THE ESTUARINE PROCESSES OF THE TA-TU RIVER, TAICHUNG, TAIWAN

— BY REMOTELY SENSED DATA ANALYSES —

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ABSTRACT

Multi-temporal LANDSAT MSS imagery and aerial photography taken in winter season from 1972 to 1981 were used to study the estuarine processes and to estimate the importance and time-scale of variability of all physical parameters influencing the study area.

The estuary of the Ta-Tu river was selected as the study area, which lies in the central part on the western coast of Taiwan, and is about 7.5Km south of Taichung Harbor. On the southern side of this estuary, a huge coastal industrial park is under construction on the tidal flats.

Previous study of the water quality of the river proved that this river is seriously polluted by urban sewage and industrial waste water. It is also reported that the annual average amount of suspended silt and sand entering into coastal area from this river is 4.935 million tons.

The analyses of current meter records concluded that the flood tide current is northbound along the coast and the ebb tide current is southbound. In winter season, the waves in the central part of Taiwan Strait come mainly from the north. It is also proved that there is a small branch of the Kuroshio current flows steadily northward along the western coast of Taiwan.

Based on the physical oceanographic data in correlation with the vissual interpretation of the images, six of the ten images reveal an apparent breaking line of waves and south bound longshore current in winter season even when the tide is flooding. During the ebbing hours, the southward longshore current is strengthened by ebb tide current. It can move the river water southward in the surf zone as far as 15 Km, and be dispersed out of the breaking line by rip current. If the wave energy is not strong enough to generate apparent longshore current in the estuarine area, the river water would rush out of the breaking line of wave.

Beyong the breaking line of waves the motion of water masses is controlled mainly by the steady northward nearshore oceanic current and tidal current. Most of the streamlines can be traced

from the estuary or the head of rip current northward to the vicinity of the harbor. This proves that the steady, nearshore northward oceanic current may surpass the southward ebb tide current. Moreover, in summer season, the water motion were measured quantitatively from successive photographs in which the turbidity patterns remain recognizable from on photograph to the next.

INTRODUCTION

It is recognized that new, economical water monitoring techniques must be developed to meet the needs of current and future environmental management, especially in the coastal area. The conventional slow data gathering oceanographic techniques have a major limitation on oceanographic features in a time frame consistent with their dynamic behavior. The present monitoring of water quality with respect to physical, chemical, and biological parameters involve a variety of analytical procedures, it appears that a certain number of monitoring functions are feasible with the use of remote sensing techniques especially for the surveillance of physical processes of coastal environment.

General observation of remotely sensed imagery is dependent upon the reflectance characteristics of the scene within the portion of the spectrum. Photography and imagery obtained in the visble and invisible regions of the electromagnetic spectrum provide an unique quasi-synoptic records of the scene of intrest. This media of data recording represents a continuum of information rather than point information. In addition, the synoptic character of a paticular feature at a paticular instant of time can be recorded in a frame of image.

OBJECTIVE

The general objective of this study is to use the multi-temporal LANDSAT MSS imagery and aerial photography taken in winter season from 1972 to 1981 to study the estuarine processes and to estimate the importance and time-scale of variability of all physical parameters which influence the processes of the study area.

ENVIRONMENT OF THE STUDY AREA

A. Topography of the study area

The Taiwan Strait is the channel between mainland China and the Taiwan Island. It is 60 - 120 Km wide with a general depth of 50 - 100 m.

The estuary of the Ta-Tu river was selected as the study area (Fig. 1). This river is the fourth largest one in Taiwan, draining portions of Taichung, Nantou and Chungwa counties. The drainage basin is more than 2000 sq. Km with an average slope of 1:45. The estuary of the Ta-Tu river is located at $120^{o}39'$E, $24^{o}12'$N, and lies in the central part of the western coast of Taiwan, about 7.5 Km south of Taichung Harbor. On the southern side of this estuary, more than 6000 sq. Km of tidal flats are under construction as a coastal industrial park.

B. Quality of the river water

The quality of river water has been analyzed and shows that this river is seriously polluted by urban sewage and industrial waste water. It is also reported that the annual transportation of suspended silt and clay from this river into the coastal area is 4.935 million tons on average.

C. Physical oceanographic properties

The Physical processes of this estuary are complex. The river discharge is mixed with sea water by the action of tidal motion, steady oceanic current, wind stress on the sea surface and longshore current, and also by the river discharge forcing its way toward the sea.

Kuroshio—The main Kuroshio current flows northeastward along the eastern coast of Taiwan. A part of this current also flows southerly through the Luzon Strait, forming the counterclockwise water circulation toward the South China Sea. Another part of the current flows northerly, passing by the Pen-hu Islands, and off the western coast of Taiwan to the north, but is vagued during Northeast Monsoon in winter season (Fig. 2).

Tidal currents—The tidal currents flow into the Taiwan Strait from both the north and the south. These two opposing currents meet at $24^{o}12'$N in the vicinity of the mouth of the Ta-Chai river. In the estuary under study, the flood tide current is northward along the coast and the ebb tide current is southbound. The tidal range at both the south tip and to the northeast of Taiwan is 0.7 m being northward and southward respectively with the rising tide, which is about 4.5 m at the mouth of the Ta-Tu river.

Waves and longshore current—The waves in the central part of Taiwan Strait come mainly from the north and northeast and generate southward longshore current along the western coast of Taiwan.

LANDSAT IMAGERY AND AERIAL PHOTOGRAPHY

Ten remotely sensed data taken in the winter season of different years were used for this study. They include five sets of LANDSAT imagery taken in 1972, 1973, 1974, 1978, and 1979, and four sets of black and white aerial photography taken by RMK A 15/23 mapping camera with a scale about 1:15,000 in the year of 1973, 1974 and 1981. A mosaic of tens of strips taken by a panoramic camera was also used for the estuarine processes analyses. All the acquisition dates and their tide information of the ten images were plotted in Fig. 3.

After plotting all the image acquisition times on the idealized curves of tidal cycles, we can find that two of the ten images were taken during the time of high-tide, three were close to the time of low-tide and two were taken during the ebbing hours and the remaining three were taken while the tide was flooding. Fortunately, we have an optimistic temporal distribution of imagery for analyses.

METHODOLOGY

The river of this estuary is seriously polluted by urban sewage and industrial waste water. The dark tone polluted river water coming out from this estuary results in vissual color changes in the surrounding sea water. These changes can be detected from conventional black and white or LANDSAT MSS band 5 images. These vissual effects consititute the primary indicators of this form of pollution, and the photographic sensors provide images for detection, aerial measurement, and source location. (Strandberg, 1967).

The interpretations of the images were based primarily on the traces of streamlines, the orientation of the fronts of water masses and the color changes. The incidence of wave trains and the sea surface roughness in areial photography were also noticed. The breaking lines and longshore current of shoring waves are also important factors of the physical parameters.

Qualitative interpretation of the three forms of imagery is related to the following characteristics: steady ocean current, tide and tidal current, wave and longshore current. Fig. 4 to Fig. 6 show some of the images used in this study with their interpretation maps. Fig. 7 is the composite of two color aerial photographs taken with a time difference of 14 minutes and 41 seconds. The turbidity patterns remain recognizable from on photograph to the next. From which the water motion were measured quantitatively.

CONCLUTION REMARKS

A. The physical processes of this estuary are complex. The river discharge is mixed with sea water by the action of tidal motion and steady oceanic current, by stress of wind on the water surface and longshore current, and also by the river discharge forcing its way toward the sea.

B. In winter monsoon season, six of the ten images cover the study area reveal an apparent breaking line of waves and southbound longshore current even when the flood tide current flows northward.

C. During the ebbing hours, the southward longshore current is strengthened by the ebb tide current. This current can move the river water southward in the surf zone as far as 15 Km away and is then dispersed out of the breaking line by rip current.

D. If the wave energy is not strong enough to generate apparent longshore current in the estuarine area, the river water would rush out of the surf zone of waves for several kilometers from the opening of the river mouth.

E. Beyong the breaking lines of waves, the motion of water masses is controlled mainly by steady northward nearshore oceanic current and tidal current. In all images, most of the stream-lines can be traced from the estuary or the head of rip current northwardly to the vicinity of Taichung Harbor. This proved that the steady nearshore northward oceanic current surpasses the southward ebb tide current.

ACKNOWLEDGEMENTS

The writers are deeply indebted to Prof. C. S. Ho for his critical review of the manuscript and improve its readability. We also thank Mr. R. J. Chen for his able assistance.

REFERENCES

1. CHEN, L. S. (1981) A study on the tide and tidal waves of western coast of Taiwan. thesis of M. S. Deg., University of Chinese Culture, Taiwan.

2. CHEN, S. H. (1980) The hydrodynamical numerical models for tide and tidal current in Taiwan Strait. thesis of M. S. Deg., National College of Marine Science and Technology of Taiwan.

3. CHENG, S. T. (1976) A study on the monsoons and its effects on surrounding. thesis of M. S. Deg., University of Chinese Culture, Taiwan.

4. CHENG, T. S. AND TSENG, W. T. (1974) Priliminary investigation on the ocean outfall in Taichung Harbor District. Report No. 26, Laboratory of Fishery Biology, Taiwan Fishery Research Institute.

5. HUNG, T. C. (1978) Studies on the coastal environment and estuary of Ta-Tu River, Taichung, Taiwan, Republic of China. special publication No. 17, Institute of Oceanography, College of Science, National Taiwan University.

6. STRANDBERG, C. H. (1976) Water pollution reconnaissance, Chpt. 16 in Aerial discovery manual. John Wiley and Sons, Inc., New York, P. 195-205.

Fig 1. Index map of studied area cited on the SLAR image of Taiwan.

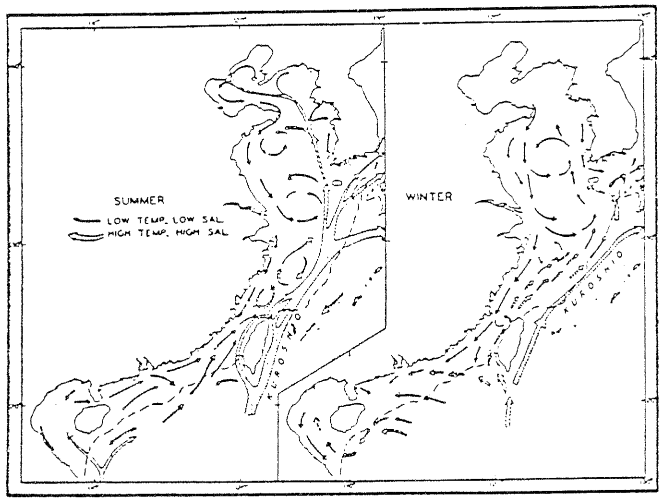

Fig 2. Schematic pattern of ocean currents near Taiwan. (K. O.Emery and R. E. Stevenson. 1972)

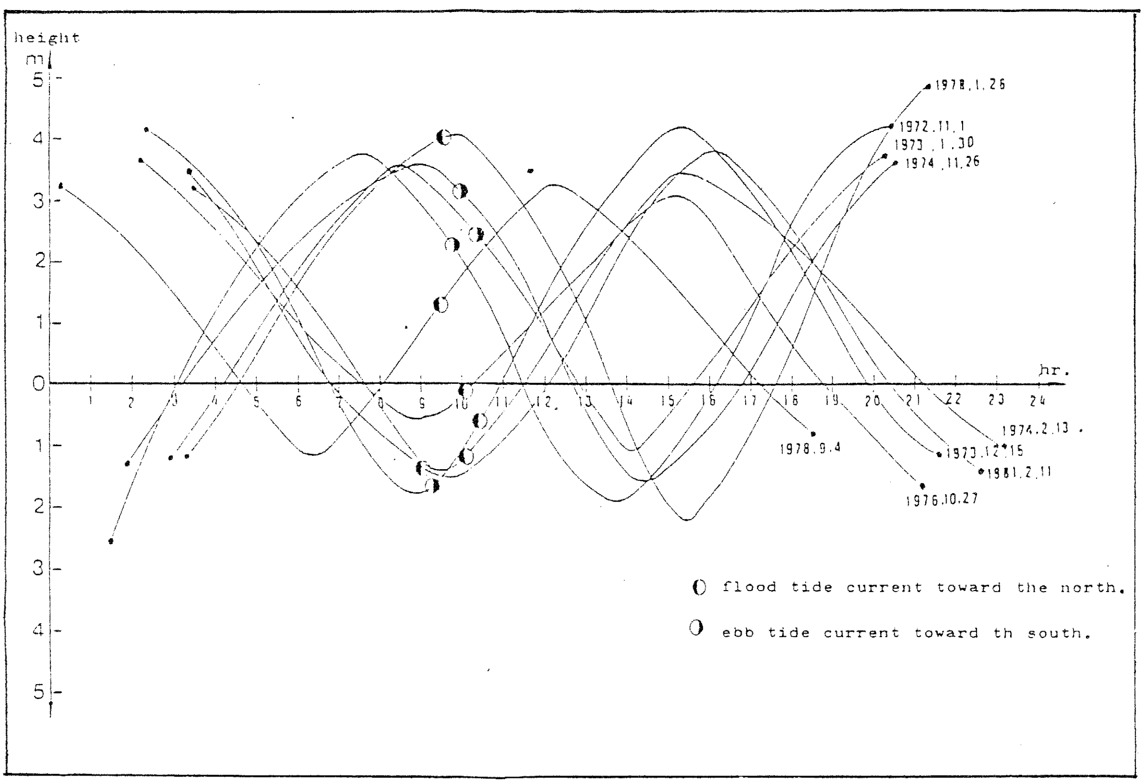

Fig 3. Ten image acqusition times plotted on the idealized tidal cycles. The distribution is very optimistic for analysis.

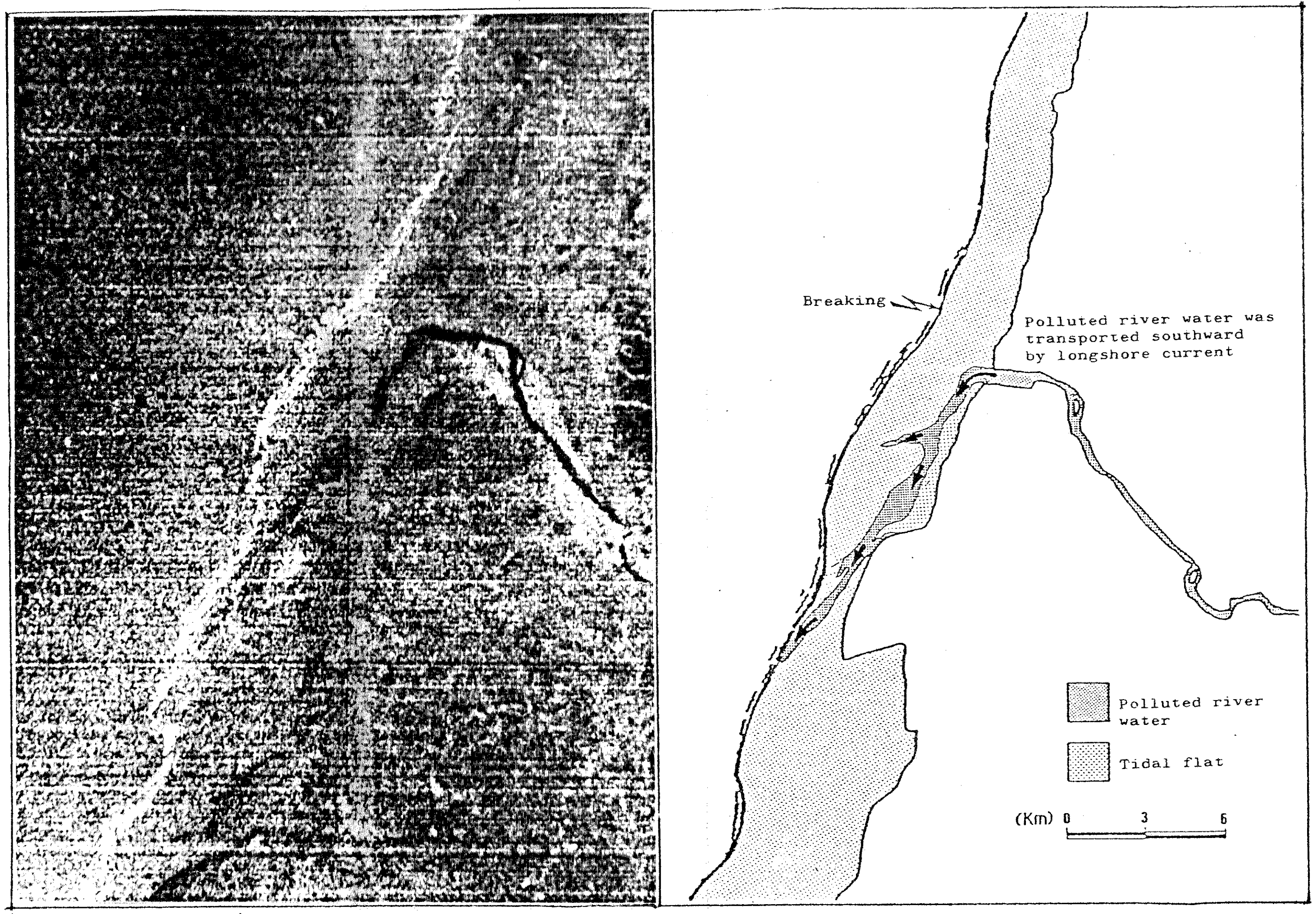

Fig 4. The LANDSAT image (band 5) taken on 1973. 1. 30. with its interpretation map. The river water moved southward mainly by the strong longshore current.

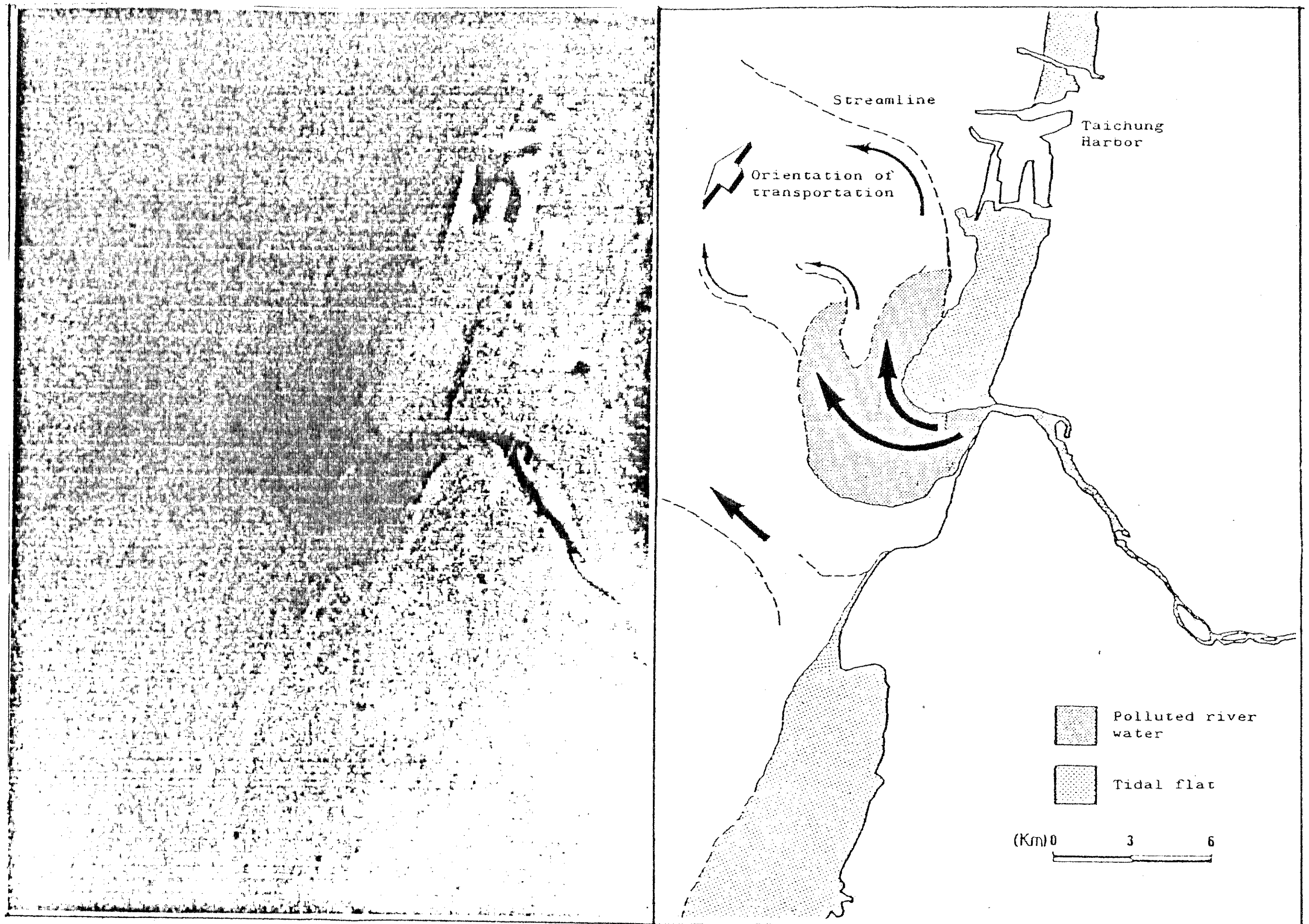

Fig 5. The LANDSAT image (band 5) taken on 1979. 1. 26. with its interpreyation map. The longshore current is not apparent. The polluted river water moves to northwest directly from the estuary.

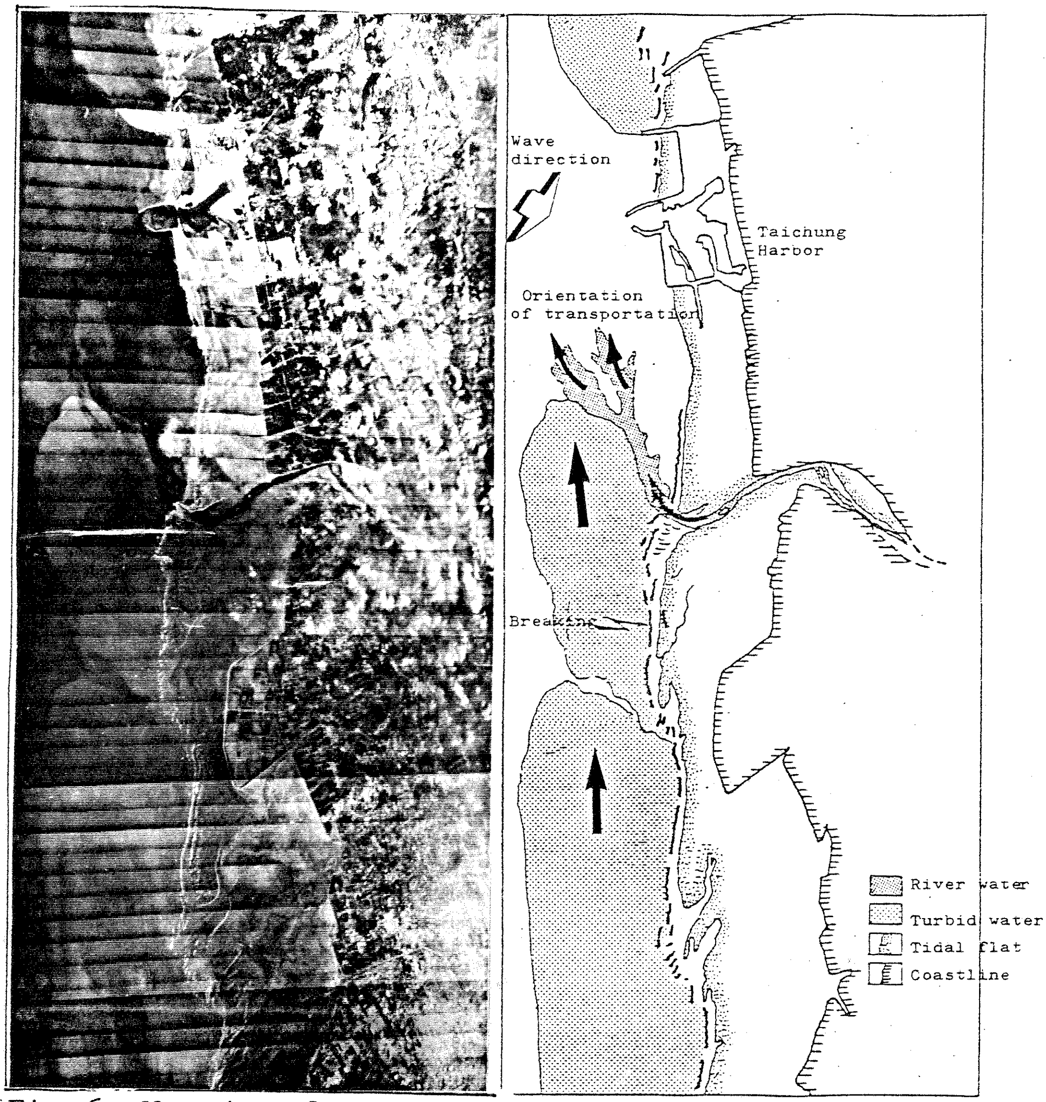

Fig 6. Mosaic of panoramic photograph taken on 1976. 10. 27. with its interpretation map. The river water moved northward directly from the estuary mainly by the nearshore current.

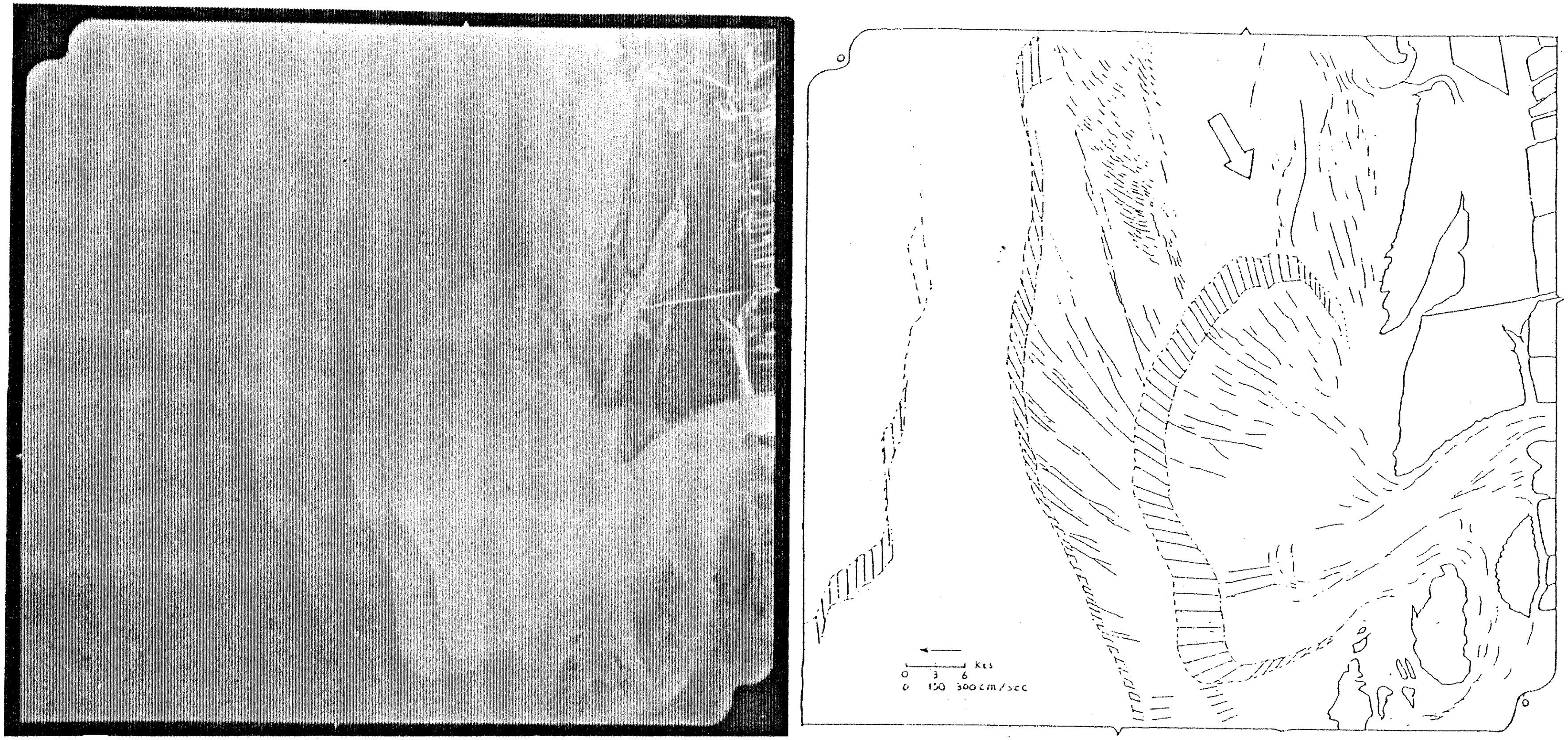

Fig 7. The water motion were measured quantitatively from successive aerial photographs. On left is the composite of two aerial photographs taken witha time interval of 14 minutes and 41 seconds. In which the turbidity patterns remains recognizable from one photograph to the next.