Technical Note: Hydrology of the Lake Chilwa wetland, Malawi

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Description

Lake Chilwa is located in the Southern region of Malawi on the country's eastern boarder with Mozambique between latitude 15°00'S and 15°30'S and between longitude 35°30′E and 35°55′E. The wetland comprises the lake (i.e. open water), typha swamps, marshes and seasonally inundated grassland floodplain. The entire wetland is approximately 40 km from east to west and 60 km from north to south with a total area of about 2,310 km^2 (EAD, 2001). The water level of the lake is at an altitude of 627 masl. There is no outflow from the lake, which consequently varies considerably in size and salinity depending on precipitation in the catchment area. The catchment is 8,349 km^2 of which 5,669 km^2 (68%) is in Malawi and 2,680km^2 (32%) is in Mozambique (EAD, 2001). A small increase in water level results in a large increase in the lakes surface area. Lake Chilwa is very shallow, averaging 1-2 metres in depth with a maximum depth of only just over 2.5 metres (Figure 1). The wetland has a history of cyclic drying and filling. In the last century alone it has dried and filled eight times. The lake dried completely 1967/68 and most recently in 1996/97[1]. The hydrology of the lake is an important control on the ecology of the wetland, determining not only the water chemistry and physical properties, but also the composition of the vegetation and soil characteristics (Howard-Williams and Walker, 1974).

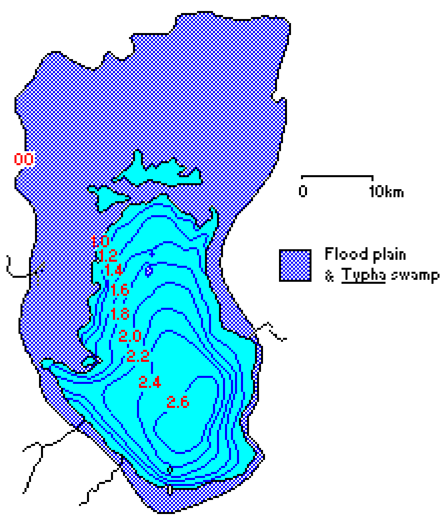

Figure 1: *Bathymetric map of Lake Chilwa* (source: UNESCO, 2004).

Climate

The climate of the region is largely controlled by the movement of air masses associated with the Inter-Tropical Convergence Zone (ITCZ). During the summer, high land temperatures produce low pressures and moisture is brought to the catchment through the inflow of maritime air masses from the Indian Ocean. During the winter, the sun moves north and the land cools, causing the

[1] For this study, an attempt was made to obtain time series of lake water level from the Ministry of Water Resources. However, currently these data are unavailable in electronic form.

development of a continental high pressure system. The descending and outflowing air produces the regional dry season. For this reason rainfall is seasonal and largely occurs during the summer months, November to April (Figure 2). Mean annual precipitation for the catchment is approximately 1363 mm, but the rainfall pattern is irregular with significant variation from one year to the next and often several concurrent years of below average rainfall (Figure 3).

Rainfall distribution in the wetland's catchment is uneven. In the highlands average annual rainfall ranges from 1,100 mm to 1,600 mm, reaching 2000 mm on the high plateaus of Zomba and Mulanje and in the Chilaka Hills. Zomba town, located at 884 masl, receives an average of approximately 1380 mm a year. The lowland plains, surrounding the lake, receive much less rainfall; 900 to 1,000 mm per year Howard-Williams and Walker, 1974; World Lakes database, 2006). In years of heavy rainfall floods are common in some parts of the catchment. Potential evapotranspiration (determined by the method of Penman-Monteith) averages approximately 1320 mm, but typically exceeds rainfall in the dry season months, May to October (Table 2; Figure 1).

Temperatures in the Lake Chilwa catchment vary with altitude. The highlands are cool throughout the year, but the plains become very hot in the months of September to November with mean maximum temperatures approaching 30^0C. The lowest mean temperatures roughly coincide with the dry season (Table 2).

Table 1: *Climate stations for which data obtained*

Nos.	**Name**	**Latitude**	**Longitude**	**Altitude (masl)**	**Distance from wetland (km)**	**Rainfall data**	**Temperature data**	**Potential Evaporation**
MW55ZMBO	Zomba (Town)	15.38 °S	35.33 °E	884	35.8	1893 – 1991 (mnthly total)	1901-1960 (mean mnthly)	Monthly average only
MW45CHKW	Chikwe	14.75°S	35.67°E	717	36.7	1982-1991 (mnthly total)	Monthly average only	N/A
MW65CHTK	Chitakali	16.00°S	35.45°E	645	76.5	1914-1988 (mnthly total)	N/A	N/A
MW65MLNJ	Mulanje	16.08°S	35.67°E	628	83.4	1981-1991 (mnthly total)	Monthly average only	Monthly average only
MW65MMSO	Mimosa	16.08°S	35.58°E	653	83.8	1954-1992 (mnthly total)	Monthly average only	N/A
MW54CHLK	Chileka	15.68 °S	34.97 °E	767	84.5	1939-1996 (mnthly total)	1939-1991 (mean mnthly)	Monthly average only
MZ65MLNG	Milange*	16.10°S	35.78°E	745	86.6	1914-1968 (mnthly total)	Monthly average only	Monthly average only

* Located in Mozambique
(source: FAO databases FAOClim and LocClim)

Table 2: *Mean monthly climate data* (simple arithmetic mean of data from different stations)

Month	Catchment Precipitation (mm)	Potential Evapotranspiration (mm) (Penman-Monteith)	Mean Daily Temperature (°C)
Jan	273	131	24
Feb	246	114	24
Mar	225	118	24
Apr	92	106	23
May	31	96	21
Jun	27	79	19
Jul	23	87	18
Aug	21	109	20
Sep	17	131	23
Oct	44	163	25
Nov	114	148	25
Dec	248	133	25
Annual	1363	1414	22

(source: FAO LocClim database)

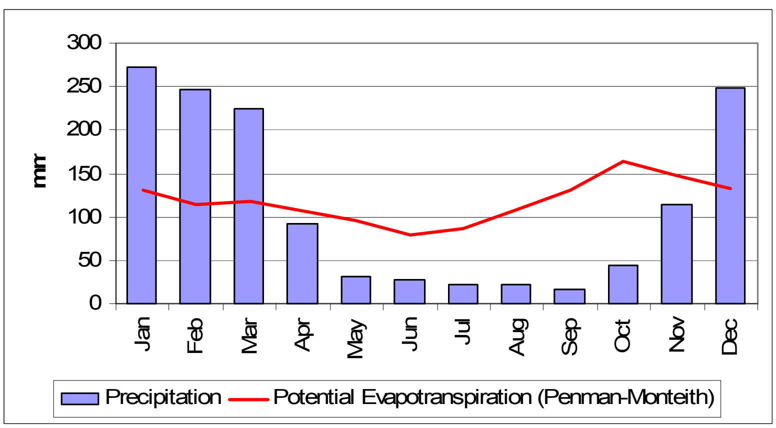

Figure 2: *Mean monthly rainfall and Potential Evapotranspiration (Penman-Monteith) derived from the FAO Loc-Clim database.*

a) b)

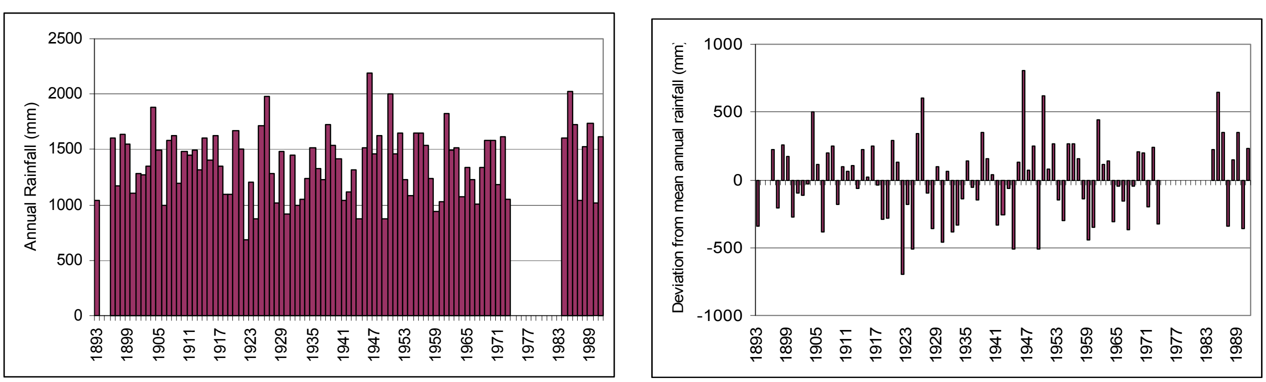

Figure 3: *Rainfall measured at Zomba: a annual time series b) deviation from the annual mean*

River flows

Several rivers flow into Lake Chilwa, but only the six most prominent rivers (i.e., the Sombani, Namdzi, Likangala, Thondwe, Domasi and Phalombe) are perennial. Abstractions for human use are relatively low; about 0.15 Mm^3 per day, with by far the largest abstractions (0.12 Mm^3 per day) being for irrigation. However, there is some concern that as population in the catchment rises abstractions will increase (EAD, 2001). At present there is no water management plan for the catchment.

Flow is measured on several of these rivers. Figure 4 shows graphs of time series of flow for the four gauging stations for which flow data were made available by the Ministry of Water Resources (Table 3). Although, as a consequence of different data availability, they cover different periods of time, the graphs illustrate:

i. the high seasonal variation in flow.
ii. the considerable inter-annual variability in flow in all the rivers
iii. the frequent occurrence of consecutive years in which flow is below the mean annual discharge
iv. the extremely poor data collection from the early 1980s to date; there are almost no years with complete data at any of the three stations still operating.

Table 3: *Gauging stations for which mean monthly flow data are available*

Gauge number	River	Length of record	Nos. of complete years	Latitude	Longitude	Catchment area (km^2)
20221	Likangali at Nkokanguqo	1959-2002	20	15.41°S	35.44°E	144.0
20102	Sombani at Phaloni Hill	1951-1979 (closed)	24	15.63°S	35.76 °E	843.0
20303	Domasi at Domasi TTC	1957-1998	24	15.28 °S	35.38 °E	72.8
20222	Thondwe at Jali	1959-2002	19	15.49 °S	35.48 °E	302.0

Annual flows on all the rivers correlate reasonably well with annual rainfall (Figure 5). However, analyses of runoff (i.e., flow effectively normalized for catchment area), indicates considerable differences between the rivers. Although the seasonal pattern is the same at all the gauging stations (i.e. typically 77-85% of total annual runoff occurring between January and May) there are considerable differences in the magnitude of runoff measured at each of the gauging stations (Figure 6). This most likely reflects differences in rainfall between the different catchments; higher rainfall over higher altitude catchments resulting in more runoff. However, the altitudes of the gauging stations and areal weighted rainfall over each catchment are not available to confirm this hypothesis.

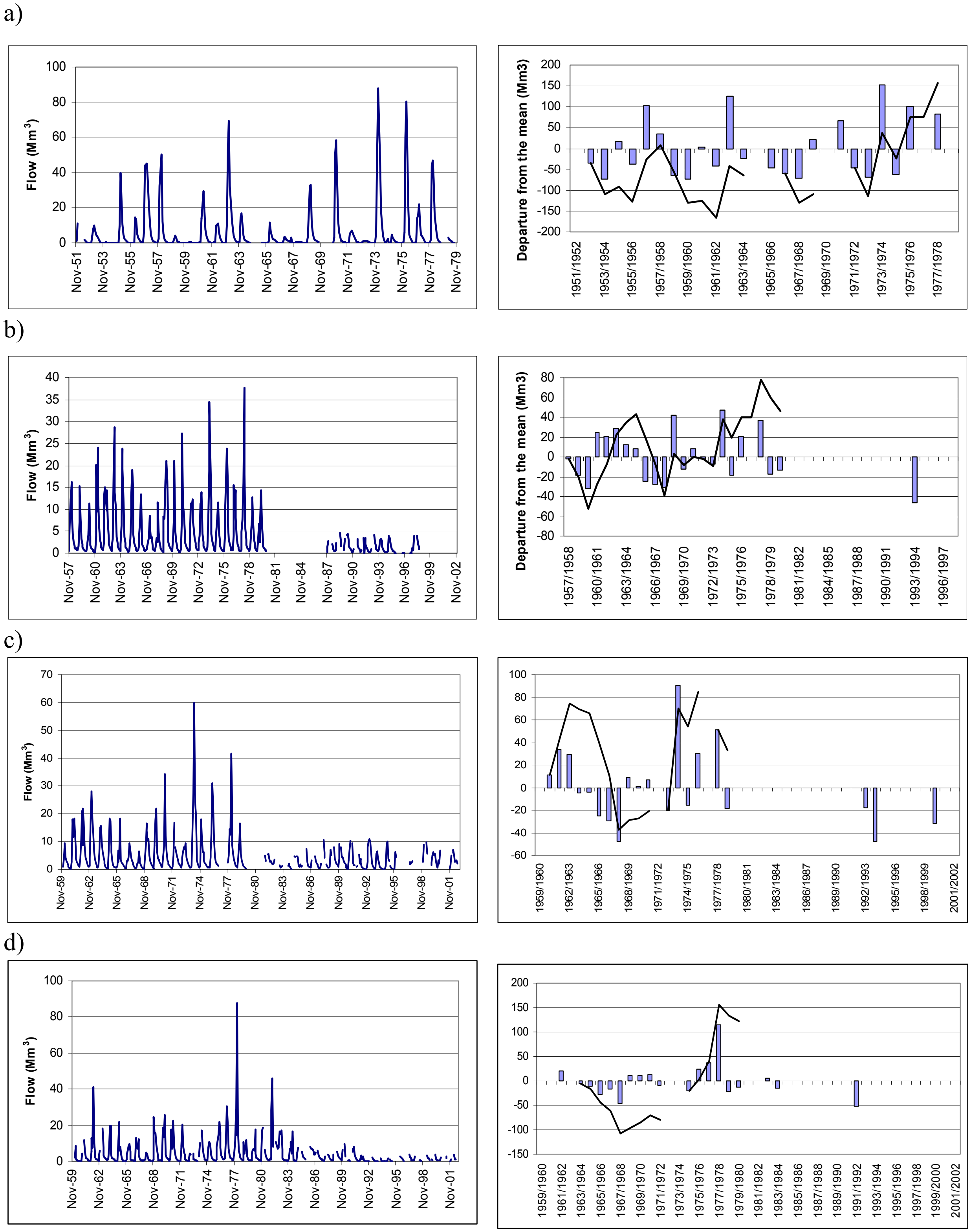

Figure 4: *Flow measured at gauging stations on rivers flowing into lake Chilwa and departure from the mean annual flow: a) Sombani at Phaloni Hill; b) Domasi at Domasi TTC; c) Likangala at Nkokanguwo; d) Thondwe at Jali*

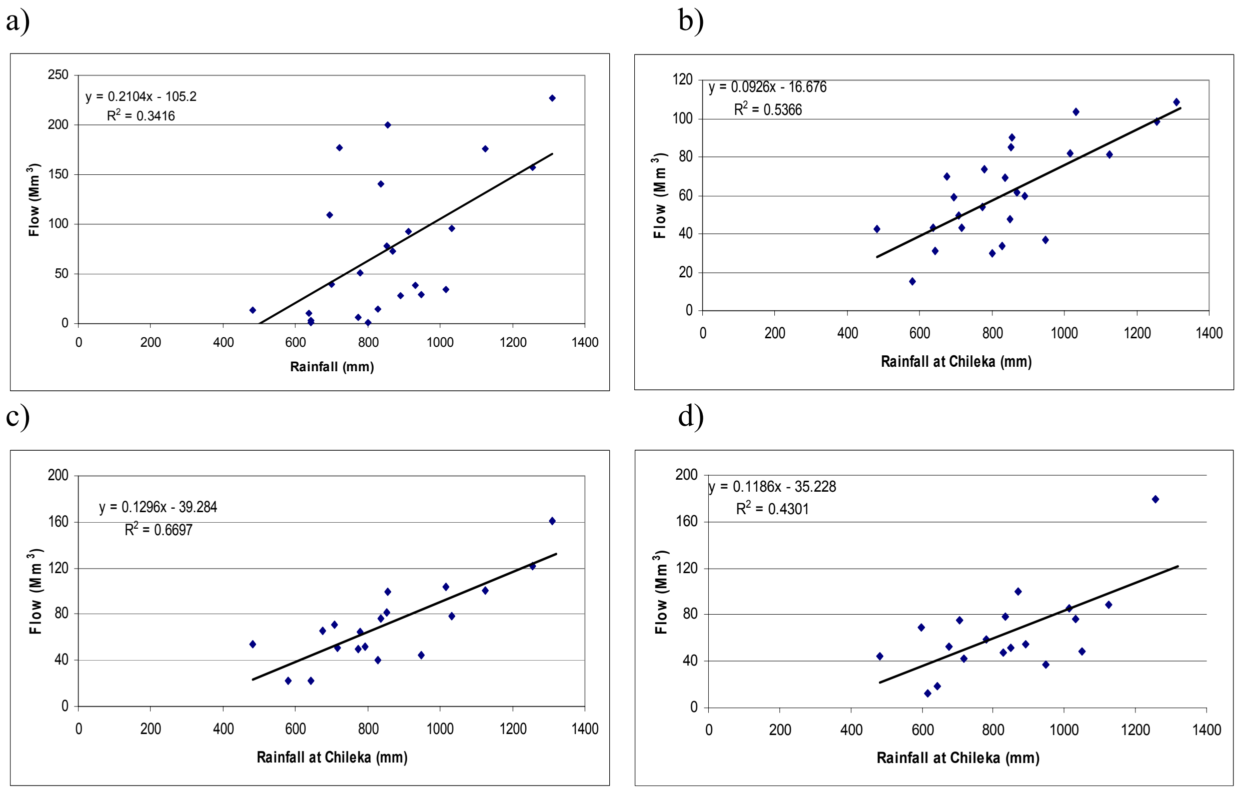

Figure 5: *Correlation between annual rainfall and annual flow at: a) Sombani at Phaloni Hill; b) Domasi at Domasi TTC; c) Likangala at Nkokanguwo; d) Thondwe at Jali*

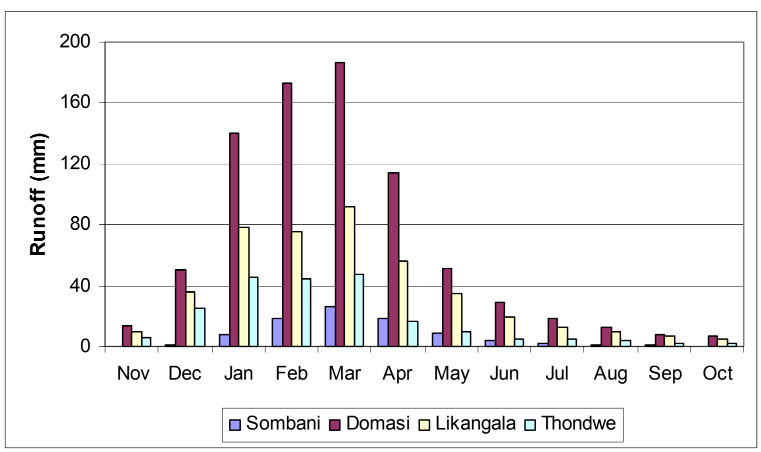

Figure 6: *Comparison of runoff (mm) from each of the catchments*

Wetland water budget

A crude (back of the envelope) estimate of the average annual water budget for the wetland was determined. The water budget of the wetland is approximated by the equation:

$$P + Q_i = E + Q_o \qquad \text{(equation 1)}$$

Where:
- P = precipitation onto the wetland
- Q_i = inflow into the wetland
- E = evapotranspiration from the wetland (a combination of open water evaporation and evapotranspiration from the swamps and grass)
- Q_o = outflow

Mean annual evapotranspiration from the wetland was estimated to be 3,782 Mm^3 (Table 4). This estimate was derived from assumed areas for the different wetland vegetation types (EAD, 2001) and estimates of likely evapotranspiration losses. Open water evaporation was assumed to be 1,800 mm. Evapotranspiration from the typha swamp and marshes was assumed to be 1,700 mm. Potential evaporation from floodplain grasses was assumed to be 1,400 mm, with actual evapotranspiration slightly less in the dry season due to water deficit. Actual evapotranspiration from cultivated areas was assumed to be 1,350 mm, since these areas are irrigated and so water deficits are low.

Table 4: *Estimated evapotranspiration from different parts of the wetland.*

	Area		Evapotranspiration (mm)				
	Wet season*	Dry season *	Wet season		Dry season		Annual Total
	(km^2)	(km^2)	mm	Mm^3	mm	Mm^3	Mm^3
Open water	1054	648	900	948.6	900	583.2	1531.8
Typha swamp	640	699	900	576.0	800	559.2	1135.2
Marsh	163	300	900	146.7	800	240.0	386.7
Floodplain	220	430	707	155.5	600	258.0	413.5
Cultivated+	233	233	750	174.8	600	139.8	314.6
			Total	2001.6		1,780.2	3781.8

* wet season is November to April and dry season is May to October
+ irrigated rice, wetland rice and vegetable gardens (dimbas)

Table 5 presents a summary of the mean annual water fluxes, with inflow (Q_i) computed from equation 1. The estimation suggests that approximately 60% of the water in the wetland originates as direct rainfall onto the wetland, with 40% originating as flow from the surrounding catchment. The estimated inflow of 1,472 Mm^3 equates to an average annual runoff from the catchment (6,039 km^2) of 244 mm. Assuming an average annual rainfall over the catchment of 1,363 mm (Table 1) this corresponds to a coefficient of runoff of 17.9%.

Table 5: *Estimate of the average annual water fluxes (Mm^3) into and out of the Lake Chilwa wetland*

	Wet Season	Dry Season	Annual
Direct rainfall onto the wetland[+]	2,033	277	2,310
Evapotranspiration from the wetland	2,002	1,780	3,782
Outflow from the wetland	0	0	0
Inflow	1,177	294	1,472

[+] Estimated to be 1,000 mm with 88% falling in the wet season

Data requirements to improve the analyses

i) time series of water levels measured in the lake
ii) any additional data on inflows into the lake
iii) a water-level volume relationship for the wetland
iv) better estimates of areal coverage of different wetland/vegetation types and variation between the wet and dry season - from image analysis

References

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