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SALINITY DISTRIBUTION IN KHAWR AL-ZUBAIR, SOUTH OF IRAQ

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ABSTRACT

Observations on salinity, freshwater input and tidal ranges in Khawr Al-Zubair (north west of the Arabian Gulf) have shown that, freshwater input control the transition of Khawr Al-Zubair from a lagoonal environment to an estuarine environment. Downstream of Umm Qasr, the water column was nearly homogeneous; horizontal salinity gradients and stratification were well developed at high freshwater discharge upstream of Umm Qasr. A good correlation between salinity and salinity gradient with freshwater discharge was noticed.

Key words: Salinity, estuary, Khawr Al-Zubair.

INTRODUCTION

Khawr Al-Zubair is an estuarine/lagoonal environment situated south west of Basrah (Fig. 1). The lower boundary of Khawr Al-Zubair is located near Warba Island about 8km south east of Umm Qasr. The total length of the channel is about 40km from the upper reaches to the lower boundary at Khawr Sakaa. The width of the channel ranges between 10-20 meters, with mean tidal depth of the navigational channel ranges between 10-20 meters, with mean tidal range of 3.2 meters. At high water on an average spring tide, the area covered by the water is approximately 60 sq. km.

In 1983, an artificial channel (Shatt Al-Basrah, Fig. 1) has been opened to connect the Euphrates river beyond Al-Hammar lake to Khawr Al-Zubair The length of this channel is about 37 km. The freshwater discharge from Euphrates river is controled by a dam built at a distance of 22 km from the entrance of the channel (15 km from the upper reaches of Khawr Al-Zubair). North of the control dam, the mean depth of the channel is about 4.5m, while south of the dam, the mean depth is about 7.5m. Before the opening of this channel, the environment of Khawr Al-Zubair was a lagoonal or as a "negative estuary", because the evaporation exceeded the freshwater inflow plus precipitation, and the salinity was as high as 47‰ in summer months (Emery and Stevenson, 1957). After the opening of Shatt Al-Basrah channel (1983). the environment of Khawr Al-Zubair has completely changed to form a positively estuarine environment, and a longitudinal salinity gradient is well developed.

MATERIALS AND METHODS

Salinity, currents (speed and direction) and temperature measurements were made for the water column over a complete tidal cycles at three stations (KZ1, KZ2, KZ3), located in the main channel of Khawr Al-Zubair (Fig. 1). These measurements have been made during 16-18 May, 1983 (Spring tide), 15-16 November, 1983 (Neap tide) and 22-24 October, 1984 (Neap tide). A control station (KZC) was chosen at a distance of 22 km seaward of Umm Qasr. Salinity measurements at two depths, 1 and 10m were made for over 25 hours each month from Jan. to Dec. 1983 and April 1984.

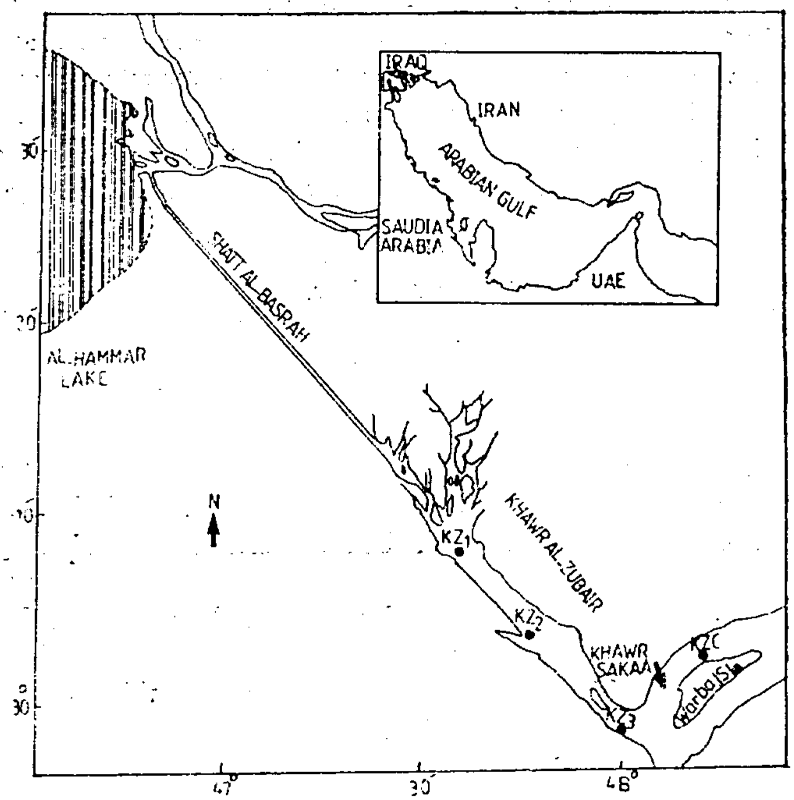


Fig. 1. Location map showing area of study

Data on the freshwater discharge into the estuary of Khawr Al-Zubair during the period, March 1983-April 1984 were provided by the Department of Irrigation in Basrah. In order to obtain depth mean salinity, the salinity values were tabulated for each lunar hour for various fractions of total water depth h i.e. $z/h = 0.05, 0.2\ 0.4, 0.6, 0.8$ and 0.95 (for this purpose, a lunar hour was taken as one twelfth of the interval between successive high water time). The depth mean values (s) were obtained by weighing various depth fractions by the factors 1, 2, 2, 2, 2, 1 respectively (Bowden and Sharaf El Din, 1966), finally average was taken for the complete tidal cycle to provide tidally-averaged salinity $(\bar{S})$

RESULTS AND DISCUSSION

Salinity variation

During a mid-channel surveys conducted as a part of the present study, incorporating tidal cycle variability, salinity water levels were determined through Neap and Spring tidal cycles. Figures 2 and 3, summarises the variations in depth mean salinity (s) and water level, against time, throughout typical Neap (15-16 November 1983) and Spring (16-18 May 1983) tidal cycles (with salinity values being obtained by taking the average over the water column). The phase relationships represented by the diagrams are indicative of the type of tidal wave propagation within the estuary (Dyer, 1973).

During Neap tide (Fig. 2), salinity maximum occurred near high water at stations KZ1 and KZ3; the comparable salinity minimum occurred near low water at both stations. During Spring tide (Fig. 3) the salinity maximum occurred 45 minutes, 50 minutes and 30 minutes after the high water at stations KZ1, KZ2 and KZ3 respectively. Salinity minimum occurred near low water at stations KZ1 and KZ3 and 30 minutes after low water at station KZ2.

Salinity variations during the tidal period increased with the range of tide and freshwater discharge. The maximum salinity range was durisg the Spring tide associated with a relatively high freshwater discharge. The vertical gradient of salinity was greatest near low water tended to vanish at mid-tide especially on the floor.

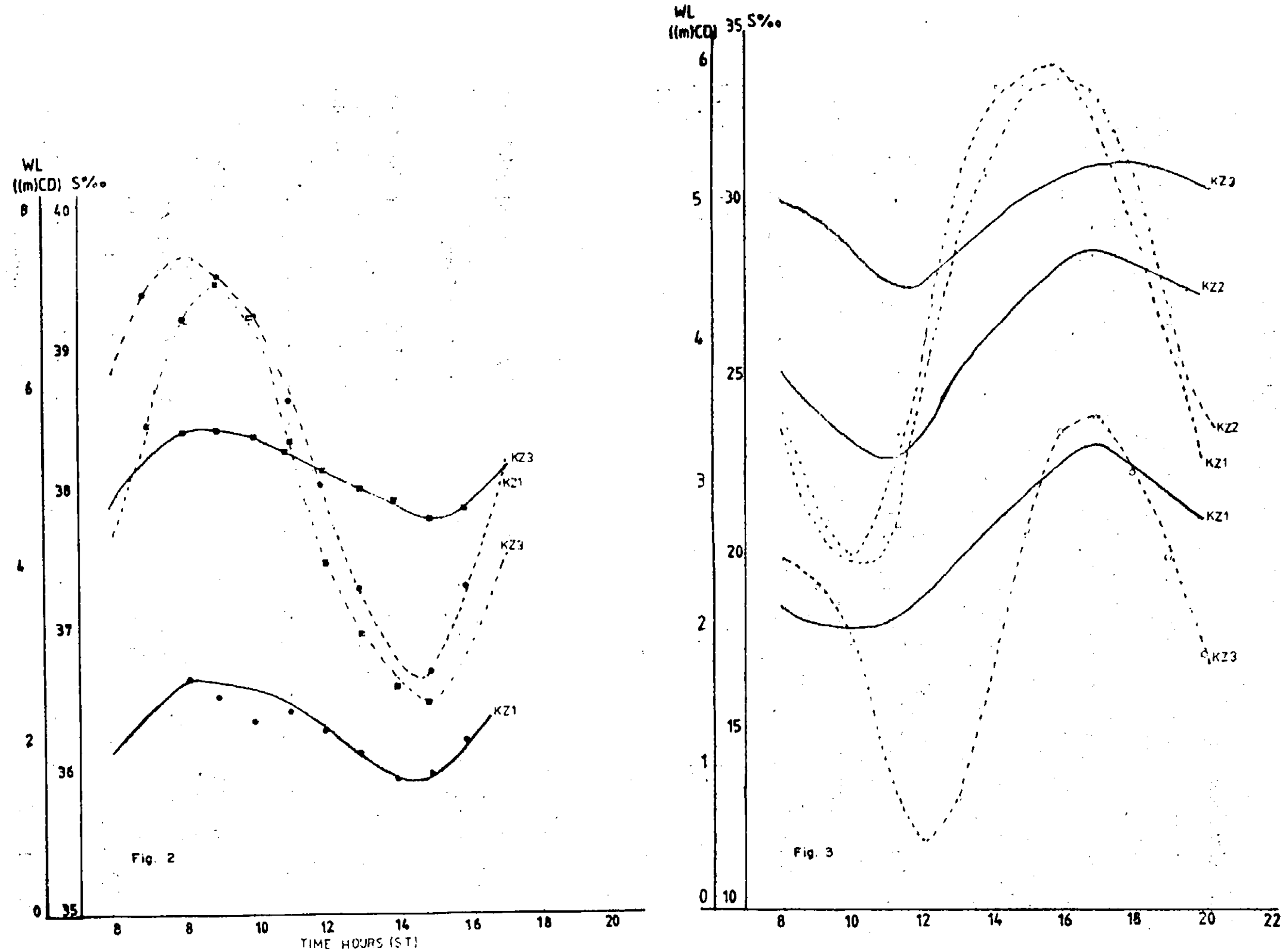
Longitudinal (and vertical) salinity variations

Instantaneous vertical and longitudinal salinity distributions at High and Low waters, for typical Neap and Spring tides are shown in figures 4 and 5 respectively. The data are based on observations from 3 stations.

The salinity difference between the surface and the bottom at the landward station KZ1 ranged between 0.3-4.75‰ on the Neap tide and 0.75-2.5‰ on Spring tide at the seaward station KZ3, the salinity difference between the surface and the bottom did not exceed 0.4‰ in all cases; this is likely to have been caused by a reduction in the surface salinity by the freshwater input.

During both the Neap and Spring periods, the longitudinal salinity gradient was higher under the Low water condition than at High water. The gradient at this time, is controlled by freshwater drainage from Shatt Al-Basrah on ebb. The general longitudinal displacement of the isohalines from Low water to High water can be seen in figures (4 and 5) for each of the tides.

In general, the pattern of the longitudinal (and vertical) salinity distributions for all the tides (Neap and Spring) demonstrate that, at both High and Low



Figs 2 & 3. Variation in depth-mean salinity S and water level throughout neap (15-16 Nov. 1983) & spring (16-18 May, 1983), tidal cycles resply. (Salinity —, water level ...)

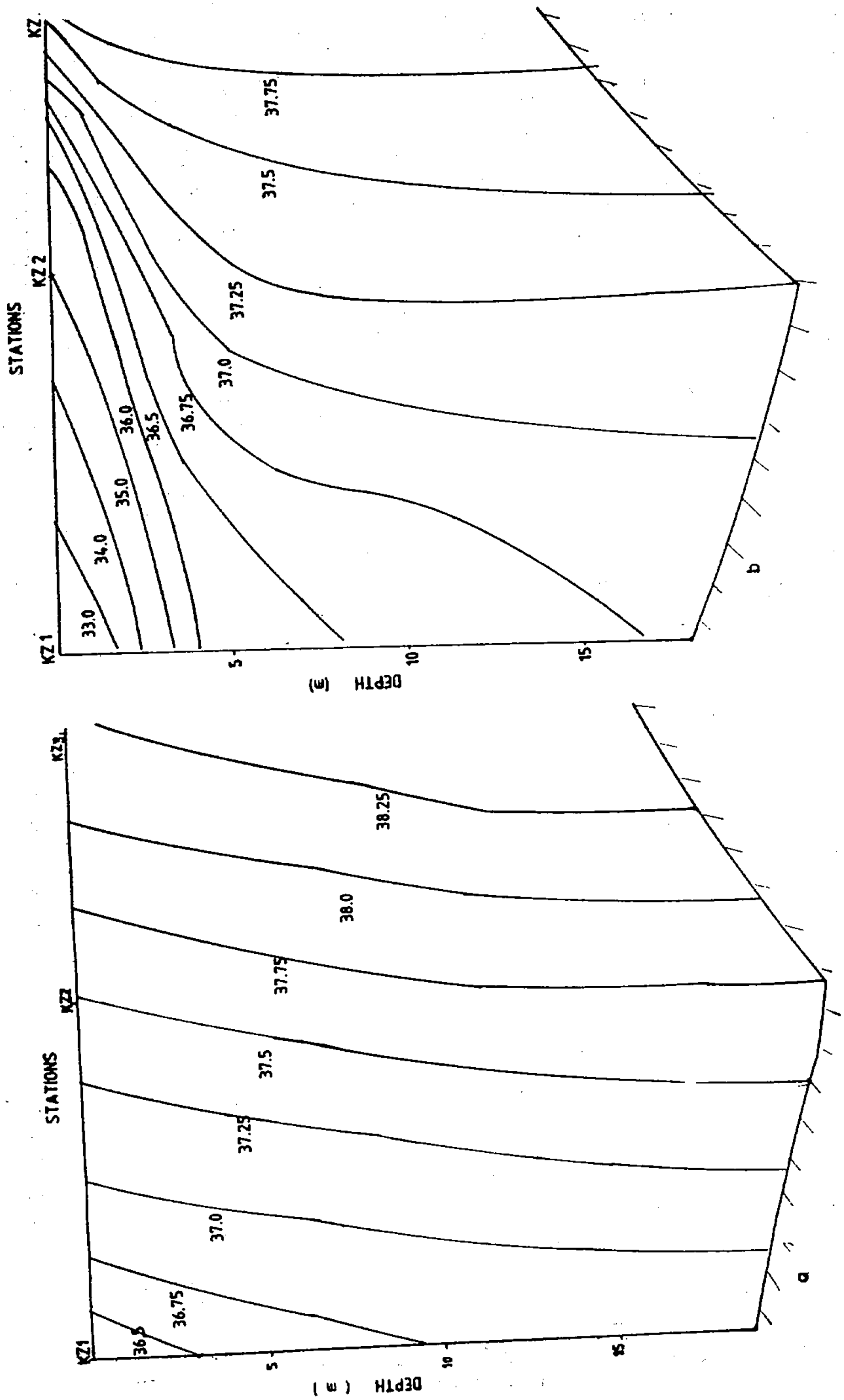


Fig. 4a & b. Neap tide (15-16, Nov. 1983); vertical & longitudinal salinity distribution at HW & LW resply.

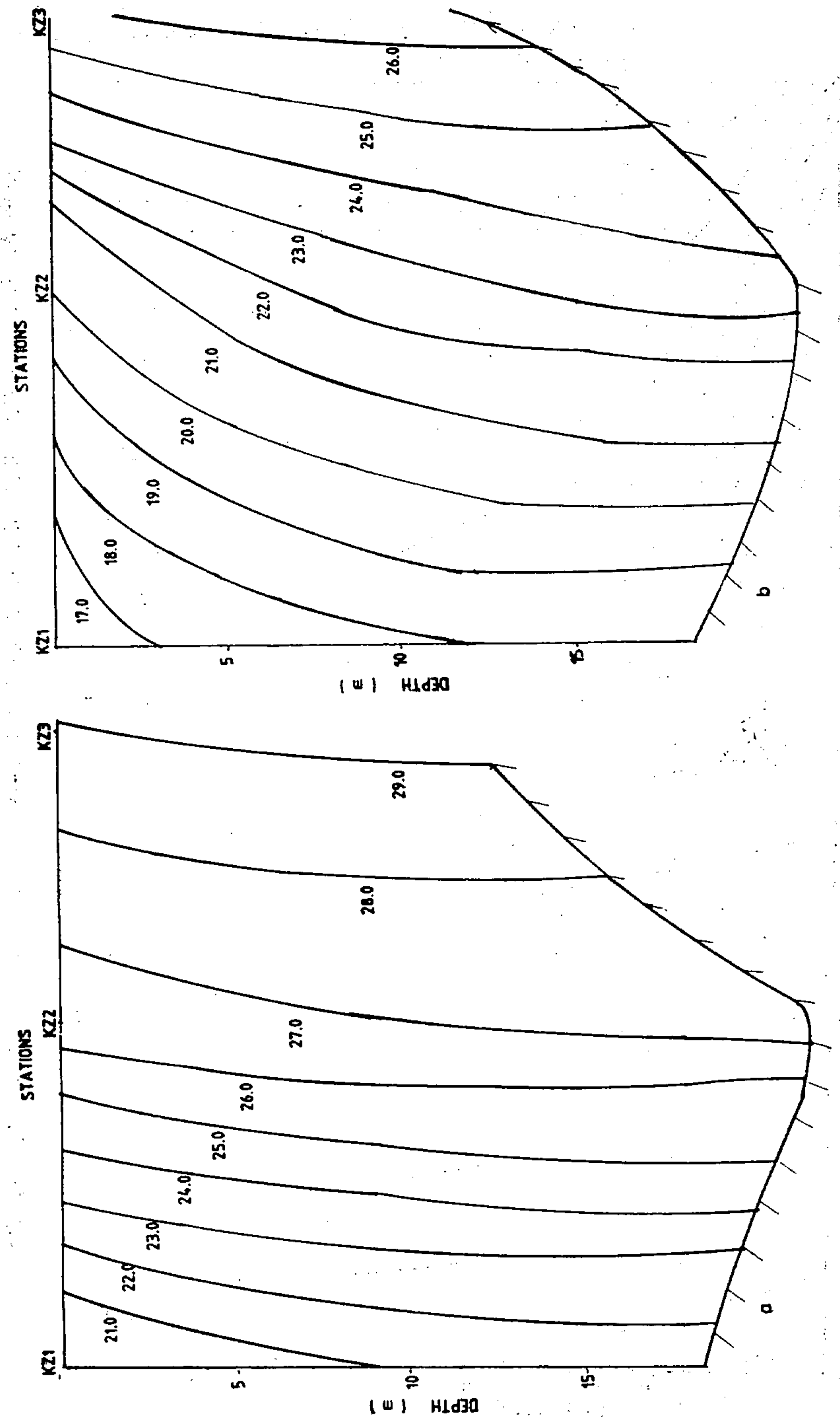


Fig. 5a & b. Spring tide (16-18 May, 1983), Vertical and longitudinal salinity distribution at HW & LW resply.

water the lower reaches of Khawr Al-Zubair is almost homogeneous (vertically) with slight stratification towards the head.

Long term variations in salinity

The rate of freshwater discharge into Khawr Al-Zubair varies considerably during the course of the year; it might be expected that such variability, combined with tidal influence, would have a marked effect on the distribution of salinity, the density current flow and on mixing processes.

Salinity data at the control Station KZC (Fig. 1), were collected at monthly interval throughout the period March 1983 to April 1984. Such sampling programme was organised in an attempt to take into account the variations in tidal range between Neap and Spring tides and differing freshwater input. For example, the total freshwater input ranged from a mean daily discharge of 0-109m^3/s, and the comparable tidal ranges (predicted) at Umm Qasr ranged from 1.38 to 5.12m. The comparison between the freshwater discharge curve and salinity curve (Fig. 6) demonstrates that the overall peak in the freshwater discharge in to

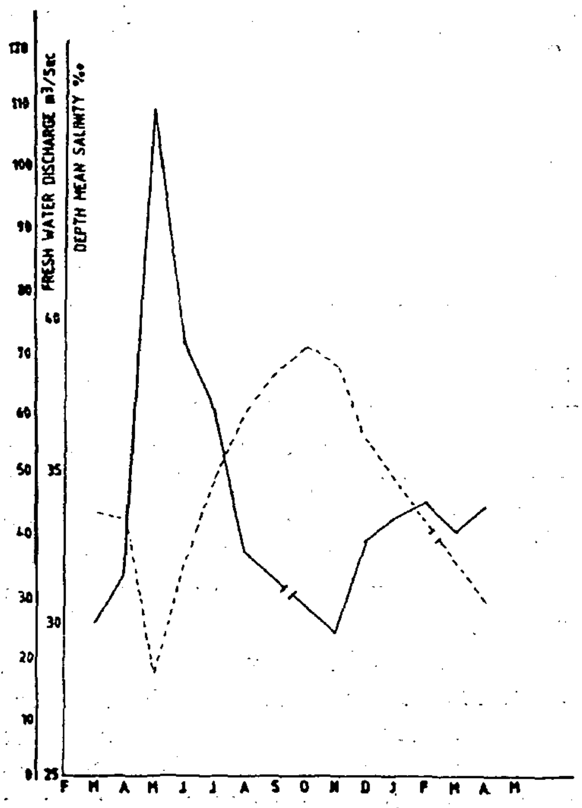


Fig 6. Monthly values of freshwater discharge (—) and depth mean salinity (— —) at station KZC.

Khawr Al-Zubair occurred in May 1983 and is generally associated with minimum in salinity over the same period. The maximum salinity occurred between September and November 1983 when there was no freshwater discharge from Shatt Al-Basrah (dry season). The inverse peaks demonstrate the significance of freshwater inputs in controlling the distribution of salinity within Khawr Al-Zubair. Such inverse correlation between freshwater discharge and salinity appears to be proven, at least in a discriptive sense.

Relationship between the overall salinity distribution, freshwater discharge and tidal range

In studying the quantitative relationship between the mean monthly salinity at Station KZC and the total freshwater discharge, various methods of averaging the discharge were examined, for example, the following were considered:

Table I - Variability of salinity with freshwater discharge (Station KZC).

Period before sampling (days)	Corr. Coeff.
0	-0.007
2	-0.385
3	-0.740
4	-0.585
5	-0.450
6	-0.085
7	-0.140

The discharge on the day of sampling, the mean of some 2,3,4,5,5 and 7 days discharges terminating on the day of sampling. From the results of the correlation analyses (Table I) and salinity values (cf. figure 6), it was decided to adopt freshwater discharge values, averaged over three days terminating on the day of sampling The comparison of this variable with mean monthly salinity gave a correlation coefficient of -0.74 with a mean monthly salinity averaged out at 33.83‰. For the period of the survey the mean river discharge was $58.85 m^3/s$ with a standard deviation of some $17.18 m^2/s$. The data was further examined in terms of salinity and salinity gradients, in relation to freshwater discharge and tidal range. The results in Table II demonstrate that there is a strong negative correlatnon between salinity and freshwater discharge. At the same time, there is a tendency for the vertical differences between the surface and bottom tidally averaged salinities to increase with increasing freshwater flow. The increase of salinity difference between the surface and the bottom will increase the salinity gradient, which in turn decreases the mixing processes by diffusion.

Table II - Variation of salinity and vertical salinity gradient with river discharge (R) and tidal range (T) (Station KZC)

	Salinity	Vertical salinity difference
Mean values ‰	33.830	0.278
Standard deviation	2.950	0.296
Correlation with R	–0.740	0.910
Correlation with T	0.270	–0.290
Total correlation	0.996	0.938

The partial correlation between each of the quantities (salinity and vertical salinity difference) and the two variables (freshwater discharge and the tidal range) was investigated and the coefficients of partial correlation are presented in Table II. The total (multiple) correlation coefficient is also presented. It can be seen that the influence of change in freshwater discharge are greater than that of the tidal ranges. This indicates that although Khawr Al-Zubair appears to be tidally dominated, the freshwater plays an important role in the distribution of salinity in the estuary depending upon the rate of freshwater discharge (Pritchard, 1968). However, the mixing processes are primarily controlled by tide, wind and stratification. Wind effects are important in promoting mixing in the shallower parts of the estuary (Chase, 1975). During periods of strong winds, the surface wave action can break down the normal stratification. Assuming that there is a liner (arithmatic) relationships between the salinity, vertical salinity difference, freshwater discharge (R) and tidal range (T), the following regression equations for the salinity and vertical salinity difference at station KZC, were derived (Note: in the equations, salinity differences expressed in‰, R in m^3/s and T in m).

$$S = 28.567 - 0.157R + 4.697T$$
$$\Delta z\ S = 0.332 + 0.030R - 0.585T$$

From these equations, one can estimate the salinity and vertical salinity gradient for different conditions of freshwater input and tidal ranges.

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