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THE UNIVERSITY OF NEW SOUTH WALES

WATER RESEARCH LABORATORY

REPORT No. 24

Flood Forecasting for the City of Launceston

by

D. N. Foster

AUGUST, 1960

The University of New South Wales

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FLOOD FORECASTING FOR THE CITY OF LAUNCESTON

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Report to the Launceston City Council.

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PREFACE

This study was undertaken at the Water Research Laboratory of the University of New South Wales, Manly Vale, N.S.W. for Unisearch Ltd. on behalf of the Launceston City Council, Tasmania.

The study, which was conducted by D.N.Foster, B.E., A.M.I.E. Lecturer in Civil Engineering, was commenced on 20th July 1960 and completed on 26th August, 1960.

The assistance of the Hydro-Electric Commission of Tasmania and the Bureau of Meteorology, Hobart, in providing streamflow and rainfall data for the investigation is gratefully acknowledged.

H.R. Vallentine
Associate Professor of Civil Engineering
Officer in Charge of the Water Research Laboratory.

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SUMMARY

A procedure based on rainfall records at seven index stations to predict the peak discharge and time of peak for major floods has been developed. The period of warning of overtopping of the levee banks using daily rainfall records is approximately 15 hours and the accuracy of the estimate approximately ± 15 per cent.

1.0 Introduction

An investigation to study methods of mitigating floods at Launceston was completed by the Launceston Flood Protection Authority in September 1959. In the final report on this investigation (Ref.1 p.C59) it was recommended that prior to the construction of the protection works that the flood plain be evacuated when a flood discharge of 70,000 cusecs was forecasted in the South Esk River. At the present time, however, there is no systematic method of forecasting accurately the peak discharge at Launceston for major floods, and before this recommendation could be put into effect a quantitative flood warning procedure is required.

Descriptions of various techniques for flood forecasting have been previously documented (Refs. 1 and 2). However, the majority of the standard procedures proposed would require the installation of more instruments and the collection of additional data over a period of several years. As the time interval before completion of the protection works is relatively short, the value of the standard methods of flood forecasting is therefore limited in their application to the local problem at Launceston and this investigation was aimed at devising the best flood forecasting procedure based on existing data and using existing instruments.

On this basis it was considered that an estimate of the peak discharge at Launceston to within ± 20 per cent might be possible by either of two basic methods:-

(a) By correlating from records of past floods, the flood stage at Launceston with stage readings upstream. This method is known as the index station method and flood stages at selected head-water stations are used as indices of subsequent stages in the main stream.

(b) By estimating the average rainfall depth over the catchment from records at selected index stations and applying this rainfall to the unithydrograph for the South Esk River after appropriate allowances have been made for rainfall losses and groundwater flow.

Both of these methods have been investigated but owing to the lack of data on major flood stages upstream only the second procedure is considered applicable at the present time.

2.0 Index Station Method

This method attempts to correlate upstream gauge readings with flood stages at Launceston.

The catchment of the South Esk River (Fig.4) has an area above Launceston of 3,355 sq. miles and can be roughly divided into four main sectors as follows:-

(a) The South Esk River (not including major tributaries) with a catchment area of 1,304 sq. miles draining the Eastern zone.

(b) The Meander River, a tributary of the South Esk, draining the N.W. area of 589 sq. miles.

(c) The Lake River (not including the Macquarie) a tributary of the South Esk draining 444 sq. miles in the S.W. sector.

(d) The Macquarie River, a tributary of the Lake River, having a catchment area of 1,018 sq. miles draining the S.E. portion.

A typical correlation between flood stages at index stations on the headwaters of these catchments and flood stage at Launceston would take the form -

$$M = C_1 m_1 + C_2 m_2 + C_3 m_3 + C_4 m_4$$

where M = flood stage at Launceston

m_1 to m_4 = flood stage at index stations on the headwaters of each of the major tributaries

C_1 to C_4 = constants determined by trial and error from records of past floods

There was insufficient flood stage data at suitable stations on these rivers, which extended over a sufficient period of time to enable this method to be used for major floods.

An attempt, however, was made to correlate flood levels at Llewellyn on the South Esk River with flood discharge at Launceston (Figure 1). Although a trend was evident, the plotted points showed a large degree of scatter, due probably to the non-uniform areal distribution of rainfall in the various storms considered.

For these reasons no further investigation of the index station method was undertaken.

3.0 Prediction of Peak Discharges from Rainfall Records

3.1 General

A flood forecasting procedure based on forecasting peak discharges at Launceston from rainfall records would include estimates of the following:-

(i) The gross rainfall depth on the catchment.

(ii) The rainfall losses, to obtain the rainfall excess. This involves an estimate of:-

(a) The initial loss to rainfall at the start of the storm as required to satisfy interception and depression storage.

(b) The average loss rate after initial loss has been completed.

(iii) Snowmelt during the storm.

(iv) The temporal variation of the precipitation during the storm.

Once the above data are known the rainfall excess can be applied to the unithydrograph for the catchment to obtain the flood hydrograph at Launceston.

3.2 Estimation of Gross Rainfall Depth

Because of the pronounced orographic effects on the areal distribution of rainfall over the South Esk catchment, the most accurate method of estimating the rainfall depth for a storm would be by drawing an isohyetal map and averaging the rainfall according to the areas between the isohyets (Ref.3 p.78). For practical reasons this method is unsuitable as it would require a much more extensive network of telegraphic rainfall stations than is at present available as well as increasing the number of man hours required to estimate the rainfall depths.

For this reason, an attempt was made to estimate the average rainfall depth by applying weighting factors to the rainfalls recorded at selected index stations according to the Thiessen method (Ref. 3, p.78).

Rainfall depths during six storms were obtained for seven, eleven and fourteen station averages and compared with the more accurate rainfall depth obtained from isohyetal averages of the storms. The stations selected for this analysis and their weighting factors are shown in Appendix "A" and the results of the study have been summarized in Table I. Only stations which at present report daily rainfall records to the Hobart Weather Bureau by telegraph were used in the analysis in order to avoid the installation of any new instruments.

TABLE I

Average Rainfall Depths by the Thiessen Method as compared with the Actual Rainfall Depth.

Storm	Actual Rainfall Depth from Isohyetal Map	7 Station Average		11 Station Average		14 Station Average	
		Rainfall Depth	Correction Factor	Rainfall Depth	Correction Factor	Fainfall Depth	Correction Factor
April 29	6.10	7.16	0.85	6.48	0.94	6.99	0.87
Sept. 52	2.39	2.31	1.03	2.18	1.10	2.33	1.02
2-3 May 56	2.42	2.17	1.11	1.93	1.25	2.01	1.2
22-23 May 56	1.96	2.57	0.76	1.85	1.06	1.85	1.06
22-26 May 58	2.34	2.28	1.03	2.11	1.11	2.22	1.05
Aug.58	1.62	2.44	0.66	1.62	0.92	1.88	1.16

These results indicate that an estimate of rainfall depth to within about 20 per cent could be obtained by either an eleven or fourteen station average. This was considered satisfactory. It was therefore decided to adopt the eleven station average for estimating the depth of precipitation over the catchment.

It was subsequently found, however, that when the rainfall as obtained by the eleven station average was applied to the unitgraph flood peaks were over estimated for uniform areally distributed storms. It was considered that this was due to the nature of the topography of the catchment. It was felt that the majority of the flood runoff was produced from the surrounding mountain ranges, with negligible contribution to streamflow from rainfall on the Midland plains. To allow for non-uniformity in the areal pattern of the rainfall it was therefore decided to modify the eleven station rainfall average by neglecting the rainfall at each of the four stations on the plains. Following this modification it was then necessary to make some slight alterations to the weighting factors of the remaining seven index stations in order to ensure that the true volume of runoff was obtained. Although this meant that the true average gross rainfall depth over the catchment was not calculated the forecasted flood peaks showed closer agreement with the actual peak discharge.

The final index stations and weighting factors adopted were:-

Station	Weighting Factor
Avoca	0.135
Lake Leake	0.103
Mathinna	0.107
Meander	0.126
Shannon	0.083
St. Marys	0.059
Upper Blessington	0.059

3.3 Estimate of Rainfall Losses

3.31 Initial Loss. During the initial period of a storm the majority of the precipitation is used to satisfy the interception and depression storage. It is not until after this initial period that any substantial surface runoff will occur. The volume of rain that falls during this period is termed "initial loss" and may be defined at the quantity of rain that occurs without producing significant run-off.

One method of obtaining an estimate of initial loss is to determine the average rainfall over the catchment for two types of storms - those which produce no significant surface runoff and those which result in only small amounts of surface runoff. Initial loss would then lie somewhere between the two. If some index of catchment saturation could be determined a plot of the curve separating these two types of storms against the catchment wetness index would give an estimate of initial loss. Seven storms have been studied and the results have been plotted in Figure 2 using groundwater flow at the start of rise as an index of catchment wetness.

3.32 Loss Rates. Loss rates from five storms were obtained during the hydrologic studies for the investigation of methods of mitigating floods in Launceston (Ref. 1 p. C17). These varied from 2.4 pts/hr to 9.5 pts/hr. Further research has indicated, however, that this variation was mainly due to the different methods used in assessing initial loss. Provided the method discussed in Section 3.21 above is used throughout, it was found that a constant loss rate of 2.5 pts/hr could be used for flood forecasting without introducing significant errors. This value was therefore adopted.

3.4 Estimation of Snowmelt

Although snow falls in some of the higher elevations of the catchment, the area affected is small and the depth and duration of snow is negligible.

3.5 Estimation of Temporal Pattern of Precipitation

For all the major storms analysed for this investigation it was found that:-

(i) the duration of storm runoff was approximately constant on all parts of the catchment,

(ii) the mass curves of rainfall at all pluviometers were approximately the same when plotted as percentage of total storm rainfall at that station against time after the start of rain.

For these reasons the temporal variation of rainfall can be obtained from any available pluviograph on or adjacent to the catchment. In this investigation the records of the pluviograph at Launceston have been used as it was assumed that the headquarters for the calculation of the flood forecast would be best situated in this city.

3.6 Derivation of Unithydrographs

Five 6-hour unit hydrographs were derived for the South Esk catchment during the course of the hydrologic studies for the investigation of flood mitigation measures for Launceston (Ref. 1 p.C19). It was considered that these were also satisfactory for this study and no further work was carried out on this phase of the investigation.

Further research has indicated, however, that the unit period of the unit hydrograph could be substantially increased without introducing significant errors. In other words either a 12-hour or a 24-hour unitgraph could be used with a consequent saving in the time required to forecast the flood peak.

As the daily rainfall stations record every 24 hours it could be argued that a 24 hour period would be the best to adopt. In some cases, however, this period would be so much greater than the actual duration of the rainfall that a significant error may arise. For this reason, a 12-hour unitgraph was adopted.

It should also be noted that if the index rainfall stations reported rainfalls every 12 hours (at say 0900 and 2100 hrs.) instead of daily as at present, an additional period of 12 hours warning could be obtained in some cases by using a 12 hour unitgraph.

The average 12 hour unitgraph as derived from the average 6 hour unitgraph given in Ref.1 is shown in Figure 3.

3.7 Derivation of Flood Hydrograph

To predict a flood from a design storm by the use of the unitgraph the first step is to deduct appropriate loss rates and initial loss from the gross rainfall pattern. The remainder is the excess rainfall hyetograph and is presented with periods corresponding to the unit period of the unitgraph. The surface runoff hydrograph can then be computed from the unitgraph and the excess rainfall hydrograph using the series of equations shown below. In these equations P_n is the excess rainfall in inches during the nth period and X_n and Y_n are the unitgraph and hydrograph ordinates in cusecs at the end of the nth period after the start of rain.

$$P_1X_1 = Y_1 \qquad ---- (P)$$

$$P_1X_2 + P_2X_1 = Y_2 \qquad ---- (2)$$

$$P_1X_n + P_2X_{n-1} + \ldots = Y_n \qquad ---- (n)$$

$$P_rX_a = Y_b \qquad ---- (a + (r-1))$$

where r = No. of rainfall periods
a = No. of unitgraph periods
b = No. of hydrograph periods
$= a + (r-1)$

To obtain the total peak flood discharge, base flow must be added to the surface runoff hydrograph. Insufficient data are at present available to determine accurately what this increase should be. For major floods, however, the error introduced by an incorrect assessment of base flow is small and a suggested allowance is tabulated in Table 5 below. This table may warrant alteration at a later date in the light of additional experience.

TABLE 2.

Increases in Peak Surface Runoff to allow for Base Flow

Peak Surface Runoff (cusecs)	Quantity of Base Flow (cusecs)
20,000 to 40,000	5,000
40,000 to 60,000	6,000
60,000 to 80,000	7,000
80,000 to 100,000	8,000
100,000 to 150,000	10,000
150,000 to 200,000	12,000
200,000 to 250,000	14,000

4.0 Summary of Final Flood Forecasting Procedure

4.1 General

The proposed procedure for flood forecasting can best be summarised by reference to the example given in Appendix "B" to predict the peak discharge of the April 1929 flood.

4.2 Step 1 - Gross Rainfall

The average gross rainfall over each 24 hour period after the start of rain is obtained by multiplying the daily rainfall records at the seven index stations by the weighting factors given in Section 4.1 and summing as shown in Table 3 of Appendix "B". Thus for the period ending 0900 hours on the 2nd April, 49 points were recorded at Avoca, 18 points at Lake Leake and so on. Multiplying these figures by the weighting factors of 0.135 for Avoca, 0.103 for Lake Leake etc. we obtain the weighted rainfalls of 6.6 points at Avoca, 1.9 points at Lake Leake etc.

By summing this column, the average rainfall depth over the catchment during the first day is calculated at 26.7 points. Similarly the average depth of precipitation for the 24 hour periods ending 0900 hours on 3.4.29; 4.4.29; 5.4.29 and 6.4.29 are 9.8; 196.4; 412 and 46.4 points respectively.

4.3 Step 2 - Initial Loss

Initial loss is obtained directly from Figure 2 provided the discharge in the South Esk River at Launceston prior to the start of rain is known. In April 1929 discharge at Launceston on the 1st April was 437 cusecs. From Figure 2 the initial loss corresponding to this flow is 110 points.

This means that the initial loss was satisfied by the light rain which fell on the 1st and 2nd (recorded at 0900 hrs. on 2nd and 3rd) plus 73 points of the total rain which fell on the 3rd.

The query arises as to what degree light rain prior to the start of the main storm goes towards satisfying initial loss. The author has found that for the floods analysed, best results were obtained by considering the rainfall for the three days only prior to the start of excess rainfall. It is felt that rainfall earlier than this will be reflected in the groundwater flow and will therefore be catered for in Figure 2. Very light rain preceding the main storm, however, should be discounted as evaporation would make its effect on initial loss negligible.

4.4 Step 3 - Excess Rainfall Hyetograph

As discussed in Section 3.4 the mass curve of rainfall at any pluviograph on the catchment is approximately constant when plotted as cumulative percentage of total rain against time. Thus the average mass curve of gross rainfall for the entire catchment can be obtained by multiplying the mass curve as recorded at the Launceston pluviograph by the ratio of average rainfall on the catchment over a given period to the rainfall at Launceston for the same period.

If the assumption of a constant temporal pattern of rainfall over the entire catchment was strictly correct then this multiplication factor would be a constant irrespective of the time period chosen. In practice, however, its value will depend on the time interval selected and must be allowed for in the computations.

The method is illustrated in Table 4 of Appendix "B". As all the rainfall which fell during the 48 hours ending 0900 hrs. on the 3.4.29 is used to satisfy initial loss, computation of the mass curve need only be calculated after this time. The mass curve of gross rainfall as recorded at the pluviograph at Launceston is shown in columns 1 to 3; rain commencing at 1800 hrs. on the 3rd.

Multiplication factors as calculated for each of the time intervals beginning at the start of rainfall and ending at 0900 hours on the 4th, 5th and 6th April respectively are tabulated on page (i) of Appendix "B". Their values correspond to 2.36 for the 15 hour period ending 0900 hrs. on the 4th, 2.46 for the 39 hr. period ending 0900 hrs. on the 5th and 2.06 for the 64 hr. period ending 0900 hrs. on the 6th. To obtain the cumulated gross rainfall over the catchment at the corresponding times, the cumulated gross rainfall at Launceston is multiplied directly by these factors, as shown in Columns 3 to 5 of Table 4 at 0800 hrs. on the 4th, 5th and 6th respectively. Intermediate values are determined by proportioning the multiplication factors equally between the values obtained above on the assumption of a linear variation as shown in Column 4. The computed cumulated gross rainfall over the catchment is tabulated in Column 5.

To obtain the mass curve of excess rainfall, the initial loss as previously determined and thereafter a constant loss rate of 2.5 pts/hr (or the rainfall rate whichever is the lesser) is deducted from the gross rainfall mass curve. The cumulated loss is shown in Column 6. The balance of the initial loss of 73 pts. is satisfied somewhere between 2400 hrs. on the 3rd and 0200 hrs. on the 4th and is recorded against the reading at 2400 hrs. The cumulated loss is then obtained by adding the 5 points loss which occurs in each of the two hour periods giving a cumulated loss of 78 pts. at 0200 hrs. on the 4th, 82 pts. at 0400 hrs. on the 5th etc. By deducting the cumulated loss (Column 6) from the cumulated gross rainfall (Column 5) the mass curve of excess rainfall is obtained as tabulated in Column (7).

From the excess rainfall mass curve the quantity of rainfall excess which fell in each 12 hour period can be determined directly as shown in Column 8. The first 12 hour period ends at 1200 hrs. on the 4th, the rainfall excess being 134 pts. The second 12 hour period ends at 2400 hrs. on the 4th, the cumulated rainfall excess then being 280 pts. of which 134 pts. fell in the first 12 hour period. The rainfall excess in the second period is therefore 146 pts. and so on for the other periods.

<u>Note 1</u>. In this example a time interval of 2 hours is used to define the mass curve. It is considered that this period will be adequate for all storms which produce major floods at Launceston.

<u>Note 2</u>. When the duration of the last period of excess rainfall is not exactly equal to 12 hours it should be allowed for according to the following rules. If the time interval is 6 hours or more it can be considered as a 12 hour period without any adjustment. If the period is five hours or less the rainfall should be added to that of the preceding 12 hour period.

In the above example the 4 pts. fell in the last period of 2 hours and would therefore be added to the 195 pts. which fell in the preceding 12 hours making the total excess rain which fell in this period equal to 199 pts.

Note 3. Where the rainfall rate over a 2 hour period is less than the loss rate of 2.5 pts/hr., the total rainfall during this period should only be considered as loss since the losses can never exceed rainfall.

4.5 Step 4 - Prediction of the Surface Runoff Hydrograph

Once the 12 hour excess rainfall hyetograph is known the surface runoff hydrograph can be calculated by the method described in Section 4.0.

Sample computations for the flood of April 1929 are shown in Table 5 of Appendix "B". Ordinates of the 12 hour unitgraph at 6 hour time intervals are shown in Column (2) whilst the excess rainfall for each 12 hour period after the start of excess rain is shown along the first row.

The surface runoff produced by each period of rainfall excess is obtained by multiplying the unitgraph ordinates by the rainfall excess in that particular period as shown in Columns 3, 4 and 6. The total surface runoff is then computed by summing these values with the start of runoff delayed by intervals of 12 hours. Thus the total surface runoff after 24 hours of excess rainfall is calculated by the addition of Columns (3) and (4) as tabulated in Column (5) and after 36 hours by the addition of Columns (5) and (6) as shown in Column (7).

Note. Sufficient calculations need only be made to assess the time and value of the peak discharge.

4.6 Step 5 - Prediction of Total Peak Discharge

Table 5 shows the magnitude of the peak surface runoff. In this example its value corresponds to 150,400 cusecs. In order to obtain the total peak discharge base flow must be added according to Table 2 in Section 4.0. From this table base flow will increase a surface runoff peak of 150,400 cusecs by 12,000 cusecs. Thus the total predicted peak is 162,400 cusecs.

It will be noted that in step 5 of this example a preliminary peak discharge of 100,600 cusecs was forecasted at 1000 hrs. on the 5.4.29 before the completion of all rainfall excess. This would enable evacuation of the flood plain to take place 24 hours before the final forecast was made.

4.7 Step 6. Allowance for Storms with non-uniform Temporal Patterns of Rain

The peak discharges of six past floods for which records are available were predicted according to the above procedure. The results are summarized in Table 8 below.

Table 8

Estimated Flood Peaks for Past Floods

Date	Forecasted Peak cfs	Actual Peak cfs	Remarks
13th Oct.58	53,000	48,000	
18th Aug. 58	50,000	43,000	
26th May, 56	37,000	49,000	Uneven temporal pattern
5th May, 56	31,000	31,000	
21st Sept.52	21,000	33,000	" " "
6th April, 29	162,400	150,000	True Temporal Pattern and Flood Peak estimated

It will be noted that with the exception of the floods of 26th May 1956 and 21st September 1952 the forecasted peak flood discharge is within 15 per cent and generally within 10 per cent of the true peak. For these two floods the temporal patterns of rainfall were extremely uneven, there being at least one or more 12 hour periods during the total storm duration when the rainfall rate did not exceed losses.

To allow for storms in which the temporal pattern is extremely uneven, it would appear that the forecasted peak should be increased. To fix accurately the percentage increase, analyses of a much larger number of storms of this type would be required. Data on such storms are at present not available and it is suggested that until this can be carried out that percentage increases based on the above estimates be applied according to the following rule.

"Where the excess rainfall in any period of 12 hours during the total storm duration is equal to zero then the forecasted peak discharge should be increased by one third".

This rule applied to the floods of 26th May 1956 and 21st September 1952 would increase the forecasted peaks to 49,000 and 28,000 cusecs respectively as compared with the actual peak flows of 49,000 and 33,000 respectively.

4.8 Step 7 - Final Forecast

The magnitude of the peak flood discharge is calculated in Step 5 or Step 6 according to the type of storm being analysed.

From Table 4, showing the mass curve of rainfall excess, and Table 5, showing the surface runoff hydrograph, the time when excess rainfall commenced and the time to peak after the start of rainfall excess can be determined respectively. This data enables the time of arrival of the flood crest to be calculated as shown in Appendix "B".

Preliminary forecasts prior to the completion of rain can be obtained in the same manner if so desired. For example for the flood of April 1929 as tabulated in Appendix "B" a peak of at least 100,600 cusecs occurring at 0600 hrs. on 6.4.29 is predicted 24 hours before the final forecast of 162,400 cusecs occurring at 1800 hrs. on 6.4.29 is made.

Similarly the time when the levee banks will be overtopped can also be estimated. The average discharge at which the levee banks are overtopped is estimated at 90,000 cusecs (Ref.1 p.C59). For the April 1929 flood it is seen from Table 5 that this flow discharge less the allowance of 8,000 cusecs for base flow, occurred 40 hours after the start of rainfall excess at 2400 hrs. on 3.4.29. Thus the time when the levee banks are overtopped is estimated at 1600 hrs. on 5.4.29. The actual time when the levee banks were overtopped was 0130 hrs. on 6.4.29 or 5½ hrs. later than that forecasted.

5.0 Results of Forecasting Procedure Applied to Past Floods

The procedure developed above has been applied to six past floods for which records are available. The results are summarised in Table 9 below:-

Table 9

Estimates of Flood Peaks and Time of Peak for Past Floods

Date of Storm	Time of Forecast	Forecasted Peak cusecs	Actual Peak cusecs	Forecasted Time of Peak	Actual Time of Peak
Oct.58	1000 hrs. on 12th	53,000	48,000	1500 hrs. on 13th	2200 hrs. on 13th
Aug.58	1000 hrs. on 16th	50,000	43,000	0800 hrs. on 18th	0600 hrs. on 18th
May 56	1000 hrs. on 24th	49,000	49,000	0200 hrs. on 26th	0500 hrs. on 26th
May 56	1000 hrs. on 3rd	31,000	31,000	0200 hrs. on 5th	0100 hrs. on 5th
Sept.52	1000 hrs. on 20th	28,000	33,000	1000 hrs. on 21st	1800 hrs. on 21st
April 29(1)	1000 hrs. on 5th	100,600	150,000	0600 hrs. on 6th	2400 hrs. on 6th
April 29(2)	1000 hrs. on 6th	162,400		1800 hrs. on 7th	

6.0 Data Required for the Operation of the Flood Warning Scheme

6.1 Daily Rainfall Records

Daily rainfall records as read at 0900 hrs. should be telegraphed to the flood warning centre as early as possible after 0900 hrs.

The index rainfall stations selected for the scheme are shown below with suggested alternative stations shown in brackets in the case of an emergency breakdown in the reports on rainfall during a flood.

Avoca (Lewis Hill, Fingal)
Lake Leake (Lewis Hill)
Mathinna (Tower Hill)
Meander (Golden Valley, Caveside, Mole Creek)
Shannon (Breona, Steppes, Arthur Lakes, Interlaken)
St. Marys (German Town, Cullenswood)
Upper Blessington (Ringarooma)

These station alternatives are only intended for use in the case when telegraphic contact to any of the main index stations is broken.

Each of the main index stations selected are at present telegraphic stations for the Hobart Weather Bureau although in some cases no reports are given on Sundays.

6.2 Pluviograph Records

Pluviograph records are required from any arbitrary station on or adjacent to the catchment. In the procedure described above, records from Launceston are used although this is not essential. In the case of a breakdown in operation of the pluviograph at Launceston, additional instruments are located at Western Junction Aerodrome and Scottsdale which would be satisfactory.

6.3 Streamflow Records

Discharge in the South Esk River at Launceston prior to the start of rain is required to estimate initial loss. This will necessitate daily records of flow either by the H.E.C. at Trevallyn Dam or by a separate observer at the H.E.C. gauging station at Hadspen.

6.4 Calculations

All calculations can be carried out to sufficient accuracy by slide rule. A suggested form of tabulation is shown in Appendix "B".

7.0 Conclusion

Insufficient data are available to enable stage forecasting of major floods at Launceston to be used with any degree of confidence. However, a procedure for forecasting peak flood discharges from rainfall records has been developed which has given an accuracy of 15 per cent or better in the forecasted peak discharge for six past floods and can therefore be expected to work satisfactorily for future storms.

For the flood of April 1929 a forecast that the levee banks would be overtopped was made 15½ hours preceding their failure while the peak discharge was predicted 14 hours before its occurrence. This period of warning could be increased if rainfalls at the index stations were reported every 12 hours instead of daily as at present.

References

1. C.H. Munro - "Flood Mitigation Measures for the City of Launceston" - Report No.8 Water Research Laboratory, University N.S.W.

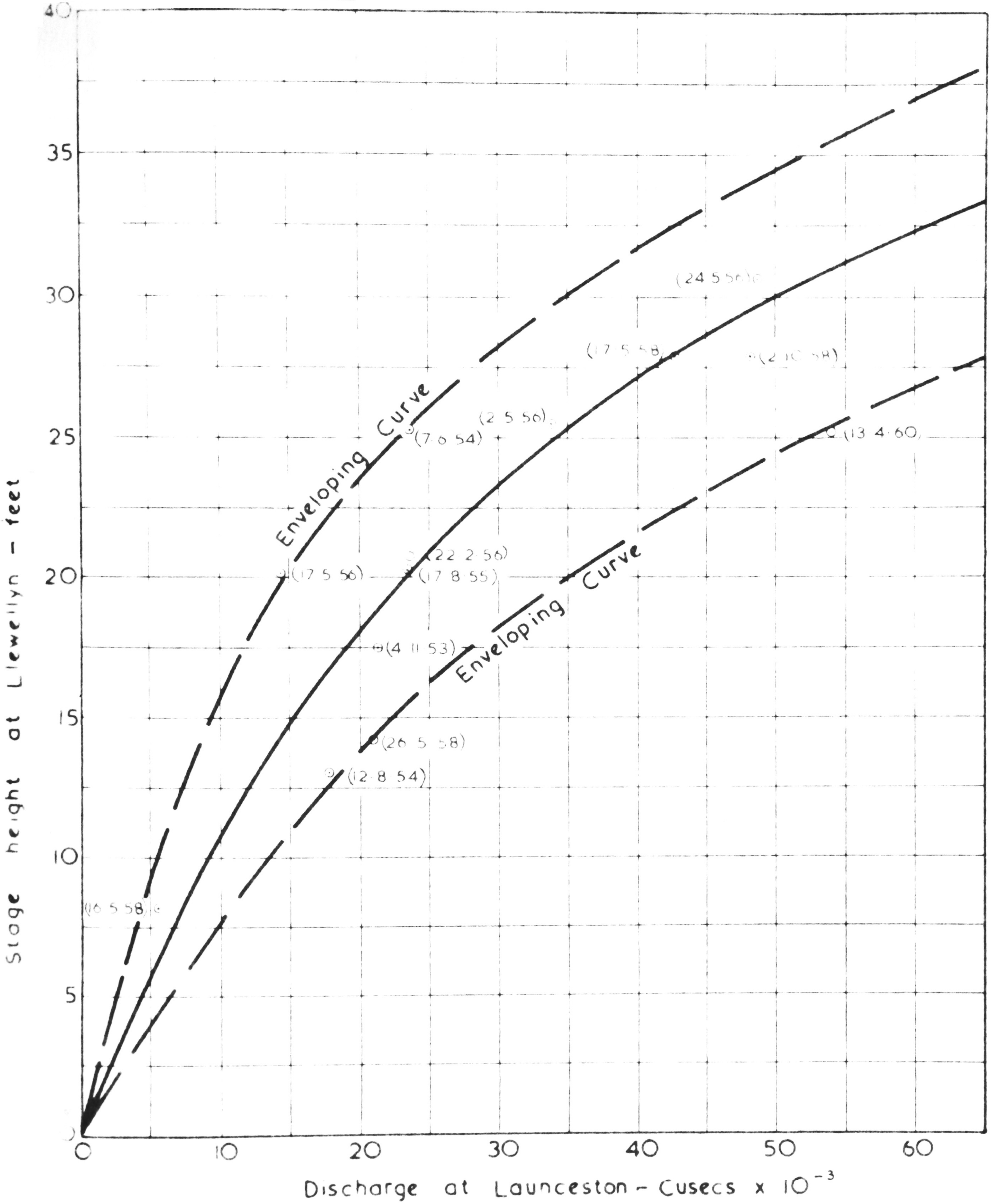
2. E.M. Laurenson - "Flood Forecasting" - Bulletin No.2, Water Research Foundation of Australia.

3. Linsley, Kohler and Paulhus - "Applied Hydrology" - McGraw Hill Pub.

Appendix "A"

Thiessen Weights for Seven, Eleven and Fourteen Index Stations on the South Esk Catchment.

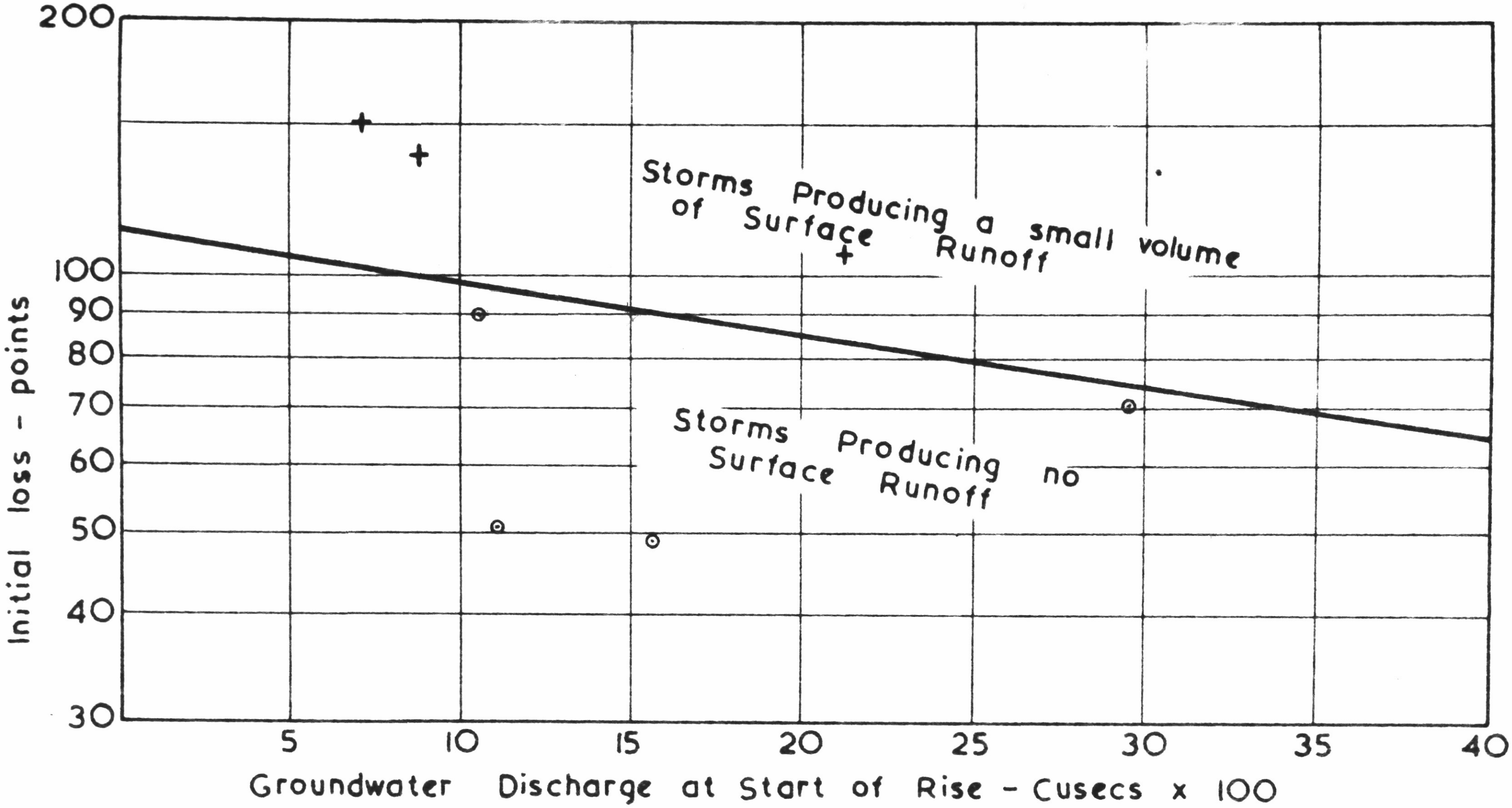
Station Name	Thiessen Wts. for 14 Station Average	Thiessen Wts. for 10 Station Average	Thiessen Wts. for 7 Station Average
Avoca	0.1200	0.1222	*
Breona	0.0265	*	*
Campbelltown	0.1278	0.1399	*
Cressy	0.1347	0.1591	0.2435
Interlaken	0.0451	*	*
Launceston	0.0265	0.0576	*
Lake Leake	0.0825	0.0856	0.2115
Mathinna	0.0872	0.0894	*
Meander	0.0530	0.1048	0.1175
Oatlands	0.0592	0.0744	0.0910
Shannon	0.0553	0.0687	0.0820
St. Marys	0.0491	0.0495	0.1115
Upper Blessington	0.0483	0.0488	0.1430
Westbury	0.0848	*	*



FLOOD FORECASTING SCHEME FOR LAUNCESTON
CORRELATION BETWEEN FLOOD STAGES AT
LLEWELLYN & FLOOD DISCHARGE AT LAUNCESTON

CE-E-1966

FIGURE No. 1.



FLOOD FORECASTING SCHEME FOR LAUNCESTON

RELATION BETWEEN INITIAL LOSS & GROUNDWATER FLOW FOR THE SOUTH ESK RIVER

FIGURE No. 2

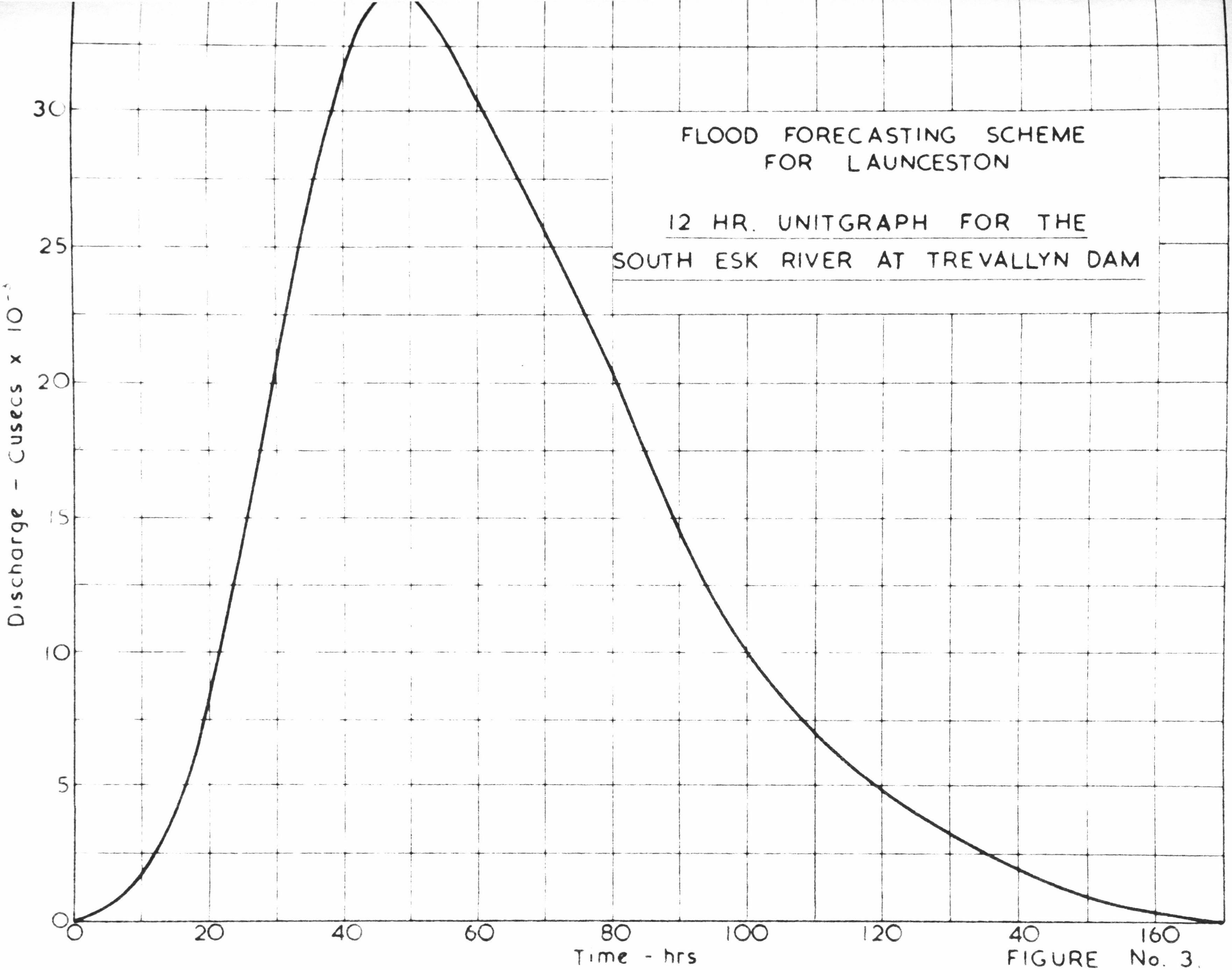
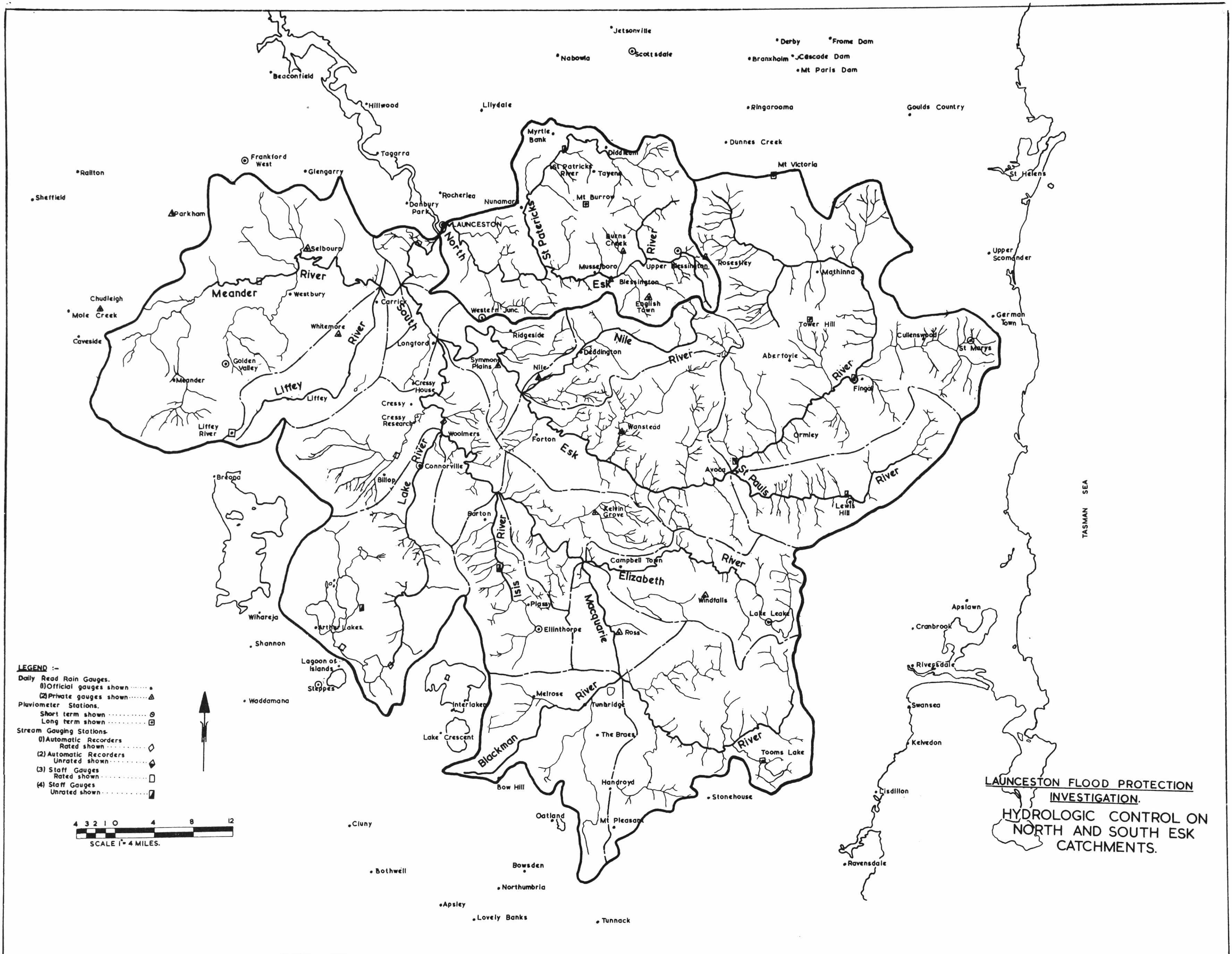

FLOOD FORECASTING SCHEME
FOR LAUNCESTON
12 HR. UNITGRAPH FOR THE
SOUTH ESK RIVER AT TREVALLYN DAM
Discharge - Cusecs x 10⁻³
0
5
10
15
20
25
30
0
20
40
60
80
100
120
40
160
Time - hrs

FIGURE No. 3.



LAUNCESTON FLOOD PROTECTION INVESTIGATION.

HYDROLOGIC CONTROL ON NORTH AND SOUTH ESK CATCHMENTS.

FIG. No. 4.

APPENDIX 'B'

FLOOD FORECAST AT LAUNCESTON FOR STORM OF APRIL 1929

GROSS RAINFALL.

TABLE 3.

Date		2 · 4 · 29		3 · 4 · 29		4 · 4 · 29		5 · 4 · 29		6 · 4 · 29	
Station	Weighting Factor	1st. Day Rainfall (pts.)	Weighted Rainfall (pts.)	2nd. Day Rainfall (pts.)	Weighted Rainfall (pts.)	3rd. Day Rainfall (pts.)	Weighted Rainfall (pts.)	4th. Day Rainfall (pts.)	Weighted Rainfall (pts.)	5th. Day Rainfall (pts.)	Weighted Rainfall (pts.)
Avoca	0·135	49	6·6	12	1·6	149	20·1	250	33·8	38	5·1
Lake Leake	0 103	18	1·9	8	0·8	161	16·6	650	66·9	10	1·0
Mathinna	0 107	45	4·8	22	2·4	520	55·6	1325	141·8	22	2·4
Meander	0·126	55	6·9	0	0	145	18 3	300	37·8	172	21·7
Shannon	0·083	53	4·4	4	0·3	370	30·7	529	43·9	113	9·4
St. Marys	0·059	0	0	65	3·8	618	36·4	821	48·4	10	0·6
Upper Blessington	0·059	35	2·1	15	0·9	317	18·7	668	39·4	105	6·2
TOTALS			26·7		9·8		196·4		412·0		46·4

INITIAL LOSS.

Discharge at Start of Rise = 437 cusecs

Initial Loss = 110 pts

Initial Loss to be satisfied by rain which fell after 0900 hrs. on 3·4·29 = 110 − (27 + 10) = 73 pts.

MASS CURVE

$$\text{Multiplication Factors} = \frac{\text{Rainfall on Catchment over given period}}{\text{Rainfall at Launceston over same period}}$$

15 hrs. ending 0900 hrs. on 4·4·29 = 196/83 = 2·36
39 " " " " " 5·4·29 = 608/251 = 2·46
64 " " " " " 6·4·29 = 654/318 = 2·06

TABLE 4.

Date	Time (Hrs)	Gross P at L'ton (pts)	Mult Factor	Gross P on catchment (pts)	Loss (pts)	Mass Curve of Excess Rain (pts)	12 Hour Excess Rain (pts)	Date	Time (Hrs)	Gross P at L'ton (pts)	Mult Factor	Gross P on catchment (pts)	Loss (pts)	Mass Curve of Excess Rain (pts)	12 Hour Excess Rain (pts)
1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
3rd	0900	0						5th	0200	187	2·44	456	138	318	
	1800	0	2·36	0					0400	209	2·45	493	143	350	
	2000	10	2·36	24					0600	225	2·46	554	148	406	
	2200	19	2·36	45					0800	244	2·46	601	153	448	
	2400	29	2·36	68	73	0			1000	258	2·43	627	158	469	
4th	0200	39	2·36	92	78	14			1200	267	2·39	638	163	475	195
	0400	48	2·36	113	83	30			1400	274	2·36	647	168	479	
	0600	64	2·36	151	88	63			1600	278	2·33	648	169	479	
	0800	77	2·36	182	93	89			1800	284	2·29	651	172	479	
	1000	90	2·36	212	98	114			2000	286	2·26	651	172	479	
	1200	100	2·37	237	103	134	134		2200	293	2·23	653	174	479	
	1400	109	2·38	259	108	151			2400	296	2·19	653	174	479	4
	1600	119	2·39	284	113	171		6th	0200	299	2·16	653	174	479	
	1800	126	2·40	302	118	184			0400	306	2·13	653	174	479	
	2000	138	2·41	332	123	209			0600	309	2·10	653	174	479	
	2200	154	2·42	372	128	244			0800	315	2·06	653	174	479	
	2400	170	2·43	413	133	280	146		1000	322	2·06	654	175	479	

4. SURFACE RUNOFF HYDROGRAPH

TABLE 5.

12 Hr. Excess Rain Hyetograph		$P_{e_1} = 1 \cdot 34$	$P_{e_2} = 1 \cdot 46$		$P_{e_3} = 1 \cdot 99$							
Time after start of excess rain hrs	Ordinates of 12 hr. unitgraph cusecs x 10^{-2}	Surface runoff from 1st 12hrs P_e cusecs x 10^{-2}	Surface runoff from 2nd. 12hrs P_e cusecs x 10^{-2}	Total surface runoff after 24hrs. rainfall cusecs x 10^{-2}	Surface runoff from 3rd. 12hrs P_e cusecs x 10^{-2}	Total surface runoff after 36hrs. rainfall cusecs x 10^{-2}	Surface runoff from 4th. 12hrs P_e cusecs x 10^{-2}	Total surface runoff after 48hrs. rainfall cusecs x 10^{-2}	Surface runoff from 5th. 12hrs P_e cusecs x 10^{-2}	Total surface runoff after 60hrs. rainfall cusecs x 10^{-2}	Surface runoff from 6th 12hrs P_e cusecs x 10^{-2}	Total surface runoff after 72 hrs rainfall cusecs x 10^{-2}
1	2	$3 = P_{e_1} \times (2)$	$4 = P_{e_2} \times (2)$	5 = (3) + (4)	$6 = P_{e_3} \times (2)$	7 = (5) + (6)	8	9	10	11	12	13
0	0	0	–	0	–	0						
6	7	9	–	9	–	9						
12	25	33	0	33	–	33						
18	62	83	10	93	–	93						
24	128	171	37	208	0	208						
30	203	272	91	363	14	377						
36	275	368	187	555	50	605	0					
42	329	441	296	737	123	860						
48	348	466	402	868	255	1123						
54	332	445	481	926	404	1330			0			
60	301	403	508	911	548	1459						
66	271	363	485	848	656	1504						
72	246	330	440	770	693	1463					0	
78	215											
84	176											
90	142											
96	114											
102	92											
108	74											
114	61											
120	48											
126	38											
132	29											
138	21											

5. TOTAL FLOOD DISCHARGE

TABLE 6.

	Preliminary Forecast	Final Forecast
Time	1000 Hrs. on 5 · 4 · 29	1000 Hrs. on 6 · 4 · 29
Peak Surface Runoff	92,600	150,400
Allowance for Base Flow	8,000	12,000
TOTAL FLOOD PEAK	100,600	162,400

6. ALLOWANCE FOR STORMS WITH NON-UNIFORM TEMPORAL PATTERNS OF RAIN

Is excess rainfall in any 12 hr. period equal to zero? = No

If answer is Yes --

Total Flood Peak from Step 5. = –

$\frac{1}{3}$ Total Flood Peak from Step 5 = --

∴ TOTAL FORECASTED PEAK = –

7 FINAL FORECAST

TABLE 7.

	Preliminary Forecast	Final Forecast
Time	1000 Hrs. on 5 · 4 · 29	1000 Hrs. on 6 · 4 · 29
Peak Discharge	100,600	162 400
Rainfall Excess commenced	2400 Hrs on 3 · 4 · 29	2400 Hrs on 3 · 4 · 29
Time to Peak	54 Hrs.	66 Hrs
Time of Peak	0600 Hrs on 6 · 4 · 29	1800 Hrs. on 6 · 4 29
Time to Surface Runoff of 82,000 c. f. s	45 Hrs.	40 Hrs
Time when levees overtopped	2100 Hrs. on 5 · 4 · 29	1600 Hrs. on 5 · 4 · 29