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Ministry of Mineral and Water Resources

NATIONAL WATER CENTRE

A BRIEF DESCRIPTION OF MAJOR DRAINAGE BASINS AFFECTING SOMALIA WITH SPECIAL REFERENCE TO SURFACE WATER RESOURCES

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NATIONAL WATER CENTRE

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1. INTRODUCTION

A significant portion of the water resources of Somalia has its origin in neighbouring countries. This applies not only to surface water but also to a lesser extend to groundwater. General knowledge of the occurrence and movement of water in neighbouring areas is therefore of importance when it comes to studying the potential resources of Somalia itself.

The purpose of this report is to provide a brief general description of the topography, drainage, rainfall and evapotranspiration of the areas concerned. Where available, this is supplemented by additional hydrological information. The report is meant to form a basis for future more detailed studies on the subject.

It should be pointed out that lack of data for large parts of the drainage basins (particularly those situated in Ethiopia) has meant that the information contained in this report had to be kept rather general.

2. GENERAL DESCRIPTION OF THE AREA

2.1 The area

The entire surface drainage area affecting Somalia is shown in Fig. 1. It covers much of what is commonly referred to as "the Horn of Africa". It is bordered to the west by the East African Rift Valley and to the south by the Tana River Basin. To the north and east are the Gulf of Aden and the Indian Ocean. The area includes the Ethiopian part of the Juba and Shebelle river catchments as well as part of the Ogaden desert and northeast Kenya. It comprises in total approximately 1.3 million square kilometers (km^2), more than half of which is located outside Somalia.

For surface water resources assessment purposes, the area can be divided into nine major drainage basins:

1. Gulf of Aden basin
2. Darror basin
3. Tug Der/Nugal basin
4. Ogaden/Central basin
5. Shebelle basin
6. Juba basin
7. Lag Dera basin
8. Lag Badana basin
9. Indian Ocean basin

2.2 Topography and drainage

The drainage and topography of the area is shown in Fig.'s 1 and 2.

With the exception of the extreme north and southwest, the area generally slopes in southeasterly direction towards the Indian Ocean (see Fig. 2). The highest elevations occur on the Eastern Ethiopian Plateau (well over 3000 metres.. The slopes here are moderately steep to very steep and the area is deeply incised by water courses. Steep slopes also occur along the Gulf of Aden and in the Mount Kenya area in the southwest. The remainder of the area can be classified as gently sloping, undulating to flat countryside with average slopes of less than one percent. Almost half the area is below 500 metres above sea level, 30 percent lies between 500 and 1000 m, and 10 percent is higher than 1500 m (see Table 1).

Table 1. Area and elevation of drainage basins.

Basin	Area km²	% of area within altitude range: 0–200	200–500	500–1000	1000–1500	1500–2000	2000–3000	3000+
1.Gulf of Aden	76,000	12	30	32	20	6	-	-
2.Darror	37,000	18	34	36	10	2	-	-
3.Tug Der/Nugal	116,000	4	20	55	15	5	1	-
4.Ogaden/Central	223,000	34	24	31	10	1	-	-
5.Shebelle	307,000	22	22	27	14	7	5	3
6.Juba	223,000	13	31	25	11	11	5	4
7.Lag Dera	253,000	23	25	34	10	5	3	+
8.Lag Badana	38,000	97	3	-	-	-	-	-
9.Indian Ocean	22,000	95	5	-	-	-	-	-
Whole area	1,295,000	24	24	30	12	5	3	2

The surface drainage closely follows the general topography of the area (Fig. 1). Much of the area drains in a southeasterly direction towards the Indian Ocean; the extreme north discharges its runoff into the Gulf of Aden. The drainage network, which is influenced by local topography, rainfall and geology, is dense to very dense in the northern mountains of Somalia, as well as along the eastern slopes of the plateau of eastern Ethiopia and in parts of northeast Kenya. It is thin or virtually non-existing in large parts of the Ogaden region and central and south Somalia.

The only two permanent rivers in the area are the Shebelle River (basin no.5) and the Juba River (basin no.6). Both rise along the slopes of the Eastern Ethiopian Plateau. The areas of the drainage basins are estimated to be 307 000 km² and 223,000 km² respectively, but most of the effective drainage takes place in the upper reaches of the basins where rainfall is high. The Somali part of the catchments and the arid border zone of Ethiopia only contribute to runoff during heavy rainfall. Flows in lower reaches of both rivers decrease considerably as a result of infiltration, over-bank spillage, evaporation and water use.

Drainage in the north of Somalia (basin no's 1, 2 and 3) generally takes place in seasonal wadis, known as "tugs". Runoff only occurs after heavy rainfall in the form of spate flows which may last from a few hours to a number of days. In their mountainous sections, particularly in reaches where bedrock is exposed, the flow may be permanent. In sandy widenings and in valley bottoms in the gently rolling countryside large quantities of water are lost by infiltration, evaporation and by over flowing. It is assumed that little surface runoff reaches the sea.

The drainage network in most of the Ogaden region and central Somalia (basin no.4) is the least developed of all areas under discussion. Localized runoff occasionally occurs in short reaches of often poorly developed water courses, but usually dissipates quickly on flat land. Virtually no water reaches the sea.

Little is known about streamflow in the N-E Kenya/Lag Dera and Lag Badana basins (no's 7 and 8). Permanent streams only occur in the Mount Kenya area and the area immediately to the north of it. The remaining part of the basins are relatively dry and flat, and have a moderately dense network of intermittent streams that only occasionally carry water. Infiltration and evaporation losses are high.

2.3 Rainfall

2.3.1. Rainfall general

Fig. 3 shows the isohyet map of mean annual rainfall for the entire drainage area. Data for this map was obtained from different sources and is of varying quality and detail:

(i) Data for Somalia was extracted from technical reports no's 1 to 10 on "Daily, Monthly and Annual Rainfall for Somalia" published by the Food Early Warning Department, Somalia, in 1988/1989. This data is generally considered to be of good quality. The information contained in the reports is also sufficiently detailed to allow for certain statistical analyses, as well as for correlations between stations with short records and those with long ones enabling adjustments of short-term averages to better reflect the long-term rainfall trends at various locations. The resulting isohyetal map for the Somali part of the drainage basins is regarded to be of good quality.

(ii) Data for northeast Kenya was obtained from two different publications: "Climatological Statistics for Kenya", published by the Kenya Meteorological Department in 1984, and "Agroclimatological Data - Africa" , a 1984 FAO publication. The first report lists monthly and annual rainfall means for various stations together with the period of record for which they apply; the second one only gives averages without any further details. Although the information contained in the first publication has made it possible to apply particular "weights' to individual station values, lack of further information has resulted in a map that should be treated with a certain degree of caution.

(iii) The only source of data for the Ethiopian part of the drainage basins, which the author had access to, was the 1984 FAO publication referred to above. Taking into account the fact that the station network in that area is also very sparse, the isohyets drawn on the map should be regarded as approximations only.

Looking at the area as a whole, the highest rainfall occurs on the Eastern Ethiopian Plateau where annual falls at high altitudes are in excess of 1250 mm, with some stations recording more than 1500 mm per year. Rainfall is also high on the eastern flanks of the same plateau and in the Mount Kenya area (1000 mm and more).

Moderate falls (500 to 600 mm) are experienced at high altitudes in the northern mountains of Somalia and in part of southern Somalia. Elsewhere precipitation is low to very low, ranging from around 300 mm in a large part of northeast Kenya to less than 200 mm in central Somalia and well under 100 mm in the northeast Somalia and in the coastal strip along the Gulf of Aden.

Seasonal distribution of rainfall in the area outside Somalia varies from one place to another, but does show certain uniformity (see Table 2). In the northern zone of the Eastern Ethiopian Plateau, 75 to 85% of the annual rain falls in the period March through September, with June generally being a slightly drier month than the others. The southern zone of the same plateau experiences a much more pronounced two-peak rainfall distribution. Here, on the average, 45% of the rain occurs between March and May and 30% in October/November. A similar distribution pattern applies to the remaining part of Ethiopia and most of northeast Kenya, where the first wet period is in April/May (40 to 60% of the annual fall) and the second one in October/November (20 to 40%). The exception to this is the Mount Kenya area, where rainfall is again more evenly distributed and 60% of the annual fall occurs between April and August.

2.3.2. Rainfall in Somalia

The rainfall distribution in Somalia can generally be described in three major zones : a) the southern zone, which has an average annual rainfall ranging from less than 300 mm in the inland border areas to over 500 mm in large parts of the central/south-eastern half of the zone; b) the central and north-eastern zone, with a mean annual rainfall decreasing from more than 200 mm in the south to less than 100 mm in the north-east; and c) the northern mountain zone, where average annual rainfall exceeds 500 mm at high altitudes decreasing sharply towards the north coast and somewhat less pronounced towards the valleys to the south (see Fig 1).

The rainfall pattern over the country is erratic in both areal distribution and annual amount. Yearly rainfall can vary as much as 300% in the northern zones, and even more in the central and north-eastern areas.

Large parts of the country experience a two peak rainfall distribution. This is most evident in the inland areas of the southern zone and in the central and north-eastern zone where most rain falls in the months April/May and October/November. In the mountain zone in the north the peaks are less pronounced, the rainfall being more evenly distributed during the period April through September with only July being somewhat drier. In the southern coastal area the first rainy period extends from April to July, the second peak rainfall (October/November) is much less pronounced.

Table 2. Monthly and annual rainfall for a few selected stations located outside Somalia

Station	Lat.	Long.	Alt.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Harer	9.12N	42.07E	1856	13	30	55	97	126	99	145	121	94	42	28	9	856
Degehabur	8.09N	43.33E	1000	6	1	34	79	68	28	5	12	43	61	21	1	350
Ticho	7.49N	39.32E	2800	46	87	135	155	101	95	157	165	144	103	54	23	1265
Hamaro	7.22N	42.13E	750	6	9	23	80	102	12	1	2	26	37	10	2	310
Danot	7.23N	45.18E	677	0	0	9	26	106	0	1	1	18	54	14	1	230
Adola	5.55N	39.05E	2170	20	30	87	224	116	43	35	50	72	160	87	34	958
Gode	6.06N	43.35E	320	0	6	19	100	69	2	0	0	5	74	60	5	340
Mega	4.05N	38.20E	2215	34	52	70	149	103	16	22	10	11	120	74	11	672
Mandera	3.56N	41.52E	331	2	7	19	93	31	1	1	2	2	44	44	9	255
Marsabit	2.18N	37.54E	1345	92	60	91	149	54	14	17	8	9	62	91	46	693
Wajir	1.45N	40.04E	244	8	5	35	75	34	2	3	2	5	28	63	23	293
Fuauruti	0.16N	36.33E	1770	21	19	41	82	60	45	96	81	35	31	55	32	599

Notes: 1. Rainfall in millimetres
2. Lat. denotes latitude in degrees and minutes
3. Long. denotes longitude in degrees and minutes
4. Alt. denotes altitude in metres

Although the seasonal rainfall distribution in Somalia is controlled by the annual, cyclic north and south movement of the Intertropical Convergence Zone over the country, monthly amounts can vary greatly from year to year. The beginnings and ends of the rainy periods also have an unreliable character.

Table 3 lists the monthly means, standard deviation (S.D.) and coefficient of variation (C.V.) for a number of selected stations. In general, it shows that the greater the mean monthly rainfall, the higher the standard deviation. Except for stations in the north, S.D.'s often exceed 50 mm even for months with means of less than 50 to 60 mm. Such values are high and emphasize the variability of monthly rainfall in the country.

Although coefficients of variation (S.D. divided by monthly mean) for stations with very low monthly means are, in a practical sense, of little value, Table 3 shows that C.V.'s, even for wet months, are rather high. With the exception of one or two stations, they are seldom less than 1.0 (or 100%), which again confirms the highly variable nature of monthly rainfall in most parts of Somalia.

No quantitative information has been published on short-duration rainfall intensities, however some frequency analyses of daily rainfall have been carried out. Table 4 shows the proportion (%) of raindays per month for a number of selected stations. In all cases the proportion is rather low and rarely exceeds 35%, even for stations with high rainfall.

The distribution (%) of daily intensities for those days when rain occurred does provide some interesting information (see Table 5). Although the distributions vary somewhat from station to station, there does not appear to be any geographical variation, nor does the shape of the distribution appear to depend on the mean annual rainfall. Hutchinson and Polishchouk therefore concluded in their 1989 report (LC 371) that "what makes a difference to annual rainfall over the country is not the type or intensity of the rainfall, but the number of raindays". Table 5 also shows that more than 30% of the daily rainfall intensities are less than 20 mm for all the stations except Dinsor (71%).

Table 3. Mean monthly/annual rainfall at selected stations in Somalia with Standard Deviation (S.D.) and Coefficient of Variation (C.V.)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1. Erigavo													
Mean	11.9	8.8	23.4	32.3	63.8	42.0	6.3	30.7	83.4	4.6	8.3	1.2	316.7
S.D.	25	15	30	33	45	32	11	35	41	6	16	3	110
C.V.	2.1	1.7	1.3	1.0	0.7	0.8	1.8	1.1	0.5	1.4	1.9	2.1	0.4
2. Bosaso													
Mean	0.5	0.2	0.4	4.0	1.7	0.0	0.0	0.0	0.8	1.6	4.0	1.4	14.6
S.D.	1	1	1	14	6	0	0	0	4	4	9	4	20
C.V.	2.1	5.3	3.5	3.4	3.3	5.4	5.4	-	5.4	2.8	2.2	3.0	1.3
3. Qardo													
Mean	0.2	0.9	6.5	23.9	32.5	5.3	0.5	3.0	9.3	24.2	4.8	1.2	112.3
S.D.	1	4	22	38	38	12	2	18	17	38	9	7	87
C.V.	6.1	4.1	3.4	1.6	1.2	2.3	4.1	5.9	1.9	1.6	1.9	5.8	0.8
4. Obbia													
Mean	10.4	1.8	16.9	29.1	45.2	3.6	0.3	0.1	2.6	28.9	45.8	19.2	203.9
S.D.	18	6	38	50	51	15	1	0	9	34	62	33	131
C.V.	1.7	3.4	2.2	1.7	1.1	4.1	3.6	5.9	3.3	1.2	1.3	1.7	0.7
5. Mogadishu													
Mean	0.5	0.9	7.2	60.0	63.7	80.4	65.6	40.8	20.1	30.4	49.3	9.1	428.0
S.D.	2	7	32	57	65	63	50	51	33	43	56	17	188
C.V.	3.3	7.8	4.5	0.9	1.0	0.8	0.8	1.3	1.7	1.4	1.1	1.8	0.4
6. Kismayo													
Mean	0.3	0.7	3.5	30.4	97.7	110.4	58.0	22.3	14.5	15.4	12.9	4.5	370.6
S.D.	1	3	15	30	89	80	50	26	23	34	21	13	149
C.V.	3.7	3.9	4.3	1.0	0.9	0.7	0.9	1.2	1.6	2.2	1.6	2.9	0.4
7. Bardere													
mean	5.4	6.1	23.1	97.9	61.0	12.3	20.0	6.4	7.9	74.5	80.1	24.3	419.0
S.D.	13	17	35	70	65	22	30	12	19	75	75	28	177
C.V.	2.3	2.7	1.5	0.7	[illegible]	[illegible]	[illegible]	[illegible]	2.4	1.0	[illegible]	1.1	0.4
8. Belet Uen													
Mean	0.2	0.4	6.3	61.5	71.6	9.6	1.8	2.1	9.6	66.5	30.5	6.3	266.4
S.D.	1	2	18	51	50	25	5	5	15	65	43	13	150
C.V.	3.9	4.6	2.9	0.8	0.7	2.6	2.7	2.3	1.6	1.0	1.4	2.1	0.6
9. Galcayo													
Mean	0.2	1.4	3.0	29.1	53.3	4.3	0.4	1.5	3.2	46.5	14.5	1.4	158.9
S.D.	1	7	15	39	67	13	1	6	8	55	29	4	92
C.V.	4.3	4.8	4.8	1.3	1.3	3.0	3.3	4.0	2.4	1.2	2.0	3.2	0.6
10. Hargeisa													
Mean	3.1	9.5	28.3	63.8	66.9	45.7	42.9	69.7	60.6	22.2	8.6	1.8	423.3
S.D.	10	27	51	61	51	33	28	38	32	29	19	4	134
C.V.	3.3	2.8	1.8	1.0	0.8	0.7	0.6	0.5	0.5	1.3	2.1	2.2	0.3

Table 4. Proportion (%) of raindays for each month at selected stations

Station	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
Afgoi	1	1	3	24	26	28	31	15	5	12	26	8	15
Alessandra	1	1	2	31	35	30	31	18	7	13	23	15	17
Baidoa	2	2	8	34	23	12	14	7	5	32	23	5	14
Belet Uen	0	0	2	17	19	3	1	1	3	19	11	3	7
Berbera	4	4	4	3	3	0	1	3	1	1	1	2	2
Dinsor	0	0	6	21	13	13	2	2	5	14	18	3	8
Galcayo	0	0	1	7	12	1	0	0	1	12	5	1	3
Genale	1	0	2	24	29	33	29	15	5	10	17	5	14
Hargeisa	1	2	7	17	22	22	20	28	31	11	3	1	14
Jowhar	3	0	4	25	23	19	21	14	6	26	23	9	14
Kismayo	1	1	2	31	35	30	31	18	7	13	23	15	17
Mogadishu	1	0	2	16	21	38	40	28	15	12	15	5	1
Obbia	4	0	3	9	10	2	2	1	1	10	8	4	5

Copied from : Hutchinson, P. and Polishchouk, O., 1989 (LC 371)
"The Agroclimatology of Somalia", FEWS/MA,
Mogadishu, Jan. 1989.

Table 5. Distribution(%) of daily intensities for those days when rain occured

Range in mm / Station	>0-9.9	10-19.9	20-29.9	30-39.9	40-49.9	50-59.9	60-69.9	70-79.9	80-89.9	90-99.9	100+
Afgoi	71	16	5	3	2	1	1	0	0	0	0
Alessandra	71	15	7	3	2	1	1	0	0	0	0
Baidoa	67	16	6	5	2	1	1	1	0	0	1
Belet Uen	64	18	8	4	2	1	1	1	0	0	1
Berbera	79	10	5	4	1	1	0	0	[illegible]	0	1
Dinsor	54	18	12	6	5	2	1	0	3	0	0
Galcayo	60	20	7	6	3	2	1	0	0	0	1
Genale	72	16	5	3	2	1	0	1	0	0	0
Hargeisa	74	15	6	3	1	1	0	0	0	0	0
Jowhar	70	14	7	4	2	2	1	0	0	0	0
Kismayo	71	15	7	3	2	1	1	0	0	0	0
Mogadishu	81	10	4	2	1	1	1	0	0	0	0
Obbia	61	19	6	6	3	2	0	2	0	1	1

Copied from : Hutchinson, P. and Polishchouk, O., 1989 (LC 371)
"The Agroclimatology of Somalia", FEWS/MA,
Mogadishu, Jan. 1989.

2.4 Evapotranspiration

Fig. 4 shows a simplified map of mean annual potential evapotranspiration (PET) for the drainage basins . The data for this map was again obtained from the FAO-1984 publication: "Agroclimatological Data - Africa" (LC 172 and LC 173). As the quality of this data is unknown (the publication does not give an indication about the period of record from which the data have been derived), the results shown on the map should be treated with a certain degree of caution.

On an annual basis, the highest potential evapotranspiration occurs along the northern coastline of Somalia, with values exceeding 2750 mm/yr. The main contributory factor in these generally high figures is the high air temperature. Wind is locally important, particularly in the northern mountain range, where, despite rather cooler air temperatures, evapotranspiration rates are relatively high.

Geographically, there is a reduction in potential evapotranspiration from north to south and from east to west. The lowest annual means occur on the Eastern Ethiopian Plateau and in the Mount Kenya area where values are estimated to be less than 1000 mm/yr at high altitudes. In the remaining part of the area there is a fair correlation between PET and altitude, except for the Ogaden region and the northwestern border zone of southern Somalia which suffer rather more potential evapotranspiration than their latitude and altitude might indicate.

With the exception of the extreme north, the potential evapotranspiration is rather uniform throughout the year. Estimated monthly PET values for stations in basin no. 7 and 8 tend to be fairly constant except during the first quarter of the year when monthly means are slightly higher (see Table 6). The same applies to basin no's 5 and 6, but values here tend to peak in March. In the north, on the other hand (basins 1,2 and 3), maximum values occur between June and August.

Maximum monthly values vary from one location to another from just over 100 mm/month at high altitudes in the west to about 400 mm/month on the north coast of Somalia. Minimum values also vary, but much less (i.e. from 90 to 160 mm/month). The lowest values generally occur at the end of the year (November and December).

Table 5. Mean monthly and annual potential evapotranspiration at selected stations.

Station	Lat.	Long.	Alt.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Berbera	10.26N	45.01E	9	162	149	188	191	233	385	380	413	281	200	160	144	2886
Jigjiga	9.20N	42.43E	1644	106	103	129	125	127	116	110	112	114	113	109	111	1375
Gardo	9.30N	49.05E	730	180	143	185	178	210	251	208	246	243	179	128	149	2310
Goba	7.01N	40.00E	2700	82	89	106	90	92	69	85	87	83	76	72	75	1029
Hamaro	7.22N	42.13E	750	141	141	159	139	137	145	141	144	149	135	134	133	1698
Galkayo	6.46N	47.25E	286	163	158	196	174	179	198	195	199	190	144	139	158	2092
Adola	5.55N	39.05E	2170	104	105	130	113	106	94	90	99	104	102	96	92	1235
Gode	6.02N	43.35E	320	153	161	182	152	149	149	158	167	175	150	136	145	182
Moyale	3.32N	39.03E	1097	160	150	152	117	108	108	112	121	127	119	116	127	1517
Lugh	3.48N	42.33E	150	221	194	217	172	174	180	173	170	187	179	168	181	2216
Bulo Burti	3.51N	45.34E	148	184	197	197	183	154	150	149	160	170	164	160	166	2034
Marsabit	2.18N	37.54E	1345	119	111	120	105	105	100	103	107	114	113	99	96	1292
Wajir	1.45N	40.04E	244	171	165	170	142	142	139	141	143	151	146	132	142	1784
Mogadishu	2.02N	45.18E	54	155	149	172	159	156	133	139	148	150	157	149	152	1818
Nanyuki	0.01N	37.05E	1943	123	123	129	99	95	93	93	100	110	109	89	101	1263
Afmadow	0.31N	42.04E	22	154	176	194	146	131	125	128	145	167	154	133	149	1847

Notes : 1. Evapotranspiration in millimetres
2. Lat. denotes latitude in degrees and minutes
3. Long. denotes longitude in degrees and minutes
4. Alt. denotes altitude in metres

3. DESCRIPTION OF DRAINGE BASINS

3.1 Gulf of Aden basin

The Gulf of Aden basin (76,000 km²), situated on the north coast of Somalia, includes a variety of morphological features, such as accentuated reliefs, escarpments, steep slopes, coastal plains, internal plateaus and valleys. Although the climate is semi-arid (mountainous areas) to arid (coastal plain) the drainge basin possesses major water resources particularly in its western region.

The southern part of the western region is marked by a gently sloping plateau (elevation between 1600 and 1000 m) crossed by numerous seasonal streams (wadis or tugs). North of this plateau a mountain range extends in east - west direction in which a number of streams, originating from the plateau, are deeply incised. The area north of the mountain range is constituted by a sloping plain and a coastal strip ranging in elevation from 600 m to sealevel. Rainfall ranges from more than 500 mm in the south to less than 50 mm along the coast. Potential evapotranspiration is high particularly in the coastal zone where values exceed 2750 mm/yr. Elsewhere the annual rates are lower, ranging from 2000 to 1700 mm along the southern catchment boundary (see also Fig's 1 to 4).

A number of large tugs are located in western part of the Gulf of Aden Basin. They include from east to west Tug Waheen (3000 km²), Tug Durdur (3850 km²), Tug Biji (3560 km²) and Tug Silil (1930 km²). Runoff, originating from heavy rainfall in the upstream (plateau) sections of these catchments, occurs in the form of short, violent floods which may last from a few hours to a number of days. In the mountain gorges, particularly in reaches where bedrock is exposed, the flow may be permanent.
In sandy widenings, in valley bottoms and on the coastal plains large quantities of water are lost by infiltration, evaporation and over flowing. It is assumed that little or no water reaches the sea.

Sogreah carried out an intensive one-year programme of observations in these catchments in 1980/1981 and arrived at the following estimates of runoff volumes and losses:

Table 7. Estimated mean annual volumes of runoff and infiltration losses in four catchments in north-west Somalia (in millions of m^3)

	Waheen	Biji	Durdur	Silil
Potential upstream runoff	130	100	160	89
Water lost by infiltration upstream of gorges	90	56	120	85
Water passing gorges	40	44	40	4
Infiltration on the coastal plain	40	44	40	4

Sogreah (LC 112) also concluded that, on average, for unit drainage areas of 100 km^2 on the plateau, the runoff threshold is 24 mm and the corresponding runoff coefficient is 0.65.

The central region of the Gulf of Aden basin is marked by a high mountain range running west to east parallel to the coast and south to north along the 47°E meridian (highest peak 2410 m). The area is deeplv incised by numerous tugs, the major ones being the Tug Jangarra (3,700 km^2), Tug Hodmo (3,800 km^2) and Tug Belgeabili (4,800 km^2). Rainfall ranges from between 250 mm and 700 mm along the inland catchment boundary, to less than 100 mm on the coast. Evapotranspiration varies from 2750 mm at the coast to less than 2000 mm at high altitudes. Little is known about flood frequencies and runoff volumes. Like in the western region, water normally does not break through the coastal sand dunes but infiltrates in the coastal plain.

The eastern part of the basin consists of a relatively narrow strip of land bordered to south by a mountain range varying in altitude from well over 2000 m to less than 500 m. Rainfall decreases in easterly direction from around 700 mm to less than 100 mm. The coastal belt is very dry. Annual evapotranspiration is between 1700 and 2500 mm.

The drainage network in this area is very dense. Numerous short tugs disect the escarptment facing the Gulf of Aden. Although short duration storms often generate brief spate flows, total runoff volumes are relatively small. The limited size of the catchments and lack of rainfall along the coast and in the east of the area do not support more runoff.

3.2 Darror basin

The Darror basin covers an area of approximately 37,000 km^2 more than half of which is lower than 500 m (see Table 1). To the north it shares its catchment boundary with the eastern part of Gulf of Aden basin (highest peak 2130 m): to the south are featureless plateaus with little relief (maximum elevation around 1500m). Average annual rainfall over the basin is just under 100 mm and ranges from more than 300 mm at high elevations in the northern mountains to about 50 mm in much of the eastern part of the basin. Potential evapotranspiration in most areas exceeds 2250 mm/yr except in the mountains where values are less than 2000 mm (see also Fig. 2 to 4).

The area is drained by a fairly dense network of seasonal streams. The northern - most one of these is Wadi Jaeil with a catchment of over 3,800 km^2. The main water course, Tug Dhut, also named Tug Jaeil, drains the Darror Valley and its western extension over a total distance of 350 km covering an area of more than 25,000 km^2 (Fig.1).

With the exception of the mountainous areas in the north, which occasionally produce runoff after heavy rain, surface water resources in the area are scarse. This is due to very low and infrequent rainfall and to high evaporation and infiltration losses.

3.3 Tug Der/Nugal basin

The Tug Der/Nugal basin (area approximately 116,000 km^2) lies to the south of the Darror Valley and the mountain range in the central part of north Somalia. It ranges in altitude from sealevel to well over 2000 m. The highest point is 2410 m. Most of the area (55%) is between 500 and 1000 m in elevation. 15% is in the altitude range of 1000 to 1500 m ard, only 6% is higher than 1500 m (see Table 1 and Fig. 2). Large parts consist of featureless gently sloping plains such as the Sool Plateau and the Sool Haud Plateau, and the Karman and Gubato plains.

Mean annual basin rainfall is approximately 160 mm. The highest falls occur in the northern mountains (250 to 600 mm/yr). More than 90% of the area receives less than 200 mm/yr: the driest part is the northeast with annual falls of less than 100 mm (see Fig 3.). Mean annual evapotranspiration in most of the area is higher than 2250 mm except in the northern mountains and along the southern catchment boundary (see Fig.4)

The main drainage feature in the area is the Tug Der and the Tug Nugal which together have formed a very large valley extending over 600 km in length and making up most of the southern and western part of the drainage basin (Fig. 1). The total catchment area is estimated to be 70,000 km^2 which includes a number of tributaries draining the mountain range to the north. An interesting feature is the Hinga'ol Internal Drainage Basin which receives water from the Haded Plateau. The north eastern most part of the area drains east into the Indian Ocean.

Looking at the area as a whole, the drainage network is relatively dense in the major valleys and on sloping land, it is little developed on the plateaus and the plains.

As in most other areas of northern Somalia, it would appear that little work has been done to monitor flows in tugs. The only records available are for the Tug Der at Burao where during the six years from 1945 until 1950 an average of 32.5 spates were recorded each year. 85% of these ocurred during the five months from May to September (reference LC 70). No indication has been given regarding the actual duration of these spates or their runoff volumes, but estimates suggest that an average runoff of 33 million m^3 per year (or 22 mm) might be expected from this 1500 km^2 catchment (runoff coefficient 0.06).

Elsewhere, seasonal water courses receive runoff after heavy rainfall, but this dissipates quickly in valley floors and on floodable plains. Little water reaches the coast, even floods in the Tug Der/Nugal valley rarely reach the sea.

In summary, the mountainous zone of the Tug Der/Nugal basin does contain some surface water resources, in the remainder of the area, where rainfall is low and losses are high, such resources are scarse.

3.4 Ogaden/Central basin

The Ogaden /Central basin is roughly triangular in shape and has a total area of about 223,000 km^2. It rises in altitude from sealevel to just over 1800 m. More than half of the area (58%) is below 500 m ; 31% lies between 500 and 1000 m (see Table 1 and Fig.2).

Mean annual rainfall varies from 130 to 800 mm averaging 200 mm for the entire area. Precipitation in central Somalia decreases from 300 mm in the south to just under 150 mm in the north. In the Ethiopian and northern Somali part of the basin it increase from less than 200 mm to about 500 mm at 1500 m altitude. Above this level increases are more rapid (see Fig.3).

Average potential evapotranspiration ranges from between 2,000 and 2,200 mm/yr in the Somali part of the basin, to less than 1700 mm in the extreme west (Fig.4).

The drainage network in most of the Ogaden region and central Somalia is very thin and ill defined (Fig.1) . The only reasonably well developed water course is the Bokh Valley in northern Somalia which has a total length of about 180 km. Elsewhere, localized runoff occasionally occurs in short reaches of often poorly developed, seasonal streambeds, but generally quickly dissipates in valley floors and on flat land. No water reaches the sea.

Thus, the lack of rainfall, combined with high losses, makes the Ogaden/Central Basin an extremely marginal area where it [illegible] surface water resources.

3.5 Shebelle Basin

In contrast with the Ogaden/Central region, the Shebelle basin posseses major surface water resources. The area is drained by one of the two main, permanent rivers in the study area, the Shebelle River.

The total area of the basin is approximately 307,000 km², almost two third of which lies within Ethiopia (199,000 km²), the remainder (108,000 km²) in Somalia. It ranges in altitude from about 20 m above sealevel in the south to well over 3000 m on the Eastern Ethiopian Plateau (highest peak 4230 m). Less than half of the area is below 500 m (44%) ; about 40% is in the altitude range of 500 to 1500 m, and 15% is higher than 1500 m (see Table 1 and Fig.2).

The Shebelle River rises on the eastern flanks of the eastern Ethiopian highlands where its tributaries are deeply incised and where slopes are generally very steep. The total length of the river from its source to the border with Somalia is approximately 900 km. Its main tributary in Ethiopia is the Fanfan which drains the northern part of the basin and the Far Depression (catchment area approximately 40,000 km²). The Fanfan is intermittent in its lower reaches and its waters do not reach the Shebelle during seasons of low rainfall.

The drainage network in the Ethiopian part of the catchment is dense to very dense, except in the border zone with Somalia and in the area east of 44°E longitude, where seasonal water courses are often ill developed on the gently sloping plains (see Fig.1).

The river enters Somalia at the border town of Ferfer. From there it flows south to Balad (near Mogadishu), where it turns south west and continues roughly parallel to the coast, from which it is separated by a range of sand hills. Halfway along the coast it runs into a series of swamps which extend to Avai. Downstream from Avai, the river resumes a defined channel, but flows are very much reduced and only in times of exceptional floods will the Shebelle discharge into the Juba river. Most of the flow in this reach normally originates from local catchments in the inter-riverine area, which only add water to the system during periods of heavy rain. The total length of the Shebelle in Somalia is approximately 800 km.

The drainage network in the Somali part of the basin is thin to non-existent. With the exception of the Bur escarpment, where a number of streams are spring-fed, some runoff does occur in a few local catchments, but these contribute to the river flow only in times of heavy rainfall.

Rainfall in the Shebelle basin varies considerably, geographically. The lowest falls occur in border zone between Ethiopia and Somalia (on the average less than 200 mm/yr), increasing in a southerly direction to more than 500 mm, and in north-westerly direction to well over 1000 mm in the mountains (see Fig.3). The average annual fall over the entire basin is approximately 455 mm ; the mean for the Ethiopian part of the catchment is 475 mm and for the Somali part 415 mm.

Except for the east Ethiopian mountain zone, where 75% to 80% of the annual rain falls in the period March through September, much of the basin experiences a distinct two-peak rainfall distribution. On the eastern slopes of the plateau, the first rainy period is in April/May, with on average around 50% of the annual fall, and the second one in September/October, when 25% of the rain occurs. A similar distribution applies to the middle and lower sections of the basin, although the second rainy season here is slightly later (October/November) and falls are slightly higher (35 to 40% of the annual total). Rainfall in the southern coastal belt is again more evenly distributed, peaking in June and decreasing towards November.

Mean annual potential evapotranspiration also varies from one area to another . The highest values (over 2000 mm) occur in a zone just south of the Somali/Ethiopian border, the lowest (less than 1000 mm) in the east Ethiopian mountains (see Fig.4). Potential evapotranspiration rates decrease with increasing altitude from about 1800 mm at an elevation of 500 m to just under 1250 mm at 2000 m. Annual rates in the south are around 1750 mm. Evapotranspiration in most areas is rather uniform throughout the year except during March when values are generally slightly higher.

On a monthly basis, almost the entire catchment experiences a negative waterbalance, with average potential evapotranspiration always exceeding rainfall. The only area where this does not apply is the mountain range in the northwest, where, at altitudes higher than 1500 m, the months of July, August and September generally have a positive waterbalance, and where at elevations over 3000 m monthly rainfall exceeds potential evapotranspiration during the entire period April through October.

Very little quantitative information is available in Somalia on streamflows in the Ethiopian zone of the catchment, but it is clear that, most of the discharge in the river originates from runoff in the eastern Ethiopian highlands. Further down the slope, towards the middle reaches of the river, losses increase through infiltration and evaporation, and , in sections, through over-bank spillage and water use. By the time the Shebelle reaches the Somali border, a significant part of the flow originating from the highlands is lost, but, as these losses are compensated in season by inflow from tributaries in the middle section of the catchment, the volume of water entering Somalia is still substantial during most of the year.

Table 8 lists the mean monthly discharges at Beled Weyn, a town some 30 km downstream from the border. These values are based on data observed intermittently during the period 1951-1989. Table 8 shows a two-peak flow distribution , with the highest monthly means occuring in May and September (133 and 151 m^3/sec respectively) and the lowest in January/February (11 to 12 m^3/sec). The distribution closely follows the incidence of rainfall in the Ethiopian part of the catchment where most rain falls in April/May and August/September and very little during the early part of the year.

Monthly flows vary considerably from one year to another (see Table 8). Maximum and minimum flows for a particular month can differ by as much as 300 m^3/sec . The variability is particularly high in December and March, which are transition months at the begining and the end of the low-flow season (C.V values about 1.30). Other months also show a high degree of variability except August and September which have C.V values lower than 0.4

The mean annual discharge for the entire period of record is 75.6 m^3/sec (or 2.384 million m^3). For a catchment of 207.000 km^2, this corresponds with a runoff depth of 11.5 mm/yr and an average annual runoff coefficient of 0.024 (catchment rainfall is 475 mm). The median daily flow (50% exceedance probability) is 53 m^3/sec (4.6 million m^3); 90% of the time flows exceed 6.2 m^3/sec, and 10% of the time the, are higher than 190 m^3/sec (see Table 9). Peak discharge rarely exceeds 450 m^3/sec.

No quantitative information is available on inflow volumes into the Shebelle River downstream from Beled Weyn, but it is generally assumed that . in a normal year. less than 10% of the annual river discharge is contributed by run-off from local catchments in Somalia.

Table 8. Monthly streamflow data for the Shebelle River at Beled Weyn with Standart Deviation (S.D.) and Coefficient of Variation (C.V.)

	Mean		Max.	Min.		
	m^3/sec	million m^3	m^3/sec	m^3/sec	S.D.	C.V.
Jan	13.0	35	46	2	11	0.82
Feb	12.0	29	62	0	13	1.05
Mar	25.1	67	123	0	33	1.29
Apr	76.3	198	347	7	68	0.89
May	133.0	356	318	32	85	0.64
Jun	74.8	194	307	10	68	0.90
Jul	49.6	133	106	13	26	0.53
Aug	104.0	279	167	23	38	0.37
Sep	151.0	391	317	64	56	0.37
Oct	136.0	364	297	50	62	0.46
Nov	87.9	228	274	17	67	0.77
Dec	40.9	110	259	6	53	1.30
Year	75.6	2,384	120	33		

Table 9. One-day flow duration table for the Shebelle River at Beled Weyn

% of time flow exceeded	m^3/sec	million m^3/day
95	3.4	0.29
90	6.2	0.54
75	15.4	1.33
50	53.0	4.58
25	121.3	10.48
10	190.2	16.43
5	239.8	20.72

The discharge of the river in Somalia decreases considerably as it flows towards its confluence with the Juba River (see Table 10). This reduction in flow is not only due to losses by seepage and evaporation, but is to a large extend also caused by consumptive use and overbank spillage.

Table 10. Mean annual discharge at gauging stations on the Shebelle River.

Station	Latitude	Longitude	Altitude	m^3/sec	million m^3
Beled Weyn	4.45 N	45.12 E	176	75.6	2,384
Bulo Burti	3.51 N	45.34 E	133	70.9	2,236
Mahadey Weyn	2.58 N	45.32 E	105	67.0	2,113
Balad	2.09 N	45.24 F	95	51.8	1,634
Afgoi	2.09 N	45.08 E	77	49.1	1,548
Audegle	1.59 N	44.50 E	70	46.0	1,451

As stated above, much of the losses can be attributed to the attenuation of flood flows which is due to a decrease in channel capacity in downstream direction. At Beled Weyn the channel capacity is in the order of 400 m^3/sec, decreasing to 160 m3/sec by the time it reaches Mahaddey Weyn. At Balad, the capacity is further reduced to 110 m^3/sec, and at Audegle only 90 m3/sec can pass. Other losses are caused by water being diverted from the river for irrigation purposes. This is in particular the case between Mahaddey Weyn and Balad where large volumes of water are diverted into the the Jowhar Ofstream Storage Reservoir. Downstream from Audegle losses are also substantial, particularly in the area where the river enters a series of swamps.

In summary, looking at the basin as a whole, surface water resources are abundant in the headwaters of the Shebelle River where rainfall is generally high and losses are relatively low. Further down the eastern slope of the plateau losses increase and rainfall becomes less frequent. Local runoff in this middle section of the basin is seasonal, but the river itself still carries considerable volumes of water during most of year. Downstream from the border, discharges reduce progressively, with the river often ceasing to flow in its lower reaches during the early part of the year. Elsewhere in the Somali section of the basin, resources are also limited.

3.6 Juba basin

The Juba Basin is drained by the Juba River, one of the two most important rivers in East Africa. Immediately upstream from the Somali/Ethiopian border it is fed by three major tributaries: the Wabi Gestro, the Genale Doria and the Dawa Parma. The total area of the basin is approximately 233,000 km², 65% of which are within Ethiopia, 30% in Somalia and 5% in Kenya. The three main tributaries have catchments of approximately 27,000, 57,000 and 60,000 km² respectively.

Altitudes range from just above sealevel in the south to well over 3000 m in the northwest (highest point is 4370 m) . About 45% is lower than 500 m, 20% is above 1500 m (Table 1). Slopes in the upper part of the basin are generally steep to very steep and the area is deeply incised by a dense to very dense network of water courses (see Fig.1 and Fig.2). In the middle section of the basin, particularly below the altitude of 500 m, slopes are more gentle and the network is less dense. Local runoff is seasonal. The drainage network in the lower Juba basin is very poorly developed and runoff is very localized.

Most of the discharge in the river originates from the headwaters of the Gestro, Genale and Dawa rivers, which rise in the Ethiopian highlands, and flow southeast to meet near the border with Somalia to form the Juba River. Total length of the longest tributary (the Genale) from it source to the confluence with the Gestro and Dawa is approximately 550 km. On entering Somali territory, the river continues to flow in southeasterly direction as far as the town of Lugh , from which point it flows generally towards the south. Within Somalia it traverses a distance of about 550 km.

Fig.3 shows that mean annual rainfall in the catchment varies from slightly less than 200 mm in the northern part of the border zone to well over 1500 mm at high altitudes in the mountains. In the upper part of the basin precipitation increases progressively with altitude. In the south annual falls are 600 mm just inland from the coast. On average, the rainfall in the catchment above Lugh (a gauging station some 80 km downstream from the border) is approximately 550 mm/yr.

Much of the area experiences a distinct two-peak rainfall distribution, with 40 to 45% of the annual rain occurring in the period March to May and 25 to 35% in October and November. In the extreme south and northwest, rainfall is slightly more evenly distributed, but most rain still falls in the same two seasons.

Mean annual potential evapotranspiration varies from just over 2000 mm in the area immediately south of the Somali/Ethiopian border, to slightly under 1750 mm in the far south and less than 1000 mm in the mountains in the northwest (see Fig.4). The highest values occur in March. Fluctuations during the remainder of the year are relatively small.

On average, on a monthly basis, almost the entire basin experiences a negative water balance, with potential evapotranspiration exceeding rainfall. The exceptions are a small area in the extreme south, where average rainfall is slightly higher during April and May, and the mountain ranges in Ethiopia, where at elevations higher than 1500 m rainfall exceeds evapotranspiration in April, May and October. Higher up in those same mountains, at altitudes over 2500 m, water balance are normally positive during the entire period from April to October.

In the absence of quantitative information on discharges in the three main tributaries of the Juba River in Ethiopia, the distribution of average annual rainfall between the three catchments upstream of Dolo has been determined by manual integration of the isohyetal surface (see Table 11) . These figures were compared with those for the catchment of Lugh, which is the most upstream gauging station in Somalia for which streamflow records are available.

Table 11. Areal rainfall over the upper Juba basin

Catchment	Area (km^2)	Average annual rainfall Depth(mm)	Volume($m^3 \times 10^6$)	%
Wabi Gestro	27,000	465	12,555	14
Genale Doria	57,000	760	38,190	42
Dawa Parma	60,000	565	33,900	37
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Total	144,000	550	84,645	93
Juba at Lugh	166,000	550	91,300	100

Table 11 shows that on average, the two western tributary catchments (Dawa and Genale) each contribute about 40% of the total volume of rain falling on the Lugh catchment. The Gestro catchment contributes a further 14 %, and 7% of the rainfall input is associated with the subcatchment between the confluence at Dolo and Lugh.

In order to assess the relative runoff contribution of the main tributary catchments, MacDonald and Partners in their 1978 "Bardheere Reservoir Review" report (LC 101) assumed the relationship of runoff to rain to conform to the relationship implied by the Langbein method. The results of their analysis suggest that over half the flow in the Juba downstream from the confluence is contributed by the Genale, less than 40% by the Dawa, and only about 7% by the Gestro. Comparing these runoff percentages to the areal rainfall distribution given in Table 11 suggests that the highest losses occur in the eastern catchment (Gestro), and the lowest in the middle catchment (Genale).

These differences in losses can be explained by differences in geology. Formations in much of the headwaters of the Juba basin are made up of relatively impervious basement and volcanic rock. The southeastern edge of these formations roughly coincides with the 750 mm isohyet shown in Fig.3. Infiltration losses in this high rainfall zone are low and runoff is high. Annual runoff coefficients are estimated to be in the order of 0.5 or more. Downstream from this zone, the formations mostly consist of sedimentary rock, predominantly Jurassic limestones, where infiltration losses are generally high, and runoff is much reduced by evaporation and river bed losses.

The difference in overall losses between the three catchments can partly be explained by the fact that the relatively impermeable, highly productive runoff zones make up a different percentage of their overall catchment area, but also by the difference in length the rivers traverse softer, more permeable sedimentary formations. Only about 16% of the Gestro catchment consists of volcanic rock, the length of the main river traversing sedimentary rock is about 350 km. In the Genale catchment, more than 35% of the area is relatively impermeable. Bed losses downstream from this area are also limited because basement rock continues to be exposed in the valley floors of the main river branches over a considerable distance. The remainder of the channel length on sedimentary rock is only 200 km. In the western-most catchment (Dawa) the percentage of area with basement rock is again slightly lower (just over 30%), but the length of the channel on sedimentary formations is only 180 km.

The upper-most gauging station on the Juba river for which records are available is Lugh. Lugh is located some 80 km downstream from the confluence of the main tributaries and has a catchment area of approximately 166.000 km². Mean monthly discharges at the station are given in Table 12. The values are based on data obtained, intermittently, during the period 1951-1989.

Table 12. Monthly streamflow data for the Juba River at Lugh with Standard Deviation (S.D.) and Coefficient of Variation (C.V.)

	Mean		Max.	Min.		
	m^3/sec	million m^3	m^3/sec	m^3/sec	S.D.	C.V.
Jan	49.9	133	140	9	35	0.69
Feb	34.6	83	97	3	27	0.79
Mar	40.2	107	201	3	46	1.15
Apr	163.0	422	794	11	164	1.01
May	279.0	747	598	63	157	0.56
Jun	183.0	474	550	32	107	0.58
Jul	203.0	544	353	93	61	0.30
Aug	279.0	747	490	122	94	0.34
Sep	292.0	757	491	130	89	0.30
Oct	448.0	1,200	769	179	167	0.37
Nov	327.0	847	1,069	103	201	0.62
Dec	129.0	345	453	33	96	0.74
Year	230.0	6,406	332	82		

Table 13. One-day flow duration table for the Juba River at Lugh

% of time flow exceeded	m^3/sec	million m^3/day
95	8.7	0.75
90	18.6	1.61
75	62.2	5.37
50	166.7	14.40
25	291.3	25.17
10	436.5	37.71
5	574.4	49.63

Table 12 clearly shows the bimodal nature of the river. The first (short) peak occurs in May (mean monthly discharge 279 m^3/sec), the second, and more significant one in October (448 m^3/sec). In between these peaks, mean monthly flows reduce to 203 m^3/sec in June and 35 m^3/sec in February. The low flow period is from January upto mid- April . The flow distribution closely follows the incidence of rainfall in the upper Juba catchment, where, on average, the highest falls occur during the periods March to May and October/November and the lowest in January and February.

Monthly discharges vary considerably from year to year. This is illustrated by the differences in maximum and minimum monthly flows and the often high values of the Standard Deviation and Coefficient of Variation listed in Table 12. March and April appear to be the months with the highest relative variability in flow (C.V. values higher then 1.0). Monthly discharges vary the least during the period July to September (C.V. values around 0.3.).

The mean annual discharge at Lugh for the entire period of record is 203 m^3/sec or about 6,400 million m^3. This corresponds with a runoff depth of 38.6 mm/yr and an average annual runoff coefficient of 0.07. The median daily flow (50% exceedance probability) is 167 m^3/sec ; 90% of the time flows exceed 18.6 m^3/sec, and 10% of the time they are higher than 437 m^3/sec (see Table 13). Peak discharges rarely exceed 1500 m^3/sec.

Downstream from Lugh, runoff from a few local seasonal catchments contributes little to the overall discharge in the river, and it is generally assumed that, in a normal year, well over 90% of the flow in Somalia originates from the catchment above Lugh.

The discharge of the Juba River in Somalia decreases significantly as it flows towards the sea. This reduction in flow is due to losses by seepage and evaporation and in the lower reaches to flow diversions and overbank spillage.

Table 14. Mean annual discharge at selected gauging stations on the Juba River

Station	Latitude	Longitude	Altitude	m^3/sec	million m^3
Lugh	3.47N	42.33E	141	203	6,406
Bardheere	2.19N	42.17E	89	176	5,550
Jamaame	0.04N	42.44E	?	169	5,330

In summary, the upper Juba basin possesses major surface water resources. In the middle section, losses increase, and rainfall decreases and becomes less frequent, but flows in the three main tributaries continue to be significant during most of the year. Downstream from the border discharges reduce progressively, with the river often ceasing to flow in its lower reaches during the early part of the year. Elsewhere in the Somali section of the basin, resources are limited. Runoff is generally highly localized and seasonal.

3.7 N-E Kenya/Lag Dera basin

The NE Kenya/Lag Dera basin makes up the southwestern part of the area under study. It comprises and area of 253,000 km^2, 75% of which is Kenyan territory. It ranges in altitude from sealevel to over 2,000 m in the northwest and to well over 3000 m in the southwest (see Fig.2). The highest point is Mount Kenya (5,195 m). More than 80% of the area is below 1,000 m in altitude and consists of gently sloping, undulating to flat land (see also Table 1). Slopes are steep to very steep in the mountains in the southwest and along the western boundary.

Rainfall in the area varies from less than 300 mm/yr in much of the central part of the basin as well as in a small section in the west, to well over 1250 mm on Mount Kenya (see Fig.3.). Along the northeastern boundary, precipitation increases gradually from about 250 mm in the Kenya/Somalia border zone, to more than 800 mm in the northwest, and just under 600 mm in the southeast. Mean annual rainfall depth on the basin is approximately 360 mm.

Potential evapotranspiration in areas below 1000 m varies from about 1750 mm to just under 2000 mm/yr, decreasing with altitude to around 1250 mm in the northwest and to less than 1000 mm on Mount Kenya (see Fig.4). On average, monthly evapotranspiration always exceeds monthly rainfall except in the high mountains where rainfall is generally higher in April/May and October/November.

The drainage network in much of the area is rather thin and ill defined (see Fig. 1). It consists of seasonal water courses of varying lengths which carry runoff only after heavy rainfall. Much of the runoff quickly dissipates on flat land and in broad, shallow valleys, where it is lost by infiltration and evaporation. The larger of these seasonal drainage systems are the Lag Kutula in the northeast, and the Lag Bor and the Lag Bogal in the centre of the basin.

Permanent flow only occurs in the high rainfall area in the southwest, where numerous streams drain the slopes of Mount Kenya and other mountains. After joining, these tributaries form the Ewaso N'giro. No information is available in Somalia on discharges in the Ewaso N'giro, but it is clear that flows rapidly decrease in downstream direction, and that the river becomes seasonal well before it reaches 39° longitude. Further downstream in the same drainage system, water disperses on a number of broad flood planes, and, only during periods of exceptionally high rainfall, do floods reach the Lag Dera in Somalia. Such floods, however, rarely reach the Juba river as virtually all water ceases flowing in Dheshek Wamo, a large natural depression in the south of the basin.

3.8 Lag Badana basin

The Lag Badana basin in the extreme south of the study area is relatively flat and has a thin network of poorly defined seasonal water courses. Virtually the entire area of 38,000 km² is lower than 200 m above sealevel. Rainfall varies from about 300 mm in the west, to just over 500 mm in the northeast and southeast of the basin. Average annual rainfall depth is 430 mm. Mean annual potential evapotranspiration is slightly over 1750 mm (see Fig.'s 1 to 4).

Surface water resources in the area are relatively scarse. Localized runoff does occur, but only during periods of heavy rainfall. Little water reaches the coast eventhough the long, tidal estuaries of some of the seasonal rivers may give the impression that runoff takes place throughout the year.

3.9 Indian Ocean basin

The Indian Ocean basin consists of a narrow strip of land along the Indian Ocean coast, stretching from just below the equator to about 6° latitude (area 22,000 km²). The inland boundary south of Mogadishu is formed by a range of sand hills which are generally less than 150 m in height. North of Mogadishu the strip widens and elevations along the inland boundary increase in places to 400 m. The entire range of hills effectively blocks all surface drainage from inland areas to the sea. Rainfall in the southern zone is in the order of 450 to 500 mm/yr. further north it decreases to almost 200 mm. Mean annual potential evaportanspiration varies from approximately 1700 mm in the south to 1900 mm in the north (see Fig.'s 1 to 4).

Surface drainage is very insignificant and most of the rain falling on the area is lost by infiltration and evaporation. Some highly localized, seasonal runoff does occur in the north, but losses are high and little water reaches the sea.

4. CONCLUDING_REMARKS

As described in the previous sections, surface water resources in much of the study area are relatively insignificant. They normally consist of occasional runoff in seasonal water courses, which occurs after heavy rainfall, and which is often quickly lost by infiltration and evaporation. The worst areas from a resources point of view are large sections of the Ogaden desert and much of central and northeast Somalia. Parts of southern Somalia also suffer from lack of surface water.

In contrast with this, the Juba and Shebelle catchments both posses major surface water resources. This is particularly the case in their upper sections, where rainfall is high and streams flow permanently. Further downstream, discharges in the river decrease as a result of losses by infiltration and evaporation, and because of overbank spillage and water use.

Finally, it is interesting to make a comparison of the runoff from the upper catchments of the Juba and the Shebelle.

Table 15. Comparison_of_runoff_from_the_upper_Juba_and__ Shebelle catchments_above_Lugh_and_Beled_Weyn

	Upper_Juba	Upper_Shebelle
Catchment area (km^2)	166,000	207,000
Mean annual rainfall (mm)	550	475
Mean annual runoff (m^3/sec)	203.0	75.6
Annual runoff depth (mm)	38.6	11.5
Annual runoff coefficient	0.070	0.024
Length of longest branch (km)	630	930

Table 15 shows that the mean annual discharge of the Shebelle at Beled Weyn, is only 37 % of that of the Juba at Lugh, yet the catchment is 20% larger and the rainfall only 16% lower. The large difference in runoff coefficients (0.024 and 0.070 respectively) can be explained by major differences in geology.

The "Geological Map of Ethiopia and Somalia" published in 1973 by Consiglio Nazionale delle Ricerche Italy, indicates that much of the headwater tributaries of the Juba are on basement rock and tertiary volcanics, which presumably are relatively impervious. This applies to more than 30% of the Juba catchment. In the Shebelle catchment this percentage is only around 13%. The remainder of the catchments consists of relatively soft, pervious sedimentary rock (predominantly Jurassic limestones), where infiltration losses are high and streams are influent.

Riverbed losses in the upper Juba catchment are further limited by the fact that, downstream from the basement complex, the valley floors of the two western tributaries continue to be in basement rock for another 100 to 150 km (see also Section 3.6). The distances the main branches traverse sedimentary formations are therefore relatively short (Gestro 350 km, Genale 200 km, Dawa 180 km). This is not the case in the upper Shebelle, where the total length of the influent section of the Fanfan tributary is more than 400 km, and that of the main branch of the Shebelle more than 600 km.

A final factor that may also contribute to the difference in runoff coefficients is the incidence of geological faults. According to the map referred to above, such faults are more common in the upper Shebelle catchment than in the upper Juba, possibly giving rise to higher losses there.

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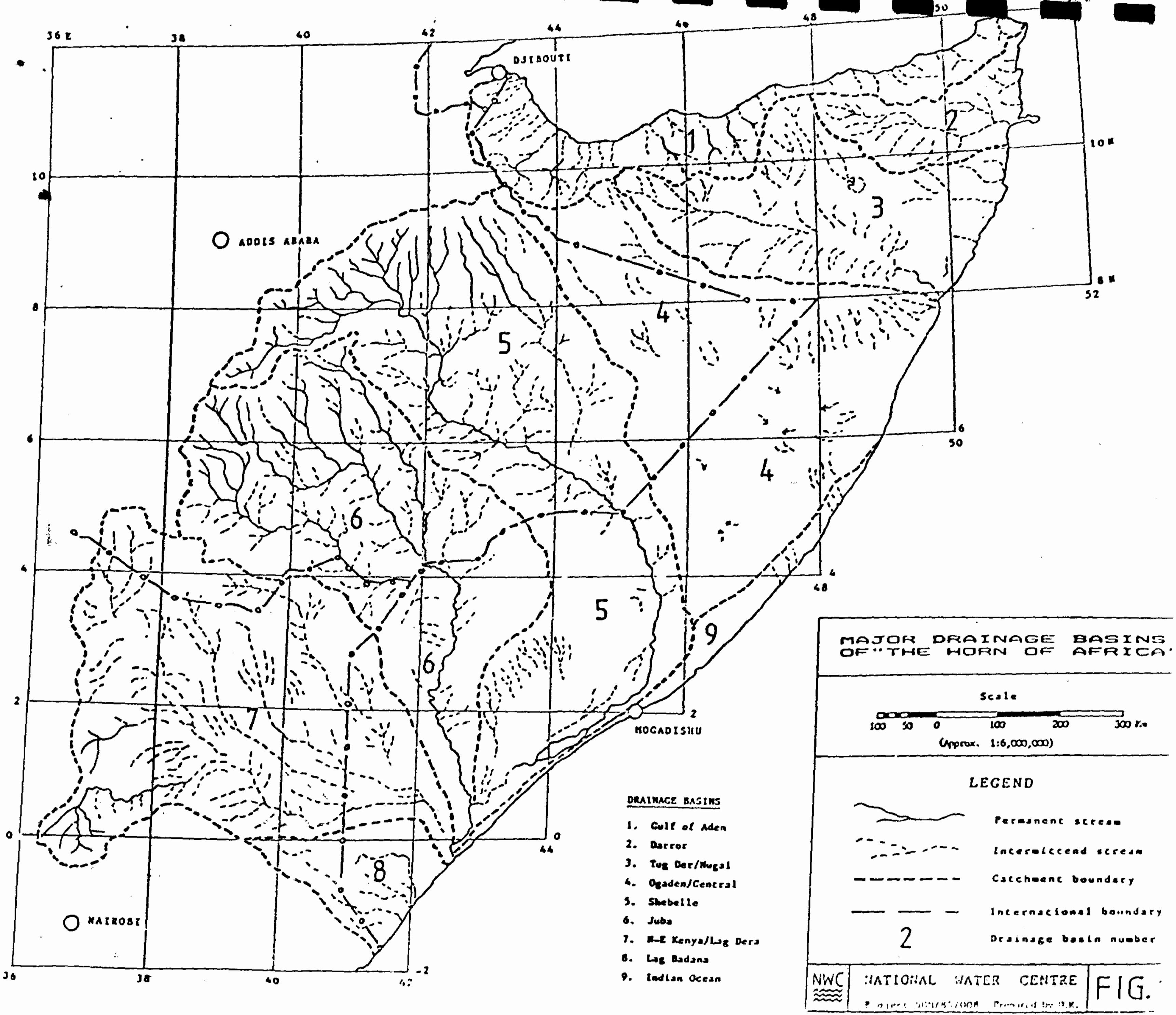
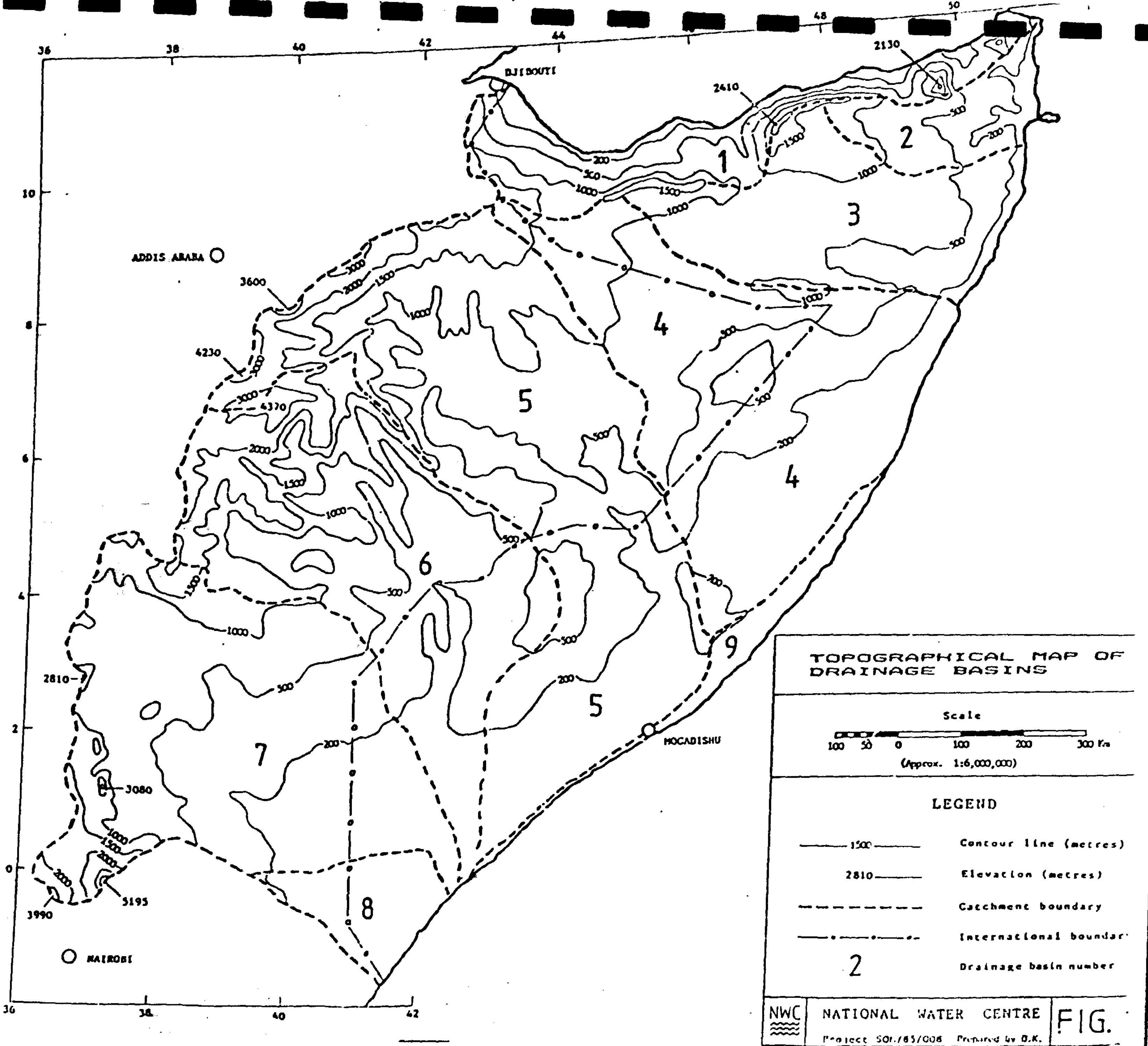
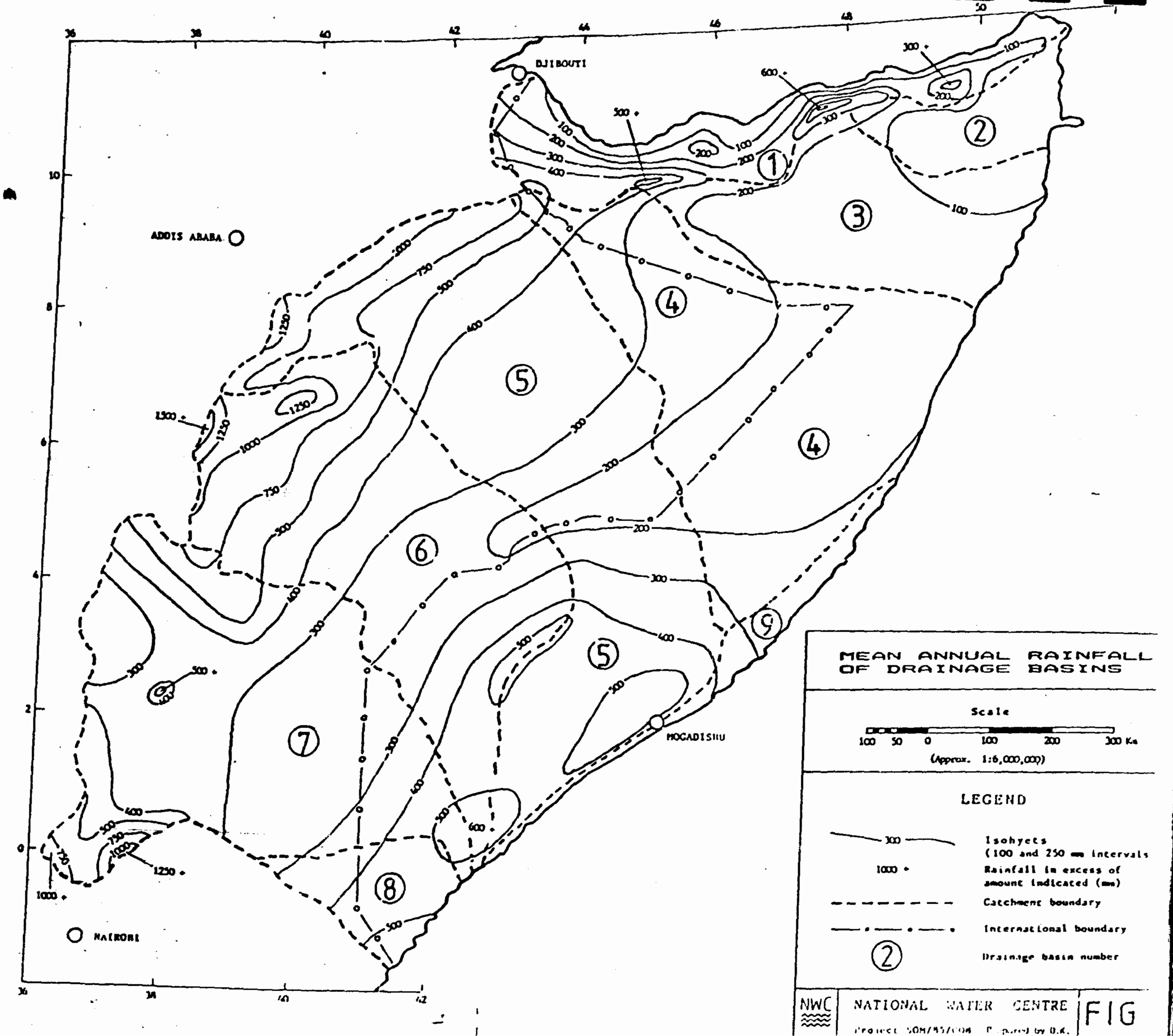


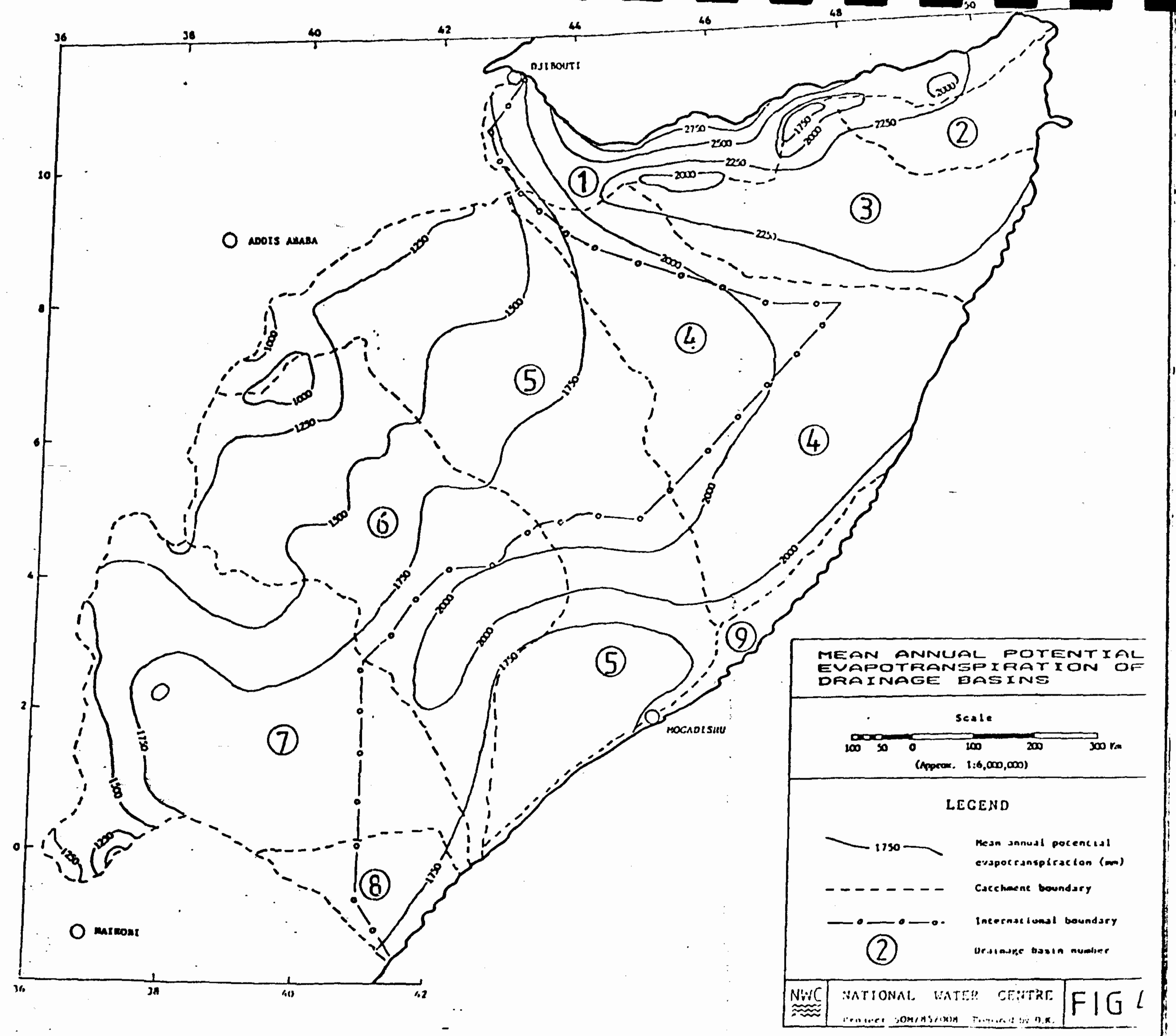
MAJOR DRAINAGE BASINS OF "THE HORN OF AFRICA"
Scale
100 50 0 100 200 300 Km
(Approx. 1:6,000,000)
LEGEND
Permanent stream
Intermittent stream
Catchment boundary
International boundary
2
Drainage basin number
DRAINAGE BASINS
1. Gulf of Aden
2. Darror
3. Tug Der/Nugal
4. Ogaden/Central
5. Shebelle
6. Juba
7. N-E Kenya/Lag Dera
8. Lag Badana
9. Indian Ocean
DJIBOUTI
ADDIS ABABA
MOGADISHU
NAIROBI
NWC
NATIONAL WATER CENTRE
FIG.



TOPOGRAPHICAL MAP OF DRAINAGE BASINS
Scale
100 50 0 100 200 300 Km
(Approx. 1:6,000,000)
LEGEND
1500 Contour line (metres)
2810 Elevation (metres)
Catchment boundary
International boundary
2 Drainage basin number
NWC
NATIONAL WATER CENTRE
Project SOM/85/008 Prepared by D.K.
FIG.
DJIBOUTI
ADDIS ABABA
MOGADISHU
NAIROBI
1
2
3
4
5
6
7
8
9
2130
2410
3600
4230
4370
2810
3080
3990
5195



MEAN ANNUAL RAINFALL OF DRAINAGE BASINS
Scale
100 50 0 100 200 300 Km
(Approx. 1:6,000,000)
LEGEND
Isohyets (100 and 250 mm intervals
Rainfall in excess of amount indicated (mm)
Catchment boundary
International boundary
Drainage basin number
NWC
NATIONAL WATER CENTRE
FIG
DJIBOUTI
ADDIS ABABA
MOGADISHU
NAIROBI



DJIBOUTI
ADDIS ABABA
NAIROBI
MOGADISHU
MEAN ANNUAL POTENTIAL EVAPOTRANSPIRATION OF DRAINAGE BASINS
Scale
100 50 0 100 200 300 Km
(Approx. 1:6,000,000)
LEGEND
1750
Mean annual potential evapotranspiration (mm)
Catchment boundary
International boundary
Drainage basin number
NWC
NATIONAL WATER CENTRE
FIG