THE INTERACTION BETWEEN FLOOD AND TIDE AT BRISBANE

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Abstract: The height curve of the 1931 flood at Brisbane is subjected to a harmonic analysis in order to separate the tidal fluctuations from the flood water heights. The tidal residuals are then correlated with predicted tides at the Pile Light, Moreton Bay, and it is shown that the tidal oscillations at the Port Office are reduced by about 60 per cent of their normal amplitude during a major flood.

1. INTRODUCTION

The Pile Light is situated in Moreton Bay about five miles from the mouth of the Brisbane River, and it is for this station that tidal predictions are published (Dept. of Harbours and Marine). At the Pile Light the following mean values apply:

High Water Springs	-	7 ft 0 in
Low Water Springs	-	0 ft 6 in
Mean Tide Level	-	3 ft 6 in

At the Port Office gauge, Brisbane, turn of tide occurs about an hour later than at the Pile Light, and the mean readings are approximately as follows:

High Water Springs	-	7 ft 0 in
Low Water Springs	-	0 ft 0 in
Mean Tide Level	-	3 ft 6 in

It is seen, therefore, that the tidal curve is very similar at the two places under normal conditions. However, when the river is discharging flood water and the Port Office gauge reading materially exceeds 7 ft it is found that the full range of the tide is not experienced at Brisbane. The following analysis was conducted in order to ascertain by what factor the amplitude of the tidal curve is reduced.

2. GENERAL

(a) The Amplitude Reduction Factor

The Brisbane 1931 flood covered a period of three days from 2100/5 February to 2100/8 February (see full line, Fig. 1). Fortunately hourly readings of the Port Office gauge are available enabling the hydrograph to be constructed and subjected to an harmonic analysis. Over a three day period there are six tidal oscillations in Moreton Bay, hence the analysis was carried as far as the sixth harmonic term. With x in degrees and 5 degrees $\equiv$ 1 hour the following equation for the Port Office gauge height, y, in feet was obtained:

$$
\begin{aligned}
y = {} & 11.08 \\
& -(2.75 \cos x + 0.87 \sin x) \\
& -(0.75 \cos 2x - 0.40 \sin 2x) \\
& -(0.30 \cos 3x + 0.25 \sin 3x) \\
& + 0.21 \sin 4x \\
& +(0.20 \cos 5x + 0.22 \sin 5x) \\
& -(0.88 \cos 6x - 0.47 \sin 6x) \qquad (1)
\end{aligned}
$$

The first term, 11.08 feet, represents the mean height of the water during the period under consideration. It can be seen that the amplitudes of the component terms decrease until the fourth harmonic, and then increase again. The fifth and sixth harmonics may be taken to represent the tidal contribution to the hydrograph and the remaining terms may be regarded as the unmodified flood hydrograph, i.e. the flood curve which would be observed in the absence of tidal fluctuations. The latter appears as a broken line in Fig. 1.

Accordingly the terms up to the fourth harmonic were added and the resulting curve subtracted from the actual hydrograph to obtain the tidal oscillations. This tidal residue curve is shown as a full curve in Fig.2, the broken curve being the predicted tide curve for the Pile Light, Moreton Bay. Since only the heights of high and low water are given in the Tide Tables, the maxima and minima were obtained from the tidal residue curve and correlated

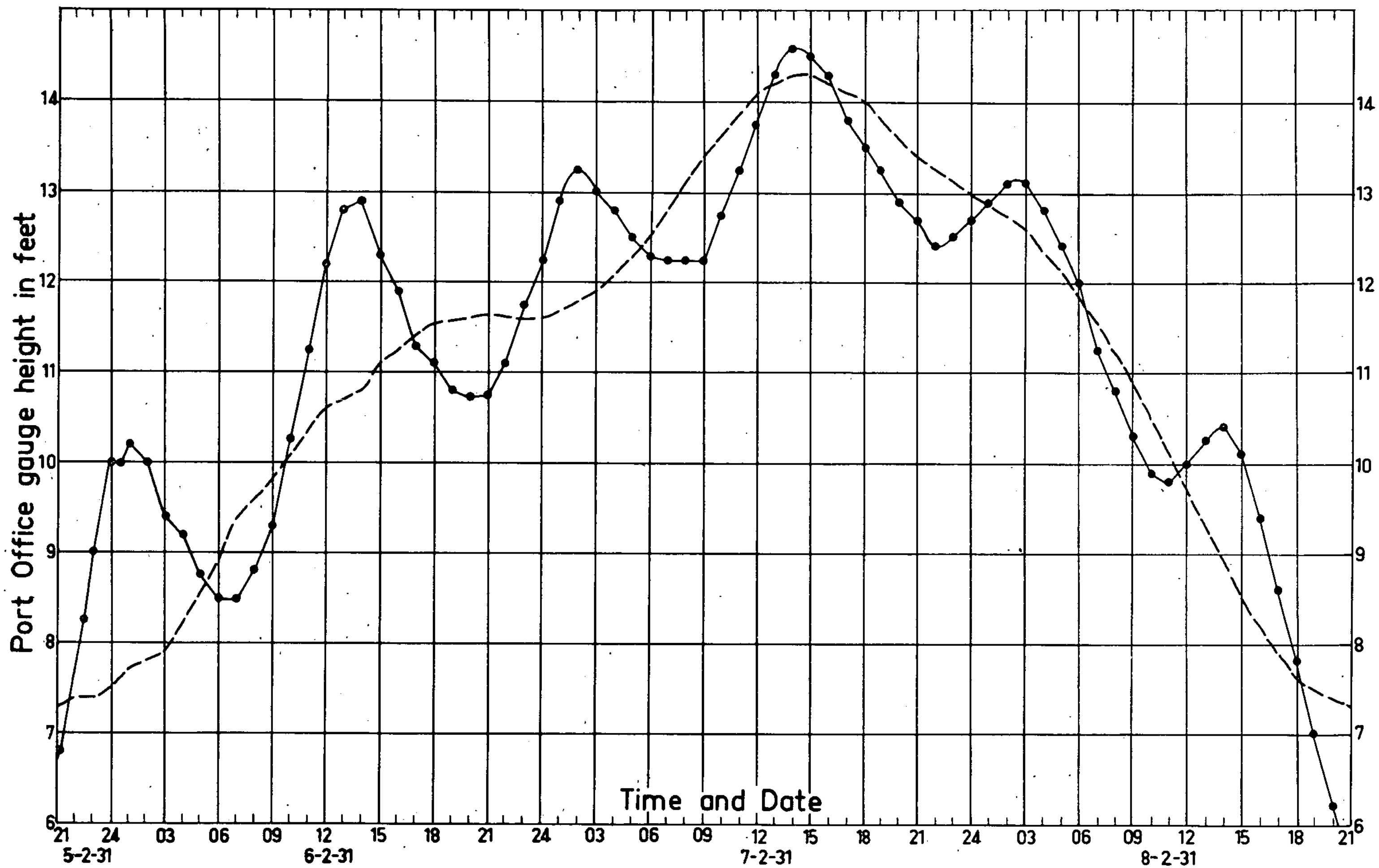

Fig 1. Heights on the Port Office gauge Brisbane (——) during the 1931 flood and the same heights minus the tidal oscillation (– – –)

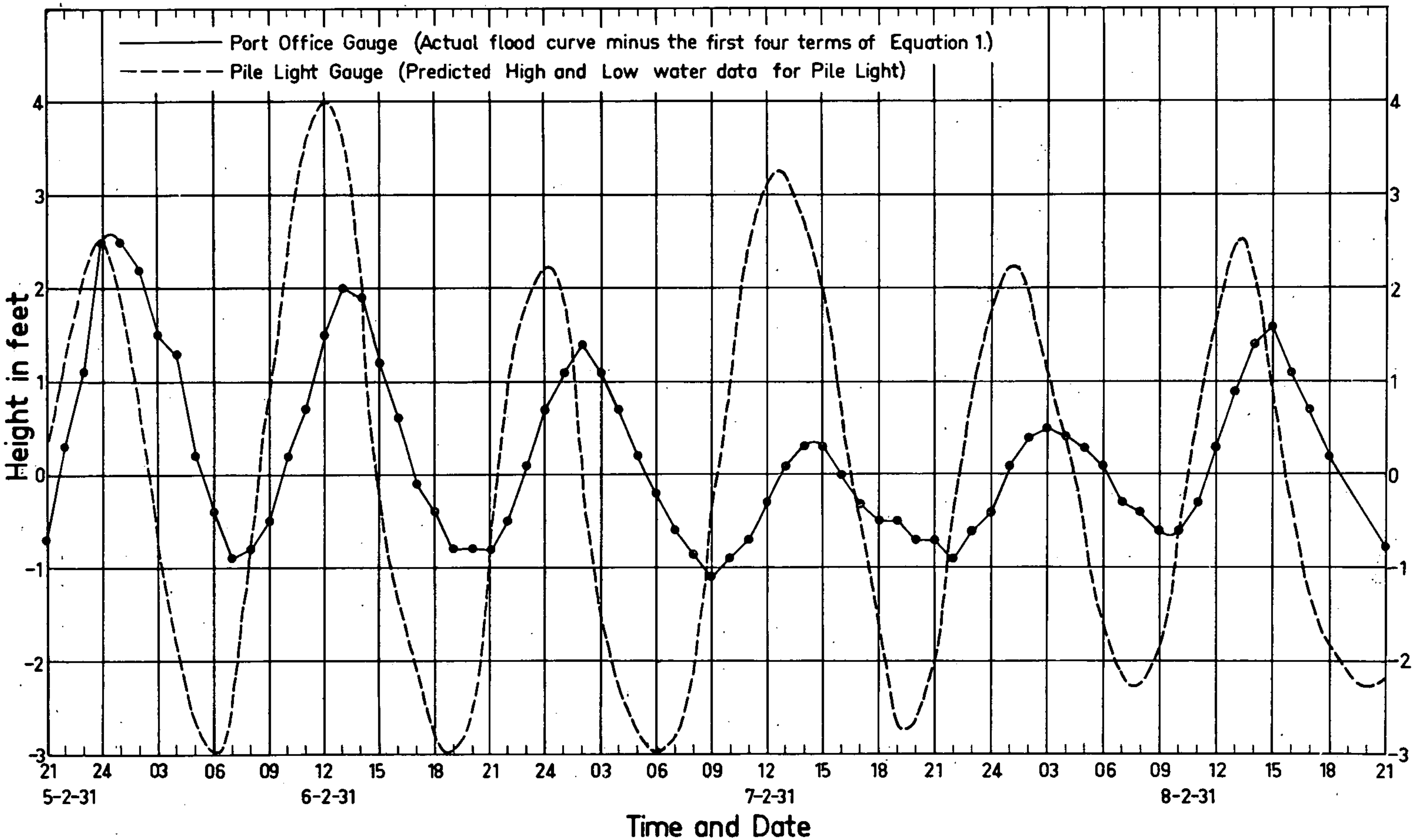

Fig 2. Tidal oscillations at the Port Office and Pile Light gauges Brisbane.

with the corresponding maxima and minima as tabulated for the Pile Light (see Table 1 below).

The correlation coefficient $r = 0.88$ with 9 degrees of freedom ($P < .001$) and the linear regression equation obtained was of the form:

$$u = 0.4v + 0.3 \qquad (2)$$

where u = amplitude (ft) of the tidal oscillation at the Port Office and v= amplitude (ft) of the tidal oscillation from Mean Tide Level at the Pile Light. Normally u and v are approximately equal, and it is seen that during periods of flood run off the amplitude of u is reduced by a factor of 60 per cent.

(b) The Regression Equation for Use in Forecasting Flood Height

An inspection of the regression equation (2) as drawn in on the scatter diagram revealed satisfactory agreement at the minimal points but the maximal points were not so well fitted, and it appeared that the unmodified flood-height might be a contributing factor.

The values of the corresponding maxima and minima at the Pile Light and the Port Office are listed in Table 1, together with the height of flood-water taken from the broken curve of Fig. 1, i.e. the unmodified height which would have been experienced in the absence of tidal oscillations.

The partial regression equation was found to be:

$$u = 0.4 \quad V - 0.1 w, \qquad (3)$$

where u = amplitude of the tidal oscillation at the Port Office as above,

V = tide height at the Pile Light, and
w = unmodified flood height on the Port Office gauge.

As a check, oscillations predicted from equation (3) were correlated with actual observed oscillations; the multiple correlation coefficient = 0.94 with 9 d.f. ($P < .001$).

TABLE 1

Pile Light Height above datum V (ft)	Port Office Oscillation u (ft)	Unmodified Flood Height w (ft)
5.9	2.5	7.6
0.4	-0.9	8.5
7.4	2.0	10.9
0.5	-0.8	11.6
5.8	1.4	11.8
0.6	-1.1	13.4
6.7	0.3	14.3
0.8	-0.9	13.3
5.8	0.5	12.5
1.2	-0.6	10.7
6.1	1.6	8.2

One difficulty that arises in practice is that w is not immediately known. However, as mentioned above, equation (2) gives good agreement at minima. Hence, at a minimum on the Port Office gauge it is possible to derive u from equation (2) and to apply it as a correction to the observed gauge height and to obtain w, the unmodified flood height. The application of equation (3), with values of V and w known, then enables the prediction of u for a later time, e.g. the subsequent high tide. Knowing u and w we can obtain the Port Office gauge reading at that instant by simple addition, because gauge height = u + w (plus any change in w due to the flood).

(c) Example of the Use of the Equations (w constant)

At Low Water in the River the height on the Port Office gauge is 5.8 feet and the Tide Tables predict 1.9 feet at the Pile Light. What will be the gauge reading at High Water, when the Pile Light tide is expected to record 6.6 ft?

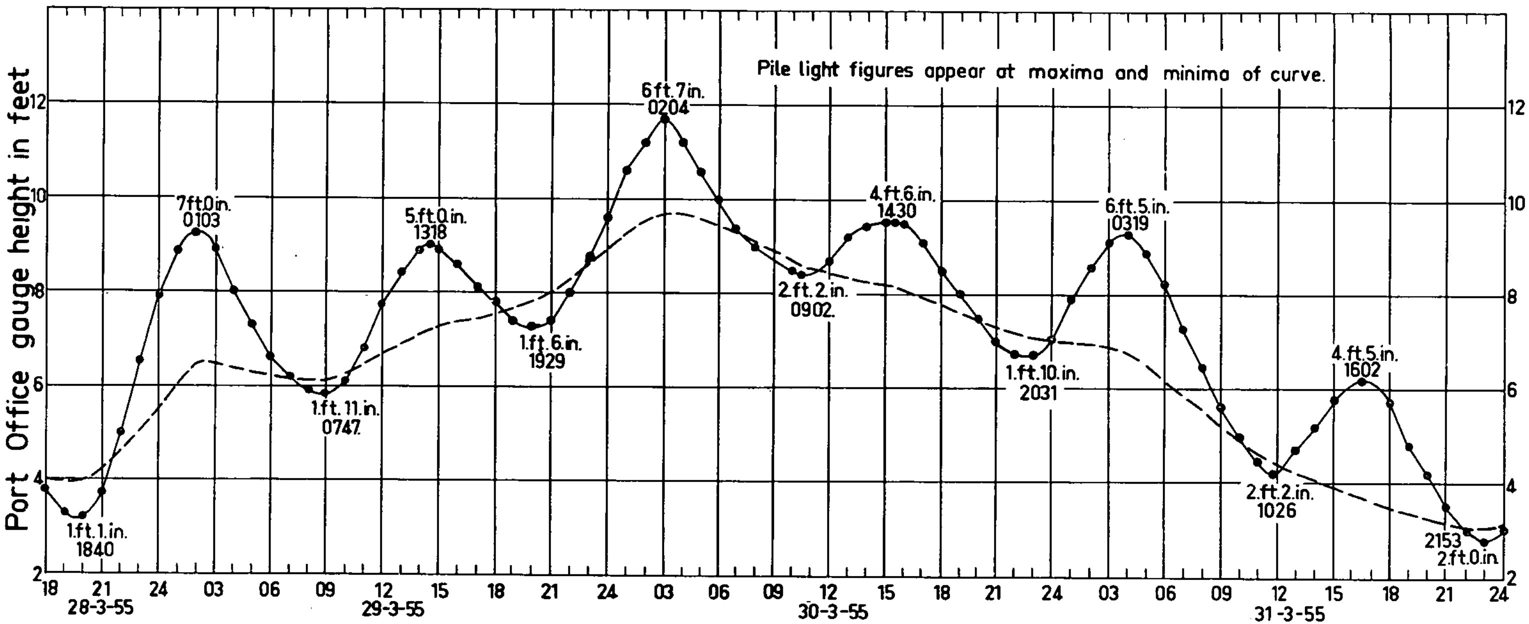

Fig 3. Heights on the Port Office gauge Brisbane (———) during the 1955 flood and the same heights minus the tidal oscillation.(– – –)

Applying equation (2) we have:

$$u_1 = 0.4 \times (1.9 - 3.5) + 0.3$$
$$= - 0.3 \text{ ft.}$$

∴ Unmodified flood height w = 5.8 -(-0.3) = 6.1 ft.
Now applying equation (3) for the high tide we have,

$u_2 = (0.4 \times 6.6) - (0.1 \times 6.1)$, assuming w remains constant;

∴ u_2 = 2.0 feet, i.e. the gauge reading at High Water will be approximately 6.1 + 2.0 = 8.1 feet.

Prior to this investigation it was the practice to add the full range of tide. This obviously led to overestimations of the resultant flooding and caused unnecessary action on the part of the public in the form of evacuation of threatened homes and warehouses.

(d) Caution

The above equations were derived on the basis that normal atmospheric conditions existed. In an estuary, abnormally low barometric pressure and gale force winds can cause a very great increase in tide height. The highest abnormal tide at the Pile Light was recorded on 8/6/1891 when the tide rose 9.5 ft above datum. On this occasion the wind was ESE, Beaufort Force 9 and the pressure (1005 mb) was about 14 mb below normal.

3. APPLICATION OF THE EQUATIONS TO THE 1955 FLOOD.

Since the 1931 flood, much work has been done on straightening the lower reaches of the river and deepening it, and rock training walls have been completed right down to the mouth so that it is now self-scouring. It is to be expected, therefore, that the above equations may not apply exactly to present day flood conditions, but the principle of a considerable reduction in the amplitude of the tidal oscillation must still apply.

A minor flood occurred in the river from 28 to 31 March, 1955 (Fig. 3). The above equations were employed to derive the probable unmodified (or corrected) flood curve. This is shown as a broken line in Fig. 3. It can be seen that the equations give a reasonable representation of the unmodified hydrograph, particularly as the flood subsides, the test being, of course, the smoothness of the corrected curve obtained.

4. CONCLUSIONS

1. An analysis of the 1931 flood at Brisbane shows that during a major flood, tidal oscillations at the Port Office gauge are reduced in amplitude by about sixty percent This result has been confirmed by the 1955 flood, despite channel widening, straightening and deepening in the lower reaches.

2. By applying the equations flood peaks may be estimated with considerably increased precision.