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TIDAL HYDROLOGY IN PEGASUS BAY

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Abstract

Changes in the geomorphology of the coastal plain river mouths of Pegasus Bay over the last 100 years are considered. Comment is also made on estuarine sediment and flow, the difficulty of measuring these two quantities and the need to treat the estuarine channel of a river as an important part of the catchment.

INTRODUCTION

New Zealand hydrologists are very much concerned with river catchment analysis but as yet have not considered the tidal section in detail. The river channel from its mouth to the maximum distance upstream of tidal influence is a complex section where fluvial and marine processes combine and conventional flow gauging methods prove unreliable. Observations from the lower reaches of some typical New Zealand rivers (Blake, 1963) indicate some of the tidal channel details and gauging problems. The rivers studied in North Canterbury were:—

River	Catchment Area (Sq. Miles)	Flow	Slope of channel (100-0 ft. m.s.l.) (ft/ft)	Upstream Saline limit approx. (mls)	Foreshore Sediment at mouth
Waimakariri	1250	Perennial	0.0018	2.00	Sand
Ashley	447	Perennial	0.0034	0.75	Sand
Kowhai	95	Inter-mittent	0.0054	0.25	Shingle
Waipara	285	Perennial	0.0054	0.25	Shingle

CHANNEL FORM

Wave action, generally reduced but variable flow velocities, aggradation and the tendency to meander combine to cause the mouth to migrate along the coastline. In several hundred years the Waimakariri river has moved along fifty miles of coastline north and south of Banks Peninsula (Jobberns, 1927). These changes involved a major re-orientation of the channel for much of its length. If the change is local, the length of the tidal section is increased, parallel to the coast, and separated from the sea by a river mouth spit (sand) or barrier (shingle). The channel slope is reduced to an inefficient gradient and the section rapidly becomes vestigial after a more direct route to the sea is opened by a flood. Figures 1-5 show changes in the morphology of the river mouths over the past 100 years.

The estuary of the spring fed Avon and Heathcote rivers is included to compete the sequence of rivers traversing the Pegasus Bay coastal plain.

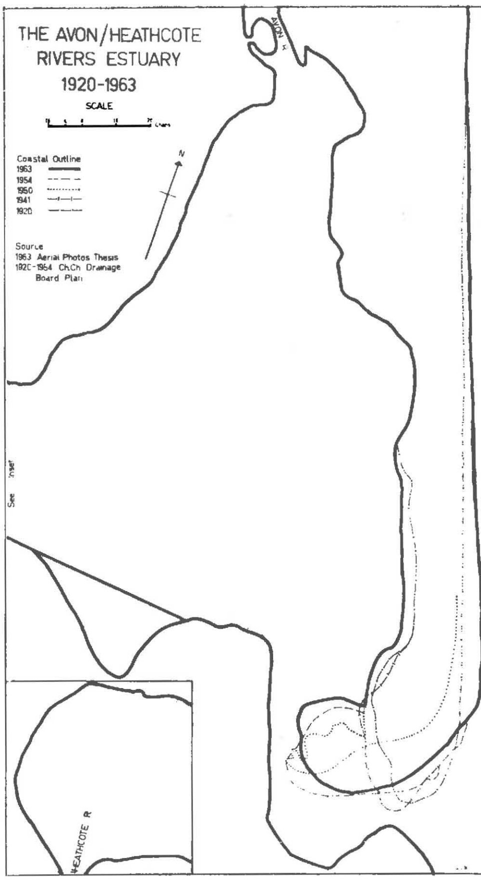

Fig 1

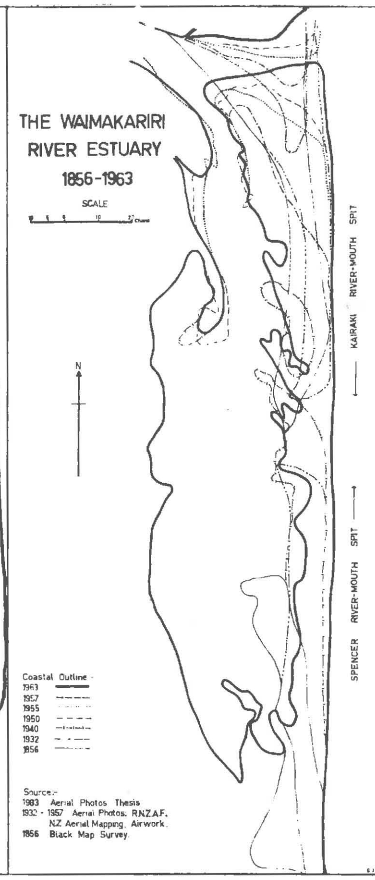

Fig 2

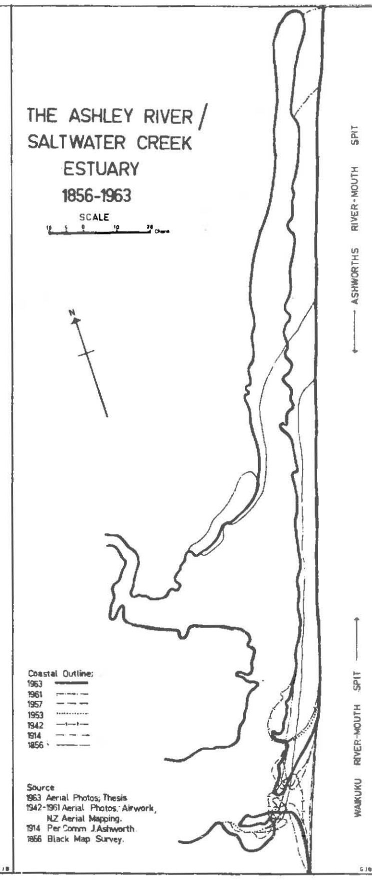

Fig 3

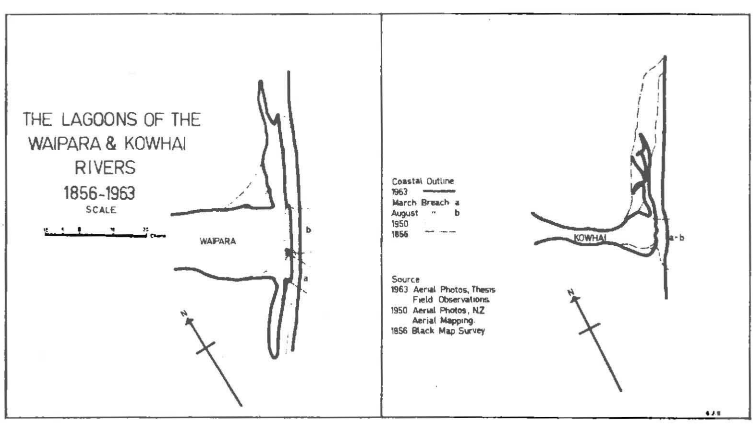

Fig 4 & 5

With the exception of silting in the estuarine channels only the spit has changed during the period of European settlement. When the Avon was a Waimakariri distributary larger flow probably caused it to enter Pegasus Bay 4 miles north of the present mouth which is prevented from further migration south by Banks Peninsula. Since 1850 this oldest spit in Pegasus Bay has become more recumbent with sediment discharged by the Waimakariri, a small river discharge and the ponding effect provided by Banks Peninsula. Fluctuations in the adjacent foreshore are closely associated with changes in position of the main tidal channel.

The Black Map Survey (1856) although indefinite in coastal outline, showed the Waimakariri estuary to be enclosed by the north trending Spenser spit and the south trending Kairaki spit forming a mouth 1.5 miles south of the present mouth. Migration has since been northwards at the expense of the Kairaki spit and it seemed that it would reach its northern-most position attained during fan building i.e. (0.75 miles north of present mouth) before protective measures, in the form of bank stabilisation, checked migration in 1964. The form of the consolidating Spenser spit testifies to northward migration.

Changes in the Ashley estuary have mainly occurred adjacent to the existing mouth. In the 1850's the mouth was 2 miles further north and, although it had moved a little south by 1860, was used by coastal shipping. Remnant foredunes on Ashworths spit mark former mouth positions. Extensive floods have frequently caused the mouth to return to its present direct position, to the sea, which has been stabilised by a large groyne.

The lagoons of the Kowhai and Waipara rivers, in contrast to the estuaries, have shown minor variation in form over the past 100 years. The Kowhai mouth has moved a maximum distance of 0.5 miles north and the Waipara mouth 0.5-1 miles north and south of its present position. Both rivers have aggraded channels which cause flood water to occupy the prograded plain around their mouths with much inconvenience to local farmers.

SEDIMENT

The low flows of the Kowhai and Waipara rivers are insufficient to maintain permanent mouths and wave action during these low flow periods limits tidal penetration by forming shingle barriers across their mouths. Shingle is less mobile than sand and as a result of its high porosity and rugosity a larger percentage of the flow is lost to channel storage. The Manning-n value, which gives an index of bed roughness, is approximately 0.035 for a well defined shingle channel and approximately 0.025 for a well consolidated sand channel (King and Brater, 1963). However, these figures apply to the "static bed state", and as dunes and anti-dunes form at lower velocities in sand than in shingle channels, it is possible that the rugosity of the former may be higher during stages when the bed is in motion (e.g. during floods).

RIVER AND TIDAL FLOW

In a tidal channel normal river flow is modified by the tidal range and cycle. The six foot tidal range in Pegasus Bay is near the minimum for New Zealand, but is sufficient to provide a diurnal sequence of water surface profiles that extend, in the case of the Waimakariri river, probably five to ten miles upstream.

During the ebb period river and tidal flow move in the same direction increasing normal velocities and discharge. In a sinuous channel "scour" and "bore" effects, which can disturb considerable quantities of estuarine sediment, may develop. The Pegasus Bay tidal channels empty during one tidal cycle but this is not always the case in lengthy channels.

With the flood tide the water level in the lower channel is raised, increasing the hydrostatic head and reducing the water surface slope; this causes the high tide profile to extend well into the freshwater reach, bed gradients permitting. The flood tide flow forms the most complex part of the tidal cycle. The damming effect of the tidal water is accompanied by variations in water density and mixing does not always occur. The freshwater flow may continue largely undisturbed, with the saline water occupying the bottom part of the channel (Hydraulics Res., 1960). In a wide channel the saline water may enter against one bank and retreat against the opposite bank in accordance with the "hydrofoil" theory (Pritchard, 1962). The ultimate flow pattern will depend on the relationship of mouth size to storage area upstream.

TIDAL GAUGINGS

In an attempt to provide flow data for engineering design, navigation and saltwater intrusion problems a number of tidal gaugings in rivers of varying sizes have been carried out in recent years. In the cases where the river flow was small the gaugings measured tidal flow with reasonable accuracy. However where the river flow is large meter gaugings can give a very skewed result unless the direction of flow at all depths is ascertained. This applies particularly to rivers with steep surface water profiles where the apparent or surface flow is seawards for all stages of the cycle.

A second problem of more frequent concern to the field hydrologist is the cyclic fluctuation of the water level. Stage recordings become meaningless if dependent on tidal stage. Proposed gauging sites for water resource work close to, but necessarily free of tidal influence, must be considered for tidal effect. In a large river a stage variation of 0.1 feet could appreciably distort the normal stage discharge curve.

The following details are suggested as a guide to investigations:

(i) A study of channel gradients, tidal range and the proximity of the proposed site to the coastline.

(ii) Daily stage records to show diurnal variations of the water level in accordance with the local tidal cycle.

(iii) A series of water samples and float measurements at varying depths to check saline content and direction of flow.

(iv) The channel appearance. Low velocities occur with banks either devoid of vegetation, or covered with distinctive estuarine species and silt. Animal life could also be indicative of tidal influence.

The tidal channel forms the mouth of the river catchment and, if for no other reason, should eventually be considered both from a flow and sediment point of view as part of the catchment. Measurements are difficult to make and may require the use of elaborate gauging techniques and the collaboration of the hydrologist with other scientific interests. Meanwhile New Zealand's water resource programme prefers to avoid the tidal reach.

REFERENCES

Black Map, 1856: *Survey of Canterbury,* Department of Land and Survey, Christchurch.

Blake, G. J., 1963: *Coastal progradation in Pegasus Bay;* Masters thesis, University of Canterbury, Christchurch, typed and bound, 188p.

Hydraulics Research 1960: G.B. D.S.I.R. Hydraulics Res. Board Rep. *Short term changes in the distribution of fine sediments in estuaries;* pp. 52 - 55.

Jobberns, G., 1927: *The Canterbury Plains, their origin and structure. Natural History of Canterbury.* Simpson and Williams, Christchurch, N.Z. 299 pp.

Pritchard, D. W. 1962: Estuarine hydrography in *Advances in Geophysics.* ed: Landsberg. Vol. 1, pp. 243 - 80.