THE TIDAL CURRENTS IN THE SOUTHERN PART OF THE SUEZ CANAL

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RÉSUMÉ

Il n'existe pas d'observations directes des courants dans le canal de Suez depuis Lemasson (1908) et Gruvel (1936). Plusieurs observateurs (Fox 1926, Vercelli 1927, Wüst 1934, Faouzi 1951, Morcos 1960) ont pu déduire de la distribution de la salinité, le mouvement de l'eau dans le canal. Comme l'amplitude de la marée est relativement faible à Port-Saïd (environ 30 cm) en comparaison avec celle de Suez (80 cm au minimum et 140 cm aux marées d'équinoxe), elle joue un rôle réduit dans l'induction des courants dans la partie Nord du canal.

Cette étude utilise les résultats des observations de courants fournies par l'Administration du Canal.

a) Enregistrement continu automatique par moulinet à Kosbri (Km 149.800) de 1933 à 1935 et à Ferdan (Km 64.650) au cours de 1935.

b) Mesures journalières de la vitesse et de la direction du courant à huit stations et à quatre profondeurs de 1944 à 1950 par un appareil pour la mesure du courant. Les résultats des mesures au cours d'une année complète (1.12.48 à 30.11.49) aux trois stations méridionales, caractérisés par le mouvement de flot et de jusant de la marée semi-diurne sont donnés par la figure 2.

La partie sud du canal de Suez présente une des meilleurs conditions naturelles pour l'étude des courants alternatifs et de l'influence perturbatrice des courants non de marée sur eux, particulièrement sur leurs vitesses et durées.

a) Au lieu d'avoir des courants de flot et de jusant de force approximativement égale la figure 2 indique que la moyenne mensuelle de la vitesse maxima du courant dirigé vers le Nord à Shalloufa et Goneffe, subit des fluctuations saisonnières avec un minimum en Septembre et un maximum en Janvier. La conclusion est opposée pour le courant vers le Sud. Le courant résultant, et par conséquent le courant non de marée, est dirigé vers le Nord, sauf en Juillet, Août et Septembre où il se dirige vers le Sud.

b) L'enregistrement continu par moulinet Idrac à Koubri montre que la durée du courant de flot est de 52 %, du courant d'èbe de 33 % et des étales 15 % du temps total au cours des trois années. La durée moyenne du flot présente un maximum en hiver (9 h. 19 en mars 1934) et un minimum en été (4 h. 41 en août 1934). La plus longue « chaîne » de courants Nord observés dura 38 h. 40 m. sans renversement du sens en mars 1934. Le courant d'èbe montra une durée maximum de 7 h. 06 en juillet 1935, avec un minimum de 0.55 m. en mai 1933.

Remarques additionnelles

1. Le vent du Nord soufflant sur la zone du canal de Suez présente sa fréquence maximum en septembre
2. Le niveau moyen de la mer à Suez est plus élevé qu'à Port-Saïd excepté en été. Il est supérieur de 36 cm en mars et avril, et 2,3 cm inférieur en septembre (moyenne de 14 avril 1924-1937).
3. La salinité dans le Petit Lac Amer tombe de 48 $^{0}/_{00}$ en été à moins de 43 $^{0}/_{00}$ dans le reste de l'année. Le plus haut degré de salinité se déplace vers le sud en été, tandis que l'eau moins saline de la baie de Suez est poussée vers le Nord le reste de l'année.

SUMMARY

No direct observations of the currents in the Suez Canal appeared in oceanographic literature, since Lemasson (1908 and Gruvel (1936). From the distribution of salinity in the Canal, many observers (Fox 1926, Vercelli 1927, Wüst 1934, Faouzi 1951, Morcos 1960) were able to describe the water movement in the Canal.

Since the tidal range is relatively small at Port-Said (about 30 cm.), in comparsion with that at Suez (80 cm. neap range and 140 cm. spring range), it plays a smaller role in inducing currents in the northern part of the Canal.

This study makes use of two records of currents, kindly provided by the Suez Canal authority :

a. Continuous automatic registration by Idrac currentmeter at Koubri (Km. 149.800) during 1933-35 and at Ferdan (Km. 64.650) during 1935.

b) Daily measurements of the velocity and direction of the current at eight stations and four depths from 1944 to 1950, by a submergee free-drifting biplane-shaped current drag. From a complete one-year set of daily observations (1.12.1948 to 30.11.1949), the results of the three southern stations, dominated by reversal semi-diurnal tidal current, are plotted in Figure 2.

The southern part of the Suez Canal offers one of the best natural conditions for the study of the reversing tidal currents, and the disturbing influence of the non-tidal currents on them, particularly on their velocity and duration :

a. Instead of having flood and ebb currents of approximately equal strenght, Figure 2 indicates that the monthly average of maximum velocity of the northward current at Shalloufa and Geneffe shows clear seasonal variation between the minimum in September and the maximum in January.

The opposite picture is demonstrated by the southward current. The resultant current, and hence the non-tidal current, flow to the north, except in July, August and September when it is reversed to the South.

b. The continuous registration by Idrac currentmeter at Koubri, shows that the duration of the flood current is 52 %, the ebb current 33 %, and the slack 15 % of the total time registred in three years. The average duration of flood current has a maximum in winter (9 h., 19 m. in March 1934), and minimum in summer (4 h., 41 m. in August 1934). The ebb current shows the opposite picture (2 h., 30 m. in February and 5 h., 08 m. in August 1934). The most long « chain » of northward current observed, lasted 38 h., 40 m. without reversal of current in March 1934. The Southward current showed a maximum duration of 7 h., 05 m. in July 1935. The minimum duration of the Northward current was 55 m. in May 1933.

Additional remarks :

1. The northern wind blowing on the Suez Canal area reaches its maximum frequency in September.
2. The mean sea level at Suez is higher than Port-Said except in summer. It is 36 cm. higher than Port-Said in March and April, and 2,3 cm. lower than Port-Said in September (average of 14 years 1924-1937).
3. The salinity in the Little Bitter Lake, drops from about 48 $^{0}/_{00}$ is summer to less than 43 $^{0}/_{00}$ in the rest of the year. The highly saline water of the Great Bitter Lake moves to the south in summer, while the less saline water of the Suez Bay is pushed northward in the rest of the year.

1. Introduction

The problem of the tidal currents in the Suez Canal is scarcely treated in oceanographic literature. It is only in Lemasson (1908) & Gruvel (1936) that direct observations of the currents in the Canal were studied. From the distribution of salinity in the Canal, some investigators (Fox 1926, Vercelli 1927, Wüst 1934, Faouzi 1951, and Morcos 1960) were able to conclude that the water of the Canal moves towards the north all the year except in two or three months during July, August and September, when the current is set in the opposite direction towards the Red Sea.

The present work is a part of a study on the regime of currents in the canal at different months, to find out its effect on the seasonal variation and distribution of salinity along the canal. Since the tidal range is relatively great at Port-Teufik near Suez (about 80 cm neap range and 140 cm spring range) in comparison with that at Port-Said (about 30 cm), it plays a greater role in inducing currents in the southern part of the canal, where strong semidiurnal reversing tidal currents are a characteristic feature. The part of the canal south of the Bitter Lakes, has a rather simple and uniform construction and does not exhibit the many complicated factors normally encountered in tidal estuaries. This introductory study is presented in order to raise the interest in the hydrographical problems of the Suez Canal, which offers indeed, one of the best natural conditions for the study of tidal currents and relative problems.

2. Methods of recording currents

Two different methods were used at different times by the Suez Canal authorities to obtain regular records of currents in the Canal.

A. Continuous automatic registration by Idrac current meter at Koubri (km 149.800) [1] for three years 1933-1935, and at Ferdan (km 64.650) for one year 1935. This current meter allows a continuous and automatic registration of the velocity and direction of the current (Idrac, 1938 and Rouch, 1948). A summary of the results was given in the reports of the Suez Canal «Commission Consultative Internationale des Travaux, Réunion 1936». Unfortunately, the two current meters were not checked and calibrated regularly. This renders the results less valuable, especially in comparing the two stations.

B. Daily measurements of the velocity and direction of the current in eight stations and four depths (1.5, 4, 8 and 11 m) from 1944 to 1950. The method of measuring the current made use of a sabmerged free-drifting biplaneshaped current drag, which is attached by a line to a buoy, the positive buoyance of which is just enough to support the drag. The line between the buoy and the drag is adjusted so that the drag is at the

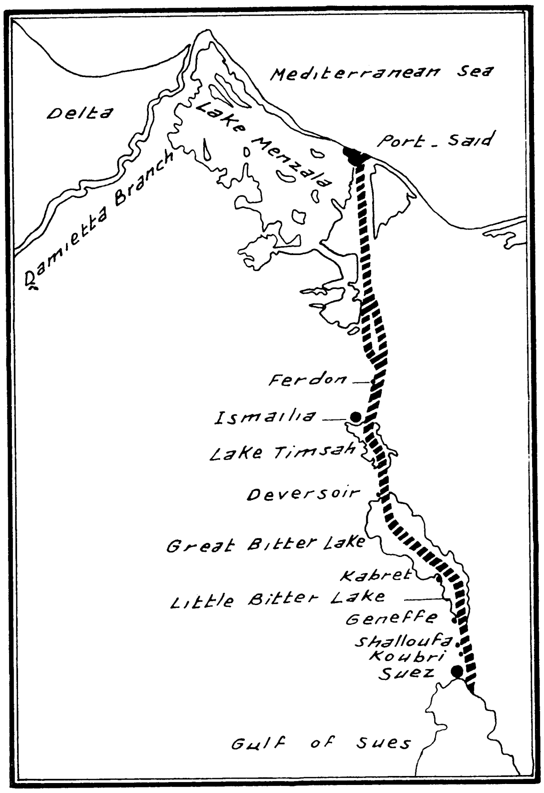

Fig. 1. Position of Stations

[1] The positions of the stations are given in the charts of the Suez Canal Organisation, as the distance in kilometers measured to the south from the Light House in Port-Said.

depth at which current measurements are to be made. From the distance and direction of the drift over a given time interval, the current velocity at a given depth can be determined. A modified method was developed later by PRITCHARD & BURT (1951) who instead of letting the drag drift freely, they attached it directly to a hydrographic wire, without a buoy, the force of the water motion on the drag is then obtained by measurement of the wire angle at the surface.

3. RESULTS

Through the kindness of the Suez Canal Organisation, I got a complete set of the latest daily observations of currents from 1.12.1948 to 30.11.1949. These records give the direction and velocity of the current in meters/hour, at four depths, at eight stations. At the five stations north of the Great Bitter Lake, the measurements were made simultaneously once every day at 9.00 A.M. In the trhee stations south of the Great Bitter Lake, where the reversal semidiurnal tidal currents are very predominant, the observations were made twice a day, one at the maximum flood current towards the north, the other at the maximum ebb current towards the south. The time of observations differed therefore from one day to another but the difference in time of daily observations in the three stations was very small or almost negligible. For the purpose of this paper, the discussion will be limited to the results of the three southern stations. They are : *Kabret* (km 120.827) between the Great and Little Bitter Lakes, *Geneffe* (km 133,950) at the southern end of the Little Bitter Lake, and *Shalloufa* (km 146.125) about 15 km north of the opening of the Canal in the Suez Bay. The position of the stations are shown in Fig. 1.

Table 1 gives the monthly average of the maximum current velocity, calculated from the daily observations at the three stations, and at 4 m depth. Positive values are assigned for northward current and negative values for the southward current. The difference between them is given as the resultant current. (The results are plotted in Fig. 2).

Every time the current was measured, the water level was recorded. The monthly averages of the water level at flood and ebb strengths were calculated from the daily observations at the three stations, and are plotted in Fig. 3.

4. CHARACTERISTICS OF THE CURRENTS

The Canal south of the Great Bitter Lake is predominated by strong tidal currents, which are subject to the disturbing influence of non-tidal currents which affect the regularity of their occurrence, especially with regard to velocity and duration.

4.1 *Velocity*

Instead of having flood and ebb currents of approximately equal strengths, Fig. 2 indicates that the monthly average of maximum velocity of the northward current at Shalloufa and Geneffe shows clear seasonal variation between the minimum in September and maximum in January. The opposite picture is demonstrated by the southward current.

MARMER (1932) noted that from the observations made at any point in a tidal stream, the tidal and non-tidal currents may be readily disentangled. The strength of tidal current will be given by half the sum of the observed flood and ebb strengths, while the velocity of the non-tidal current will be given by half the difference between the observed flood and ebb strengths. Applying this to the results in Table I, the maximum velocity of the tidal current is found to have an annual average value of about

TABLE 1

The monthly averages of maximum velocities of Currents in cm/Sec.

Month	Shalloufa (km 146.125)			Geneffe (km 133.950)			Kabret (km 120.827)		
	N	S	R	N	S	R	N	S	R
January	*107.09*	47.14 *	*59.95*	*100.65*	43.75 *	*56.90*	13.39 *	11.22	2.17 *
February	90.95	58.34	32.61	87.98	57.95	30.03	14.75	12.28	2.47
March	102.37	57.53	44.84	95.06	54.56	40.50	15.36	11.03 *	4.33
April	97.73	74.51	23.22	92.56	70.48	22.08	19.25	11.70	*7.55*
May	96.26	70.87	25.39	90.54	66.78	23.76	19.08	12.42	6.66
June	94.67	85.34	9.33	89.01	80.12	8.89	20.75	16.08	4.67
July	93.98	97.76	—3.78	87.95	89.37	—1.42	20.58	16.47	4.11
August	90.12	*98,62*	—8.50	84.84	91.84	—7.00	*21.36*	*17.53*	3.83
September	78.67 *	98.23	—19.56 *	74.01 *	*92.90*	—18.89 *	20.64	16.50	4.14
October	94.95	86.78	8.17	88.17	84.31	3.86	20.14	15.70	4.44
November	98.12	68.78	29.34	95.06	62.45	32.61	21.06	15.17	5.89
December	101.09	76.90	24.19	94.84	74.37	20.47	18.64	13.81	4.83

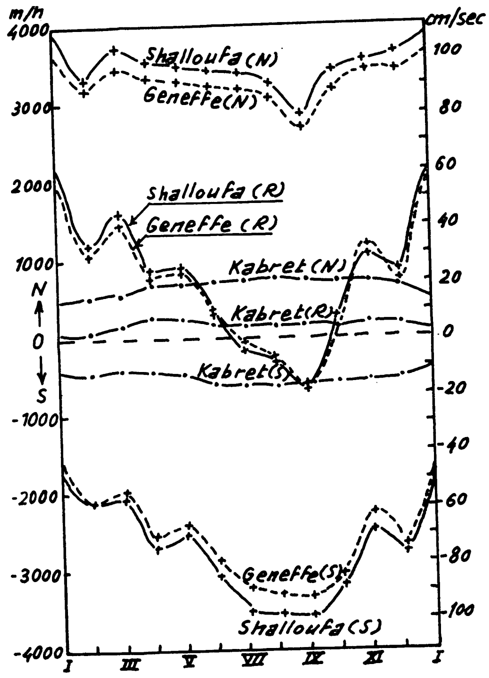

Fig. 2. Monthly average of the maximum velocity (1948-1949) of the northward current (N), the southward current (S), and the resultant (R) at : Kabret Km. 120.827, Geneffe Km. 133.950, Shalloufa Km. 146.125.

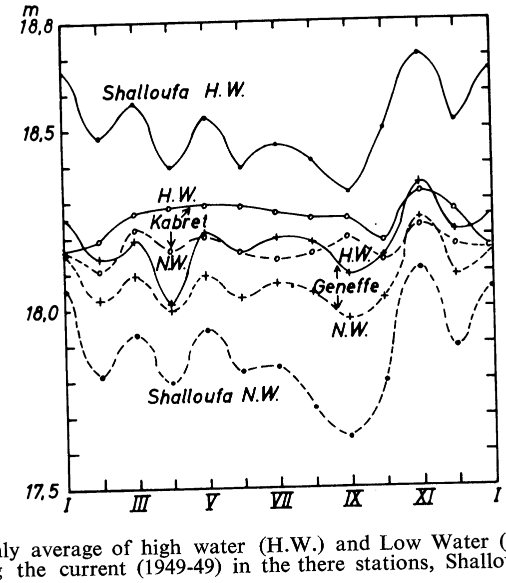

Fig. 3. Monthly average of high water (H.W.) and Low Water (L.W.) at time of measuring the current (1949-49) in the there stations, Shalloufa, Geneffe and Kabret.

86 cm/sec. in Shalloufa, 81 cm./sec. in Geneffe, and 16 cm./sec. in Kabret. The non-tidal current taken as half the resultant current (Fig. 2), undergoes a complete reversal of direction. It flows to the south in July, August and September and to the north in the rest of the year. The monthly averages have a maximum value to the south in September, and to the north in January. The velocity of the resultant current is much less in summer, when setting to the north, than in the rest of the year.

4.2 *Duration*

TABLE 2

Duration of the northward and southward currents (From the results of IDRAC Current meter at Koubri 1933, 1934 & 1935).

Total time registered in three years		Northward Current		Southward Current		Slack
		52%		33%		15%
	Year	Max.	Min.	Min.	Max.	
Monthly average duration (in hours)	1933	7.52 (Feb.)	4.19 (June)	2.33 (Nov.)	5.16 (Sept.)	
	1934	9.19 (Mar.)	4.41 (Aug.)	2.30 (Feb.)	5,08 (Aug.)	
	1935	7,28 (Mar.)	5 (July)	3,11 (Oct.)	5,30 (July)	

The results of the continuous registration at Koubri, given in table 2, show that the duration of the flood current is 52%, the ebb current 33%, and the slack 15% of the total time registered in three years. The monthly average duration of the northward current has a maximum in winter, and minimum in summer, thus coinciding with the maximum and minimum of the monthly average of the maximum velocity of current. The southward current shows the opposite picture.

It was observed that a «chain» of northward current separated with slack water, but without reversal of current, occurs sometimes every winter. The most long northward current observed in 1933-1935 period, lasted 38 h, 40 m from 22 to 24 March 1934. On the other hand, the duration of the southward current showed a maximum of 7 h, 05 m in July 1933. The minimum duration of the northward current was 55 m in May 1933. This shows that the northward current is more dominant. It may be reduced in summer but not completely abolished as it happens sometimes to the soutward current in winter months.

5. High and Low Waters

The comparison of the time of the maximum velocity of the northward and southward current with that of the high and low water in Port Tewfik showed that the strength of the flood current comes about the time of the high water, and the strength of the ebb current comes about the time of the low water. This was also observed by LEMASSON (1908), who stated that during the quadrates in April, May and November, the flood current started 3 h, 10 m after the low water in Suez and finished 3 h, 10 m after high water, and had its maximum velocity inbetween. The behaviour of the ebb current was nearly the same. The tidal movement in the Canal, therefore, is of the progressive-wave type, characterised by the occurrence of the strengths of the current at high and low water. This is exemplified, according to MARMER (1932), by the tidal movement in Hudson River.

The values of the monthly average of the daily observations of the water level in the three stations at time of maximum northward and southward currents are plotted in Fig. 3. They can be taken to represent the monthly average level of high and low water at these stations.

The tidal range between high and low water is much greater in Shalloufa than in Geneffe which is slightly greater than in Kabret. This shows a different case with regard to the velocity of currents in the three stations. The velocity of the flood and ebb currents is slightly greater in Shalloufa than in Geneffe and both are much greater than in Kabret. Geneffe lies at the connection between the Canal and the Little Bitter Lake. It is believed that the quantity of water transported to or from the lake by the relatively strong current in the narrow Canal between Shalloufa and Geneffe produces relatively smaller changes in the water level of the lake due to its comparatively great capacity.

At the strength of the southward current, the low water at Shalloufa is much lower than at Geneffe which is slightly lower than at Kabret. At the strength of the northward current, the level at Shalloufa is much higher than at Geneffe, which is slightly lower, and not higher, than at Kabret. This observation is in agreement with the results of the monthly mean sea-level, showing the level at Kabret higher than Geneffe. It should be noted also that the tidal current vanishes in the Little Bitter Lake, being imperceptible five kilometers north of Geneffe (FOX, 1926). The area of the cross section of the Lake, in its widest part (between km 123 and km 125), is about 14 times as that of the proper Canal between the Lake and the Gulf of Suez. It is believed that the water level at Kabret is much affected by the water budget of the Bitter Lakes and other hydrographical and meteorological factors. BAUSSAN (1938) is of the idea that the northern wind causes piling of the water in the Great Bitter Lake at Kabret, thus increasing its water level than at Geneffe and Deversoir (northern end of the Great Bitter Lake).

The high and low waters in Shalloufa, undergo seasonal changes resembling that of the mean sea level in Port-Tewfik (Table 3). The minimum of the high and low water in September in Shalloufa and Geneffe is accompanied with the maximum velocity of the resultant current to the south. The comparison of the curves of the velocity at Shalloufa and Geneffe (Fig. 2) with those of high and low waters (Fig. 3) shows great similarity in the seasonal variation.

6. FACTORS PRODUCING NON-TIDAL CURRENTS

There are many factors of non-tidal nature, the combined effect of them produces non-tidal currents in the Canal. Due to the complicated nature of the phenomena, it is very difficult to estimate the role played by every factor. One of the distinguished phenomena in the Canal is the difference in the mean sea level between the Red Sea and the Mediterranean at both ends of the Canal. Table (3) shows that the mean sea level at Port-Tewfik (near Suez) is higher than at Port-Said except in summer. It is 36 cm higher than Port-Said in March and April, and 2.3 cm lower than Port-Said in September (average of 14 years 1924-1937, MORCOS 1959). The greatest increase of Port-Tewfik level than Port-Said was 49.8 cm in November 1925, and the greatest decrease was 15.7 cm in september 1936. The slightest differences observed occur

TABLE 3

The monthly mean sea level (Average 1924-1937)

Month	Port-Tewfik.	Port-Said	Difference
January	18.355	18.013	0.342
February	351	17.993	0.358
March	.313	.952 *	0.361
April	.319	.956 *	*0.363*
May	.309	17.979	0.330
June	.211	18.036	0.175
July	.169	.115	0.054
August	.144	*.146*	— 0.002
September	.097 *	.120	— 0.023
October	.197	.085	0.112
November	.391	.086	0.305
December	*.407*	*.076*	0.331

usually in July, August and September. In another series of observations (1935-1937), Kabret was found to attain an intermediate level between both ends of the Canal. It is lower than Port-Tewfik and higher than Port-Said except in summer months when the conditions are reversed.

The harmonic analysis of the monthly mean sea level made by BAUSSAN (1938), showed that the annual and semiannual components in Port-Said and Port-Tewfik are independent and belong to the Mediterranean and Red Sea respectively. It is believed however that there are some local factors which contribute to the increase of the mean sea level in Port-Said than Port-Tewfik in summer. The northern wind blowing on the Suez Canal region reaches its maximum frequency in September. This helps piling of water in front of Port-Said and creating southwards current in the Canal. Moreover, the Nile flood occurs from August to December with a maximum in September. During this month, an average of 325 m^3/day is discharged from Rosetta Branch, and 147 m^3/day from Damietta Branch (average 1912-1942 after HURST, 1944). The month of Damietta Branch is only 35 miles west of Port-Said. These immense quantities of Nile water tend to mowe eastward, in the direction of Port-Said, with the surface counterclockwise current circulating the Mediterranean.

7. EFFECTS IN THE DISTRIBUTION OF SALINITY

The monthly longitudinal sections of salinity along the Canal give a clear evidence of the direct influence of the currents on the distribution of salinity and its very clear and regular annual variation in the different regions of the Canal. (MORCOS, 1960). The salinity in the northern part of the Canal increases from less than 39‰ in summer to 43-44‰ in winter. This part of the Canal is fed by the Mediterranean water diluted by the Nile flood in summer and by saline water from the Great Bitter Lakes in the rest of the year. On the other hand, the salinity in the Little Bitter Lake drops from about 48‰ in summer to less than 43‰ in the rest of the year. The highly saline water of the Great Bitter Lake moves to the south in summer, while the less saline water of the Suez Bay is pushed northward in the rest of the year.

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