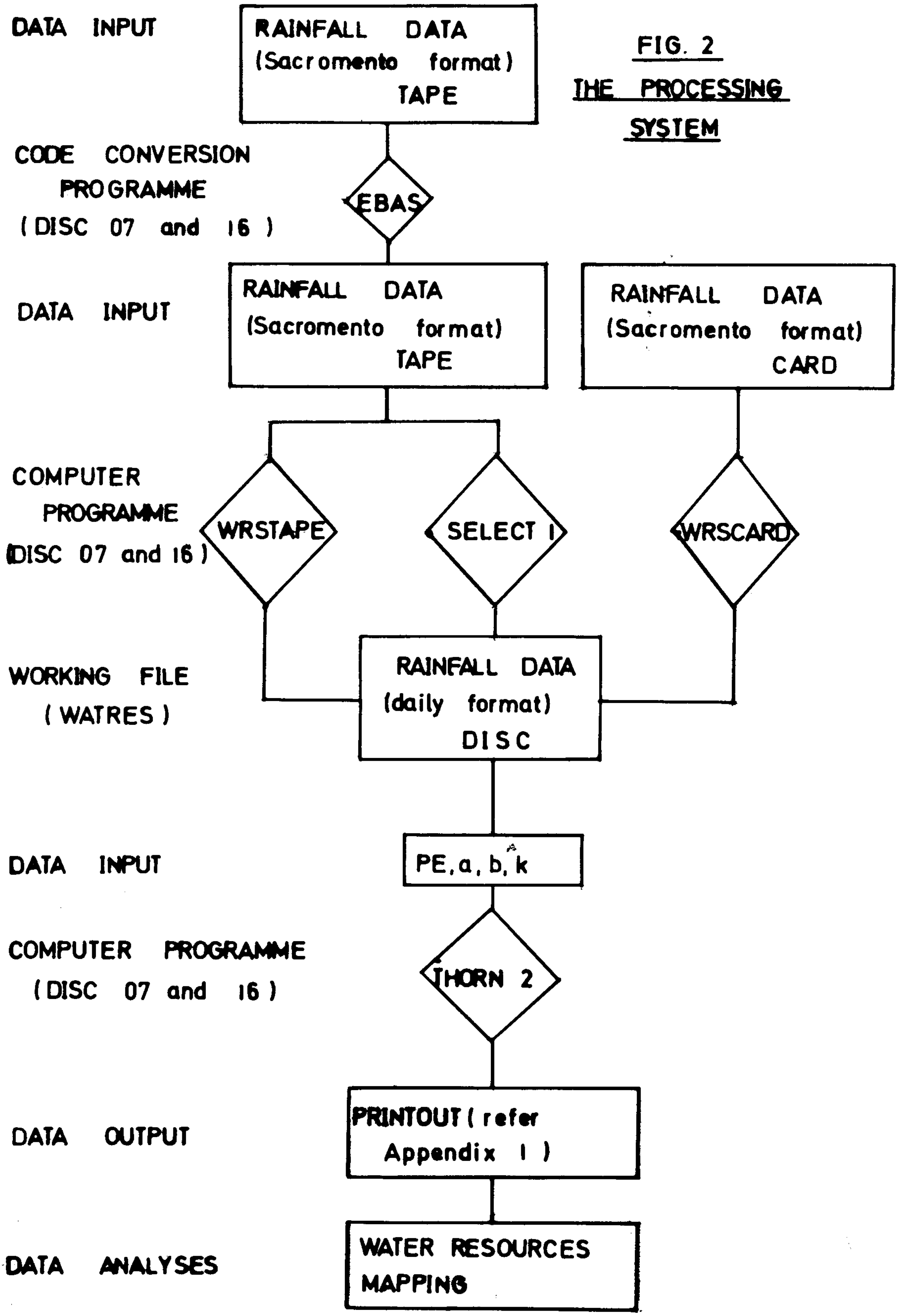
For this study the water holding capacity was fixed at 250 mm based on two assumptions:

(a) that the average rooting depth of the vegetation (forest and plantation crops) is about 1.5 metres, and

(b) that the soils in Peninsular Malaysia are predominantly silt loams, clay loams and clays.

FIG. 2

THE PROCESSING SYSTEM



In a previous study, Teh (1975) proved that the water holding capacity in the Thornthwaite and Mather model was non-sensitive and an error of ± 50% in water holding capacity affected a change in estimated water resources by less than ± 5%.

2.3.3 Soil moisture retention constants

Soil moisture retention tables corresponding to various water holding capacities are included in Thornthwaite and Mather (1955). To facilitate computer processing the relationships between soil moisture (MS) and accumulated potential precipitation deficit (APPD) were rationalised by fitting an exponential equation of the form

$$MS = ae^{b.APPD}$$

were a and b are soil moisture retention constants dependent on the water holding capacity of the soil. For a water holding capacity of 250 mm the values for a and b are 249.5 and –0.0040 respectively.

2.3.4 Recession constant

The daily recession constant equal to 0.9 recommended by Thornthwaite and Mather, was used throughout the analyses.

3. WATER RESOURCES MAPPING

3.1 Mapping average annual surface water resources

Using a map of Peninsular Malaysia witb a scale of 1:500,000 the location of each of the 600 processed rainfall stations was plotted and the computed value of mean annual runoff printed alongside. Each runoff figure derived from less than 11 years of rainfall record (i.e. 1959 – 1970) was highlighted by underlining the value.

Using an interval of 200 mm, initial isohyds were drawn based on the distribution and magnitude of the mean runoff data. Development of these isohyds was complicated in a few regions due to conflicting adjacent runoff values. Only a minority of these discrepancies could be explained by local topographical features such as an isolated hill or localised rain shadow area, and most of the conflicting runoff values were traced directly to poor quality rainfall data and/or short length where the observation period extended over a number of consecutively dry, or wet years.

Therefore this problem was partly solved by accepting the values derived from 11 years of data as being more accurate than those developed from shorter records. However this method did not satisfactorily deal with all such complex regions.

3.1.1 Adjustments according to long-term mean annual precipitation

Using all published rainfall data (DID Rainfall Records, 3 vols.) long-term mean annual rainfall totals were produced for all rainfall stations. This total was then compared with the short-term mean annual total (11 years or less) as computed by THORN2 (Appendix 1). By assuming that both totals had the same temporal patterns and satisfied the same initial loss patterns any difference between the two means was regarded as runoff component. The difference between the short and long-term mean annual rainfall was added to (or subtracted from) the short-term mean annual runoff as computed by THORN2. These new runoff values were then plotted on the map alongside the short term values.

Comparison of these two runoff values generally revealed close agreement and in the majority of cases the new values simply confirmed the positions of the sketched isohyds. Significantly, in areas where there were previously large discrepancies in adjacent station values, adoption of the long-term derived values did much to eliminate those discrepancies. In such cases it was then a relatively simple matter to adjust the isohydal pattern.

3.1.2 Isohyd estimations in areas having sparse data

While the west coast and its hinterland, and the east coast were well covered with rainfall and evaporation records, and hence plentiful computed runoff output was available, certain other regions suffered from a real shortage of such data. These areas include Ulu Kelantan, Taman Negara, Ulu Perak and the Pahang state districts of Lipis, Jerantut and Pekan. Also the Padang Terap and Sik districts in the state of Kedah have poor spatial distributions of rainfall stations. In such areas of little or no data isohyds were sketched with knowledge of local topography and reference to maps of mean annual rainfal (DID 1967; ENEX 1976) and annual forest evaporation (Scarf, 1976).

3.2 Comparison with observed water resources

The accuracy of the derived isohyd map was then tested using runoff records compiled for 82 catchments (varying in area from 21 to 19,000 square kilometres) throughout Peninsular Malaysia.

3.2.1 Method of comparison

The estimate of the catchment runoff is obtained by taking the sum of the discharges of the various catchment segments as defined by the P—AE isohyds. The equation is as follows:

$$S_t = \frac{1}{A_t} (S_1 A_1 + S_2 A_2 + S_3 A_3 + \dots\dots\dots S_n A_n)$$

where S_t is the value of mean annual runoff (in mms) from a total catchment area A_t, and A_1, A_2 ...... A_n are the areas into which the (P—AE) isohyds divide the catchment. S_1, S_2 ..... S_n are the mean isohyd values corresponding to each area (Fig. 3)

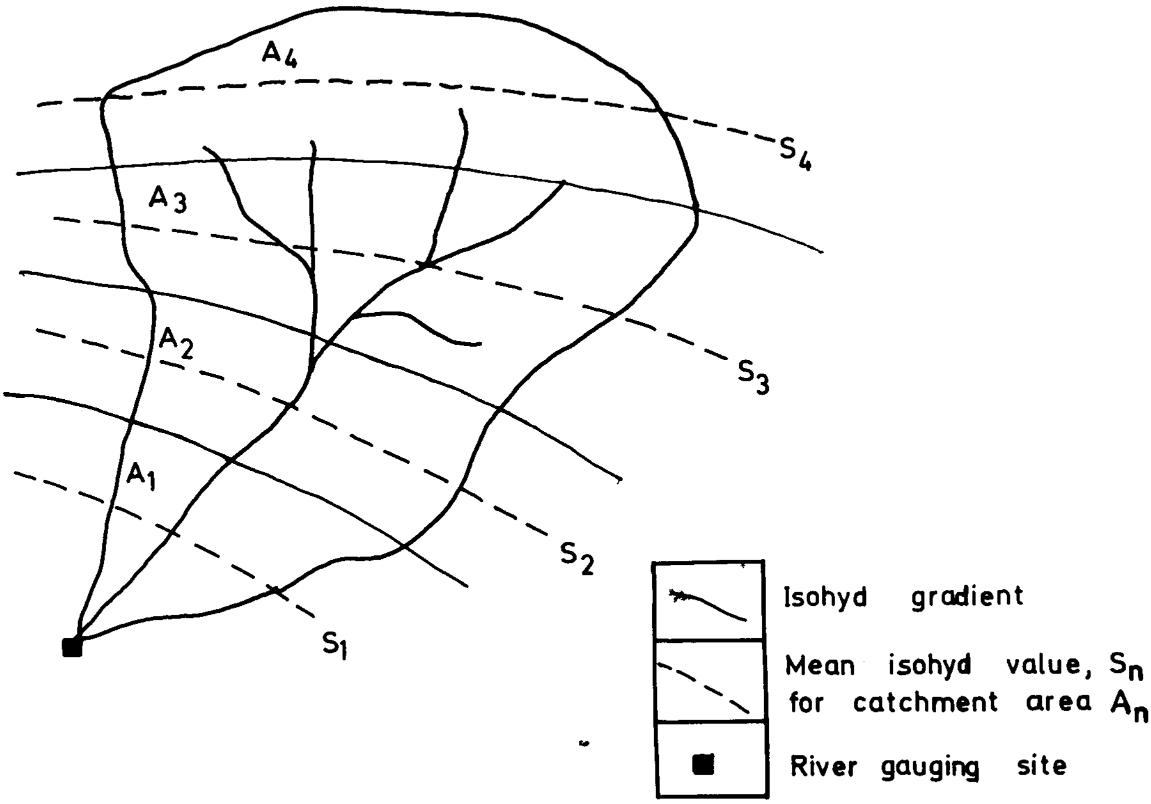


FIGURE 3 : Sample Catchment

By this integrating method estimates of mean annual runoff were developed for those catchments with existing long-term runoff records and whose mean annual flow had been calculated. The results (see Appendix 2) showed that for the majority of cases the estimated annual runoff values were within ± 15% of the observed values.

However there were fourteen catchments whose estimates were within ± 25–50% of the observed runoff. The results for this small group of catchments were then investigated to determine the causes for such poor comparative values.

3.2.2 Investigation of catchments with poor correlation

Of these fourteen catchments five, whose derived runoff estimates were well above the observed flows, were found to involve substantial irrigation and/or water supply extraction. These were the Sg. Muar at Kuala Pilah; Sg. Gombak at km. 21 Gombak; Sg. Kinta at Tg. Rambutan; Sg. Kinta at Ipoh and Sg. Padang Terap at Lengkuas. Actual amounts of such withdrawals (as opposed to design level extractions) were not available but known to vary from season to season and year to year depending on water demand. However in each case when the estimated magnitude of withdrawn water was added to the observed runoff good correlation was found with the predicted runoff.

A further four catchments (Sg. Segamat at Segamat; Sg. Slim at Kg. Slim; Sg. Pelagat at Pelagat and Sg. Golok at Rantau Panjang) have suspect stage discharge ratings resulting from shifting low flow bed controls or poor quality gauging. Additionally the Sg. Golok catchment has inadequate rainfall data since half the catchment area lies within Thai territory. For these catchments the observed runoff values were rejected as unreliable.

The remaining five catchments also appear to suffer from poor records since their predicted/observed runoff percentage differences are very different to those of neighbouring catchments. For the **Sg. Batang Padang** it is know that the National Electricity Board (NEB) diverts water from the Sg. Telom and Sg. Kial into the river. It would therefore be expected that the predicted natural flow would be less than the observed runoff. Whilst this was confirmed at the Tg. Keramat site (–16%) the upstream site at Tapah gave a difference of +31 percent. Because the catchment areas are similar (Tg. Keramat, 445 km^2; Tapah 376 km^2), the observed runoff at Tapah was considered to be suspect.

While the **Sg. Gedong** at Bidor has a difference of –26%, the neighbouring catchment, Sg. Bidor at Bidor shows very close agreement (i.e. –1%) between the observed and predicted runoffs. Based on this the flow record for the Sg. Gedong was rejected.

The **Sg. Plus** at Kg. Lintang has a percentage difference of +33% although there is no recorded irrigation or water supply extractions. This record is also rejected on the basis of comparison with the values for nearby catchments such as Sg. Plus, downstream at Kg. Pulau Mentimun, –5%; Sg. Kurau at Taiping – Ijok Road, +13%, and the Sg. Kurau at Pondok Tanjong, –3%.

Although the **Sg. Ara** is a source for irrigation supply the predicted value of annual runoff is well **below** (-33% difference), and not above the recorded runoff as would be expected with such utilisation. Once again nearby catchments reveal that this value is quite atypical, eg. Sg. Krian at Dusun Rimau, +11%; Sg. Ijok at Titi Ijok, −11%; Sg. Kurau at Pondok Tanjong, −3%.

For the **Sg. Muda** catchment at Victoria Estate, the predicted/observed runoff difference is +25%. This value is in marked contrast to the upstream Batu Pekaka catchment value of −10%, and other neighbouring catchments such as, Sg. Kulim at Ara Kuda, −8%; Sg. Sedim at Merbau Pulas, −5%; and Sg. Karangan at Titi Karangan, −2%.

Having thus accounted for the fourteen problem catchments by rejecting their runoff results (for the above mentioned reasons) it is felt that the isohyd map can predict, within ±15%, the mean annual surface water resources for any region or catchment within Peninsular Malaysia.

3.3 Spatial variability of water resources

Since the rainfall input is the dominant factor in water balance calculations it is not surprising that the surface water resources map exhibits a spatial pattern similar to the mean annual rainfall map (DID 1967). The main mountain ranges and west coast range have extensive resources corresponding to their high rainfalls and lower evapotranspiration rates. The very seasonal northeast monsoon, with its high rainfall concentrated with a few months, is responsible for the high annual water resources for Trengganu and coastal Kelantan and Pahang. Not surprisingly the lowland interior districts of Temerloh, Kuala Pilah, Tampin and Segamat with relatively low annual rainfalls and high evapotranspiration rates have the least surface water resources.

Appendix 3 lists the surface water resources for each state of Peninsular Malaysia. These totals have been computed by integration of the isohyd areas throughout each state. Therefore in the case of rivers flowing through more than one state, the water resources of that river on its point of entry into the state are included in the state containing its headwaters. That is, each state total includes only those water resources originating as runoff **within** its state boundaries.

The estimated average annual runoff for the whole of Peninsular Malaysia is 1185 mm, equivalent to 5050 m^3/sec.

3.4 Conclusion

From the water resources map it is possible to estimate the average annual discharge of a river or its tributaries at any point along its channel, to an accuracy of about ±15%.

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PREVIOUSLY PUBLISHED

1.	Surface Water Resources Map (Provisional) of Peninsular Malaysia	1974
2.	Hydrological Regions of Peninsular Malaysia	1975
3.	Sg. Tekam Experimental Basin Annual Report No. 1 ...	1975
4.	Notes on Some Hydrological Effects of Land Use Changes in Peninsular Malaysia	1975
5.	Evaporation in Peninsular Malaysia	1976

THORNTHWAITE DAILY WATER BALANCE MODEL

STATION NUMBER : 2924096 YEARLY TOTALS (IN MM) PERIOD : 1959/60–1969/70
PE : 1682

YEAR	PRECIPITATION	ACTUAL EVAPO-TRANSPIRATION	PRECIPITATION MINUS ACTUAL EVAPO-TRANSPIRATION	WATER DEFICIT	RUNOFF
1959/60	2279	1524	755	162	791
1960/61	2117	1465	651	217	676
1961/62	1831	1352	479	330	361
1962/63	1472	1302	170	380	309
1963/64	2132	1463	670	224	600
1964/65	1810	1409	401	273	370
1965/66	1775	1491	284	191	353
1966/67	2293	1480	813	202	786
1967/68	2178	1352	826	334	796
1968/69	1595	1400	195	282	181
1969/70	1737	1382	356	300	316
MEAN	1929	1420	509	263	504
STANDARD DEVIATION	283	70	245	69	229

THORNTHWAITE DAILY WATER BALANCE MODEL

STATION NUMBER : 2924096 MONTHLY WATER DEFICIT AND RUNOFF (IN MM) PERIOD : 1959/60–1969/70
PE : 1682

	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
MEAN RUNOFF	2	8	9	56	96	111	39	23	38	29	75	17
STANDARD DEVIATION	4	25	29	82	77	76	32	48	58	32	71	19
MEAN WATER DEFICIT	30	32	27	19	5	6	15	31	34	20	18	27
STANDARD DEVIATION	11	13	14	14	4	2	10	19	21	17	16	16

Station Number	River	Station	Catchment Area (in km²)	No. of Years of Flow Records	Observed Mean Annual Runoff (in mms)	Predicted Mean Annual Runoff (in mms)	% Difference	Remarks
1737451	Sg. Johor	Rantau Panjang	1,130	7	1,073	1,124	+ 6%	Negligible water supply extractions.
1931423	Sg. Sembrong	Brizay Bridge	186	8	973	930	– 5%	Negligible water extractions
2224432	Sg. Kesang	Chin Chin	161	8	526	610	+16%	Considerable extractions for irrigation.
2237471	Sg. Lenggor	42 batu Kluang/ Mersing Rd.	207	9	1,570	1,450	– 8%	Negligible water extractions.
2322413	Sg. Melaka	Pantai Belimbing	350	10	545	600	+10%	Considerable water supply & irrigation extractions.
2322414	Sg. Durian Tinggal	Durian Tinggal	82.9	5	581	630	+ 8%	Nil water resource utilisation.
2322415	Sg. Durian Tinggal	Batu 11, Ayer Resam Rd.	72.5	7	489	600	+23%	Nil water resource utilisation.
2519421	Sg. Linggi	Sua Bentong	523	5	1,125	900	–20%	Negligible water extraction.
2520423	Sg. Pedas	Kg. Pilin	111	10	1,277	1,000	–22%	Negligible water supply & irrigation extractions.
2524416	Sg. Gemencheh	Gedok	133	8	499	550	+12%	Nil water resources utilisation.
2525413	Sg. Gemencheh	Gemas-Rompin Rd.	453	9	683	550	–19%	Nil water resources utilisation.
2527411	Sg. Muar	Buloh Kasap	3,130	9	529	560	+ 6%	Negligible water supply & Irrigation extractions.
2528414	Sg. Segamat	Segamat	660	7	1,097	672	–39% *	Poor streamflow records, negligible water extractions.
2625412	Sg. Muar	57th Mile Rompin-Gemar Rd.	1,212	10	668	650	– 3%	Negligible irrigation & water supply extractions.
2719422	Sg. Linggi	Rahang	189	10	915	800	–13%	Negligible irrigation extractions.
2722413	Sg. Muar	Kuala Pilah	370	9	462	750	+62% *	Massive irrigation extractions.
2816441	Sg. Langat	Dingkil	1,240	10	970	955	– 1%	Negligible water supply & irrigation extractions.
2917442	Sg. Langat	Kajang	380	9	1,178	1,156	– 2%	Negligible extractions.
2918443	Sg. Semenyih	Seminyih	210	11	1,225	1,000	–18%	Nil water resource utilisation.
2920432	Sg. Triang	Kg. Chenor	228	5	680	700	+ 3%	Negligible irrigation extractions.
3016431	Sg. Klang	Puchong	716	4	1,103	1,206	+ 9%	Considerable water supply & industrial extractions.
3022431	Sg. Triang	Juntai	904	10	742	780	+ 5%	Negligible irrigation extractions.
3115437	Sg. Damansara	Subang	98	5	1,206	1,051	–13%	Nil water resource utilisation.
3116434	Sg. Batu	Sentul	145	14	1,264	1,201	– 5%	Nil water resource utilisation.
3117432	Sg. Klang	Market St. K.L.	470	10	1,087	1,229	+13%	Substantial water supply extractions.
3118445	Sg. Lui	Kg. Lui	70	5	1,237	1,160	– 6%	Negligible irrigation extractions.
3118447	Sg. Langat	20 Batu, Ulu Langat	80	8	1,222	1,156	– 5%	
3120436	Sg. Kenaboi	Kg. Chalim	174	8	906	1,050	+15%	
3317436	Sg. Gombak	Km.21 Gombak	41	5	1,025	1,280	+25% *	Substantial water supply & irrigation extractions.
3414421	Sg. Selangor	Rantau Panjang	1,450	10	1,390	1,360	– 2%	Negligible extractions.
3424411	Sg. Pahang	Temerloh	19,000	8	1,197	971	–19%	Negligible water supply extractions.
3516442	Sg. Selangor	Rasa	321	5	1,461	1,450	– 1%	Negligible extractions.
3517423	Sg. Selangor	Km 7. Jln. Bt. Frazer	197	8	1,394	1,430	+ 3%	Negligible extractions.
3615412	Sg. Bernam	Tanjong Malim	186	11	1,701	1,422	–16%	Negligible water supply extractions.

Station Number	River	Station	Catchment Area (in km²)	No. of Years of Flow Records	Observed Mean Annual Runoff (in mms)	Predicted Mean Annual Runoff (in mms)	% Difference	Remarks
3813411	Sg. Bernam	SKC Bridge	1,090	9	1,709	1,435	–15%	Negligible water supply extractions.
3813414	Sg. Trolak	Trolak	65.8	10	1,368	1,400	+ 2%	Nil water resources utilisation
3814413	Sg. Slim	Kg. Slim	314	10	891	1,300	+46% *	Poor site control; nil water resources utilisation.
3814415	Sg. Bil	Tg. Malim – Slim Rd.	41.4	10	1,507	1,400	– 7%	Nil water resources utilisation.
3814416	Sg. Slim	Slim River Town	455	4	1,187	1,330	+12%	Nil water resources utilisation.
3911457	Sg. Sungkai	Anson-Kampar Rd.	479	10	1,649	1,460	–11%	Negligible water extractions.
3913458	Sg. Sungkai	Sungkai	289	10	1,505	1,470	– 2%	Negligible water supply extractions.
4011451	Sg. Bidor	Batu 9, Jln. Telok Anson – Kampar	373	10	1,960	1,850	– 5%	Some irrigation & water supply extractions.
4012452	Sg. Bidor	Batu 18, Jln. Anson – Kampar	339	10	2,286	1,900	–17%	Negligible extractions.
4019462	Sg. Lipis	Benta	1,670	5	854	910	+ 6%	Negligible water supply & irrigation extractions.
4111455	Sg. Batang Padang	Tg. Keramat	445	10	2,184	1,841	–16%	Diversion of hydro-electricity waters into river.
4112454	Sg. Bidor	Bidor	84.2	10	1,874	1,860	– 1%	Negligible extractions.
4112456	Sg. Batang Padang	Tapah	376	10	1,385	1,813	+31% *	Diversion of hydro-electricity waters into river.
4112459	Sg. Gedong	Bidor	108	5	2,534	1,870	–26% *	Nil water resource utilisation.
4232451	Sg. Kemaman	Kuala Tayor	630	4	1,867	1,967	+ 5%	Nil water resource utilisation.
4311464	Sg. Kampar	Kg. Lanjut	432	10	1,290	1,495	+16%	Negligible water supply extraction.
4410461	Sg. Kinta	Batu Gajah	1,054	10	1,057	1,034	– 2%	Negligible water supply extraction.
4410465	Sg. Raia	Old Kinta Kellas Estate	251	5	998	1,228	+20%	Nil water resources utilisation.
4413418	Sg. Bertam	Robinson Falls (NEB)	21	9	1,780	1,800	+ 1%	Nil water resource utilisation.
4514417	Sg. Telom	Batu 49, Cameron Highlands (NEB)	78	9	1,775	1,776	0%	Nil water resource utilisation.
4510462	Sg. Kinta	Ipoh	313	8	912	1,134	+25% *	Substantial water supply extractions
4610466	Sg. Pari	Jln. Silibin Ipoh	245	7	1,086	900	–17%	Negligible water supply extractions.
4611463	Sg. Kinta	Tg. Rambutan	267	10	892	1,163	+30% *	Substantial water supply extractions.
4809443	Sg. Perak	Iskandar Bridge	7,769	10	855	946	+11%	Negligible water supply & irrigation extractions.
4810444	Sg. Plus	Kg. Pulau Mentimun	1,388	5	989	939	– 5%	Nil water resources utilisation.
4831441	Sg. Dungun	Kg. Jerangau	1,410	5	2,675	2,200	–17%	Nil water resources utilisation.
4907422	Sg. Kurau	Batu 14 Taiping Ijok Road	80.3	10	1,521	1,724	+13%	Negligible irrigation extractions.
4911445	Sg. Plus	Kg. Lintang	1,088	5	736	979	+33% *	Nil water resources utilisation.
5007421	Sg. Kurau	Pondok Tanjong	337	10	1,778	1,723	– 3%	Negligible irrigation extractions.
5007423	Sg. Ara	Batu 20, Taiping Ijok Rd.	140	10	2,286	1,540	–33% *	Negligible irrigation extractions.

APPENDIX 2 (Contd)

Station Number	River	Station	Catchment Area (in km²)	No. of Years of Flow Records	Observed Mean Annual Runoff (in mms)	Predicted Mean Annual Runoff (in mms)	% Difference	Remarks
5106431	Sg. Krian	Dusun Rimau	694	10	1,670	1,851	+11%	Negligible water supply & irrigation extractions.
5106433	Sg. Ijok	Titi Ijok	216	10	2,065	1,826	–11%	Some water supply & irrigation extraction.
5130432	Sg. Terengganu	Kg. Tanggol	3,340	10	2,214	1,901	–13%	Negligible water extractions.
5206432	Sg. Krian S	Selama	629	9	2,197	1,855	–15%	Negligible water supply & irrigation extractions.
5505412	Sg. Muda	Victoria Estate	4,010	10	800	985	+25% *	Some irrigation & water supply extractions.
5505421	Sg. Kulim	Ara Kuda	130	9	1,567	1,444	– 8%	Nil water resource utilisation.
5506413	Sg. Muda	Batu Pekaka	3,340	10	990	887	–10%	Some irrigation & water supply extractions.
5506416	Sg. Sedim	Merbau Pulas	440	10	1,637	1,561	– 5%	Nil water resource utilisation.
5506417	Sg. Karangan	Titi Karangan	82.9	8	1,656	1,626	– 2%	Nil water resource utilisation.
5624412	Sg. Besut	Kg. Rantau Panjang	712	7	1,766	1,767	0%	Negligible irrigation extractions.
5721442	Sg. Kelantan	Guillemard Bridge	11,900	10	1,297	1,267	– 2%	Negligible irrigation extractions.
5724411	Sg. Besut	Jerteh Bridge	787	5	1,878	1,779	– 5%	Negligible irrigation extractions.
5724413	Sg. Pelagat	Pelagat	57	5	3,030	1,880	–38% *	Poor stage discharge relationship; Nil water resources utilisation.
5806414	Sg. Muda	Jeniang	1,710	10	751	755	+ 1%	Negligible water supply extractions.
6007415	Sg. Muda	Nami	1,220	10	746	730	– 2%	Nil water resources utilisation.
6019411	Sg. Golok	Rantau Panjang	561	8	3,052	1,696	–44% *	Poor stage discharge relationship.
6022421	Sg. Kemasin	Peringat	47.9	9	1,731	1,800	+ 4%	Nil water resource utilisation.
6204421	Sg. Padang Terap	Lengkuas	1,270	8	480	728	+51% *	Massive irrigation extractions.

* See text, pp. 8, 9.

AVERAGE ANNUAL SURFACE WATER RESOURCES FOR STATES OF PENINSULAR MALAYSIA

State	Area (in km^2)	Mean Annual Runoff (in mm)
PERLIS	822	755
KEDAH		
Mainland	9,268	1,245
Pulau Langkawi	366	1,400
State Total	9,634	1,250
PENANG		
Pulau Pinang	281	1,645
Province Wellesley	744	945
State Total	1,025	1,135
PERAK	21,560	1,190
SELANGOR	8,330	1,030
NEGRI SEMBILAN	7,288	665
MELAKA	1,710	695
JOHOR	19,320	1,135
PAHANG	37,670	1,005
TRENGGANU	13,257	2,080
KELANTAN	13,807	1,275
PENINSULAR MALAYSIA (Total)	134,423	1,185

MINISTRY OF AGRICULTURE
DRAINAGE AND IRRIGATION DIVISION
SURFACE WATER RESOURCES
OF
PENINSULAR MALAYSIA
P - AE
(BASED ON RAINFALL RECORDS FROM 1959 to 1970 INCLUSIVE)
SKEL 7.89 BATU SEINCI
1:500,000
PETUNJUK
REFERENCE
Jalan Keretapi dengan Stesyen / Railway with Station
Anak Bukit
Jalan Keretapi Ringan / Light Railway
Jalan Raya / Principal Road
Sedang dibena
Lain-lain Jalan Kereta Motor / Other Motorable Road
Jalan Kereta Lembu / Cart Track
Sungai / River
Sempadan Antarabangsa / International Boundary
Sempadan Negeri / State Boundary
Sempadan Daerah, Sempadan Daerah Kecil / District Boundary, Sub-District Boundary
Bandar, Tapak-tapak Kampung, Lapangan Terbang / Town, Village Sites, Airport
Stesyen Trigonometri dengan Ukuran Tinggi, Aras Selerak / Trigonometrical Station with Height, Spot Height
Ibu Daerah / District Headquarters — PARIT BUNTAR
Nama Daerah / District Name — MACHANG
Ibu Negeri / State Capital — KOTA BHARU
Nama Negeri / State Name — KEDAH
SINGKATAN
ABBREVIATIONS
Bukit — Bt.
Cangkat — Ct.
Gunung — G.
Kampung — Kg.
Kuala — K.
Kangkar — Kr.
Perhentian — Ptn.
Padang — Pdg.
Pengkalan — Peng.
Pulau — P.
Sungai — S.
Tanjung — Tg.
Teluk — Tk.
Timur — T.
Utara — U.
Unjuran Bentukbenar Serong ditepati
Rectified Skew Orthomorphic Projection
PETA INI TIDAK BOLEH DIANGGAP SEBAGAI BUKTI YANG SAHIH UNTUK MENENTUKAN PERENGGANAN SEMPADAN ANTARABANGSA ATAU LAIN-LAIN.
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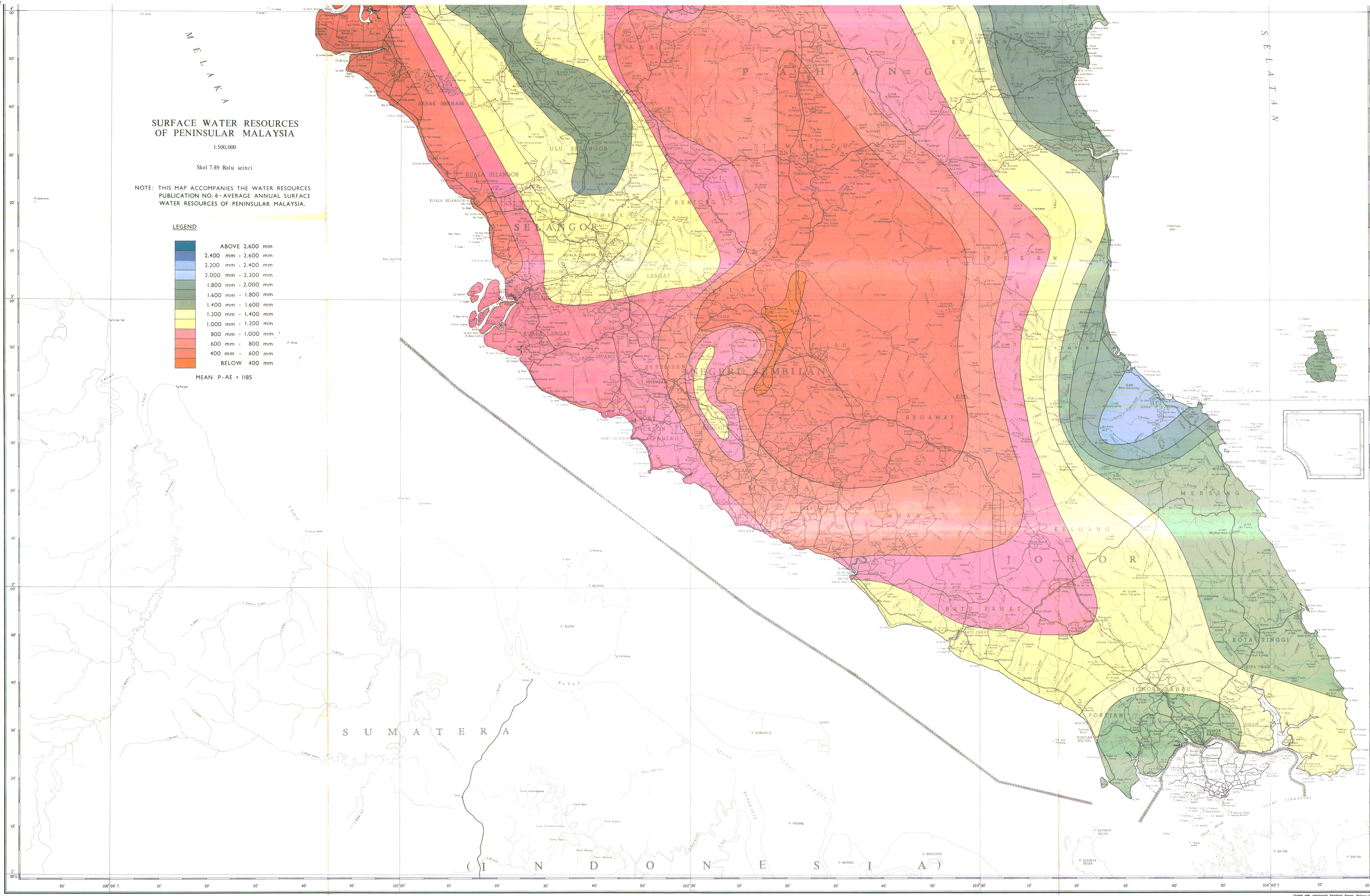
LEGEND
ABOVE 2,600 mm
2,400 mm - 2,600 mm
2,200 mm - 2,400 mm
2,000 mm - 2,200 mm
1,800 mm - 2,000 mm
1,600 mm - 1,800 mm
1,400 mm - 1,600 mm
1,200 mm - 1,400 mm
1,000 mm - 1,200 mm
800 mm - 1,000 mm
600 mm - 800 mm
400 mm - 600 mm
BELOW 400 mm
MEAN P-AE = 1185
THAILAND
PERLIS
KEDAH
KELANTAN
PERAK
TRENGGANU
LAUT CHINA
SELAT

Am. 6



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