SMOOTHING PERMANENT RECORDS OF LAKE LEVEL (NOTE)

S. M. Thompson* and R. P. Ibbitt*

INTRODUCTION

Research on floods, eutrophication, beaches and possibly other topics requires data derived from continuous measurements of lake level. The measurements are easy to make but subsequent storage and use of the data is much more difficult. Lake level is an insensitive measure of inflow, and so it is essential to extract the maximum possible resolution from the measurements when inflows are to be derived. The data processing method to be described was developed for this critical application, and is currently used routinely on measurements from 40 lakes in New Zealand. At most of these lakes there is no other measurement which represents the temporal variation of flow from the catchment. Perhaps more use will be made of these data when their scope and precision are better known.

Until recently measurements were recorded on charts with a small time scale so that unwanted oscillations of the recording pen merged together to give a wide trace, and a mean line was put through this broad trace that effectively smoothed the record. Now that punched tape recorders have been introduced more precise and objective smoothing is possible. It is important that users of processed lake level data be aware of the nature and limitations of this processing, in particular how seiches have been treated.

SEICHES

A wind seiche occurs when the surface water blown against a downwind shore is released by a change of wind. The lake surface then undergoes a seesaw oscillation. In contrast a barometric seiche, which occurs when a barometric pressure gradient passes over a lake, tilts the surface after which normal barometric pressure forces it level again. Typically barometric pressure gradients take several hours to pass over New Zealand's larger lakes while the period of wind seiches is of the order of half an hour.

Other causes of seiche including earthquakes and tributary flood flows are believed to be much less significant.

The free oscillations set up by the wind follow a regular pattern until eventually damped out by friction at the lake bed. In deep lakes damping is slow and each seiche persists until modified by a wind change. Such changes establish new patterns of oscillations, each pattern being out of phase with its predecessor. Within any one pattern, however, the oscillations have similar shapes and a constant period.

* Ministry of Works and Development, Wellington, New Zealand.

Punched tape recorders sample data at predetermined times only, and so a problem of "aliasing" arises, as illustrated in Fig.1. This record from Lake Taupo has an oscillation with period 36 minutes that persists for 15 cycles. The recorder in this case punched the level every 5 minutes which gives a good representation of the seiche. However, had the recorder been punching every 30 minutes then the record would have been the heavy line which shows a spurious oscillation, caused by aliasing, with period $1/(\frac{1}{30} - \frac{1}{36}) = 180$ minutes.

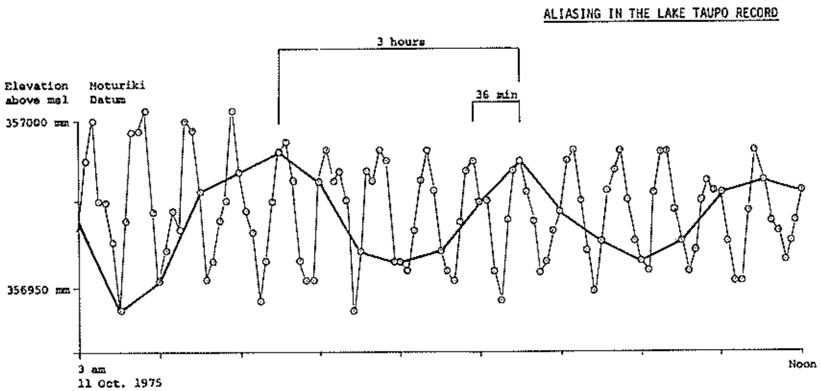

FIG.1 – Aliasing in the Lake Taupo Record 11 October 1975.

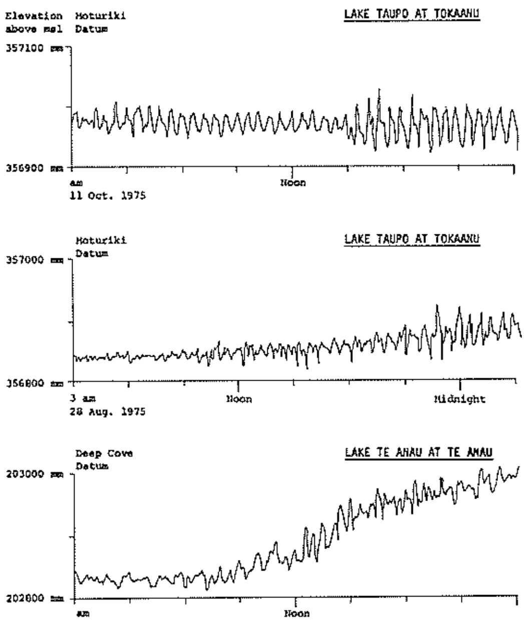

FIG.2 – Lake Taupo at Tokaanu 11 October 1975.
Lake Taupo at Tokaanu 28 August 1975.
Lake Te Anau at Te Anau 29 October 1975.

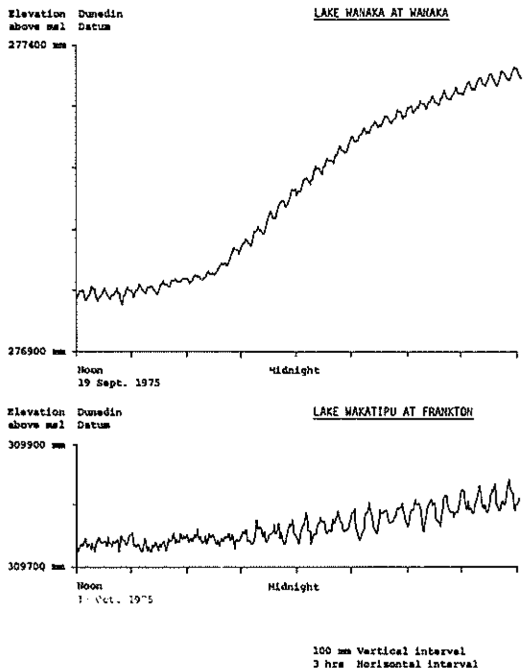

FIG.3 – Lake Wanaka at Wanaka 19 September 1975.
Lake Wakatipu at Frankton 13 October 1975.

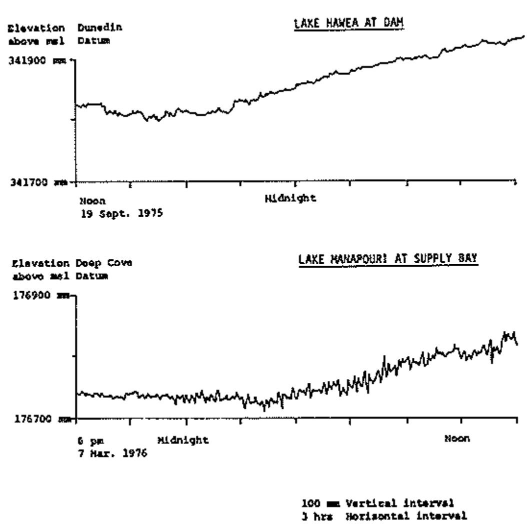

FIG.4 – Lake Hawea at Dam 19 September 1975.
Lake Manapouri at Supply Bay 7 March 1976.

Five min. punched tape recorders were installed for a short time on lakes Taupo, Te Anau, Wanaka, Wakatipu, Hawea, Manapouri and Tekapo. Figs. 2 to 4 illustrate these records with samples plotted to the same scale showing seiche amplitudes up to 6 50 mm and typical periods of 30 min. Aliasing is avoided if the punch interval is not greater than half the period so the 'standard' punch interval of 15 min. was deemed satisfactory, at least for these large lakes.

A 15 min. punch interval has been adopted in the meantime for all lakes, so that recorders need only be serviced monthly. This operational criterion may have to be overidden on the smaller lakes if inflow data are required, and a smaller punch interval adopted.

Two other comments can be made in passing about the illustrated data. The lack of seiche in the Hawea record is a warning of an impending malfunction, as the intake pipe to the recorder stilling well is partially blocked and though acting as a throttle will eventually block entirely unless remedied. The irregularity of the Manapouri record is attributed to the spider like geometry of that lake. This irregularity also assists in overcoming the effects of aliasing.

SMOOTHING

A record of the spatially averaged lake level would be ideal for calculating inflows. This ideal record would be much smoother than the oscillating record

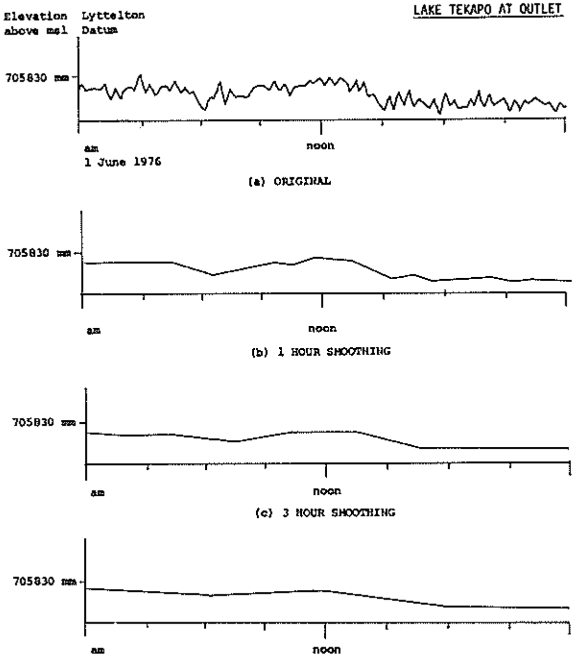

FIG.5 – Lake Tekapo at Outlet 1 June 1976.
(a) Original (c) 3 hour smoothing.
(b) 1 hour smoothing. (d) 6 hour smoothing.

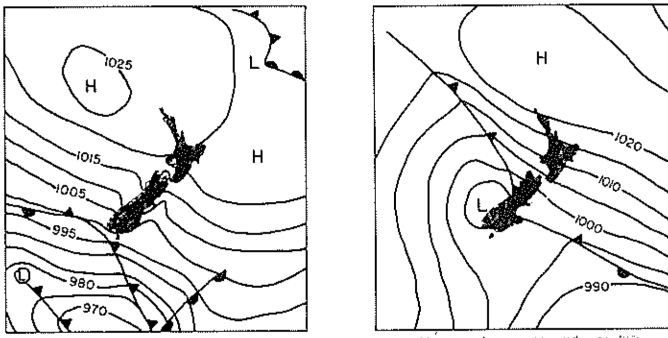

FIG.6 – Movement of steep Barometric Pressure Gradient across New Zealand.

measured at a single point and so require fewer discrete points for adequate definition of a continuous "line". Thus two objectives are sought by smoothing, firstly an approximation to the spatially averaged lake level, and secondly that the useful information is conveyed by a minimum quantity of data, the latter being important despite the capacity of modern computers.

The main difficulty in averaging the data is to pick a time interval that is sufficiently long to effectively smooth out the wind seiche oscillation, but not long enough to remove genuine changes in lake level. A series of trials was run in which the 15 min. values were averaged into non–overlapping sets of various

TABLE 1 – Calculation of Lake Tekapo inflows from lake level and outflow data.

Date 1976	*Time*	*Measured level* *m*	*Change in level* *m*	*Average change in storage over 6hrs* $m^3\ s^{-1}$	*Measured outflow* $m^3\ s^{-1}$	*Calculated inflow* $m^3\ s^{-1}$
June 1	0000	0.073				
			0.0	0.0	48.7	48.7
	0600	0.073				
			–0.001	–4.1	65.8	61.7
	1200	0.072				
			–0.010	–40.7	81.6	40.9
	1800	0.062				
			–0.012	–48.9	81.6	32.7
June 2	0000	0.050				
			–0.009	–36.7	81.5	44.8
	0600	0.041				
			+0.007	28.5	81.2	109.7 seiche
	1200	0.048				
			–0.250	–101.9	81.1	–20.8
	1800	0.023				
			–0.001	–4.1	80.9	76.8
June 3	0000	0.022				

lengths. Fig.5 illustrates the consequences of using different length smoothing intervals for Lake Tekapo and are typical of those obtained for similar sized lakes. Clearly the 1 hour smoothing fails to remove the wind seiche while 3 hour smoothing does. The 6 hour smoothing can do no more to the wind seiche and reduces the time resolution of genuine changes. Smoothing over a 3 hour interval was therefore adopted as the best compromise between retaining superfluous data and discarding useful information.

The unlikely rise and fall of Lake Tekapo on 2 June between 9.00 and 15.00 hours, Fig.5, has the hallmarks of a barometric seiche. Reference to the weather map for that day, Fig.6, shows a gradient of barometric pressure which increases from south to north at about 1 millibar per 20 km. Thus a local barometric pressure system with a difference of 3 millibars across the 20 km lake between 9.00 and 15.00 hours could have occurred and caused the surface to tilt down 15 mm at the north end and up 15 mm at the south end, where the recorder is. The calculations of lake inflows shown in Table 1 illustrate the problem caused by this seiche, with the sixth and seventh inflow values in error by significant amounts.

We are not familiar with the frequency, intensity, and duration at a point, of barometric pressure gradients which are greater than 1 millibar per 20 km, though a cursory examination of lake levels records shows that many isolated long period seiches occur each month. Thus it cannot be assumed that a smoothing period of even 12 hours will be satisfactory in general practice. In the meantime a smoothing period of 3 hours has been adopted, and all users of the resulting data are warned to make their own allowance for the effect of barometric seiches. Barographs or water level recorders at both ends of a lake would provide the necessary data to pursue this topic further, and have recently been installed for this purpose on the Tekapo to Pukaki canal.

ACKNOWLEDGEMENT

The authors wish to thank the Director of the Meteorological Office for providing the information shown in Fig.6. Permission to publish this note was given by the Commissioner of Works.

REFERENCE

Wilson, B. W. 1972: Seiches. In: Chow, V. T. (Ed.) *Advances in Hydroscience 8:* 1-94