between Lock's Mill and Marsh Road Sluice, nor for the fact that owing to this ponding the water level on the land side of the sluice would have built up and therefore the doors would open before the tidal level had dropped back to + 12.0 O.D.

It is also assumed that a certain amount of the water which has passed onto the wash will flow back through the weirs into the main river immediately the flow falls below 3,500 cusecs and this, together with pumping at Lock's Mill, will tend to extend the period of flood as shown in Fig. 4.

It can be seen that a flood of this magnitude can be passed without filling the washes above a level of + 12.75 O.D. leaving a further capacity of 200,000,000 cubic feet up to cradge bank level at the lower end of the washes. As there is much less water to be evacuated from the washes after such a flood, and owing to a quicker fall in the river after flood conditions, this evacuation can be started earlier than formerly, it seems safe to assume that, providing the agreement not to let water onto the washes until cradge bank level is reached is adhered to, then the flow in the main river between Lock's Mill and Surfleet will not exceed 3,500 cusecs for the normal maximum flood.

9. River Glen.

The River Glen and its tributaries must now be examined and a hydrograph produced for this river at Surfleet. There is now a gauging flume at Kate's Bridge on the Glen which would have given valuable information had it been in existence in 1954, but unfortunately there has been no appreciable flow in the Glen or certainly not one which could be termed a 'flood flow', since the installation of this flume. The only possible procedure, therefore, is to apply the same coefficients of run-off etc., as were calculated for the Welland.

Using this method we obtain the hydrograph for the River Glen at Surfleet as shown in Fig. 6. This shows a peak of 2,216 cusecs being reached 76 hours after the rainfall starts.

10. Vernatts Drain.

An application of Richards' theory to the area draining into the Vernatts Drain shows that the period of concentration is 12 hours, and this is borne out in fact in that in July 1958 the greatest flow reached the pumps at Pode Hole approximately 12 hours after the rainfall causing the flow commenced. As this area achieves peak flow well before either of the other streams reach theirs, it is not considered necessary to construct a hydrograph for the Vernatts, but to assume that the flow builds up to its maximum after 12 hours following a straight line on the graph.

11. Combined Hydrographs.

The hydrographs for the Welland, Glen and Vernatts at Surfleet are all three shown on Fig. 7, that of the Welland being plotted normally. The hydrograph of the Glen is plotted normally until it reaches its peak, then as the rainfall continues, the Glen will continue to discharge at maximum flow until the Welland peaks, when it will fall away. This also applies to the Vernatts, it is brought up to,a peak of 684 cusecs where it stays until 96 hours after the rainfall commenced.

To obtain the total flow immediately downstream of the Glen confluence at any time, the individual values of each contributing hydraograph must be added together, hence for a simple example, at a time 71 hours after the start of the rainfall the flows in the Vernatts, Glen

and Welland are respectively 684, 2,000 and 2,000 cusecs and the total flow would be 4,684 cusecs as shown on Fig. 7.

The total flow hydrograph is also shown on Fig. 7. This shows a peak value of 6,400 cusecs being reached after 81 hours.

It can also be noted from these hydrographs that the Glen peaks some 7 hours before the Welland, owing to the flooding of the Washes, whereas by calculation the actual peak flow of the Glen would occur 20 hours before the Welland peak. This earlier Glen peak would actually be the case for smaller floods when the Welland would not discharge onto the Washes.

12. Internal Boards Outfalls.

The flow from the various internal boards drains entering the river between Surfleet and Tab's Head at the Witham junction, where the confined channel ends, must next be calculated. As Richards' theories cannot readily be applied to areas as small as each of these, it has been assumed that, as the rainfall producing these maximum conditions is very prolonged even if not heavy, these fen areas would each be contributing its maximum which is assessed at 15 cusecs/1,000 acres, the figure usually taken for fen areas.

The inflows are as follows:-

Lord's Drain	81 cusecs
Risegate Eau	163 "
Five Towns Drain	120 "
Holbeach Outfall	175 "
Fosdyke Marsh P.S.	10 "
Kirton and Frampton Marshes	187 "

This latter includes the outmarsh and for the purpose of producing a backwater curve the whole of the off-flow from this area is assumed to enter the river at the end of the North Bank.

13. Backwater Curve.

The only thing that remains to be decided before the backwater curve is calculated is the level of commencement of the curve. This level must be the low water level of the sea between tides in the free and open wash.

The frequency of the particular flood under investigation would be

considerably increased were we to allow for abnormal tides or adverse winds, and in addition this chance of adverse tidal conditions coinciding with flood conditions in the river existed with the same effect before the carrying out of the Major Improvement Scheme.

Flood conditions could equally well occur during spring tides as during neaps, but as the neap tides give a higher low water level, it is assumed that the flood occurs during these tides, and after consulation with other authorities and with our own records, it was decided that a level of - 6.0 O.D. Newlyn would be the lowest low water neap tide which could be relied on.

The backwater curve for the river under the above conditions has been calculated and is shown in Fig. 8.

14. Flood Frequency.

It must be remembered that the flood conditions which are assumed are a normal maximum, and the frequency of such conditions with regard to rainfall only, has been assessed at 200 years. However, as we found to our cost in 1947, the conditions can also be obtained by the coincidence of a lesser rainfall on a catchment which has been frozen for a long period, and on which there is a big accumulation of snow. This must increase the probable frequency of the flood, and may even double it; in other words these conditions might be expected every 80 to 100 years.

As regards the Vernatts Drain outfall, the low tide water level recorded in 1947 was 7.25 O.D. By calculations and as a result of the investigations made under present conditions, a flood of a magnitude of 56% of a full flood would produce this level and this is likely to occur in a twelve year frequency.

15. Effects on Internal Drainage Boards Outfalls.

The flood levels as given by the backwater curve, are clearance levels, which will only obtain during the low tide period, and it must be remembered in forming any conclusions from them, that they would be at this level for less than half the whole tidal cycle and these conditions may continue for five consecutive tides or $2\frac{1}{2}$ days.

It should be borne in mind that for years past, whenever particularly

adverse tidal conditions coincided with even a moderate flood in the tidal compartment of the river, high water levels have prevailed and difficulties have arisen with the discharge from some of the Internal Drainage Board outfalls.

From the backwater curve, the anticipated effects of a full flood on the Internal Drainage Board outfalls and the low water levels which may be expected under full flood conditions can be determined. These are as follows:-

South Welland Internal Drainage Board.

(a) Holbeach River.

The calculated water level is + 2.36, which is approximately 1'-6" above the water level allowed for in preparing the recent improvement scheme, but as there is a two foot rise in the first mile to the old outfall sluice, and as there is a very high ponding volume in this section of the drain, it is not considered that the area would be seriously embarrassed during the five tidal periods involved.

(b) Lord's Drain.

With land levels below + 9.0 O.D. in places, this area would be seriously affected if the calculated low water level of + 8.15 prevailed.

North Welland Internal Drainage Board.

The general land level in both the Five Towns and Risegate Eau districts vary between + 6.0 and + 8.0 O.D.N. and with anticipated water levels at their outfalls of 4.81 and 6.77 respectively, both these districts would be seriously affected. It is understood that even under moderate flood conditions, these areas suffer from poor drainage and that schemes of improvement and pumping are already contemplated.

Deeping Fen,Spalding and Pinchbeck Internal Drainage Board.

The calculated low water level for the river at the Vernatts outfall is + 9.75 O.D. compared with a highest recorded clearance level in 1947 of + 7.25 when approximately the same quantity of water was coming down the River Welland above Spalding.

It is considered that under present conditions, the maximum low water level at Vernatts outfall should not exceed 7.25 O.D. otherwise the pumps

at Pode Hole cannot discharge their required capacity in the tide lock period and the outlet from the Counter Drain would be obstructed.

At a level of 9.75, in order to discharge the full 684 cusecs, it would be necessary to have a water level at Pode Hole of + 11.5 O.D. which would be higher than the existing bank level in places. In addition to this, two of the pumps would be out of action against such a big head, and no water could be discharged from the Counter Drain.

The calculated level of 11.5 at Pode Hole would be a minimum level under these conditions and to allow for 'ponding' the bank would have to be made up to 13.0 O.D.

16. Remedial Works.

If it is decided that work should be undertaken to overcome the probable consequences of a full normal maximum flood such as that experienced in 1947, there are three alternative schemes which may be considered.

(1) To widen the existing Welland Channel below Surfleet to accommodate the full flood at a clearance level at low water which is low enough to give adequate free discharge levels for the Internal Drainage Board outfalls.

This would involve widening the river and increasing the existing bed widths from 110 ft. to 150 ft. from Surfleet to Holbeach River outfall, a distance of 5 miles, on the South East side of the river shown red on Fig.(1). The scheme would require 40 acres land purchase and the moving back and reforming of the tidal bank from Surfleet to Fosdyke. Below Fosdyke there is already a wide slipe or outmarsh owned by the South Welland Internal Drainage Board and on this section widening could be carried out without interference with the existing banks.

The anticipated backwater curve that would be obtained is shown in Fig. 8 and the clearance levels would be as follows:-

Holbeach Outfall	+ 2.5
Five Towns	+ 4.13
Risegate Eau	+ 4.95
Lord's Drain	+ 5.60
Surfleet (Vernatts)	+ 7.00

Conditions for all concerned should, therefore, be better than those existing before the Major Improvement Scheme was carried out.

The estimated cost of these works is £231,600.

(2) Another scheme would be to provide a bye pass channel with a bed width of some 100 feet from Surfleet to Holbeach River outfall. This scheme would produce almost the same results as scheme (1) but the costs would be considerably more and are estimated to be £530,000.

In addition there would be far more severance of properties and some 250 acres of land purchase would be necessary.

(3) The third proposal would be for each Internal Drainage Board to be provided with facilities for discharging their water under conditions of full flood, which in the cases of the outfalls mentioned in para. 15, would mean the provision of additional or emergency pumping facilities and ancillary works.

The requirements of the various Boards would be as follows:-

South Welland Internal Drainage Board. Lord's Drain.

Provision of a pumping station of 81 cusecs capacity for flood periods, leaving the existing gravity outfall for normal use. Estimated cost £20,000.

North Welland Internal Drainage Board.

It is understood that in any pumping scheme for this area, it would be advantageous to combine the Five Towns and Risegate Eau Districts which would mean a total pumping capacity of 283 cusecs. The cost of the pumping station is estimated at £60,000 and this would not include any work on the drains, which in any case could not be attributed to the works on the Welland.

It is considered that the Welland River Board liability over the cost of the pumps would be to provide a 'booster' in high flood periods only, and not the provision for pumping the whole area at all times which it is understood will soon be required in any case for these areas.

Deeping Fen, Spalding and Pinchbeck Internal Drainage Board.

To provide for the full discharge for the area served by the Vernatts