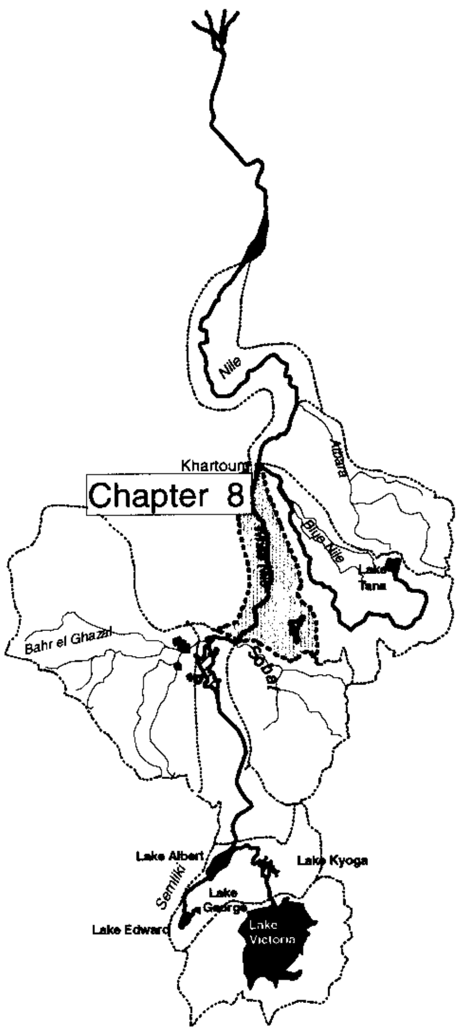
CHAPTER 8

THE WHITE NILE BELOW MALAKAL

INTRODUCTION

The White Nile from its confluence with the Sobat is reasonably self-contained and has a character of its own. Although the White Nile strictly begins at Lake No with the confluence of the Bahr el Jebel and the Bahr el Ghazal, the reach between Lake No and the Sobat mouth is essentially an extension of the Sudd, of which one outlet is the Bahr el Zeraf. The Sudd outflows are best deduced from the difference between the flows of the White Nile at Malakal and the outflows of the Sobat, and conversely the inflows to the White Nile at Malakal can be separated into its two components.

Between the Sobat mouth and the junction with the Blue Nile at Khartoum, the White Nile falls about 13 m over a reach of 840 km. The inflows from tributaries are sporadic and relatively small. The flood-plain storage results in some delay of the outflows and losses by evaporation. The backing up of the White Nile during the Blue Nile flood, which raises water levels, further increases storage and evaporation losses. Over the period of flow records the natural regime has been affected by the construction in 1934–1937 of the Jebel Aulia dam, 40 km above the confluence, and the development of irrigation along the White Nile. The dam further raised upstream river levels from June 1937, and irrigation and evaporation have both led to increased losses.



INFLOWS TO THE WHITE NILE

The inflows to the White Nile, which have been measured at Malakal since 1905, are made up of two very different components. The outflows from the Sudd have been discussed in Chapter 5, but essentially they are the highly damped and reduced inflows of the Bahr el Jebel. These outflows therefore reflect the rise in Lake Victoria and the subsequent doubling of the outflow from the lakes after 1961–1964, but the seasonal element supplied by the torrents above Mongalla has been virtually eliminated by the repeated spills and evaporation losses in the series of offstream basins and swamps through the Sudd. The rise of lake outflows was responsible for the increased area of the swamps after 1961, which in turn led to greatly increased evaporation between Mongalla and the tail of the swamps. Thus the outflow from the Bahr el Jebel swamps increased after the lake rise, but the losses have been proportionately larger and the outflows have not increased in proportion to the inflows. The

Table 8.1 Average flows at key sites for various periods (m³ × 10⁶).

Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Outflow from Sudd:						**1905–1960**						
1337	1188	1236	1140	1131	1058	1109	1159	1177	1242	1148	1231	14 157
						1961–1983						
1950	1634	1771	1619	1582	1504	1513	1589	1697	1936	1940	2064	20 799
						1905–1983						
1515	1318	1392	1280	1262	1188	1227	1284	1328	1444	1379	1473	16 091
Sobat at Doleib Hill:						**1905–1960**						
929	363	246	222	410	870	1303	1603	1779	2008	1995	1743	13 471
						1961–1983						
1059	595	341	257	419	807	1297	1619	1781	1951	1889	1656	13 672
						1905–1983						
967	431	273	232	413	851	1301	1608	1780	1992	1964	1718	13 530
White Nile at Malakal:						**1905–1960**						
2266	1551	1482	1362	1541	1928	2412	2762	2956	3250	3143	2974	27 628
						1961–1995						
2786	2058	1972	1779	1918	2228	2766	3140	3362	3718	3646	3478	32 850
						1905–1995						
2466	1746	1670	1522	1686	2043	2548	2907	3112	3430	3337	3168	29 636
White Nile at Mogren:						**1911–1935**						
2499	1723	1511	1368	1470	1634	1575	1622	2972	3773	3148	2904	26 198
						1936–1960						
2140	1887	2177	1963	1635	1601	1031	1308	1764	2658	2484	2436	23 083
						1961–1995						
2682	2047	2258	3024	2701	2042	1463	1407	2106	2786	2753	2860	28 130
						1911–1995						
2469	1905	2014	2225	2026	1792	1368	1435	2236	3024	2786	2747	26 026

outflows are illustrated by Table 8.1 and Fig. 5.4, which illustrate the lack of seasonal variability and the damped response to the increase of Sudd inflows. These flows include the outflows from the Bahr el Ghazal swamps, but as noted in Chapter 6 these are comparatively small.

The other component of the White Nile inflows is the contribution of the Sobat, which has been measured at Doleib Hill near the mouth since 1905. These flows are illustrated in Table 8.1 and Fig. 7.4 and are more seasonal than the Sudd outflows. The high flow contributions of the Baro and adjacent Ethiopian rivers are attenuated by spill, especially in years of high flow. However, the Pibor to the south contributes significant flows in some years, so the annual variability of the Sobat is greater than the upper Baro. The dry season flows are small compared with the Sudd outflows.

Thus the inflows to the White Nile system are made up from a relatively steady seasonal outflow from the Bahr el Jebel swamps, and the contribution of the Sobat which retains seasonal variability after Baro spillage. The Sobat has, to some extent, been subject to decline in flows in recent years. This decline has also been a feature of the Blue Nile and other Ethiopian tributaries.

The combined inflows to the White Nile system have been measured at Malakal; although the rating curve is somewhat looped, the number of gaugings have been sufficient at over 70 a year and the flows are accurate. They are summarized in Table 8.1 and illustrated in Fig. 8.1. These show the muted seasonality of the flows and the increase after 1961–1964 which reflects the higher Bahr el Jebel contribution. However, the flows of the White Nile have decreased again in recent years as Lake Victoria levels and outflows have fallen, and the total flows are now little above those which occurred before 1961.

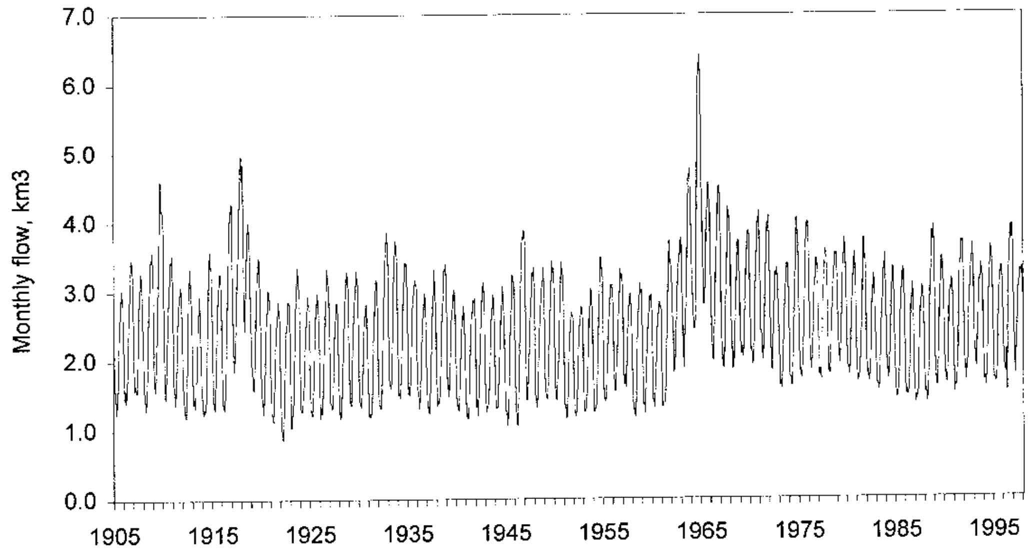


Fig. 8.1 White Nile at Malakal: monthly flows, 1905–1997.

OUTFLOWS FROM THE WHITE NILE

The White Nile outflows have been measured at the junction with the Blue Nile at Mogren in Khartoum since 1911, though the records for the first three years are incomplete during the period of the Blue Nile flood. Because the rating relation at this site is dominated by the Blue Nile levels the flows are interpolated between measurements. Thus the quality of the records is largely determined by the number of gaugings made each year; this information is summarized in Table 2.1. Between 1913 and 1943 the number of annual gaugings was usually between 60 and 120, with 150–200 in 1927–1929, but the number has declined since 1944 from 50 to about 30. However, since 1947 the number of measurements from July to October has decreased, and the discharges have been estimated from the sluice discharges at Jebel Aulia dam. This frequency of measurement is relevant to the losses derived by comparisons of inflows and outflows.

The effect on outflows in the early years of the natural backing up of the White Nile by the Blue Nile flood is illustrated by the flow record in Table 8.1, and in Fig. 8.2 by a

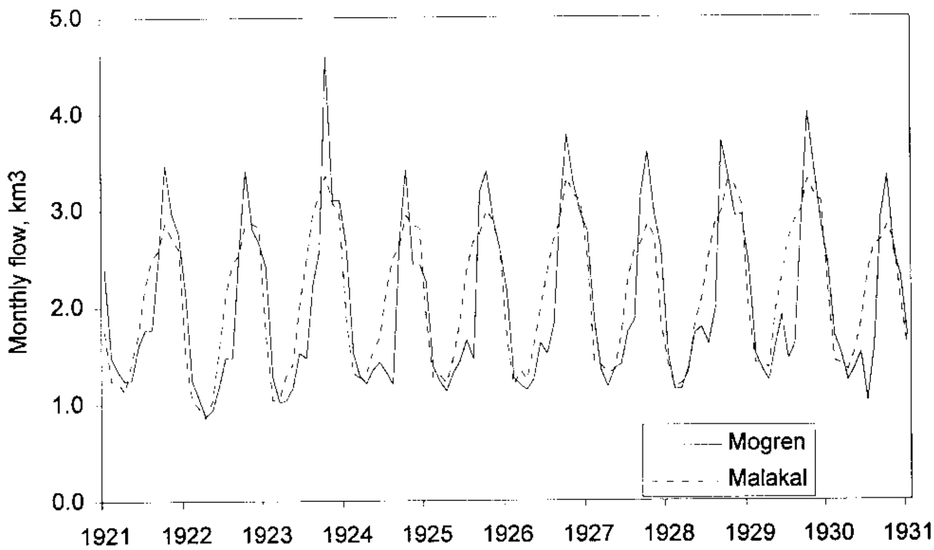


Fig. 8.2 White Nile at Malakal and Mogren: monthly flows, 1921–1930.

comparison of flows at Malakal and Mogren during the period 1921–1930. The flows at Malakal increase in June and rise to a peak in October, with a gradual recession until December or January. In contrast, the outflows at Mogren in these early years are held up by the Blue Nile flood until September or October, when the White Nile outflow exceeds the inflow at Malakal.

The flow pattern changed after 1937 when the White Nile outflow began to be controlled by the Jebel Aulia reservoir. The objective of the reservoir was to prolong the natural White Nile recession for irrigation downstream; the outflows were further decreased in July, August and September and the stored water released from October to April or May. Comparisons of flows at Malakal and Mogren are complicated by the construction of the dam and the natural increase in flows at Malakal after 1961. However, studies described below have been carried out to distinguish the natural attenuation and evaporation losses, from abstractions for irrigation and tributary contributions.

WATER BALANCE OF THE WHITE NILE FROM MALAKAL TO RENK

As part of the programme of the Jonglei Investigation Team (1954, vol. III, chapter 2) the water balance of the reach from Malakal to Renk was studied by J. W. Wright. Comparison of flows at Malakal and Renk showed that the Malakal flows exceeded those at Renk while river levels were rising, and the flows at Renk were the greater when levels were falling. This was assumed due to water spilling from the river to the flood plain and being held in storage until the river falls, when the stored water returns to the river. During the flood there is a water loss as a result of net evaporation from the water surface, and also from absorption or soil moisture recharge of newly flooded ground.

A water balance of the reach was based on measured 10-day inflows and outflows, 10-day river levels at different gauge sites and a relation between level and storage volume, with estimates of rainfall, evaporation and soil moisture recharge. The inflows and outflows, together with gauge levels, were available for 15 floods during the period 1928/29 to 1946/47. The means of rainfall records at Malakal, Melut and Renk were used to indicate rainfall over the flooded area. Open-water evaporation was estimated from Piche evaporimeter measurements at 2150 mm, which is not unreasonable. The absorption depth was estimated as 800 mm, which is high in physical terms; indeed, a much lower estimate of 300 mm was used in the water balance of the Sobat flood plain.

In order to derive a relation between gauge levels and storage volume over the valley, 22 cross-sections were analysed to provide mean idealized cross-sections linking elevation and total width. Thus the mean width, the total surface area and the volumes of the trough between Malakal and Melut and between Melut and Renk were related to the mean gauge levels at these pairs of sites. The assumption was made that the level in the flood plain coincided with the river level; this was not the case in the Bahr el Jebel basins surveyed but it is not unreasonable for the narrower flood plain of the White Nile. From this analysis the areas and volumes of flooding could be deduced for each 10-day period from the gauge levels at these three sites.

The apparent increases in storage deduced from inflows and outflows were compared with the observed levels and corresponding volumes of flood-plain storage, adjusted for absorption, rainfall on and evaporation from the flooded areas. This comparison gave a cumulative error in individual years which was attributed to inflow from tributaries along the White Nile. This analysis suggested that inflow was significant during certain years of high floods, especially on the Baro. Inflows from the Machar marshes appear to enter the White

Nile in some years and there are eye-witness accounts of such events (e.g. 1938–1939, 1942–1943, 1946–1947) but not systematic measurements. The analysis showed that the variation of flows between Malakal and Renk could be satisfactorily explained by analysis of the water balance of inflows, outflows and flood-plain storage.

Subsequent analysis (Institute of Hydrology, 1978) extended this study down to Jebel Aulia and used more recent records. Advantage was taken of the published relations (Hurst, 1950) between reservoir levels, storage volumes and surface areas to relate the total areas of flooding between Malakal and Jebel Aulia to observed water levels for the historical period. The estimation of evaporation losses from the flooded areas was based on average rainfall subtracted from Penman estimates of open water evaporation totalling 2350 mm. This had to be increased by 10%, including seepage, to equate predicted losses to those observed during the test period from 1948/49 to 1961/62, which was chosen for relatively low abstractions for irrigation. The water balance approach was found to give reasonable estimates of the total evaporation losses in this reach. When an attempt was made to estimate the effect of future levels influenced by water-saving projects like the Jonglei

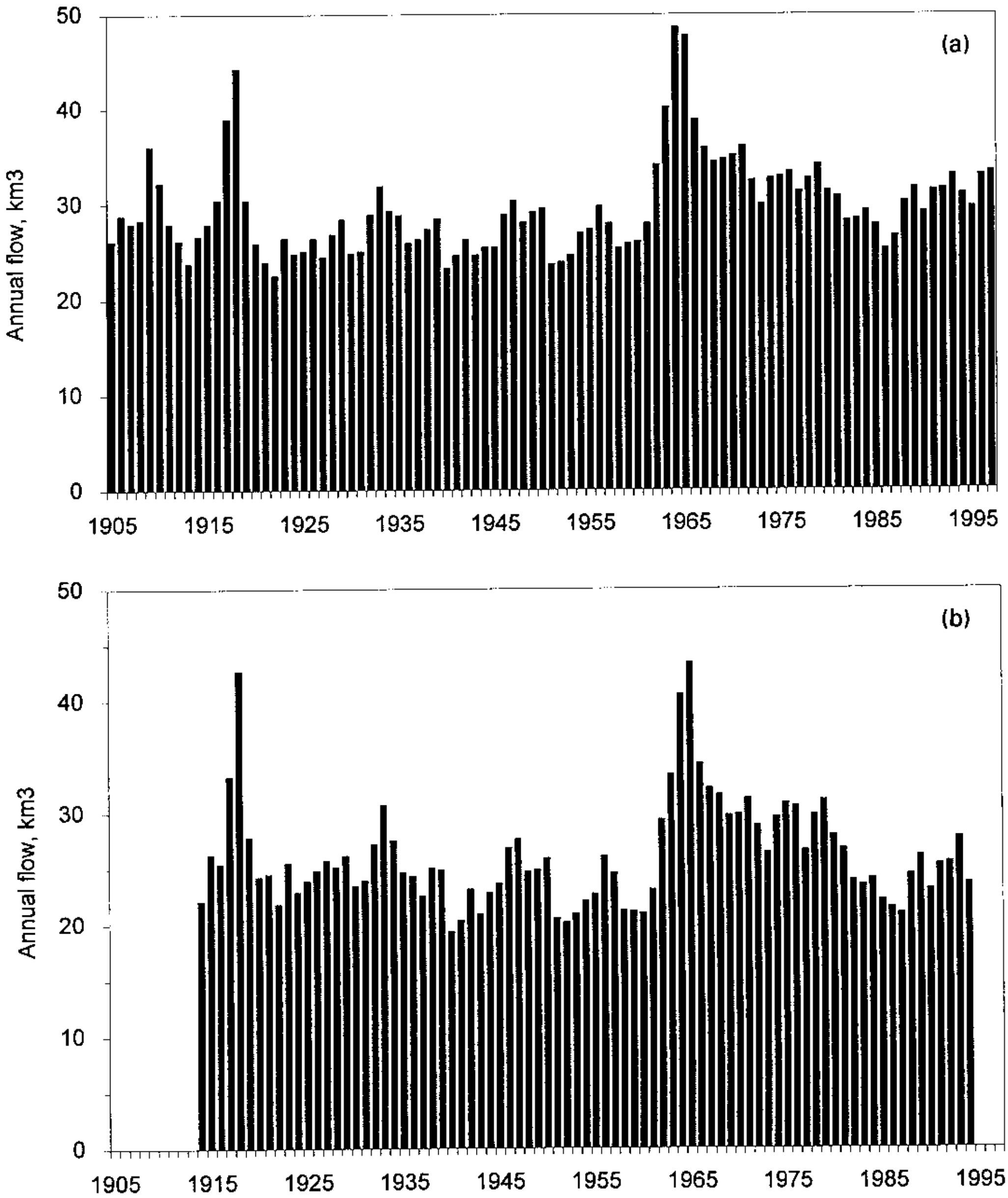


Fig. 8.3 White Nile at (a) Malakal and (b) Mogren: annual flows, 1905–1997.

Canal, Phase I, flows and thus water levels at Malakal exceeded their historic range. The rating curves at key sites and the relations between levels and valley storage required extrapolation, and hydraulic input would be needed if reliable estimates of the effect of further projects were to be made.

TRENDS OF LOSSES ON THE WHITE NILE

It is interesting to compare the measured inflows to the White Nile reach with the outflows over a longer period. Figures 8.3(a) and (b) compare the annual inflows at Malakal between 1905 and 1995 with the outflows at Mogren. The similarities between the two flow series are to be expected; the differences are shown in Fig. 8.4. The losses have clearly increased over the years, with scatter which is partly caused by random errors of measurement or over-year storage changes. The high losses in 1916–1917 are doubtless due to the high floods of that period. There is evidence of an increase in losses after the construction of the Jebel Aulia dam in 1934–1937, when the increase in maximum water surface between Melut and Jebel Aulia has been estimated as 1200 km^2 and the increased loss as 2.5 km^3. There is also an apparent rise in the losses immediately after 1961–1964, when the increased Sudd outflows led to higher river levels. The trend also reflects increased irrigation abstractions in this reach, which have been estimated to have increased from 0.2 km^3 in 1940 to 0.6 km^3 in 1977, and thereafter to 1.6 km^3.

VEGETATION OF THE WHITE NILE FLOOD PLAIN

The vegetation of the White Nile reach is affected by the large seasonal range of water levels, averaging about 2 m. Papyrus is not found in this reach, or in the White Nile upstream of the Sobat mouth, which is affected by backwater from the Sobat. Some studies carried out by the Jonglei Investigation Team have been analysed afresh and there is also a small-scale description of the White Nile flood plain near Gelhak.

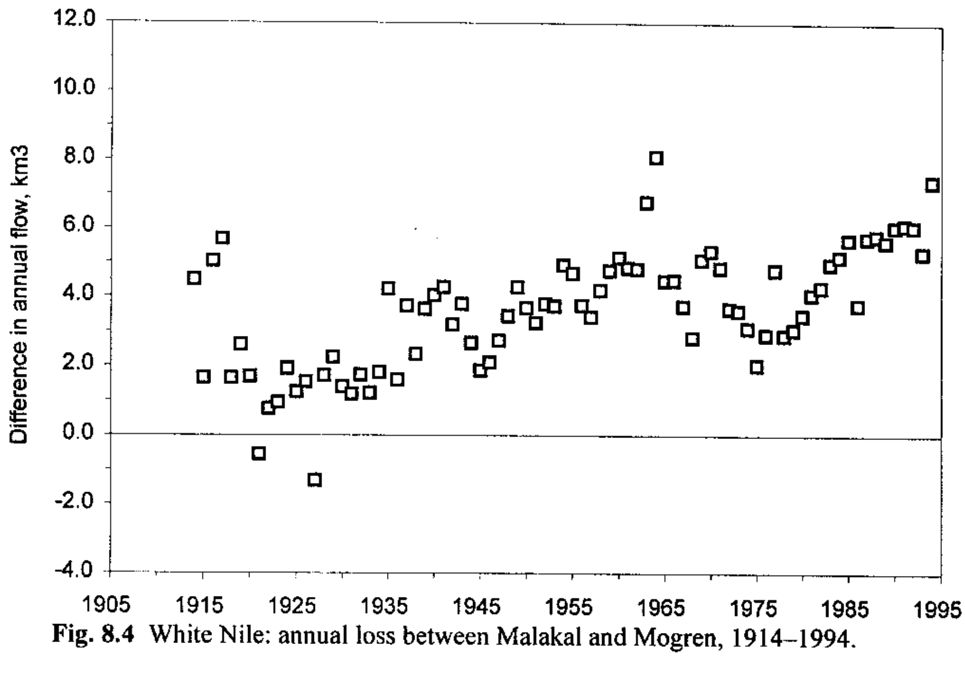


Fig. 8.4 White Nile: annual loss between Malakal and Mogren, 1914–1994.

Plate 8 The White Nile near Gelhak: view upstream from Jebel Ahmed Agha. The main river can be seen at the extreme right of the photograph.

As mentioned in Chapter 5, the Jonglei Investigation Team (1954, p. 154 *et seq.*) carried out studies of ground levels and vegetation at five sites on the White Nile. There were significant differences at each site between the levels at which various species were found, but these differences were not consistent from site to site. However, further analysis of the original data (Sutcliffe & Parks, 1996) showed that the levels of the transition between the shallow-flooded species (*Echinochloa pyramidalis* and *Oryza spp.*) and deep-flooded species (*Vossia* and *Echinochloa stagnina*) were related to maximum river levels, which were about 1.40–1.70 m above this vegetation transition.

Air photography was used to study the distribution of vegetation on the flood plain near Gelhak (11°N) and between Gelhak and Renk (11°20'N) in May 1953 during the dry season. The flood plain was divided into small basins on the same lines as the larger basins of the Bahr el Jebel swamps. There were obsolete channels parallel to the current channel which contained the remains of spill, especially where the side channels were prevented by the alluvial banks from draining back into the main river. The distribution of the vegetation, between the two bands of woodland which marked the limits of the flood plain, reflected the topography of these old channels (Plate 8). Bands of shrub or woodland flanked the banks of the river or the obsolete channels. The lower ground along the channel beds was subject to deeper flooding, which resulted in bands of *Echinochloa stagnina* with some *Vossia*. Adjacent to this deep-flooded vegetation were bands of *Echinochloa pyramidalis* and *Oryza spp.* on ground which was less deeply flooded. Thus the process of flooding in the White Nile reach was similar to that observed elsewhere, and the distribution of the flood-plain species was also similar.

EFFECT OF WATER-SAVING PROJECTS

The various projects which have been proposed to reduce evaporation losses in the wetlands of the Bahr el Jebel, Bahr el Ghazal and Machar marshes would have the effect of increasing the flows of the White Nile and perhaps of altering the seasonal variations of flow. It is clear that the ecological regime of the White Nile flood plain is similar to that of the other wetlands. The potential effects of the different proposals on water levels, evaporation losses and the flooding regime will require further investigation as the total flows will exceed those which have been experienced under natural conditions.

CONCLUSION

The White Nile receives the outflow from the Sudd, which provides the baseflow component, and the more seasonal contribution of the Sobat basin. The reach between Malakal and Khartoum caused natural attenuation through flood-plain storage, affected by the Blue Nile flood downstream. Since the construction of the Jebel Aulia dam the storage has resulted in increased evaporation, and the outflow has been delayed to supplement the Blue Nile in the low flow season.