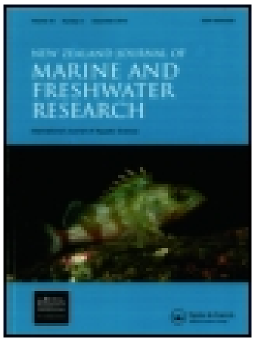

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A. E. Gilmour

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Short communication

Response of Wellington Harbour to the tsunamis of 1960 and 1964

A. E. GILMOUR
New Zealand Oceanographic Institute
Division of Water Sciences
Department of Scientific and Industrial Research
Private Bag, Kilbirnie, Wellington, New Zealand

Abstract Spectral analyses of water-level oscillations in Wellington Harbour during the 1960 Chilean and 1964 Alaskan tsunamis are given. The results are used to define the periods for the three longest-period characteristic oscillation modes. Some implications for future tsunamis are discussed.

Keywords Wellington; tsunami; oscillation modes

INTRODUCTION

Wellington Harbour is a well-sheltered harbour at the southern end of the North Island, New Zealand. Its hydrology has been described by Heath (1977). The surface area is about 85 km^2 and the maximum width about 11.1 km (Fig. 1). Access to Cook Strait is via a channel with a maximum width of 1.8 km and a maximum depth of 14 m. The average depth of the harbour is about 14 m.

Heath (1976) discussed the response of Wellington Harbour to the 1960 Chilean tsunami. Butcher & Gilmour (1987) modelled the expected characteristic frequencies of oscillation in Wellington Harbour, using data from the 1960 tsunami to support their findings. Here the harbour response to the 1960 Chilean and 1964 Alaskan tsunamis is examined in more detail. In particular, better information on characteristic oscillation periods is sought. The relative amount of energy in the different oscillations is also sought under the conditions generated by a Pacific-wide tsunami.

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DATA

Copies of the record from the Wellington Harbour Board gauge (Heath 1976) were obtained from the NZ Hydrographic Office tidal library. 32 h of record from the Chilean tsunami, from 1900 h (23 May 1960) to 0300 h (25 May 1960), were digitised with a time interval of 1/16 h giving a time series with $N = 512$ terms.

A single-frequency sine wave representing the tide was fitted to the data and subtracted from it. Thus the majority of the signal analysed was generated by the tsunami.

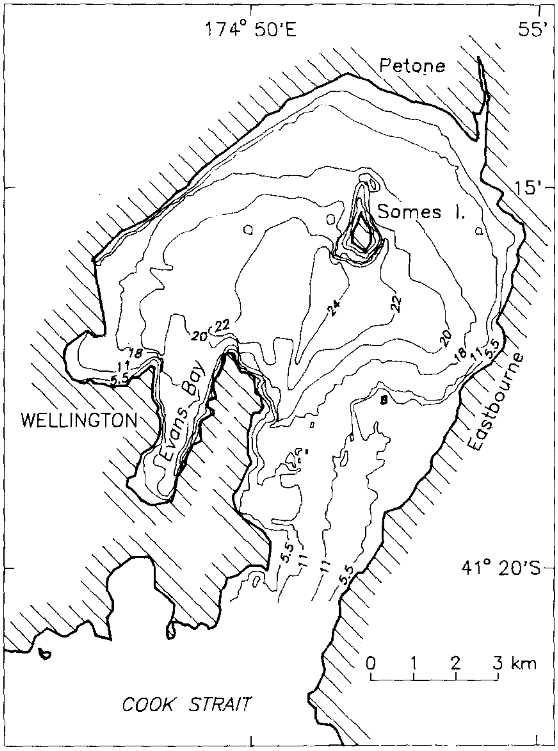

Fig. 1 Chart showing the location and approximate depth of Wellington Harbour in metres.

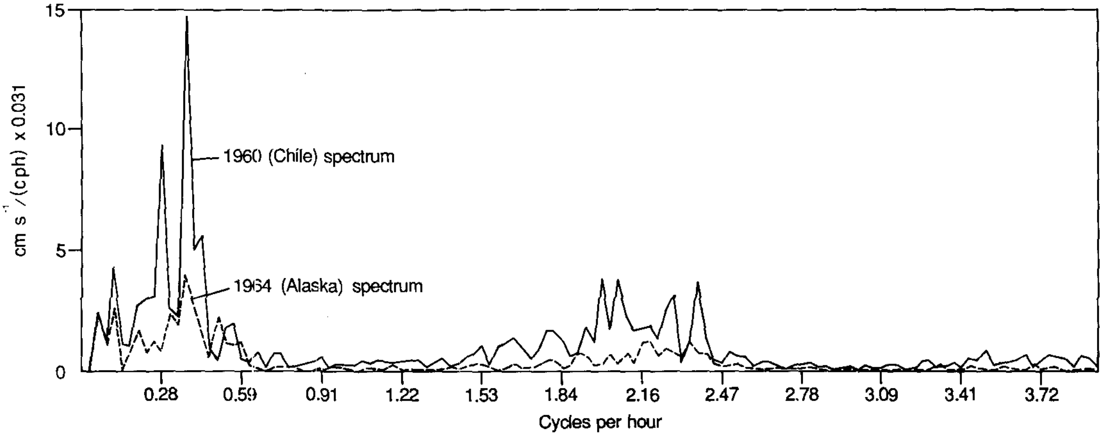

Fig. 2 Amplitude spectrum showing the response in Wellington Harbour to the 1960 Chilean tsunami and the 1964 Alaskan tsunami.

A similar time series was found for the Alaskan tsunami of 1964. The start and finish times were 1000 h (29 March 1964) and 1800 h (30 March 1964), respectively. The amplitude of both series was expressed in cm. Effects observed during the 1964 tsunami were quite small, but the data have been analysed so that comparisons can be made with the data from 1960.

RESULTS

Frequency spectra for the two series were found by a fast Fourier analysis. The square roots of the power spectra are shown in Fig. 2. Frequencies are plotted as cycles h^{-1}.

Both spectra have peaks at 12/32 = 0.375 cycles h^{-1} (period $T = 160$ min) and the 1960 tsunami has a peak at 9/32 = 0.281 cycles h^{-1} ($T = 213$ min). It is known that the fundamental period for long-wave oscillations in the harbour is close to 160 min (Butcher & Gilmour, 1987) but the 213-min oscillation period was unexpected. It may have been caused by a peak in the oceanic spectrum for the tsunami or was possibly associated with a shelf resonance in Cook Strait. Peaks at longer periods occur in both spectra. These would be caused in part by tidal effects.

Spectral peaks occur for the 1960 tsunami between 62/32 = 1.94 and 76/32 = 2.38 cycles h^{-1} (i.e., between periods of 31 and 25 min). Butcher & Gilmour (1987) predicted that the second and third oscillation modes would have periods of 28.9 and 26.1 min. It appears that the energy associated with these modes falls into diffuse spectral bands. This can be expected to some degree, because of the effects of tides on the average depth of the harbour and also because of interaction between various modes of oscillation. In this band the expected variance of the spectral values is approximately equal to the average value.

From Fig. 2 the fundamental mode is apparently close to 160 min. For Modes 2 and 3, the periods are estimated from the centres of the power distributions to be 29.5 and 25.8 min, respectively.

Butcher & Gilmour (1987) predicted periods of 18.9, 17.7, and 15.7 min for Modes 4, 5, and 6, respectively. These periods correspond to frequencies of 3.17, 3.39, and 3.82 cycles h^{-1} in Fig. 2. There is some spectral signal present close to these values, but they are not resolved.

IMPLICATIONS AND CONCLUSIONS

Two Pacific-wide tsunamis have been examined. In both case the majority of the power is located in the fundamental mode (period 160 min). Power decreases with increasing frequency. The amplitudes of the oscillations with periods close to 29.5 and 25.8 min are about one-third of the amplitude of the oscillation at 160 min. Generally, Pacific-wide tsunamis will have long characteristic periods and consequently the higher-frequency oscillation modes are less likely to be energised. However, it is quite probable that a tsunami of distant origin with a characteristic period close to 25–30 min would energise mainly the second and third harmonics. The maximum oscillation would occur after several cycles.

The results are more uncertain for tsunami generation within the harbour, but probably the fundamental mode would be less important than some of the higher-frequency modes whose spatial distribution is more complex.

The spectral curves in Fig. 2 mimic each other considerably. It is likely that future tsunamis with a distant origin will give responses similar to that for the 1960 tsunami unless the incident tsunami energy is predominantly in a period band of c. 25–30 min.

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