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SEA WATER INTRUSION IN THE KEELUNG RIVER (TAIWAN) (**) A STUDY OF THE TIDAL EFFECT

Abstract: CHANG J.C. & SHIH T.-T., *Sea water intrusion in the Keelung River (Taiwan). A study of the tidal effect.*

Based on the water level and conductivity measurements, the Keelung River is affected by tidal action up to 35 km from the confluence with Tanshui River. Actually, sea water intruded into the river only for 12 km, which is one third of the tidal effect segment. Sea water and river water mix well during spring-flood tide but a little salt wedge occurs during neap-ebb tide.

KEY WORDS: Tidal effect, Water level change, Conductivity, Spring tide, Neap tide, Keelung river (Taiwan).

Riassunto: CHANG J.-C. & SHIH, *Intrusione di acqua marina nel Fiume Keelung (Taiwan). Uno studio sugli effetti della marea.*

Sulla base di misure idrometriche e di conduttività, si è dedotto che il Fiume Keelung è interessato dall'azione della marea fino a 35 Km dalla confluenza con il Tanshui. Attualmente, l'acqua di mare si incunea in quella del fiume per 12 Km, ossia per 1/3 del percorso in cui si risentono gli effetti delle maree. Durante la marea primaverile si ha un buon mescolamento delle acque salata e dolce, ma un piccolo cuneo salino si intrude nel fiume anche durante la marea.

TERMINI CHIAVE: Effetti della marea, Intrusione salina, Conduttività, F. Keelung (Taiwan).

INTRODUCTION

The Keelung River in northern Taiwan is 80 km long and drains an area of 500 km^2 which is characterized by abundant rainfall. It meanders freely through Taipei Basin and flows into Tanshui River which debouches into Taiwan Strait. As industrial development spread rapidly along the valley since last century, the problem of water pollution has become a severe one. The proposals to deal with this problem have been made by environmental researchers recently.

Although data on water level and discharge have been collected, the tidal effect on the Keelung River is still not well known. For further understanding of the tidal effect and providing the reference for water pollution control, this work attempts to measure the sea water invasion by studying water level changes and conductivity variation.

FIELD MEASUREMENTS

In order to understanding the water level fluctuation, six gauge stations (K_1-K_6) were set in early July 1986 (fig. 1). The fieldwork was carried out on 24 July (spring tide), 31 July (neap tide), 30 August (neap tide) and 6 September (spring tide). Field measurements include two parts:

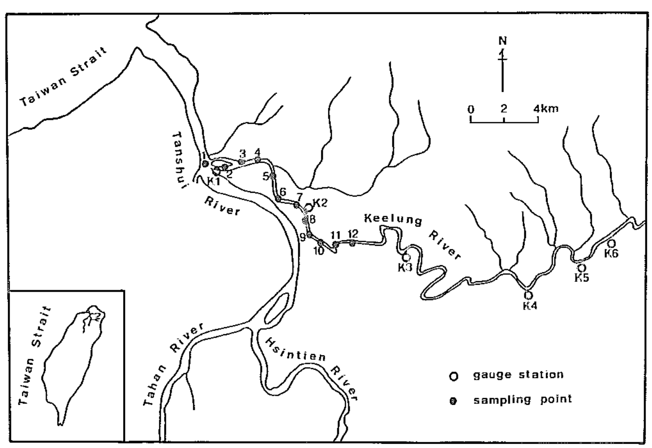

FIG. 1 - Gauge stations and sampling points along the Keelung River.
K1 Chinese Marine College
K2 Pailing Bridge
K3 Neihu Bridge
K4 Hengko Ferry
K5 Chiangpei Bridge
K6 Changan Bridge

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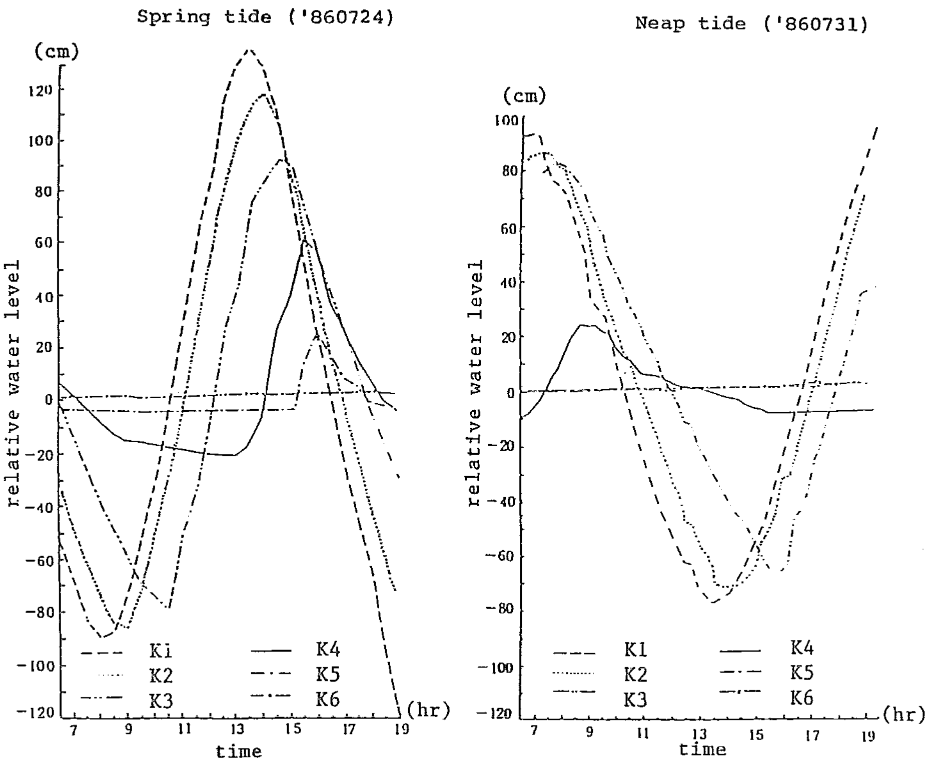

FIG. 2 - Relative water level of Keelung River during spring and neap tide.

(1) monitoring the water level at each gauge station simultaneously through one tide cycle,

(2) measuring conductivity both in situ and in the laboratory.

DISCUSSION

WATER LEVEL CHANGE

The fluctuations of water level for each gauge station during spring tide and neap tide are shown in fig. 2. The water level change decreases upstream from the confluence with Tanshui River. At station K_1, the tidal range is 250 cm but only 29 cm at K_5 and 2 cm at K_6, 36 km upstream. The lag times for high water and low water at K_5 relative to K_1 are 2.5 hrs. and 7 hrs. respectively. The interval of flood tide decreases upstream. Conversely, the interval of ebb tide increases upstream. The tidal range of neap tide is smaller than that of spring tide, however, the time lag between station for high water and low water are the same as during spring and neap tide (tab. 1).

CONDUCTIVITY VARIATION

Conductivity measurements of river water samples are different along the river. The conductivity value decreases

TABLE 1 - THE CHANGING WATER LEVEL OF KEELUNG RIVER DURING SPRING TIDE AND NEAP TIDE

Station	K_1		K_2		K_3		K_4		K_5		K_6	
	S	N	S	N	S	N	S	N	S	N	S	N
Distance* (km)	0.3		7.0		16.5		29.7		34.9		36.9	
Water level change (cm)	251	180	202	167	169	157	81	36	29	0.6	2	0.5
High water time	13:30	06:45	14:00	07:15	14:30	07:45	15:30	09:00	16:00	—	—	—
Low water time	08:00	13:30	09:00	14:30	10:30	16:00	13:00	15:30	15:00	—	—	—
High water time lag (hr)	0	0	0.5	0.5	1	1	2	—	2.5	—	—	—
Low water time lag (hr)	0	0	1	1	2.5	2.5	5	—	7	—	—	—
Flood interval (hr)	5.5	—	5	—	4	—	2.5	—	1	—	—	—
Ebb interval (hr)	6 +	6.75	—	7	—	8.25	—	—	—	—	—	—
Flood inversion	yes	yes	yes	yes	yes	yes	yes	yes	none	none	none	none

* from each station to the confluence with Tanshui River
S = Spring tide ('86 08 08)
S = Neap tide ('86 08 17)

TABLE 2 - VERTICAL DISTRIBUTION OF CONDUCTIVITY OF KEELUNG RIVER DURING SPRING TIDE, '860906 UNIT: ....μU/cm

depth(m)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0	17290	15734	18651	18898	17569	14243	10406	11524	9642	2607	1354	625
1	17758	16770	18013	19328	15459	14552	11278	11154	10377		1402	702
2	17440	19941	21327	18953	17955	15308	13446	11926	10456	2275	1371	699
3		23436	21107	19586	17976	15290	13429	11544	11227			
4		21000	20712	19217				11889	11266	2249		
5		21474		19418				12198				
6		21763		19757						4451		
7		20748										
8		23980								4300		
9		24332										
10										4447		
11												
12										4243		

remark: (1) — (12) sampling points

TABLE 3 - VERTICAL DISTRIBUTION OF CONDUCTIVITY OF KEELUNG RIVER DURING NEAP TIDE, '860830 UNIT: ....μU/cm

depth(m)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0	5425	5465	5162	4338	1735	263	315	289	289	263	298	298
1	5552	6038	5863	4771	2450	376	315	286	298	291	298	300
1.5	7547										289	291
2		8488	8750	5775	2975	371	321	306	280	284		
2.5					3238							
3		12002	13013	6563		350		289	300	291		
3.5						350		289				
4		14175		7875						284		
5		16975		8663						300		
6		18375								287		
7		19688								284		
8		19688										

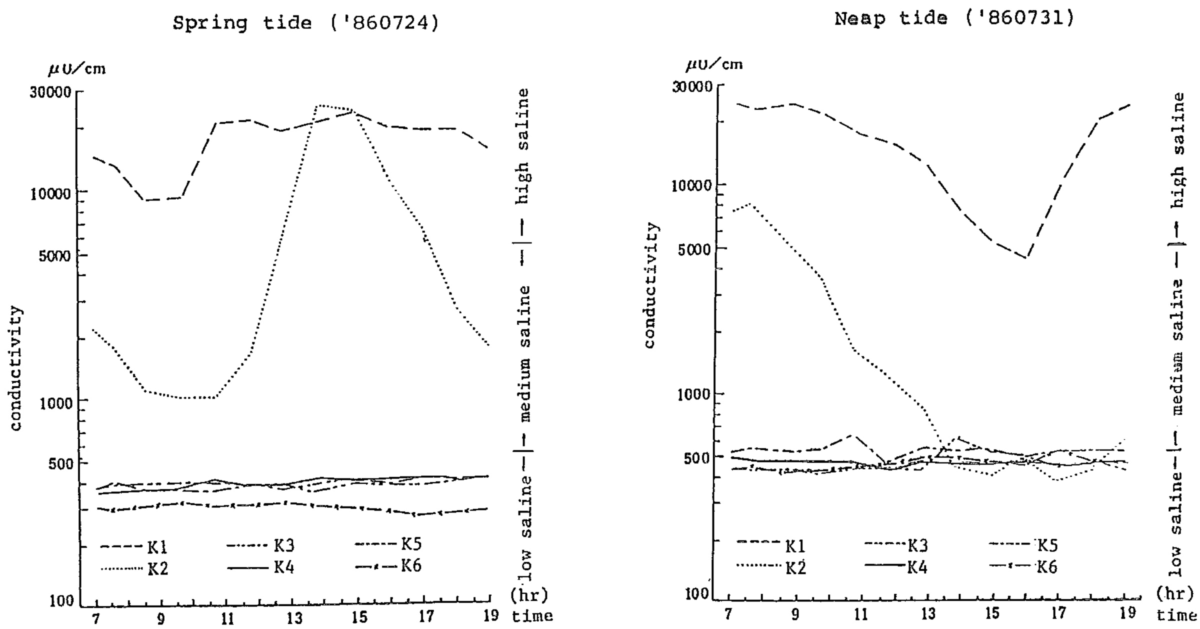

FIG. 3 - Conductivity of Keelung River during spring and neap tide.

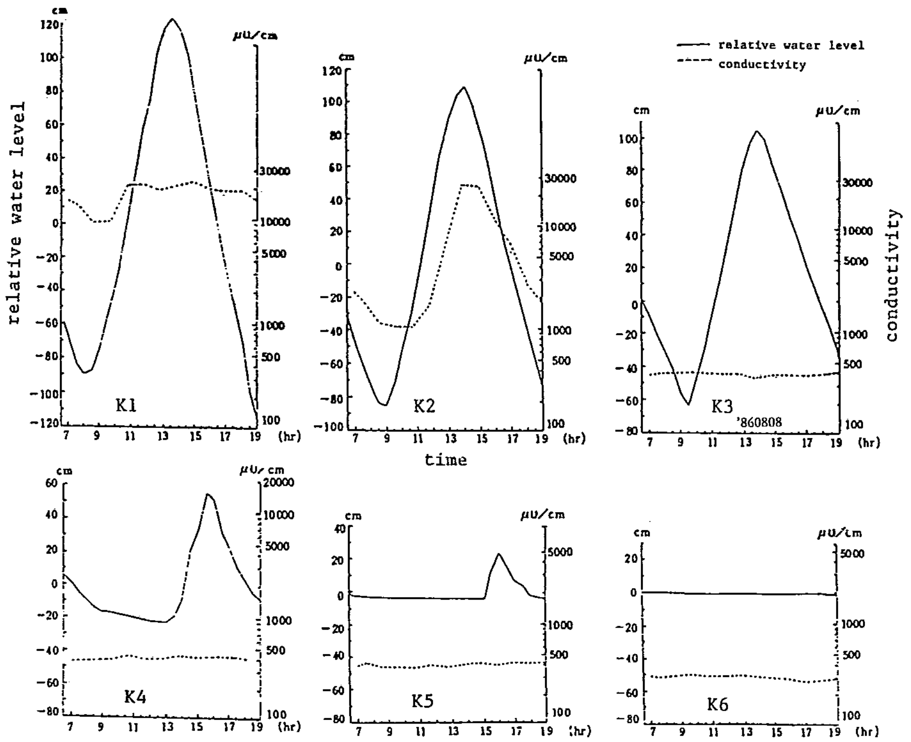

FIG. 4a - Conductivity and relative water level of Keelung River during spring tide.

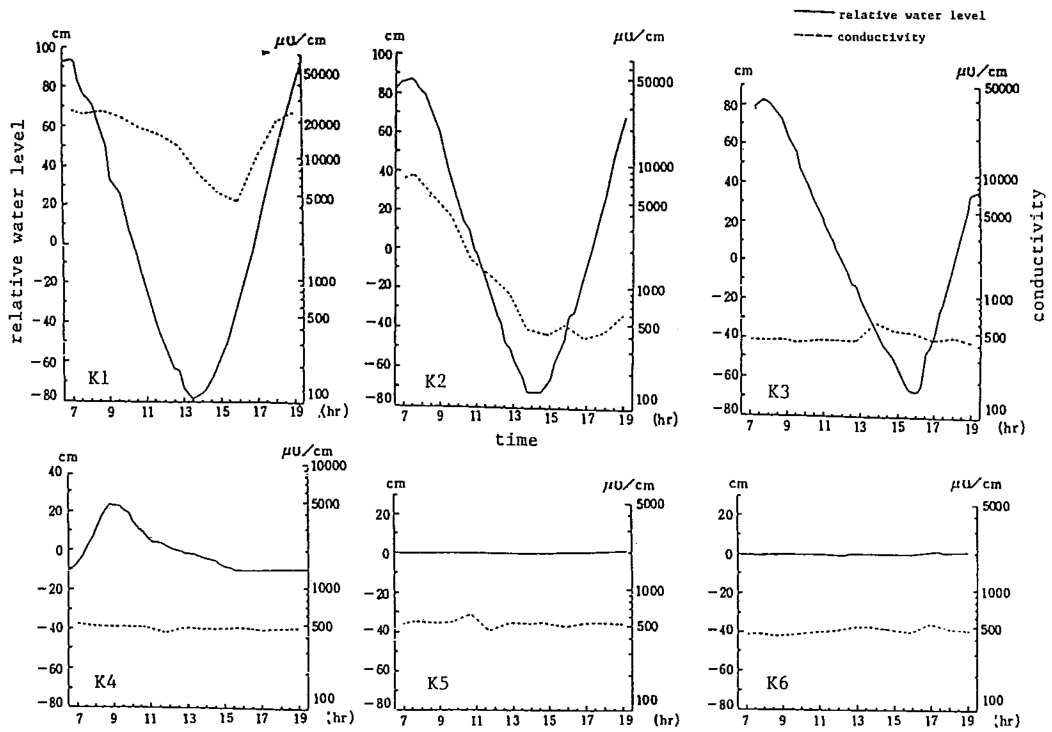

FIG. 4b - Conductivity and relative water level of Keelung River during neap tide.

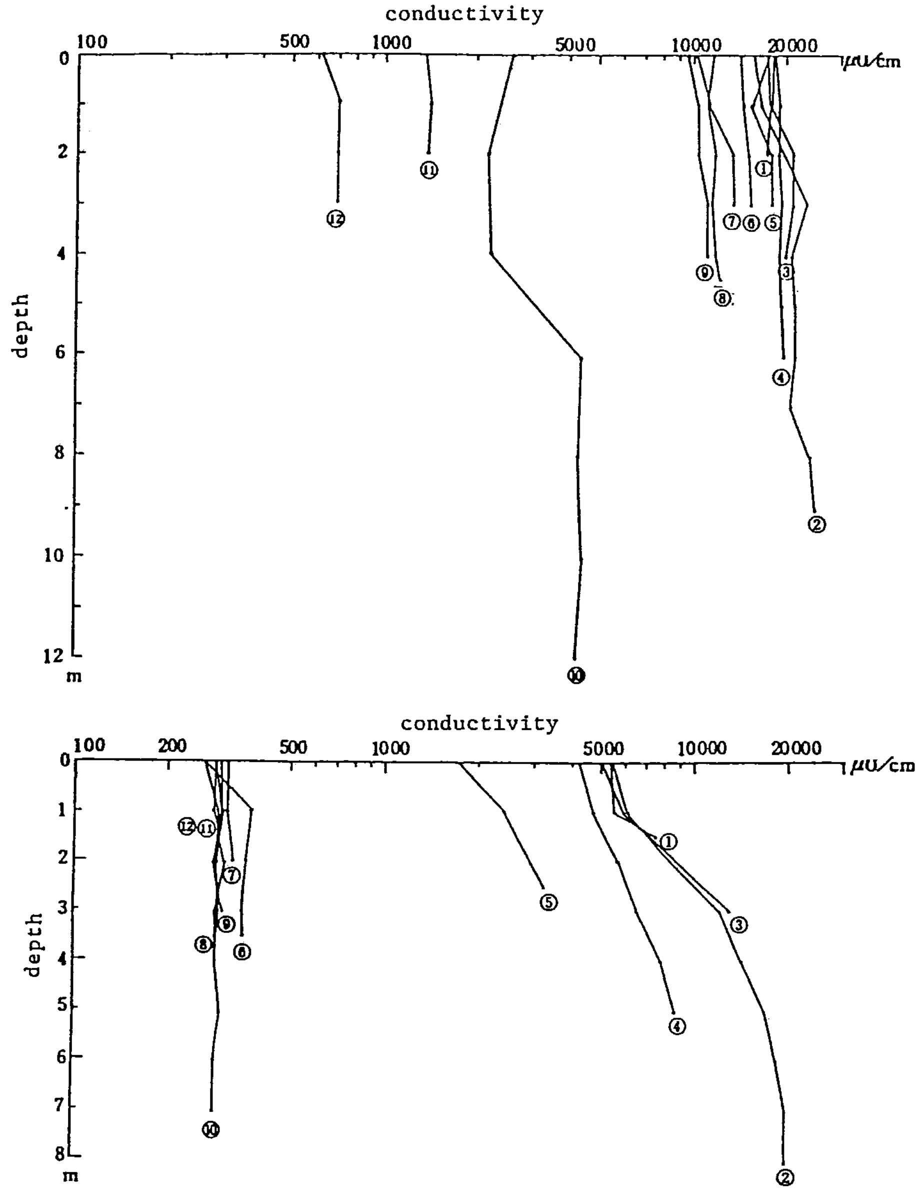

FIG. 5 - Vertical distribution of conductivity of Keelung River during spring tide.

from the confluence to inland both during spring and neap tides (fig. 3).

Conductivity remains high, ranging from 8000-20,000 μU/cm at K_1, fluctuates between 900 and 20,000 μU/cm at K_2, but drops below 500 μU/cm suddenly beyond K_3.

The relation between water level change and conductivity are also different along the river during spring tide and neap tide (fig. 4a & 4b). At K_1, conductivity remains very high even though there is a large variation of water level though a tidal cycle. Upstream at K_2, it fluctuates coincidentally with water level. From K_3 to K_5, conductivity stays low stablely but water level still changes periodically. At the uppermost station K_6, conductivity is very low and stable and variation in water level is small. From these observations, we could conclude that sea water intrude into the Keelung River no further than K_3. Beyond Neihu Bridge (K_3), the daily fluctuation of water level is produced by the effect of back water.

Although conductivity of river water decreases upstream from the confluence, there is not much vertical variation at each sampling point. A big gap in conductivity can be found between point 9 and point 10 during spring-flood tide (fig. 5 and tab. 2). During neap-ebb tide conductivity in surface water is much lower, but remains high in bottom water between point 1 and point 4 (fig. 5 and tab. 3). It could be inferred that during spring-flood tide, sea water intrude into river up to about Tachi (between K_2 to K_3). Sea water mixes well with fresh water at depth.

However, during neap-ebb tide, it retreats to Choumeli (between K_1 to K_2) and a little salt wedge occurs near the confluence which is about 11 km to the Taiwan Strait.

CONCLUSION

According to the measurements of water level and conductivity, the results reveal that the magnitude of tidal effect is decreasing from the confluence up to 35 km inland. They also show the complicated and dynamic behavior of sea water intrusion. For further modelling on this dynamic behavior of sea water intrusion, long term investigation of fresh water discharge, tidal activity, stream geometry and prevailing wind, etc., are required.

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