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CALCULATING LAKE INFLOW (NOTE)

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INTRODUCTION

The levels of most of our large lakes have been recorded for over fifty years, and Lakes Taupo and Rotoiti (north) for over seventy years. Over geological time the lake outlets have become stable so that at each lake a constant relationship exists between the level and the outflow, except where artificial control has been introduced. Consequently the level records provide our longest reliable and continuous records of flow for most of our large catchments. If good inflow records can be calculated from these lake level data valuable information of catchment behaviour is made available for hydrological analysis and for water resource management and design.

For most lakes it is not feasible to measure more than a small fraction of the inflow directly. The inflow, defined as gross inflow less surface evaporation and groundwater losses, can be obtained from the conservation of volume equation,

INFLOW = OUTFLOW + (LEVEL CHANGE) x AREA / (TIME STEP).

However, if a small time step is used to obtain good time resolution, poor quality in the level data results in unrealistic values in the calculated inflow series.

A computer programme is described which calculates inflows at a given time step and automatically checks that each value is plausible by comparing it with the adjacent values. Implausible values are adjusted and files of inflow and corresponding level are written.

DATA

Sources

Lake level and outflow data come from a variety of sources including daily staff gauge readings, half hourly power station records and five minute digital recorder files. For uncontrolled lakes the application of the level–outflow relationship to the level file produces an outflow file. (The relationship must be established by stream flow gauging at the outlet.) For controlled lakes the file of outflow must be obtained by separate measurement. The inflows should be calculated at a time step commensurate with that of the level file since they are numerically more sensitive to levels than to outflows.

Numerical Sensitivity

When the conservation of volume equation is applied to a time series of level and outflow the resulting inflow series usually contains many negative values and many isolated spikes, unless a large time step is used. This is because in a large lake a small change in level corresponds to a large volume of water. The change may be the result of inflow to the lake or it may be an error.

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Erratic Level Records

The most diligent staff gauge reader cannot avoid some error in his readings due to waves, and few automatic recorders maintain a history completely free from malfunction. Another cause of small changes in recorded lake level is the phenomenon of lake seiches which are set up by wind or by barometric pressure gradients. When a lake is seiching a level record from a point on it does not exactly represent the lake volume. Consequently some inflows calculated from such records are spurious. Level data containing the regular oscillations of wind produced seiches can be smoothed in such a way that the record represents lake volume adequately. Barometric seiches which tend to have a longer period of oscillation and do not necessarily contain both upward and downward displacement cannot be satisfactorily smoothed out. A smoothing function severe enough to remove them would also remove considerable detail of genuine volume changes.

Controlled lakes are more sensitive to the quality of the data than uncontrolled lakes. No water level recorder seems capable of accurately recording the alteration in the rate of change of level which occurs when there is a step change in outflow. In most cases this is probably due to imprecise measurement of time.

It is clear that if an inflow record is calculated with the same time resolution as a level record it will contain unrealistic periods due to simple errors, unsatisfactorily smoothed wind seiches, barometric seiches, and lack of synchronisation between level and outflow records.

PROGRAMME

Previous Method

The previous method of overcoming these difficulties involved applying an arithmetic smoothing function to the calculated inflows and where this was inadequate the level file was edited by hand. The arithmetic smoothing did not distinguish between the majority of good data and the small segments of poor data and consequently much of the detail in the record was blurred by the smoothing function.

Algorithm

When natural lake inflow recedes it does so, (very approximately), exponentially. This fact enables the sequential checking of calculated inflows. Only values which seriously violate exponential decay, relative to adjacent values are adjusted.

The programme subjects each calculated inflow to two tests involving two parameters which must be set by prior examination of the data. MAXREC is the ratio of today's inflow to yesterday's inflow, and is set to a small value, representing a high rate of recession that would never be exceeded. MININ is the minimum inflow and is set to a value which the lake inflow would never fall below.

The inflow is calculated for each time step. The first test checks that the lake level does not rise too rapidly or fall too slowly, relative to the following levels on the record, by calculating the inflow volume that these levels imply. The inflow is summed with those calculated for the following NDAY days to obtain a total inflow volume. (Typically NDAY is set to 3.) A hypothetical inflow is then calculated, such that continuous recession from it at the rate MAXREC, would yield this total volume over the same time period. This hypothetical inflow is the upper limit for the tested inflow.

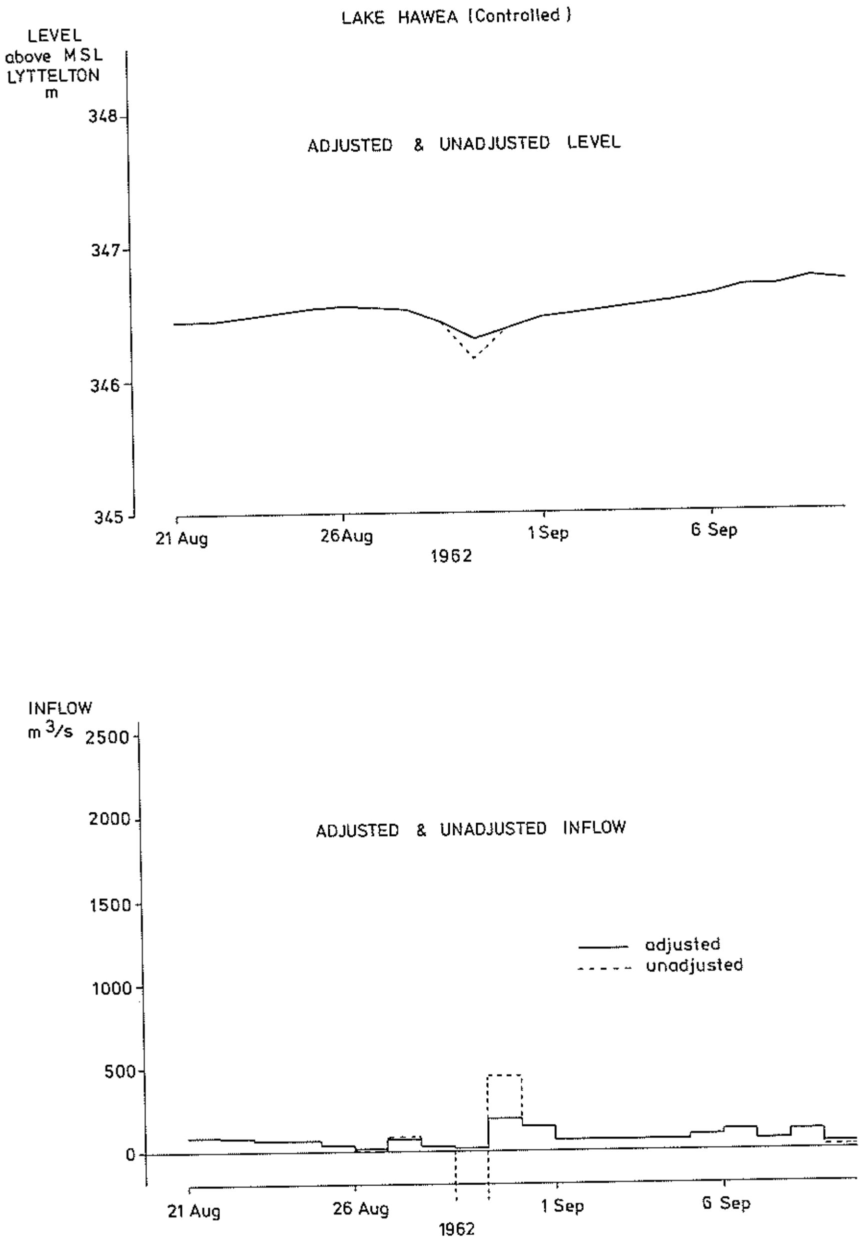

FIG.1 – Lake Hawea (controlled)
– adjusted and unadjusted level
– adjusted and unadjusted inflow

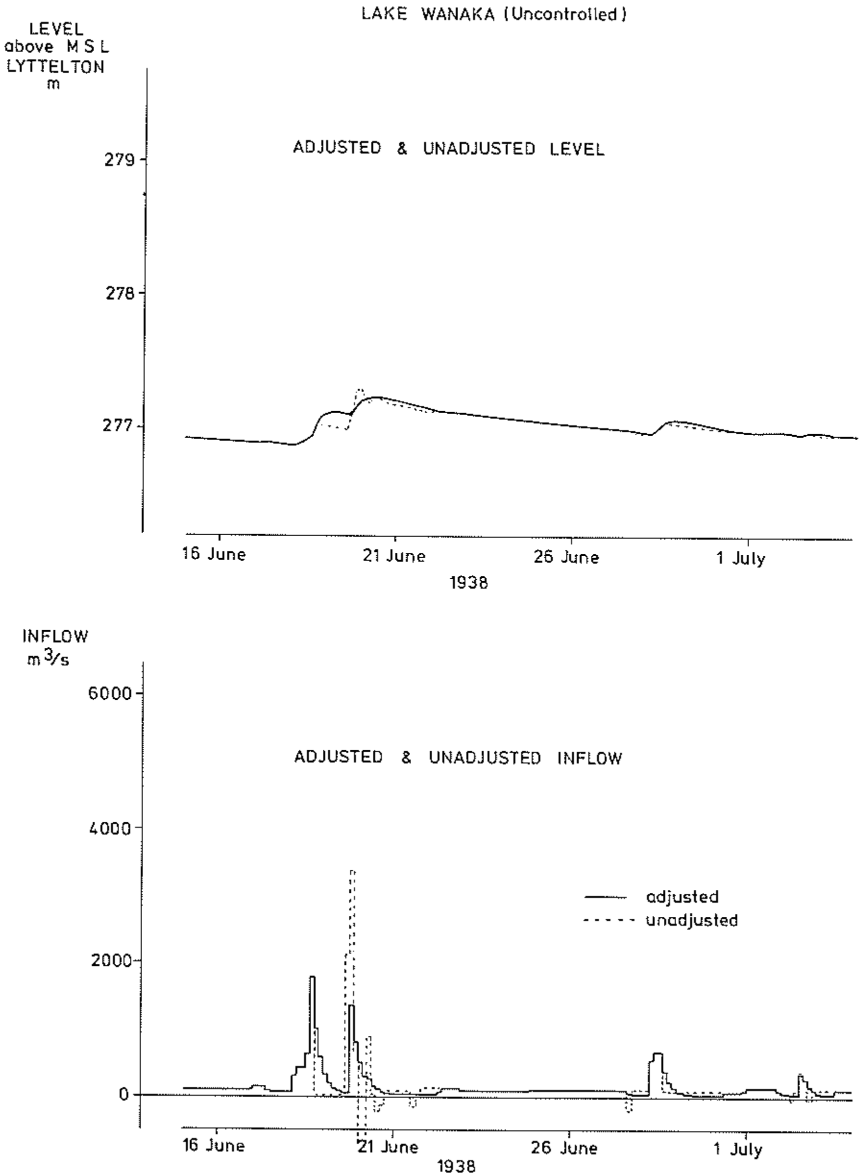

FIG.2 — Lake Wanaka (uncontrolled)
– adjusted and unadjusted level
– adjusted and unadjusted inflow

The second test checks that the level does not fall too rapidly or rise too slowly relative to the previous level on the record. The ratio of the inflow to the previous inflow must exceed MAXREC. (If the time step here is not one day MAXREC is raised to the power DELT, where DELT is the time step in days.) Recession is towards the minimum inflow, MININ.

If the calculated inflow does not satisfy one of the constraints the level file is assumed to be at fault and adjusted accordingly. (For controlled lakes this assumption may not always be correct.) The inflow and corresponding level are adjusted by the minimum amount necessary to satisfy the constraint.

If the inflow fails to satisfy both constraints it is only adjusted if it is less than MININ, and a message is printed. If it satisfies both constraints the inflow and the level read from the input file to which it corresponds, are passed directly to the output file.

Output

The output from the programme is a file of lake level and lake inflow. These two records are numerically consistent provided the lake area function and the level–outflow relationship, or for controlled lakes the outflow record, are accepted.

The algorithm has been found to give satisfactory results when applied to data from several lakes. Large errors in single values on a level record, which previously could only be removed by manual editing are automatically removed. A single low value is removed because the rate of lake fall to it implies an impossible rate of recession and a single high value is removed because the rate of lake fall from it implies an impossible rate of recession. Levels of lakes during periods of very low inflow are constrained to fall only slowly and the repeated occurrence of negatives during these periods is avoided. Cases of levels which fail to satisfy both of the constraints usually occur during such periods and do not indicate serious error in the level record.

The long term mean inflow calculated from files of level and outflow from a controlled lake are necessarily unchanged by the algorithm. For uncontrolled lakes adjustments to the level file result in changes in the calculated outflows but in practice long term mean flows are not changed by more than half a per cent. Such changes are not significant as level–outflow relationships are not deflned with this order of precision.

The most convincing test of the programme is to plot an inflow record calculated directly from a level record and to compare this with a plot of inflows and levels after adjustment. Figures 1 and 2 have been chosen as examples of adjustment of periods which include some unrealistic level data from Lakes Hawea and Wanaka.

As well as writing inflow and level files with adjustment the user has the option of calculating and writing these files without adjustment. This option is useful for examining the quality of data. There is also the option of synthesising a level file, given an inflow file. This option can be used for filling gaps in a level record if a correlated flow record is available. It can also be used to show the behaviour of a controlled lake if it had not been controlled.

System

The programme is written in the IBM programme product language CSMP III (Continuous Systems Modelling Programme) and employs the Ministry of Works and Development programme TIDEDA to access data. The programme source could be altered without difficulty to run as a FORTRAN programme.

ACKNOWLEDGEMENT

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