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CIRCULATION AND HYDROLOGY OFF THE WEST COAST OF THE NORTH ISLAND OF NEW ZEALAND BETWEEN CAPE TERAWHITI AND KAWHIA HARBOUR

by R.A. HEATH

Publications in this series result from specific enquiries for information. They record and comment on relevant available data.

The present summary was prepared to assist environmental studies of the area that might be affected by development of the Maui Gas Field.

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CIRCULATION AND HYDROLOGY OFF THE WEST COAST OF THE NORTH ISLAND OF NEW ZEALAND BETWEEN CAPE TERAWHITI AND KAWHIA HARBOUR

R.A. Heath

INTRODUCTION

This summary brings together the published physical oceanographic studies made within the area of the New Zealand west coast extending from Cape Terawhiti to Kawhia Harbour (Fig. 1) to give some indication of the physical oceanographic environment in this area.

CIRCULATION

The circulation on the west coast of New Zealand is closely connected with that on the east coast of Australia. The East Australian Current is deflected east at about 34°S after flowing down the east Australian coast (Hamon 1965).

There is a general north-easterly drift in the northern Tasman Sea, away from the Australian coast (Garner 1969a, 1970). In the southern Tasman Sea the flow is directed more easterly. On meeting the New Zealand coast this easterly flow appears to branch near Jacksons Head, the southern component flowing through Foveaux Strait and south of Stewart Island to contribute to the north-east flowing Southland Current on the east coast of the South Island (Garner 1969a). The other component flows north as the Westland Current (Fig. 1). The Subtropical Water from this flow forms the surface current in the region of interest here.

The Flow in Cook Strait

The few current measurements made in Cook Strait (principally in southern Cook Strait) have shown that the main flow is tidal and highly variable (Olsson 1955; Gilmour 1960), with current speeds of up to 7 knots (Admiralty, Hydrographic Department 1958). These strong tidal flows result from the differences in tidal height at either end of the Strait - the phase difference of the main tidal component, the principal lunar semi-diurnal constituent M_2, between Makara and Wellington (Fig. 1) is 118°. Numerical models of the tidal flow in this area have been developed by Bradford and Wooding (1974) for the tidal flow in the vicinity of Mana Island, Bye and Heath (in press) for the New Zealand M_2 tides, and by Heath (in press) for the M_2 tide in Cook Strait. The amplitude and direction of flow at each quarter of the M_2 tidal cycle for the entire New Zealand model are shown in Figs 2 and 3 respectively, and the velocities at seven positions in the Cook Strait model are shown in Fig. 4. Amplitudes in these models compare favourably with those observed; however there is little data with which to compare the velocities and they should be regarded as tentative.

The mean circulation in Cook Strait has been deduced from drift card records (Brodie 1960; Heath 1969) and changes in water characteristics (Garner 1953, 1954, 1959a, b, 1961; Heath 1971). Warm saline Subtropical Water in the D'Urville Current sweeps into the centre of Cook Strait from the north-west (Brodie 1960; Heath 1969) - this current is derived from the Westland Current flowing northwards along the west coast of the South Island. The water of the Southland Current, a current of cool less saline water flowing northwards along the east coast of the South Island (Brodie 1960; Garner 1961; Jillett 1969; Heath 1972), mixes with the warmer more saline water of the D'Urville Current in the Narrows of Cook Strait and with warm saline water over the Cook Strait Canyon derived from the East Cape Current, a current of warm saline water flowing southwards along the east coast of the North Island (Sdubbundhit and Gilmour 1964; Garner 1967, 1969a; Heath 1968, in press b). Mixed water derived from all three currents travels eastwards across Cook Strait and around Cape Palliser.

These studies then indicate a mean current of warm saline water sweeping into Cook Strait from the north-west, this water having flowed northwards along the west coast of the South Island. This flow would appear to be most concentrated on the eastern side of Cook Strait. The cooler temperature and lower salinity often found on the western side of the Strait along the entrance to the Marlborough Sounds (Fig. 1) indicate that there might sometimes be a general northerly movement there, this water being derived from the Southland Current (Heath 1971). However, in view of the large tidal flow in the area and the large barotropic currents which will be generated by the strong winds in this area, blowing mainly from the north (Garnier 1958 : 47), the circulation must be very complicated and highly variable. Some indication of the strong dependence of the direction of movement of the mean surface water on the wind in this general area is given by both the close correlation between the movement of drift cards released in Tasman Bay in different seasons and the corresponding directions of the general winds (Heath 1973) and the isolated drift cards that have travelled northwards through Cook Strait having been dispatched off the east coast of the South Island,

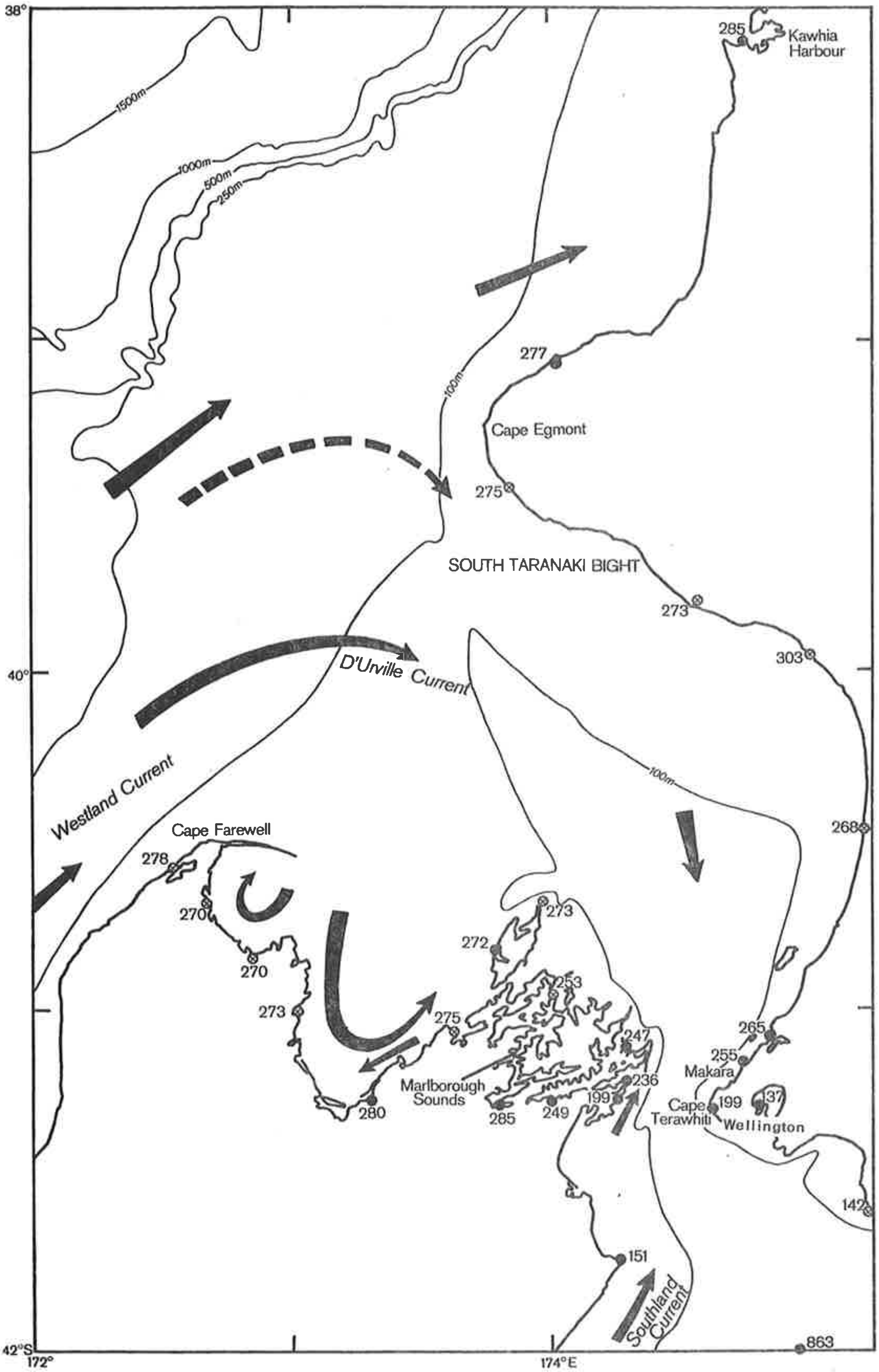

Fig. 1. Mean circulation and bathymetry (m) of the region. The numbers along the coast are the phases (°) of the principal lunar semi-diurnal tide (Admiralty, Hydrographic Department 1963). • signifies a value calculated by harmonic analysis; × signifies a value calculated from the relative time of high water.

being retrieved on the west coast of the North Island (Brodie 1960).

The only published direct current velocity measurements for the area of interest away from the Cook Strait Narrows are the tidal stream measurements given on hydrographic charts of the area - the mean flow over a tidal cycle and the largest velocities are shown on Fig. 5. However these should also be regarded as extremely tentative as they would appear to have been made over only one tidal cycle.

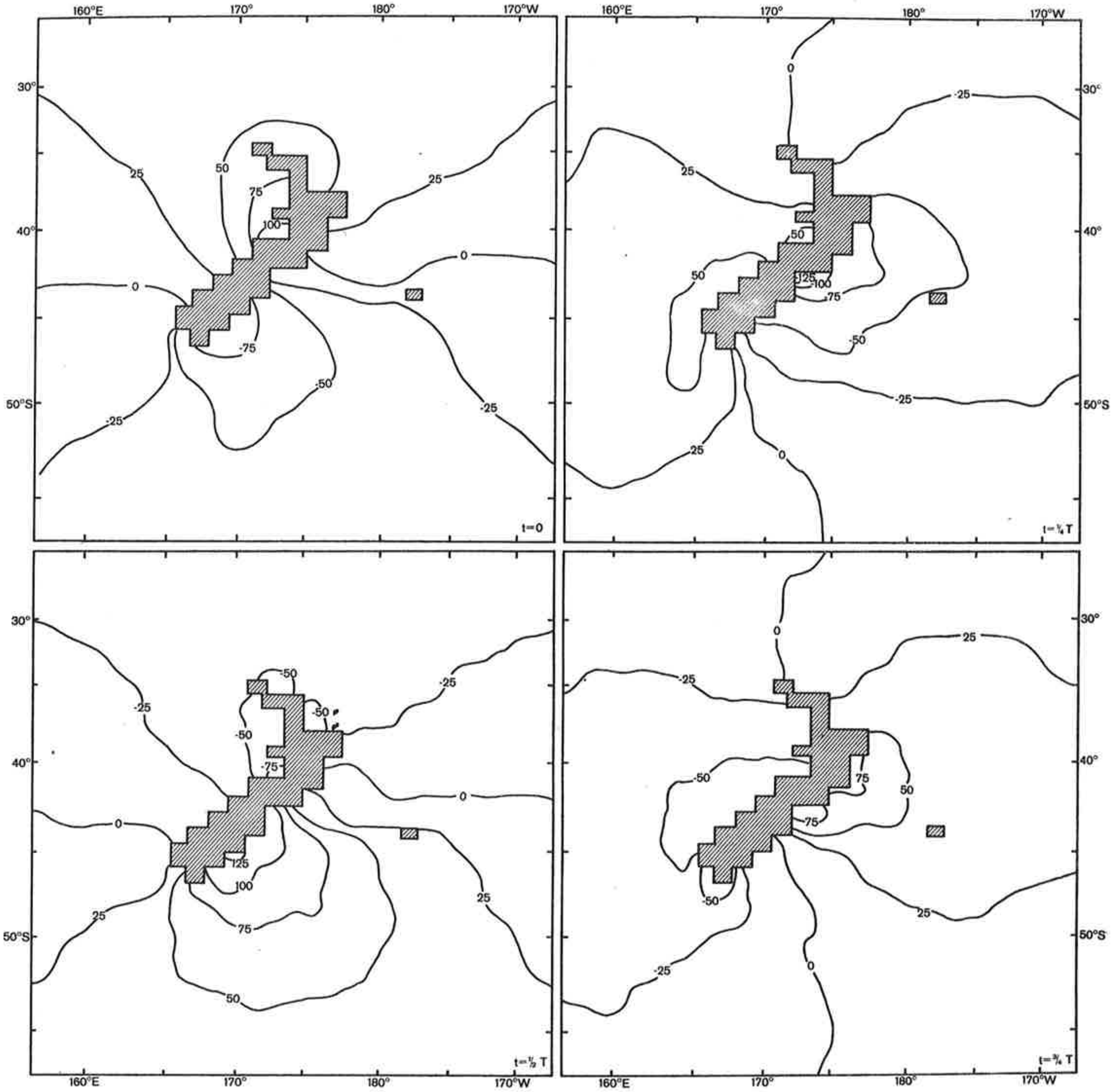

Fig. 2. Tidal elevations (cm) at quarter cycle intervals from the numerical model of Bye and Heath (in press, Fig. 3).

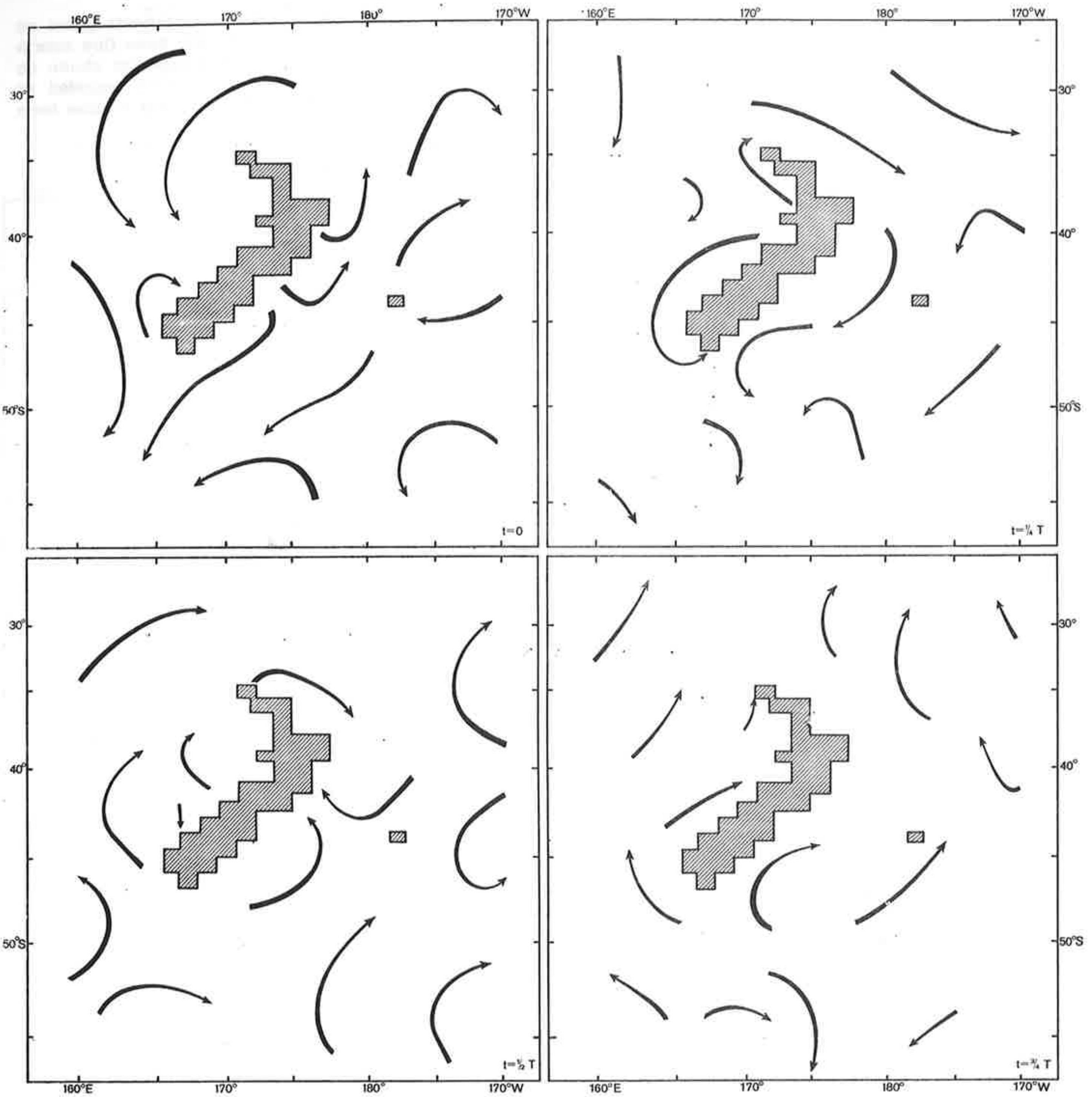

Fig. 3. Direction of the tidal stream at quarter cycle intervals from the numerical model of Bye and Heath (in press, Fig. 4).

The Flow Around and North of Cape Egmont

The detail of the flow on the west coast of the North Island north of Cape Egmont is possibly the least well known around New Zealand, for there the water is shallow (Fig. 1) and the horizontal changes in the mass field are weak - both of these facts lead to the situation where the use of the conventional tool of oceanography - the geostrophic method - is questionable. Drift cards records reported by Brodie (1960), Garner (1961) and Ridgway (1973) show a northwards drift from Cape Egmont to at least Kawhia Harbour,

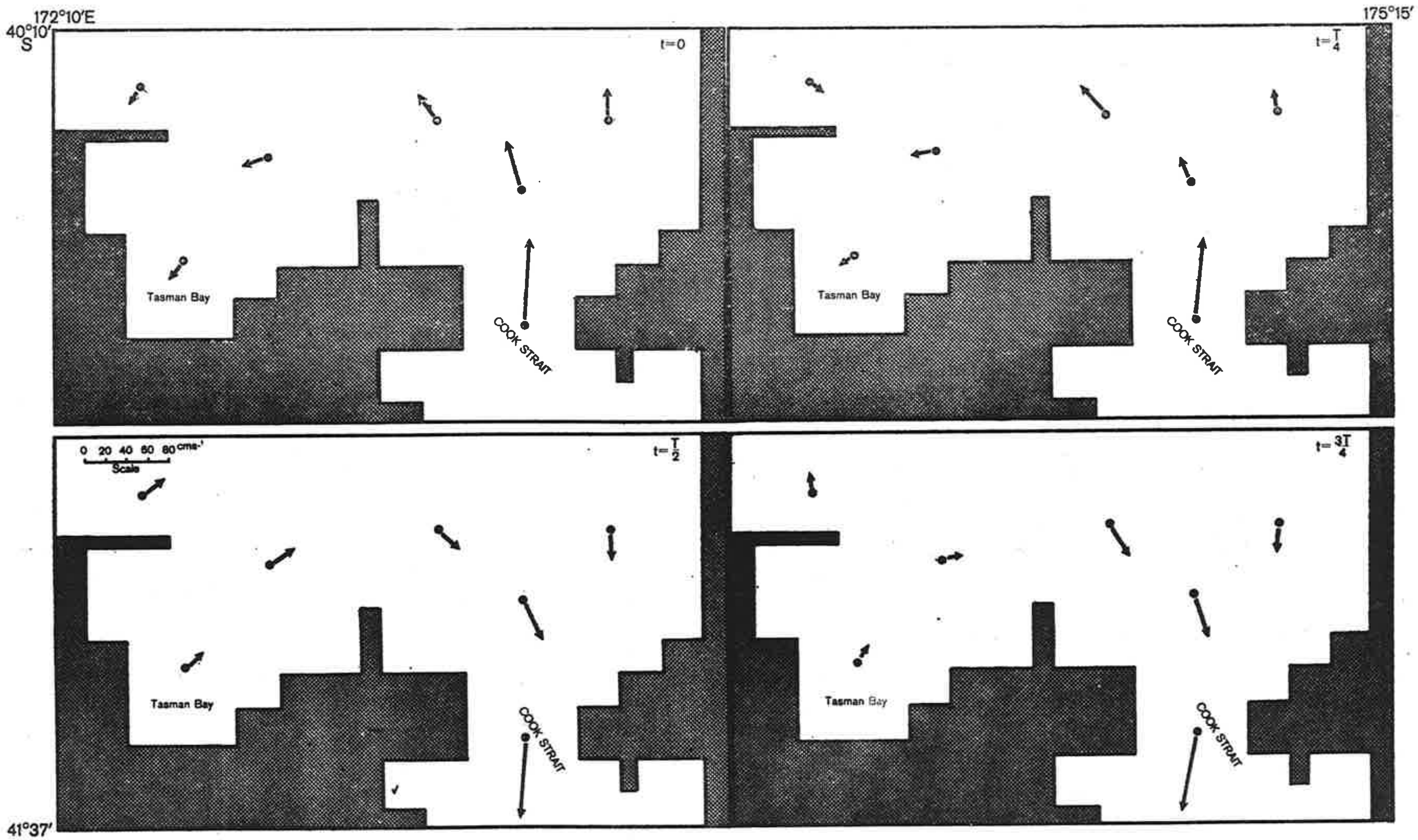

Fig. 4. Principal lunar semi-diurnal tidal velocities in Cook Strait at the end of each quarter of the tidal cycle, T the tidal period; t = o, high tide at Cape Palliser.

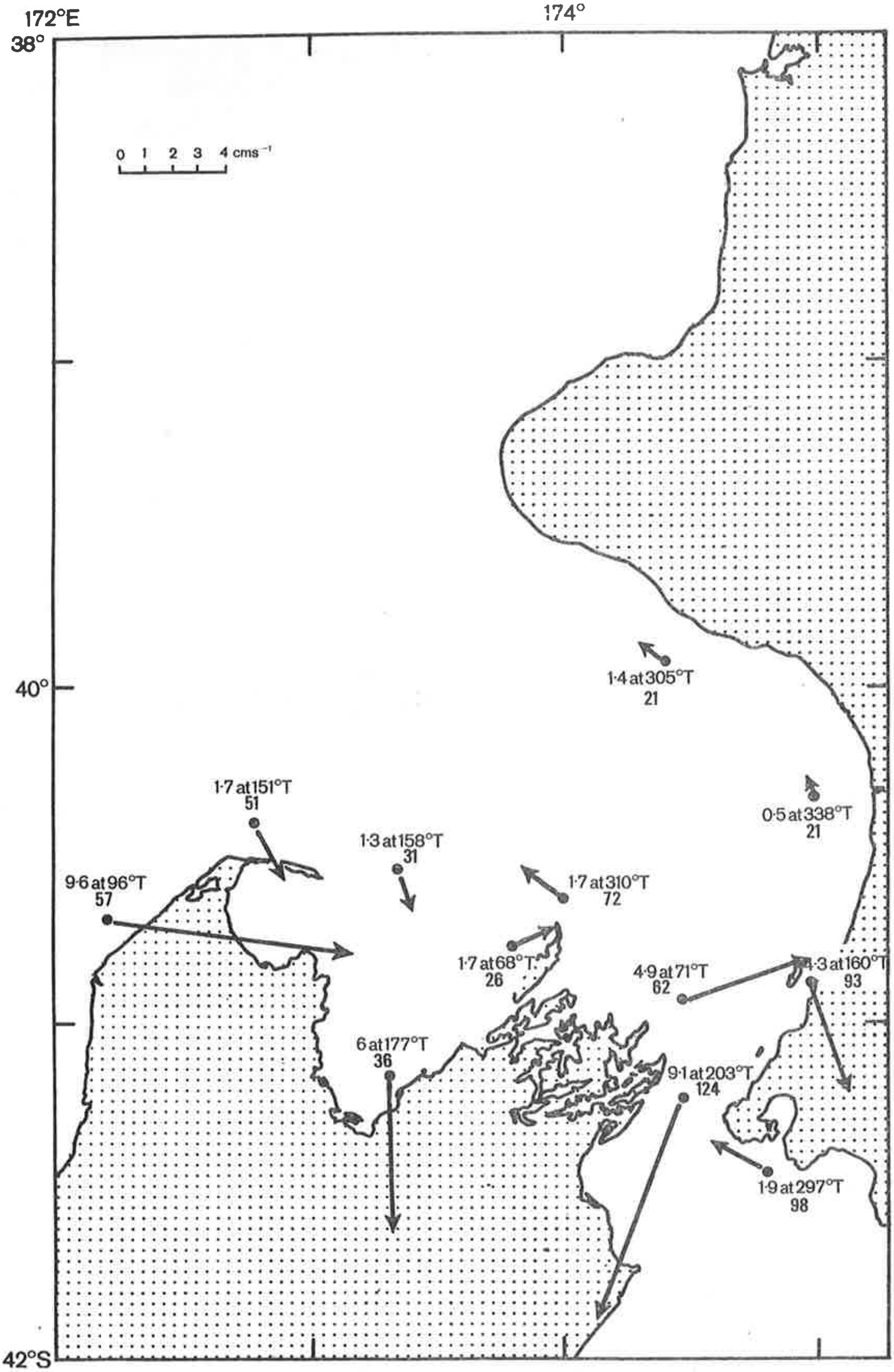

Fig. 5. Mean current vectors calculated from current velocities given on hydrographic charts (Hydrographic Office, R.N.Z.Navy 1960a, b). The upper numbers give the mean speed (cm s^{-1}) at the given direction; the lower numbers give the maximum tidal speed (cm s^{-1}).

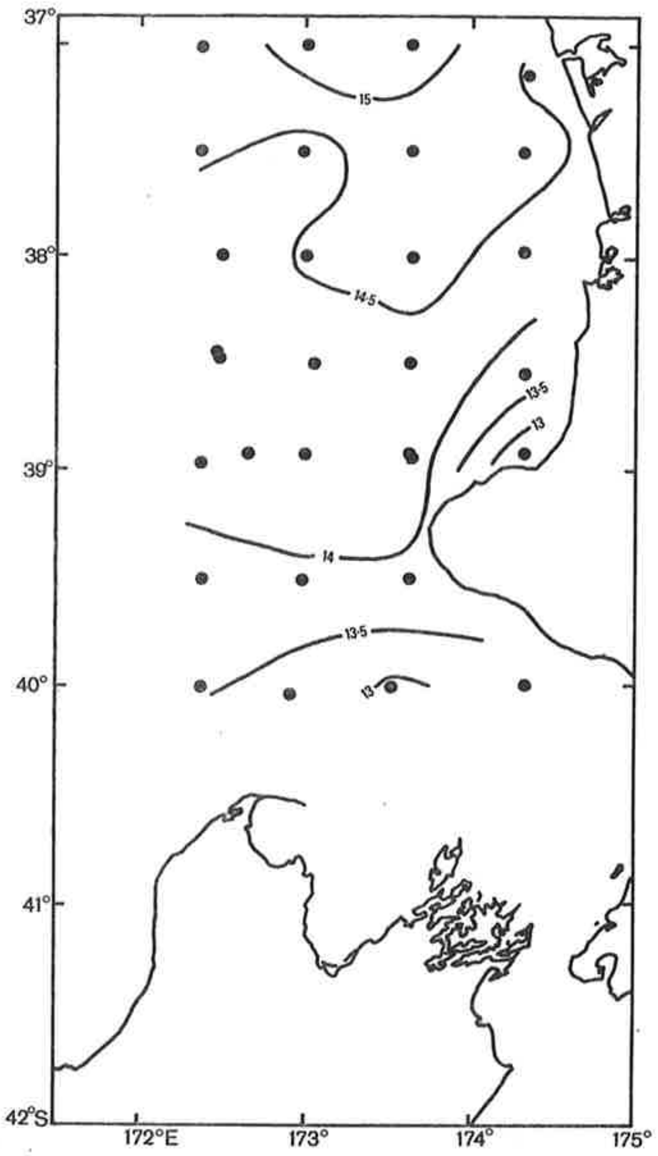

Fig. 6. Isotherms (°C) at the sea surface for observations made by Ridgway (pers. comm.) in August 1973.

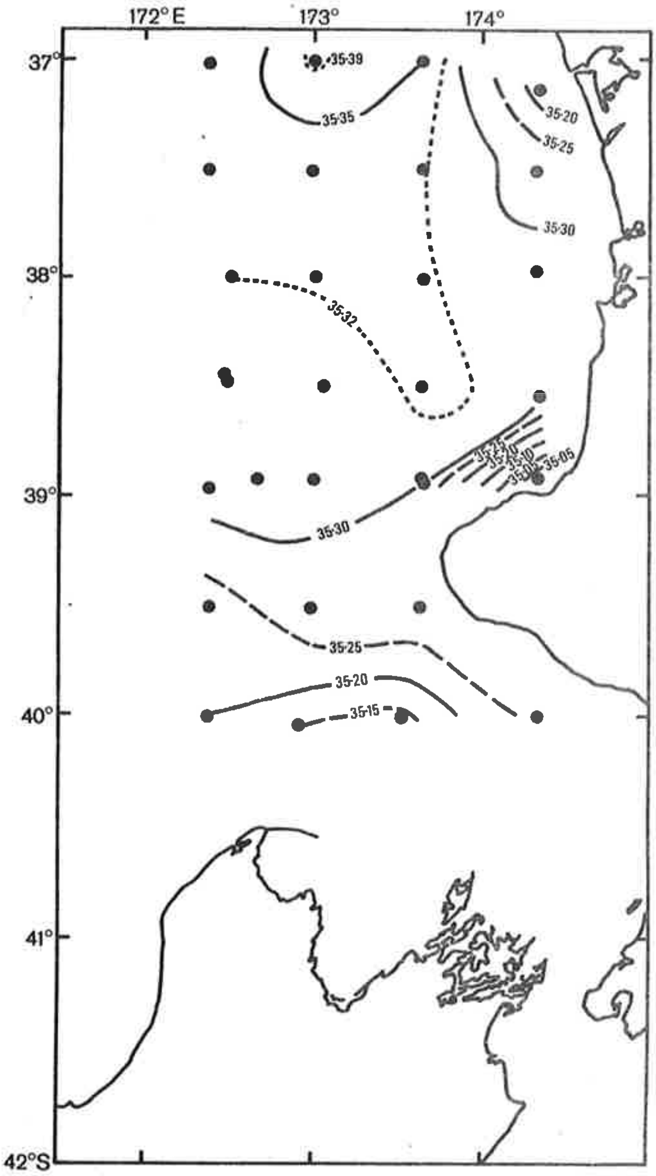

Fig. 7. Isohalines (%) at the sea surface for observations made by Ridgway (pers. comm.) in August 1973.

the area of interest here. Parachute drogue measurements made recently by Ridgway (pers. comm.) indicate a very weak northwards flow.

The region from where the flow diverges either south-eastwards in the D'Urville Current into Cook Strait or northwards in the continuation of the Westland Current is not at all well known. Drift cards released by Garner (1961) in a line westwards from Cape Egmont indicate a south-eastwards drift in this region close inshore - further offshore however (greater than about 30 km) in autumn the drift was northwards. Other localised studies near Cape Egmont show that the currents close inshore are mainly wind-induced and affected by the coastal configuration, with the tidal currents not being significant (e.g., studies made by the Taranaki Harbour Board [Ridgway 1973], Hydrographic Office 1965) - the small tidal currents in this area are expected, the phase of the M_2 tide changes very little along the coast (Fig. 1). This part of the circulation then - that close to the coast and offshore near Cape Egmont - needs extensive study.

HYDROLOGY

The water found offshore in the region of interest has subtropical characteristics. Isolines of sea surface temperature and salinity in August 1973 are shown in Figs 6 and 7 respectively (from Ridgway, pers. comm.).

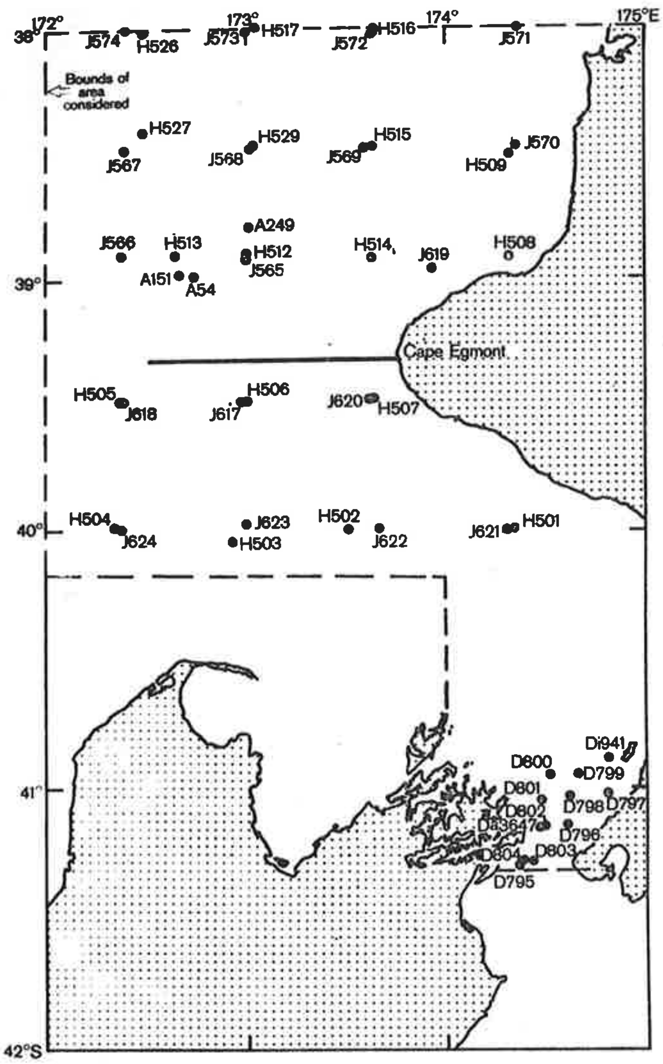

Fig. 8. Position of the available standard temperature/ salinity/depth stations (excluding stations where only surface values were measured). Stns A54, A151, A249, Di 941, Da 3647 from Garner (1962); Stns D795-D804 (occupied in December 1968) from Heath (1971); Stns H501-H509, H512-H517, H526, H527, H529 (occupied in August 1973); Stns J565-J574, J617-J624 (occupied in February 1974) all from Ridgway (pers. comm.). The line off Cape Egmont is the line along which Garner (1961) occupied stations at approximately 5-mile intervals in February, May and October 1955.

The positions of the available standard temperature/ salinity with depth stations (excluding stations where only surface values were measured) are shown along with the reference to the observations in Fig. 8. In summer when a seasonal thermocline is developed at a depth of about 25 m, the water offshore where the bottom depth is around 100 m has surface and bottom temperatures of 17°C and 13°C respectively near Cape Farewell increasing to 20°C and 14°C respectively near Kawhia Harbour (Garner 1969b). In winter the water is nearly isothermal with depth, the corresponding horizontal temperature range being from 13°C near Cape Farewell to 14.5°C near Kawhia Harbour (Garner 1969b). The salinity of water on the continental shelf which has not obviously been diluted by freshwater inflow is around 35.0‰ in summer and 34.8‰ in winter (Garner 1961). Temperatures and salinity generally decrease eastwards towards Cook Strait Narrows where typical surface summer and winter values are 17°C, 34.9‰ and 12°C, 34.8‰ respectively. Cook Strait Narrows itself is a region where three water masses of different origin meet and mix, the large amount of turbulent energy in the tides presumably enhancing this mixing. There is then a rapid spatial change in the parameters (Fig. 9). The large amount of energy available for mixing probably also accounts for the near homogeneous nature of the water with depth immediately north of Cook Strait Narrows even in summer (Fig. 9).

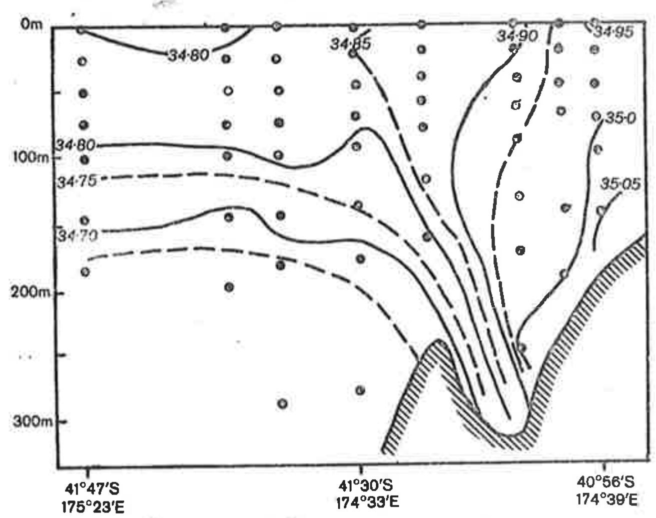

Fig. 9. Cross-sectional salinity (‰) profile through Cook Strait (after Heath 1971).

Surface distribution of temperatures and salinities of the area in northern Cook Strait often show tongue-like features pointing into the Strait from the west (Garner 1961; Roberts*, pers. comm.). Close to the coast in the South Taranaki Bight (Fig. 1) tongues of low salinity water resulting from river discharge have been found extending westwards towards Cape Egmont (Garner 1961; Roberts*, pers. comm.) indicating a flow towards the west close inshore. Rapid spatial changes in temperature observed near Cape Egmont support the view that the circulation in this area is complicated and probably highly variable.

* Report in preparation by P.E. Roberts and L.J. Paul of Fisheries Research Division, Ministry of Agriculture and Fisheries, on surface and bottom temperatures and salinities off the west coast of the North Island.

Similar distributions on the west coast of the North Island immediately north from Cape Egmont generally show isolines running parallel to the coast with both the temperature and salinity increasing westwards (Figs 6, 7). These isolines form part of the eastern margin of a high salinity tongue extending southwards off the west coast of the North Island (Ridgway, pers. comm.; Roberts*, pers. comm.). Localised regions of warm water inshore can, however, develop in summer.

REFERENCES

ADMIRALTY, HYDROGRAPHIC DEPARTMENT 1958: 'The New Zealand Pilot' 12th Ed. London. 500 pp.

ADMIRALTY, HYDROGRAPHIC DEPARTMENT 1963: 'The Admiralty Tide Tables. Volume 3. Pacific and adjacent seas.'. London.

BRADFORD, E.; WOODING, R.A. 1974: Tidal flow in the vicinity of Mana Island. *Tech. Rep. Applied Math. Div. N.Z. Dep. scient. ind. Res. 19.*

BRODIE, J.W. 1960: Coastal surface currents around New Zealand. *N.Z. Jl Geol. Geophys. 3(2)* : 235-52.

BYE, J.A.T.; HEATH, R.A. (in press): The New Zealand semi-diurnal tide. *J. Mar. Res.*

GARNER, D.M. 1953: Physical characteristics of inshore surface waters between Cook Strait and Banks Peninsula, New Zealand. *N.Z. Jl Sci. Technol. Sect. B. 35(3)* : 239-46.

GARNER, D.M. 1954: Sea surface temperature in the Southwest Pacific Ocean from 1949 to 1952. *N.Z. Jl Sci. Technol. Sect. B. 36(3)* : 285-303.

GARNER, D.M. 1959a: Nomenclature of water masses in the Tasman Sea. *Aust. J. mar. Freshwat. Res. 10(1)* : 1-6.

GARNER, D.M. 1959b: The Sub-tropical Convergence in New Zealand surface waters. *N.Z. Jl Geol. Geophys. 2(2)* : 315-57.

GARNER, D.M. 1961: Hydrology of New Zealand coastal waters, 1955. *Mem. N.Z. oceanogr. Inst. 8. (Bull. N.Z. Dep. scient. ind. Res. 138).*

GARNER, D.M. 1962: Analysis of hydrological observations in the New Zealand region 1874-1955. *Mem. N.Z. oceanogr. Inst. 9. (Bull. N.Z. Dep. scient. ind. Res. 144).*

GARNER, D.M. 1967: Hydrology of the Southern Hikurangi Trench region. *Mem. N.Z. oceanogr. Inst. 39. (Bull. N.Z. Dep. scient. ind. Res. 177).*

GARNER, D.M. 1969a: The geopotential topography of the ocean surface around New Zealand. *N.Z. Jl mar. Freshwat. Res. 3(2)* : 209-19.

GARNER, D.M. 1969b: The seasonal range of sea temperature on the New Zealand shelf. *N.Z. Jl mar. Freshwat. Res. 3(2)* : 201-8.

GARNER, D.M. 1970: Hydrological studies in the New Zealand region 1966 and 1967. Oceanic hydrology north-west of New Zealand. Hydrology of the north-east Tasman Sea. *Mem. N.Z. oceanogr. Inst. 58. (Bull. N.Z. Dep. scient. ind. Res. 202).*

GARNIER, B.J. 1958: 'The Climate of New Zealand. A geographic survey'. Arnold, London. 191 pp.

GILMOUR, A.E. 1960: Currents in Cook Strait. *N Z Jl Geol. Geophys. 3(3)* : 410-31.

HAMON, B.V. 1965: The East Australian Current, 1960-1964. *Deep Sea Res. 12(6)* : 899-921.

HEATH, R.A. 1968: Geostrophic currents derived from oceanic density measurements north and south of the Subtropical Convergence east of New Zealand. *N.Z. Jl mar. Freshwat. Res. 2(4)* : 708-11.

HEATH, R.A. 1969: Drift card observations of currents in the central New Zealand region. *N.Z. Jl mar. Freshwat. Res. 3(1)* : 3-12.

HEATH, R.A. 1971: Hydrology and circulation in central and southern Cook Strait, New Zealand. *N.Z. Jl mar. Freshwat. Res. 5(1)* : 178-99.

HEATH, R.A. 1972: The Southland Current. *N.Z. Jl mar. Jl mar. Freshwat. Res. 6(4)* : 497-523.

HEATH, R.A. 1973: Meteorological effects on the surface circulation and hydrology of Tasman Bay, New Zealand. *N.Z. Jl mar. Freshwat. Res. 7(1 & 2)*: 111-23.

HEATH, R.A. (in press, a): A numerical model of the lunar semi-diurnal tide in Cook Strait, New Zealand. *Dt. hydrogr. Z.*

HEATH, R.A. (in press, b): Oceanic circulation off the east coast of New Zealand. *Mem. N.Z. oceanogr. Inst. 55.*

HYDROGRAPHIC OFFICE, ROYAL NEW ZEALAND NAVY 1960a: Chart NZ 61, Karamea River to Stephens Island 1:200,000.

HYDROGRAPHIC OFFICE, ROYAL NEW ZEALAND NAVY 1960b: Chart NZ 46, Wellington to Patea including Cook Strait 1:200,000.

HYDROGRAPHIC OFFICE, ROYAL NEW ZEALAND NAVY 1965: Chart NZ 45, Port Taranaki to Patea 1:200,000.

JILLETT, J.B. 1969: Seasonal hydrology of waters off the Otago Peninsula, southeastern New Zealand. *N.Z. Jl mar. Freshwat. Res. 3* : 349-75.

OLSSON, B.K. 1955: The electrical effects of tidal streams in Cook Strait, New Zealand. *Deep Sea Res. 2(3)* : 204-12.

RIDGWAY, N.M. 1973: Some oceanographic observations in the vicinity of proposed thermal power stations. II. New Plymouth. *In* Zwartz, D. (ed.) 'Proceedings of the Pollution Research Conference, Wairakei, New Zealand, 20-21 June 1973'. *Bull. N.Z. Dep. scient. ind. Res. 212* : 505-18.

SDUBBHUNDHIT, Cha Erb; GILMOUR, A.E. 1964: Geostrophic currents derived from oceanic density over the Hikurangi Trench. *N.Z. Jl Geol. Geophys. 7(2)* : 271-78.

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