WATER RESOURCES PUBLICATION NO. 9

SG. LUI REPRESENTATIVE BASIN REPORT NO : 2 FOR 1974 / 75 TO 1975 / 76

1978

JABATAN PENGAIRAN DAN SALIRAN
KEMENTERIAN PERTANIAN MALAYSIA

Water Resources Publication No. 9

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Contributor: KOH KAH HOCK

BAHAGIAN PARIT DAN TALIAIR
KEMENTERIAN PERTANIAN

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CONTENTS

SUMMARY

The report presents results from analyses of hydrological records observed from the Sg. Lui Representative Basin during the period July 1974 to June 1976.

The research programme during this period concentrated on basic data collection. The Kent natural syphon recording raingauge at Lawin was replaced by a Capricorder 1599 event rainfall recorder while the other Kent recorders at Lallang and Sawah were replaced by storage gauges as proposed by Scarf (1976). Rainfall records for Lawin were regarded as unreliable and discarded. Performance of the Capricorder 1598 event water level recorder was quite poor resulting in many periods of missing records.

A mathematical rainfall-runoff model (based on the Boughton Model) was calibrated using the continuous records available from July 1972 to June 1974. The model was then used to generate the missing flow records for the period of study of this report.

1. INTRODUCTION

The basin research objectives are as stated in the earlier report by Scarf (1977).

Basin geography, geology, soils and landuse have been documented in previous papers by Low (1971) and Scarf (1977).

Very little development has taken place in the catchment during this period of two years and the typical foothill landscape of orchard and rubber small holdings is shown in Plate 1.

2. INSTRUMENTATION AND OBSERVATION

2.1 Climate

A climate station has been proposed for the basin but has yet to be sited and instrumented. Scarf (1977) suggested for this purpose the installation of a multichannel Capricorder at Sekolah. The nearest fully instrumented station at Subang International Airport, Kuala Lumpur has been maintained in good order by the MMS. Evaporation records are available for a standard Class A Pan (painted black) at Ampang which is also in good order (Fig. 3).

2.2 Rainfall

(a) Sekolah : The Capricorder 1599 event rainfall recorder and weekly check gauge remained unchanged (Plate 2).

(b) Lallang : The Kent natural syphon recording raingauge and weekly check gauge were replaced by a long term storage gauge on 1/6/76 (Plate 3).

(c) Sawah : The Kent natural syphon recording raingauge and weekly check gauge were also replaced by a long term storage gauge (Plate 4) just after the end of the period covered in this report (on 14/9/76).

(d) Lawin : The Kent natural syphon recording raingauge and weekly check gauge were removed on 20/1/76. Problems of maintaining the receiving funnel (set at treetop height) free of debris such as leaf litter led to the decision to relocate the gauge on the ground. Hence the forest area was cleared to a radius of about 80 metres to obtain satisfactory exposure conditions and a Capricorder with weekly check gauge was installed on 5/10/76 (Plate 5).

Clock stoppages and poor chart traces were responsible for periods of missing records which were particularly frequent after November, 1975.

Plate 1: Typical Foothill vegetation in the Sg. Lui catchment. This photo is taken from the walking track leading to the Sawah rainfall station.

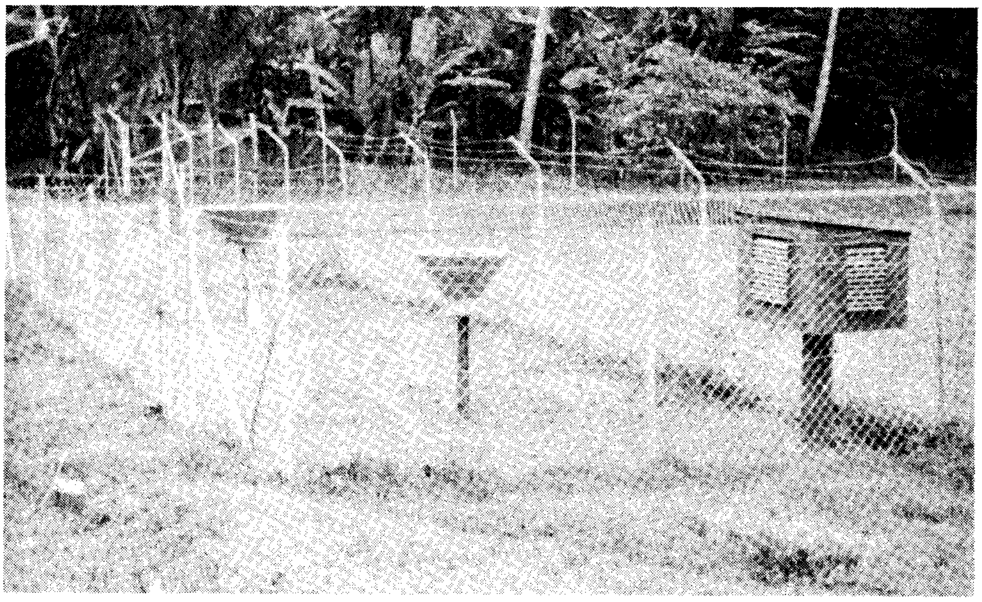


Plate 2: Capricorder and Storage Gauge at Sekolah

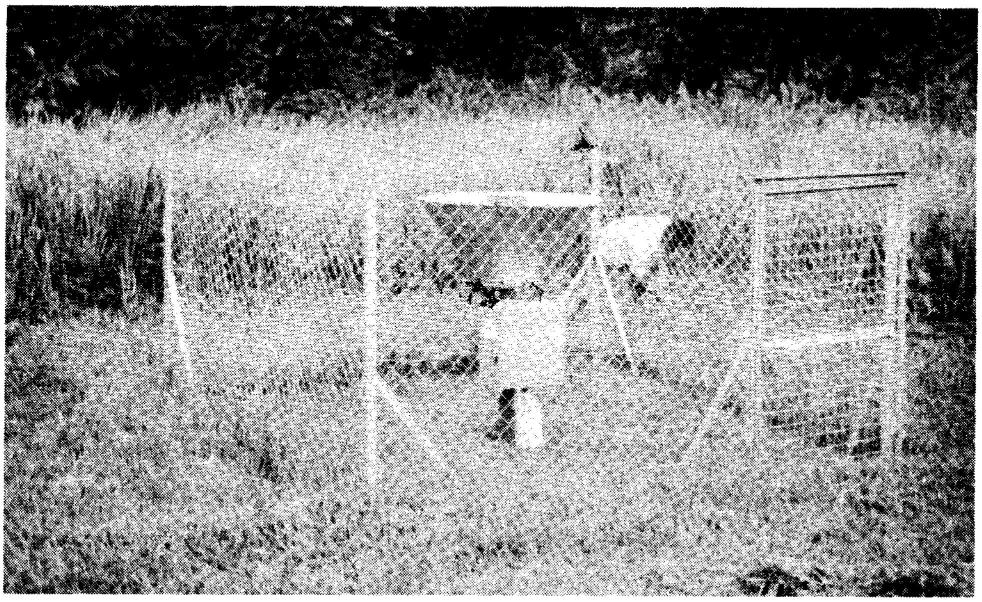


Plate 3: Storage Gauge at Lallang

Plate 4: Storage Gauge at Sawah

Plate 5: Capricorder and Storage Gauge at Lawin

Table 1 — Summary of Climatic Data for Subang Airport, Kuala Lumpur.

Year		Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Mean Annual
74/75	Mean Temp. °C	25.9	26.8	25.8	26.7	26.0	25.7	26.2	25.8	26.1	26.5	26.8	26.5	26.2
	Rel. humidity %	84.8	81.6	86.6	83.2	86.2	86.3	81.9	84.0	83.8	85.4	83.5	83.5	84.2
	Sunshine hrs/day	6.3	6.4	4.9	5.7	4.2	6.1	6.8	5.7	6.3	6.6	6.5	5.7	5.9
	Wind knots	1.4	1.7	1.5	1.3	1.2	1.2	0.7	0.8	0.9	0.8	0.9	1.1	1.1
75/76	Mean Temp. °C	25.5	26.3	25.8	26.2	25.4	25.4	25.2	26.1	26.1	26.2	26.7	26.2	25.9
	Rel. humidity %	86.3	83.0	85.5	84.7	88.7	86.1	82.2	79.6	84.1	87.0	83.4	84.0	84.6
	Sunshine hrs/day	5.8	7.2	5.5	5.9	4.3	4.9	6.7	7.1	6.5	6.5	7.1	6.2	6.1
	Wind knots	0.7	1.2	0.9	0.9	0.5	0.7	0.9	1.3	1.3	0.9	0.7	0.9	0.9

CORRIGENDUM "A 1"

WATER RESOURCES PUBLICATION NO. 9

SG. LUI REPRESENTAITVE BASIN REPORT NO.2 FOR 1974/75 TO 1975/76

(PAGE 6) TABLE 1 - SUMMARY OF CLIMATIC DATA FOR SUBANG AIRPORT, KUALA LUMPUR.

Year		Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Mean Annual
74/75	Mean Temp. °C	25.9	26.8	25.8	26.7	26.0	25.7	26.2	25.8	26.1	26.5	26.8	26.5	26.2
	Rel. humidity %	84.8	81.6	86.6	83.2	86.2	86.3	81.9	84.0	83.8	85.4	83.5	83.5	84.2
	Sunshine hrs/day	6.3	6.4	4.9	5.7	4.2	6.1	6.8	5.7	6.3	6.6	6.5	5.7	5.9
	Wind m/s	0.7	0.9	0.8	0.7	0.6	0.6	0.7	0.8	0.9	0.8	0.9	1.1	0.8
75/76	Mean Temp. °C	25.5	26.3	25.8	26.2	25.4	25.4	25.2	26.1	26.1	26.2	26.7	26.2	25.9
	Rel. humidity %	86.3	83.0	85.5	84.7	88.7	86.1	82.2	79.6	84.1	87.0	83.4	84.0	84.6
	Sunshine hrs/day	5.8	7.2	5.5	5.9	4.3	4.9	6.7	7.1	6.5	6.5	7.1	6.2	6.1
	Wind m/s	0.7	1.2	0.9	0.9	0.5	0.7	0.9	1.3	1.3	0.9	0.7	0.9	0.9

2.3 Flow

To date, river stage has been recorded by a Capricorder 1598 event water level recorder. Determination of discharge was by the rating curve developed from a model test (D.I.D. Memo No. 157) and given in Appendix 1. Scarf (1977) proposed a field rating of the structure to check the correctness of the rating curve, but this has yet to be carried out.

2.4 Water Quality

Samples for surface water quality analysis are collected at a road bridge upstream of the flow recording site (Fig. 3). They are delivered to the Chemistry Department laboratory, Petaling Jaya as soon as practicable but no attempt is made to preserve the samples prior to delivery.

3. DATA PROCESSING

3.1 Climate

Details of the typical climate for this basin were discussed by Scarf (1977). A summary of climatic data observed at Subang Airport, Kuala Lumpur is given in Table 1.

Average monthly and annual evaporation data recorded at Ampang Research Station is summarised in Table 2.

Table 2 – Average Monthly and Annual Evaporation*
Data at Ampang in mm

Year	Yrs. of record	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annual
1974/75	1	126	159	134	154	124	153	168	148	162	157	162	138	1785
1975/76	1	139	163	136	144	110	120	164	188	163	144	185	137	1793
1963–1976	13	157	163	148	153	142	145	167	171	186	173	173	154	1932

* The evaporation data are recorded by a Class A (Black) pan. From correlation studies carried out previously, monthly evaporation recorded by Class A pan = 0.92 x monthly evaporation recorded by Class A (Black) pan (D.I.D. Research Station Memorandum No. 128).

3.1.1 Evapotranspiration

Using data observed at Subang International Airport, the average monthly and annual evapotranspiration were calculated using Penman Procedure (Scarf, 1976). An albedo r = 0.18 for deciduous forest has been assumed and results are shown in Table 3.

Table 3 – Summary of Penman Forest Evaporation Data (mm)

Year	Yrs. of Record	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annual
1974/75	1	119	128	117	125	106	115	124	109	131	131	125	116	1446
1975/76	1	113	130	121	124	103	105	120	124	133	129	129	118	1449
1964–1976	12	122	126	124	122	113	109	121	120	138	133	130	122	1480

3.2 Rainfall

Daily rainfall totals were retrieved from the data bank. For those Capricorder tapes unable to be translated due to misalignment of holes on tapes, manual reading was carried out. Other missing records were filled in based on the check gauge total and automatic records from other stations according to proposals by Scarf (1977).

Daily rainfall records for all stations are held on file and only monthly and annual totals are included in Table 4. Records of the station at Lawin were rejected (see para. 6.1).

Table 4 – Monthly and annual rainfall totals (mm) for Sg. Lui rainfall stations

Station	Year	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annual Total
Sekolah	74/75	201	93	351	154	279	157	116	235	193	228*	274	137	2418
Sawah	74/75	187	132	333	141	246	204	127	193	227	216	286	109	2402
Lawin	74/75	–	–	–	–	–	–	–	–	–	–	–	–	–
Lallang	74/75	287	34	215	161	158	167	178	201*	199	228	379	113*	2320
Sekolah	75/76	326	142	217	164	256*	179*	41*	36*	228	197	243*	236	2265
Sawah	75/76	349	143	280	142	251*	251*	31*	47*	183	196*	223*	272*	2368
Lawin	75/76	–	–	–	–	–	–	–	–	–	–	–	–	–
Lallang	75/76	221	129	255	193	246	237	67*	51	209	236	171*	227	2242

* Short term missing records filled in by manual reading of poorly translated tapes and by using check gauge readings.

Table 5a – TABULATION OF DAILY RAINFALL AND RUNOFF FOR WATER YEAR 1974/75 (mm)

	July		August		September		October		November		December		January		February		March		April		May		June		Date
Date	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	
1	–	0.82	7.0	2.26	5.0	0.40	2.5	1.07	–		8.0	1.32	20.5	1.38	–	0.60	2.5	1.16	–	1.90	6.0	1.09	4.0	0.88	1
2	1.0	0.71	–	1.79	5.0	0.54	4.5	1.29	–		3.0	1.32	8.5	1.31	–	0.57	2.0	1.20	–	1.22	–	1.00	6.5	0.97	2
3	4.0	0.64	–	1.51	2.0	0.59	3.0	1.15	4.5		12.5	1.41	2.0	1.19	–	0.55	42.0	3.82	6.0	1.21	–	0.89	32.5	2.30	3
4	–	0.70	–	1.32	27.0	0.81	–	1.01	8.5		2.5	1.63	4.0	0.89	3.0	0.64	–	2.03	26.0	2.76	–	0.82	5.0	1.77	4
5	–	0.60	9.5	1.65	–	1.46	–	0.90	–		–	1.21	1.0	1.02	–	0.75	11.0	1.71	–	2.56	–	0.72	–	1.09	5
6	26.0	1.00	–	1.14	–	0.67	–	0.84	–		–	1.08	1.0	0.87	–	0.53	12.5	1.69	5.0	1.61	9.5	0.73	–	0.93	6
7	5.0	1.72	18.0	1.35	–	0.58	–	0.81	–		2.5	1.05	–	0.77	–	0.51	4.5	1.96	61.0	1.98	7.5	0.96	–	0.84	7
8	–	1.14	16.0	1.40	9.0	0.61	9.0		–		4.5	0.96	1.5	0.69	5.0	0.59	23.5	2.28	20.5	7.42	37.0	1.68	–	0.79	8
9	5.0	9.50	–	1.55	3.0	0.77	15.0		1.5		5.5	0.93	2.0	0.78	36.0	2.48	4.0	2.16	1.0	3.31	–	1.93	14.5	1.14	9
10	–	1.12	–	1.16	6.0	0.91	13.5		–		56.5	3.58	5.0	0.81	10.0	0.93	–	1.48	2.0	2.45	7.0	1.09	2.5	1.84	10
11	–	0.90	–	1.07	18.0	1.06	–		15.5		–	1.76	22.5	1.18	22.0	2.30	–	1.29	1.0	2.15	–	0.91	–	1.31	11
12	23.5	0.91	–	0.98	–	1.10	–		9.5		1.0	1.14	3.5	1.21	18.0	2.44	17.5	1.97	–	1.85	–	0.83	2.5	1.28	12
13	26.5	2.61	–	0.88	5.0	0.75	6.5		–		–	1.01	26.5	1.76	9.5	1.83	3.0	1.88	–	1.63	12.0	0.82	–	1.23	13
14	6.0	1.73	1.5	0.84	–	0.57	–		7.5		4.5	0.96	–	1.63	20.0	1.74	4.0	1.47	1.0	1.54	8.5	0.91	–	1.19	14
15	–	1.50	–	0.82	–	0.49	–		11.5		7.5	1.02	35.5	2.87	7.5	1.82	–	1.26	–	1.48	2.0	0.88	21.0	1.53	15
16	–	1.19	–	0.75	17.5	0.57	–		4.5		1.0	0.98	–	2.46	19.0	2.68	6.0	1.21	16.5	1.50	4.5	0.82	7.5	1.32	16
17	4.0	1.07	–	0.68	46.5	2.06	46.5		1.0		1.0	0.90	3.5	1.50	11.5	2.39	4.5	1.25	7.0	1.71	–	0.79	1.0	1.25	17
18	–	1.03	–	0.63	55.5	5.30	–		24.0		5.5	0.90	8.0	1.48	16.5	3.02	1.5	1.36	20.0	2.12	–	0.70	–	1.15	18
19	–	0.90	–	0.61	5.0	5.62	–		1.5		17.0	1.20	–	1.41	–	3.60	8.0	1.48	14.0	2.62	12.5	0.70	2.0	1.13	19
20	–	0.84	13.0	0.65	11.0	1.83	–		–		6.0	1.02	–	1.16	–	1.82	6.0	1.74	1.0	2.52	57.0	1.89	–	1.07	20
21	6.0	0.81	–	0.74	8.5	3.70	–		4.5	1.20	–	0.85	–	1.05	–	1.47	3.0	2.26	5.0	1.87	58.5	4.20	–	1.05	21
22	2.0	0.85	–	0.56	38.0	3.78	1.0		–	0.95	–	0.78	–	0.98	–	1.31	3.0	1.51	3.0	1.89	8.5	1.54	–	0.99	22
23	19.5	1.27	–	0.50	2.0	2.94	9.0		27.5	1.00	–	0.71	–	0.94	11.5	1.43	–	1.56	5.5	1.91	–	0.92	1.5	1.00	23
24	10.5	1.30	–	0.46	–	1.89	–		11.0	5.33	–	0.67	–	0.87	5.0	1.45	4.5	1.39	7.0	1.86	–	0.76	–	0.97	24
25	15.0	1.40	–	0.44	4.5	1.61	26.5		–	3.31	–	0.76	–	0.81	1.5	1.44	–	1.32	17.0	2.31	22.5	0.85	–	0.93	25
26	–	1.58	–	0.43	–	1.30	–		–	1.70	–	0.67	–	0.77	7.5	1.45	1.0	1.19	4.0	3.19	5.5	0.96	–	0.88	26
27	4.5	1.14	–	0.41	–	1.17	4.5		–	1.40	–	0.68	–	0.75	–	1.44	–	1.14	–	2.62	1.0	0.81	–	0.85	27
28	8.0	1.10	–	0.40	8.0	1.12	–		65.5	9.02	26.0	1.27	–	0.76	–	1.22	3.0	1.04	–	2.40	48.5	0.96	–	0.84	28
29	14.0	1.24	–	0.38	1.0	1.30	–		8.0	2.13	4.5	0.84	–	0.70			6.5	1.03	–	2.13	8.0	4.80	–	0.85	29
30	49.0	3.83	10.0	0.36	–	1.12	–		–	1.47	–	0.74	–	0.67			26.0	2.59	–	1.31	8.0	1.35	10.0	1.09	30
31		3.75	1.0	0.43			6.5				6.5	0.70	–	0.61			7.0	2.10			–	1.01			31
Total	229.5	48.9	76.0	28.15	277.5	46.62	148.0		206.0		175.5	34.05	145.0	35.28	203.5	43.00	206.5	51.53	223.5	67.03	324.0	38.32	110.5	34.46	Total

Notes:–
(i) All values in mm
(ii) – indicates no rain
(iii) A blank indicates no record

Table 5b – TABULATION OF DAILY RAINFALL AND RUNOFF FOR WATER YEAR 1975/76 (mm)

Date	July		August		September		October		November		December		January		February		March		April		May		June		Date
	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	P	Q	
1	–	0.86	–		20.0		–		8.0	1.18	–	1.32	9.0		–	0.42	1.0	0.39	10.0	0.39	–	0.96	–		1
2	1.0		–		18.5		–		5.5	1.40	–	1.25	–		1.0	0.43	–	0.37	5.5	0.74	–	0.85	9.0	1.04	2
3	–		6.5		12.5		–		–	1.12	–	1.19	–		–	0.45	–	0.32	11.0	0.80	8.5	0.85	2.5	0.96	3
4	–		–		1.0		–		–	0.99	13.5	1.28	–		10.0	0.49	–	0.28	4.5	0.53	–	0.91	32.0	2.36	4
5	19.5		3.5		31.0		–		2.0	0.93	10.0	1.63	–		–	0.57	–	0.27	–	0.45	2.0		57.0	5.20	5
6	1.0		–		–	2.12	18.0		25.0	1.11	8.0	1.63	–		–	0.48	–	0.26	5.0	0.57	7.5		1.0	4.66	6
7	13.5		–		8.5	1.35	31.5		3.0	1.32	24.0	2.29	2.0		–	0.42	–	0.25	–	0.53	27.0		1.0	1.61	7
8	–		33.5		–	1.34	–		22.0	1.50	45.0	5.29	–		–	0.41	–	0.24	34.5	0.91	7.0		–	1.37	8
9	2.0		2.5		–	1.12	–		30.5	3.60	4.0	3.55	–		–	0.41	19.5	0.41	–	1.14	–		–	1.18	9
10	–		–		1.0	1.02	–		–	2.10	7.0	2.25	–		–	0.39	4.0	0.68	1.0	0.66	73.0		–	1.07	10
11	–		–		–	0.95	17.0		2.5	1.48	4.5	2.08	–		–	0.38	4.5	0.43	14.0	0.79	38.5		13.0	1.12	11
12	32.5		–		–	0.84	4.0		–	1.23	–	1.79	–		–	0.36	–	0.44	–	1.22	–		23.0	1.56	12
13	10.5		–		11.5	0.87	1.0		1.0	1.19	16.5	1.68	–		–	0.35	25.0	0.38	–	0.62	20.5		–	1.36	13
14	3.0		–		15.0	1.36	15.0		2.0	1.11	1.5	1.80	–		–	0.35	52.0	2.31	1.5	0.51	–		–	1.03	14
15	3.5		–		11.5	1.27	–		18.5	1.55	2.0	1.51	–		–	0.35	10.0	1.37	6.5	1.30	–		–	0.95	15
16	2.0		–		–	1.55	2.0		14.5	2.05	–		33.0		–	0.33	–	0.63	36.0	2.42	–		10.0	0.96	16
17	19.0		–		19.5	1.07	7.0		4.5	1.54	–		–		–	0.31	9.0	0.61	–	1.50	–		–	1.00	17
18	9.0		5.0		–	1.29	–		42.0	–	–		3.5		–	0.31	7.0	0.65	5.5	1.04	–		1.0	0.86	18
19	23.0		–		–	1.00	–		1.0		–		–		–	0.30	–	0.51	10.0	1.07	–		–	0.80	19
20	41.5		25.0		–	0.89	–		16.5		1.5		–		–	0.29	–	0.38	–	1.41	–		–	0.71	20
21	57.0		–		1.0	0.84	3.5		9.0		5.0		–		–	0.27	–	0.38	3.0	0.95	–		–	0.65	21
22	4.5		–		6.5	0.84	–		7.0		30.0		–	0.83	–	0.27	–	0.37	20.5	1.56	2.0		2.0	0.66	22
23	5.0		–		21.5	1.63	–		6.5		13.0		–	0.59	–	0.27	–	0.34	8.5	1.51	–		–		23
24	1.0		–		2.0	1.45	–		4.5		1.0		–	0.56	–	0.28	–	0.32	7.5	1.41	–		–		24
25	1.0		2.0		27.0	0.97	20.0		3.0		32.0		–	0.54	–	0.27	9.5	0.37	8.0	1.47	–		87.0		25
26	16.5		–		15.0	1.21	33.0	1.48	11.0		–		–	0.52	18.5	0.34	8.5	0.47	6.5	1.70	–				26
27	16.5		1.0		17.5	1.76	4.0	2.21	5.0	1.67	12.0		–	0.51	9.5	0.75	33.0	0.98	9.0	1.46	–		3.0		27
28	1.0		1.0		10.0	1.18	3.0	1.28	3.5	1.75	–		–	0.48	5.0	0.59	8.0	0.98	2.5	1.75	1.5		–		28
29	7.5		17.0		2.5	1.95	1.0	1.14	–	1.69	–		–	0.46	–	0.43	5.0	0.75	1.0	1.55	–		–		29
30	–		25.5		–	1.61	1.0	1.04	–	1.51	1.5		–	0.44			–	0.72	1.0	1.16	2.0		–		30
31	–		9.0				3.5	1.10			3.0		–	0.43			1.5	0.41							31
Total	291.0		131.5		253.0		164.5		248.0		235.0		47.5		44.0	11.27	197.5	17.27	212.5	33.12	197.5		244.5		Total

Notes:–
(i) All values in mm
(ii) – indicates no rain
(iii) A blank indicates no record

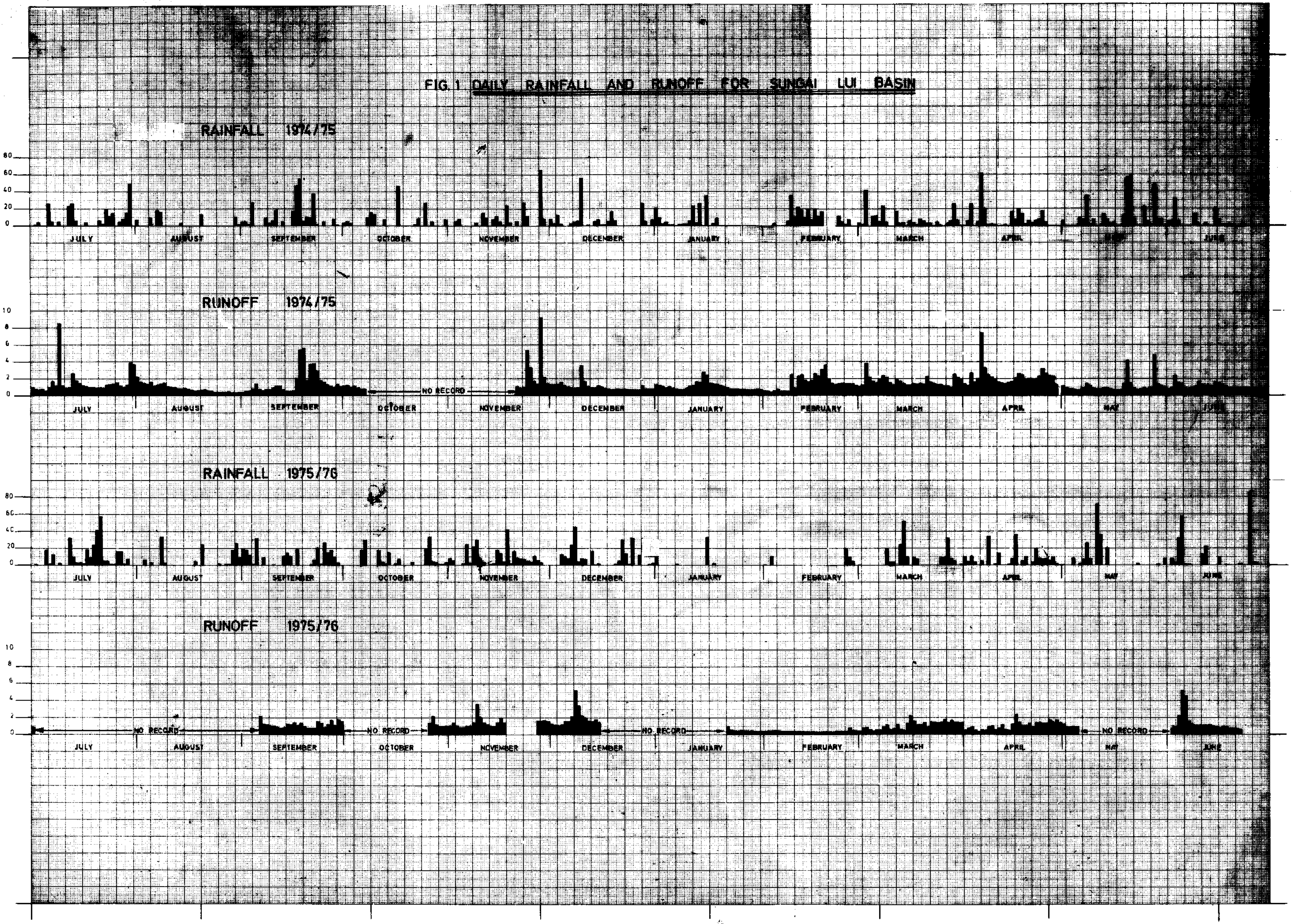
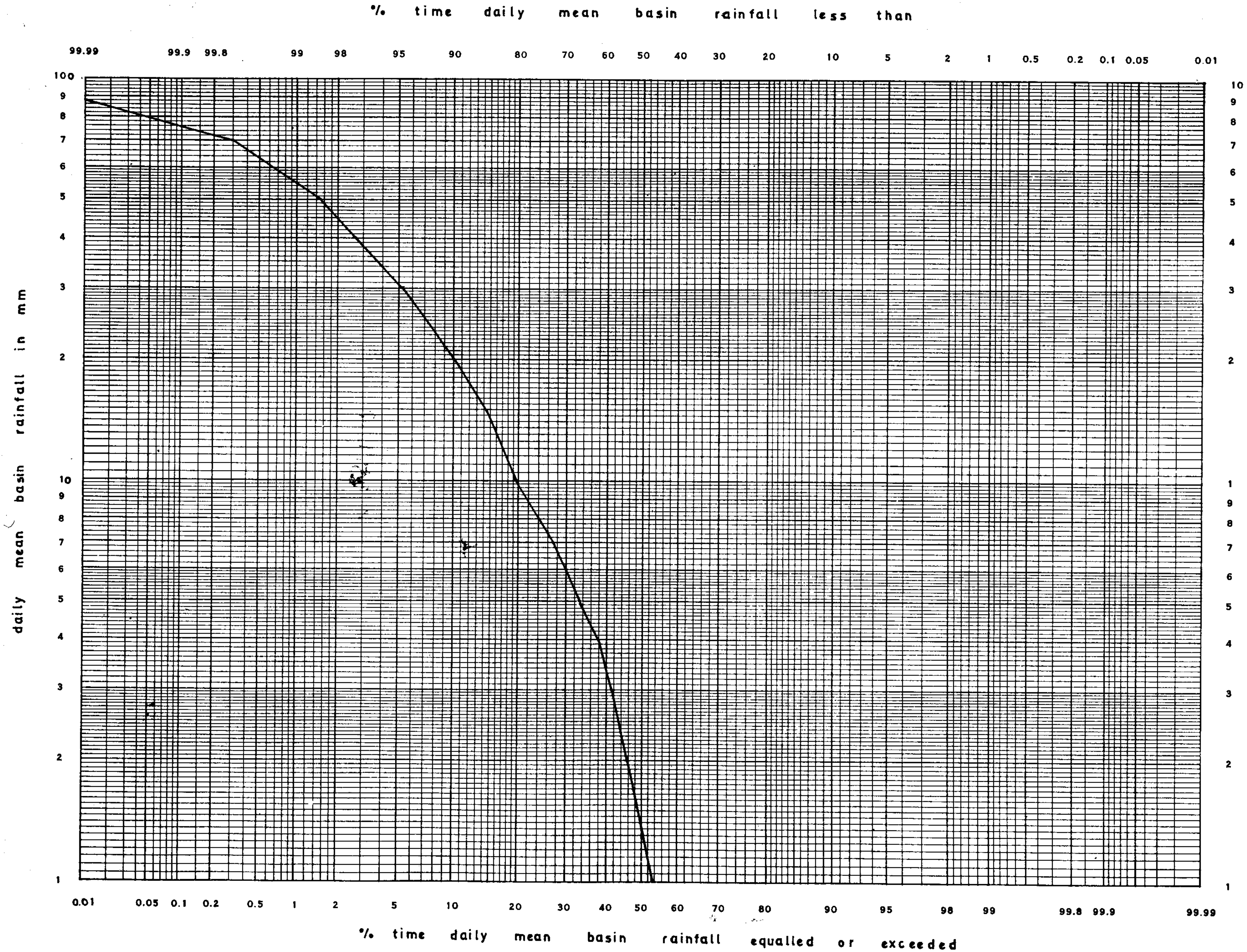


FIG. 1 DAILY RAINFALL AND RUNOFF FOR SUNGAI LUI BASIN

Fig. 2 Rainfall Duration Curve



3.3 Flow

Many periods of missing records resulting from clock failures, faulty translation and misalignment of holes in tapes were encountered. Therefore manual reading was carried out to check the translation results.

3.4 Water Quality

Results of chemical analysis were processed according to the Department procedures (Faiia, 1975) and the results are given in Appendix 2.

4. DATA ANALYSES

4.1 Rainfall

Daily mean basin rainfall was derived using the Theissen Method, the weighing factors for each rainfall site being as follows:—

Sekolah	0.163
Sawah	0.376
Lallang	0.461

The records from Lawin were suspected to be faulty. The magnitude and pattern of rainfall were extremely different from records of other stations and also its own previous records. Frequent blockage of the treetop funnel was the most likely source of error.

Results are shown in Table 5a and 5b and plotted in Fig. 1.

To evaluate the time distribution of daily rainfall, a rainfall duration curve for the total study period was calculated and shown in Fig. 2. This shows the expected number of days when less than 1.0 mm/day is recorded in the catchment is 46.8% of the time, i.e. 171 days/year. The percentage time when mean daily basin rainfall exceeds 50 mm/day is 1.5% (5 days/year) and 20 mm/day, 10.0% (36 days/year).

During the study period basin rainfall exceeded 80mm on only one occasion; on 25th June, 1976. Allowing that a daily rainfall of 1 mm or less does not contribute significantly to runoff and can be considered rainless, the maximum number of consecutive rainless days was 21 days in February, 1976. Periods of 16 consecutive days were also recorded in January-February, 1975 and January-February, 1976.

4.2 Flow

Daily runoff totals were calculated and are tabulated in Tables 5a and 5b and plotted in Fig. 1. Monthly flow records were generated from rainfall records using a simulation model (see para. 5).

4.3 Water Balance

The Penman evapotranspiration estimate (Table 3) is used to establish the monthly water balance. Results are tabulated in Table 6 for months with complete runoff records.

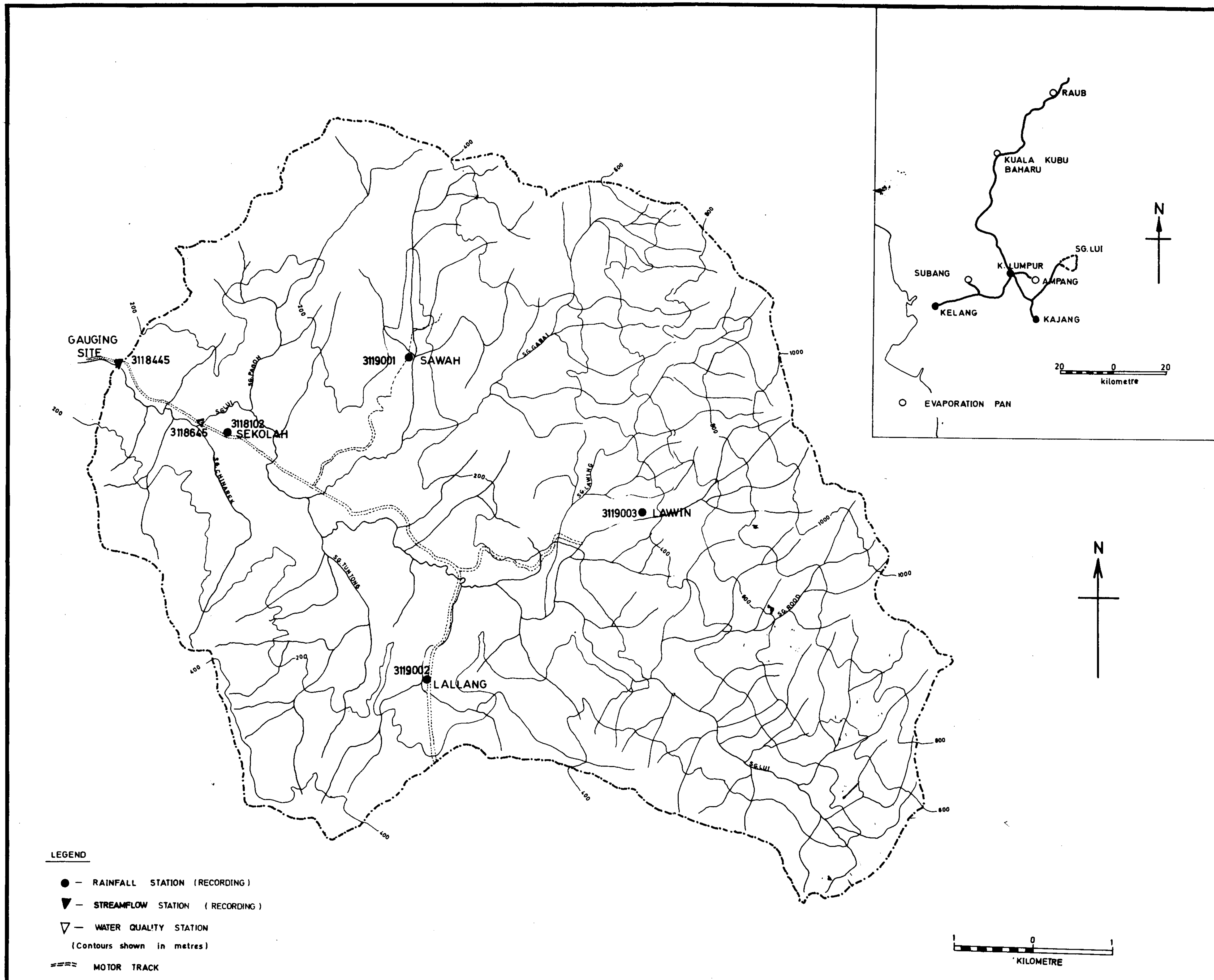


FIG.3:— BASIN AND LOCALITY MAP FOR SUNGAI LUI AND HYDROLOGICAL NETWORK

31-12-1975

Table 6 – Monthly Water Balance

1974/75	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annual
Precipitation (mm) P	230	76	278	148	206	176	145	204	207	224	324	111	2329
Runoff (mm) Q	49	28	47	–	–	34	35	43	52	67	38	34	–
Evapotranspiration (mm) E	119	128	117	125	106	115	124	109	131	131	125	116	1446
P – Q – E	+62	–80	+114	–	–	+27	–14	+52	+24	+26	+161	–39	–

1975/76	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Annual
Precipitation (mm) P	291	131	253	165	248	235	48	44	198	213	198	245	2269
Runoff (mm) Q	–	–	–	–	–	–	–	11	17	33	–	–	–
Evapotranspiration (mm) E	113	130	121	124	103	105	120	124	133	129	129	118	1449
P – Q – E	–	–	–	–	–	–	–	–91	+48	–51	–	–	–

Note: – indicates that data is not available.

4.4 Water Quality

The mean and standard deviation for each parameter is listed in table 7.

5. MATHEMATICAL MODELLING

5.1 The Boughton Model

The catchment model adopted was that developed by Boughton (1968). The model simulates daily runoff from daily rainfall and evapotranspiration inputs and operates in three distinct cycles – wetting, drying and drainage. The wetting cycle is only considered on rainfall days, while the drying and drainage cycles operate each day.

The model consists of four storages representing interception, upper-soil, drainage and the lower soil zones.

The interception store represents water stored on vegetation during rain periods. It fills during the wetting cycle and evaporates (at the potential rate) during the drying cycle.

TABLE 7: BAHAGIAN PARIT DAN TALIAIR

SUMMARY OF WATER QUALITY DATA

STATION 3118645 SG. LUI AT KAMPUNG LUI 74/08/07 TO 76/06/30

	TOTAL SOLIDS RESIDUE AT 105C) (MG/L)	DISSOLVED SOLIDS (NON-FIL- TERABLE RESIDUE) (MG/L)	SPECIFIC CONDUCT- ANCE (MICROMHOS /CM)	ALKALI- NITY ((MG/L) CALCIUM CARBO- NATE)	PH (UNITS)	SILICA (MG/L)	CALCIUM (MG/L)	MAGNESIUM (MG/L)	SODIUM (MG/L)	POTASSIUM (MG/L)	CHLORIDE (MG/L)	SULPHATE (MG/L)
MAXIMUM VALUE=	440.	106.	[illegible]0.	49.	8. 8	24. 0	32. 0	8. 0	8. 1	29. 0	8. 0	25. 8
MINIMUM VALUE=	21.	14.	25.	6.	6. 2	12. 0	1. 6	0. 2	0. 6	1. 6	1. 0	NIL
MEAN VALUE=	81.	49.	38.	23.	6. 8	18. 4	3. 9	1. 2	4. 2	2. 9	2. 5	2. 0
DIS. WTD. AVE. =	85.	50.	30.	19.	6. 7	17. 5	3. 1	0. 8	4. 1	3. 5	2. 1	1. 5
NO. SAMP. IN MEAN=	50.	50.	50.	50.	50.	45.	50.	50.	50.	50.	49.	49.

	COLOUR (HAZEN UNITS)	TURBIDITY (FULLERS EARTH)	TEMPERATURE (DEGREE. C)	DISSOLVED OXYGEN (%SAT)	BIOLOGICAL OXYGEN DEMAND (MG/L)	CHEMICAL OXYGEN DEMAND (MG/L)	NITRATE (MG/L)	AMMONIA (MG/L)	PHOSPHATE (HYDROLY- ZABLE) (MG/L)	IRON (MG/L)	MANGANESE (MG/L)	FLUORIDE (MG/L)
MAX. VAL. =	125.	273.	29.	90.	5. 1	48. 8	3. 6	0. 16	3. 28	17. 00	0. 60	0. 22
MIN. VAL. =	5.	2.	21.	83.	0. 2	1. 2	0. 4	0. 01	NIL	0. 40	NIL	0. 04
MEAN =	24.	28.	25.	86.	1. 2	11. 2	1. 2	0. 04	0. 18	2. 94	0. 04	0. 12
DIS. AVE. =	23.	26.	25.	83.	1. 4	9. 5	0. 9	0. 04	0. 18	1. 97	0. 03	0. 10
SAMPLES =	48.	46.	49.	2.	27.	27.	45.	39.	43.	42.	42.	42.

When the interception store is full, excess rainfall is admitted to the upper soil store which represents the moisture holding capacity of the top soil. Water is lost from this store by evapotranspiration.

The drainage store fills during the wetting cycle only after the upper soil store is full. This is intended to represent water in the upper soil which can later drain under gravity to the lower soil zone. If the drainage store is filled (i.e. the soil is saturated), surface runoff occurs. The drainage store is depleted by water transferring to the lower soil store.

The lower soil store represents water held in the sub-soil zone. Infiltration from the drainage store adds to the volume in storage, whilst evapotranspiration, deep percolation and base flow depletes it.

In adopting the Boughton model for the Sg. Lui catchment no consideration was given to the time lag factor in surface runoff since Scarf (1977) had established that for this catchment the time lag was less than 6 hours. For the purposes of this study it was felt sufficient to predict runoff on a monthly basis only. Hence by summing up the daily values, errors in the time distribution of discharge will be limited only to the first and last day of the month.

Initial input parameters were estimated from the values adopted by Boughton (1968) and adjusted according to local conditions. The parameters were then optimised using the steepest ascent method (Boughton, 1968) by minimizing the sum of squares of the differences between the recorded and simulated monthly runoffs for the period June 1972 to June 1974.

5.2 Results

The computer programme name for this model is ROMOD and is stored in disk 7 of the Nova 1220 computer at D.I.D. Hydrology Branch. ROMOD reads the daily rainfall and daily runoff data from disk and the monthly potential evapotranspiration, store capacities and initial values from cards. Output consists of daily parameter values together with the daily and monthly sum of squares of the differences between recorded and simulated runoffs.

The programme calls a supporting function FIXIT and a subroutine ROSUB. FIXIT computes the actual evapotranspiration contributed by the upper and lower soil stores. ROSUB contains a table which allows interpolation to obtain a coefficient for baseflow determination. Listings of ROMOD, FIXIT and ROSUB are given in Appendix 3 along with a sample monthly output.

Table 8 – Comparison of recorded (RRO) and simulated (SRO) runoffs (mm) for Sg. Lui Catchment

Month	RRO	SRO	Month	RRO	SRO	Month	RRO	SRO
1972			**1974**			**1976**		
Jan.	–	–	Jan.	61	51	Jan.	–	58
Feb.	–	–	Feb.	45	28	Feb.	11	24
Mar.	–	–	Mar.	48	51	Mar.	17	26
Apr.	–	–	Apr.	39	45	Apr.	33	52
May	–	–	May	93	85	May	–	78
June	63	65	June	45	41	June	–	74
July	48	41	July	49	81			
Aug.	35	25	Aug.	28	73			
Sept.	54	59	Sept.	47	63			
Oct.	76	99	Oct.	–	62			
Nov.	86	95	Nov.	–	46			
Dec.	66	78	Dec.	34	84			
1973			**1975**					
Jan.	51	48	Jan.	35	76			
Feb.	39	20	Feb.	43	65			
Mar.	52	56	Mar.	52	75			
Apr.	61	93	Apr.	67	79			
May	81	109	May	38	80			
June	70	92	June	34	73			
July	51	45	July	–	65			
Aug.	67	30	Aug.	–	63			
Sept.	73	41	Sept.	–	81			
Oct.	81	82	Oct.	–	82			
Nov.	141	103	Nov.	–	89			
Dec.	134	93	Dec.	–	96			

The iteration steps in the calibration of the model using the steepest ascent method are shown in Appendix 4.

Table 8 gives the summary of monthly results for both the calibration period (June 1972 – June 1974) and the simulation period (July 1974 – June 1976).

5.3 Discussion

The modified Boughton model has proved satisfactory in establishing a rainfall/runoff relationship for the period when records of runoff were available. Use of the model to generate runoff records for the period July 1974 to June 1976 produced consistently higher monthly totals than were actually recorded (Table 8).

Logical interpretation of certain parameter values on any one day is not possible with this model because the model is not based on physical processes. In order to model the processes realistically records other than rainfall and runoff—such as soil moisture levels, sources of partial area runoff, deep percolation rates — are required. However in this study the parameter values have been selected by a trial and error approach to obtain best agreement between calculated runoff and recorded runoff. That is, the parameter values have no real physical meaning in relation to the runoff process.

Thus in using this particular model it is possible that no direct runoff will be generated despite two or three consecutive days of high rainfall. In addition the simulated records have a higher recession rate than the actual runoff.

Another limitation of the model is the maximum possible simulated runoff value of 3.62 mm due to zero direct runoff and depletion of a finite maximum sub-surface storage. It seems likely that further adjustment of the sub-surface storage-depletion characteristics would improve the results.

6. RECOMMENDATIONS FOR FURTHER INSTRUMENTATION AND RESEARCH

6.1 Instrumentation

As recommended by Scarf (1977) a station to study climatic conditions should be established at Sekolah rainfall station when a multi-channel Capricorder is available for installation.

A programme should be implemented to field rate the weir as a check of the original laboratory model rating (D.I.D. Research Station Memorandum No. 157). If the rating results obtained by wading are significantly (say ± 5%) different to the theoretical rating then a cableway should be erected to rate the weir for high flows.

The rainfall and water level recorders should be carefully checked every fortnight to minimize the possible loss of valuable records.

6.2 Research

Once the theoretical rating of the Sg. Lui Weir has been verified the Boughton catchment simulation model should be recalibrated for the new runoff values for June 1972 to September 1974.

While it would be desirable to use more sophisticated models (such as the Sacramento model) to improve on the Boughton simulation results the availability of only two years of continuous runoff data is not really adequate for calibration purposes.

To investigate the water balance of the Sg. Lui catchment as representative of a humid tropical rain forest consideration could be given to using the Thornthwaite daily water balance model to estimate both water deficit and surplus amounts.

7. REFERENCES

Boughton, W.C. 1968 : A Mathematical Catchment Model For Estimating Runoff. Journal of Hydrology (N.Z.) 7(2):75–100

D.I.D. Research Station Memorandum 1972 : Memorandum No. 157 – Calibration of weir across Sg. Lui. D.I.D. K.L.

Faii, S. 1975 : Water Quality Sampling Programme Working Papers. Hydrology Branch, D.I.D. Internal report only.

Low, K. S. 1971 : Rainfall and Runoff on the Sungei Lui Catchment, West Malaysia. Thesis submitted for Ph.D to University of Hull, England. 261p

Scarf, F. 1977 : Sungai Lui Representative Basin Report No. 1 for 1971/72 to 1973/74. Ministry of Agriculture. W.R. Publication No. 7.

APPENDIX 1

STAGE–DISCHARGE RATING TABLE FOR SG. LUI WEIR

Stage in m	0.00	0.02	0.04	0.06	0.08
	DISCHARGE IN CUMECS				
76.7	0.200	0.255	0.283	0.340	0.396
76.8	0.436	0.500	0.552	0.623	0.708
76.9	0.800	0.877	0.962	1.075	1.189
77.0	1.274	1.410	1.599	1.755	2.009
77.1	2.250	2.406	2.660	2.802	3.113
77.2	3.400	3.831	4.387	4.528	5.094
77.3	5.380	5.970	6.509	7.075	7.358
77.4	8.210	8.490	8.915	9.340	9.905
77.5	10.61	11.04	11.60	12.17	12.88
77.6	13.30	14.15	14.72	15.57	16.27
77.7	16.98	17.55	17.11	18.96	19.81
77.8	20.38	21.61	22.07	23.21	23.77
77.9	24.90	25.47	26.60	27.17	28.30
78.0	28.86	29.72	31.13	32.55	32.83
78.1	34.53	35.38	36.79	37.36	38.49
78.2	39.62	40.47	41.88	42.45	43.87
78.3	45.28	46.13	46.70	48.11	48.68
78.4	50.94	52.36	53.20	54.05	55.19
78.5	56.60	57.16	58.01	59.43	61.69
78.6	62.26	63.68	65.09	65.66	67.35
78.7	67.92	69.34	70.75	72.17	73.01
78.8	73.58	74.43	76.41	76.69	77.83
78.9	79.24	79.81	80.66	82.07	83.45
79.0	83.48				

APPENDIX 2 : BAHAGIAN PARIT DAN TALIAIR

DATA KUALITI AIR

STATION 3118645 SG. LUI AT KAMPUNG LUI 74/08/07 TO 76/06/30

SAMPLING DATE	DISCHARGE (LITRE/S)	TOTAL SOLIDS (RESIDUE AT 105C) (MG/L)	SUSPENDED SOLIDS (NON-FILTERABLE RESIDUE) (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS /CM)	ALKALINITY (MG/L) CALCIUM CARBONATE	PH (UNITS)	SILICA (MG/L)	CALCIUM (MG/L)	MAGNESIUM (MG/L)	SODIUM (MG/L)	POTASSIUM (MG/L)	CHLORIDE (MG/L)	SULPHATE (MG/L)
7/ 8/74	1400	21	7	27	16	6.7	21	2.8	1.9	2.9	1.9	1	0.5
13/ 8/74	1130	54	24	35	21	7.3	-	2.8	1.4	3.5	1.8	-	0.6
27/ 8/74	700	42	2	30	17	7.0	-	2.8	0.2	2.7	1.6	1	NIL
10/ 9/74	1275	39	1	30	15	6.7	-	2.8	0.2	2.4	2.7	2	0.9
24/ 9/74	2850	78	25	35	15	7.6	20	3.0	0.2	4.4	2.3	4	3.5
8/10/74	1100	96	33	35	20	7.1	24	3.6	1.5	6.0	3.9	2	0.8
22/10/74	1130	90	9	30	16	6.3	12	2.8	0.7	2.5	2.5	2	1.3
5/11/74	990	48	7	30	19	6.6	20	2.4	0.7	4.2	2.3	1	0.9
19/11/74	29750	120	67	28	18	6.4	18	2.4	0.5	2.8	2.4	1	0.8
3/12/74	1925	72	17	30	17	6.4	18	2.4	0.7	2.9	3.2	2	1.0
17/12/74	990	48	11	29	6	6.6	-	2.4	0.7	2.9	2.4	2	0.7
31/12/74	1270	36	14	30	13	6.4	20	2.8	0.7	2.9	2.4	2	NIL
14/ 1/75	2150	127	62	30	13	6.6	18	2.4	0.5	2.1	2.4	1	0.6
28/ 1/75	1100	72	14	30	20	6.4	22	3.2	0.5	2.6	2.1	4	1.0
11/ 2/75	1100	113	38	55	30	8.8	-	2.8	0.5	3.5	3.0	4	-
25/ 2/75	1600	115	71	30	14	6.8	18	2.8	0.5	4.4	2.8	2	0.8
11/ 3/75	1600	89	31	30	18	6.8	22	4.0	2.7	2.3	1.7	3	0.6
25/ 3/75	1400	134	28	30	18	6.7	20	4.8	2.7	3.9	2.4	8	8.1
8/ 4/75	4300	130	102	25	23	6.9	16	6.4	2.2	3.8	2.2	6	2.6
22/ 4/75	-	60	4	80	25	6.6	20	6.8	8.0	4.0	2.1	2	5.5

DASHES INDICATE LABORATORY ANALYSIS WAS NOT PERFORMED
NIL INDICATES A VALUE BELOW THE LOWEST LIMITS OF DETECTION.
THE LOWEST LIMITS OF DETECTION ARE: MAGNESIUM LESS THAN 0.4(MG/L)
CHLORIDE LESS THAN 1(MG/L)
SULPHATE LESS THAN 0.3(MG/L)

STATION 3118645 SG. LUI AT KAMPUNG LUI 74/08/07 TO 76/06/30(CONTINUED)

SAMPLING DATE	COLOUR (HAZEN UNITS)	TURBIDITY (FULLERS EARTH)	TEMPERATURE (DEGREE C)	DISSOLVED OXYGEN (% SAT)	BIOLOGICAL OXYGEN DEMAND (MG/L)	CHEMICAL OXYGEN DEMAND (MG/L)	NITRATE (MG/L)	AMMONIA (MG/L)	PHOSPHATE (HYDROLY-ZABLE) (MG/L)	IRON (MG/L)	MANGANESE (MG/L)	FLUORIDE (MG/L)
7/ 8/74	20	-	23.5	-	-	-	-	-	-	-	-	-
13/ 8/74	5	-	25.0	-	-	-	-	-	-	-	-	-
27/ 8/74	-	-	21.7	-	-	-	-	-	-	-	-	-
10/ 9/74	-	-	21.1	-	-	-	-	-	-	-	-	-
24/ 9/74	25	15	24.0	-	-	-	0.6	-	NIL	-	-	-
8/10/74	20	8	22.0	-	-	-	1.4	-	3.28	-	-	-
22/10/74	15	12	24.0	-	-	-	0.7	-	NIL	-	-	-
5/11/74	20	15	25.0	-	-	-	-	-	NIL	-	-	-
19/11/74	35	50	24.0	83	-	-	0.7	0.03	NIL	1.20	0.03	0.07
3/12/74	15	32	24.5	90	-	-	1.1	0.01	NIL	0.40	NIL	0.05
17/12/74	10	14	24.0	-	-	-	0.6	-	-	0.80	NIL	0.09
31/12/74	20	24	24.0	-	-	-	0.7	-	-	0.72	0.01	0.11
14/ 1/75	25	50	24.0	-	-	-	0.9	0.03	0.04	1.80	0.05	0.09
28/ 1/75	25	15	25.0	-	-	-	0.5	0.14	0.04	1.20	NIL	0.09
11/ 2/75	55	60	24.0	-	-	-	0.9	-	-	1.60	0.03	0.06
25/ 2/75	25	52	25.0	-	0.7	8	1.1	0.03	0.08	2.40	0.06	0.07
11/ 3/75	10	19	24.0	-	-	-	0.5	0.03	NIL	3.20	0.06	0.08
25/ 3/75	10	13	26.0	-	-	-	1.0	0.04	0.06	4.00	0.06	0.07
8/ 4/75	15	53	28.0	-	-	-	1.8	0.16	NIL	2.00	0.07	0.07
22/ 4/75	15	25	24.5	-	-	-	1.0	0.03	0.04	0.64	0.04	0.09

DASHES INDICATE LABORATORY ANALYSIS WAS NOT PERFORMED
NIL INDICATES A VALUE BELOW THE LOWEST LIMITS OF DETECTION
THE LOWEST LIMITS OF DETECTION ARE: COLOUR LESS THAN 5 UNITS
NITRATE LESS THAN 0.1(MG/L)
AMMONIA LESS THAN 0.01(MG/L)
PHOSPHATE LESS THAN 0.01(MG/L)
IRON: LESS THAN 0.01(MG/L)
MANGANESE: LESS THANO.01(MG/L)
FLUORIDE: LESS THAN 0.01(MG/L)

BAHAGIAN PARIT DAN TALIAIR

DATA KUALITI AIR

STATION 3118645 SG. LUI AT KAMPUNG LUI 74/08/07 TO 76/06/30

SAMPLING DATE	DISCHARGE (LITRE/S)	TOTAL SOLIDS (RESIDUE AT 105C) (MG/L)	SUSPENDED SOLIDS (NON-FILTERABLE RESIDUE) (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS /CM)	ALKALINITY (MG/L) CALCIUM CARBONATE	PH (UNITS)	SILICA (MG/L)	CALCIUM (MG/L)	MAGNESIUM (MG/L)	SODIUM (MG/L)	POTASSIUM (MG/L)	CHLORIDE (MG/L)	SULPHATE (MG/L)
6/ 5/75	1200	57	10	30	20	6.6	22	2.8	1.9	5.6	1.9	4	1.7
20/ 5/75	1300	46	5	30	21	6.5	22	3.2	1.0	4.7	2.2	3	1.4
3/ 6/75	-	42	3	35	17	6.6	18	7.6	2.9	3.3	1.9	4	1.7
17/ 6/75	-	69	25	35	17	7.3	18	3.2	2.2	4.4	2.4	3	1.3
1/ 7/75	4080	60	5	32	16	6.7	16	2.8	1.0	6.5	2.6	2	1.6
9/ 7/75	-	60	5	25	15	7.0	18	1.6	0.5	5.7	2.0	3	2.0
29/ 7/75	4120	65	15	30	17	6.8	14	2.8	0.5	0.6	3.5	2	1.3
12/ 8/75	3880	65	10	32	18	6.8	16	2.8	0.5	8.1	3.1	2	1.9
26/ 8/75	4080	50	30	32	17	6.9	12	2.8	0.2	6.9	29.0	2	1.6
9/ 9/75	4320	70	20	32	20	6.7	14	2.8	0.5	5.6	2.4	2	1.7
23/ 9/75	-	362	278	30	19	6.2	12	2.4	0.2	1.8	1.8	2	2.6
7/10/75	4056	65	18	30	14	6.8	16	3.2	0.2	4.8	2.1	2	NIL
21/10/75	3696	80	2	31	29	6.8	20	2.8	0.2	4.2	1.8	3	1.5
4/11/75	3790	58	8	31	21	6.5	16	2.8	0.2	7.4	2.8	2	5.0
18/11/75	4080	56	9	32	17	6.5	16	2.8	1.7	6.8	2.2	2	1.2
2/12/75	-	62	20	36	24	6.6	20	3.2	0.7	4.1	2.4	2	25.8
16/12/75	4100	52	14	30	19	6.6	20	2.8	0.7	4.1	2.1	1	1.5
76/ 1/13	-	35	5	36	8	6.7	18	2.8	0.5	5.1	1.8	3	4.7
76/ 1/27	520	46	8	36	35	7.1	18	2.8	1.9	4.7	2.3	2	4.3
76/ 2/10	400	62	10	36	36	6.8	18	4.0	0.2	3.5	2.2	2	0.5

DASHES INDICATE LABORATORY ANALYSIS WAS NOT PERFORMED
NIL INDICATES A VALUE BELOW THE LOWEST LIMITS OF DETECTION.
THE LOWEST LIMITS OF DETECTION ARE: MAGNESIUM LESS THAN 0.4(MG/L)
CHLORIDE LESS THAN 1(MG/L)
SULPHATE LESS THAN 0.3(MG/L)

STATION 3118645 SG. LUI AT KAMPUNG LUI 74/08/07 TO 76/06/30(CONTINUED)

SAMPLING DATE	COLOUR (HAZEN UNITS)	TURBIDITY (FULLERS EARTH)	TEMPERATURE (DEGREE C)	DISSOLVED OXYGEN (% SAT)	BIOLOGICAL OXYGEN DEMAND (MG/L)	CHEMICAL OXYGEN DEMAND (MG/L)	NITRATE (MG/L)	AMMONIA (MG/L)	PHOSPHATE (HYDROLY-ZABLE) (MG/L)	IRON (MG/L)	MANGANESE (MG/L)	FLUORIDE (MG/L)
6/ 5/75	10	8	26.0	-	-	-	1.4	0.03	NIL	4.00	0.03	0.19
20/ 5/75	10	12	27.0	-	-	-	0.7	0.03	0.76	2.80	0.02	0.22
3/ 6/75	20	21	23.0	-	-	-	0.5	0.03	0.50	0.80	0.03	0.18
17/ 6/75	10	10	24.0	-	-	-	1.1	0.03	0.06	3.60	0.03	0.10
1/ 7/75	10	2	26.0	-	0.8	14	0.4	0.04	NIL	4.00	0.03	0.10
9/ 7/75	15	25	24.0	-	0.9	6	1.1	0.03	0.06	0.80	0.02	0.14
29/ 7/75	10	6	24.0	-	1.0	6	1.1	0.03	0.10	3.60	0.03	0.10
12/ 8/75	10	6	28.0	-	1.6	10	0.5	0.03	0.06	0.40	0.03	0.10
26/ 8/75	10	8	25.0	-	0.7	1	0.4	0.03	0.06	0.80	0.04	0.20
9/ 9/75	10	17	27.0	-	0.8	3	0.4	0.03	0.10	0.40	0.03	0.10
23/ 9/75	50	210	26.0	-	2.1	42	1.7	0.03	0.40	1.00	0.20	0.09
7/10/75	20	10	26.0	-	0.6	4	0.4	0.01	0.04	0.60	0.01	0.20
21/10/75	20	12	-	-	2.5	2	0.6	0.06	0.04	0.80	0.01	0.20
4/11/75	10	2	29.0	-	5.1	6	0.6	0.01	NIL	0.60	0.01	0.10
18/11/75	15	4	26.0	-	0.9	7	1.1	0.01	NIL	2.00	0.01	0.10
2/12/75	15	6	25.0	-	0.5	1	2.3	0.03	0.20	0.80	0.01	0.04
16/12/75	20	4	26.0	-	0.6	35	1.3	0.04	0.04	8.00	0.02	0.09
76/ 1/13	20	6	27.5	-	1.1	8	1.1	0.16	0.04	3.20	NIL	0.10
76/ 1/27	25	8	24.5	-	0.5	10	1.0	0.01	0.04	2.40	NIL	0.10
76/ 2/10	40	14	24.0	-	0.6	6	0.9	0.06	0.04	9.00	NIL	0.20

DASHES INDICATE LABORATORY ANALYSIS WAS NOT PERFORMED
NIL INDICATES A VALUE BELOW THE LOWEST LIMITS OF DETECTION
THE LOWEST LIMITS OF DETECTION ARE: COLOUR LESS THAN 5 UNITS
NITRATE LESS THAN 0.1(MG/L)
AMMONIA LESS THAN 0.01(MG/L)
PHOSPHATE LESS THAN 0.01(MG/L)
IRON: LESS THAN 0.01(MG/L)
MANGANESE: LESS THANO.01(MG/L)
FLUORIDE: LESS THAN 0.01(MG/L)

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DATA KUALITI AIR

STATION 3118645 SG. LUI AT KAMPUNG LUI 74/08/07 TO 76/06/30

SAMPLING DATE	DISCHARGE (LITRE/S)	TOTAL SOLIDS (RESIDUE AT 105C) (MG/L)	SUSPENDED SOLIDS (NON-FILTERABLE RESIDUE) (MG/L)	SPECIFIC CONDUCTANCE (MICROMHOS /CM)	ALKALINITY (MG/L) CALCIUM CARBONATE	PH (UNITS)	SILICA (MG/L)	CALCIUM (MG/L)	MAGNESIUM (MG/L)	SODIUM (MG/L)	POTASSIUM (MG/L)	CHLORIDE (MG/L)	SULPHATE (MG/L)
76/ 2/24	280	52	3	32	36	6. 5	20	32. 0	0. 5	4. 1	1. 7	2	0. 4
76/ 3/ 9	230	64	6	35	33	7. 0	20	3. 6	1. 9	6. 2	2. 1	3	0. 2
76/ 3/23	340	55	7	35	39	7. 0	18	2. 8	2. 9	4. 7	3. 1	3	0. 5
76/ 4/ 6	440	30	10	34	40	6. 9	16	3. 2	0. 2	4. 5	2. 2	3	0. 1
76/ 4/20	1600	87	42	32	30	6. 3	20	7. 2	0. 7	4. 7	2. 6	2	0. 5
76/ 5/ 4	960	69	22	36	40	6. 9	20	2. 8	2. 4	5. 6	2. 5	2	0. 1
76/ 5/18	-	52	7	38	42	6. 8	20	3. 6	0. 9	4. 3	2. 4	3	0. 2
76/ 6/ 1	-	440	392	32	34	6. 5	20	2. 8	1. 2	4. 3	2. 8	3	1. 2
76/ 6/15	970	61	11	32	36	6. 2	20	4. 4	3. 1	2. 3	2. 0	3	1. 0
76/ 6/29	-	76	26	31	49	6. 7	20	3. 6	1. 4	3. 5	2. 0	2	0. 0

DASHES INDICATE LABORATORY ANALYSIS WAS NOT PERFORMED
NIL INDICATES A VALUE BELOW THE LOWEST LIMITS OF DETECTION.
THE LOWEST LIMITS OF DETECTION ARE: MAGNESIUM LESS THAN 0. 4(MG/L)
CHLORIDE LESS THAN 1(MG/L)
SULPHATE LESS THAN 0. 3(MG/L)

STATION 3118645 SG. LUI AT KAMPUNG LUI 74/08/07 TO 76/06/30(CONTINUED)

SAMPLING DATE	COLOUR (HAZEN UNITS)	TURBIDITY (FULLERS EARTH)	TEMPERATURE (DEGREE C)	DISSOLVED OXYGEN (% SAT)	BIOLOGICAL OXYGEN DEMAND (MG/L)	CHEMICAL OXYGEN DEMAND (MG/L)	NITRATE (MG/L)	AMMONIA (MG/L)	PHOSPHATE (HYDROLY-ZABLE) (MG/L)	IRON (MG/L)	MANGANESE (MG/L)	FLUORIDE (MG/L)
76/ 2/24	30	7	26. 0	-	1. 4	2	1. 0	0. 01	0. 04	2. 40	NIL	0. 20
76/ 3/ 9	30	12	26. 0	-	0. 2	6	0. 9	0. 01	0. 08	3. 60	NIL	0. 20
76/ 3/23	125	12	28. 0	-	0. 6	5	1. 4	0. 07	0. 16	2. 00	0. 03	0. 18
76/ 4/ 6	30	10	26. 0	-	1. 4	7	1. 4	0. 04	0. 16	2. 00	0. 03	0. 11
76/ 4/20	50	24	26. 0	-	1. 2	16	1. 7	0. 04	0. 16	4. 80	0. 03	0. 14
76/ 5/ 4	30	29	24. 5	-	2. 4	11	1. 9	0. 07	0. 18	7. 00	NIL	0. 09
76/ 5/18	25	17	26. 0	-	1. 2	9	1. 1	0. 07	0. 04	4. 40	NIL	0. 07
76/ 6/ 1	80	273	27. 0	-	0. 6	48	2. 5	0. 06	0. 57	17. 00	0. 60	0. 10
76/ 6/15	30	19	26. 0	-	0. 6	12	3. 6	0. 04	0. 14	2. 80	0. 02	0. 12
76/ 6/29	20	24	26. 0	-	1. 5	3	2. 9	0. 04	0. 04	8. 00	0. 03	0. 11

DASHES INDICATE LABORATORY ANALYSIS WAS NOT PERFORMED
NIL INDICATES A VALUE BELOW THE LOWEST LIMITS OF DETECTION
THE LOWEST LIMITS OF DETECTION ARE: COLOUR LESS THAN 5 UNITS
NITRATE LESS THAN 0. 1(MG/L)
AMMONIA LESS THAN 0. 01(MG/L)
PHOSPHATE LESS THAN 0. 01(MG/L)
IRON: LESS THAN 0. 01(MG/L)
MANGANESE: LESS THANO. 01(MG/L)
FLUORIDE: LESS THAN 0. 01(MG/L)

```
      COMPILER NOSTACK
C     ROMOD
C     MODIFIED BOUGHTON CATCHMENT MODEL SIMULATES RUNOFF FROM RAINFALL AND
C     EVAPORATION DATA
      DIMENSION RAIN(31),EVAP(12),RRO(31),NDAY(12),IRAIN(31),IRRO(31)
      INTEGER YR,YRF
      DATA NDAY/31,28,31,30,31,30,31,31,30,31,30,31/
      READ(9,1000)CEPMX,USMAX,DRMAX,SSMAX,
1000  FORMAT(F5.1,3F5.0)
      READ(9,1000)CEP,US,DR,SS
      READ(9,1001)FO,FC,AAK,PCUS
1001  FORMAT(2F5.0,2F6.4,F5.0)
      WRITE(12,1002)
1002  FORMAT(/"BOUGHTON WATER BALANCE MODEL",/5X,"CEPMX   USMAX   DRMAX   SSMAX
     1   CEP      US      DR      SS      FO      FC      AAK      PCUS")
      WRITE(12,1003)CEPMX,USMAX,DRMAX,SSAAX,CEP,US,DR,SS,FO,FC,AAK,PCUS
1003  FORMAT(5X,F5.1,3(3X,F5.0),3X,F5.1,5(3X,F5.0),2X,F6.4,3X,F5.0)
      READ(9,1004)(EVAP(M),M=1,12)
1004  FORMAT(12F5.0)
      DO 1005 M=1,12
1005  EVAP(M)=EVAP(M)/NDAY(M)
      SUM=CEPMX+USMAX+DRMAX
      CALL OPEN(2,"RODATA")
      WRITE(12,1006)
1006  FORMAT(/5X,"DY MT     RAIN     PEVAP      CEP",6X,"US",6X,"DR",6X,"SS",5X,
     1"DEF      RUN      GW      SRO      RRO      ASSX")
1044  READ(2,1007)MT,YR,(IRAIN(J),J=1,31)
1007  FORMAT(2I2,19I4/4X,12I4)
      IF(YR.EQ.0)GO TO 1009
      READ(2,1007)MTF,YRF,(IRRO(J),J=1,31)
      IF(MTF.NE.MT.OR.YRF.NE.YR)GO TO 1010
      IF(MT.NE.2)GO TO 1011
      NDAY(2)=28
      IF(MOD(YR,4).EQ.0)NDAY(2)=29
1011  TSRO=0.
      TRRO=0.
      L=NDAY(MT)
      DO 1013 J=1,L
      SPILL=0.0
      RUN=0.0
      RRO(J)=IRRO(J)/100.0
      RAIN(J)=IRAIN(J)/10.0
      IF(RAIN(J))1013,1014,1015
1015  CEP=CEP+RAIN(J)
      IF(CEPMX-CEP)1016,1014,1014
1016  EX=CEP-CEPMX
      CEP=CEPMX
      US=US+EX
      IF(USMAX-US)1017,1014,1014
1017  EX=US-USMAX
      US=USMAX
      DR=DR+EX
      IF(DRMAX-DR)1018,1014,1014
1018  EX=DR-DRMAX
      IF(SSMAX-SS)1019,1019,1020
1019  F=FC+0.01
      GO TO 1021
1020  IF(SS)1022,1022,1023
1022  F=FO
      GO TO 1021
```

APPENDIX 3

FIG A3.1 = Listing of Programme ROMOD

```
1023  F=FC+(FO-FC)/EXP(AAK*SS)
1021  A=EXP(EX/F)
      B=1.0/A
      RUN=EX-F*(A-B)/(A+B)
      IF(RUN.LT.0.0)RUN=0.0
      DR=DR-RUN
      IF(SSMAX-SS-F)1024,1025,1025
1024  SPILL=SS+F-SSMAX
1025  SPILL=0.0
      DEF=0.0
      DEFMX=0.0
1014  CEP=CEP-EVAP(MT)
      IF(CEP)1026,1027,1027
1026  EP=ABS(CEP)
      CEP=0.0
      US=US-PCUS*FIXIT(US,USMAX,EVAP(MT),EP)/100.0
      SS=SS-(100.0-PCUS)*FIXIT(SS,SSMAX,EVAP(MT),EP)/100.0
1027  IF(DR)1028,1040,1030
1028  DR=0.0
      GO TO 1040
1030  IF(SSMAX-SS)1031,1031,1032
1031  F=FC+0.01
      GO TO 1033
1032  IF(SS)1034,1034,1035
1034  F=FO
      GO TO 1033
1035  F=FC+(FO-FC)/EXP(AAK*SS)
1033  IF(DR-F)1036,1036,1037
1036  SS=SS+DR
      DR=0.0
      GO TO 1038
1037  SS=SS+F
      DR=DR-F
1038  IF(SSMAX-SS)1039,1040,1040
1039  SS=SSMAX
 1040 CALL ROSUB(ACC,SS)
      GW=SS*(1.0-ACC)
      SS=SS-GW
      SRO=RUN+SPILL+GW
      TSRO=TSRO+SRO
      DEF=SUM-CEP-US-DR
      IF(DEFMX-DEF)1041,1042,1042
1041  DEFMX=DEF
1042  ASSX=(RRO(J)-SRO)**2
      TRRO=TRRO+RRO(J)
      WRITE(12,1043)J,MT,RAIN(J),EVAP(MT),CEP,US,DR,SS,DEF,RUN,GW,SRO,
     1RRO(J),ASSX
1043  FORMAT(5X,I2,1X,I2,5X,7(F5.1,3X),5(F5.2,3X),F7.2)
1013  CONTINUE
      BSSX=(TSRO-TRRO)**2
      CSSX=CSSX+BSSX
      WRITE(12,1051 )CSSX
1051  FORMAT(5X,"TOTAL SUM SQUARES FOR MONTHLY RUNOFF TOTALS =",F7.1)
      GO TO 1044
1010  TYPE"RAINFALL AND RUNOFF DATA DO NOT MATCH"
1009  CONTINUE
      END
```

FIG A3.1 = Listing of Programme ROMOD
(continued)

```
      FUNCTION FIXIT(SMLEV,SMMAX,EV,ET)
        POINT=EV*SMLEV/SMMAX
        IF(POINT-ET)1100,1100,1101
1100    FIXIT=POINT
        RETURN
1101    FIXIT=ET
        RETURN
        END
```

```
      SUBROUTINE ROSUB(SSK,SSSS)
        COMMON/ROCOM/ISS(23),IK(23)
        DATA ISS/1,4,9,15,22,28,44,59,80,92,106,116,130,140,147,155,165,172,176,18
       11,186,192,200/
        DATA IK/983,982,981,980,979,978,977,976,975,974,973,972,971,970,969,968,96
       16,964,963,960,957,945,920/
        DO 1 I=1,23
        TSS=ISS(I)/1.0
        IF(SSSS.LE.TSS)GO TO 3
      1 CONTINUE
        GO TO 4
      3 SSK=(IK(I)-IK(I-1))*(SSK-ISS(I-1))/((ISS(I)-ISS(I-1))*1000.)+IK(I-1)
      4 RETURN
        END
```

<u>FIG A3.2</u> = Listing of Function FIXIT and Subroutine ROSUB

BOUGHTON WATER BALANCE MODEL

CEPMX	USMAX	DRMAX	SSMAX	CEP	US	DR	SS	FO	FC	AAK	PCUS
5.0	90.	42.	126.	1.0	60.	10.	100.	410.	2.	0.0014	100.

DY	MT	RAIN	PEVAP	CEP	US	DR	SS	DEF	RUN	GW	SRO	RRO	ASSX
1	6	16.2	4.1	0.9	72.2	0.0	107.0	63.9	0.00	3.01	3.01	3.51	0.25
2	6	2.4	4.1	0.0	71.4	0.0	104.1	65.6	0.00	2.90	2.90	3.72	0.67
3	6	0.0	4.1	0.0	68.1	0.0	101.3	68.9	0.00	2.80	2.80	2.49	0.09
4	6	0.0	4.1	0.0	65.0	0.0	98.6	72.0	0.00	2.70	2.70	2.24	0.21
5	6	1.6	4.1	0.0	62.5	0.0	96.0	74.5	0.00	2.61	2.61	2.10	0.26
6	6	0.0	4.1	0.0	59.7	0.0	93.5	77.3	0.00	2.52	2.52	1.95	0.33
7	6	0.5	4.1	0.0	57.0	0.0	91.0	80.0	0.00	2.44	2.44	1.88	0.31
8	6	0.4	4.1	0.0	54.4	0.0	88.7	82.6	0.00	2.36	2.36	1.79	0.32
9	6	0.0	4.1	0.0	51.9	0.0	86.4	85.1	0.00	2.28	2.28	1.75	0.28
10	6	0.0	4.1	0.0	49.5	0.0	84.2	87.5	0.00	2.21	2.21	1.75	0.21
11	6	0.7	4.1	0.0	47.3	0.0	82.0	89.7	0.00	2.13	2.13	1.74	0.15
12	6	0.4	4.1	0.0	45.1	0.0	80.0	91.9	0.00	2.06	2.06	1.74	0.11
13	6	0.0	4.1	0.0	43.1	0.0	78.0	93.9	0.00	2.00	2.00	1.68	0.10
14	6	45.5	4.1	0.9	83.6	0.0	76.0	52.5	0.00	1.94	1.94	2.15	0.04
15	6	0.0	4.1	0.0	80.4	0.0	74.1	56.6	0.00	1.89	1.89	2.87	0.97
16	6	2.1	4.1	0.0	78.4	0.0	72.3	58.6	0.00	1.83	1.83	1.89	0.00
17	6	9.1	4.1	0.9	82.5	0.0	70.5	53.6	0.00	1.78	1.78	1.88	0.01
18	6	0.1	4.1	0.0	79.4	0.0	68.8	57.6	0.00	1.73	1.73	1.84	0.01
19	6	19.0	4.1	0.9	90.0	0.0	70.4	46.1	0.00	1.78	1.78	2.55	0.60
20	6	0.1	4.1	0.0	86.9	0.0	68.7	50.1	0.00	1.73	1.73	2.44	0.51
21	6	1.9	4.1	0.0	84.7	0.0	67.0	52.3	0.00	1.68	1.68	2.21	0.28
22	6	1.2	4.1	0.0	81.8	0.0	65.4	55.2	0.00	1.63	1.63	2.31	0.46
23	6	0.0	4.1	0.0	78.1	0.0	63.8	58.9	0.00	1.59	1.59	2.08	0.24
24	6	0.0	4.1	0.0	74.5	0.0	62.2	62.5	0.00	1.54	1.54	1.93	0.15
25	6	0.0	4.1	0.0	71.1	0.0	60.7	65.9	0.00	1.50	1.50	1.85	0.12
26	6	0.0	4.1	0.0	67.9	0.0	59.3	69.1	0.00	1.46	1.46	1.79	0.11
27	6	0.0	4.1	0.0	64.8	0.0	57.8	72.2	0.00	1.42	1.42	1.72	0.08
28	6	0.0	4.1	0.0	61.8	0.0	56.4	75.2	0.00	1.38	1.38	1.64	0.06
29	6	0.0	4.1	0.0	59.0	0.0	55.1	78.0	0.00	1.35	1.35	1.60	0.06
30	6	0.0	4.1	0.0	56.3	0.0	53.8	80.7	0.00	1.31	1.31	1.55	0.06

TOTAL SUM SQUARES FOR MONTHLY RUNOFF TOTALS = 9.4

TABLE A3.1 = Typical Monthly Printout from Programme ROMOD

APPENDIX 4

STEEPEST ASCENT ADJUSTMENT IN CALIBRATING THE BOUGHTON MODEL FOR THE SG. LUI CATCHMENT

	USMAX	DRMAX	SSMAX	FO	FC	K	PCUS	SUM OF SQUARES	CHANGE	REMARK
	120	42	140	410	2.2	0.0014	100	12392		
1st Set of Trials	132	42	140	410	2.2	0.0014	100	12616	+ 224	
	120	46	140	410	2.2	0.0014	100	12385	– 7	
	120	42	154	410	2.2	0.0014	100	16273	+ 3981	
	120	42	140	450	2.2	0.0014	100	12386	– 6	
	120	42	140	410	2.4	0.0014	100	12392	0	
	120	42	140	410	2.2	0.0016	100	12394	+ 2	
	120	42	140	410	2.2	0.0014	90	12564	+ 172	
1st Round of Adjustment	102	42	126	410	2.2	0.0014	100	10563		
	90	42	114	410	2.2	0.0014	100	11211		
Best Result after 1st round	102	42	126	410	2.2	0.0014	100	10563		
2nd Set of Trials	90	42	126	410	2.2	0.0014	100	10194	– 369	
	102	46	126	410	2.2	0.0014	100	10560	– 3	
	102	42	138	410	2.2	0.0014	100	11679	+ 1116	
	102	42	126	450	2.2	0.0014	100	10560	– 3	
	102	42	126	410	2.4	0.0014	100	10563	0	
	102	42	126	410	2.2	0.0016	100	10564	+ 1	
	102	42	126	410	2.2	0.0014	90	10816	+ 253	
2nd Round of Adjustments	90	42	114	410	2.2	0.0014	100	11211		
By further Adjustment	70	42	126	410	2.2	0.0014	100	9755		

WATER RESOURCES PUBLICATIONS PUBLISHED

1. Surface Water Resources Map (Provisional) of Peninsular Màlaysia (1974) .. .. $ 5.00

2. Hydrological Regions of Peninsular Malaysia (1974) ... .. $ 6.00

3. Sungei Tekam Experimental Basin Annual Report No. 1 for 1973–1974 (1975) .. .. $ 5.00

4. Notes on Some Hydrological Effects of Land Use Changes in Peninsular Malaysia (1975) .. .. $ 5.00

5. Evaporation in Peninsular Malaysia (1976) .. .. $ 5.00

6. Average Annual Surface Water Resources of Peninsular Malaysia (1976) .. .. $ 5.00

7. Sungei Lui Representative Basin Report No. 1 for 1971/72 to 1973/74 (1977) .. .. $ 5.00

8. Water Resources for Irrigation of Upland Crops in South Kelantan (1977) .. .. $ 5.00