CHAPTER 3 MODELLING OF RIVER BASIN

In order to clarify the flow regime of the main rivers in Zambia, 45 locations were selected as a discharge reference point and the whole country of Zambia was divided into 56 river basins based on these discharge reference points. The catchment areas are presented in detail in Table 3-2. Table 3-1 summarises the number of the discharge reference points and the river basin areas by the main river systems. The location of the discharge reference points and the main basins is shown in Figure 3-2. The discharge reference points were selected employing the following criteria :

- To be situated at a main river or a large tributary
- To be situated at a confluence of large tributaries or main rivers
- To be situated at a hydrometric station
- To be near main towns or cities

Most of the basin areas were clarified from the results of satellite imagery interpretation results implemented by the Study Team, and is often different from the DWA's figure. However some of the basin area which stretch outside Zambia, mainly the Zambezi River basin, come from the DWA Hydrological Year Book or from SADC Project Office' data.

The river model presented in Figure 3-1, is employed to clarify structure of the river systems, namely basins, reference points, lakes, swamps and flood plains.

Table 3-1 Summary of Discharge Reference Points and River Basins

River System	Catchment Area (km²)			Nos. of Discharge Ref. Points	Nos. of River Basin	Main Tributaries
	in Zambia Territory	out of Zambia Territory	Total Area			
Zambezi	268,235	418,814	687,049	17	20	Kabompo Lungwebungu Luena Luanginga
Kafue	156,995	0	156,995	13	15	Mwambashi Luswishi Lunga
Luangwa	144,358	3,264	147,622	5	8	Lukusashi Lunsemfwa
Chambeshi	44,427	0	44,427	3	3	Lukulu
Luapula	113,323	60,073	173,396	6	6	Kalungwishi
Lake Tanganyika	15,856	233,144	249,000	1	2	Lufubu
Other Basin	8,658	-	8,658	-	2	
Total	751,852	482,151	1,225,345	45	56	

Note: 1) Catchment areas are obtained from Landsat Satellite Imagery analysis by the Study Team.
2) Catchment area of Zambezi river excludes the areas of Kafue river and Luangwa river.
3) Catchment area of Luapula river excludes the area of Chambeshi river.

Table 3-2 (1) Catchment Area of Discharge Reference Points and Basins

Main River	Item	No.	Name (and Number)	Catchment Area (km^2)		
				Total	In Zambia	Out of Zambia
Zambezi River	Discharge Reference Point	PZ-01	Chavuma Falls (1-105)	75,967	3,469	72,498
		PZ-02	Zambezi Pump House (1-150)	87,275	9,175	78,100
		PZ-03	Kabompo Boma (1-650)	42,740	41,021	1,719
		PZ-04(1)	Conf. (Kabompo R. Before Dongwe R.)	45,505	43,786	1,719
		PZ-04(2)	Conf. (Dongwe R. Portion)	20,870	20,870	0
		PZ-04(3)	Conf. (Kabompo R. After Dongwe R.)	66,375	64,656	1,719
		PZ-05	Watopa Pontoon (1-950)	67,261	65,542	1,719
		PZ-06(1)	Conf. (Before Kabompo R.)	89,874	11,774	78,100
		PZ-06(2)	Conf. (Kabompo R. Portion.)	72,751	71,032	1,719
		PZ-06(3)	Conf. (After Kabompo R.)	162,625	81,806	80,819
		PZ-07	Lukulu (2-030)	206,531	92,290	114,241
		PZ-08	Kalabo (2-250)	34,621	7,465	27,156
		PZ-09(1)	Conf. (Luena R. Portion)	24,178	24,178	0
		PZ-09(2)	Conf. (Luanginga R. Portion.)	43,619	16,383	27,236
		PZ-09(3)	Conf. (After Luena R. and Luanginga R.)	274,328	132,851	141,477
		PZ-10	Senanga (2-400)	284,538	143,061	141,477
		PZ-11	Sesheke (2-700)	336,053	186,504	149,549
		PZ-12(1)	Conf. (Before Chobe R.)	362,953	212,394	150,559
		PZ-12(2)	Conf. (Chobe R. Portion.)	144,400	14,178	130,222
		PZ-12(3)	Conf. (After Chobe R.)	507,353	226,572	280,781
		PZ-13	Victoria Fall Big Tree (ZRA)	513,780	228,243	285,537
		PZ-14(1)	Kariba Dam (Inflow)	663,880	254,228	409,652
		PZ-14(2)	Kariba Dam (Outflow)	663,880	254,228	409,652
		PZ-15(1)	Conf. (Before Kafue R.)	667,970	257,150	410,820
		PZ-15(2)	Conf. (Kafue R. Portion)	156,995	156,995	0
		PZ-15(3)	Conf. (After Kafue R.)	824,965	414,145	410,820
		PZ-16	Feira Boma (5-099)	844,044	425,230	418,814
		PZ-17(1)	Conf. (Luangwa R. Portion)	147,622	144,358	3,264
		PZ-17(2)	Conf. (After Luangwa R.)	991,666	569,588	422,078
	Basin	AZ-01	Upper Zambezi	75,967	3,469	72,498
		AZ-02	Chavuma to Zambezi Pump House	11,308	5,706	5,602
		AZ-03	Zambezi Pump house to Kabompo R.	2,599	2,599	0
		AZ-04	Upper Kabompo R.	42,740	41,021	1,719
		AZ-05	Middle Kabompo R.	2,765	2,765	0
		AZ-06	Dongwe R.	20,870	20,870	0
		AZ-07	Dongwe R. to Watopa Pontoon	886	886	0
		AZ-08	Mumbezi R. and Lutali R.	5,490	5,490	0
		AZ-09	Lungwebungu R.	43,906	9,484	34,422
		AZ-10	Luena R.	24,178	24,178	0
		AZ-11	Upper Luanginga R.	34,621	7,465	27,156
		AZ-12	Lower Luanginga R. (Luambimba R.)	8,998	8,918	80
		AZ-13	Mongu to Senanga	10,210	10,210	0
		AZ-14	Senanga to Sesheke	51,515	43,443	8,072
		AZ-15	Sesheke to Conf. (Mambova.)	26,900	25,890	1,010
		AZ-16	Chobe R.	144,400	14,178	130,222
		AZ-17	Conf. (Mambova) to Livingstone	6,427	1,671	4,756
		AZ-18	Livingstone to Kariba Dam	150,100	25,985	124,115
		AZ-19	Kariba Dam to Conf. of Kafue R.	4,090	2,922	1,168
		AZ-20	Conf. of Kafue R. to Feira Boma	19,079	11,085	7,994
Kafue River	Discharge Reference Point	PK-01	Raglan Farm (4-050)	5,775	5,775	0
		PK-02	Mwambashi (4-120)	827	827	0
		PK-03	Smith's Bridge (4-130)	8,914	8,914	0
		PK-04	Mpatamatu (4-200)	12,001	12,001	0
		PK-05	Machiya Ferry (4-280)	23,065	23,065	0
		PK-06(1)	Conf. (Before Luswishi R.)	24,264	24,264	0
		PK-06(2)	Conf. (Luswishi R. Portion)	8,839	8,839	0
		PK-06(3)	Conf. (After Luswishi R.)	33,103	33,103	0
		PK-07	Chilenga (4-350)	34,451	34,451	0
		PK-08	Lubungu (4-450)	55,962	55,962	0
		PK-09	Chifumpa Pontoon (4-560)	20,999	20,999	0
		PK-10(1)	Conf. (Lunga R. Portion)	23,767	23,767	0
		PK-10(2)	Conf. (After Lunga R.)	79,729	79,729	0
		PK-11	Kafue Hook Bridge (4-669)	96,239	96,239	0

Table 3-2 (2) Catchment Area of Discharge Reference Points and Basins

Main River	Item	No.	Name (and Number)	Catchment Area (km²)		
				Total	In Zambia	Out of Zambia
Kafue River	Discharge Reference Point	PK-12(1)	Itezhi-Tezhi Dam (Inflow)	107,191	107,191	0
		PK-12(2)	Itezhi-Tezhi Dam (Outflow)	107,191	107,191	0
		PK-13(1)	Kafue Gorge Dam (Inflow)	153,826	153,826	0
		PK-13(2)	Kafue Gorge Dam (Outflow)	153,826	153,826	0
		PZ-15(2)	Conf. (Kafue R. Portion)	156,995	156,995	0
	Basin	AK-01	Upper Kafue R.	5,775	5,775	0
		AK-02	Mwambashi R.	827	827	0
		AK-03	Mufulira	2,312	2,312	0
		AK-04	Smith's Bridge to Mpatamatu.	3,087	3,087	0
		AK-05	Kafulafuta R. and Lufwanyama R.	11,064	11,064	0
		AK-06	Machiya Ferry to Conf.	1,199	1,199	0
		AK-07	Luswishi R.	8,839	8,839	0
		AK-08	Conf. to Chilenga	1,348	1,348	0
		AK-09	Lukanga Swamp	21,511	21,511	0
		AK-10	Upper Lunga R.	20,999	20,999	0
		AK-11	Lower Lunga R.	2,768	2,768	0
		AK-12	Lufupa R. and others	16,510	16,510	0
		AK-13	Itezhi-Tezhi Reservoir	10,952	10,952	0
		AK-14	Kafue Flats	46,635	46,635	0
		AK-15	Lower Kafue R.	3,169	3,169	0
Luangwa River	Discharge Reference Point	PL-01	Mfuwe (5-650)	73,422	73,422	0
		PL-02	Ndevu Camp (5-800)	91,861	91,861	0
		PL-03(1)	Conf. (Lunsemfwa R. Before Lukusashi R.)	27,443	27,443	0
		PL-3(2)	Conf. (Lukusashi R. Portion)	14,711	14,711	0
		PL-03(3)	Conf. (Lunsemfwa R. After Lukusashi R.)	42,154	42,154	0
		PL-04(1)	Conf. (Before Lunsemfwa R.)	96,877	96,517	360
		PL-04(2)	Conf. (Lunsemfwa R. Portion)	43,137	43,137	0
		PL-04(3)	Conf. (After Lunsemfwa R.)	140,014	139,654	360
		PL-05	Luangwa Road Bridge (5-940)	140,922	140,562	360
		PZ-17(1)	Conf. (Luangwa R. Portion)	147,622	144,358	3,264
	Basin	AL-01	Upper Luangwa R.	73,422	73,422	0
		AL-02	Middle Luangwa R.	18,439	18,439	0
		AL-03	Ndevu Camp to Conf. of Lunsemfwa R.	5,016	4,656	360
		AL-04	Upper Lunsemfwa R.	27,443	27,443	0
		AL-05	Lukusashi R.	14,711	14,711	0
		AL-06	Lower Lunsemfwa R.	983	983	0
		AL-07	Conf. to Luangwa Road Bridge	908	908	0
		AL-08	Lower Luangwa R.	6,700	3,796	2,904
Chambeshi and Luapula River	Discharge Reference Points	PC-01	Chambeshi Old Pontoon. (6-289)	34,745	34,745	0
		PC-02	Kasama - Luwingu Road Bridge (6-350)	6,504	6,504	0
		PC-03	Mbati (6-400)	44,427	44,427	0
		PP-01	Mukuku (Border Town)	92,452	92,452	0
		PP-02	Chembe Ferry (6-670)	123,072	109,932	13,140
		PP-03	Kashiba (6-785)	161,275	124,202	37,073
		PP-04	Kundabwika Falls (6-900)	12,396	12,396	0
		PP-05	Conf. of Kalungwishi R.	25,936	22,936	3,000
		PP-06	Pweto (ZAIRE)	217,823	157,750	60,073
	Basin	AC-01	Upper Chambeshi R.	34,745	34,745	0
		AC-02	Upper Lukulu R.	6,504	6,504	0
		AC-03	Lower Chambeshi R. and Lower Lukulu R.	3,178	3,178	0
		AP-01	Lake Bangweulu	48,025	48,025	0
		AP-02	Luela R. and others	30,620	17,480	13,140
		AP-03	Chembe Ferry to Kashiba	38,203	14,270	23,933
		AP-04	Upper Kalungwishi R.	12,396	12,396	0
		AP-05	Kalungwishi R. and Lake Mweru-Wantipa	13,540	10,540	3,000
		AP-06	Rest of Lake Mweru	30,612	10,612	20,000
Lake Tanganyika	Point	PT-01	Keso Falls (7-750)	9,027	9,027	0
	Basin	AT-01	Lufubu R.	9,027	9,027	0
		AT-02	Rest of Lake Tanganyika	-	6,829	-
Other Rivers	Basin	AO-01	Northernmost of Northern Province	-	1,615	-
		AO-02	Southernmost of Eastern Province	-	7,043	-

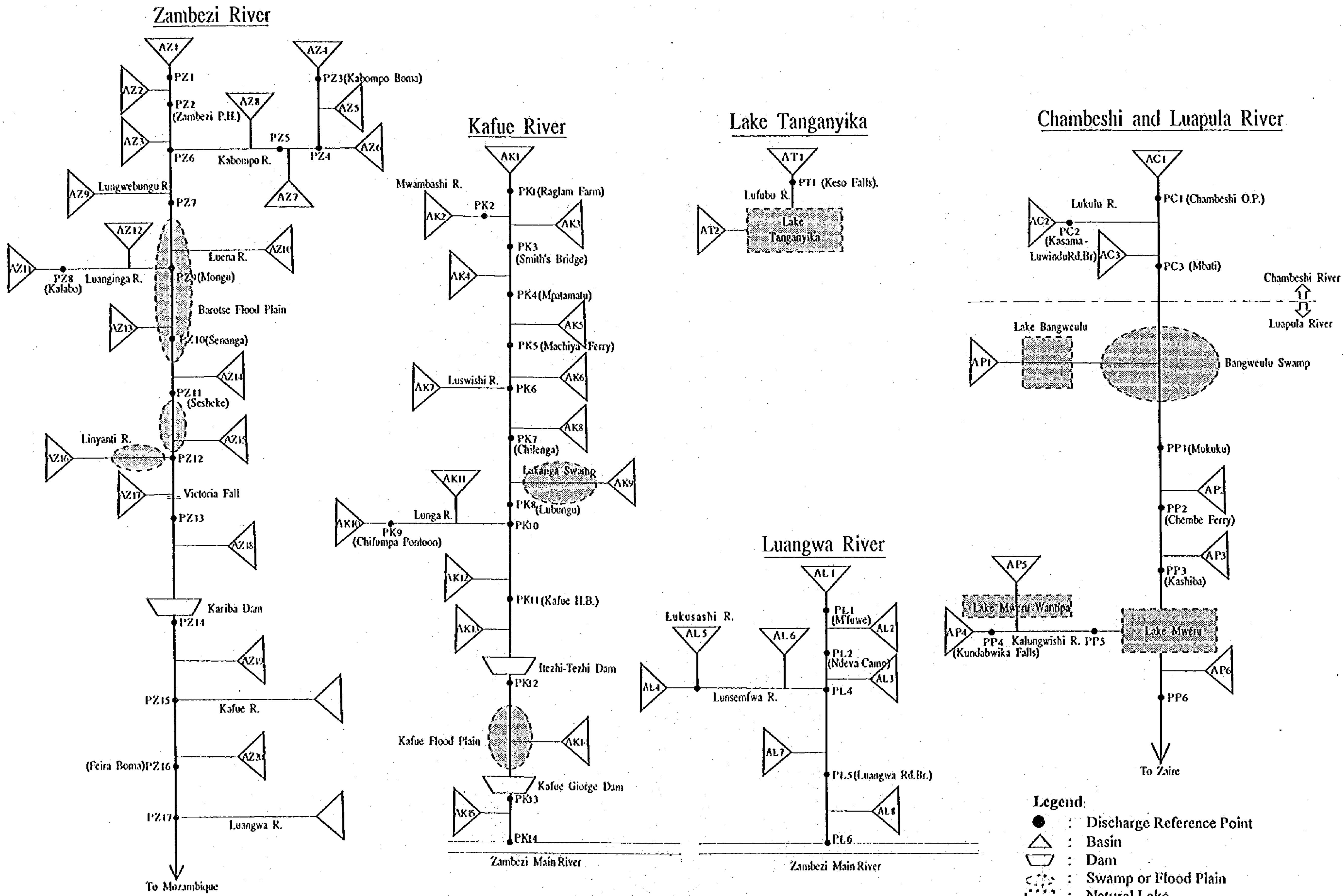


Figure 3-1 River Models in Zambia

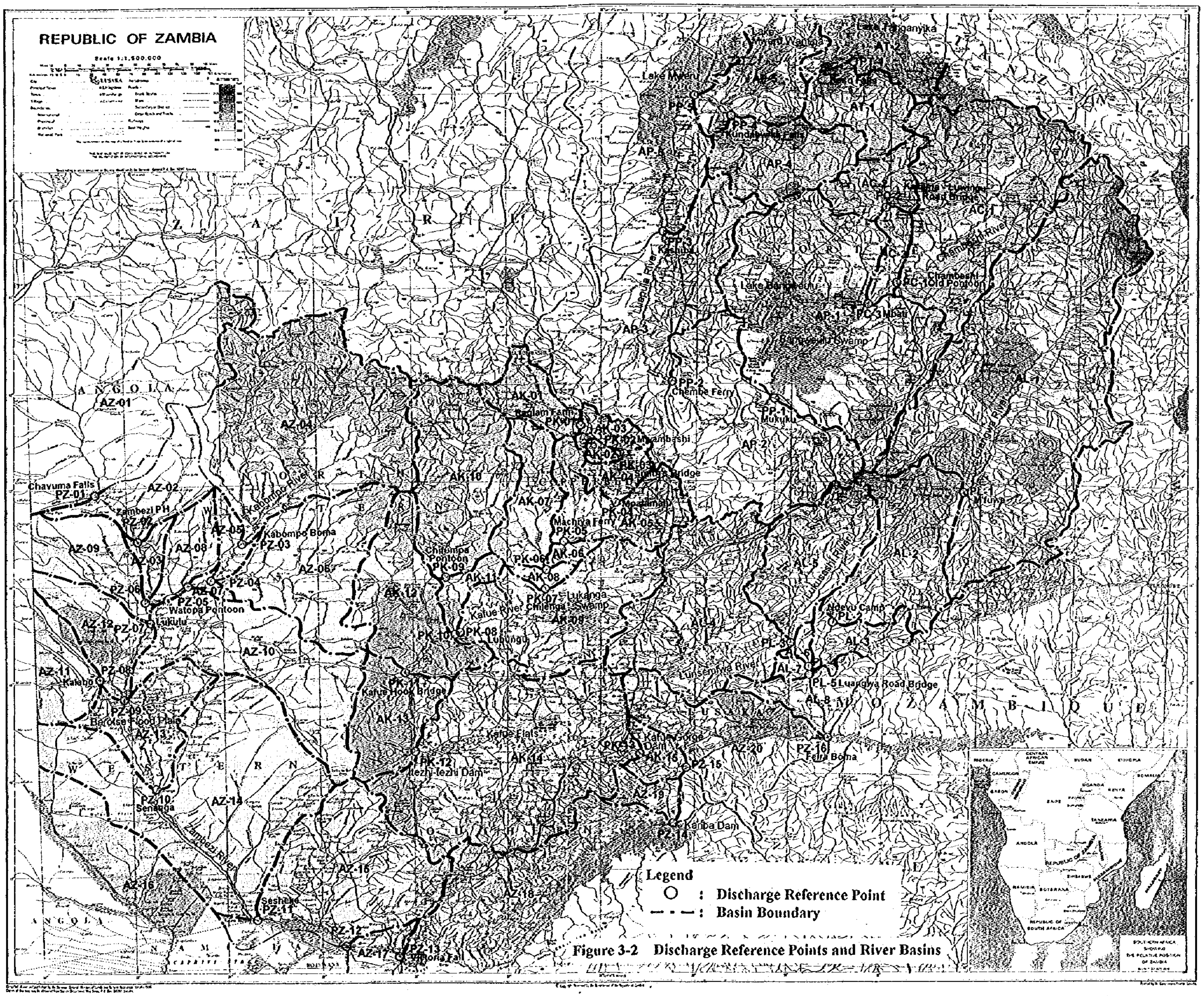


Figure 3-2 Discharge Reference Points and River Basins

CHAPTER 4 RECORDED RIVER FLOW

4.1 Establishment of Discharge Rating Curves

The establishment of a reliable relationship between the monitored water level and the corresponding discharge is essential at all river hydrometric stations. The discharge rating curve can often be represented by an equation of the following form :

$$Q = a \times (H - H_0)^b$$

where Q: discharge (m^3/s) H : gauge water level (m) a, b, H_0 : constants

All the discharge measurements, Q, at the hydrometric stations were plotted against the corresponding water levels, H. Assuming the constant b to be 2.0, the value of the constant a and H_0 were found by the least-squares fit. The discharge rating curves at the hydrometric stations were analysed and are presented in Table 4-1.

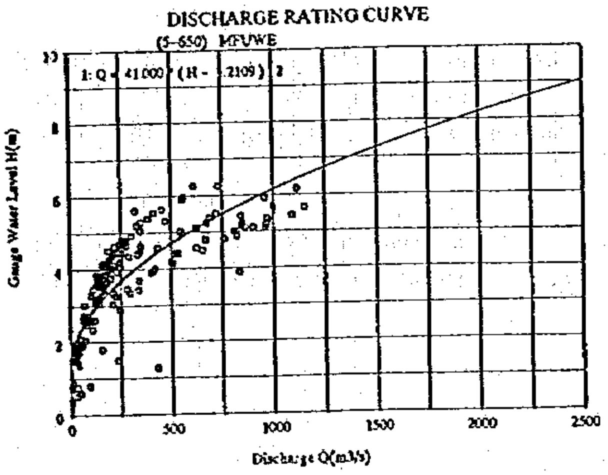
This calibration of hydrometric stations is dependent on the nature of channel section. Condition of a natural river are rarely stable for any length of time. However in Zambia, river flow channel seems stable according to the field reconnaissance and to the H-Q (water height [H] - discharge [Q]) plotting position. Then all the discharge rating curves were applied to all the period of water level observed, excluding the Mfuwe hydrometric station. The H-Q plotting positions at the Mfuwe hydrometric station scatter referring to the Figure 4-1(a) . The causes are supposed to be as follows :

- changing of the river channel section by erosion or sedimentation
- replacing of the water level gauge

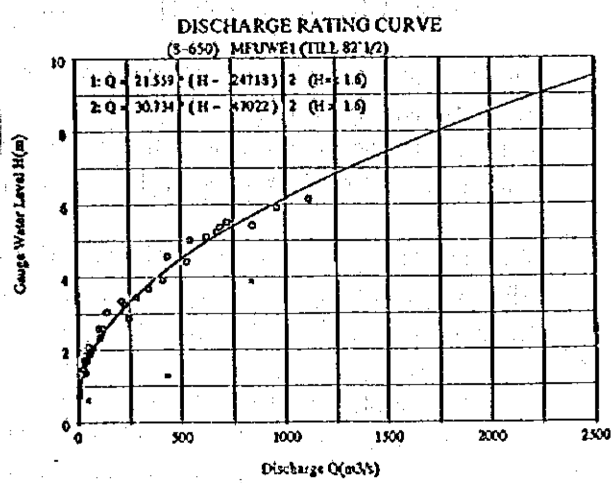
The plotting positions seem to be divided into three categories after carefully studying the figure. The plotting position could be divided into the three discharge rating curves of three periods by a process of trial and error. Referring to Figure 4-1(b), (c), (d). Although the DWA file has no report about the replacing of the gauge at Mfuwe, it is supposed that the gauge had been replaced because it is not supposed that natural erosion or sedimentation causes such big difference of the discharge rating curves.

Table 4-1 Discharge Rating Curve at Discharge Reference Points

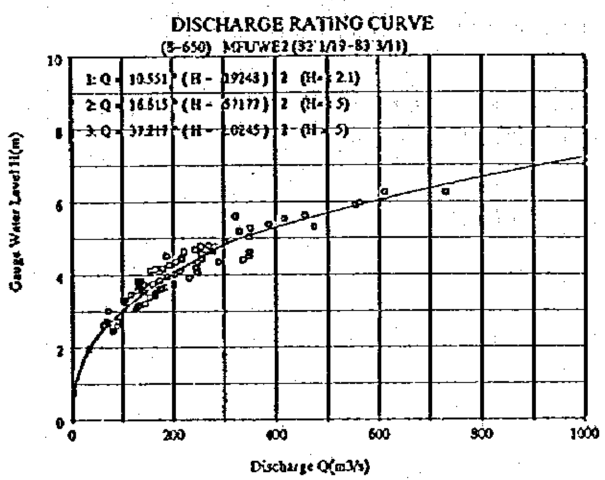
No.	Station Name & Number		Discharge Rating Curve	Water Level Range
PZ-02	Zambezi Pump House (1-150)		$Q = 27.665(H + 0.889)^2$	All of H
PZ-03	Kabompo Boma (1-650)		$Q = 77.029(H - 0.842)^2$	All of H
PZ-05	Watopa Pontoon (1-950)		$Q = 37.190(H - 0.523)^2$	H≦4.2 m
			$Q = 14.203(H + 1.755)^2$	H>4.2 m
PZ-07	Lukulu (2-030)		$Q = 33.862(H + 2.121)^2$	All of H
PZ-08	Kalabo (2-250)		$Q = 10.591(H + 0.293)^2$	H≦3.4 m
			$Q = 169.37(H - 2.454)^2$	H>3.4 m
PZ-10	Senanga (2-400)		$Q = 64.534(H + 1.305)^2$	All of H
PK-01	Raglan Farm (4-050)		$Q = 7.586(H - 1.007)^2$	H≦2.5 m
			$Q = 3.587(H + 1.144)^2$	H>2.5 m
PK-02	Mwambashi (4-120)		$Q = 2.112(H - 0.069)^2$	H≦2.8 m
			$Q = 6.168(H - 1.223)^2$	H>2.8 m
PK-03	Smith's Bridge (4-130)		$Q = 6.251(H + 0.133)^2$	All of H
PK-04	Mpatamatu (4-200)		$Q = 7.507(H + 0.619)^2$	All of H
PK-05	Machiya Ferry (4-280)		$Q = 11.409(H - 1.075)^2$	All of H
PK-07	Chilenga (4-350)		$Q = 9.716(H + 0.291)^2$	H≦5.5 m
			$Q = 51.843(H - 2.976)^2$	H>5.5 m
PK-08	Lubungu (4-450)		$Q = 32.665(H - 0.509)^2$	All of H
PK-09	Chifumpa Pontoon (4-560)		$Q = 26.533(H + 0.484)^2$	All of H
PK-11	Kafue Hook Bridge (4-669)		$Q = 115.30(H - 0.975)^2$	All of H
PL-1	Mfuwe (5-650)	(~82'02)	$Q = 21.559(H - 0.247)^2$	H≦1.60 m
			$Q = 30.734(H - 0.470)^2$	H>1.60 m
		(82'02 ~ 83'09)	$Q = 10.551(H - 0.192)^2$	H≦2.10 m
			$Q = 16.615(H - 0.572)^2$	2.10<H≦5.00 m
			$Q = 37.217(H - 2.025)^2$	H>5.00 m
		(83'10 ~)	$Q = 2.034H^2$	H≦1.50 m
			$Q = 57.813(H - 1.219)^2$	H>1.50 m
PL-2	Ndevu Camp (5-800)		$Q = 2.292H^2$	H≦1.20 m
			$Q = 70.526(H - 0.984)^2$	H>1.20 m
PL-5	Luangwa Road Bridge (5-940)		$Q = 6.222H^2$	H≦1.50 m
			$Q = 61.5586(H - 1.023)^2$	H>1.50 m
PC-1	Chambeshi Old Pontoon. (6-289)		$Q = 19.756(H - 0.018)^2$	All of H
PC-2	Kasama-Luwingu Rd.Br. (6-350)		$Q = 16.644(H - 6.522)^2$	All of H
PP-2	Chembe Ferry (6-670)		$Q = 74.290(H - 2.299)^2$	All of H
PP-3	Kashiba (6-785)		$Q = 33.143(H + 0.648)^2$	H≦6.0 m
			$Q = 82.427(H - 1.803)^2$	H>6.0 m
PP-4	Kundabwika Falls (6-900)		$Q = 62.437(H + 0.196)^2$	All of H
PT-1	Keso Falls (7-750)		$Q = 65.551(H - 0.573)^2$	All of H



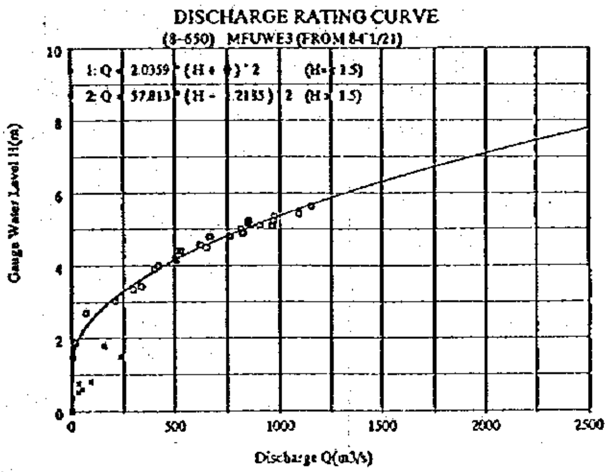
(a) M'fuwe : all data plotted (not adopted)



(b) M'fuwe : data [~82'01]

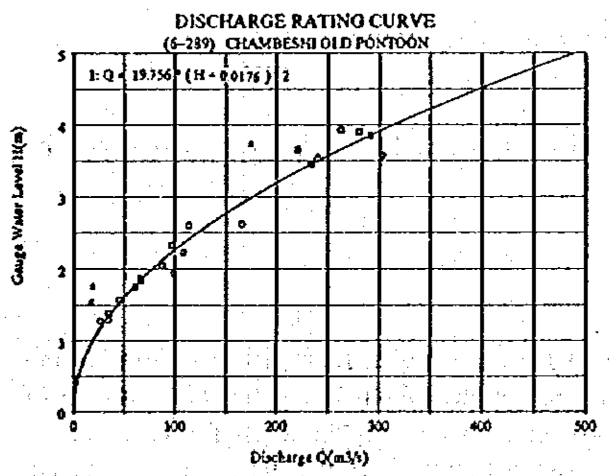


(c) M'fuwe : data [82'02~83'09]

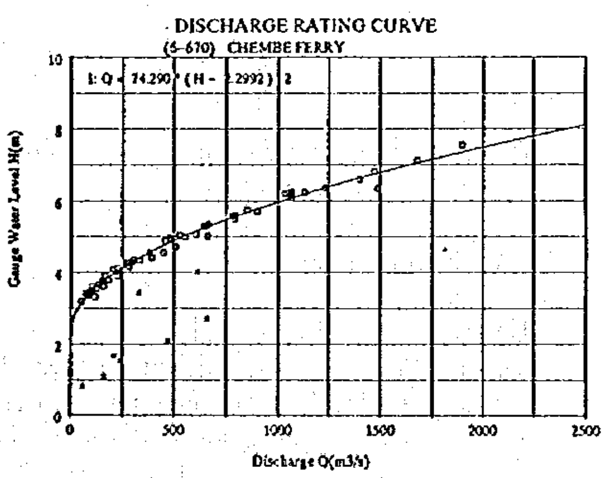


(d) M'fuwe : data [83'10~]

<u>M'fuwe in Luangwa River</u>



Chambeshi O.P. in Chambeshi River



Chembe Ferry in Luapula River

Figure 4-1 Discharge Rating Curves at M'fuwe, Chambeshi O.P. and Chembe Ferry

4.2 Flow Characteristics of Main River Systems

Daily river discharges at the hydrometric stations operated by DWA are calculated, using the daily water levels and the discharge rating curves. In addition, the Study Team collected daily discharges of Victoria Falls Big Tree, Kariba Dam, Itezhi-Tezhi Dam and Kafue Gorge Dam from the ZRA and SADC Project Office.

Average monthly mean discharge and average flow regime over the last 30 years (1963/64-1992/92) were compiled using the daily discharges and are summarised in Figure 4-4. These figures presents the following flow summaries:

- Monthly mean discharge
- Flow regime (Refer to Figure 4-2)
  - Q95 : High Discharge (a flow exceeded on 95 days a year)
  - Q185 : Median Discharge (a flow exceeded on 185 days a year)
  - Q275 : Low Discharge (a flow exceeded on 275 days a year)
  - Q355 : Drought Discharge (a flow exceeded on 355 days a year)
- Flow duration curve
- River longitudinal flow regime for median discharge (annual 185th discharge)
- Relationship between catchment area and specific discharge

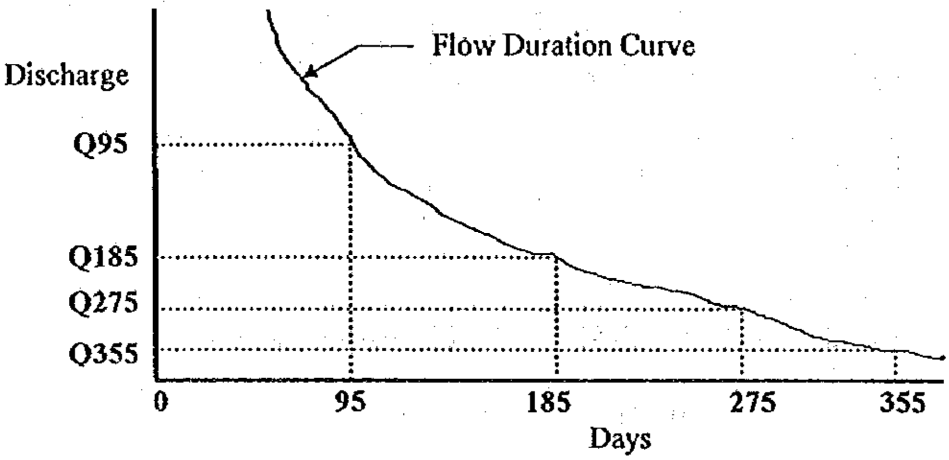


Figure 4-2 Concept of Flow Regime

Based on these flow summaries, the flow characteristics for each river system can be summarised as follows :

(a) Zambezi River

<u>Lower discharge at Lukulu</u>
The monthly mean discharge at Zambezi Pump House is higher than that at Lukulu during the rainy season between February and April, although Lukulu is located downstream of Zambezi Pump House. Flow at Lukulu is assumed to be flooded when the discharge is gushier than 1000 m^3/s, judging from the cross section and from a field reconnaissance. Under flood conditions, the discharge from upstream flows not only in the main stream but also across the flood plain.

Large effect of the Barrotse flood plain
The monthly mean discharge at Zambezi Pump House increases rapidly from December to February and peaks in March, whereas the monthly discharge downstream increases more gradually and later. The peak monthly discharge is delayed by half a month at Lukulu and by a month at Senanga and Livingstone. The flow duration curve at Zambezi Pump House is obviously different from the others. All the curves above 30% of the time have the same trend, however the curve at Zambezi Pump House has a different trend, showing a rapid decrease in discharge. These characteristics suggest that the huge flood plain has a large effect on both discharge and flood control.

Specific discharge at Watopa Pontoon
The specific discharge of the median flow at Watopa Pontoon of 2.16 $m^3/s/1000km^2$ is smaller than that at Kabompo Boma and Zambezi Pump House, 3.45 and 2.67 $m^3/s/1000km^2$ respectively. This was assumed to mainly result from the small discharge from Dongwe River. However the specific discharge at Watopa Pontoon, 2.16, is nearly the same as that at Lubungu, 1.99, on the Kafue River with almost the same catchment area. Thus 2.16 $m^3/s/1000km^2$ at Watopa Pontoon is assumed to be a reasonable figure in Zambia and the specific discharges at Zambezi Pump House, Lukulu and Senanga along the Zambezi Main River are clearly larger than the Kafue River.

Luanginga River
The specific discharge of the median flow at Kalabo on the Luanginga River, 0.93 $m^3/s/1000km^2$, is quite low and is only 35 % of that at Zambezi Pump House, 2.67 $m^3/s/1000km^2$.

(b) Kafue River

Effect of Lukanga Swamp
The specific discharge of the median flow at Lubungu, 1.99 $m^3/s/1000km^2$, is small, compared with those at Chilenga upstream and Kafue Hook Bridge downstream. A major cause of this discharge loss is considered to be evapotranspiration from the Lukanga Swamp located between Chilenga and Lubungu.

Flood and low flow discharge peaks
Flood flow in the Kafue River peaks in March. The peaks in low flow occur in October or November.

Catchment area and specific discharge
The Kafue River has a definite relationship between the catchment areas and specific discharge. Based on the curve in Figure 4-4(2), the relationship is as follows :

Catchment area	Specific median discharge	Catchment area	Specific media discharge
20,000 km^2	3.5 $m^3/s/1000\ km^2$	40,000 km^2	2.6 $m^3/s/1000\ km^2$
60,000 km^2	2.2 $m^3/s/1000\ km^2$	80,000 km^2	1.9 $m^3/s/1000\ km^2$
100,000 km^2	1.8 $m^3/s/1000\ km^2$		

Low specific discharge at Chifumpa Pontoon on Lunga River
Although the basin of Lunga River is located in a high rainfall area (annual rainfall 1,100~1,300 mm) , the specific discharge of the median flow at Chifumpa Pontoon, 2.24

$m^3/s/1000\ km^2$, is lower (only 72%) than that at Machiya Ferry which has almost same catchment area.

Effect of groundwater drainage from copper mines
The specific discharge of the median flow at Smith's Bridge, 4.54 $m^3/s/1000\ km^2$, is slightly higher than that at Raglan Farm, 3.50 $m^3/s/1000\ km^2$. In this area there are many copper mines which pump groundwater to the Kafue River. Groundwater volume pumped from these mines was reported by ZCCM to total 640,928 m^3/day (7.4 m^3/s) in May 1994. There is no copper mining upstream of Raglan Farm but many mines upstream of Smith's Bridge. The recorded specific discharge and the one after 7.4 m^3/s deduction is compared at Smith's Bridge in May 1994 as follows :

Gauge station	Specific discharge in May 1994
Raglan Farm	9.46 $m^3/s/1000\ km^2$
Smith's Bridge	10.37 $m^3/s/1000\ km^2$
Smith's Bridge after 7.4 m^3/s deduction	9.54 $m^3/s/1000\ km^2$

Accordingly, a major cause of the larger specific discharge downstream of Raglan Farm is considered to be groundwater pumped from the copper mines. The small swamp area upstream of Raglan Farm is also thought to be a cause of the slightly low specific discharge at Raglan Farm.

(c) Luangwa River

Flood and low flow discharge peaks
Flood flow in the Luangwa River peaks in February and low flow peaks occur in October.

Lower discharge at Ndevu Camp
The monthly mean discharge at Ndevu Camp is lower than that at Mfuwe in the dry season from April to November, although Ndevu Camp is located downstream of Mfuwe. The specific discharge of the median flow is also lower than that at Mfuwe. No obvious cause of the low discharge at Ndevu Camp is apparent but it is assumed to be caused by the inaccuracy of the discharge rating curve in low flow range.

(d) Chambeshi, Luapula River and Lake Tanganyika Basin

Flood and low flow discharge peaks
Flood flow in the Luangwa River peaks in between March and April and low flow peaks occur in November.

Lukulu River, Kalungwishi River and Lufubu River
The specific discharges of the median flow of the neighbouring rivers, such as Kasama-Luwingu Road Bridge on Lukulu River, Kundabwika Falls on Kalungwishi River and Keso Falls on Lufubu River, range from 6.41 to 8.65 $m^3/s/1000km^2$ and are approximately the same.

Effect of Lake Bangweulu
The specific discharges of the median flow on the Chambeshi River and the Luapula River seem to increase downstream as shown in Figure 4-4(4). However the monthly mean specific discharge in Figure 4-3 shows the following :

- The specific discharge at Chambeshi Old Pontoon is higher during October to May, and lower during June to September, than the others.
- The specific discharge from Chambeshi Old Pontoon to Chembe Ferry decreases noticeably by 3 $m^3/s/1000km^2$ between January and April.
- The specific discharge from Chembe Ferry to Kashiba increases for all months.

Taking account of Lake Bangweulu and the Bangweulu Swamp, the facts mentioned above suggest the following : The Chambeshi River supplies water to Lake Bangweulu between December and April. Lake Bangweulu starts to supply water stored in the rainy season from May. This is a discharge regulation function of Lake Bangweulu. This helps explains why the specific discharges at Chembe Ferry and Kashiba are larger during October to May, and smaller during June to September, than that at Chambeshi Old Pontoon.

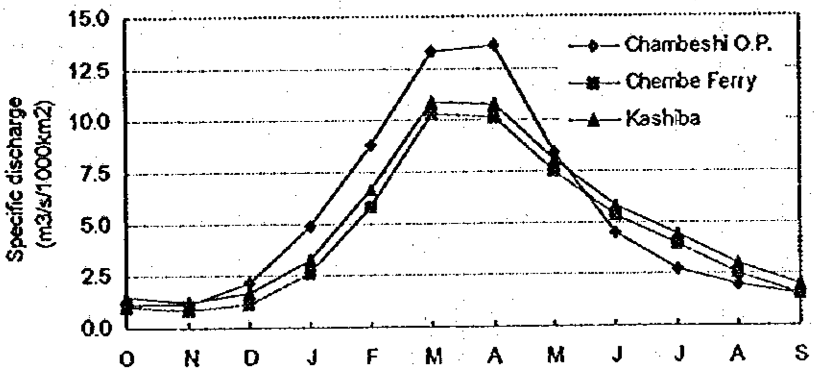


Figure 4-3 Monthly Mean Specific Discharge (Luapula River)

Average Flow Summary in ZAMBEZI RIVER during Last 30 years (1963-1992)

No.	Reference Point	Catchment Area(km2)	Monthly Mean Discharge (m3/s) Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Flow regime (m3/s) Max.	Q(95)	Q(185)	Q(275)	Q(355)	Min.	Average	Annual runoff (Mm3)
PZ-02	Zambezi P.H.	87275	72	94	225	662	1409	2000	1851	763	314	179	122	86	2853	910	233	105	66	59	646	20413
PZ-03	Kabompo B.	42740	66	88	172	258	392	508	477	245	155	123	95	73	686	299	148	90	54	52	221	6980
PZ-05	Watopa P.	67261	71	92	176	297	475	594	522	244	146	119	98	79	790	340	143	93	64	60	242	7768
PZ-07	Lukulu	206531	296	336	498	863	1336	1726	1663	957	569	428	358	312	2134	1076	503	342	282	270	777	24593
PZ-08	Kalabo	34621	8	7	11	34	126	216	188	102	68	43	24	14	345	99	32	10	6	6	70	2203
PZ-10	Senanga	284538	306	339	486	771	1211	1853	2173	1855	1205	689	461	357	2372	1452	664	384	291	279	963	31252
PZ-13	Victoria Fall	513780	337	354	507	777	1270	1972	2762	2577	1770	949	579	423	3225	1766	777	449	316	298	1187	37811
PZ-14(2)	Kariba Dam	663880	919	998	1055	1294	1664	1849	1927	1615	1216	1225	970	885	6668	1083	904	729	482	455	1299	40964

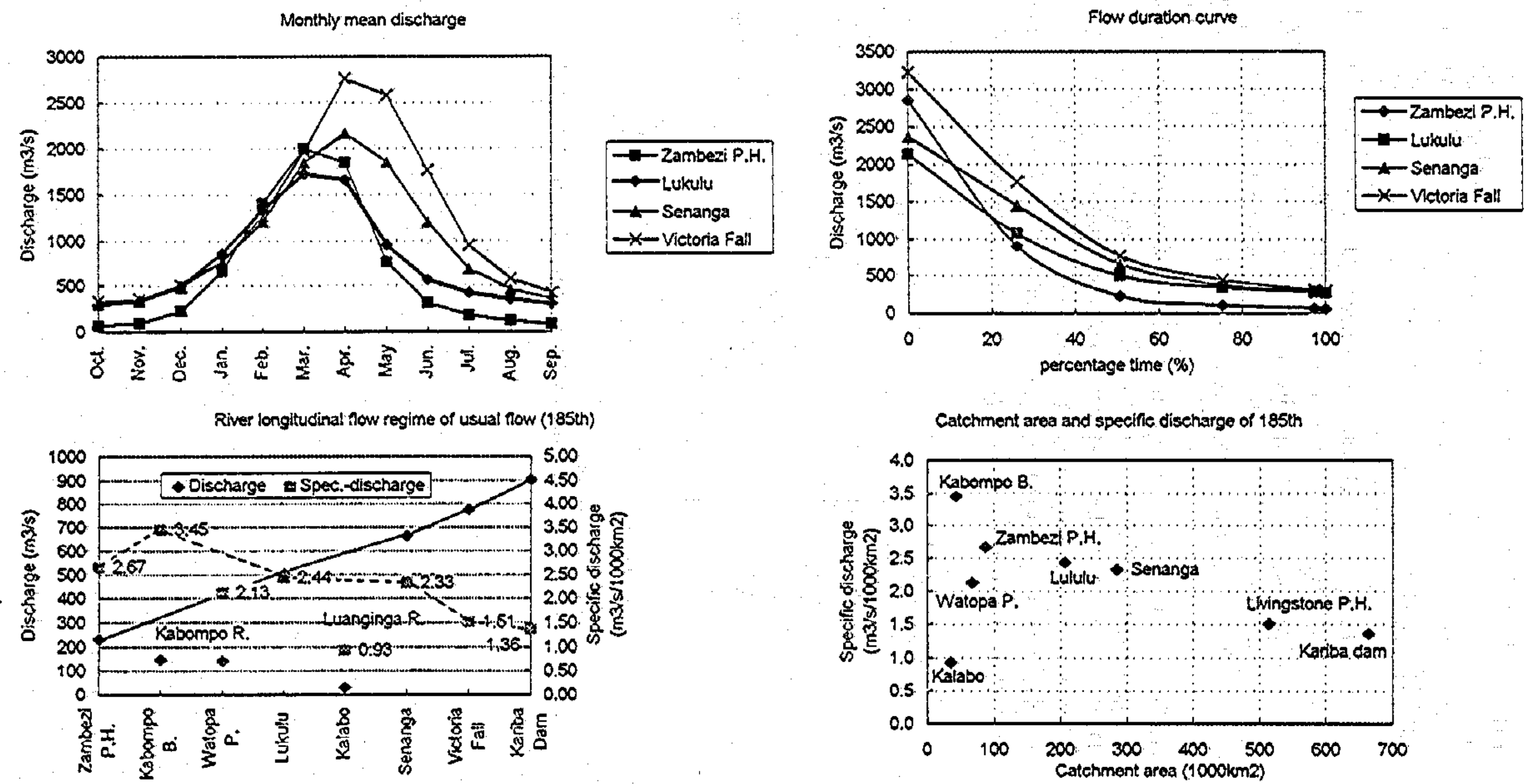
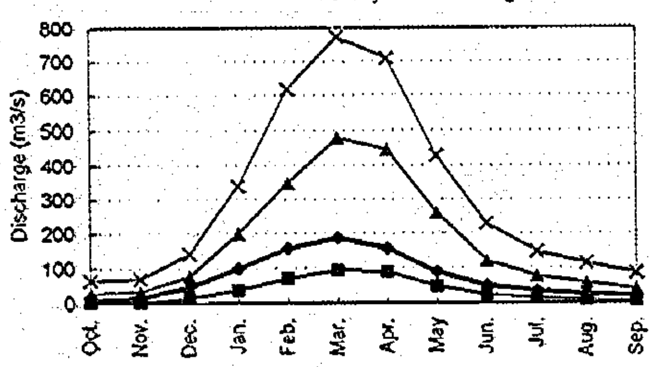
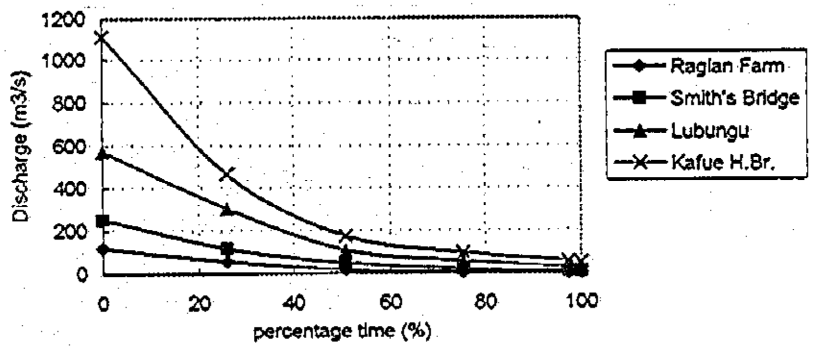


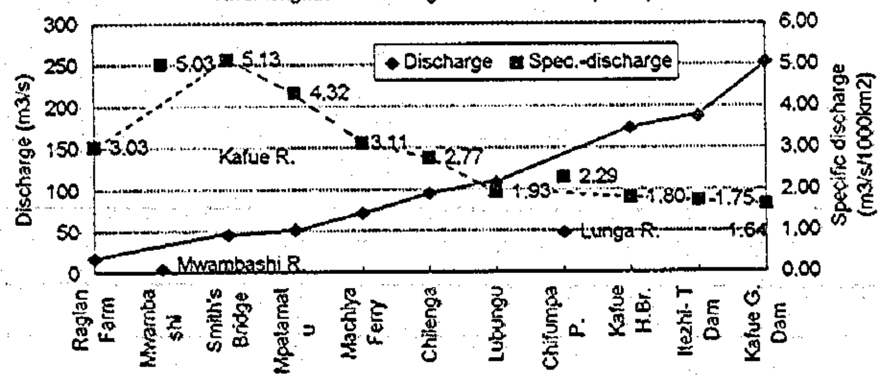
Figure 4-4(1) Flow Characteristics in Zambezi River

Average Flow Summary in KAFUE RIVER during Last 30 years (1963-1992)

No.	Reference Point	Catchment Area(km2)	Monthly Mean Discharge (m3/s) Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Flow regime (m3/s) Max.	Q(95)	Q(185)	Q(275)	Q(355)	Min.	Average	Annual runoff (Mm3)
PK-01	Raglan Farm	5775	3	4	14	37	72	95	89	47	22	13	9	5	117	55	18	6	2	2	34	1072
PK-02	Mwambashi	827	2	2	6	12	18	19	13	6	4	3	3	2	35	11	4	2	1	1	7	236
PK-03	Smith's Bridge	8914	12	16	46	100	157	186	156	89	50	33	24	17	251	116	46	21	10	9	74	2368
PK-04	Mpatamatu	12001	18	23	58	129	214	244	191	98	55	39	30	23	330	139	52	27	15	14	93	2924
PK-05	Machiya Ferry	23065	24	28	71	180	308	372	316	160	81	57	44	32	453	213	72	37	21	19	138	4366
PK-07	Chilenga	34451	29	32	77	199	347	479	445	260	121	77	56	39	571	281	95	44	24	23	179	5650
PK-08	Lubungu	55962	36	39	81	208	359	463	450	291	151	92	68	49	575	304	108	55	29	27	189	5979
PK-09	Chifumpa P.	20999	22	26	55	107	193	239	188	82	50	41	34	26	431	116	48	30	19	18	88	2777
PK-11	Kafue H.Br.	96239	66	70	142	338	619	774	709	428	229	147	113	86	1113	469	173	95	55	49	308	9723
PK-12(2)	Itezhi- T Dam	107191	181	177	193	252	370	485	474	340	249	172	163	176	832	325	188	147	109	85	278	8259
PK-13(2)	Kafue G. Dam	153826	183	169	181	205	290	361	441	466	447	396	298	218	574	402	253	177	123	100	296	9278







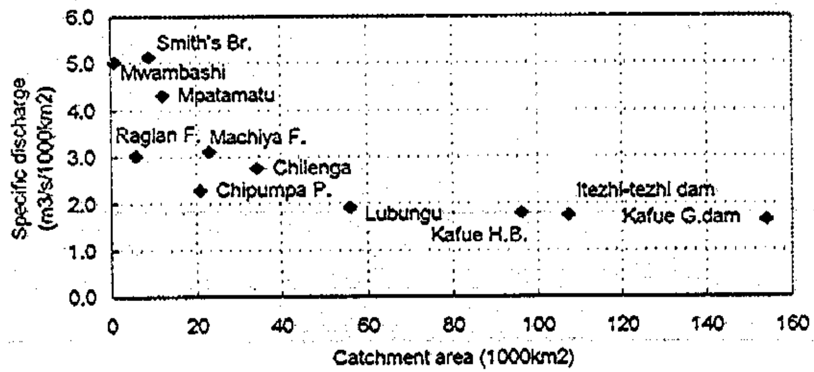


Figure 4-4(2) Flow Characteristics in Kafue River

Average Flow Summary in LUANGWA RIVER during Last 30 years (1963-1992)

No.	Reference Point	Catchment Area(km2)	Monthly Mean Discharge (m3/s) Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Flow regime (m3/s) Max.	Q(95)	Q(185)	Q(275)	Q(355)	Min.	Average	Annual runoff (Mm3)
PL-1	M'fuwe	73422	55	56	185	487	813	800	469	212	133	100	80	64	1610	376	126	73	39	34	283	8894
PL-2	Ndevu Camp	91861	21	31	208	638	1232	888	446	165	83	56	37	24	3329	387	82	34	12	11	327	10270
PL-5	Luangwa Rd.Br.	140922	56	67	424	1320	1917	1865	1121	420	214	146	104	73	4258	849	202	87	39	36	639	19637

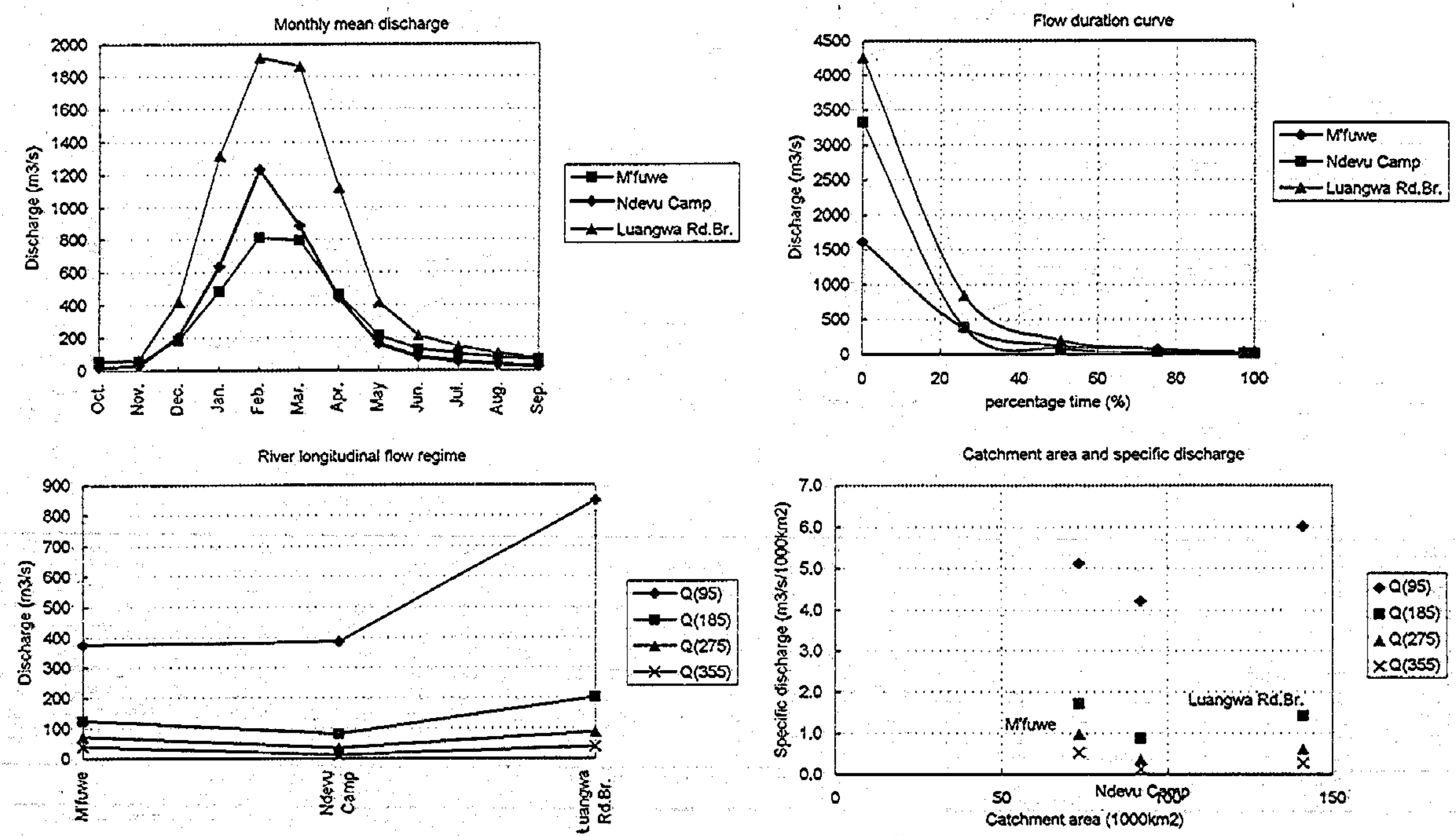


Figure 4-4(3) Flow Characteristics in Luangwa River

Average Flow Summary in CHAMBESHI & LUAPULA RIVER, LAKE TANGANYIKA during Last 30 years (1963-1992)

No.	Reference Point	Catchment Area(km2)	Monthly Mean Discharge (m3/s) Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Flow regime (m3/s) Max.	Q(95)	Q(185)	Q(275)	Q(355)	Min.	Average	Annual runoff (Mm3)
PC-1	Chambeshi O.P.	34745	40	40	75	170	307	461	471	294	155	96	68	51	582	280	108	55	35	33	185	5833
PC-2	Kasama L.Rd.Br.	6504	34	39	65	93	117	139	122	75	57	49	43	36	206	95	55	41	31	30	73	2291
PP-2	Chembe Ferry	123072	129	104	141	321	711	1264	1248	922	655	479	316	188	1470	768	385	168	99	87	499	17724
PP-3	Kashiba	161275	237	195	265	536	1068	1758	1741	1295	931	712	488	323	2021	1096	606	294	190	174	741	26044
PP-4	Kundabwika F.	12396	58	65	111	168	202	261	256	154	109	90	74	62	387	181	104	71	51	49	136	4101
PT-1	Keso Falls	9027	17	20	41	77	112	161	149	77	48	34	25	19	301	89	41	23	15	14	66	1999

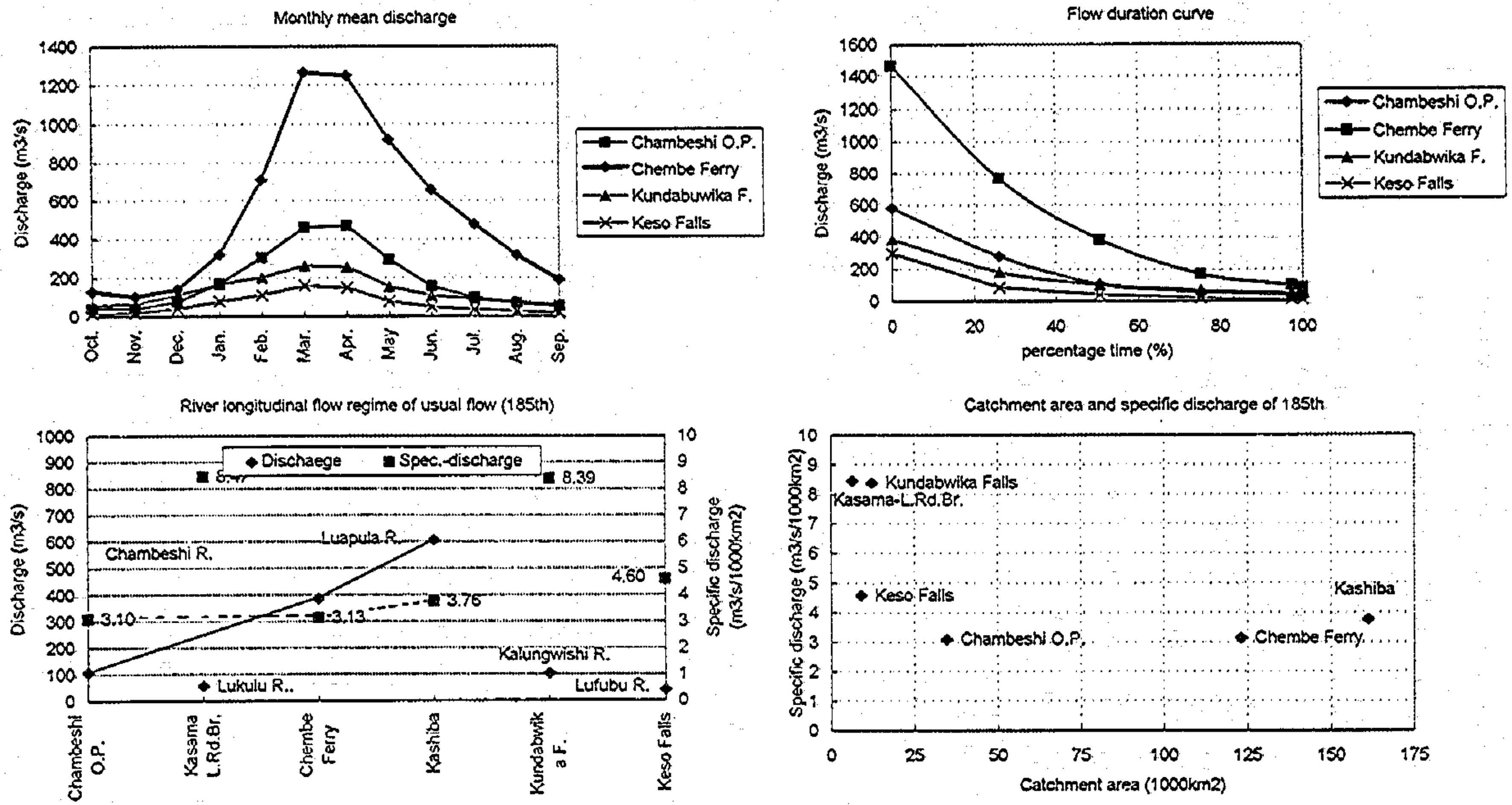


Figure 4-4(4) Flow Characteristics in Chambeshi River, Luapula River and Lake Tanganyika

CHAPTER 5 RIVER FLOW SUMMARIES

5.1 Monthly Discharge and Flow Regime

The monthly discharges and flow regime at the remaining discharge reference points, which have no measured discharges, are calculated according to the ratio of catchment areas of the discharges measured upstream and downstream. The monthly discharges and flow regime at all the discharge reference points, are shown in Table 5-1. The Figure 5-1 presents flow regime of discharge reference points, namely average discharge, high discharge (Q95), median discharge (Q185), low discharge (Q275) and drought discharge (Q355). Besides Figure 5-2 shows river-longitudinal variation of average discharge in the main rivers.

5.2 Probable Discharge

Probable minimum discharge for a 30-year return period and probable drought discharge for 2, 5, 10-year return periods are studied using the Thomas plot method and are shown in Table 5-2. Thomas equation is one of the equations of order statistics and is shown as follows:

$$W = \frac{i}{(N+1)}$$

Where, W : probability of exceedance, T : return period ($T = \frac{1}{W}$)

i : order from maximum or minimum

N : sample size (number of observation years)

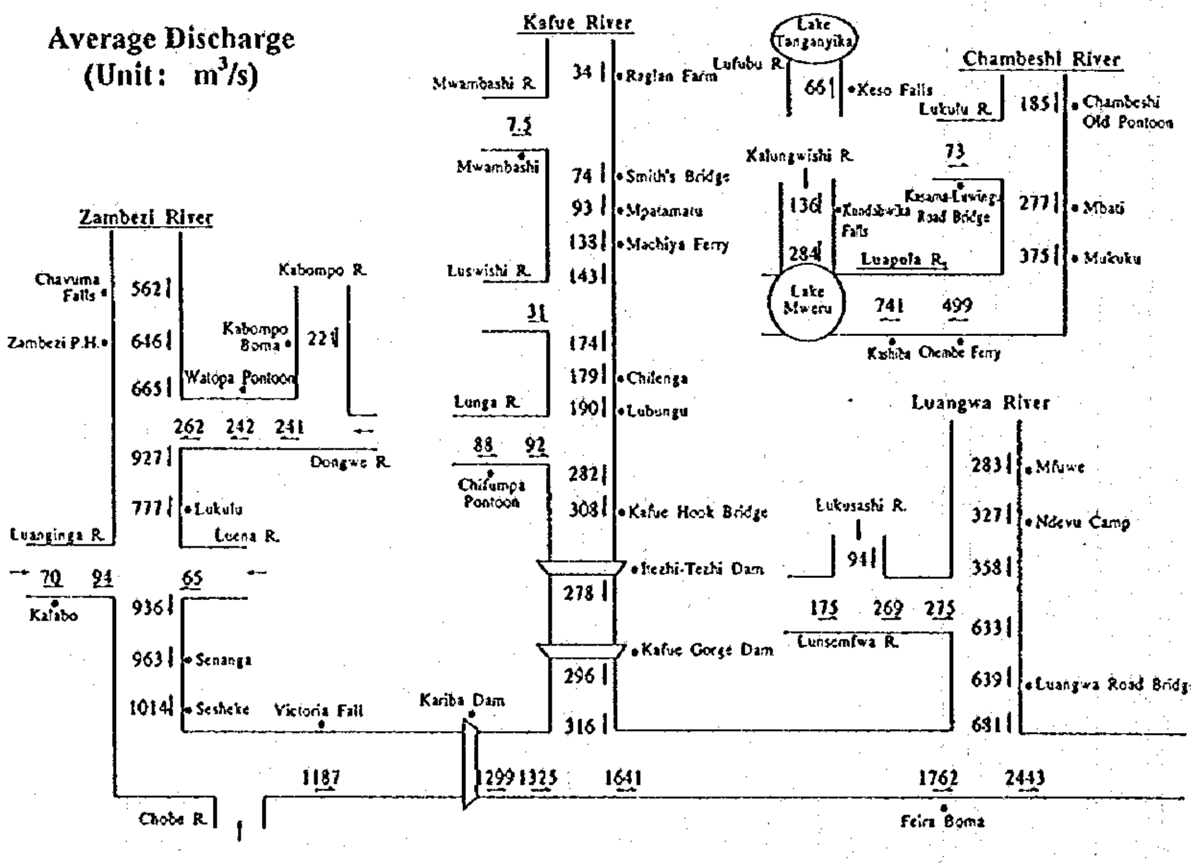


Figure 5-1 (1) Flow Regime in Main Rivers (Average Discharge)

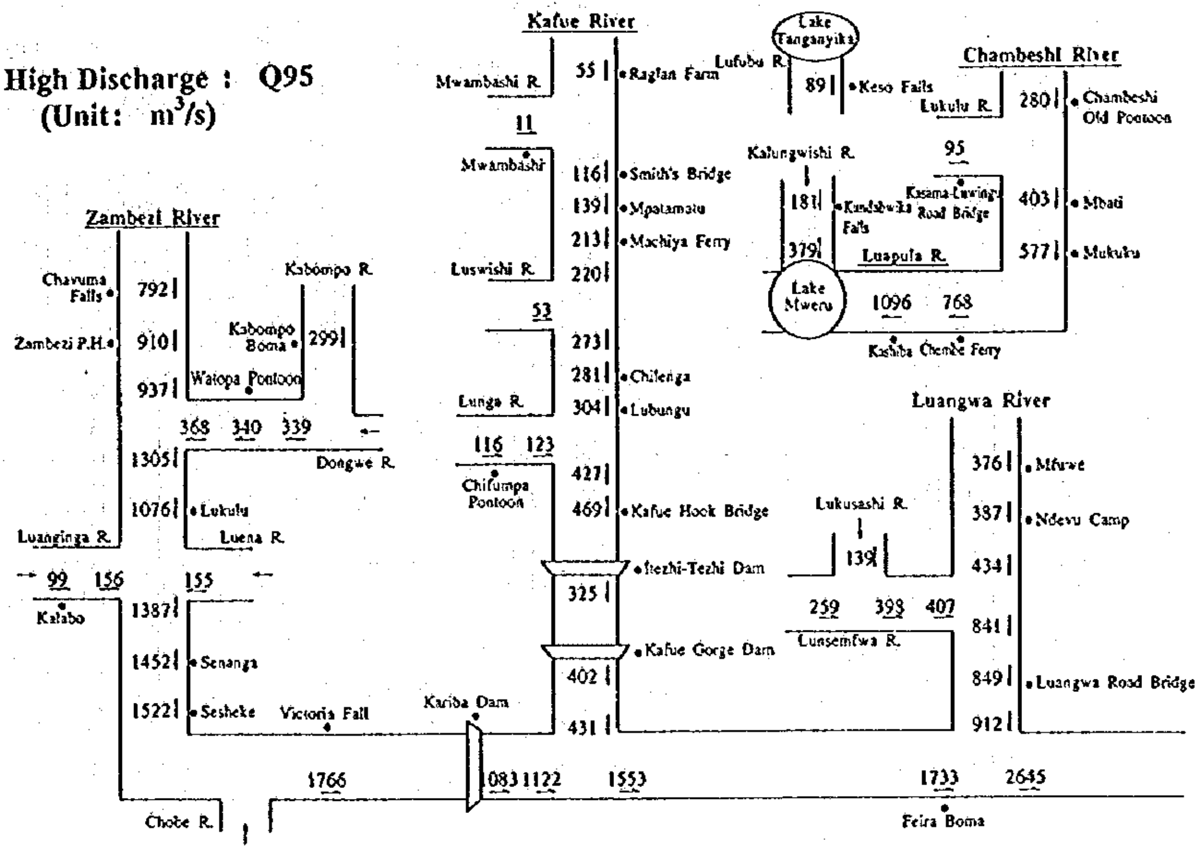


Figure 5-1 (2) Flow Regime in Main Rivers (High Discharge)

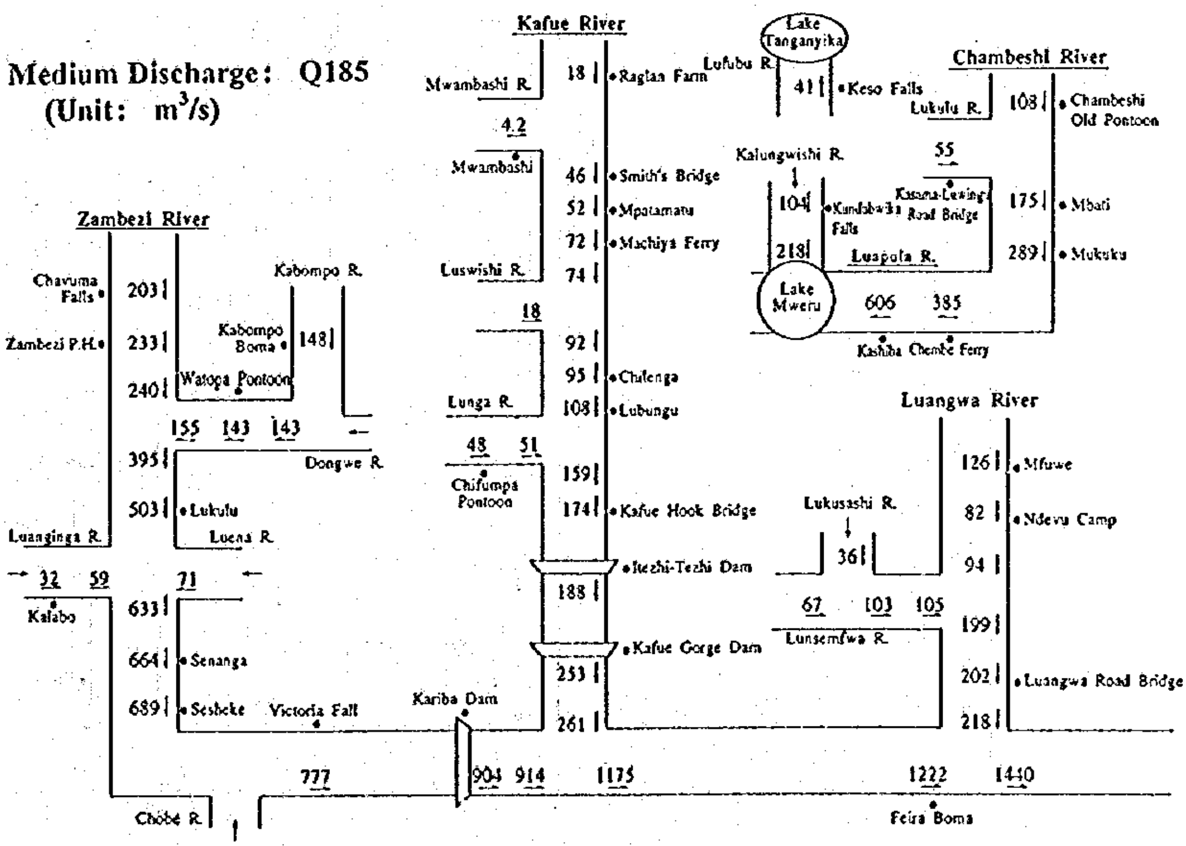


Figure 5-1 (3) Flow Regime in Main Rivers (Medium Discharge)

Low Discharge : Q275
(Unit: m^3/s)

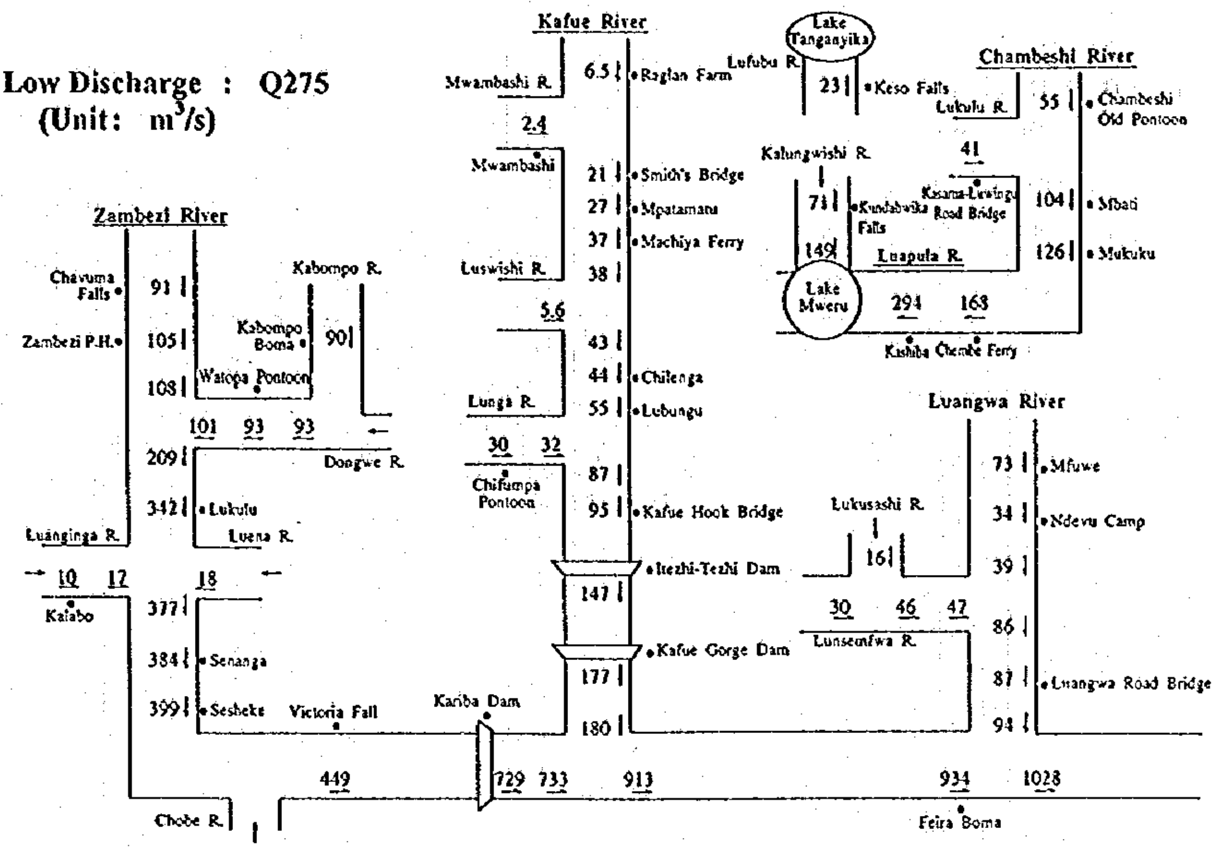


Figure 5-1 (4) Flow Regime in Main Rivers (Low Discharge)

Drought Discharge: Q355
(Unit: m^3/s)

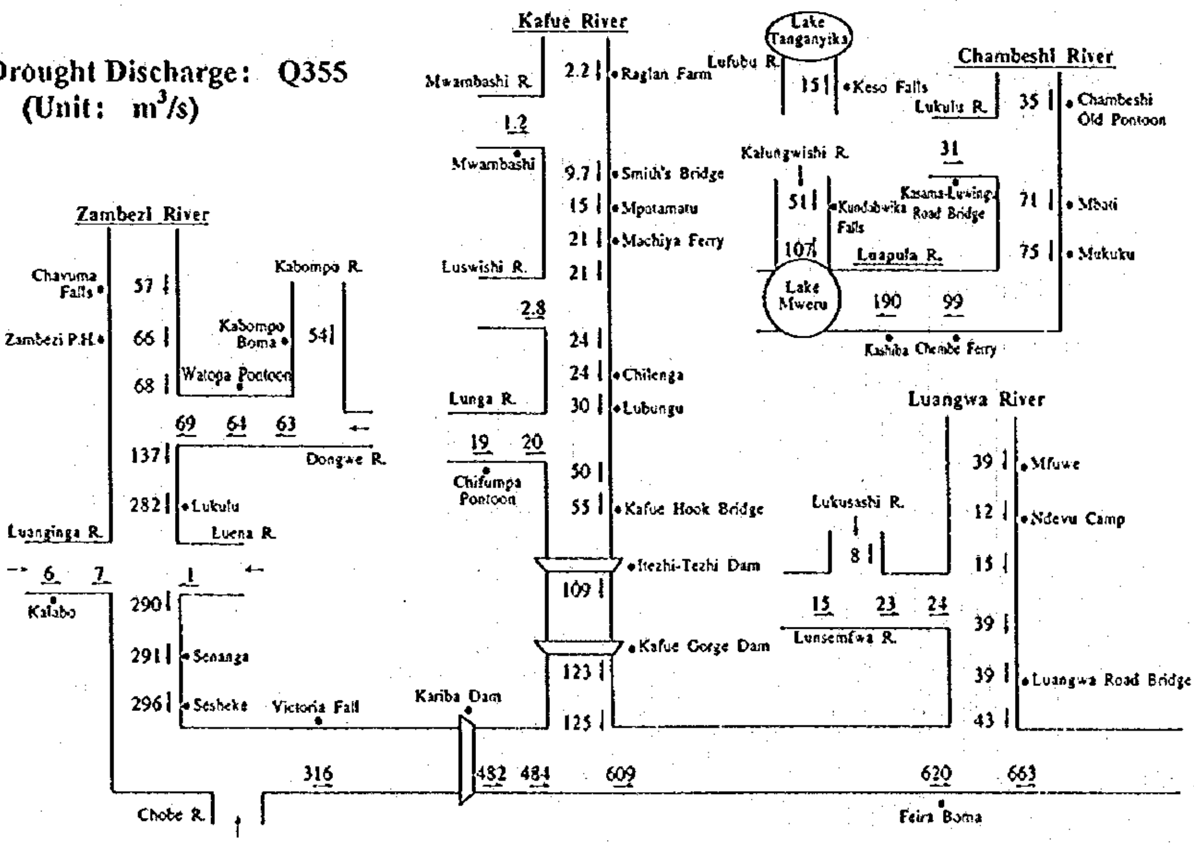


Figure 5-1 (5) Flow Regime in Main Rivers (Drought Discharge)

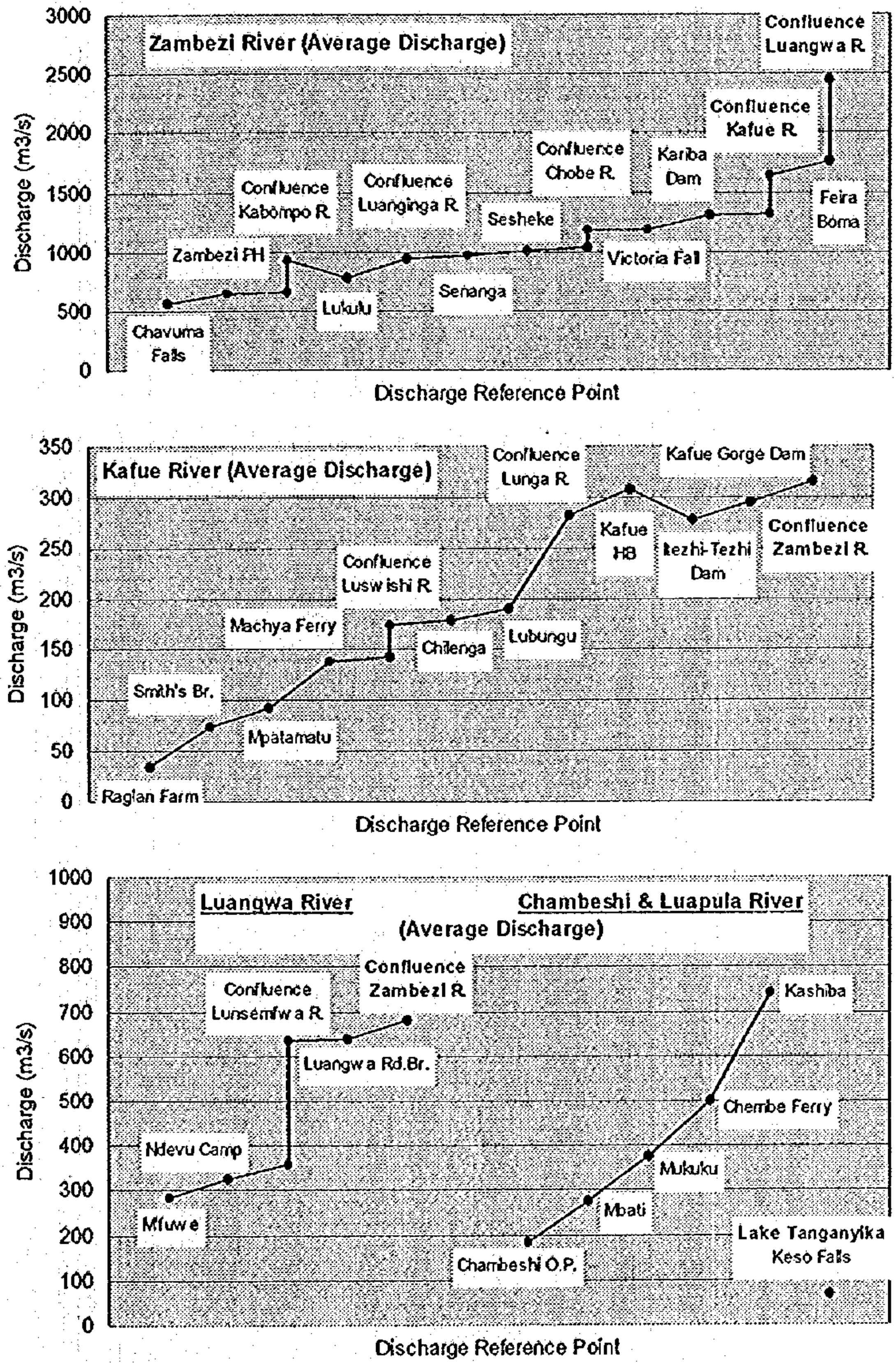


Figure 5-2 River-longitudinal Variation of Average Discharge

Table 5-1(1) Monthly Discharge and Flow Regime (30 years average : 1963-1992)

No.	Reference Point Name	Catchment Area (km2)	Monthly Mean Discharge (m3/s) Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Flow Regime (m3/s) Max.	Q (95)	Q (185)	Q (275)	Q (355)	Min.	*1 Average Ave-rage	10-year drought	Annual Runoff (Mm3)
ZAMBEZI RIVER																							
PZ-01	Chavuma Falls (1-105)	75,967	63	82	196	576	1226	1741	1612	664	274	156	106	74	2483	792	203	91	57	51	562	258	17768
PZ-02	Zambezi Pump House (1-150)	87,275	72	94	225	662	1409	2000	1851	763	314	179	122	86	2853	910	233	105	66	59	646	296	20413
PZ-03	Kabompo Boma (1-650)	42,740	66	88	172	258	392	508	477	245	155	123	95	73	686	299	148	90	54	52	221	119	6980
PZ-04(3)	Confluence (Kabompo R. After Dongwe R.)	66,375	71	92	176	295	472	591	521	244	147	119	98	79	786	339	143	93	63	60	241	137	7739
PZ-05	Watopa Pontoon (1-950)	67,261	71	92	176	297	475	594	522	244	146	119	98	79	790	340	143	93	64	60	242	138	7768
PZ-06(1)	Confluence (Before Kabompo R.)	89,874	74	97	232	682	1451	2060	1907	786	324	184	126	88	2938	937	240	108	68	61	665	305	21021
PZ-06(2)	Confluence (Kabompo R. Portion.)	72,751	77	100	190	321	514	642	565	264	158	129	106	85	854	368	155	101	69	65	262	149	8402
PZ-06(3)	Confluence (After Kabompo R.)	162,625	151	196	422	1003	1964	2702	2471	1050	482	313	232	173	3792	1305	395	209	137	126	927	454	29423
PZ-07	Lukulu (2-030)	206,531	296	336	498	863	1336	1726	1663	957	569	428	358	312	2134	1076	503	342	282	270	777	538	24593
PZ-08	Kalabo (2-250)	34,621	8	7	11	34	126	216	188	102	68	43	24	14	345	99	32	10	6	6	70	31	2203
PZ-09(2)	Confluence (Luanginga R. Portion.)	43,619	9	6	7	8	74	198	255	267	186	88	41	20	323	156	59	17	7	6	94	53	3127
PZ-09(3)	Confluence (After Luena R. and Luanginga R.)	274,328	305	340	491	801	1270	1874	2097	1668	1071	638	443	350	2397	1387	633	377	290	278	936	651	30203
PZ-10	Senanga (2-400)	284,538	306	339	486	771	1211	1853	2173	1855	1205	689	461	357	2372	1452	664	384	291	279	963	676	31252
PZ-11	Sesheke (2-700)	336,053	313	342	491	773	1224	1880	2305	2017	1332	747	488	372	2564	1522	689	399	296	283	1014	691	32726
PZ-12(1)	Confluence (Before Chobe R.)	362,953	316	344	493	773	1231	1894	2375	2102	1399	778	502	380	2664	1559	702	406	299	286	1040	699	33495
PZ-12(2)	Confluence (Chobe R. Portion.)	144,400	20	9	13	4	37	75	371	455	356	164	74	42	537	198	71	41	16	12	141	43	4132
PZ-12(3)	Confluence (After Chobe R.)	507,353	336	353	507	777	1269	1969	2745	2557	1754	941	576	422	3201	1758	774	447	315	298	1181	742	37627
PZ-13	Victoria Fall Big Tree (ZRA)	513,780	337	354	507	777	1270	1972	2762	2577	1770	949	579	423	3225	1766	777	449	316	298	1187	744	37811
PZ-14(2)	Kariba Dam (Outflow)	663,880	919	998	1055	1294	1664	1849	1927	1615	1216	1225	970	885	6668	1083	904	729	482	455	1299	756	40964
PZ-15(1)	Confluence (Before Kafue R.)	667,970	922	1001	1073	1351	1721	1930	1983	1636	1227	1232	976	889	6745	1122	914	733	484	457	1325	765	41745
PZ-15(2)	Confluence (Kafue R. Portion)	156,995	186	171	195	249	334	425	485	482	456	401	302	221	634	431	261	180	125	102	316	169	9882
PZ-15(3)	Confluence (After Kafue R.)	824,965	1108	1173	1268	1600	2055	2355	2468	2118	1682	1634	1278	1111	7379	1553	1175	913	609	559	1641	933	51627
PZ-16	Feira Boma (5-099)	844,044	1122	1187	1352	1865	2321	2735	2731	2218	1733	1669	1304	1130	7740	1732	1222	934	620	569	1762	974	55270
PZ-17(1)	Confluence (Luangwa R. Portion)	147,622	61	72	454	1413	2010	1998	1214	455	231	158	113	80	4385	912	218	94	43	40	681	337	22318
PZ-17(2)	Confluence (After Luangwa R.)	991,666	1182	1258	1805	3278	4332	4733	3944	2673	1964	1827	1418	1210	12125	2645	1440	1028	663	608	2443	1311	77588
LAKE TANGANYIKA																							
PT-1	Keso Falls (7-750)	9,027	17	20	41	77	112	161	149	77	48	34	25	19	301	89	41	23	15	14	66	36	1999

: This discharges are calculated acording to the ratio of chatchment area. (The others are recorded discharge.)

*1. : Average : 30 years average discharge, 10-year Drought : Average discharge of drought with 10-year return period)

Table 5-1(2) Monthly Discharge and Flow Regime (30 years average : 1963-1992)

No.	Reference Point Name	Catchment Area (km2)	Monthly Mean Discharge (m3/s) Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Flow Regime (m3/s) Max.	Q (95)	Q (185)	Q (275)	Q (355)	Min.	*1 Average Ave-rage	10-year drought	Annual Runoff (Mm3)
KAFUE RIVER																							
PK-01	Raglam Farm (4-050)	5,775	2.8	3.9	14	37	72	95	89	47	22	13	9.3	5.3	117	55	18	6.5	2.2	2.0	34	19	1072
PK-02	Mwambashi (4-120)	827	1.5	2.2	6.1	12	18	19	13	6.3	4.1	3.3	2.6	1.9	35	11	4.2	2.4	1.2	1.0	7.5	3.7	236
PK-03	Smith's Bridge (4-130)	8,914	12	16	46	100	157	186	156	89	50	33	24	17	251	116	46	21	9.7	8.6	74	39	2368
PK-04	Mpatamatu (4-200)	12,001	18	23	58	129	214	244	191	98	55	39	30	23	330	139	52	27	15	14	93	50	2924
PK-05	Machiya Ferry (4-280)	23,065	24	28	71	180	308	372	316	160	81	57	44	32	453	213	72	37	21	19	138	73	4366
PK-06(1)	Confluence (Before Luswishi R.)	24,264	25	29	71	182	312	383	329	171	85	59	45	33	466	220	74	38	21	20	143	75	4502
PK-06(2)	Confluence (Luswishi R. Portion)	8,839	3.4	3.2	4.6	14	31	83	101	77	31	16	10	5	91	53	18	6	3	3	31	15	996
PK-06(3)	Confluence (After Luswishi R.)	33,103	28	32	76	197	343	466	430	248	116	75	55	38	557	273	92	43	24	22	174	89	5498
PK-07	Chilenga (4-350)	34,451	29	32	77	199	347	479	445	260	121	77	56	39	571	281	95	44	24	23	179	92	5650
PK-08	Lubungu (4-450)	55,962	36	39	81	208	359	463	450	291	151	92	68	49	575	304	108	55	29	27	189	93	5979
PK-09	Chifumpa Pontoon (4-560)	20,999	22	26	55	107	193	239	188	82	50	41	34	26	431	116	48	30	19	18	88	40	2777
PK-10(1)	Confluence (Lunga R. Portion)	23,767	23	26	56	111	203	249	198	90	54	43	36	28	446	123	51	32	20	18	92	44	2916
PK-10(2)	Confluence (After Lunga R.)	79,729	59	65	137	319	562	712	649	381	205	134	104	77	1021	427	159	87	50	45	282	137	8895
PK-11	Kafue Hook Bridge (4-669)	96,239	66	70	142	338	619	774	709	428	229	147	113	86	1113	469	173	95	55	49	308	161	9723
PK-12(2)	Itezhi- Tezhi Dam (Outflow)	107,191	181	177	193	252	370	485	474	340	249	172	163	176	832	325	188	147	109	85	278	162	8259
PK-13(2)	Kafue Gorge Dam (Outflow)	153,826	183	169	181	205	290	361	441	466	447	396	298	218	574	402	253	177	123	100	296	163	9278
PZ-15(2)	Confluence (Kafue R. Portion)	156,995	186	171	195	249	334	425	485	482	456	401	302	221	634	431	261	180	125	102	316	170	9882
LUANGWA RIVER																							
PL-1	M'fuwe (5-650)	73,422	55	56	185	487	813	800	469	212	133	100	80	64	1610	376	126	73	39	34	283	181	8894
PL-2	Ndevu Camp (5-800)	91,861	21	31	208	638	1232	888	446	165	83	56	37	24	3329	387	82	34	12	11	327	219	10270
PL-3(1)	Confluence (Lunsemfwa R. Before Lukusashi R.)	27,443	20	20	121	382	383	546	378	143	73	50	38	27	520	259	67	30	15	14	175	58	5240
PL-3(2)	Confluence (Lukusashi R. Portion)	14,711	11	11	65	205	205	293	203	77	39	27	20	15	279	139	36	16	8	7	94	31	2809
PL-3(3)	Confluence (Lunsemfwa R. After Lukusashi R.)	42,154	30	31	186	586	588	839	580	220	112	77	58	42	798	398	103	46	23	21	269	89	8049
PL-4(1)	Confluence (Before Lunsemfwa R.)	96,877	24	35	230	707	1302	988	515	191	97	65	44	29	3424	434	94	39	15	14	358	230	11228
PL-4(2)	Confluence (Lunsemfwa R. Portion)	43,137	31	31	190	600	602	859	594	225	115	79	59	43	817	407	105	47	24	22	275	91	8236
PL-4(3)	Confluence (After Lunsemfwa R.)	140,014	55	66	420	1307	1904	1847	1109	415	211	144	103	72	4241	841	199	86	39	36	633	321	19464
PL-5	Luangwa Road Bridge (5-940)	140,922	56	67	424	1320	1917	1865	1121	420	214	146	104	73	4258	849	202	87	39	36	639	323	19637
PZ-17(1)	Confluence (Luangwa R. Portion)	147,622	61	72	454	1413	2010	1998	1214	455	231	158	113	80	4385	912	218	94	43	40	681	337	22318
CHAMBESHI RIVER and LUAPULA RIVER																							
PC-1	Chambeshi Old Pontoon. (6-289)	34,745	40	40	75	170	307	461	471	294	155	96	68	51	582	280	108	55	35	33	185	98	5833
PC-2	Kasama - Luwindu Road Bridge (6-350)	6,504	34	39	65	93	117	139	122	75	57	49	43	36	206	95	55	41	31	30	73	56	2291
PC-3	Mbati (6-400)	44,427	80	85	152	283	456	647	639	397	228	156	120	94	849	403	175	104	71	68	277	166	8750
PP-1	Mukuku (Border Town)	92,452	97	78	106	241	534	950	938	693	492	360	237	141	1105	577	289	126	75	65	375	221	13314
PP-2	Chembe Ferry (6-670)	123,072	129	104	141	321	711	1264	1248	922	655	479	316	188	1470	768	385	168	99	87	499	294	17724
PP-3	Kashiba (6-785)	161,275	237	195	265	536	1068	1758	1741	1295	931	712	488	323	2021	1096	606	294	190	174	741	425	26044
PP-4	Kundabwika Falls (6-900)	12,396	58	65	111	168	202	261	256	154	109	90	74	62	387	181	104	71	51	49	136	110	4101
PP-5	Confluence of Kalungwishi R.	25,936	120	136	231	351	422	547	535	322	228	188	154	130	810	379	218	149	107	102	284	230	8580
PP-6	Pweto (ZAIRE)	217,823	445	405	596	1059	1776	2701	2671	1916	1379	1087	780	561	3272	1738	1000	544	370	345	1218	759	41291

: This discharges are calculated acording to the ratio of chatchment area. (The others are recorded discharge.)

*1. : Average : 30 years average discharge, 10-year Drought : Average discharge of drought with 10-year return period)

Table 5-2 Probable Drought and Minimum Discharge Unit : m3/s

No.	Reference Point Name	Catchment Area (km2)	Drought Discharge for a Return Period of 10 year	Drought Discharge for a Return Period of 5 year	Drought Discharge for a Return Period of 2 year	Minimum Discharge 30 year
ZAMBEZI RIVER						
PZ-01	Chavuma Falls (1-105)	75,967	40	45	54	34
PZ-02	Zambezi Pump House (1-150)	87,275	47	51	62	39
PZ-03	Kabompo Boma (1-650)	42,740	27	32	46	20
PZ-04(1)	Confluence (Kabompo R. Before Dongwe R.)	45,505	29	34	47	21
PZ-04(2)	Confluence (Dongwe R. Portion)	20,870	13	13	12	12
PZ-04(3)	Confluence (Kabompo R. After Dongwe R.)	66,375	42	47	59	34
PZ-05	Watopa Pontoon (1-950)	67,261	42	48	59	34
PZ-06(1)	Confluence (Before Kabompo R.)	89,874	48	53	64	40
PZ-06(2)	Confluence (Kabompo R. Portion.)	72,751	46	51	64	37
PZ-06(3)	Confluence (After Kabompo R.)	162,625	94	104	128	77
PZ-07	Lukulu (2-030)	206,531	202	221	262	175
PZ-08	Kalabo (2-250)	34,621	2.4	3.2	5.3	1.6
PZ-09(1)	Confluence (Luena R. Portion)	24,178	18	17	14	18
PZ-09(2)	Confluence (Luanginga R. Portion.)	43,619	9.0	9.4	10	8.3
PZ-09(3)	Confluence (After Luena R. and Luanginga R.)	274,328	229	247	286	202
PZ-10	Senanga (2-400)	284,538	236	254	292	209
PZ-11	Sesheke (2-700)	336,053	236	256	297	207
PZ-12(1)	Confluence (Before Chobe R.)	362,953	236	256	300	206
PZ-12(2)	Confluence (Chobe R. Portion.)	144,400	0.5	4.7	15	0.0
PZ-12(3)	Confluence (After Chobe R.)	507,353	237	261	314	206
PZ-13	Victoria Fall Big Tree (ZRA)	513,780	237	261	315	200
PZ-14(2)	Kariba Dam (Outflow)	663,880	463	523	662	396
PZ-15(1)	Confluence (Before Kafue R.)	667,970	463	524	664	396
PZ-15(2)	Confluence (Kafue R. Portion)	156,995	69	84	121	60
PZ-15(3)	Confluence (After Kafue R.)	824,965	532	608	785	456
PZ-16	Feira Boma (5-099)	844,044	533	610	790	457
PZ-17(1)	Confluence (Luangwa R. Portion)	147,622	8.1	12	28	4.0
PZ-17(2)	Confluence (After Luangwa R.)	991,666	541	622	818	461
KAFUE RIVER						
PK-01	Raglam Farm (4-050)	5,775	1.0	1.3	1.9	0.8
PK-02	Mwambashi (4-120)	827	0.7	0.8	1.1	0.6
PK-03	Smith's Bridge (4-130)	8,914	3.9	5.0	8.1	2.6
PK-04	Mpatamatu (4-200)	12,001	7.7	9.1	13	5.7
PK-05	Machiya Ferry (4-280)	23,065	12	15	20	9.2
PK-06(1)	Confluence (Before Luswishi R.)	24,264	12	15	20	9.4
PK-06(2)	Confluence (Luswishi R. Portion)	8,839	1.4	1.7	2.6	1.3
PK-06(3)	Confluence (After Luswishi R.)	33,103	14	16	23	11
PK-07	Chilenga (4-350)	34,451	14	17	23	11
PK-08	Lubungu (4-450)	55,962	11	15	23	7.8
PK-09	Chifumpa Pontoon (4-560)	20,999	12	14	19	9.5
PK-10(1)	Confluence (Lunga R. Portion)	23,767	12	15	20	9.5
PK-10(2)	Confluence (After Lunga R.)	79,729	24	29	43	17
PK-11	Kafue Hook Bridge (4-669)	96,239	26	32	49	17
PK-12(2)	Itezhi- Tezhi Dam (Outflow)	107,191	81	89	107	53
PK-13(2)	Kafue Gorge Dam (Outflow)	153,826	69	84	120	60
PZ-15(2)	Confluence (Kafue R. Portion)	156,995	69	84	121	60
LUANGWA RIVER						
PL-1	M'fuwe (5-650)	73,422	1.5	3.3	14	0.5
PL-2	Ndevu Camp (5-800)	91,861	4.3	5.9	11	2.2
PL-3(1)	Confluence (Lunsemfwa R. Before Lukusashi R.)	27,443	1.8	3.1	8.2	0.9
PL-3(2)	Confluence (Lukusashi R. Portion)	14,711	1.0	1.7	4.4	0.5
PL-3(3)	Confluence (Lunsemfwa R. After Lukunsashi R.)	42,154	2.8	4.8	13	1.4
PL-4(1)	Confluence (Before Lunsemfwa R.)	96,877	4.6	6.5	12	2.4
PL-4(2)	Confluence (Lunsemfwa R. Portion)	43,137	2.9	4.9	13	1.4
PL-4(3)	Confluence (After Lunsemfwa R.)	140,014	7.5	11	25	3.8
PL-5	Luangwa Road Bridge (5-940)	140,922	7.6	12	26	3.8
PZ-17(1)	Confluence (Luangwa R. Portion)	147,622	8.1	12	28	4.0
CHAMBESHI RIVER and LUAPULA RIVER						
PC-1	Chambeshi Old Pontoon. (6-289)	34,745	22	26	33	18
PC-2	Kasama - Luwindu Road Bridge (6-350)	6,504	21	24	30	17
PC-3	Mbati (6-400)	44,427	47	53	68	38
PP-1	Mukuku (Border Town)	92,452	27	36	61	17
PP-2	Chembe Ferry (6-670)	123,072	36	47	82	22
PP-3	Kashiba (6-785)	161,275	74	96	157	50
PP-4	Kundabwika Falls (6-900)	12,396	29	34	48	21
PP-5	Confluence of Kalungwishi R.	25,936	60	72	100	43
PP-6	Pweto (ZAIRE)	217,823	166	207	318	115
LAKE TANGANYIKA						
PT-1	Keso Falls (7-750)	9,027	8.6	10	14	5.4

(shaded) : This discharges are calculated acording to the ratio of chatchment area.

5.3 Runoff Percentage

(1) Basin Mean Rainfall

The simplest objective method of calculating the average rainfall over an area is the arithmetic mean method. Simultaneous measurements of rainfall at all gauge stations are summed and the total divided by the number of stations. The rainfall stations used in the calculation are principally those inside the catchment area but neighbouring stations outside the boundary are included if it is considered that the stations are representative of the nearby parts of the catchment.

Basin mean rainfall for Zambia was estimated using the arithmetic mean method as follows:

1) Basin mean rainfall from the voluntary and the meteorological stations, *Rv*, is calculated but rainfall data only for the period of 1980/81-1989/90 is available at the voluntary stations.
2) Basin mean rainfall from the meteorological stations, *Rm*, is calculated and there are usually more than 30 years records available at the meteorological stations.
3) Regression linear equation between *Rm* and *Rv* is found by a least-squares fit as follows : $Rv = a \times Rm + b$ where a, b : constants.
4) The long-term basin mean rainfall, *Rv*, is calculated by using *Rm* and the regression equation.

(2) Runoff Percentage of River Basin

In terms of the closed basins inside Zambia, the runoff percentages of the basins were estimated by using the basin mean rainfalls and the runoff at the main discharge reference points. The runoff percentages are presented in Table 5-4. These figures were plotted according to the corresponding basin area as shown in Figure 5-3. Runoff percentages of the main rivers are summarised in Table 5-3 and as follows :

- In the Zambezi River (Kabompo River), Kafue River, Chambeshi River and Lake Tanganyika basin, the common trend that runoff percentage decreases with increase in catchment area, was found.
- The Luangwa River and the Luapula River have larger runoff percentages than the other rivers. The causes are not clear but one of causes is thought to be that the narrow basin width of the Luangwa River and the Luapula River causes rapid runoff to the main river so that water can flow downstream without much loss.

Table 5-3 Runoff Percentage of Main Rivers

River System	Runoff Percentage	Discharge Reference Point	Catchment Area
Zambezi River (Kabompo R.)	9.5 %	Watopa Pontoon	67,261 km^2
Upper Kafue River	22.6 %	Smith's Bridge	8,914 km^2
Middle Kafue River	8.8 %	Kafue Hook Bridge	96,239 km^2
Lower Kafue River	4.7 %	Kafue Gorge Dam	153,826 km^2
Luangwa River	16.7 %	Luangwa Road Bridge	140,922 km^2
Chambeshi River	14.9 %	Mbati	44,427 km^2
Luapula River	13.8 %	Kashiba	171,275 km^2
Lake Tanganyika (Lufubu R.)	19.4 %	Keso Falls	9,027 km^2

Table 5-4 30 Years (1963 - 1992) Average Runoff Percentage

No.	Discharge Reference Point Name	Catchment Area (km^2)	Basin Rainfall (mm)	Runoff Depth (mm)	Runoff Percentage (%)
ZAMBEZI RIVER					
PZ-03	Kabompo Boma (1-650)	42,740	1292.7	163.3	12.6
PZ-05	Watopa Pontoon (1-950)	67,261	1177.5	112.0	9.5
KAFUE RIVER					
PK-01	Raglam Farm (4-050)	5,775	1337.1	200.3	15.0
PK-02	Mwambashi (4-120)	827	1254.7	308.8	24.6
PK-03	Smith's Bridge (4-130)	8,914	1250.5	282.2	22.6
PK-04	Mpatamatu (4-200)	12,001	1217.5	254.6	20.9
PK-05	Machiya Ferry (4-280)	23,065	1179.6	197.5	16.7
PK-6(2)	Conf.(Luswishi R. Portion)	8,839	1270.8	119.9	9.4
PK-07	Chilenga (4-350)	34,451	1177.8	170.6	14.5
PK-08	Lubungu (4-450)	55,962	1172.5	110.7	9.4
PK-09	Chifumpa Pontoon (4-560)	20,999	959.7	132.2	13.8
PK-10(2)	Conf.(After Lunga R.)	79,729	1193.9	111.4	9.3
PK-11	Kafue Hook Bridge (4-669)	96,239	1184.1	104.6	8.8
PK-12(2)	Itezhi- Tezhi Dam (Outflow)	107,191	1128.9	77.0	6.8
PK-13(2)	Kafue Gorge Dam (Outflow)	153,826	1114.1	52.3	4.7
LUANGWA RIVER					
PL-1	M'fuwe (5-650)	73,422	931.8	122.6	13.2
PL-2	Ndevu Camp (5-800)	91,861	928.5	111.8	12.0
PL-3(1)	Conf.(Lunsemfwa R. before Lukusashi R.)	27,443	853.6	124.2	14.6
PL-3(2)	Conf.(Lukusashi R. Portion)	14,711	987.0	124.2	12.6
PL-3(3)	Conf.(Lunsemfwa R. After Lukusashi R.)	42,154	874.8	124.2	14.2
PL-5	Luangwa Road Bridge (5-940)	140,922	877.0	146.4	16.7
CHAMBESHI RIVER and LUAPULA RIVER					
PC-1	Chambeshi Old Pontoon. (6-289)	34,745	1322.6	167.9	12.7
PC-2	Kasama - Luwingu Road Bridge (6-350)	6,504	1331.4	352.2	26.5
PC-3	Mbati (6-400)	44,427	1322.6	197.0	14.9
PP-1	Mukuku (Border Town)	92,452	1115.2	144.0	12.9
PP-2	Chembe Ferry (6-670)	123,072	1170.7	139.3	11.9
PP-3	Kashiba (6-785)	161,275	1166.9	161.5	13.8
PP-4	Kundabwika Falls (6-900)	12,396	1263.1	325.0	25.7
LAKE TANGANYIKA					
PT-1	Keso Falls (7-750)	9,027	1140.5	221.4	19.4

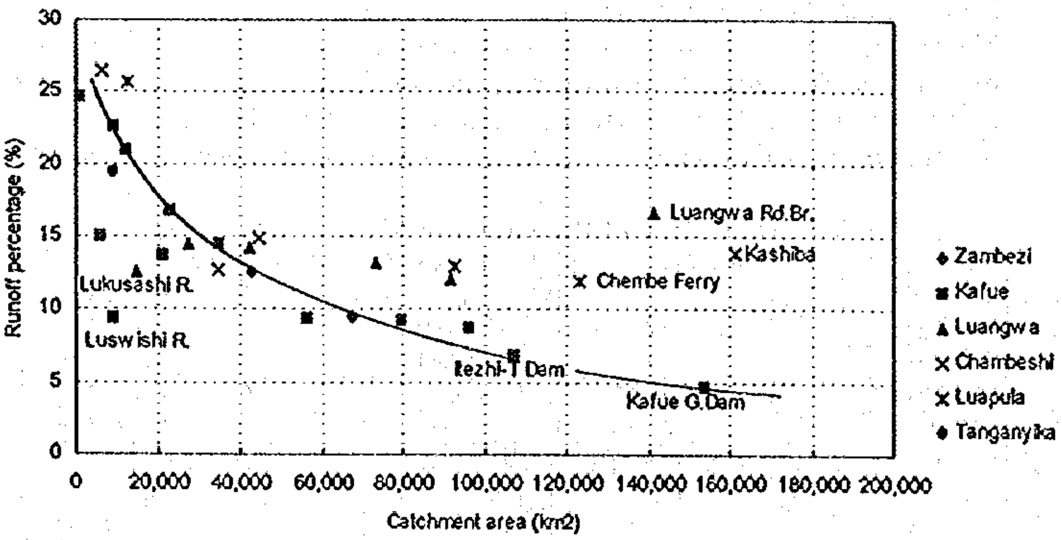


Figure 5-3 Runoff Percentage and Catchment Area

CHAPTER 6 LAKES, FLOOD PLAINS AND EXISTING DAM RESERVOIRS

6.1 Lakes and Flood Plains

6.1.1 Lakes

There are four major natural lakes in Zambia, namely Lake Bangweulu, Lake Tanganyika, Lake Mweru Wantipa and Lake Mweru. Of these, Lake Bangweulu and Lake Mweru Wantipa lie within the country and the rest are along the country's borders. Water level of these four lakes are investigated at the hydrometric stations shown in Figure 6-1. Monthly variations and secular variations of lake water levels are shown in Table 6-1, Figure 6-2 and Figure 6-3.

<u>**Lake Bangweulu**</u>
Lake Bangweulu has a surface area of 2,289 km^2. The lake water level usually starts rising on December and reaches its peak on April. Annual fluctuation of lake water level is 1.3 m on an average. Maximum annual fluctuation is 2.66 m recorded from November 1961 to April 1962. Annual fluctuation of water level is relatively high but secular variation is not high and the annual mean lake water level has fluctuates by only 1.10 m during last 35 years.

<u>**Lake Tanganyika**</u>
Lake Tanganyika has a surface area of 32,000 km^2 (1,974 km^2 in the territory of Zambia), maximum depth of 1,430 m (mean depth 572 m) and elevation of EL.773 m. This lake is the second deepest lake in the world. The lake water level usually starts rising on December and reaches its peak on May. Annual fluctuation of lake water level is 0.67 m on an average. Maximum annual fluctuation of water level is 1.55 m recorded from October 1961 to June 1962. Annual fluctuation is relatively small but secular variation is high. Especially from hydrological year 1960/61 to 1963/64, the annual mean lake water level had been rising by 2.45 m for three years.

<u>**Lake Mweru Wantipa**</u>
Lake Mweru Wantipa has a surface area of 1,587 km^2, maximum depth of 25 m. The lake water level usually starts rising on December and reaches its peak on May. Annual fluctuation of lake water level is 0.93 m on an average. Maximum annual fluctuation of water level is 2.85 m recorded from October 1961 to June 1962. Annual fluctuation is relatively small but secular variation is high. Especially from hydrological year 1958/59 to 1963/64, the annual mean lake water level had been rising by 5.55 m for 5 years.

<u>**Lake Mweru**</u>
Lake Mweru has a surface area of 4,580 km^2, maximum depth of 37 m. The lake water level usually starts rising on January and reaches its peak on May. Annual fluctuation of lake water level is 1.78 m on an average. Maximum annual fluctuation of water level is 4.61 m recorded from November 1961 to May 1962. Annual fluctuation is relatively high and secular variation is also fairly high and frequent. The annual mean lake water level had been rising by 2.85 m during 5 years from hydrological year 1958/59 to 1963/64, and had been falling by 2.30 m during 3 years from hydrological year 1963/64 to 1966/67.

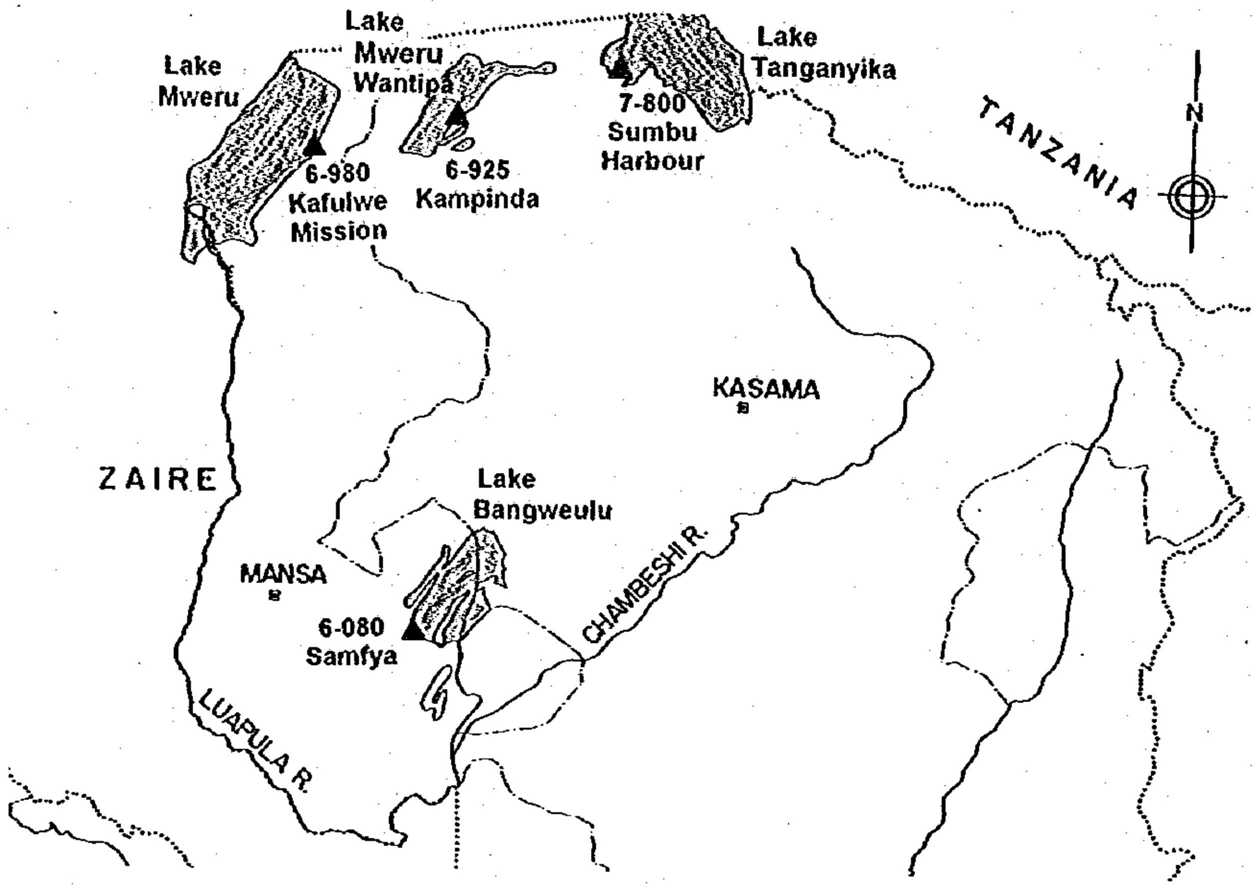


Figure 6-1 Location of Lakes and Hydrometric Stations

Table 6-1 Lake Water Level

Lake Name		Bangweulu	Tanganyika	Muweru-Wantipa	Mweru
Total Surface Area (km^2)		2,289	32,000	1,587	4,580
Maximum Depth (m)		-	1,430	25	37
Surface Area in Zambia (%)		100	6	100	64
Hydrometric Station Number		6-080	7-800	6-925	6-980
Hydrometric Station Name		Samfya	Sumbu Harbour	Kampinda	Kafulwe Mission
Water Level Data Available		1956-90	1960-91	1958-90	1956-90
Average Annual Fluctuation		1.30 m	0.67 m	0.93 m	1.78 m
Maximum Annual Fluctuation		2.66 m	1.55 m	2.85 m	4.61 m
Average Monthly Water Level (m)	Oct	1.49	2.28	7.11	2.80
	Nov	1.35	2.27	7.03	2.54
	Dec	1.46	2.38	7.10	2.43
	Jan	1.69	2.50	7.24	2.50
	Feb	2.04	2.58	7.37	2.77
	Mar	2.43	2.70	7.56	3.26
	Apr	2.65	2.85	7.86	3.94
	May	2.53	2.94	7.96	4.21
	Jun	2.31	2.85	7.89	4.06
	Jul.	2.09	2.67	7.80	3.79
	Aug	1.90	2.49	7.69	3.47
	Sep	1.71	2.37	7.58	3.15
	Annual Mean	1.97	2.57	7.51	3.24
	Difference	1.30	0.67	0.93	1.78

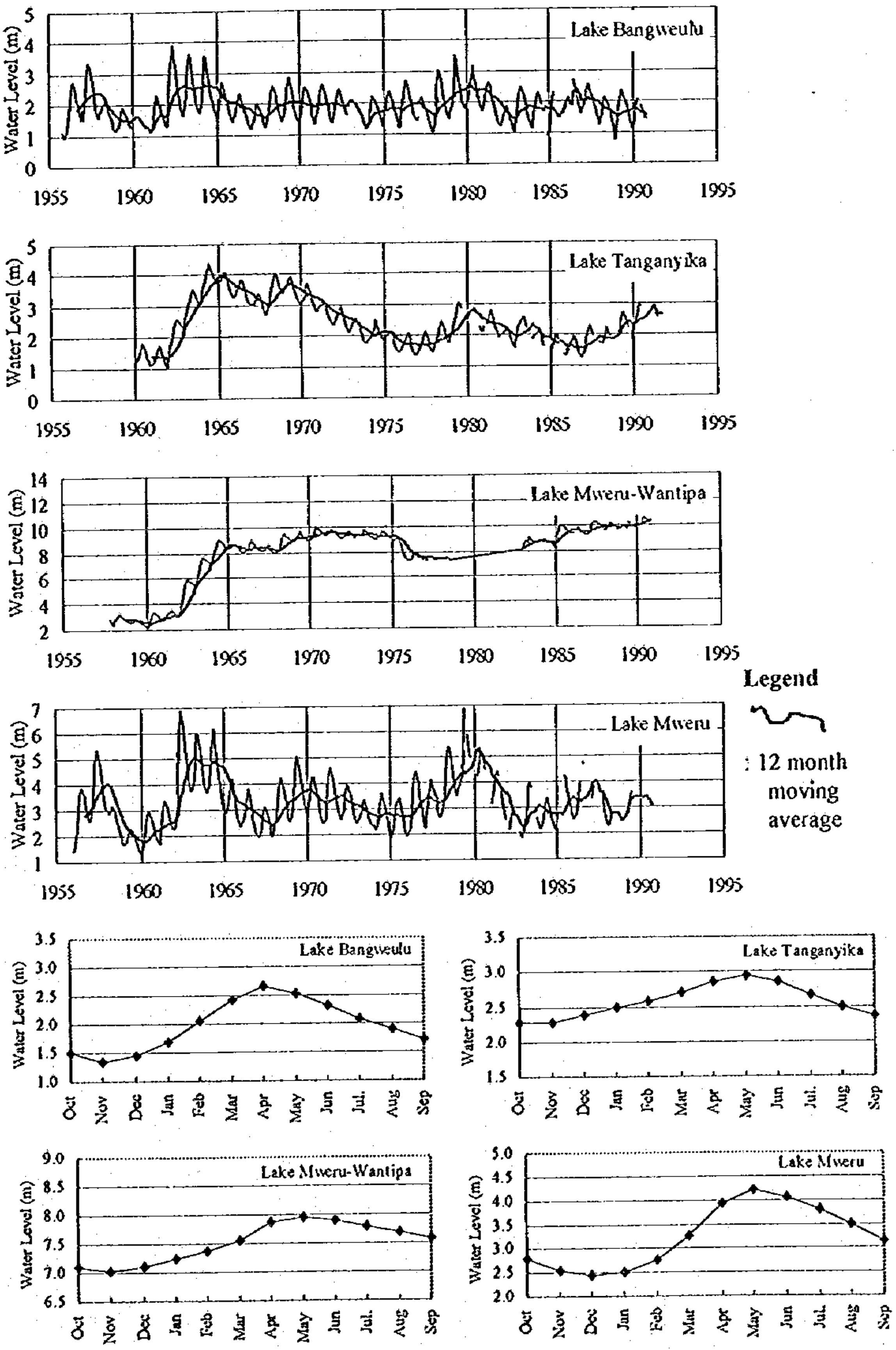


Figure 6-2 Annual Variation and Secular Variation of Lake Water Level

6.1.2 Flood Plain

Barrotse Flood Plain and Kafue Flats are the main large flood plains in Zambia. The water levels of both the flood plains were investigated at near hydrometric stations shown in Figure 6-3. Annual variation and secular variation of the water level are shown in Table 6-2, Figure 6-4 and Figure 6-5.

Barrotse Flood Plain
The water level usually starts rising on November and reaches its peak on March or April. Annual fluctuation of water level ranges from 3.45 m to 4.35 m on an average but maximum annual fluctuation reaches to about 6 m.

Kafue Flats
The water level usually starts rising on December and reaches its peak on March. Annual fluctuation of water level ranges from 3.79 m to 4.75 m on an average but maximum annual fluctuation reaches to about 7 m.

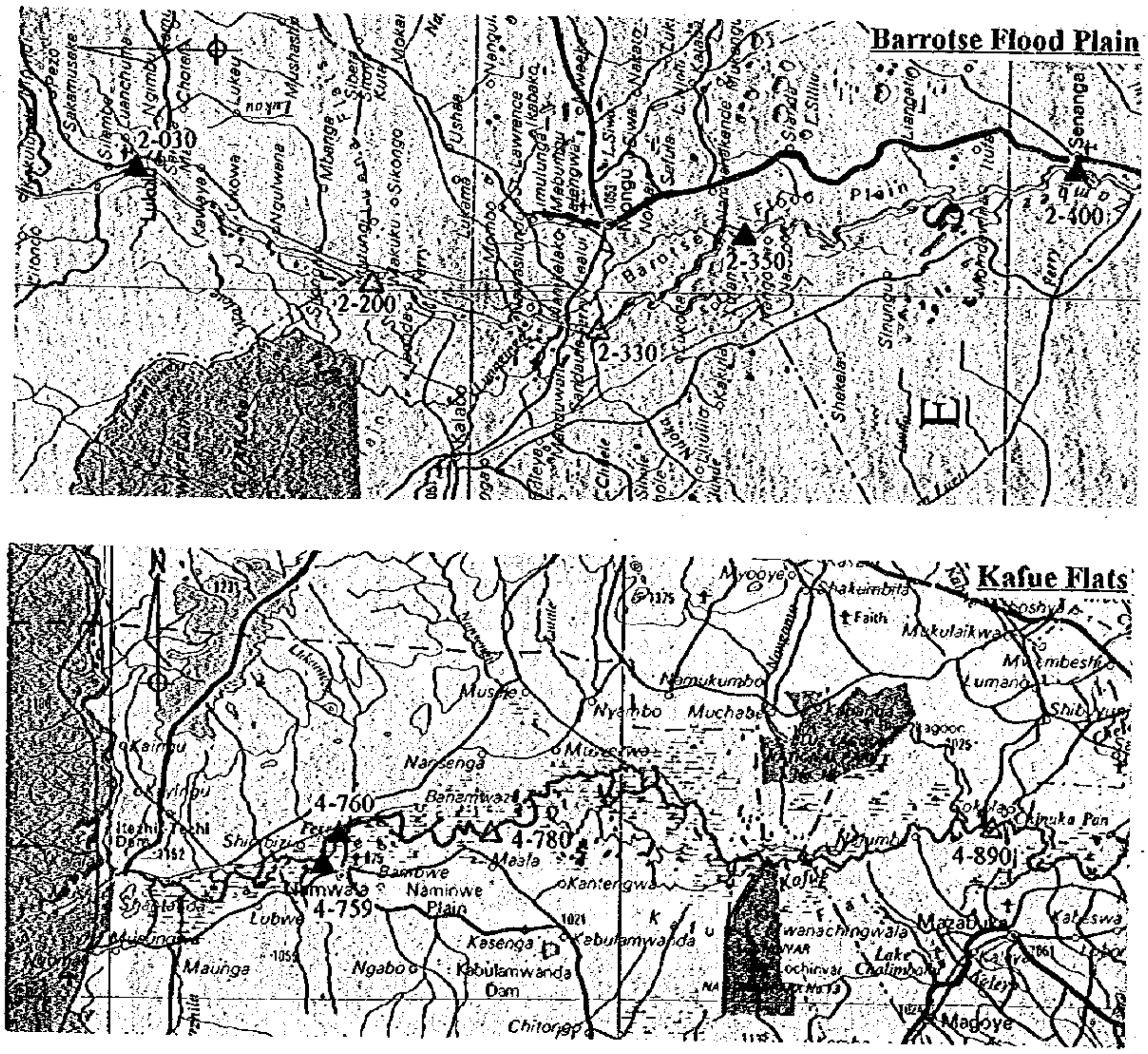


Figure 6-3 Location of Flood Plains and Hydrometric Stations

Table 6-2 Water Level in Kafue Flats and Barrotse Flood Plain

Area Name		Barrotse Flood Plain				Kafue Flats				
Hydrometric Station Number		2-030	2-200	2-330	2-350	2-400	4-759	4-760	4-780	4-890
Hydrometric Station Name		Lukulu	Likapai	Matonge Platform	Nalolo	Senanga	Kafue	Namwala Pontoon	Busanga	Nyimba
Water Level Data Available		1951-93	1962-72	1956-94	1962-72	1948-93	1951-93	1951-94	1963-87	1963-86
Water Level (m)	Oct	0.74	0.91	2.01	0.88	0.89	3.65	3.42	2.41	2.97
	Nov	0.94	1.06	2.13	1.03	0.98	3.59	3.34	2.16	2.66
	Dec	1.57	1.96	2.82	1.76	1.42	4.22	3.97	3.00	3.32
	Jan	2.72	3.18	4.03	2.78	2.14	5.67	5.30	4.70	4.50
	Feb	4.20	4.16	5.20	3.66	3.11	7.00	6.65	5.95	5.51
	Mar	5.27	4.70	6.15	4.33	4.30	7.91	7.62	6.91	6.12
	Apr	4.86	4.51	6.31	4.32	4.69	7.68	7.34	6.57	6.45
	May	3.18	3.27	5.66	3.64	4.17	6.62	6.31	5.71	6.40
	Jun	1.97	2.17	4.46	2.79	3.15	5.29	5.03	4.63	6.04
	Jul.	1.42	1.64	3.29	1.97	2.09	4.51	4.29	3.77	5.41
	Aug	1.09	1.34	2.59	1.46	1.46	4.15	3.95	3.14	4.53
	Sep	0.85	1.10	2.22	1.08	1.10	3.94	3.73	2.74	3.75
	Annual Mean	2.40	2.50	3.91	2.47	2.46	5.35	5.08	4.31	4.80
	Difference	4.35	3.79	4.30	3.45	3.80	4.32	4.28	4.75	3.79

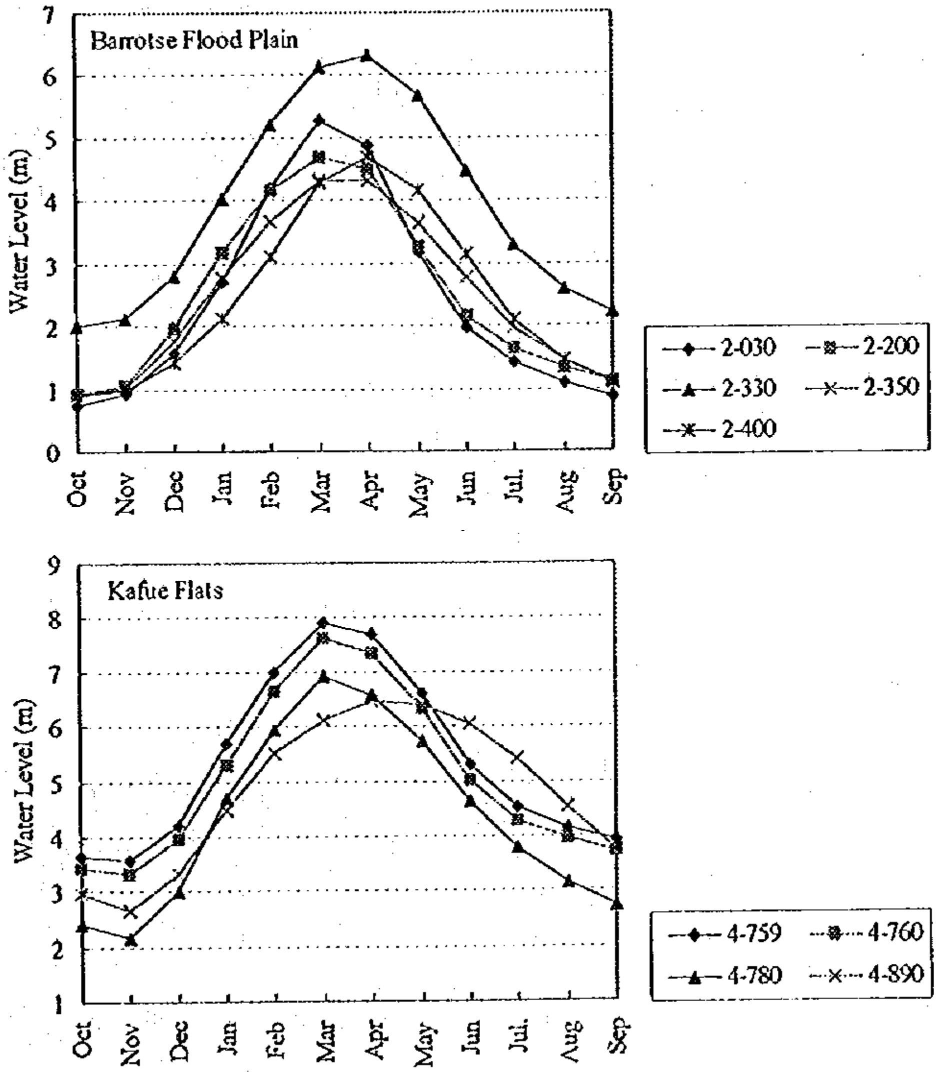


Figure 6-4 Water Level in Barrotse Flood Plain and Kafue Flats

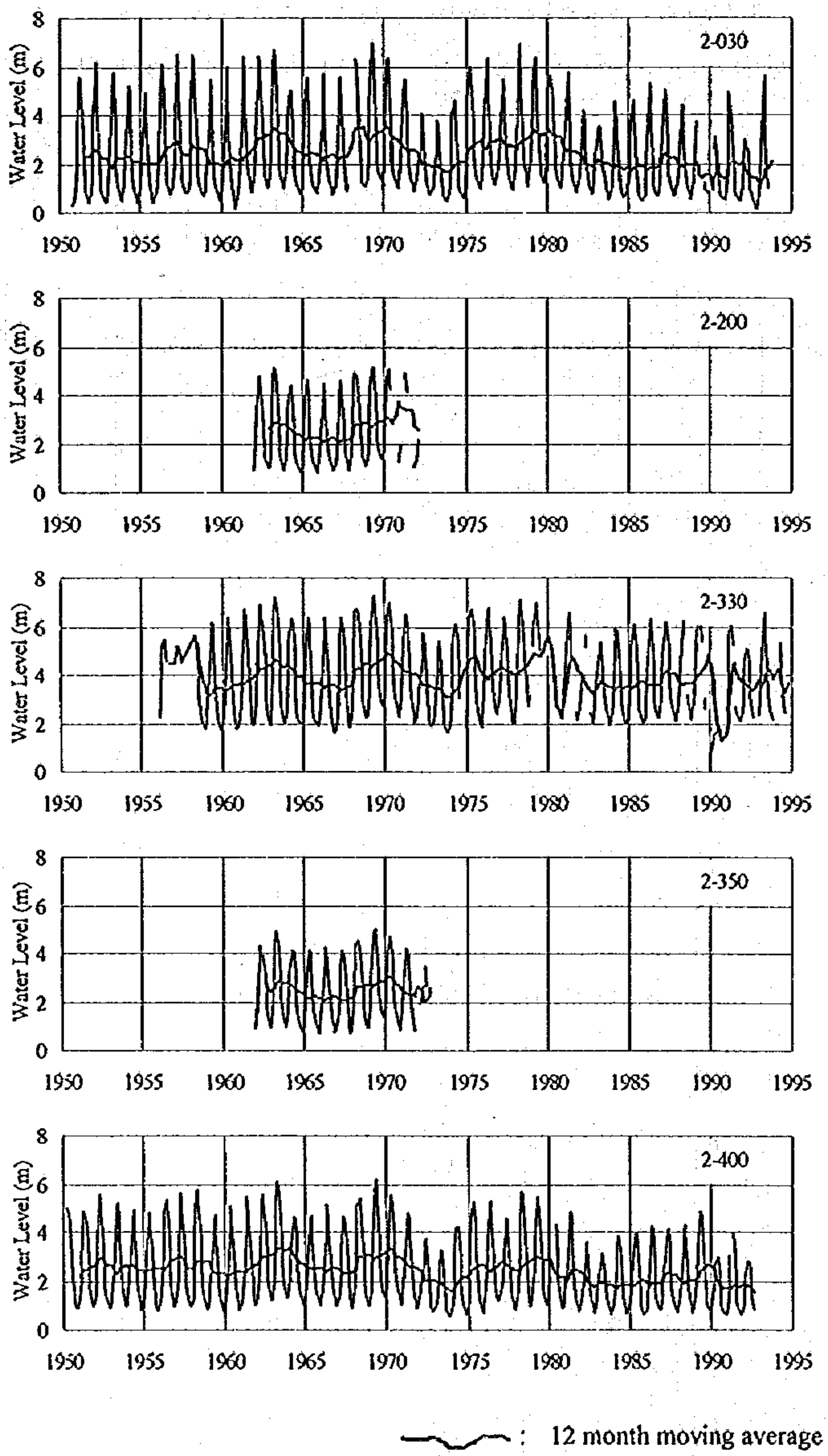


Figure 6-5 (1) Secular Variation of Water Level at Barrotse Flood Plain

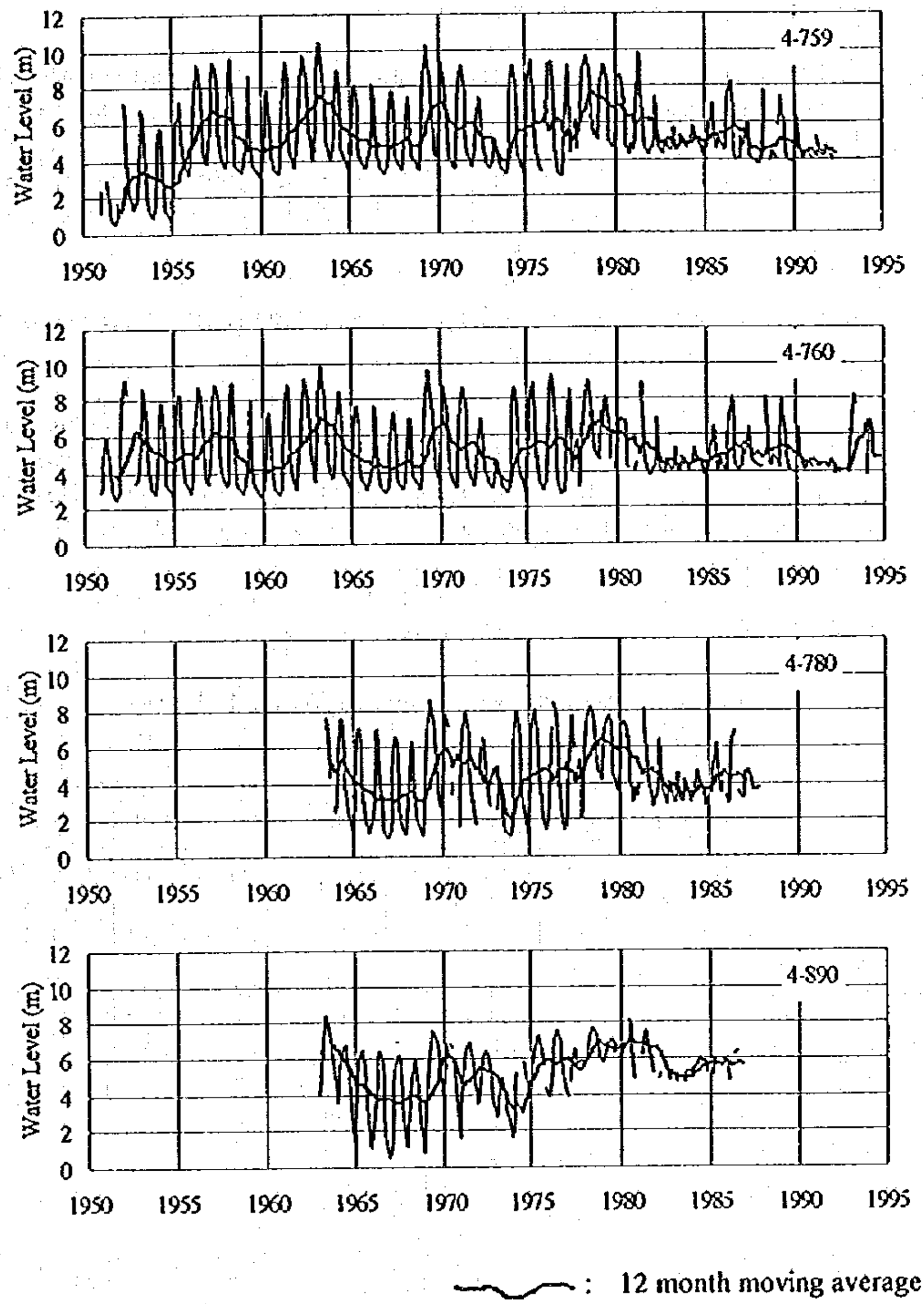


Figure 6-5 (2) Secular Variation of Water Level at Kafue Flats

6.2 Water Balances at Existing Dam Reservoirs

To understand the factors influencing reservoir water balance, a simulation was carried out at the three main dams, Itezhi-Tezhi Dam, Kafue Gorge Dam and Kariba Dam. These dams have the following outlet:

- Kariba Dam : 1) North turbine (Kariba North Hydroelectric Power Station)
  2) South turbine (Kariba South Hydroelectric Power Station)
  3) Spillway
- Itezhi-Tezhi Dam : 1) Regulation Gate 2) Spillway 3) Emergency Spillway
- Kafue Gorge Dam : 1) Turbine (Kafue Gorge Hydroelectric Power Station)
  2) Spillway

The average inflow, outflow, evaporation loss and change of volume are summarised in Table 6-3 and Figure 6-6. The reservoir water balances are summarised as follows :

- Spillway discharge at Kafue Gorge Dam amounts to 106.4 m^3/s (39.2%). A Kariba Dam spillway discharge amounts to 500.7 m^3/s (37.4%) on the average, but have been zero for the last 10 years.
- Evaporation loss from the reservoirs of Itezhi-Tezhi Dam, Kafue Gorge Dam and Kariba Dam, are 2.1%, 5.3% and 9.1% respectively.

Table 6-3 Summary of Reservoir Water Balance

Item		Itezhi-Tezhi Dam		Kafue Gorge Dam		Kariba Dam			
		C.A.= 107,191 km^2 S.A.= 370 km^2		C.A.= 153,826 km^2 S.A.= 800 km^2		C.A.= 663,880 km^2 S.A.= 5,180 km^2			
		Discharge (m^3/s)	Percentage (%)	Discharge (m^3/s)	Percentage (%)	Discharge (m^3/s)	Percentage (%)	Discharge (m^3/s)	Percentage (%)
Simulation Period		14 yrs.(1979-1992)		15 yrs.(1978-1992)		30 yrs.(1963-1992)		10 yrs.(1983-1992)	
Inflow	Qin	254.8	100.0	271.6	100.0	1339.6	100.0	989.4	100.0
Outflow	Qout	238.0	93.8	256.2	94.3	1301.4	97.1	896.1	90.6
Regulation Gate	Qrg	238.0	93.8	-	-	-	-	-	-
Hydro Power	Qhp	-	-	149.8	55.2	800.7	59.8	896.1	90.6
Spillway	Qsw	-	-	106.4	39.2	500.7	37.4	0.0	0.0
Evaporation Loss	Eloss	5.4	2.1	14.5	5.3	73.1	5.5	89.7	9.1
Change of Volume	Vcg	10.4	4.1	0.9	0.3	-34.9	-2.6	3.6	0.4

Note. C.A.: Catchment Area S.A.: Reservoir Surface Area

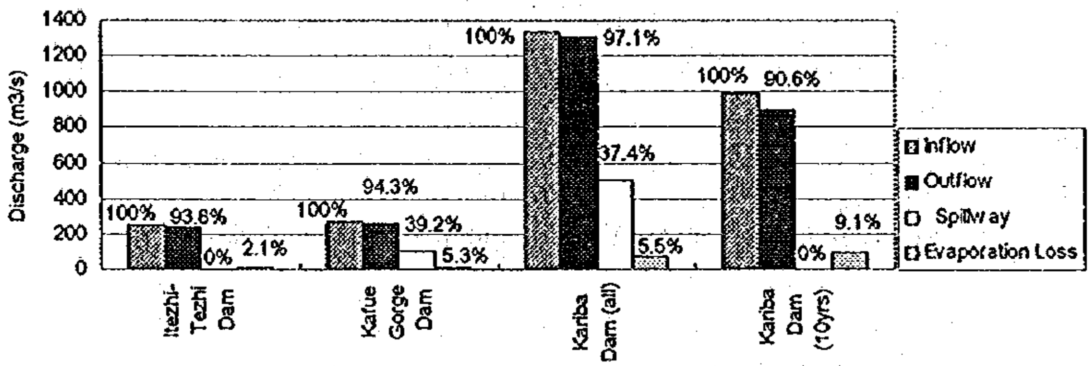


Figure 6-6 Summary of Reservoir Water Balance

(b) Secular Variation of Reservoir Water Level, Inflow and Outflow

The variation of reservoir water level, inflow and outflow in the main three dams is shown in Figure 6-7. In Kariba Dam, the spillway has not been opened since 1981/82.

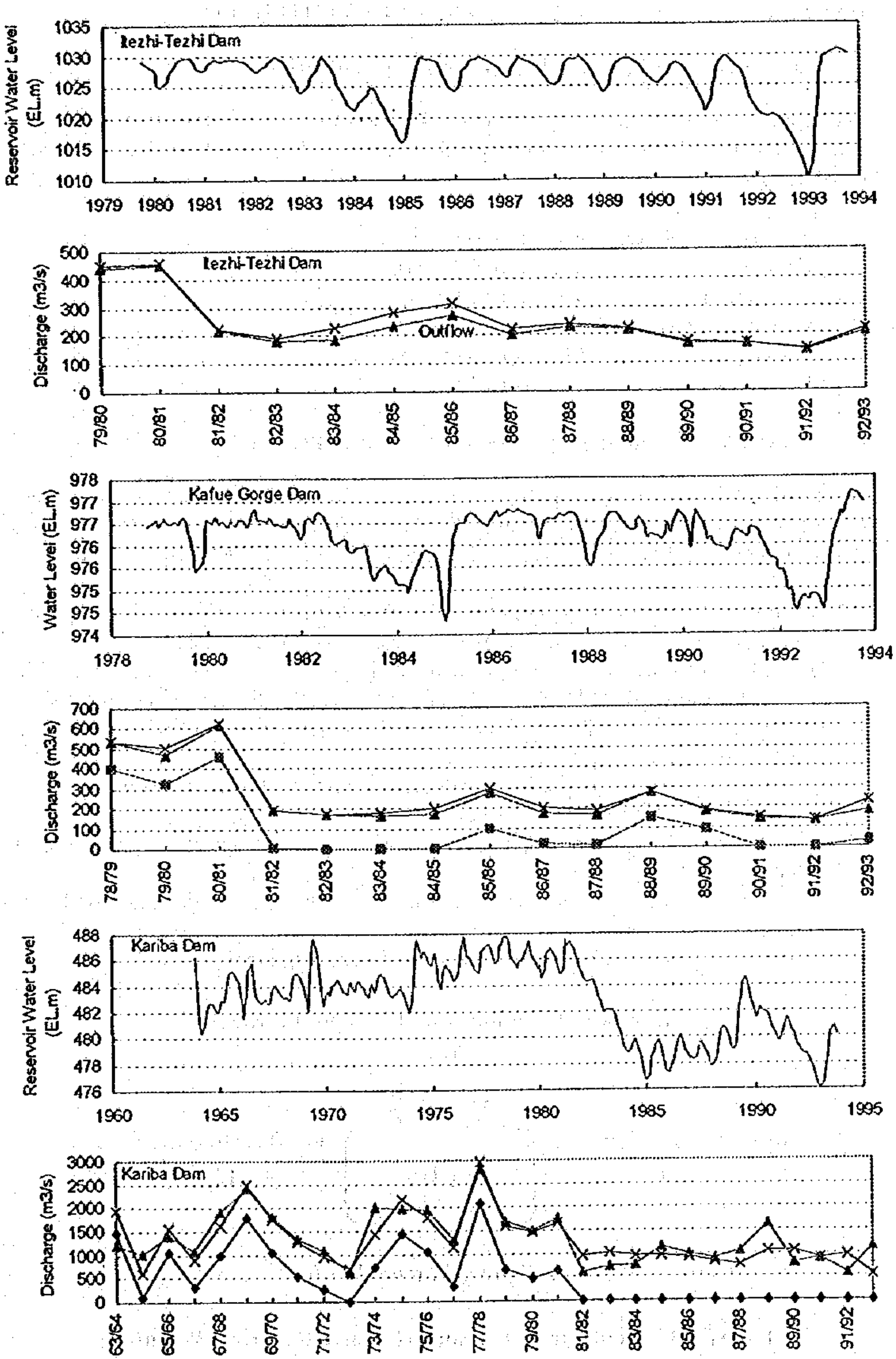


Figure 6-7 Reservoir Water Level, Inflow and Outflow (Itezhi-Tezhi, Kafue Gorge, Kariba Reservoirs)

CHAPTER 7 SURFACE WATER RESOURCES POTENTIAL

7.1 Block Division for Surface Water Resources Potential

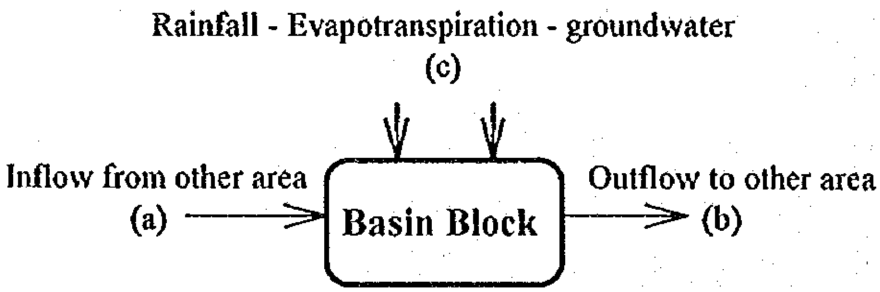
River basins in Zambia as shown in Figure 3-1, were combined into 34 blocks for the surface water resources potential study, which is shown in Figure 7-2. Each river basin was divided as follows :

- Zambezi Main River: 9 blocks (BZ-1~ 9)
- Kafue River : 11 blocks (BK-1~11)
- Luangwa River : 5 blocks (BL-1~ 5)
- Chambeshi River : 2 blocks (BC-1~ 2)
- Luapula River : 5 blocks (BP-1~ 5)
- Lake Tanganyika : 2 blocks (BT-1~ 2)

7.2 Estimation Method of Surface Water Resources Potential

It is defined in this Study that the surface water resources potential is the total surface water produced in a particular area. Referring to Figure 7-1 illustrating the methodology, surface water resources potential in a basin block are estimated based on the following method :

1) Inflow average discharge, Qi, of main rivers or large tributaries to a block (near the inlet of the block) is taken from the river discharge analysis results.
2) Outflow average discharge, Qo, of main rivers or large tributaries from a block (near the outlet of the block) is taken from the river discharge analysis results.
3) The balance of the inflow and outflow, $Qo-Qi$, and the balance of both catchment areas, $Ao-Ai$, are calculated.
4) The specific discharge, Qs, is estimated based on the following equation :
   $Qs = (Qo - Qi) / (Ao - Ai)$
5) This specific discharge, Qs, is adopted as an average specific discharge of the block.
6) The surface water resources potential in the block, Qp, is estimated based on the following equation :
   $Qp = Qs \cdot Ab$ where, Ab : area of block



(Surface Water Resources Potential) = (c) = (b) - (a)

Figure 7-1 Methodology of Surface Water Resources Potential

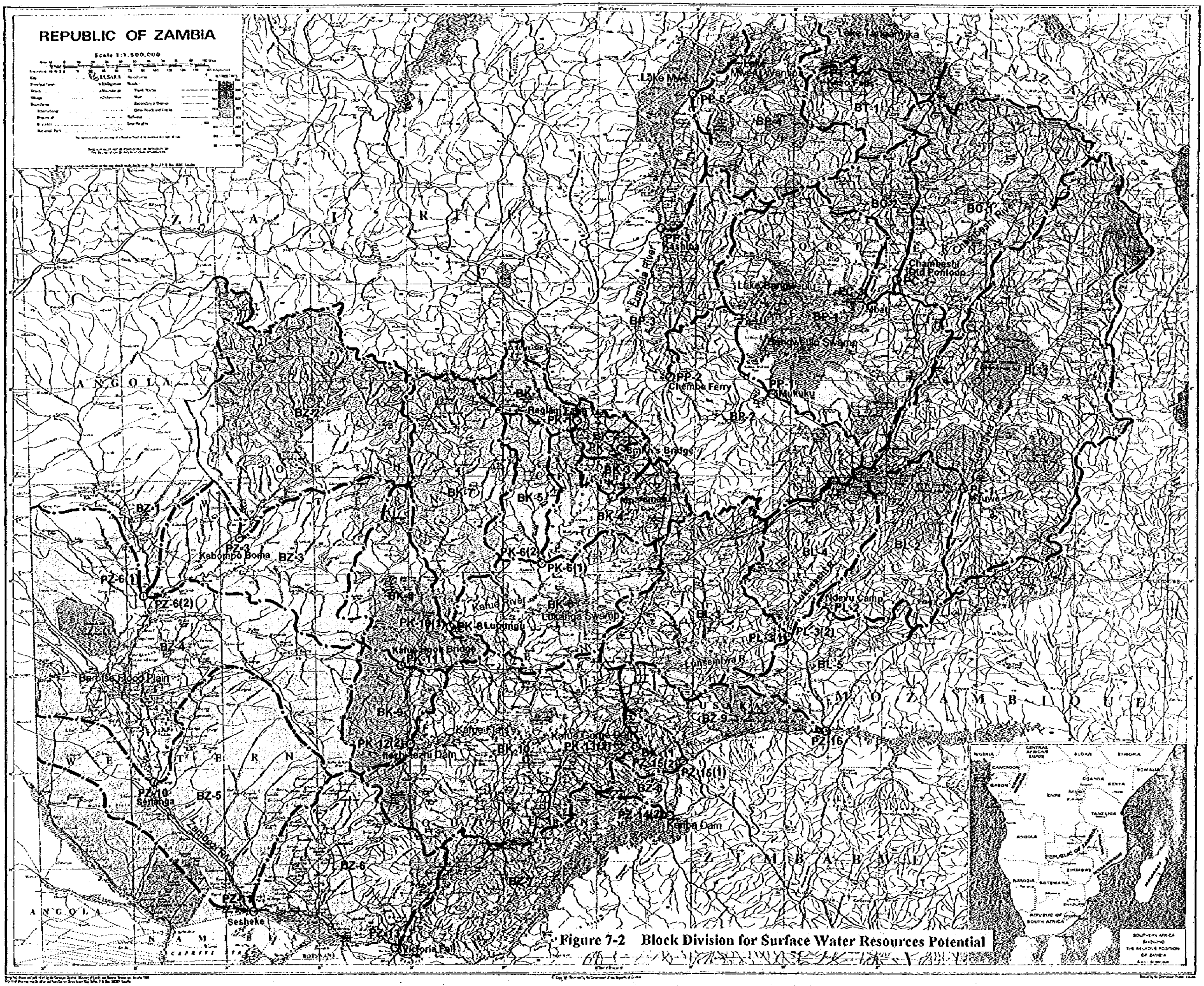


Figure 7-2 Block Division for Surface Water Resources Potential

7.3 Surface Water Resources Potential

Following the above method, surface water resources potential by each basin block were estimated in the two cases of average year and drought year with 10-year return period. The results are shown in Table 7-2. Thus the surface water resources potential of the six main river basins are summarised by summing up the basin block potentials. Further by combining all the basin blocks potential into the 9 provinces, surface water resources potential by each province are summarised. Refer to Table 7-3. The surface water resources potential by the main river basins and by the provinces are shown in Table 7-1 and Figure 7-3. Regional variation of the surface water resources potential are summarised as follows:

- The surface water resources potential in case of drought year with 10-year return period is 57 % on an average, comparing to that in case of average year. This ratio is very low in Lusaka, Central and Southern Province, amounting to 23-34 %.
- Southern, Lusaka and Copperbelt Province have lower surface water resources potentials, 5.3, 10.8 and 13.0 Mm^3/day in case of average year, 1.2, 3.7 and 6.6 Mm^3/day in case of drought year, respectively. Moreover as these provinces have high populations the water potential per capita is relatively low, 6~11 m^3/day/capita in case of average year, 1~5 m^3/day/capita in case of drought year.
- Northern and Northwestern Province have the highest surface water resources potentials, 67.5 and 38.9 Mm^3/day in case of average year, 44.8 and 21.5 Mm^3/day in case of drought year.
- The surface water resources potential per a unit area of 1 km^2, for Western and Southern Province were estimated to be very low, 62 and 160 m^3/day/km^2 in case of average year. These low unit water potentials are thought to be caused by evaporation losses from Barrotse Flood Plain in Western Province and from Kariba Dam and Kafue Flood Plain in Southern Province.
- Comparing the surface water resources potential per 1 km^2 of the main river systems, the rivers in the north, namely Chambeshi River, Luapula River and Lake Tanganyika, have more potential, ranged from 478 to 632 m^3/day/km^2 in case of average year, and from 323 to 345 m^3/day/km^2 in case of drought year. However the rivers in south, namely Zambezi Main River, Kafue River and Luangwa River have less potential, ranged from 189 to 396 m^3/day/km^2 in case of average year, and from 93 to 198 m^3/day/km^2 in case of drought year.

Table 7-1 Surface Water Resources Potential by River Basin and Province

River Basin Province	Population	Area in Zambia	Surface Water Resources Potential				Ratio Drought / Average
			Average Year (30 years average)		Drought Year (10-year return period)		
	(person)	(km^2)	(m^3/s)	($1000m^3/day$)	(m^3/s)	($1000m^3/day$)	(%)
Zambezi R.	1,699,062	268,23	693.4	59,914	384.4	33,209	55 %
Kafue R.	2,864,334	156,99	343.8	29,704	168.6	14,567	49 %
Luangwa R.	1,310,998	144,35	661.4	57,142	330.0	28,516	50 %
Chambeshi R.	375,861	44,42	277.0	23,933	166.0	14,342	60 %
Luapula R.	832,900	113,32	626.5	54,133	443.1	38,285	71 %
Lake Tanganyika	80,725	15,85	115.9	10,016	63.2	5,463	55 %
Others	219,204	8,65	28.6	2,472	21.0	1,811	73 %
Total	7,383,084	751,85	2,746.7	237,315	1,576.3	136,193	57 %
Lusaka Pro.	987,106	22,09	125.5	10,846	42.4	3,661	34 %
Copperbelt Pro.	1,427,528	31,21	150.4	12,997	76.8	6,633	51 %
Central Pro.	720,628	94,68	388.5	33,567	127.8	11,046	33 %
Northwestern Pro.	387,554	125,28	449.8	38,864	248.9	21,509	55 %
Western Pro.	606,813	127,34	235.4	20,337	188.1	16,253	80 %
Southern Pro.	907,150	85,19	61.3	5,299	13.9	1,197	23 %
Luapula Pro.	525,160	49,59	304.8	26,335	205.0	17,712	67 %
Northern Pro.	855,177	147,29	781.7	67,540	518.8	44,824	66 %
Eastern Pro.	965,968	69,14	249.2	21,528	154.6	13,357	62 %
Total	7,383,084	751,85	2,746.7	237,315	1,576.3	136,193	57 %

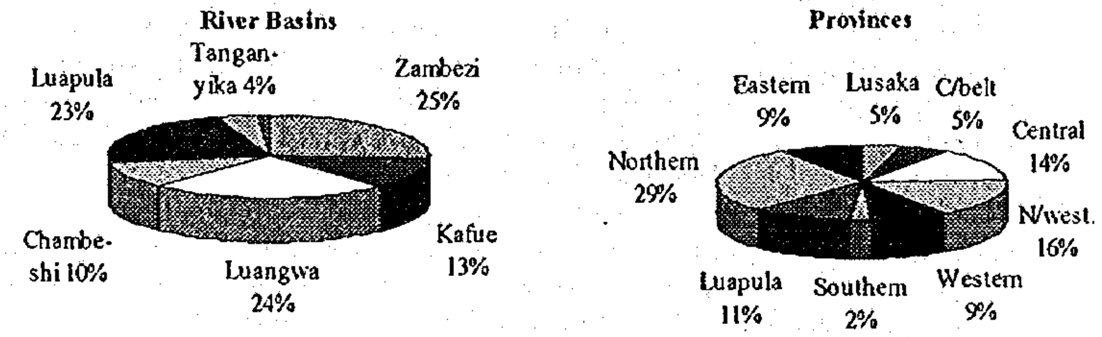


Figure 7-3 (1) Water Resources Potential by River Basins and Provinces (Average Year : 30 years Average)

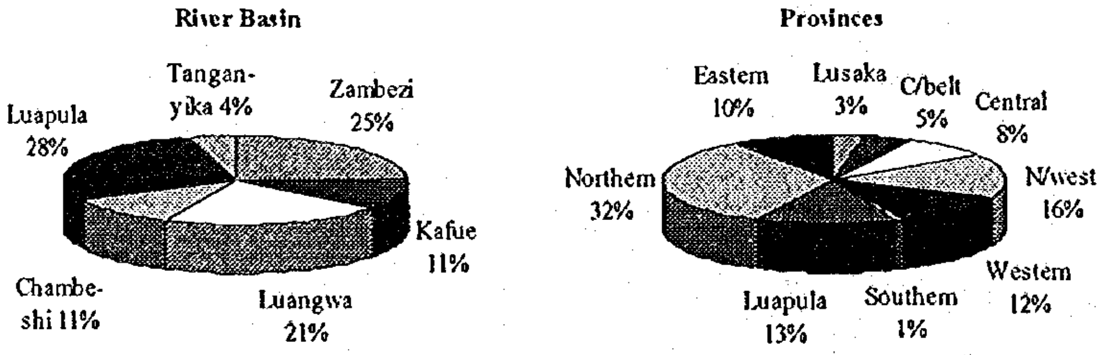


Figure 7-3 (2) Water Resources Potential by River Basins and Provinces (Drought Year : 10-year Return Period)

Table 7-2(1) Surface Water Resources Potential by Basin Block (Average Year : 30 years Average)

Basin Block	Block Population	Block Area inside of Zambia	Basin Runoff								Block Specific Discharge	Block Water Resources Potential			
			Inflow			Outflow			Balance			Discharge	Daily Discharge	Specific Daily Discharge	Daily Discharge per Capita
-	(person)	(km2)	Sub-basin	C.A. (km2)	Discharge (m3/s)	Sub-basin	C.A. (km2)	Discharge (m3/s)	C.A. (km2)	Discharge (m3/s)	(m3/s/1000km2)	(m3/s)	(Tm3/day)	(m3/day/km2)	(m3/day/capita)
Zambezi R.	1,699,062	268,235	-	-	-	-	-	-	379,157	800	2.11	693.4	69,914	223	36
BZ-01	81,772	11,774	PZ-01	75,967	562	PZ-06(1)	89,874	665	13,907	103	7.41	87.2	7,534	640	92
BZ-02	134,402	41,021	-	-	-	PZ-03	42,740	221	42,740	221	5.17	212.1	18,326	447	136
BZ-03	62,714	30,011	PZ-03	42740	221	PZ-06(2)	72,751	262	30,011	41	1.37	41.0	3,542	118	56
BZ-04	396,993	60,255	PZ-07/09(2)	250150	871	PZ-10	284,538	963	34,388	92	2.68	161.2	13,928	231	35
BZ-05	120,250	43,443	PZ-10	284538	963	PZ-11	336,053	1,014	51,515	51	0.99	43.0	3,716	86	31
BZ-06	119,176	41,739	PZ-11/12(2)	480453	1155	PZ-13	513,780	1,187	33,327	32	0.96	40.1	3,463	83	29
BZ-07	378,422	25,985	PZ-13	513,780	1,187	PZ-14(2)	663,880	1,299	150,100	112	0.75	19.4	1,675	64	4
BZ-08	47,871	2,922	PZ-14(2)	663,880	1,299	PZ-15(1)	667,970	1,325	4,090	26	6.36	18.6	1,605	549	34
BZ-09	357,462	11,085	PZ-15(3)	824965	1636	PZ-16	844,044	1,758	19,079	122	6.39	70.9	6,124	552	17
Kafue R.	2,864,334	156,995	-	-	-	-	-	-	156,995	344	2.19	343.8	29,704	189	10
BK-01	34,813	5,775	-	-	-	PK-01	5,775	34.0	5,775	34	5.89	34.0	2,938	509	84
BK-02	405,483	3,139	PK-01	5,775	34.0	PK-03	8,914	73.6	3,139	40	12.62	39.6	3,421	1,090	8
BK-03	486,089	3,087	PK-03	8,914	73.6	PK-04	12,001	92.6	3,087	19	6.15	19.0	1,642	532	3
BK-04	492,497	12,263	PK-04	12,001	92.6	PK-06(1)	24,264	142.7	12,263	50	4.09	50.1	4,329	353	9
BK-05	13,145	8,839	-	-	-	PK-06(2)	8,839	31.6	8,839	32	3.58	31.6	2,730	309	208
BK-06	93,063	22,859	PK-6(1),(2)	33,103	174	PK-08	55,962	189.5	22,859	15	0.66	15.2	1,313	57	14
BK-07	82,448	23,767	-	-	-	PK-10(1)	23,767	92.4	23,767	92	3.89	92.4	7,983	336	97
BK-08	21,566	16,510	PK-10(2)	79729	281.9	PK-11	96,239	308.1	16,510	26	1.59	26.2	2,264	137	105
BK-09	2,778	10,952	PK-11	96,239	275.3	PK-12(2)	107,191	278.4	10,952	3	0.28	3.1	268	24	96
BK-10	1,211,319	46,635	PK-12(2)	107,191	278.4	PK-13(2)	153,826	295.6	46,635	17	0.37	17.2	1,486	32	1
BK-11	21,133	3,169	PK-13(2)	153,826	295.6	PZ-15(2)	156,995	311.0	3,169	15	4.86	15.4	1,331	420	63
Luangwa R.	1,310,998	144,358	-	-	-	-	-	-	147,622	682	4.62	661.4	57,142	396	44
BL-01	683,317	73,422	-	-	-	PL-01	73,422	283	73,422	283	3.85	283.0	24,451	333	36
BL-02	152,964	18,439	PL-01	73,422	283	PL-02	91,861	327	18,439	44	2.39	44.0	3,802	206	25
BL-03	340,366	27,443	-	-	-	PL-03(1)	27,443	175	27,443	175	6.38	175.0	15,120	551	44
BL-04	43,980	14,711	-	-	-	PL-03(2)	14,711	94	14,711	94	6.39	94.0	8,122	552	185
BL-05	90,371	10,343	PL-02/03(3)	134015	595	PZ-17(1)	147,622	681	13,607	86	6.32	65.4	5,648	546	62
Chambeshi R.	376,861	44,427	-	-	-	-	-	-	44,427	277	6.23	277.0	23,933	539	64
BC-01	276,312	34,745	-	-	-	PC-01	34,745	185	34,745	185	5.32	185.0	15,984	460	58
BC-02	99,549	9,682	PC-01	34,745	185	PC-03	44,427	277	9,682	92	9.50	92.0	7,949	821	80
Luapula R.	832,900	113,323	-	-	-	-	-	-	142,784	748	5.24	626.6	54,133	478	66
BP-01	299,736	48,025	PC-03	44,427	277	PP-01	92,452	375	48,025	98	2.04	98.0	8,467	176	28
BP-02	88,375	17,480	PP-01	92,452	375	PP-02	123,072	499	30,620	124	4.05	70.8	6,116	350	69
BP-03	119,591	14,270	PP-02	123,072	499	PP-03	161,275	741	38,203	242	6.33	90.4	7,810	547	65
BP-04	109,464	22,936	-	-	-	PP-05	25,936	284	25,936	284	10.95	251.1	21,699	946	198
BP-05	215,734	10,612	-	-	-	-	-	-	-	-	10.95	116.2	10,040	946	47
L.Tanganyika	80,725	15,856	-	-	-	-	-	-	9,027	66	7.31	115.9	10,016	632	124
BT-01	17,769	9,027	-	-	-	PT-01	9,027	66	9,027	66	7.31	66.0	5,702	632	321
BT-02	62,956	6,829	-	-	-	-	-	-	-	-	7.31	49.9	4,314	632	69
Others	219,204	8,668	-	-	-	-	-	-	-	-	-	28.6	2,472	286	11
Total	7,383,084	751,852	-	-	-	-	-	-	880,012	2,917	3.31	2,746.7	237,316	316	32

Table 7-2(2) Surface Water Resources Potential by Basin Block (Drought Year : 10-year return period)

Basin Block	Block Population	Block Area Inside of Zambia	Basin Runoff								Block Specific Discharge	Block Water Resources Potential			
			Inflow			Outflow			Balance			Discharge	Daily Discharge	Specific Daily Discharge	Daily Discharge per Capita
	(person)	(km2)	Sub-basin	C.A. (km2)	Discharge (m3/s)	Sub-basin	C.A. (km2)	Discharge (m3/s)	C.A. (km2)	Discharge (m3/s)	(m3/s/1000km2)	(m3/s)	(Tm3/day)	(m3/day/km2)	(m3/day/capita)
Zambezi R.	**1,699,062**	**268,235**	-	-	-	-	-	-	**379,157**	**368**	**0.94**	**384.4**	**33,209**	**124**	**20**
BZ-01	81,772	11,774	PZ-01	75,967	258	PZ-06(1)	89,874	305	13,907	47	3.38	39.8	3,438	292	42
BZ-02	134,402	41,021	-	-	-	PZ-03	42,740	119	42,740	119	2.78	114.2	9,868	241	73
BZ-03	62,714	30,011	PZ-03	42740	119	PZ-06(2)	72,751	149	30,011	30	1.00	30.0	2,592	86	41
BZ-04	396,993	60,255	PZ-07/09(2)	250150	591	PZ-10	284,538	676	34,388	85	2.47	148.9	12,868	214	32
BZ-05	120,250	43,443	PZ-10	284538	676	PZ-11	336,053	691	51,515	15	0.29	12.6	1,093	25	9
BZ-06	119,176	41,739	PZ-11/12(2)	480453	734	PZ-13	513,780	744	33,327	10	0.30	12.5	1,082	26	9
BZ-07	378,422	25,985	PZ-13	513,780	744	PZ-14(2)	663,880	756	150,100	12	0.08	2.1	179	7	0
BZ-08	47,871	2,922	PZ-14(2)	663,880	756	PZ-15(1)	667,970	763	4,090	7	1.71	5.0	432	148	9
BZ-09	357,462	11,085	PZ-15(3)	824965	938	PZ-16	844,044	971	19,079	33	1.73	19.2	1,657	149	5
Kafue R.	**2,864,334**	**156,995**	-	-	-	-	-	-	**166,995**	**169**	**1.07**	**168.6**	**14,567**	**93**	**5**
BK-01	34,813	5,775	-	-	-	PK-01	5,775	18.5	5,775	19	3.20	18.5	1,598	277	46
BK-02	405,483	3,139	PK-01	5,775	18.5	PK-03	8,914	38.7	3,139	20	6.44	20.2	1,745	556	4
BK-03	486,089	3,087	PK-03	8,914	38.7	PK-04	12,001	50.0	3,087	11	3.66	11.3	976	316	2
BK-04	492,497	12,263	PK-04	12,001	50.0	PK-06(1)	24,264	74.9	12,263	25	2.03	24.9	2,151	175	4
BK-05	13,145	8,839	-	-	-	PK-06(2)	8,839	14.5	8,839	15	1.64	14.5	1,253	142	95
BK-06	93,063	22,859	PK-6(1),(2)	33,103	89.4	PK-08	55,962	93.0	22,859	4	0.16	3.6	311	14	3
BK-07	82,448	23,767	-	-	-	PK-10(1)	23,767	44.2	23,767	44	1.86	44.2	3,819	161	46
BK-08	21,566	16,510	PK-10(2)	79729	137.2	PK-11	96,239	160.6	16,510	23	1.42	23.4	2,022	122	94
BK-09	2,778	10,952	PK-11	96,239	160.6	PK-12(2)	107,191	162.0	10,952	1	0.13	1.4	121	11	44
BK-10	1,211,319	46,635	PK-12(2)	107,191	162.0	PK-13(2)	153,826	163.0	46,635	1	0.02	1.0	86	2	0
BK-11	21,133	3,169	PK-13(2)	153,826	163.0	PZ-15(2)	156,995	168.6	3,169	6	1.77	5.6	484	153	23
Luangwa R.	**1,310,998**	**144,358**	-	-	-	-	-	-	**147,622**	**337**	**2.28**	**330.0**	**28,516**	**198**	**22**
BL-01	683,317	73,422	-	-	-	PL-01	73,422	181	73,422	181	2.47	181.0	15,638	213	23
BL-02	152,964	18,439	PL-01	73,422	181	PL-02	91,861	219	18,439	38	2.06	38.0	3,283	178	21
BL-03	340,366	27,443	-	-	-	PL-03(1)	27,443	58	27,443	58	2.11	58.0	5,011	183	15
BL-04	43,980	14,711	-	-	-	PL-03(2)	14,711	31	14,711	31	2.11	31.0	2,678	182	61
BL-05	90,371	10,343	PL-02/03(3)	134015	308	PZ-17(1)	147,622	337	13,607	29	2.13	22.0	1,905	184	21
Chambeshi R.	**375,861**	**44,427**	-	-	-	-	-	-	**44,427**	**166**	**3.74**	**166.0**	**14,342**	**323**	**38**
BC-01	276,312	34,745	-	-	-	PC-01	34,745	98	34,745	98	2.82	98.0	8,467	244	31
BC-02	99,549	9,682	PC-01	34,745	98	PC-03	44,427	166	9,682	68	7.02	68.0	5,875	607	59
Luapula R.	**832,900**	**113,323**	-	-	-	-	-	-	**142,784**	**489**	**3.42**	**443.1**	**38,286**	**338**	**46**
BP-01	299,736	48,025	PC-03	44,427	166	PP-01	92,452	221	48,025	55	1.15	55.0	4,752	99	16
BP-02	88,375	17,480	PP-01	92,452	221	PP-02	123,072	294	30,620	73	2.38	41.7	3,601	206	41
BP-03	119,591	14,270	PP-02	123,072	294	PP-03	161,275	425	38,203	131	3.43	48.9	4,228	296	35
BP-04	109,464	22,936	-	-	-	PP-05	25,936	230	25,936	230	8.87	203.4	17,573	766	161
BP-05	215,734	10,612	-	-	-	-	-	-	-	-	8.87	94.1	8,131	766	38
L.Tanganyika	**80,725**	**15,856**	-	-	-	-	-	-	**9,027**	**36**	**3.99**	**63.2**	**5,463**	**345**	**68**
BT-01	17,769	9,027	-	-	-	PT-01	9,027	36	9,027	36	3.99	36.0	3,110	345	175
BT-02	62,956	6,829	-	-	-	-	-	-	-	-	3.99	27.2	2,353	345	37
Others	**219,204**	**8,658**	-	-	-	-	-	-	-	-	-	**21.0**	**1,811**	**209**	**8**
Total	**7,383,084**	**761,862**	-	-	-	-	-	-	**880,012**	**1,656**	**1.77**	**1,676.3**	**136,193**	**181**	**18**

Table 7-3 (1) Surface Water Resources Potential by Province (Average Year : 30 years Average)

Basin Block	Block Population (person)	Block Area inside of Zambia (km²)	Block Water Resources Potential: Discharge (m³/s)	Daily Discharge (Tm³/day)	Specific Daily Discharge (m³/day/km²)	Daily Discharge per Capita (m³/day/capita)
Lusaka Pro.	**987,106**	**22,094**	**125.6**	**10,846**	**491**	**11**
BZ-09	357,462	11,085	70.9	6,124	552	17
BK-11	21,133	3,169	15.4	1,331	420	63
Total & Ave.	378,595	14,254	86.3	7,455	523	20
C/belt Pro.	**1,427,528**	**31,217**	**150.4**	**12,997**	**416**	**9**
BK-02	405,483	3,139	39.6	3,421	1,090	8
BK-03	486,089	3,087	19.0	1,642	532	3
BK-04	492,497	12,263	50.1	4,329	353	9
BK-05	13,145	8,839	31.6	2,730	309	208
Total & Ave.	1,397,214	27,328	140.3	12,122	444	9
Central Pro.	**720,628**	**94,684**	**388.6**	**33,567**	**355**	**47**
BK-06	93,063	22,859	15.2	1,313	57	14
BL-03	340,366	27,443	175.0	15,120	551	44
BL-04	43,980	14,711	94.0	8,122	552	185
Total & Ave.	477,409	65,013	284.2	24,555	378	51
N/western Pro.	**387,654**	**125,280**	**449.8**	**38,864**	**310**	**100**
BZ-01	81,772	11,774	87.2	7,534	640	92
BZ-02	134,402	41,021	212.1	18,326	447	136
BZ-03	62,714	30,011	41.0	3,542	118	56
BK-01	34,813	5,775	34.0	2,938	509	84
BK-07	82,448	23,767	92.4	7,983	336	97
BK-08	21,566	16,510	26.2	2,264	137	105
Total & Ave.	417,715	128,858	492.9	42,588	331	102
Western Pro.	**606,813**	**127,344**	**235.4**	**20,337**	**160**	**34**
BZ-04	396,993	60,255	161.2	13,928	231	35
BZ-05	120,250	43,443	43.0	3,716	86	31
Total & Ave.	517,243	103,698	204.2	17,644	170	34
Southern Pro.	**907,150**	**85,199**	**61.3**	**6,299**	**62**	**6**
BZ-06	119,176	41,739	40.1	3,463	83	29
BZ-07	378,422	25,985	19.4	1,675	64	4
BZ-08	47,871	2,922	18.6	1,605	549	34
BK-09	2,778	10,952	3.1	268	24	96
BK-10	1,211,319	46,635	17.2	1,486	32	1
Total & Ave.	1,759,566	128,233	98.3	8,497	66	5
Luapula Pro.	**525,160**	**49,694**	**304.8**	**26,335**	**531**	**50**
BP-02	88,375	17,480	70.8	6,116	350	69
BP-03	119,591	14,270	90.4	7,810	547	65
BP-05	215,734	10,612	116.2	10,040	946	47
Total & Ave.	423,700	42,362	277.4	23,966	566	57
Northern Pro.	**855,177**	**147,294**	**781.7**	**67,540**	**459**	**79**
BC-01	276,312	34,745	185.0	15,984	460	58
BC-02	99,549	9,682	92.0	7,949	821	80
BP-01	299,736	48,025	98.0	8,467	176	28
BP-04	109,464	22,936	251.1	21,699	946	198
BT-01	17,769	9,027	66.0	5,702	632	321
BT-02	62,956	6,829	49.9	4,314	632	69
Total & Ave.	865,786	131,244	742.1	64,116	489	74
Eastern Pro.	**965,968**	**69,146**	**249.2**	**21,528**	**311**	**22**
BL-01	683,317	73,422	283.0	24,451	333	36
BL-02	152,964	18,439	44.0	3,802	206	25
BL-05	90,371	10,343	65.4	5,648	546	62
Total & Ave.	926,652	102,204	392.4	33,901	332	37
Total	**7,383,084**	**751,852**	**2,746.7**	**237,315**	**316**	**32**

Table 7-3 (2) Surface Water Resources Potential by Province (Drought Year : 10-year return period)

Basin Block	Block Population (person)	Block Area Inside of Zambia (km²)	Block Water Resources Potential: Discharge (m^3/s)	Daily Discharge (Tm^3/day)	Specific Daily Discharge ($m^3/day/km^2$)	Daily Discharge per Capita ($m^3/day/capita$)
Lusaka Pro.	**987,106**	**22,094**	**42.4**	**3,661**	**166**	**4**
BZ-09	357,462	11,085	23.2	2,008	181	6
BK-11	21,133	3,169	5.6	484	153	23
Total & Ave.	378,595	14,254	28.8	2,492	175	7
C/belt Pro.	**1,427,628**	**31,217**	**76.8**	**6,633**	**212**	**5**
BK-02	405,483	3,139	20.2	1,745	556	4
BK-03	486,089	3,087	11.3	976	316	2
BK-04	492,497	12,263	24.9	2,151	175	4
BK-05	13,145	8,839	14.5	1,253	142	95
Total & Ave.	1,397,214	27,328	70.9	6,126	224	4
Central Pro.	**720,628**	**94,684**	**127.8**	**11,046**	**117**	**15**
BK-06	93,063	22,859	3.6	311	14	3
BL-03	340,366	27,443	58.0	5,011	183	15
BL-04	43,980	14,711	31.0	2,678	182	61
Total & Ave.	477,409	65,013	92.6	8,001	123	17
N/western Pro.	**387,654**	**126,280**	**248.9**	**21,509**	**172**	**55**
BZ-01	81,772	11,774	39.8	3,438	292	42
BZ-02	134,402	41,021	114.2	9,868	241	73
BZ-03	62,714	30,011	30.0	2,592	86	41
BK-01	34,813	5,775	18.5	1,598	277	46
BK-07	82,448	23,767	44.2	3,819	161	46
BK-08	21,566	16,510	23.4	2,022	122	94
Total & Ave.	417,715	128,858	270.1	23,337	181	56
Western Pro.	**606,813**	**127,344**	**188.1**	**16,253**	**128**	**27**
BZ-04	396,993	60,255	148.9	12,868	214	32
BZ-05	120,250	43,443	12.6	1,093	25	9
Total & Ave.	517,243	103,698	161.6	13,961	135	27
Southern Pro.	**907,160**	**85,199**	**13.9**	**1,197**	**14**	**1**
BZ-06	119,176	41,739	12.5	1,082	26	9
BZ-07	378,422	25,985	2.1	179	7	0
BZ-08	47,871	2,922	5.0	432	148	9
BK-09	2,778	10,952	1.4	121	11	44
BK-10	1,211,319	46,635	1.0	86	2	0
Total & Ave.	1,759,566	128,233	22.0	1,901	15	1
Luapula Pro.	**525,160**	**49,694**	**205.0**	**17,712**	**357**	**34**
BP-02	88,375	17,480	41.7	3,601	206	41
BP-03	119,591	14,270	48.9	4,228	296	35
BP-05	215,734	10,612	94.1	8,131	766	38
Total & Ave.	423,700	42,362	184.7	15,959	377	38
Northern Pro.	**855,177**	**147,294**	**518.8**	**44,824**	**304**	**52**
BC-01	276,312	34,745	98.0	8,467	244	31
BC-02	99,549	9,682	68.0	5,875	607	59
BP-01	299,736	48,025	55.0	4,752	99	16
BP-04	109,464	22,936	203.4	17,573	766	161
BT-01	17,769	9,027	36.0	3,110	345	175
BT-02	62,956	6,829	27.2	2,353	345	37
Total & Ave.	865,786	131,244	487.6	42,131	321	49
Eastern Pro.	**965,968**	**69,146**	**154.6**	**13,357**	**193**	**14**
BL-01	683,317	73,422	181.0	15,638	213	23
BL-02	152,964	18,439	38.0	3,283	178	21
BL-05	90,371	10,343	22.0	1,905	184	21
Total & Ave.	926,652	102,204	241.0	20,826	204	22
Total	**7,383,084**	**751,852**	**1,576.3**	**136,193**	**181**	**18**

CHAPTER 8 INTAKE RATE POTENTIAL FROM RIVER

8.1 Estimation Method of Intake Rate Potential

Intake rate potential is defined as the discharge which is able to be abstracted from a river without constructing water storage facility. The intake rate potential from river, Qp, was estimated by subtracting the compensation discharge, Qc, from the probable drought discharge, Qd. Compensation discharge is the discharge which is necessary to be flowed downstream and satisfies both the maintenance discharge, Qm, and the water-use discharge, Qu. These can be presented as following equations:

$$Qp = Qd - Qc \ , \qquad \text{where } Qc = Qm + Qu$$

<u>Maintenance Discharge</u>

The maintenance discharge of a perennial river is required to maintain river water depth, conservation of groundwater, and the people's amenity. In the Study, the probable minimum discharge for a 30-year return period was assumed as the maintenance discharge. This discharge approximately corresponds to the recorded minimum daily discharge because the period of river flow record is around 30 years or more. In the estimation of the intake rate potential from a river, the recorded minimum discharge is employed instead of average drought discharge used in dam development, because of the following reasons :

- At a dam development site, the flow corresponding to the maintenance discharge usually flows downstream and the frequency of the extreme low flow condition is relatively high. To the contrary, at a development site from which flow is directly abstracted, low flow conditions such as maintenance flow, rarely occurred.
- The utilisation percentage of river flow in Zambia is still so low that even the minimum flow is considered to be good for environmental management.

<u>Water-use Discharge</u>

The water-use discharge is the discharge which is necessary for the exclusive use of river flow at all points downstream. In the Study, water-use discharge is not counted because:

- It is fairly certain that the present minimum flow condition satisfies all water-uses downstream.
- Minimum discharge is employed as the maintenance discharge.
- Thus it is likely that the maintenance discharge includes the water-use discharge.

8.2 Intake Rate Potential from River

According to the above method, the intake rate potential by the basin block is estimated for three cases, which correspond to water use security of 2-year, 5-year and 10-year return periods. The intake rate potential shows the potential at the most downstream point of each block. Then it is obvious that if water is abstracted in an upstream block, the intake rate potential in the downstream block is reduced. The intake rate potentials by the basin blocks are presented in Table 8-1 and Figure 8-4. The relationship between the intake rate potential and catchment area, and between the intake rate potential and basin mean annual rainfall, in case of return period 10-year, are shown in Figure 8-2 and Figure 8-3. According to the table and the figures, the intake rate potential with 10-year of return period are summarised as follows :

- The intake rate potentials in the main rivers are 76.6 m^3/s (6,619,000 m^3/day) at Feira Boma in Zambezi River, 8.6 m^3/s (743,000 m^3/day) at Kafue H.B. in Kafue River, 4.1 m^3/s (354,000 m^3/day) at Luangwa Rd.Br. in Luangwa River, 9.2 m^3/s (795,000 m^3/day) at Mbati in Chambeshi River, 17.6 m^3/s (1,521,000 m^3/day) at Kashiba in Luapula River and 3.2 m^3/s (276,000 m^3/day) at Keso Falls in Lufubu River of Lake Tanganyika Basin.
- Intake rate potential has the approximate trend that it becomes large with increasing catchment area.
- There is no relationship between specific intake rate potential and catchment area. The specific intake rate potential in the Luangwa river is very low, 1.18~2.94 $m^3/day/km^2$. In the other rivers, it varies widely, 5~14 $m^3/day/km^2$.
- There is the obvious relationship between specific intake rate potential and basin annual rainfall as shown in Figure 8-3. Specific intake rate potential becomes large with increases in the basin's annual rainfall.

Intake rate potential in a small basin was also studied at proposed dam sites to be described in Supporting Report [O] : Dam Development Plan. The results are shown in Figure 8-1. Judging only from the results from small basins, the following circumstance becomes clear : For basin under 2,000 km^2, the specific intake rate potential ranges from 9 to 35 $m^3/day/km^2$ in the four wet provinces, namely Northern, Northwestern, Copperbelt and Central Province. In the other provinces, there is no intake rate potential for basin under 2,000 km^2.

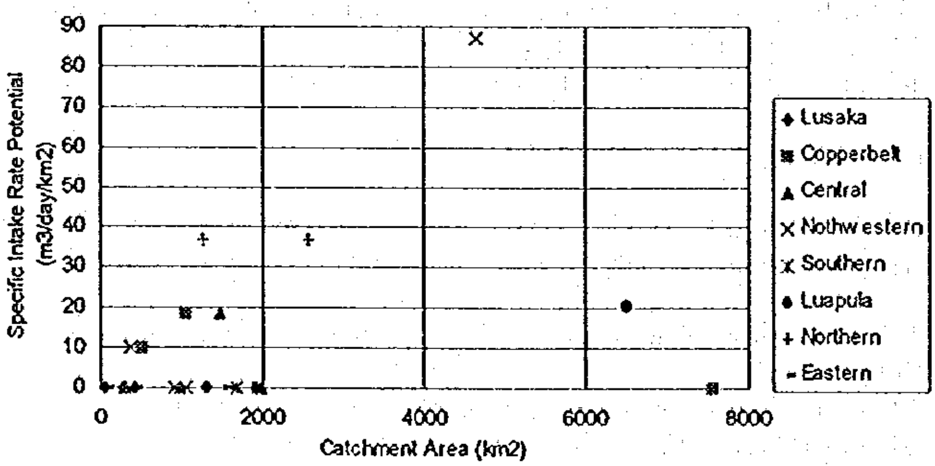


Figure 8-1 Specific Intake Rate Potential in Small River Basin

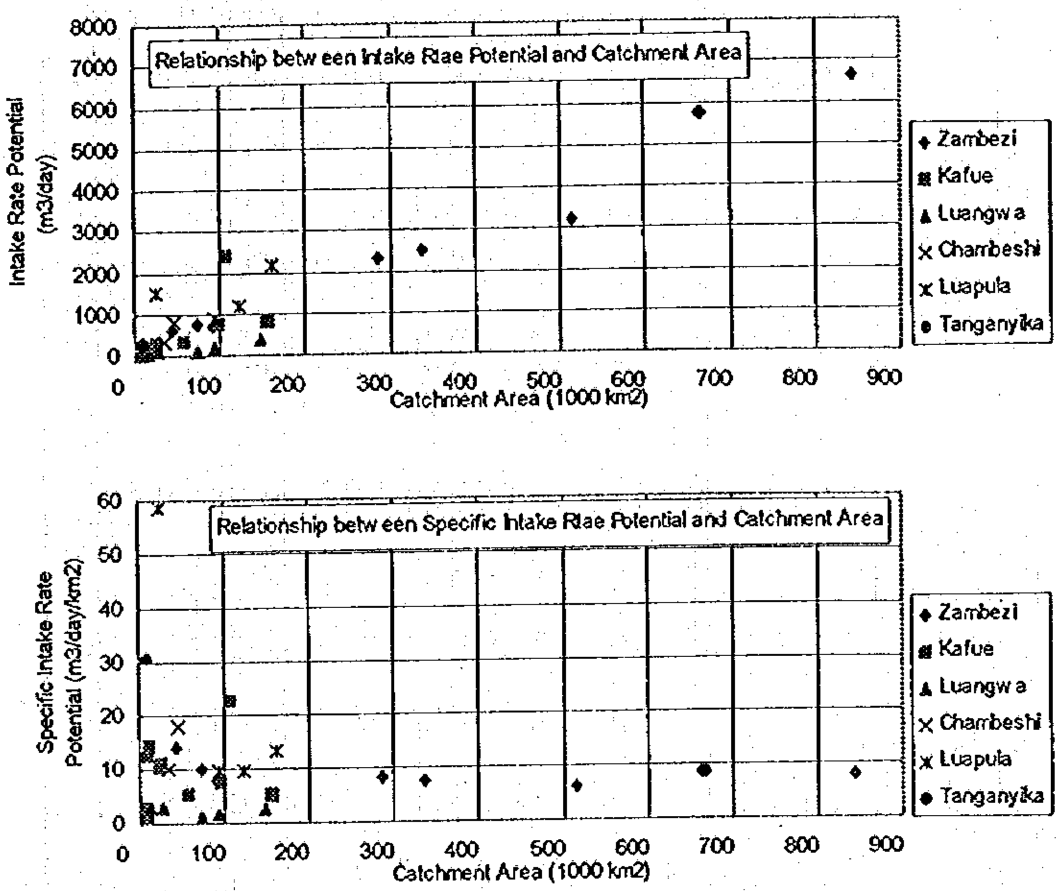


Figure 8-2 Relationship between Intake Rate Potential and Catchment Area

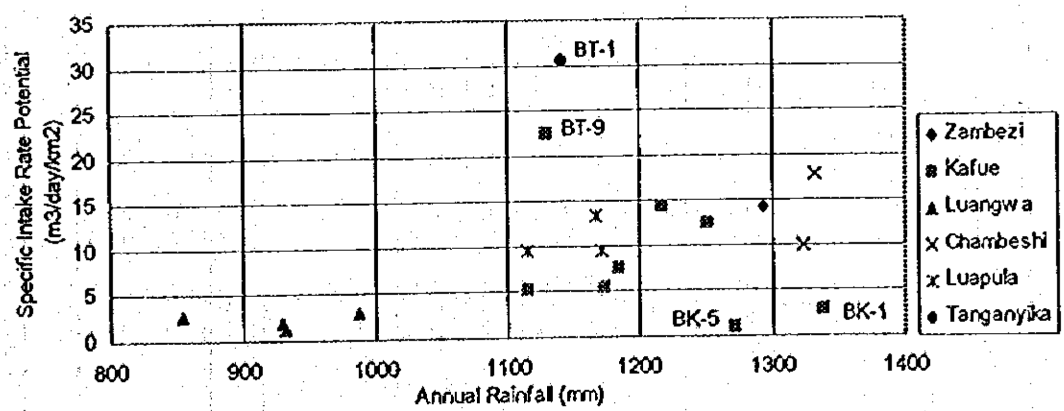


Figure 8-3 Relationship between Intake Rate Potential and Annual Rainfall

Table 8-1 Intake Rate Potential at the Most Downstream of Basin Block

River Basin	Basin Block	Discharge Reference Point	Catchment Area (km2)	Drought Discharge (m3/s) Return Period 10-year	Drought Discharge (m3/s) Return Period 5-year	Drought Discharge (m3/s) Return Period 2-year	Minimum Discharge (30-year) *1 (m3/s)	Water Right Amount (m3/s)	*2 Intake Rate (m3/s) 10-year	*2 Intake Rate (m3/s) 5-year	*2 Intake Rate (m3/s) 2-year	*2 Intake Rate (1000 m3/day) 10-year	*2 Intake Rate (1000 m3/day) 5-year	*2 Intake Rate (1000 m3/day) 2-year	Specific Intake Rate (m3/day/km2) 10-year	Specific Intake Rate (m3/day/km2) 5-year	Specific Intake Rate (m3/day/km2) 2-year	30 Years Average Flow Regime (m3/s) Max.	Q (95)	Q (185)	Q (275)	Q (355)	Min.	Average
Zambezi	BZ-1	PZ-6(1)	89,874	47.9	52.8	63.7	39.7	0.2	8.2	13.1	24.0	708	1,132	2,074	7.88	12.59	23.07	2938	937	240	108	68	61	665
(Kabompo)	BZ-2	PZ-3	42,740	26.8	32.2	45.7	19.8	0.6	7.0	12.4	25.9	605	1,071	2,238	14.15	25.07	52.36	686	299	148	90	54	52	221
(Kabompo)	BZ-3	PZ-6(2)	72,751	45.8	51.4	64.2	37.2	0.6	8.6	14.2	27.0	743	1,227	2,333	10.21	16.86	32.07	854	368	155	101	69	65	262
	BZ-4	PZ-10	284,538	236.1	253.9	291.8	209.3	0.9	26.8	44.6	82.5	2,316	3,853	7,128	8.14	13.54	25.05	2372	1452	664	384	291	279	963
	BZ-5	PZ-11	336,053	236.3	255.6	297.0	207.2	0.9	29.1	48.4	89.8	2,514	4,182	7,759	7.48	12.44	23.09	2564	1522	689	399	296	283	1014
	BZ-6	PZ-13	513,780	236.9	261.3	315.1	200.0	0.9	36.9	61.3	115.1	3,188	5,296	9,945	6.21	10.31	19.36	3225	1766	777	449	316	298	1187
(Kariba)	BZ-7	PZ-14(2)	663,880	462.5	523.2	662.3	396.1	4.2	66.4	127.1	266.2	5,737	10,981	23,000	8.64	16.54	34.64	6668	1083	904	729	482	455	1299
	BZ-8	PZ-15(1)	667,970	462.8	523.7	663.5	396.2	4.3	66.5	127.4	267.3	5,749	11,010	23,094	8.61	16.48	34.57	6745	1122	914	733	484	457	1325
	BZ-9	PZ-16	844,044	533.2	609.7	790.5	456.6	6.9	76.6	153.1	333.9	6,619	13,232	28,852	7.84	15.68	34.18	7775	1724	1219	933	620	568	1758
Kafue	BK-1	PK-1	5,775	1.0	1.3	1.9	0.8	0.0	0.2	0.5	1.1	17	43	95	2.99	7.48	16.46	117	55	18	6.5	2.2	2.0	34
	BK-2	PK-3	8,914	3.9	5.0	8.1	2.6	15.9	1.3	2.4	5.5	112	207	475	12.60	23.26	53.31	251	116	46	21	10	8.6	74
	BK-3	PK-4	12,001	7.7	9.1	12.6	5.7	27.9	2.0	3.4	6.9	173	294	596	14.40	24.48	49.68	330	139	52	27	15	14	93
	BK-4	PK-6(1)	24,264	12.5	14.7	19.9	9.4	39.6	3.1	5.3	10.5	268	458	907	11.04	18.87	37.39	466	220	74	38	21	20	143
(Luswishi)	BK-5	PK-6(2)	8,839	1.4	1.7	2.6	1.3	0.0	0.1	0.4	1.3	9	35	112	0.98	3.91	12.71	91	53	18	5.6	2.8	2.7	32
	BK-6	PK-8	55,962	11.4	14.6	23.2	7.8	41.6	3.6	6.8	15.4	311	588	1,331	5.56	10.50	23.78	575	304	108	55	29	27	189
(Lunga)	BK-7	PK-10(1)	23,767	12.4	14.6	19.9	9.5	1.0	2.9	5.1	10.4	251	441	899	10.54	18.54	37.81	446	123	51	32	20	18	92
	BK-8	PK-11	96,239	25.6	31.9	48.8	17.0	42.6	8.6	14.9	31.8	743	1,287	2,748	7.72	13.38	28.55	1113	469	173	95	55	49	308
(Itezhi-T.)	BK-9	PK-12(2)	107,191	80.8	89.1	107.4	52.9	42.6	27.9	36.2	54.5	2,411	3,128	4,709	22.49	29.18	43.93	832	325	188	147	109	85	278
(Kafue G.)	BK-10	PK-13(2) *3	153,826	68.9	83.5	120.3	59.6	74.8	9.3	23.9	60.7	804	2,065	5,244	5.22	13.42	34.09	574	402	253	177	123	100	296
	BK-11	PZ-15(2)	156,995	69.1	83.9	121.2	59.7	74.8	9.4	24.2	61.5	812	2,091	5,314	5.17	13.32	33.85	634	432	261	180	125	101	316
Luangwa	BL-1	PL-1	73,422	1.5	3.3	14.2	0.5	0.4	1.0	2.8	13.7	86	242	1,184	1.18	3.29	16.12	1610	376	126	73	39	34	283
	BL-2	PL-2	91,861	4.3	5.9	10.9	2.2	0.5	2.1	3.7	8.7	181	320	752	1.98	3.48	8.18	3329	387	82	34	12	11	327
(Lunsemfwa)	BL-3	PL-3(1)	27,443	1.8	3.1	8.2	0.9	3.6	0.9	2.2	7.3	78	190	631	2.83	6.93	22.98	520	259	67	30	15	14	175
(Lukusashi)	BL-4	PL-3(2)	14,711	1.0	1.7	4.4	0.5	1.3	0.5	1.2	3.9	43	104	337	2.94	7.05	22.91	279	139	36	16	8.1	7.5	94
	BL-5	PZ-17(1)	147,622	8.1	12.3	27.6	4.0	5.5	4.1	8.3	23.6	354	717	2,039	2.40	4.86	13.81	4385	912	218	94	43	40	681
Chambeshi	BC-1	PC-1	34,745	22.4	25.5	32.6	18.4	1.5	4.0	7.1	14.2	346	613	1,227	9.95	17.66	35.31	582	280	108	55	35	33	185
	BC-2	PC-3	44,427	46.9	53.2	67.5	37.7	2.7	9.2	15.5	29.8	795	1,339	2,575	17.89	30.14	57.95	849	403	175	104	71	68	277
Luapula	BP-1	PP-1	92,452	26.8	35.6	61.4	16.6	3.4	10.2	19.0	44.8	881	1,642	3,871	9.53	17.76	41.87	1105	577	289	126	75	65	375
	BP-2	PP-2	123,072	35.7	47.4	81.7	22.1	4.2	13.6	25.3	59.6	1,175	2,186	5,149	9.55	17.76	41.84	1470	768	385	168	99	87	499
	BP-3	PP-3	161,275	74.4	96.2	157.1	49.6	4.8	24.8	46.6	107.5	2,143	4,026	9,288	13.29	24.97	57.59	2021	1096	606	294	190	174	741
(Kalungwishi)	BP-4	PP-5	25,936	60.5	71.8	100.0	42.9	1.3	17.6	28.9	57.1	1,521	2,497	4,933	58.63	96.27	190.22	810	379	218	149	107	102	284
	BP-5	PP-6	217,823	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Tanganyika	BT-1	PT-1	9,027	8.6	10.0	13.5	5.4	2.3	3.2	4.6	8.1	276	397	700	30.63	44.03	77.53	301	89	41	23	15	14	66
	BT-2	-	15,856	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

*1 Minimum Discharge of 30-year Return Period (Recorded Minimum Discharge)
*2 Intake Rate Potential = Drought Discharge - Minimum Discharge
*3 Average spillway discharge during last 10 years, 39.7 m3/s, will be available with optimum gate operation of Itezhi-Tezhi Dam.

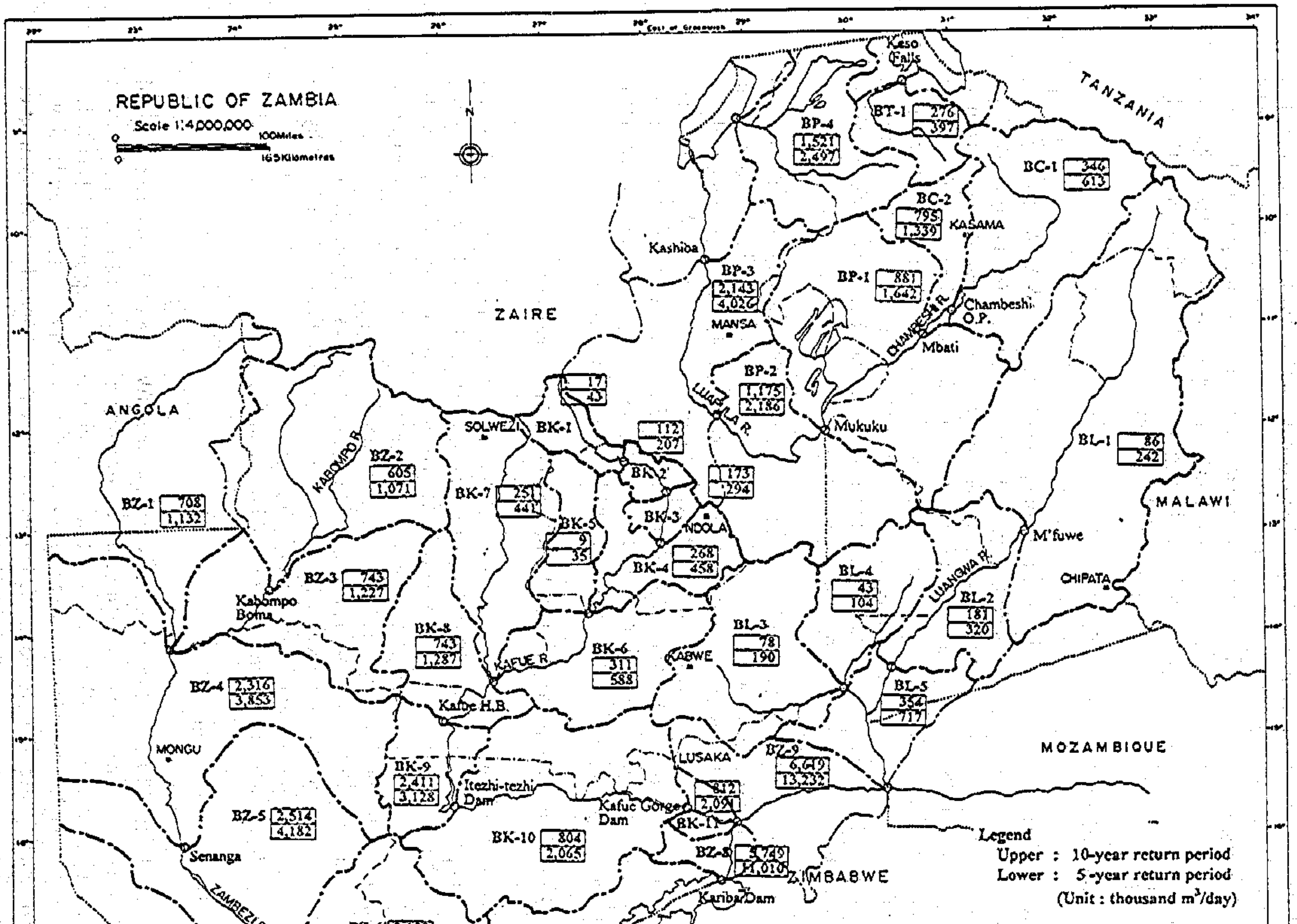


Figure 8-4 Intake Rate Potential at the Most Downstream of Basin Block

Intake Rate Potential : Discharge subtracting minimum discharge from probable drought discharge