The effect of the Suez Canal development on the tide and tidal current- model study

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Khaled A. Alam El-Din
Alexandria University

Fahmy Mohamed Eid
Alexandria University

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Alam El-Din K.A., S.H.Sharaf El-Din and F.M.Eid

Department of Oceanography, Faculty of Science,
University of Alexandria, EGYPT
Tel. 002047569406 Fax: 002 03 543 5956

Abstract

The effects of deepening and widening the Canal on the tide and tidal current was studied using the Princeton Ocean Model (POM). There is a relatively large increase of tidal range inside the canal. The total increase of tidal range in Great Bitter Lake after finishing the two stages of the development project is more than 120 % from that before 1975. The peak of S-N current in the southern section increases from 68 cm/sec before 1975 to 76 cm/sec in the present stage and to 83 after finishing the stage II of the development project. The peak of N-S current increases from 83 cm/sec to 94 cm/sec in the present stage and to 105 after finishing the stage II. The maximum ratio of increasing of the tidal current is occurred in the northern section (between Lake Timsah and Port Said). The S-N current increases at El-Tina from 21 cm/sec to 37 cm/sec with a ratio more than 75 %. While, the N-S current increases from 35 cm/sec to 52 cm/sec with a ratio of about 50 %.

Introduction

Since the opening of the Suez Canal in 1869, it has become one of the World's main shipping routes. 7% of sea transported World trade passes through the Suez Canal. About 16,000 ships of different types passes through the Suez Canal per year with 290 million tons of different kind of goods. The total annual oil tanker traffic is about 3,000 vessels with 60 million tons of oil (Haggag, 1996).

The information of water current in the Suez Canal is necessary since fully laden tankers passing through the canal are sensitive to small changes in water current

(Hydraulics Research Station, HRS, 1976). Also it is a well known that the variations in water level in any navigable waterway are very important for navigation.

This investigation is to study the effect of deepening and widening the canal on the tide and tidal currents by using three-dimension numerical modeling.

Literature Review

The first scientific observations of tides that carried out in the southern part of Suez Canal go back to engineer "Carsten Niebuhr (1773)" who observed tidal amplitudes for 6 days on year 1762 at Suez. Later on, "Jacques - Marie' Le Pere" collected some tidal records from the 20th to 30th of January 1799. Lieussou (1856) studies the tide for more than one month of year 1856. Ferdinand de Lesseps (1871) wrote some notes about tides under the heading "Sur le Service Mareographique de' Canal de' Suez". Studies conducted by the Suez Canal Company (1884, 1906, 1919 & 1936). Tidal records at Port Tawfik for a period of 18 years from 1931 to 1949 were analyzed by Goby (1951).

The first direct observations of the tidal currents in the Suez Canal appeared in the oceanographic literature are Lemasson (1908) and Gruvel (1936). To study the effect of increasing the cross-sectional area of the Canal on the tidal current, the Suez Canal Company (1919) conducted a comparative study between the current velocity recordings of the years 1871 to 1876, 1905 and 1915. They concluded from their study that there is no any appreciable effect of the increased cross-section on the tidal current in the Suez Canal, in that range of cross-sections. From the distribution of salinity in the canal, many observers, Fox (1926), Vercelli (1927), Wüst (1934) and Fauzi (1951) tried to describe the water movement in the canal.

During the period 1953-1955 Morcos made monthly cruises along the Suez Canal in order to study the stratification and circulation of water in the canal (Morcos 1959, 1960 a). Morcos (1960 b) studied the tidal current in the southern part of the canal. Morcos & Messieh (1973) studied the effect of the Aswan High Dam on the current regime in the Suez Canal. El-Sabh (1967, 1968& 1969) analyzed the results of five cruises carried out along the Suez Canal during the period from April 1966 to April 1967. Shukry (1968) studied the tide and tidal current in the southern part of the Canal. Morcos and Gerges (1974) studied the circulation and mean sea level in the Suez Canal. Sharaf El-Din (1975) analyzed the records for an 11 years period (1956-1966) from tide gauge at Port Said and Port Tawfik.

In January 1976 the Suez Canal Authority (S.C.A), commissioned the Hydraulics Research Station (H R S) to carry out an investigation of the effect of deepening and widening the Canal on tide and tidal current.

Alam El-din (1993) studied the sea level fluctuations along the Canal. Eid, Sharaf El-Din and Alam El-Din (1997) investigated the difference of the sea level between the two ends of the Suez Canal during the period (1980-1986).

Area of Study

The Suez Canal lies between latitudes 31° 15´ N and 29° 55´ N and longitudes 32° 17´ E and 32° 35´ E and connecting between the Mediterranean and the Red Sea.

Figure (1) shows the map of the Suez Canal, measured kilometrically from its Mediterranean end at Port Said to the Red Sea end at Suez (Port Tawfik).

Historical Outline

It is historically recorded that the canal which connecting the Mediterranean and Red Sea was the first canal dug across the land with a view to activate World trade. The first canal was dug under the reign of Senausret III, Pharaon of Egypt (1887-1840 BC) linking the Mediterranean Sea in the North to the Red Sea in the south Via the River Nile and its branches. This canal often abandoned to silting and was successively reopened to navigation by Sity I (1310 BC), Nkhaw (610 BC), Persian King Darius I, Ptolemy II (285 BC), Emperor Trajan (117-AD), and Amro Ibn El-Ass, following the Islamic conquest. The Suez Canal is actually the first canal directly linking the Mediterranean Sea to the Red Sea. It was opened for international navigation on 17 November 1869. The canal was closed five times. The last time was the most serious since it lasted for 8 years following the 1967 war. The canal was then reopened for navigation in 5 June 1975.

The development of the Suez Canal

The Canal has always been subject to continuous development on several stages. The depth of the Canal at the opening (1869) was 8 meter only and the cross-sectional area was 304 m^2. It increased during the period 1870 - 1960 to a depth of 14.5 m and cross-sectional area 1800 m^2. After the nationalization of the Canal on 26 July 1956, the development was continued to a depth 15.5-m and cross-sectional area 2100 m^2 in 1964. The development was stopped and the Canal was closed for 8 years following the 1967 war. The canal was then reopened on 1975 with the same dimensions of 1964. The Suez Canal Authority (SCA) started a project to develop the Canal in two stages. The first stage was finished in 1980.

Some of the achievements of the Canal Development Project (first stage 1975-1980) (SCA 1994) are as the follows:

- Widening the Canal by 70-90 m.
- Deepening it by five meters (to 19.5-20.0 m) thus expanding its wet cross-sectional area from 1800 m^2 to 3600 m^2.
- Doubling the Canal over a distance of 68 km.

Figure (2) shows the Canal cross section and its development during the period (1975-1994).

The characteristics of the present canal (SCA, 1994) are:

• Overall length	193.00	km
• From Port Said to Port Tawfik	162.25	km
• The length of doubled parts	68.00	km
• Width at water level	300-365	m
• Width between buoys	180-205	m
• Maximum permissible draught of ships	56.00	ft
• Depth	19.50	m
• Cross-sectional area	3900-4300	m^2

Model and Domain

The Blumberg and Mellor (1987) three-dimensional coastal ocean circulation model which known as the Princeton Ocean Model (POM) was used to simulate the tide and tidal current in the Suez Canal. The POM model is a three-dimensional, primitive equation, time-dependent, σ coordinate and free surface numerical model designed for coastal circulation studies. It has successfully used in open ocean and shallow water areas and the interaction between the two regimes.

The Suez Canal is very narrow compared with its length, then it is necessary to choose different scales in the horizontal plane. The ratio between the X and Y scales is about 1:20 times. The model domain is 31x 65 points, with grid interval in X-direction of 80, 100 and 120 meters (for different stages of the Canal development project) through the channel parts and 500 meter in the lake regions, and in Y-direction 2000 meter (2 km) as shown in figure (3). The depths of the channel used in the model are 15.5, 19.5 and 23.5 for different stages of the Canal development project.

Boundary Conditions and Initial Values

The normal and tangential velocities are set to zero at the sidewalls everywhere. The values of sea level at the two entrances of the Canal are defined by the tidal elevation calculated from the major 7 tidal harmonic constituents at both Port Said and Port Tawfik.

The initial values of velocities are assumed to be zero. The initial values of sea level obtained by calculating the tidal elevations at 9 stations along the Canal at the starting time and interpolate these values with respect to y distance.

Comparative test

To test the sensitivity of the model, a comparison between the tidal elevation obtained from the model results and that calculated using the harmonic constituents at 6 stations along the Suez Canal are done over 20 tidal cycle (during 10 days).

Figures (4) to (9) show the comparison between the tidal elevation calculated from harmonic components and model results at Ras El-Eish, Kantra, Ismailia, Deveresoir, Gineva and Shallufa. From these figures, it is clearly that there is a good agreement between the model results and the tidal elevation calculated from harmonic constituents

Tidal range

The range of tidal elevation along the Canal at different stages of the Suez Canal development project is shown in table (1) and figure (10). From this figure it is clearly that the behavior of the tidal range is the same at all stages. It takes its maximum value at Port Tawfik (133 cm) which decrease rapidly to reach Kabrit and then increase slightly through the Great Bitter Lake. The Tidal range decrease again to reach its minimum at Kantra and finally it increase to about (31 cm) at Port Said. Also from this table and figure it is clearly that the range of vertical tide does not change at the entrances of the Canal. But a relatively large increase of tidal range inside the canal occurs in the region of Great Bitter Lake. The range increased by about 56 per cent from 18 cm to 28 cm at Kabrit (southern entrance of Great Bitter Lake) after the first stage of the Canal development. At Deversoir the range increased from 20 cm to 32 cm by about 60 per cent. These results are agreed with the actual tidal range in previous and present stages (Shukry, 1968, Kuwakino, 1988 and Alam El-din, 1993). But it differs with results excepted by Hydraulics Research Station (1976) using one dimension numerical model, which excepted that the range increase by about 100 per cent in the Great Bitter Lake after the first stage. The total increase of tidal range in Great Bitter Lake after finishing the two stages of the development project is more than 120 per cent from that before 1975. The range of increase at Ismailia and Kantra is about 25 per cent in the first stage and about 47 in the second one.

Table (1): The range of tidal elevation at different stages of the Canal development and the ratio between them

Station Name	Range in cm			Ratio of increase %		
	15.5	19.5	23.5	Stage I	Stage II	Total
Port Said	31	31	31	0	0	0
Ras El-Eish	29	29	29	0	0	0
El-Tina	21	22	25	5	14	20
Kantra	12	15	22	25	47	83
Ismailia	15	25	36	67	44	140
Deversoir	20	32	44	60	38	120
Kabrit	18	28	40	56	43	122
Gineva	33	38	46	15	21	39
Shallufa	86	90	95	5	6	10
Port Tawfik	133	133	133	0	0	0

Current range

The extreme value of peak currents in the Suez Canal with different Canal dimensions are shown in Table (2) and figure (11). From this table and figure we can summarized the effect of deepening and widening of the Canal (increasing of the Canal cross section) on tidal current as following:

- The peak S-N current (flood current) at Port Tawfik increases from 68 cm/sec before 1975 to 76 cm/sec in the present stage and to 83 after finishing the stage II of the development project. The peak N-S current (ebb current) increases from 83 cm/sec to 94 cm/sec in the present stage and to 105 after finishing the stage II.
- The effect of increasing of the Canal cross-section on the tidal current at Shallufa and Gineva is nearly as that occurs at Port Tawfik.
- The ratio of increasing the current in southern section of the Canal is about 10 per cent with each stage.
- At Kabrit (between Great and Little Bitter Lakes) the S-N current increases by about 13 per cent in the two stages. While, the N-S current increases by about 54 per cent.
- At Deversoir (the northern entrance of Bitter Lake) the S-N current increases from 7 cm/sec to 9 cm/sec and the N-S current increases from 28 cm/sec to 35 cm/sec with the total ratio of increase in the two stages of about 25 per cent for each direction.
- At Ismailia (in Lake Timsah) the ratio of increase is 50 per cent for the N-S current and about 25 per cent for S-N current. The total increase is only 4 cm/sec in both directions.
- The maximum ratio of increasing of the tidal current is occurred in the northern section (between Lake Timsah and Port Said). The S-N current increases at El-Tina from 21 cm/sec to 37 cm/sec with a ratio more than 75 per cent, while, the N-S current increases from 35 cm/sec to 52 cm/sec with a ratio of about 50 per cent.
- At Port Said the current is very weak in all stages but it increases from 7 cm/sec to 9 cm/sec in S-N direction and from 4 cm/sec to 7 cm/sec in the other one.

Table (V-3): The extreme value of peak currents at different Canal dimensions and the ratio of the current increase after different stages of the Canal development.

Station	Peak (S-N)current in cm/sec			Ratio of increasing (S-N) current %			Peak (N-S)current in cm/sec			Ratio of increasing (N-S) current %		
Name	15.5	19.5	23.5	S. I	S. II	Total	15.5	19.5	23.5	S. I	S. II	Total
Port Said	7	8	9	14	13	29	4	5	7	25	40	75
Ras El-Eish	13	18	24	38	33	85	21	25	31	19	24	48
El-Tina	21	29	37	38	28	76	35	43	52	23	21	49
Kantra	21	28	35	33	25	67	37	45	52	22	16	41
Ismailia	8	10	12	25	20	50	15	17	19	13	12	27
Deversoir	7	8	9	14	13	29	28	31	35	11	13	25
Kabrit	15	16	17	07	06	13	13	15	17	15	33	54
Gineva	72	78	86	08	10	19	75	86	94	15	09	25
Shallufa	72	78	86	11	10	23	81	90	98	11	09	21
Port Tawfik	68	76	83	12	9	22	83	94	105	13	12	27

Summary and conclusion

The effects of deepening and widening the Canal on the tide and tidal current was studied using the Princeton Ocean Model (POM). There is a relatively large increase of tidal range inside the canal. The total increase of tidal range in Great Bitter Lake after finishing the two stages of the development project is more than 120 % from that before 1975. The peak of S-N current (flood current) in the southern section increases from 68 cm/sec before 1975 to 76 cm/sec in the present stage and to 83 after finishing the stage II of the development project. The peak of N-S current (ebb current) increases from 83 cm/sec to 94 cm/sec in the present stage and to 105 after finishing the stage II. The maximum ratio of increasing of the tidal current is occurred in the northern section (between Lake Timsah and Port Said). The S-N current increases at El-Tina from 21 cm/sec to 37 cm/sec with a ratio more than 75 %. While, the N-S current increases from 35 cm/sec to 52 cm/sec with a ratio of about 50 %.

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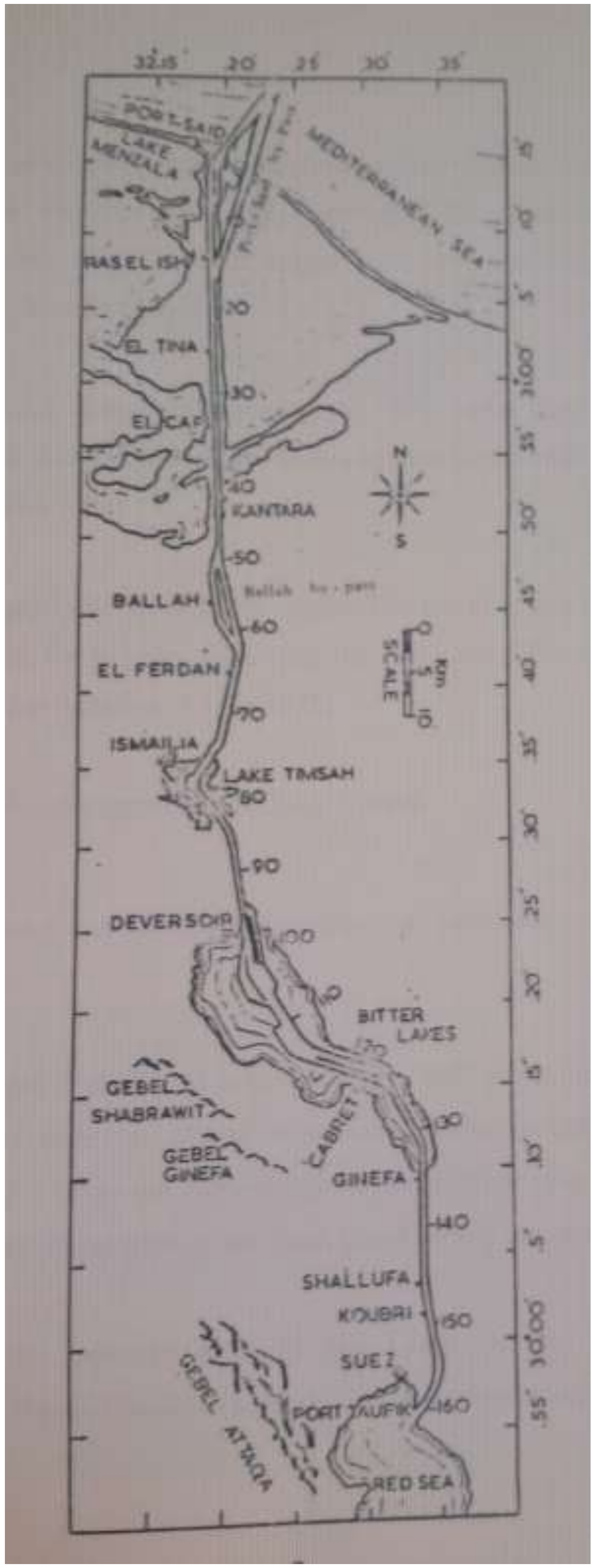


Figure (1) Map of the Suez Canal, measured kilometrically from its Mediterranean end at Port Said to the Red Sea end at Suez (Port Tawfik).

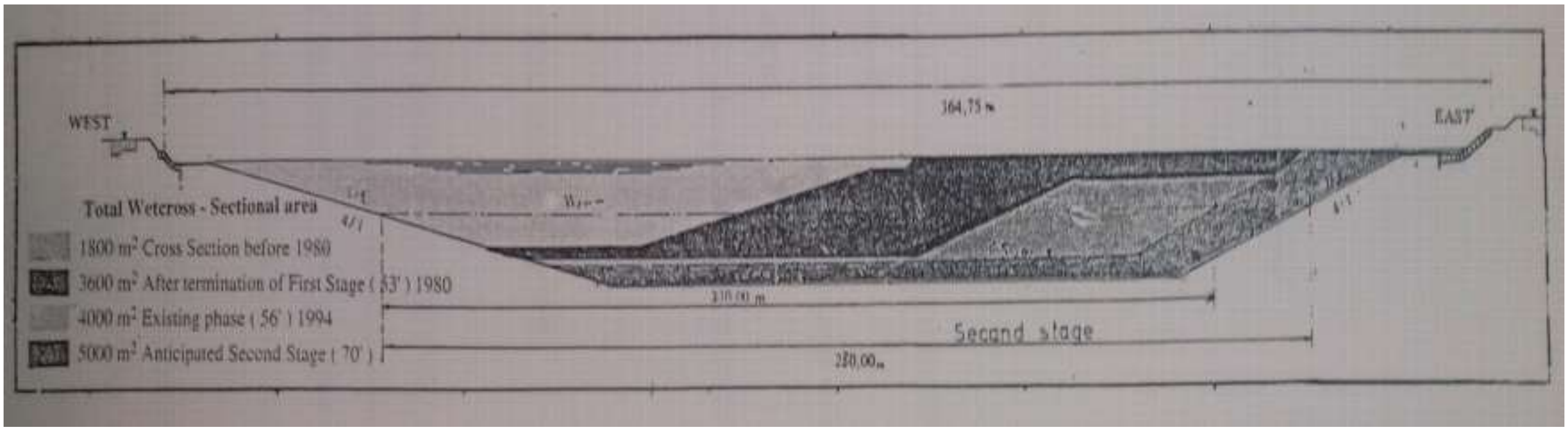


Figure (2) Suez Canal cross section and its development during the period (1975-1994).

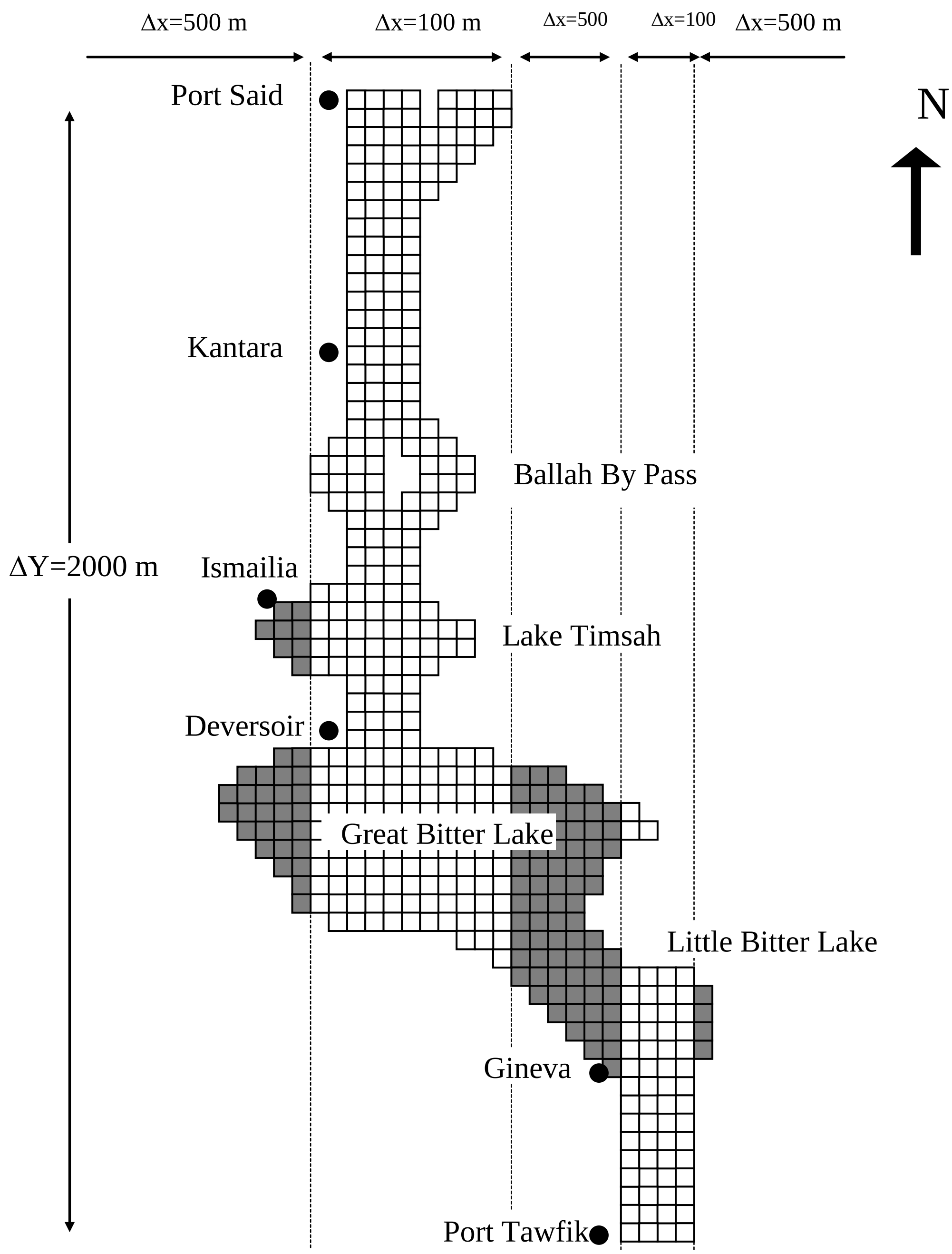


Figure (3): Finite difference grid used for the Suez Canal numerical simulation

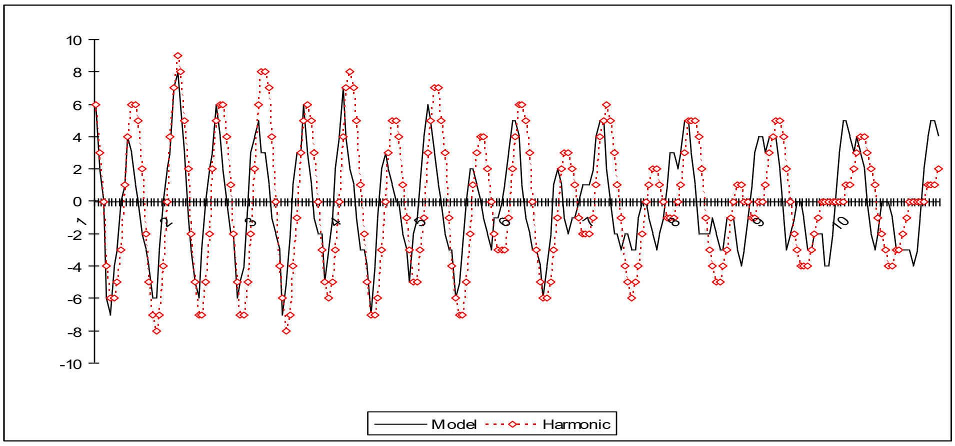


Figure (4): Comparison between tidal elevation at **Ras El-Eish** calculated from harmonic constituents and results of POM model

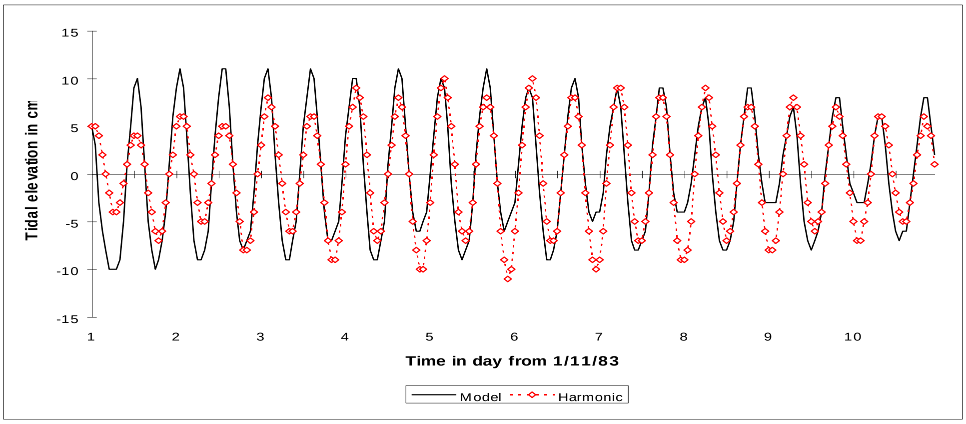


Figure (5): Comparison between tidal elevation at **Kantra** calculated from harmonic constituents and results of POM model

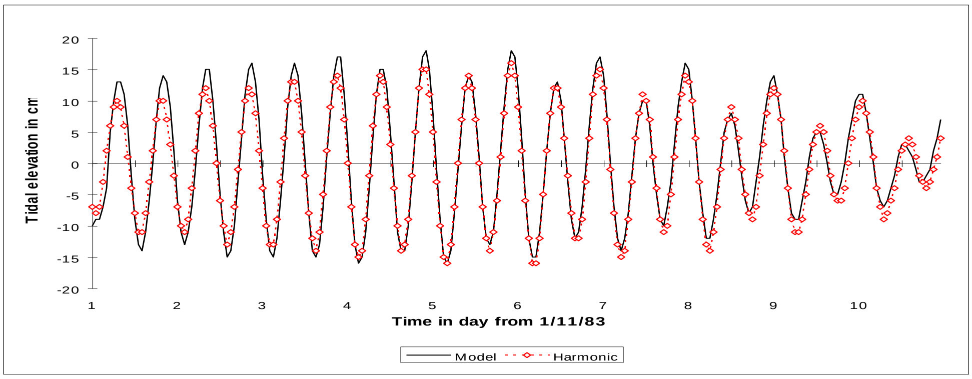


Figure (6): Comparison between tidal elevation at **Ismailia** calculated from harmonic constituents and results of POM model

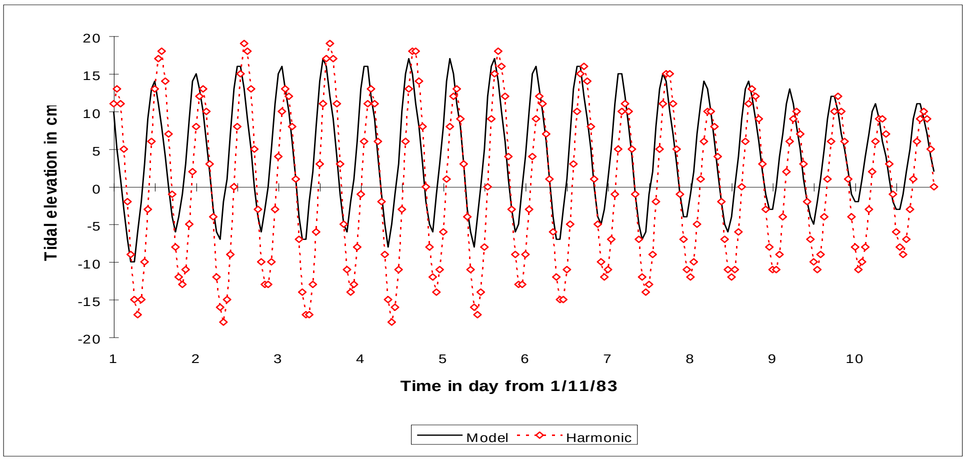


Figure (7): Comparison between tidal elevation at **Deversoir** calculated from harmonic constituents and results of POM model

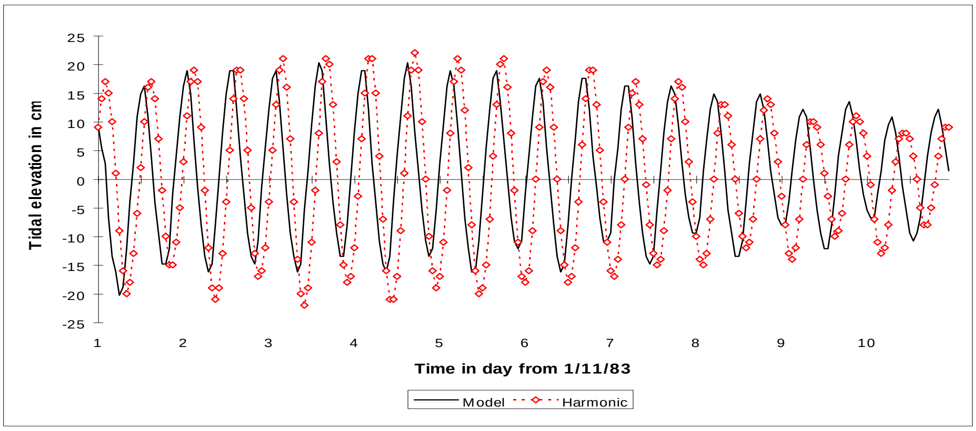


Figure (8): Comparison between tidal elevation at **Gineva** calculated from harmonic constituents and results of POM model

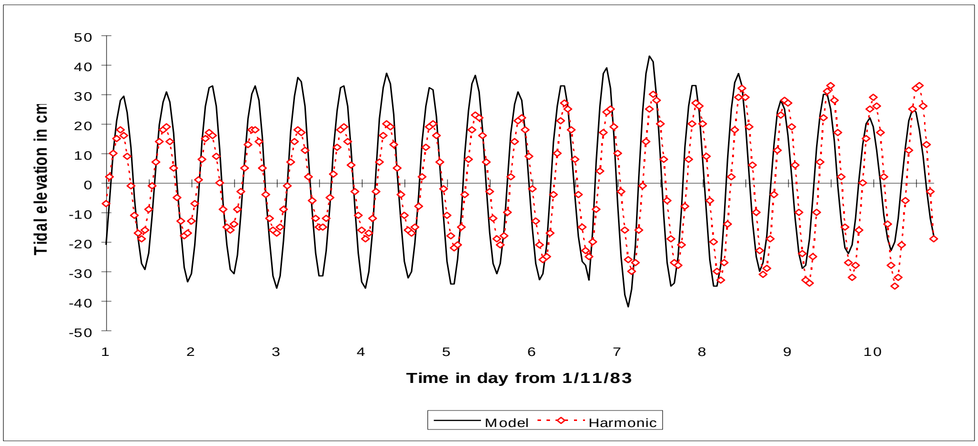


Figure (9): Comparison between tidal elevation at **Shallufa** calculated from harmonic constituents and results of POM model

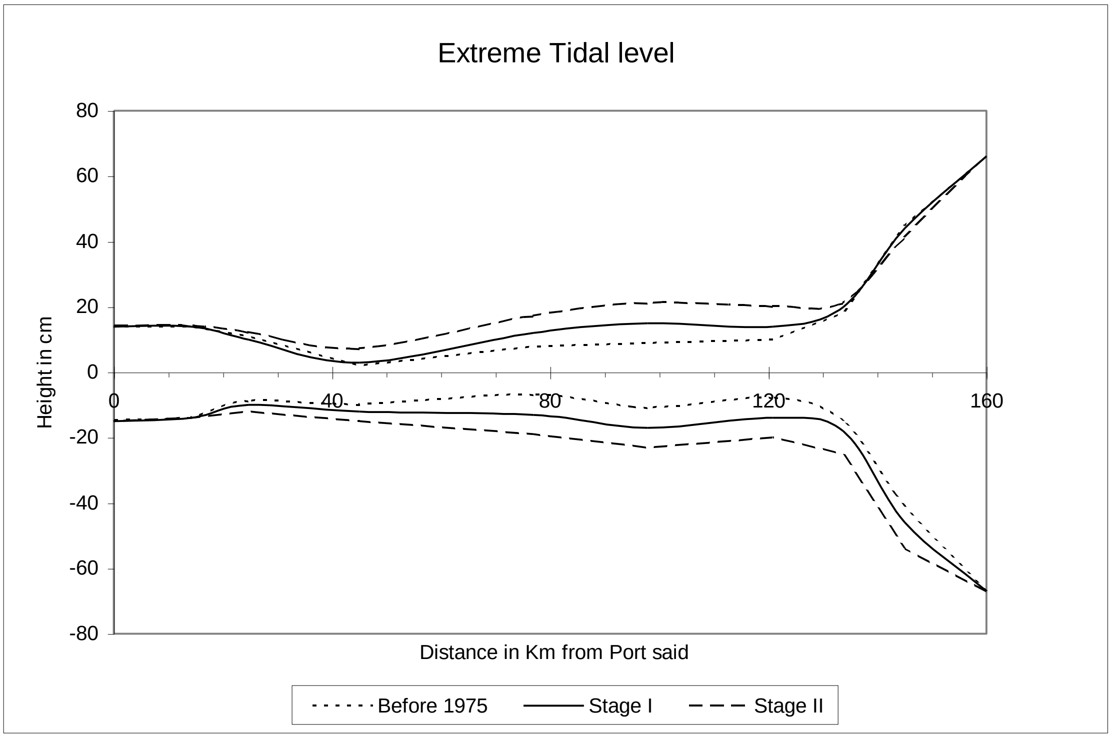


Figure (10): The extreme tidal elevation in the Suez Canal with different stages of the Canal development.

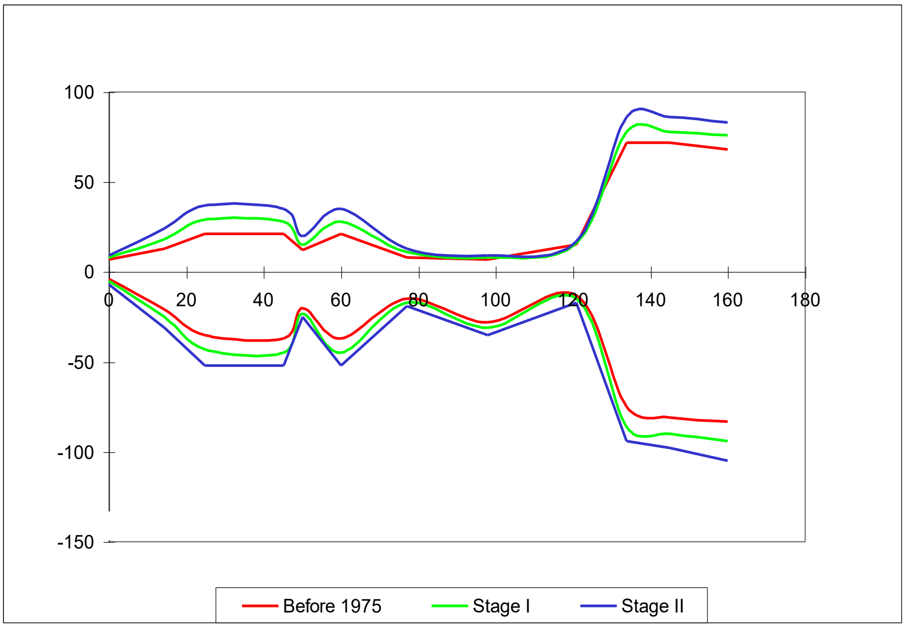


Figure (11): The extreme value of peak currents in the Suez Canal with different stages of the Canal development.

Key wards

Suez Canal
Numerical Modelling
Numerical simulation
Three dimension model
Tide
Tidal level
Tidal stream
Tidal current
Princeton Ocean model (POM)
Navigable channel

CHAPTER VIII

NATURAL CONDITIONS

Art.84 - Tides and Currents in SC :

The SC is divided into three main sectors according to the nature of tide in each.

The characteristics of each can be summarized as follows :

A -The Northern Sector:

This part is located between Port Said and the G.B.L. :

(1) The height of tide at Port Said co-oscillates with the tide of the Mediterranean Sea with 0.65-meter extreme tidal range (Difference between successive crests and trough levels of tidal wave) at Spring tides. This extreme tidal range decreases gradually going South, to be about 0.55 meter at the entrance of Lake Timsah. The average tidal rang is about 0.3 meter at both Port Said and Timsah Lake.

(2) In this sector, the peak tidal current may reach 1.6 knot.

(3) Currents may increased by strong prevailing winds and other factors.

(4) Peak currents occur about 30 and 90 minutes after predicted HW and LW at Port Said.

(5) The duration and velocity of currents in this sector are greatly affected by the relative mean sea levels between the Mediterranean Sea, the Bitter Lakes and the Red Sea as follows:

a) In Summer: between July and October, the mean sea level at Port Said is slightly higher than that of the Bitter Lakes. This difference (which reaches its maximum of about 0.20 meter in September), beside the great evaporation at the Bitter Lakes, causes the predominance of the Southward current in duration and velocity.

b) In Winter: between December and May, the Mean sea level at the Bitter Lakes is slightly higher than that of Port Said. This difference, which reaches its Maximum of about 0.30 meter in January, causes the predominance of the Northward current in duration and velocity.

B -The Lakes : (Timsah and Bitter Lakes) :

(1)The Lakes along the Canal have an important role in dampening the effects of sudden meteorological changes.

(2)The Bitter Lakes with a surface of about 250 Km^2 reduce the vertical movement of the tide to a minimum between Km.100 and Km. 130.

(3)The main high spring tide range (MHWS) in G.B.L. may reach 0.25 meter.

(4)The phase of the vertical tide in G.B.L. is about 3 hours later than that of Port Tewfik.

(5)The vertical tide in Lake Timsah is almost in phase with the tide in G.B.L.

C -The Southern Region :

This part is located between Port of Suez and the Bitter Lakes :

(1) The height of tide in Suez co-oscillates with the tides of the Red Sea with extreme tidal range of about 1.90 meters at Spring tides. This range decreases gradually going North till the Little Bitter Lakes entrance at Genefa where this extreme value becomes about 060 meter. The average tidal rang is about 1.0 and 0.3 meters at port Taufiq and Gineifa respectively.

(2) The tidal volume of the Bitter Lakes is very large compared to the tidal volume of the Southern section. Consequently, the currents are relatively strong and almost uniform between Port Tewfik and Genefa

(3) In this region, the Northward current is called Flood and the Southward current is called Ebb.

(4) Peak currents occur about 50 minutes after predicted HW and LW at Port Tewfik.

(5) At the entrance of the Canal, Km. 159, the Flood tide starts at an average of 3 hours after the Low Water at Suez. The Ebb tide 3 hours after H .W. in Suez.

(6) Generally in summer, the duration of the Ebb exceeds the average of 6 hours. In winter, the Flood is the predominant. The Ebb is prolonged by " Strong Northerly Winds". The Flood is prolonged by "Strong Southerly Winds".

(7) In this region, the average peak current is about 2.2 knots. In Spring tides, current may reach 4.0 knots.

D -Current Buoys:

In the Canal, there are current buoys indicating the direction of the current :

Head Current : Red & White horizontal bands or 1 reflector at night.

Stern Current : Black & White vertical stripes or 2 reflectors at night.

These buoys are laid in the following positions :

Port Fouad .... Km. 2.750 East

El Raswa .... Km. 3.710 "

Ras El Ech (E) .... Km. 12.800 "

Ras El Ech (W) .... Km. 14.304 "

Tineh .... Km. 24.775 "

Cap ....Km. 35.420 "

Kantara .... Km. 45.130 "

Ballah (E & W) .... Km. 54.770 "

Ferdan .... Km. 64.894 "

Ismailia .... Km. 76.133 "

Toussoum .... Km. 86.780 "

Deversoir (E & W) .... Km. 97.845 "

Kabrit (E & W) .... Km.120.827 "

Gineifa .... Km.133.950 "

Shallufa .... Km.146.125 "

Port Tewfik .... Km.160.300 "

Art. 85 - Weather Forecast :

Six Meteorological stations are installed on the Canal area. Information about weather will be passed to vessels through pilots, Ismailia Radio station.

Chapter 1 Present facilities, equipment and natural condition

1.1 The Canal

The Suez Canal is a waterway of 162.25km in length, which bridges the Mediterranean Sea and the Red Sea. North and South Approaches are set at both ends of the Canal. Timsah Lake, the Great Bitter Lake and the Little Bitter Lake are situated along the Canal. Layout of the Canal is shown in Figure 1.1.1.

Table 1.1.1 Outline of the Suez Canal

Overall length	190.250km
From Port Said to Port Tewfic	162.250km
From Port Said to Ismailia	78.500km
From Ismailia to Port Tewfic	83.750km
From the fairway buoy to Port Said lighthouse	19.500km
From the waiting area to the southern entrance	15.000km
The length of doubled parts	78.000km
Width at water level (North/South)	345/280m
Width between buoys (North/South)	210/180m
Maximum permissible draught for ships	58ft
Cross section area (North/South)	4,500/3,900m^2
Being increased	4,700/4,000m^2
Permissible speed for tankers group	11-15km/hr
for other vessels	13-16km/hr

Source) SCA

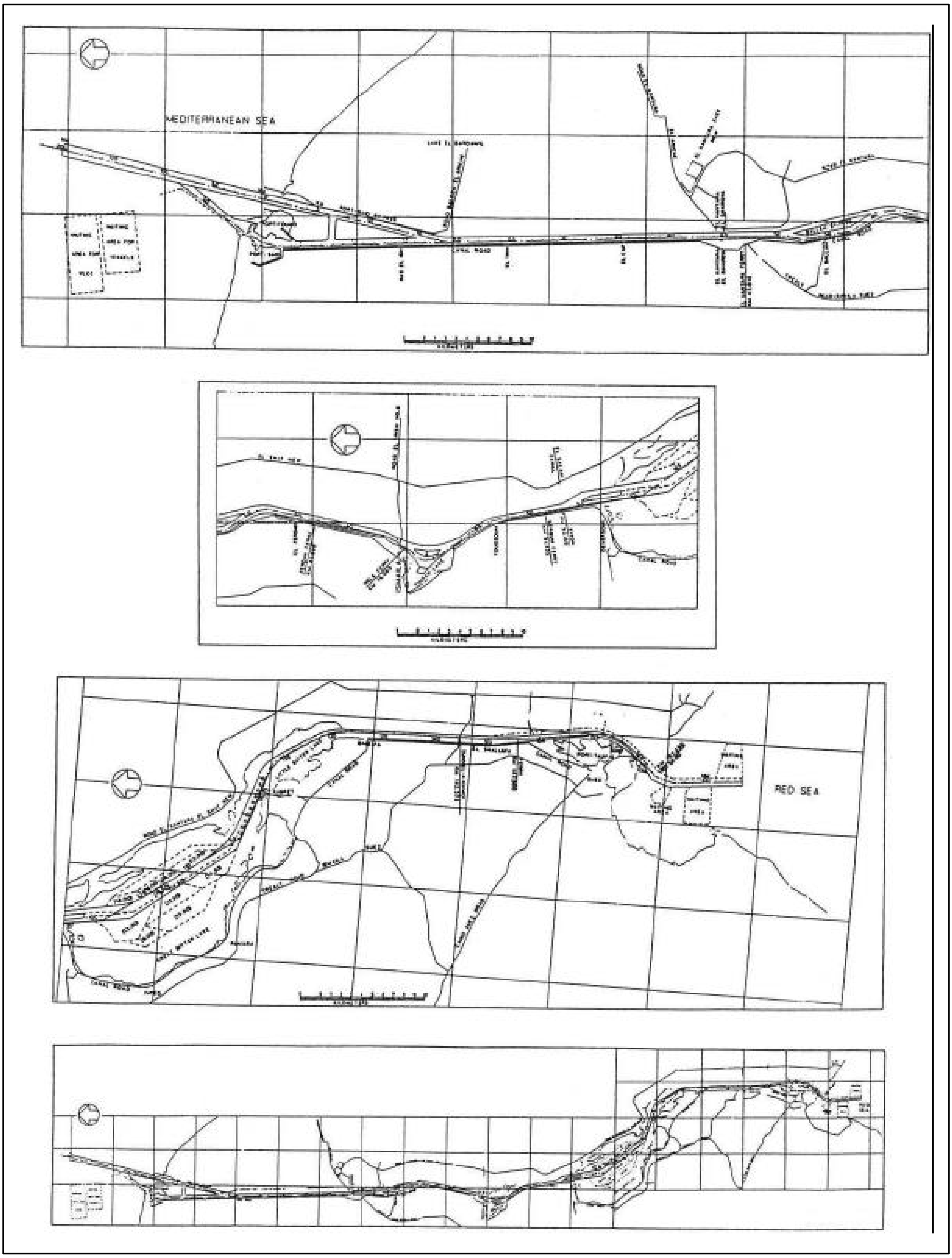
Table 1.1.2 Historical Progress of the Suez Canal

Item	1869	1956	1962	1980	1994	1996	2000
Overall Length (km)	164	175	175	190.25	190.25	190.25	190.25
Doubled Parts (km)	-	29	29	78	78	78	78
Width at 11m depth (m)	-	60	90	160	210/180	210/180	210/200
Water Depth (m)	10	14	15.5	19.5	20.5	21	21
Max. Draft of Ship (feet)	22	35	38	53	56	58	58
Cross Section Area (m^2)	304	1,100	1,800	3,600	4,300 /3,800	4,500 /3,900	4,500 /4,100
Max. Tonnage (DWT)	5,000	30,000	80,000	150,000	180,000	185,000	195,000

Source) "Yearly Report 1999", SCA

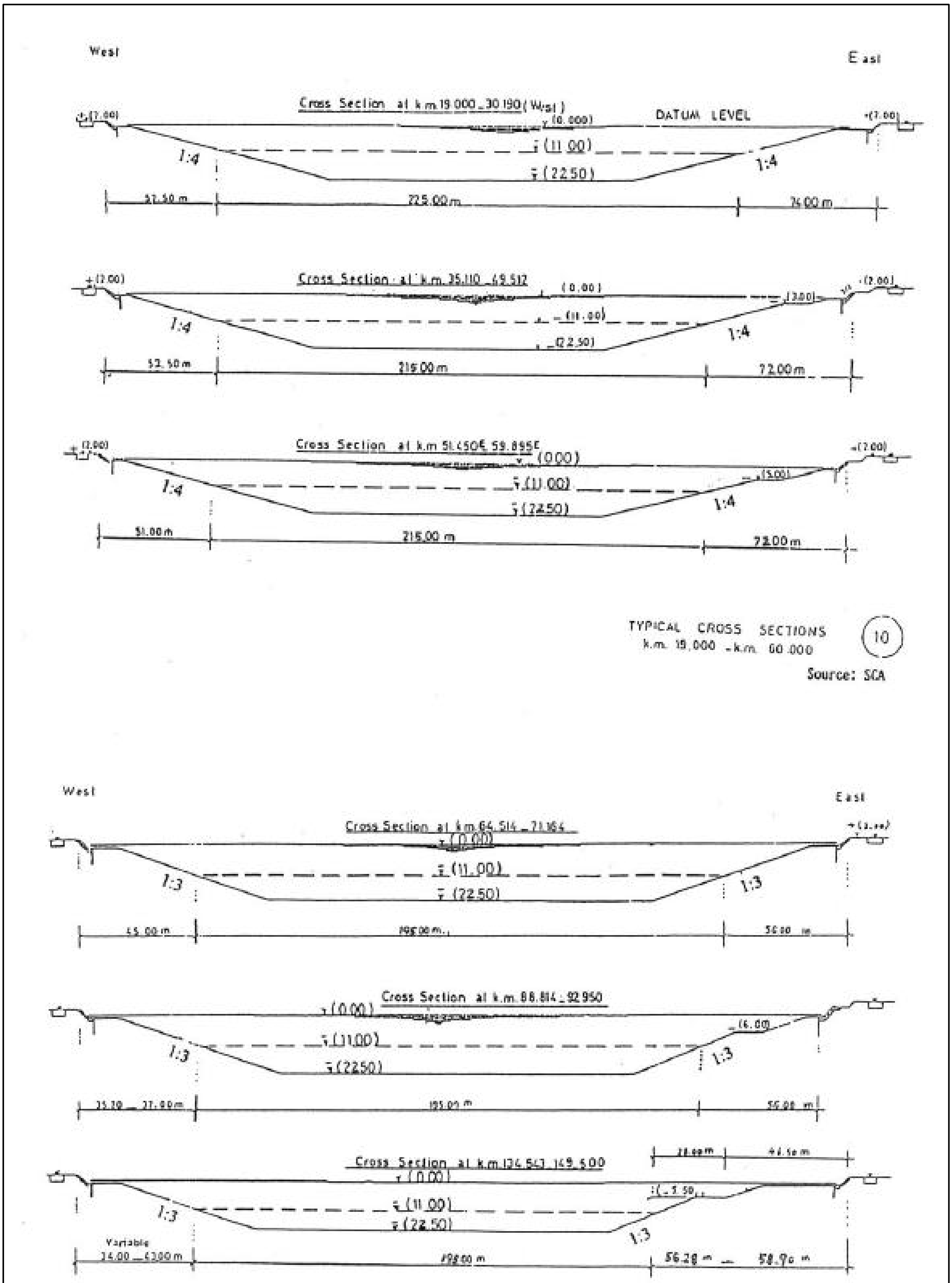
1.1.1 Cross section and Depth of the Canal

Cross section and depth of different parts of the Canal is shown in Figure 1.1.2 (1) and (2), Table 1.1.3 (1) and (2). The depth of the main channel, including the eastern branches of the by-pass sections, will be 22.5m (permissible ship draught is 62ft) in 2001, while that of the western branches is 15.5m (partially 14.5m). The Canal cross sections are trapezoidal in shape, having side slopes of 4/1 in the northern part up to Km.61.00 and 3/1 in the southern part.



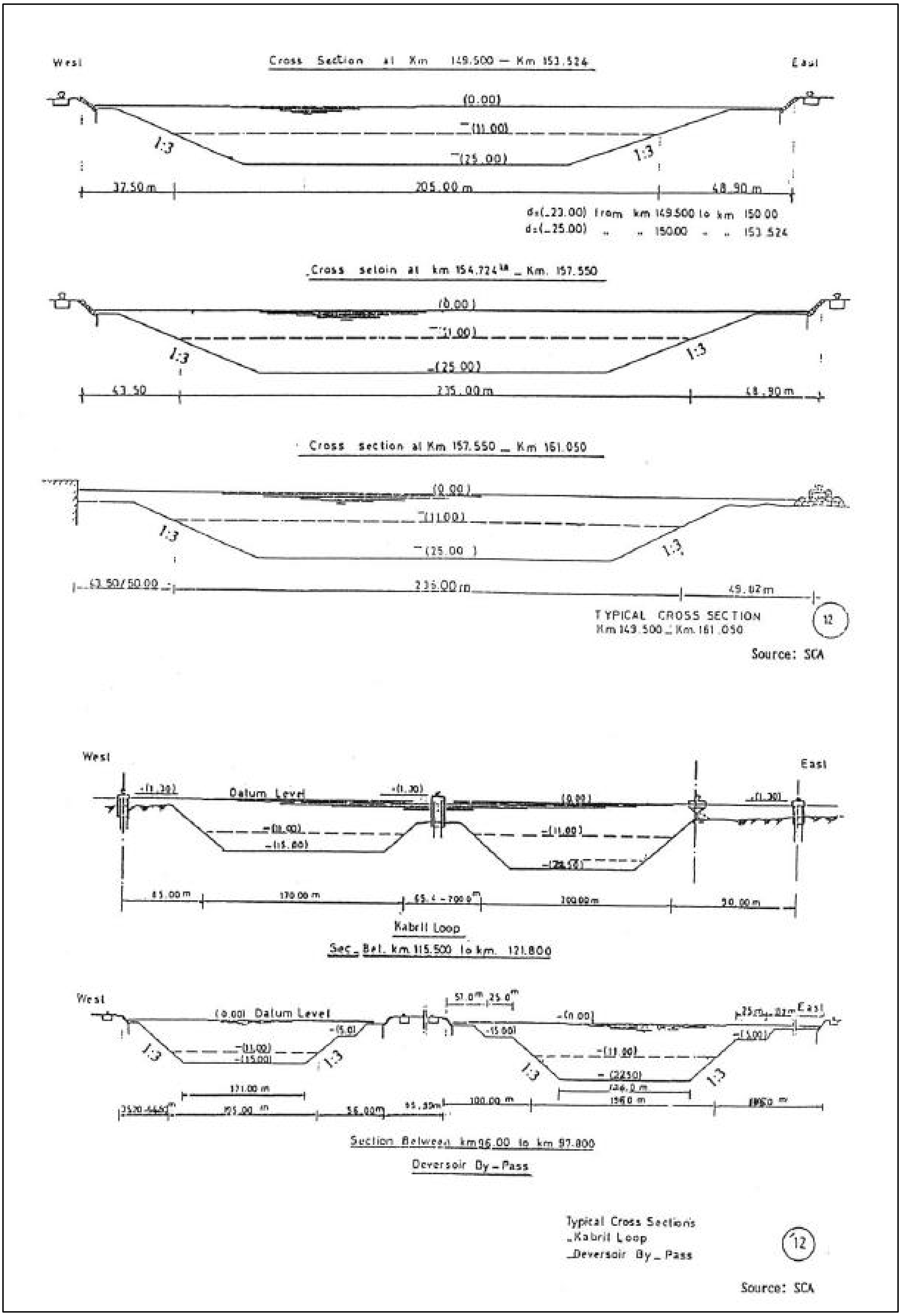
Source) SCA

Figure 1.1.1 Layout of the Suez Canal



Source) SCA

Figure 1.1.2 (1) Cross Sections



Source) SCA

Figure 1.1.2 (2) Cross Sections

Table 1.1.3 (1) Depth of the Canal
(Main Canal and Bitter Lake East Channel)

Kilometric position		Designation of different parts of the Canal	Theoretical depth (m)	Remarks
From Km.	To Km.			
2.400 E	3.400 E*	Junction	22.5	East Port Said Branch
3.400 E	15.190 E	Straight line	22.5	East Port Said Branch
15.190 E	15.540 E	Junction	22.5	East Port Said Branch
17.000	19.000	Southern entrance to Port Said by-Passes	22.5	
19.000	30.430	Straight line	22.5	
30.430	32.350	Northern approach to encoche (siding)	22.5	
32.350	32.950	East encoche of Km. 32(siding of Km32)	22.5	
32.950	35.110	Southern approach to encoche (siding)	22.5	
35.110	49.512	Straight line	22.5	
49.512	51.477	Northern approach to Ballah Loop	22.5	
51.449 E	51.785 E	Curve of Km. 51 East	22.5	
51.785 E	59.943 E	Straight line	22.5	
60.308	60.333	Curve of Km. 61	22.5	
60.333	63.419	Curve of Km. 61	22.5	
63.419	64.514	Approach to curve	22.5	
64.514	71.164	Straight line	22.5	
71.164	71.964	Approach to curve	22.5	
71.964	75.311	" S " Curves	22.5	
75.311	76.033	Straight line	22.5	
76.033	76.519	Straight line	22.5	East timsah By - Pass
76.519	78.900 E	Curve of Timsah	22.5	East timsah By - Pass
78.900 E	80.949 E	Encoche of Km. 80 (East)	22.5	East timsah By - Pass
80.949 E	81.692 E	Curve of Timsah	22.5	
81.000	82.000	Junction	22.5	
82.000	85.027	Straight line	22.5	
85.027	87.414	Curve of Km. 85	22.5	
87.414	88.814	Approach to Curve	22.5	
88.814	92.950	Straight line	22.5	
92.950	93.050	Junction to Syphons zone	22.5	
93.050	93.446	Syphons Zone	22.5	
93.446	95.000	Junction to Deversoir by-pass	22.5	
95.000	95.250	Junction to East Branch	22.5	Deversoir East branch
95.250	96.000	Junction to East Branch	22.5	Deversoir East branch
96.000 E	100.666 E	Straight line	22.5	Deversoir East branch
100.666 E	102.600 E	Straight line	22.5	Deversoir East branch
102.600	105.030	Curve	22.5	Bitter Lakes East Channel
105.030	112.860 E	Main Channel (straight line)	22.5	Bitter Lakes East Channel
112.860 E	114.200	Junction	22.5	Bitter Lakes East Channel
114.200	114.957	Junction With Kabrit-Loop	22.5	Bitter Lakes East Channel
114.957	115.320 E	Junction	22.5	Kabrit Loop East Channel
115.320 E	121.937 E	Straight line	22.5	Kabrit Loop East Channel
121.937 E	122.100 E	Beginning of Km. 122 Curve	22.5	Kabrit Loop East Channel
122.100	125.507	Curve of Km. 122	22.5	
125.507	129.499	Straight Line	22.5	
129.499	131.975	Curve of Km. 130	22.5	
131.975	133.175	Approach to curve	22.5	
133.175	144.714	Straight line	22.5	
144.714	147.146	Encoche of Km.146(siding of Km.146)	22.5	
147.146	149.500	Straight line	22.5	
149.500	153.524	Straight line	25.0	
153.524	154.724	Approach to curve	25.0	
154.724	155.724	Curve of Km. 154	25.0	
155.724	156.274	Straight line	25.0	
156.274	159.998	Curve of Km. 157	25.0	
159.998	161.050	Straight line	25.0	
161.050	162.250	Southern approach of the Canal	25.0	

Notes) 1. Origin Point of KM is axis of Port Said Lighthouse.
2. (E*) means east kilometer base line.

Source) SCA

Table 1.1.3 (2) Depth of the Canal
(Canal West Branches and Bitter Lake West Channel)

Kilometric position		Designation of different parts of the Canal	Theoretical depth (m)	Remarks
From Km.	To Km.			
0.000	1.450	Ismailia Basin	15.5	Port
1.450	3.650	Basins For Coal & Fuel oil vessels	15.5	port
3.729	4.890	Junction (1)	15.5	Port Said West Branch
4.890	6.000	Junction (2)	15.5	Port Said West Branch
6.000	16.500	Straight line	15.5	Port Said West Branch
16.500	16.663	Straight line	15.50 - 19.00	Port Said West Branch
16.663	17.000	Junction (siding of Km. 17.00)	19.0	
51.477	51.800	Straight line (siding of Km. 51.00)	18.5	West Branch Ballah Loop
51.800	52.054	Straight line	15.5	West Branch Ballah Loop
52.054	53.298	Curve Km. 53	15.5	West Branch Ballah Loop
53.298	54.098	Approach to curve	15.5	West Branch Ballah Loop
54.098	56.397	Straight line	15.5	West Branch Ballah Loop
56.397	56.871	Approach to curve Km. 57	15.5	West Branch Ballah Loop
56.871	58.797	Curve of Km. 57	15.5	West Branch Ballah Loop
58.797	59.269	Approach to curve	15.5	West Branch Ballah Loop
59.269	59.900	Straight line	15.5	West Branch Ballah Loop
59.900	60.308	Straight line(siding of Km.60.000)	18.5	West Branch Ballah Loop
76.033	77.371	Curve (Centre on West Bank)	15.5	West Branch Timsah Lake
77.371	77.672	Junction	15.5	West Branch Timsah Lake
77.672	77.912	Junction	15.5	West Branch Timsah Lake
77.912	79.800	Curve of Like Timsah (centre on East Bank)	15.5	West Branch Timsah Lake
79.800	81.000	Straight line(siding of Km.80.000)	19.0	West Branch Timsah Lake
95.000	95.500	Junction to West Branch (siding of Km.95.000)	18.0	Deversoir West Branch
95.500	100.200	Straight line	15.0	Deversoir West Branch
100.200	101.050	Junction	14.5	Deversoir West Branch
101.050	103.759	Straight line	14.5	Bitter Lake West Channel
103.759	(103.957W.)	Junction	14.5	Bitter Lake West Channel
104.160	114.200	West Channel	14.5	Bitter Lake West Channel
114.200	115.603	Junction	15.0	Kabrit Loop West Branch
115.603	122.100	Straight line	15.0	Kabrit Loop West Branch

Notes) 1. Origin Point of KM is axis of Port Said Lighthouse.
2. (E*) means east kilometer base line.

Source) SCA

1.1.2 By-passes and Loop

The Canal is provided with five by-passes of which plans are shown in Figure 1.1.3 (1), (2) and (3).

(1) Port Said By-Pass

This by-pass starts at Km.17.00 and extends north to join the existing Port Said roadstead at Hm.94.90 and continues till Hm.195. It is fitted with bollards on the Western side, spaced every 100 meters.

(2) Ballah Loop

Between Km.51 and Km.61, the Canal is doubled in the East by a branch. The zone comprising the 2 branches of the Canal limited by the North and South ends where the 2 branches meet is called "Ballah Loop". The length of the East Branch is 8.490 Km.

	West Branch	EastBranch
- Kilometric marking of North end	51.477	51.449 E
- Kilometric marking of South end	60.333	59.943 E

In the West branch, 15 mooring berths are situated on the Eastern bank.

(3) Timsah By-Pass

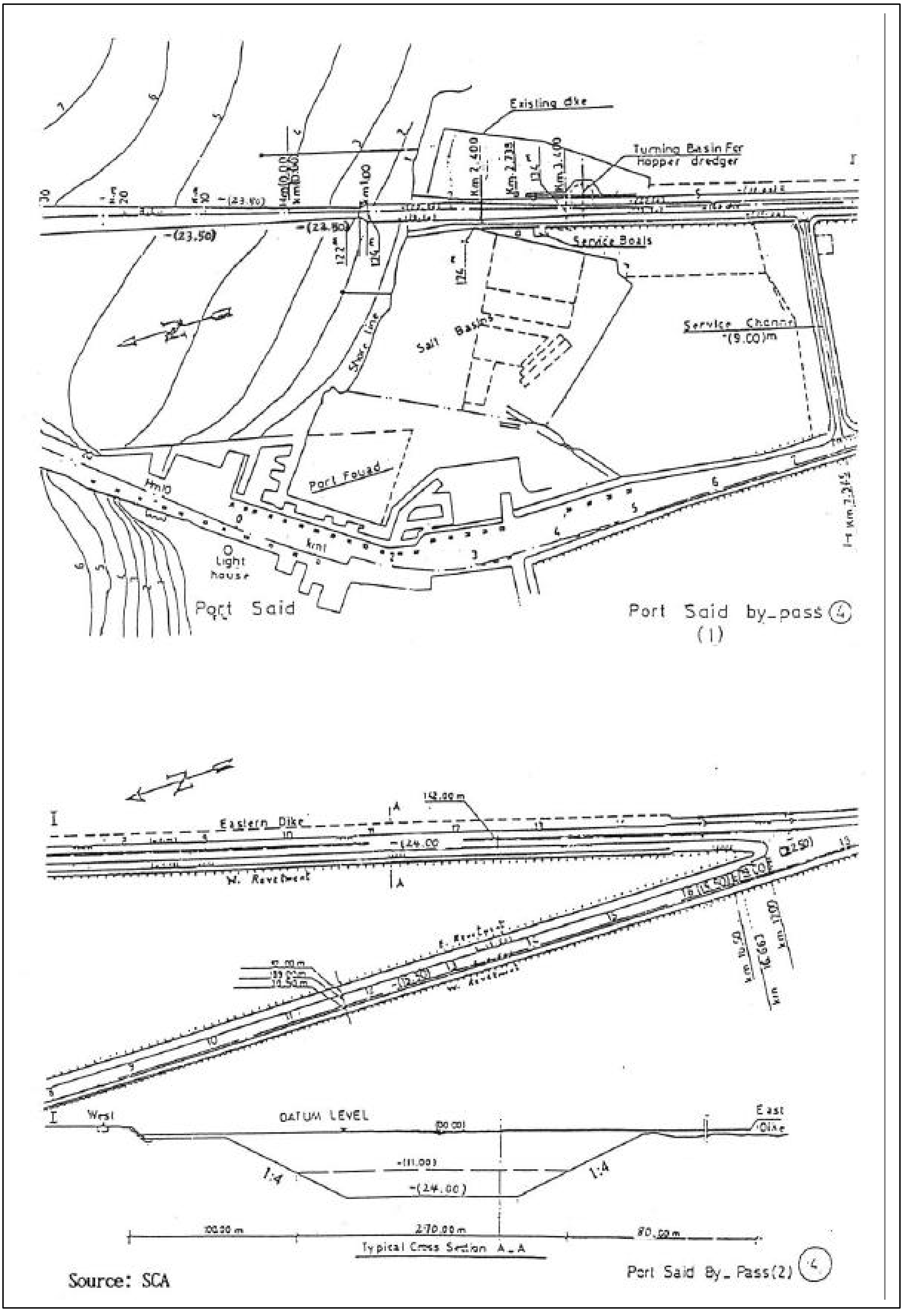
This by-pass situates between Km. 76.580 and Km 81.700 E. The length is 5.110 Km, counted at right angle from Km. 76.578 to Km. 81.700. The by-pass is used by Northbound and Southbound vessels.

(4) Deversoir By-Pass

This branch begins at Km.95.000 and joins the main East channel in the Great Bitter Lake at Km.104.160. The length is 9.160 km.

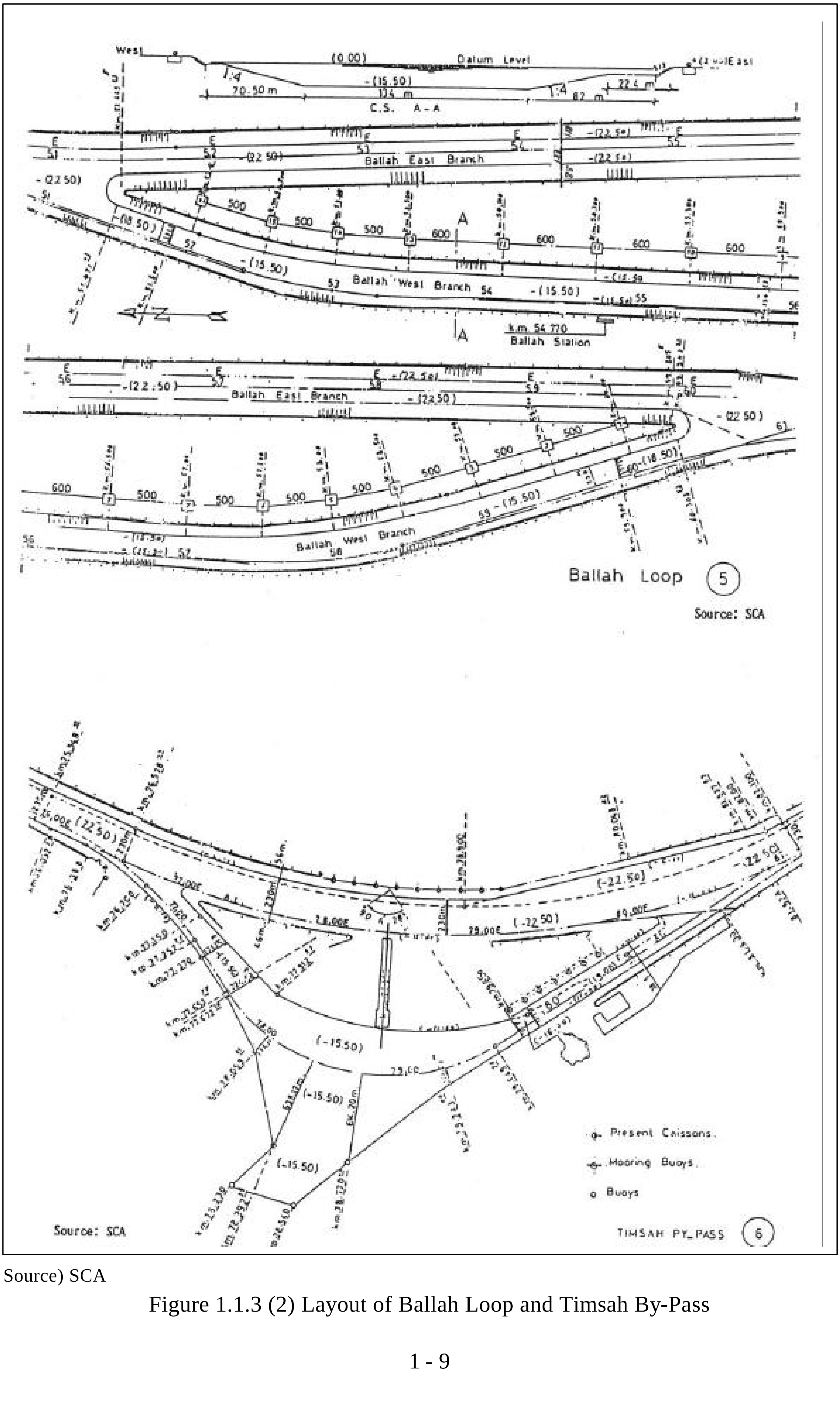
(5) Kabrit By-Pass

The By-Pass begins at Km.114.957 and ends at Km.122.100. The by-pass is separated from west branch by a submerged island at a depth between 2 and 6 meters. The width of the island varies between 200 meters in the North and 65.4 meters in the South.



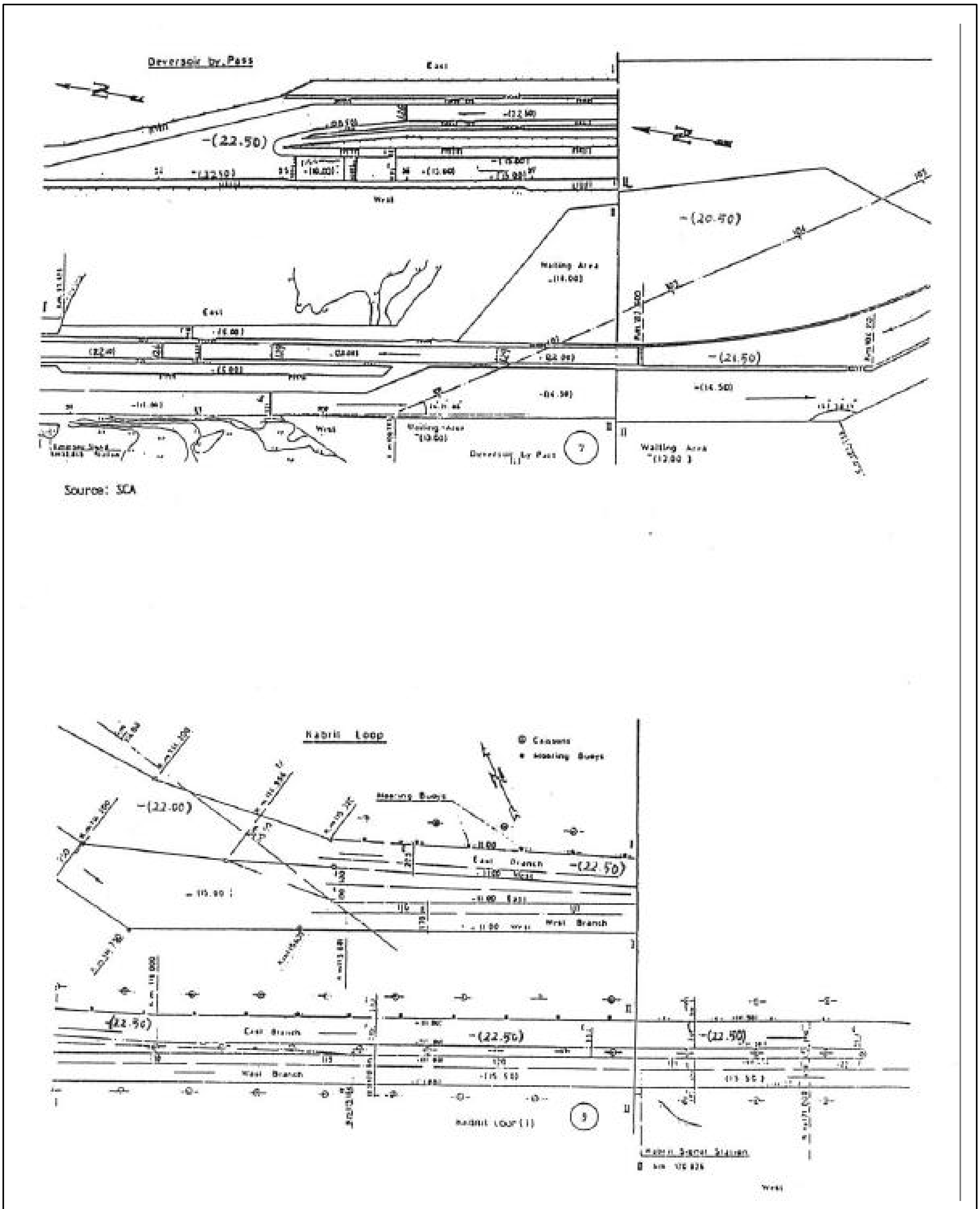
Source) SCA

Figure 1.1.3 (1) Layout of Port Said By-Pass



Source) SCA

Figure 1.1.3 (2) Layout of Ballah Loop and Timsah By-Pass



Source) SCA

Figure 1.1.3 (3) Layout of Deversoir By-Pass and Kabrit By-Pass

1.1.3 Bends in the Canal

The bends in the navigable channel have the following characteristics:

- Radius of navigation line = 5000 meters.
- Width of channel at 11.00 meters depth = 225 - 245 meters.
- Width of channel at 21.00 meters depth. North of Km. 61.000 (side slopes 4/1) = 165 meters.
- Width of channel at 21.00 meters depth, South of Km. 61.000 (side slopes 3/1) = 165 meters.
- At the two ends of bends, there is usually a funnel made to allow increasing the width of the channel from the width of the straight part to the width of the curves.
- Location of beginning and end of each bend are included in the following table :

Table 1.1.4 Location of Bends in the Canal

Canal Bends	Kilometric indication of beginning point	Kilometric indication of end point
Km.51	Km.49.510	Km.51.480W Km.51.790E
Km.53	Km.52.050	Km.53.520
Km.57	Km.56.870	Km.58.800
Km.61	Km.60.310W Km.59.940E	Km.63.300
S' curves	Km.71.960	Km.75.300
Timsah curve	Km.76.520	Km.81.700 E
Km.85	Km.85.030	Km.87.400
Km.103	Km.102.600	Km.105.30
Km.122	Km.121.940E Km.122.500W	Km.125.510
Km.130	Km.129.500	Km.131.980
Km.146	Km.145.500	Km.146.330
Km.154	Km.154.700	Km.155.720
Km.157	Km.156.280	Km.160.000

Note) At the approaches of the by-passes, bends are made with radius more than 5,000 meters.
Source) Rules of Navigation, 1995, SCA

1.1.4 Lakes

(1) Lake Timsah

Lake Timsah extends from Km. 76.500 to Km. 80.520. In the presence of the Timsah by-pass, Lake Timsah is used mainly as an anchorage area.

(2) Great Bitter Lake

There are 2 dredged channels in G.B.L. The East is the main channel about 406 meters wide at 11.00 meters depth and dredged to 22.50 meters for Northbound vessels. The West channel 250 meters wide at 11.00 meters depth dredged to 14.50 meters depth for Southbound vessels. These channels divide the Great Bitter Lake into two anchorage areas:

- One to the East for the Northbound convoy
- One to the West for the Southbound convoy

1.1.5 Waiting areas

(1) Port Said

Incoming vessels have two anchorage areas:
Northern Area is comprised of two zones; Zone One is for vessels with draught over 42 ft (12.8 m), of which center lies on NNW 6.7 miles (12.4 km) off the Fairway Buoy. Zone Two is comprised of designated anchorages V1 to V8 for VLCCs, 4th generation container ships, 3rd generation container ships and vessels over 39 ft (11.9 m) draught up to 42 ft (12.8 m) lies on NW 3.7 miles (6.8 km) off the Fairway Buoy.

Southern area for all other vessels lies southward of Zone two, of which center on MNW 2.1 miles (3.9 km) off the Fairway Buoy, and is comprised of designated anchorages C1 to C5.

Two areas for trans-shipment anchorages have been designated, A, for vessels over 60 ft (18.3 m) draught, on NE 7¾ miles (14.3 km) off the Fairway Buoy, and B, for vessels up to 60 ft (18.3 m) draught, on NE 5 ¾ miles (10.5 km) off the Fairway Buoy. Those areas are shown on the chart (234, UK).

(2) Port of Suez

Anchorage for Deep-draught Vessels (all N-bound deep-draught vessels, in excess of 11.6 m draught, including VLCCs, bulk carriers and third generation container ships, awaiting a pilot) is in the area SSE of Conry Rock (29º 48’ N, 32º 34’ E), which is marked to the E by light-buoy L, moored 5 miles SE of the rock. Designated anchorage V1 to V9 inclusive are shown on the chart (2098,UK).

Designated anchorages 1 to 29 of the waiting area for all other N-bound vessels awaiting a pilot is N of Conry Rock which is shown on the chart (2098, UK) and bounded on the N and E by light buoys A, B, C, D, N and M.

Two areas for trans-shipment anchorages have been designated, A, 6½ miles SE and B, 12 miles SSE of Conry Rock Light-float, as shown on the chart (2098, UK).

(3) Waiting areas in the Canal

Lake Timsah:
Three anchorages (1 to 3) which depths are 15.5 m lie at W-ward of W-branch channel of the lake, in addition, the other three anchorages (4 to 6) for smaller vessels lie further

W-ward of the above. Those anchorages are shown on the chart (233,UK).

Great Bitter Lake:
The waiting areas, E1 to E4 and W1 to W5 mainly for S-bound vessels, lie to the outer sides of E and W branches of the lake, which are bounded by lighted buoys respectively. The details can be seen on the chart (233, UK).

El Kabrit East Branch:
Three berths are available for emergency use.

1.1.6 Breakwaters and revetments

The west approach channel at Port Said is protected by two breakwaters:

- The western breakwater protecting the west approach channel is situated to the west of the channel and extends from land boundary till Hm. 73 with a submerged part from Hm.50. This part is marked by cigar shaped unlit buoys.
- The eastern breakwater extends from land boundary till Hm. 21.2 and has an occulting red light at its northern end.

The east approach channel at Port Said is protected by two breakwaters:

- The eastern extends for 2Km from the land boundary, and the Western extends for 0.53 Km from the land boundary. Each breakwater has a small fixed white light on its end.

Both sides of the Canal are protected with different types of revetment depending on the surrounding conditions (soil properties, tide, current, etc.).

1.1.7 Buoyage system in the Canal

The navigable channel is marked by pairs of light buoys. All buoys in the Canal and its approaches are fitted with radar reflectors.

- On the east side: Green buoys showing Green light.
- On the west side: Red buoys showing Red light.
- Distance between each pair: In the straight parts: 1.5km (north section)
  1.0km (south section)
  In the curves: less than 1.0km

1.2 Facilities and equipment of SCA

1.2.1 Shipyards

(1) Port Said Shipyard

Port Said Shipyard has more than 90 years of experience in ship repair and more than 40 years in shipbuilding. Main activities of the shipyard are as follows:

- Ship repairs for different ships and floating units.
- Shipbuilding of different type of vessels such as ships, tugs, etc.
- General engineering works and manufacturing of spare parts.
- Salvage works and under water welding and cutting operations.

Main facilities of the shipyard are as follows:

- Building berth of 150m in length and 43m in width, arranged for building 2 vessels 12,000DWT each or one vessel 20,000DWT.
- Four floating docks of 5,000, 10,000, 17,000 and 25,000 tons lifting capacity.
- Floating cranes with 500 tons lifting capacity on the main hook.
- A total of 2,000m long repair quays and a repair area of 8,500m^2.
- Different workshops for carrying out the works required for the shipyard activities including shipbuilding, machine tools, foundry, carpentry, motors, pipes and electricity. These workshops are equipped with the most up-to-date CNC equipment (cutting machine and lathes).
- Marine salvage team provided with the most up-to-date diving , salvage and survey equipment to undertake the underwater operations such as damage identification, welding and cutting.
- Training center with total capacity of 800 trainees.

(2) Port Tawfic Shipyard

Main activities of the shipyard are as follows:

- Shipbuilding and repairs of medium and small size floating units.
- Manufacturing the fiberglass products particularly floating units up to 40m long.

Main facilities of the shipyard are as follows:

- Ship lift with 2,000 tons capacity having 5 lanes each of 100m long for shipbuilding and repair works.
- A factory for fiberglass products, considered to be the biggest of its kind in the region.
- Floating cranes having lifting capacities up to 500 tons on the main hook, and up to 1,400 tons on the boat davit.
- It is well equipped with workshops for shipbuilding, machine tools and electricity, etc.

1.2.2 Dredgers

- Widening and deepening of the Canal is proceeding step by step using the SCA dredgers from draught 58ft. to 62ft. (Planned to be completed by the end of year 2000)

- Working in the East Port Said development project, the dredgers have removed about 5.9 million m^3 of dredged soil as of the end of 1999.

- During 1999, the SCA fleet of dredgers removed 32.3 million m^3 of dredged soil.

- This fleet encompasses the different kinds of dredgers required for dredging operations in the different kind of soil.

Table 1.2.1 Dredgers of SCA

Name / Type	Dimensions L/B/D/d (m)	Dredging Depth (m)	D/P Power	Cutter Power	Hopper /Bucket Capacity (m^3)	Year Built	Total Installed Power (HP)	Ship Yard	SUC /DEL (m m)
MASHOUR / CS	140.3/22.4 /7.5/4.95	35 max. at 50 deg	2/5400kw +LAD.P 2400kw	2/1200kw		1996	Abt. 30,000	I.H.C. Holland	1000 /900
OBOOR PORT SAID / TH	116.3/20.8 /10.5/8.5	30 max.	2/1200kw	2/750HP	6,557	1984	18,100	M.H.I. Japan	950 /915
SALAH EL-DIN ELAYOBY / TH	119.91/19.6 10.5/9.2	30 max with extension	2/5000HP		6,328	1977	15,500	M.H.I. Japan	1040 /915
AL-SEDIEK / CS	121.32/21 5.3/4.5	25.00	2/5000HP +LAD.P 1540kw	2/800kw		1980	19,070	M.H.I. Japan	1000 /850
AL-KHATTAB / CS	121.32/21 5.3/4.5	25.00	2/5000HP +LAD.P 1540kw	2/800kw		1980	19,070	M.H.I. Japan	1000 /850
TAREK-IBEN ZEYAD / CS	117.3/18 5.3/4.3	30.00	2/5000HP +LAD.P 1450kw	2/700kw		1977	16,770	M.H.I. Japan	950 /850
MAHMOUD YONES / CS	102.3/15 5/3	25.50	5000HP	2/750HP		1978	9,630	P.S. Shipyard SCA	850 /750
SAMY HARRAZ / SUC.	47.2/11 3.6/2.4		2500HP			1980	4,048	I.H.C. Holland	700 /600
NEFERTITY / CS	15/5.55 2.11/1.05	8	350HP	HYD 100HP		1968	545	Timsah SCA	350 /350
MINA No.2 / BL	61.3/12.06 3.65/2.4	24.65		Bucket Chain 4/137.5	550 /750 Lt.	1973	1,393	P.S. Shipyard SCA	
BARAKAT / BWS	59.7/14 3.2/2	20	1/3300HP	HYD. 1/600HP		1993	6,415	P.S. Shipyard SCA	560 /600

Notes) CS=cutter suction, TH=trailing hopper, BL=bucket, BWS=bucket wheel suction, SUC=suction, DEL=delivery

Source) "Yearly Report 1999", SCA

1.2.3 Tugs

SCA owns a fleet of 35 multi type tugs, ranging from 1,600HP to 16,000HP used for towing, salvage, firefighting and berthing of ships.

(1) Ocean-going multipurpose tugs "BARAKI1 and EZZAT ADEL"

- The most powerful in the Middle East with continuous bollard pull rated 160 tons
- Length: 69.2m, beam: 15.5m, depth: 7.4m, draught: 6.4m
- Total dead weight capacity: 2,320 tons, Deck area: 434m^2 with a strength of 15t/m^2
- Four diesel engines: 3,990HP each at 600 rpm, Marine range: 6,000 miles and speed: 17.5 kts
- Equipped with two fire fighting pumps delivering 3,600 m^3/hr for each and two water monitors remotely controlled from the wheel house (150m height above sea level and 193m trajectory)
- Equipped with a 200 m^3 tank, so they can participate in antipollution and lightering operations
- They carried out many successful towing operations in the high sea for oilrigs, floating docks, ships, barges and oil derricks

(2) Lightering vessels "NAGDA1 and NAGDA2"

- These vessels are used for lightering, bunkering, water supply and carrying containers
- Oil carrying capacity: 3,045 tons, fresh water capacity: 1,000 tons
- Length: 87m, beam: 15.5m, depth: 4m
- Container carrying capacity: 56 TEUs
- Deadweight: 3,320 tons
- Two engines 1,125 HP each at 1,000 rpm, speed: 10 kts

(3) Salvage and firefighting tug "SALAM5"

- Modern, newly built and fully equipped tug
- Used for salvage, firefighting, mooring large tankers and other services
- The tug is highly maneuverable for operations in harbors and escorting
- Equipped with 5,000 HP diesel engine and Voith-Schnider propeller

(4) Other tugs

The other tugs are used as salvage, escort and firefighting units at the Suez Canal. They are also used for berthing ships at the waiting areas and harbors.

1.2.4 Floating Docks

There are five floating docks at the Canal. Four floating docks (ATAKA, EID EL NASR, EL SALAM and floating dock of 5,000 tons) belong to Port Said Shipyard of SCA.

(1) ATAKA

- Lifting capacity: 17,000 tons
- Length overall: 182.5m, clear breadth: 48m
- Lifting Time: 170 minutes
- Equipped with two tower cranes capacity 17 tons each
- Year of Built: 1986, renewed and developed 2000

(2) EID EL NASR

- Lifting capacity: 25,000 tons
- Length overall: 220m, length of pontoon: 210m
- Breadth overall: 44m, clear breadth: 36m
- Lifting Time: 170 minutes
- Equipped with two dock cranes capacity 12 tons and 7.5 tons
- Year of Built: 1960, the dock was lifted for repair on 18/12/1999 by the floating dock "ATAKA" at Port Said Shipyard.

(3) EL SALAM

- Lifting capacity: 10,000 tons
- Length overall: 185m, length of pontoon: 170m
- Breadth overall: 36.6m, clear breadth: 28m
- Lifting Time: 150 minutes
- Equipped with two dock cranes capacity 10 tons each
- Year of Built: 1979

(4) Floating dock of 5,000 tons (no name)

- Lifting capacity: 5,000 tons
- Length overall: 120m, length of pontoon: 106m
- Breadth overall: 29.2m, clear breadth: 21m
- Lifting Time: 90 minutes
- Equipped with two dock cranes capacity 6 tons each
- Year of Built: 1950, renewed 2000

(5) SOMS (temporally name)

- Owner: Suez Odense Marine Services, a joint venture between SCA and Odense Steel Shipyard Ltd., a member of the A.P. Moller Group (Denmark)
- Lifting Capacity: 55,000 tons
- Length overall: 302m, Breadth overall: 71.08m, Length of Pontoon: 270m
- Lifting Time: 120 minutes
- Equipped with 3 gantry cranes capacity 60 tons each, and 2 slewing cranes capacity 16 tons each
- Year of Built: 1977

1.3 Natural conditions of the Canal

1.3.1 Tides and Currents in SC

The SC is divided into three main sectors according to the nature of tide in each. The characteristics of each can be summarized as follows:

A -The Northern Sector:
This part is located between Port Said and the G.B.L.:

(1) The height of tide at Port Said co-oscillates with the tide of the Mediterranean Sea with 0.50 meter extreme tidal range (Difference between highest and lowest levels) at Spring tides. This tidal range decreases gradually going South, to be about 0.20 meter at the entrance of Lake Timsah.
(2) In this sector, the peak tidal current may reach 1.0 knot (in case of no wind).
(3) Currents may be doubled by strong prevailing winds.
(4) Peak currents occur about 50 minutes after predicted HW and LW at Port Said.
(5) The duration and velocity of currents in this sector are greatly affected by the relative mean sea levels between the Mediterranean Sea, the Bitter Lakes and the Red Sea as follows:
   a) In summer: between July and October, the mean sea level at Port Said is slightly higher than that of the Bitter Lakes. This difference (which reaches its maximum of about 0.20 meter in September), beside the great evaporation at the Bitter Lakes, causes the predominance of the Southward current in duration and velocity.
   b) In winter: between December and May, the Mean sea level at the Bitter Lakes is slightly higher than that of Port Said. This difference which reaches its Maximum of about 0.30 meter in January, causes the predominance of the northward current in duration and velocity.

B -The Lakes (Timsah and Bitter Lakes):

(1) The Lakes along the Canal have an important role in dampening the effects of sudden meteorological changes.
(2) The Bitter Lakes with a surface of about 250 Km2 reduce the vertical movement of the tide to a minimum between Km.100 and Km. 130.
(3) The high spring tide range (MHWS) in G.B.L. may reach 0.25 meter.
(4) The phase of the vertical tide in G.B.L. is about 3 hours later than that of Port Tewfik.
(5) The vertical tide in Lake Timsah is almost in phase with the tide in G.B.L.

C -The Southern Region:
This part is located between Port of Suez and the Bitter Lakes:

(1) The height of tide in Suez co-oscillates with the tides of the Red Sea with extreme tidal range of about 1.90 meters at Spring tides. This range decreases gradually going north till the Bitter Lakes entrance to be 0.15 meter at Genefa.
(2) The tidal volume of the Bitter Lakes is very large compared to the tidal

volume of the southern section. Consequently, the currents are relatively strong and almost uniform between Port Tewfik and Genefa

(3) In this region, the Northward current is called flood and the southward current is called ebb.

(4) Peak currents occur about 50 minutes after predicted HW and LW at Port Tewfik.

(5) At the entrance of the Canal, Km. 159, the flood tide starts at an average of 3 hours after the low water at Suez. The ebb tide 3 hours after high water in Suez.

(6) Generally in summer, the duration of the ebb exceeds the average of 6 hours. In winter, the flood is the predominant. The ebb is prolonged by " strong northerly winds". The flood is prolonged by "strong southerly winds".

(7) In this region, the average peak current is about 1.5 knots. In spring tides, currents may reach 2.5 knots.

(8) The change of current occurs 5 to 10 minutes later on the bottom of the Canal, than on its surface.

1.3.2 Climate and weather

The Canal Zone is hot and humid in summer, and remains warm in winter. The weather is fairly stable over the zone. Rainfall is scarce along the whole area. The average temperature in summer (May to October) is 31ºC to 37ºC and in the others are 20ºC to 28ºC.

Winds are mainly gentle and it is rarely that strong gale is experienced. The general wind direction at 0800 in the morning is N (49%) followed by NW (20%) and NE (15%), and 1400 in the afternoon, the distribution is almost same i.e. N (51%) followed by NW (13%) and S (12%). Visibility is rather poor in the morning in summer, particularly. See Table 6.3.1 Climatic Table at Suez.

Table 1.3.1 Climatic Table

SUWEIS (29° 56′ N, 32° 33′ E) Height above MSL—10 m

Climatic Table compiled from 30 years' observations, 1941 to 1970

Month	Average pressure at MSL	Temperature: Mean daily max.	Temperature: Mean daily min.	Temperature: Mean highest in each month	Temperature: Mean lowest in each month	Average humidity 0800	Average humidity 1400	Average cloud cover 0800	Average cloud cover 1400	Precipitation: Average	Precipitation: No of days with 0·1 mm or more	Wind 0800 % frequency N	NE	E	SE	S	SW	W	NW	Calm	Wind 1400 % frequency N	NE	E	SE	S	SW	W	NW	Calm	Mean wind speed 0800	Mean wind speed 1400	No of days with wind 34 kts and over	No of days with vis < 2 km at 0800
	mb	°C	°C	°C	°C	%	%	Oktas		mm																				Knots			
January	1018	20	9	23	6	75	45	3	3	3	1	28	9	7	9	10	7	5	13	12	24	8	3	10	18	11	8	14	4	3	5	0	⊕
February	1016	21	10	26	6	70	41	2	2	3	1	28	12	5	8	11	3	5	17	11	24	7	3	9	22	9	9	12	5	3	5	0	0
March	1015	24	12	32	8	71	35	2	2	5	1	34	8	4	6	6	5	2	24	11	38	5	2	8	20	6	4	16	1	4	5	0	1
April	1013	28	15	33	11	68	32	2	2	0	⊕	44	6	4	5	8	2	1	23	7	41	5	2	6	20	8	6	10	2	5	5	0	0
May	1012	33	18	38	14	66	29	3	2	0	⊕	53	7	1	2	7	2	1	23	4	57	6	1	2	13	5	1	12	3	5	5	0	0
June	1010	35	21	42	18	69	29	1	⊕	0	⊕	61	7	1	2	2	1	1	21	4	68	8	1	1	7	1	1	12	1	5	6	0	0
July	1007	37	23	41	20	73	31	1	⊕	0	0	68	8	0	1	0	0	0	18	5	65	11	0	1	9	1	0	11	2	4	5	0	0
August	1008	36	23	40	21	75	33	1	⊕	0	0	69	6	1	0	0	0	0	21	3	68	10	1	1	4	1	0	13	2	4	6	0	0
September	1011	34	21	38	18	76	36	1	⊕	0	0	71	5	0	1	1	0	0	18	4	75	7	0	1	2	0	1	13	1	4	6	0	0
October	1014	31	19	36	16	76	39	1	1	3	1	54	9	1	2	2	1	1	25	5	58	10	0	3	9	2	1	11	6	4	4	0	0
November	1016	27	16	32	11	76	45	2	2	5	1	44	9	2	5	3	2	2	25	8	49	7	2	3	9	4	4	15	7	3	4	0	0
December	1018	22	11	26	7	74	47	3	3	5	1	33	15	4	5	4	1	3	16	19	39	12	3	6	14	4	3	14	5	3	4	0	1
Means	1013	29	17	42*	5§	72	37	2	2	—	—	49	8	2	4	5	2	2	20	8	51	8	2	4	12	4	3	13	3	4	5	—	—
Totals	—	—	—	—	—	—	—	—	—	24	6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	2
Extreme values	—	—	—	44†	1‡	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
No of years' observations												17									17												

*Mean of highest each year.
§Mean of lowest each year.

†Highest recorded temperature.
‡Lowest recorded temperature.

⊕Rare.
⊖All observations.