WELLAND RIVER BOARD

REPORT
ON THE INVESTIGATION INTO FLOOD LEVELS
IN THE
TIDAL SECTION OF THE RIVER WELLAND

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1. As instructed by the Board at their meeting in April 1959, the following is a report on the anticipated flood conditions in the tidal section of the River Welland after carrying out a full and comprehensive survey of the tidal section of the river from Spalding to the junction with the River Witham at Tab's Head.

2. Catchment Area.

It is first necessary to make a study of the catchment area as a whole.

The area shown in Diagram 1, also shows the principal points in the catchment, and the sub-catchment areas.

The upper section of the catchment area consists of a number of steep sided valleys, all of which have a fairly steep gradient and have their confluence into the two main rivers, the Welland and the Glen.

The River Welland enters the fenland at Market Deeping and the Glen at Kate's Bridge, from which points they become high level water carriers, carrying freshwater only down to Spalding and Surfleet respectively, where they come under tidal influence. The confluence of the two rivers and also of the Vernatt's Drain, which carries both pumped and gravity drained water, is at Surfleet, from whence the river flows through Fosdyke to reach the end of its confined channel in the Wash at Tab's Head, where it joins with the River Witham.

3. Data.

Investigations of problems such as these can only be based on information collected during past floods, and there has only been one period, i.e. December 1954, during which the flows could be described as reaching 'flood' proportions since the Welland Major Improvement Scheme was completed, in actual fact it was approximately half the 1947 magnitude. It is, therefore, on this fairly comprehensive and accurate information obtained in 1954 that the calculations are based.

In earlier days it had been the practice to assume that in a heavy flood the highland parts of the catchment would give a 'run-Off' of $\frac{3}{8}$" in

24 hours and that the fenland run-off could be taken as $\frac{1}{4}$" in 24 hours. These figures were then taken as a 'maximum flood' and no consideration was given to the way a flood built up or died away, factors which should be taken into account when considering the flood levels at Surfleet.

4. Factors to Consider.

The flow of water into a river from a catchment depends on the following factors:-

a. Intensity, distribution and duration of rainfall.

b. Climatic conditions immediately preceeding the rainfall.

c. The area of the catchment.

d. The shape of the catchment.

e. The slope of the catchment.

f. The geological formation of the catchment.

Although it has been well known in the past that these factors all influence the flow in a river, a reasonably accurate formula allowing sufficiently for all these factors had never been produced until Mr.B.D. Richards, B.Sc., M.I.C.E., published a theory in 1944, by the application of which to past floods, there can be obtained a fairly accurate run-Off coefficient for the area, and also by means of which the flow in the river for a given rainfall can be calculated at all stages of the flood. This is most important when considering whether a separate outfall into the main river has a sufficiently long discharge period; i.e. the period when water levels in the main river are low enough for that particular outfall to discharge water.

5. Hydrographs.

Referring to diagram No.2, an example of 'flood plotting' is shown. The graph is a 'hydrograph', - for such are the flood graphs called - for the River Welland at Folly River junction. The horizontal base of the diagram is divided into hours and the vertical measurement indicates cusecs (cubic feet per second). The amount of water flowing can be read off at any time after the start of the rainfall, this being represented by 0 hours. For example the flow in the river 40 hours after the start of the rainfall is found, as shown on the hydrograph, to be 700 cusecs.

However, the immediate object is to compare the results obtained in practice in December 1954 with the theoretical results obtained by applying Richards' theory. The main river flow readings were taken at Four Mile Bar footbridge, Maxey South Drain Sluice, Folly River, Maxey North Drain and at Deeping St. James. The hydrograph has been calculated for the confluence of these streams and is shown on Diagram 3. This shows a maximum value of 2,500 cusecs for the flow occurring at 80 hours after the commencement of the rainfall.

This time of 80 hours is known as the period or time of concentration for that point in the river, and it means that for the whole of the catchment area above that point to be contributing to the flood, it must continue to rain for 80 hours; otherwise the run-off from those areas nearest the point considered will have ceased before that from the remoter parts has reached there.

The recorded flow in this instance was at a maximum on the 15th December after the following rainfalls:-

Date.	Dogsthorpe.	Seaton.	Market Harborough.	Oakham.
Dec. 8th.	0.83	1.40	1.33	1.18
" 9th.	Nil.	Nil.	0.01	0.01
" 10th.	Nil.	Nil.	Nil.	Nil.
" 11th.	0.26	0.25	0.29	0.13
" 12th.	0.15	0.33	0.27	0.28
" 13th.	0.57	0.66	0.61	0.73
" 14th.	Nil.	0.04	0.03	0.02
" 15th.	Nil.	Nil.	Nil.	Nil.

It is interesting to note from the above figures the influence of the second of the list of factors which were listed earlier, namely 'the climatic conditions preceeding the rainfall' - in this case the 'initial state of wetness' of the catchment. On the 15th December the maximum flows were recorded - presumably as a result of the rainfall of the 11th - 13th. Previously, although the river had been above normal, it had not reached flood proportions even though a much heavier rainfall occurred on the 8th. The answer being that there was no recorded rainfall for several days before the 8th, whereas there was an average of 0.25 inches on both the 11th and the 12th. The effect is that although the rainfall on the 8th in general exceeded that of the three day total of the 11th, 12th and 13th, the actual run-off was much heavier on the 13th.

Unfortunately there is no record of the time at which the rainfall commenced on the 11th.

The maximum flow occurred at Four Mile Bar at about mid-day which indicates a time of concentration at Four Mile Bar of 87 hours. The calculations have been made for a point in the main river immediately downstream of the Folly River junction which is some 40,000 ft. upstream of Four Mile Bar so that a deduction can be made from this figure. The maximum velocity which would be experienced in this section of the river would be 2.5 - 3.0 ft/sec. giving an average velocity - which would also be the velocity of the flood peak - of 1.6 to 2.0 ft/sec. This would mean a deduction of approximately 6 to 7 hours bringing the time of concentration at Four Mile Bar down to 80 hours which was the figure also arrived at by calculation.

Similarly the time of concentration for the Welland at Surfleet which is 56,000 ft. downstream of Four Mile Bar should be 87 hours plus 8 hours, which is 95 hours, whereas by calculation Richards' formula gives 96 hours.

It seems, therefore, that the flood formula are reasonably accurate when applied to the Welland and the information can now be expanded to appl to floods of larger magnitude, but less frequency.

.6. <u>References.</u>

A committee of the Institution of Civil Engineers produced a report in 1933 which suggested that the '<u>normal maximum flood</u>' of an upland catchment was caused by a rainfall intensity given by the expression $I = \frac{4}{T + 1}$ where I is the rainfall intensity in inches per hour, and T is the time of concentration of the catchment under consideration in hours. This expression broadly speaking means that four inches of rain falls on the catchment during the time of concentration.

In his article in 'The Engineer' dated August 22nd 1952, George Bransby-Williams, M.I.C.E., also produced an expression for rainfall frequency which was based on a variety of catchments and found that the Institution Committee curve coincided with his own '200 year frequency curv almost exactly.

It is obvious that one cannot state simply that a certain flood flow will be the maximum possible; it is necessary to choose a frequency within reason and base the calculations on that probability. As the Flood

Committee of the Institution of Civil Engineers suggest the formula $I = \frac{4}{T + 1}$ and Bransby-Williams suggest a frequency of 200 years for this rainfall intensity it would seem reasonable to employ the same figure for the 'normal maximum flood' of the Welland Catchment area.

7. Folly River Junction.

Taking this figure for the rainfall, and the run-off and other coefficients obtained from the 1954 flow; the 'normal maximum' hydrograph for Folly River Junction can now be constructed. This is shown on Fig. 3.

It will be noted that the time of concentration is unaltered in this case, and 'the maximum flood' of 4,850 cusecs is reached 80 hours after the start of the rainfall.

It is also interesting to compare this volume of flood with the conditions obtaining in the 1947 flood. Although there were no really accurate gaugings carried out in this area during the flood period, an estimate of the flow was made at Stamford by means of float readings and it was found that approximately 4,000 cusecs were passing.

At Folly River junction with the inclusion of the River Gwash, Maxey and Car Dyke areas, it can be seen that the 1947 flood and the 'normal maximum' flood are of very similar magnitudes.

The figure of 4,850 cusecs represents a run-off of 24.9 cusecs per 1,000 acres of catchment compared with the previously assumed average of 25. This is an average figure it must be remembered, and it could not be applied to the individual valleys forming the catchment. For example in 1947 when the total run-off was roughly the same as the above figure, the run-off from the Eye Brook, which is the steepest valley of the catchment, was almost 40 cusecs per 1,000 acres.

In recent floods at Market Harborough a run-off of 80 - 100 cusecs per 1,000 acres has occurred.

8. Crowland and Cowbit Washes.

Returning to Fig. 3, we must now consider the effect of the Cowbit and Crowland Washes on this flow. A study of the section and gradient of the river flowing alongside the washland shows that the quantity which will flow along this section would be 3,500 when the water levels had reached those of the cradge bank level as designed. Under the recent agreement, the river can be allowed to build up to this level before water is let on to the washes. It is obvious then that any flows in the river in excess of 3,500 cusecs must be discharged onto the wash land until the water level on the washes builds up to cradge bank level.

The Welland hydrograph is again shown in Fig. 4, and a horizontal line has been drawn at 3,500 cusecs, the area above, coloured pink, being the total quantity of water in excess of 3,500 cusecs which must be accommodated on the washes.

The volume of this water is 173,500,000 cu.ft., so that with a wash area of 2,500 acres and an average land level of 8 - 10 O.D. Newlyn, the water level after receiving this quantity would be 11.5 O.D.

In addition to this flow there would also be a quantity of water driven onto the wash as a result of the ponding effect of the river caused by the closing of the doors at Marsh Road Sluice during the high tide periods.

9. Marsh Road Sluices.

Under present conditions the free discharge level - that is the level at which the water would flow were there no tidal influence - at Marsh Road Sluice with 3,500 cusecs flowing is + 12.0 O.D. This level has been shown on Fig. 5 drawn on a set of typical spring tide curves. Also shown on the curve is the Welland hydrograph for Marsh Road Sluice, this time the period of concentration being 90 hours. Before the flood builds up to 3,500 cusecs, it is assumed that, as the river level is below cradge bank level, there would be sufficient ponding volume in the channel itself to be able to take the flow during the closed period. During the time that the main river flow is over 3,500 cusecs, the tidal level is above + 12.0 O.D. five times for a total of 11¼ hours. It is assumed for the sake of calculation that during this time, as no water is being discharged through the sluices, the whole river flow must be passed onto the washes, and this extra flow, which is shown coloured green on Fig. 4, amounts to 141,750,000 cubic feet, and would further build up the water level on the washes to + 12.75 O.D. In actual fact the quantity would be less than this as no allowance has been made for the ponding capacity of the main channel and the old river