*Discussion on Paper No. 6657**

Standards for lowland drainage and flood alleviation and drainage of peat lands, with special reference to the Crossens Scheme

by

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and

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Mr F. D. Ashton (Senior Engineer, Ministry of Agriculture, Fisheries and Food) complimented the Authors on an interesting Paper which provided much food for thought and discussion. It also described works that would provide further food to eat by increasing the production from the pumped area. The object of the scheme had been to prevent a repetition of the serious flooding which had occurred in 1954 and 1956, and also, at the same time, to bring into production a rather larger area and to drain it by pumping instead of gravity. As the area had to be pumped, it was necessary to make sure the pumping capacity was such that there was no danger of flooding. The essence of the scheme, because of the large peat area, was the close control of water levels at the pumping station and the anticipation of floods by reducing the levels, as necessary, in advance to allow maximum storage capacity in the drains.

97. The capacity of the old pumping station was 20 cusecs/1000 acres, which seemed to be a reasonable standard for that part of the country, but it would be seen from the Paper that the pumps had been starved of water because the channels had not been of sufficient capacity to get the water to the old pumping station. The design of the new pumping station might be criticized on the ground that there were a large number of the Allen 24-in. centrifugal pumps in the centre bay to pump the low-lying Middle System, but as they had already had five units in good condition at the existing pumping station, they had therefore made use of those five pumps in the new pumping station.

98. During the work there had been some bed heave and slipping, of which mention had been made in the Paper. He wondered whether the Authors thought that it would have been advisable in the new channels to do the work in two sections, or to do it as two cuts, to give the ground time to dry out. The fact that excavation could be done very quickly with modern machinery often gave rise to the problem of slipping and bed heaving.

99. In § 65 there was mention of trouble with an underdrain which was attributed to a stop for welding. He would like to know the length of time of the stop. His experience of pile-driving in silts had been that only a long stop, such as overnight or for 24 hours, would cause the pile to seize and make it difficult to continue driving.

100. In § 80 the gravity sluice was mentioned; it was still in existence. That had been retained on the grounds that if there was an emergency, it could be used. There was reference in the Paper to the dual function of both the gravity sluice and the pumping; but the dual function, of both gravitation and pumping at the same site,

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* *Proc. Instn civ. Engrs*, vol. 24, February 1963, pp. 177–206.

was not usually effective. He would not have thought that any advantage would be gained by keeping the sluice in operation as a gravity outfall at the site of the pumping station, although it might be useful to have it there for use in an emergency.

Mr M. Nixon (Chief Engineer, Trent River Board) said his first impression on reading the first part of the Paper had been that the Authors were implying that the British approach to the standards for land drainage work was somewhat haphazard. There was no doubt that the British practice was open to criticism. The usual excuses were either that not enough was known about the hydrology of the area concerned, or that some financial stringency had affected the choice of the standards. Clearly both these factors had inherent dangers and it was unnecessary to enlarge on them.

102. In Holland the delta works had been designed against conditions having a frequency of once in 10 000 years and what were called minor works against a standard of once in 4000, but these frequencies referred to the actual overtopping of flood defences, whereas the Authors had quoted the frequencies at which their design conditions arose. It would be most interesting if the Authors could state whether their main channels would ever overflow, and if so, what the frequency of the overflow would be, because in his submission that was the real standard of their scheme.

103. In Appendix 2 the Authors stated that their design run-off of 0·5 in. in 24 hours occurred once in 20 years, but they went on to say that they could, in addition, accept 0·2 in. of rainfall in storage and another 0·15 in. due to the gravity outfall. This was an increase over their design run-off of some 70%, but this apparently only increased the standard to a frequency of once in 25 years, which was only a 25% increase. This was difficult to understand as usually a small variation of standards when approaching extreme conditions had a great effect on frequencies. In the River Trent, for instance, a 6-in. rise in water level at Nottingham at a high flood level altered the frequency of occurrence from once in 100 years to once in 200 years. He would like the Authors to comment on this point.

104. Mr Nixon agreed that generally the standard of design of land drainage work was increasing with the years. He did not think that was surprising, because it was accepted statistically that the highest known flood must ultimately be exceeded, and, therefore, as time went on flood-banks became higher and higher. That was a natural evolution which must be accepted and was a valid reason for increasing standards.

105. He would like the Authors to explain what seemed to be an inconsistency. Some 2 ft of shrinkage was expected and the pumps were designed to accept a lowering of the water level of 2 ft, but the underdrains and other structures were designed to accept a lowering of only 1 ft. It might infer that the Authors' freeboard of 3–4 ft was 1 ft too much, and that there was a danger of over-drainage which they hoped that time would correct.

Mr P. O. Wolf (Reader in Hydrology, Department of Civil Engineering, Imperial College of Science and Technology, University of London) proposed to concentrate on the hydrology of the Crossens Scheme. Mr Nixon had made some observations on this subject, with which Mr Wolf was in general agreement, and there were further matters of detail to be discussed and a general conclusion to be drawn.

107. The Authors had been good enough to enable Mr Wolf to discuss their approach with them before the meeting, and it was clear that, in the limited space allowed for a Paper on so many important aspects of a drainage scheme, they had had to give a much abbreviated account of their hydrological work. Although brief, however, their account seemed to indicate that they could have used better techniques.

108. In Table 1, and again in § 7, reference was made to the absence of minimum standards in the design of urban flood-alleviation schemes. That subject would come up for fuller discussion at a forthcoming meeting,[1] and all that seemed appropriate at that point was to mention that the 'Ministry of Health' design-storm intensities in fact represented just such minimum standards.

109. The first two headings of Table 1 and §§ 2–4 commented on the fact that continental standards were related to mean annual rainfall. That statement was only partly correct, for different administrations laid down different guide-lines for drainage design, and clearly administrative boundaries would coincide with annual isohyets only by accident. It might also be right to report that for some of the most modern continental drainage schemes, e.g. in the Dutch Zuider Zee polders, the designs had been evolved with reference to soil properties and crops. However, there was some sense in the idea of allowing mean annual rainfall to enter the calculations of probable run-off from rainstorms, for, in areas of high annual rainfall, the frequency as well as the magnitude of rainstorms could be taken as being greater than in the areas of lower annual rainfall. More frequent rain would leave a catchment in a wetter average condition with the result that any heavy storm would yield a comparatively high flood run-off.

110. Analysis of the frequency of the heaviest storms, at least in the British Isles, indicated that there was little connexion between their incidence and the mean annual precipitation or the elevation. As schemes such as that described in the Paper were designed to deal with the run-off from rare heavy storms, it would be difficult to justify major variations in design capacities with mean annual precipitation.

111. That observation led to some comments on the treatment of the Bilham formula both in the Paper and in Dr Prus-Chacinski's introduction. When Bilham published his analysis of heavy rainstorms recorded at three points, he emphasized that it was valid as a guide for storm frequencies greater than once in ten years. The Authors had used the formula for frequencies of once in 20 or 25 years, and extrapolation from 10 to 25 years was probably permissible, although it would not give very reliable results. Moreover, since Bilham's day, the Meteorological Office had analysed a large amount of rainfall recorder data and had come to the conclusion that both the form of the Bilham formula and the parameters proposed by Bilham required revision. If engineers needed the best rainfall frequency-magnitude-duration diagrams for any area, they should obtain the advice of the Meteorological Office. Mr Wolf wondered why Dr Prus-Chacinski used the Bilham formula when, according to the diagrams shown in his introduction, it was in error to the extent of 50 or 60%.

112. There were two further criticisms of the Authors' use of the Bilham formula. Daily rainfalls were not properly equivalent to Bilham's 24-hour maxima because Bilham had used the totals for 24 consecutive hours which, in most cases, would form part of two calendar days: that might be one of the reasons for the large apparent discrepancies on Dr Prus-Chacinski's diagrams. His one-day rainfalls were probably the results, in most cases, of storms lasting less than 24 hours.

113. The other difficulty arose out of the idea of using the point rainfalls with area coefficients, as mentioned in § 91. Where there were only a few rain gauges on a catchment, none could be expected to receive the peak intensity of any one rainstorm, and, as had been shown in the study of the Exmoor storm of 1952, the application of a low area factor to anything but the peak precipitation gave a distorted picture.

114. On another point of the use of run-off coefficients, Mr Wolf was glad to have found that there was no basic disagreement between the Authors and himself. In § 87 they had quoted run-off coefficients from 0·05 up to 0·6, and nowadays everybody agreed that such coefficients varied not only with the wetness of the catchment but also with the gross rainfall to which they had to be applied. It would seem best, therefore, if the phrase could be left behind with the old-fashioned concept of a constant 'impermeability'.

115. Mention had already been made of the generous margins of safety in capacity which had been built into the drainage scheme, but there had been no reference to yet another addition to that margin arising out of the use of axial-flow pumps. Mr Wolf assumed that the Crossens pumps had the usual flat head-discharge curve. In other words, the discharge would increase appreciably if the head was reduced, both as a result of the drain filling up on the upstream side and of the tide receding on the downstream side. Adding together all the factors enumerated in the discussion, he estimated that the discharge capacity of Crossens was approaching 1 in./d. That might be a proper capacity to install, but the Paper gave no indication that it had been deliberately chosen as the correct design value.

116. Mr Wolf concluded with a general plea in favour of a better study of the hydrological factors. Land drainage schemes were installed for the purpose of controlling the water table for optimum plant growth, and the total capacity was determined by the estimated design flood. That flood had to be related to a frequency giving the most economical balance of the costs of the drainage scheme and of the occasional flood damage to crops, etc. The Authors had not been fair to themselves when they attempted to make such estimates on the basis of daily rainfall data, of pumping records of the old station, which had an installed capacity much in excess of the carrying capacity of the old drains, and of a rainfall-frequency formula which they knew to be in error. They had, no doubt, used the best methods of site investigation in terms of topographical surveys and soil mechanics: they should have done equally careful work in the determination of the most important design basis, namely, the installed pumping capacity and drain sizes, by installing continuous recorders of rainfall, run-off and water table and by an analysis of the data: in short, by the best possible hydrological site investigation.

Mr J. D. T. Firth (Chief Engineer, Mersey River Board) said that the Authors must be left to fight their own battles, but felt on reading the Paper that a great debt of gratitude was due to them for the tremendous amount of information which they had provided, and for the very effective researches that they had carried out in trying to assess the standards of their design.

118. He had been surprised by the very close similarity of their figures to figures which his Board were now investigating and working on in a somewhat smaller area a little further down the coast.

119. In § 7 the Authors said:

> 'The present trend in this country seems to be to base design upon the last flood with some freeboard, except where there is danger to life, in which case higher standards may be adopted.'

Surely the position was not as bad as that? Research into the expected frequency and the economic design of flood flows was increasing rapidly in this country, and people knew what they were doing when they designed a scheme.

120. Reference had been made to standards. Mr Firth would not like to see standards broadly set up and meticulously applied in various parts of the country. The standards differed in different areas. There were different needs in similar areas. He would be very sorry if it came to be said: 'This is the standard, and it must be applied to this particular job.'

121. It would be of interest if the Authors could eventually say something more about the effect below their pumping station. Judging from the figures, it must have been an appalling channel to maintain, but the Mersey River Board proposed to do exactly the same thing in a smaller river, namely, cut off the gravity flow. There was a boat club immediately below them which was very anxious to know the result of the Board's activities, and frankly Mr Firth was a little anxious himself. He had been interested to hear the question of gravity outflow mentioned, and he knew that it was not always considered to be the most efficient way to combine gravity and

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pumped outfall. His Board had investigated the matter very closely and he was hoping to include the gravity outfall in their pumping scheme.

122. He welcomed the summary of costs given at the end of the Paper and was pleased to see that the cost per acre was about £40. He had not attempted to compare that with the flood damage per acre, although the facts could be obtained from the Paper. Instead of assessing the cost of a flood by the amount of damage done, he would like to refer to a Paper known to many engineers, which said: 'The total cost of restoring the damage of each flood which could occur within the economic or design life of the scheme should be taken as the flood damage.'

Mr H. H. Hunt (Norwest Construction Co. Ltd) disclaimed any intention of commenting on the design of the scheme, which was not the province of the contractor, but hoped to provide some useful information as an addendum to the Paper, particularly on the subject of peat. The Authors spoke of 25-year periods, 30-year periods and so on, and one was liable to think in those terms and forget what happened in the first few months.

124. A few years ago his firm had dug a very large hole in peat, adequately timbered and piled, and carried out prolonged pumping. There had been some delay due to shortage of steel, and in a matter of months a noticeable local subsidence had occurred all round. That had been investigated not only by themselves but by the consulting engineers, and the decision had been that it was due to an immediate shrinkage of peat. Though nothing like 2–3 ft, even an inch or two could do a great deal of damage to a nearby structure. Contractors should remember that when dealing with peat. It had not proved costly to his firm, but it might have been so.

125. The pH value of peat could be less than five in some cases, but as soon as horticulturists saw it, they would say that it was acid, and they knew a lot about it without having any knowledge of the pH value.

126. The silt was a most difficult material to handle and flowed like porridge. It had to be allowed to dry before it could be spread on the land, but the farmers seemed very pleased with it now that they had it. That was true also of the peat, especially where it was mixed. The Authors spoke only of it being spread, but a great deal had had to go to tip. The silt was very difficult to handle on a tip and it was not possible to travel out on it to a tipping end. What was needed was a big field over which to dump it and leave it to dry, dealing with it afterwards.

127. The question had been asked of why the thrust-bore failed after being stopped for welding the pipe. His firm had not been responsible; it had been dealt with by specialists and the answer should come from the Authors; but, having had a little experience, Mr Hunt could say that had he been directly in charge he would not have left it as long. They had tried the experiment of putting a shovel into the excavated material from the thrust-bore, and after it had been left there for a minute, one man had not been able to pull it out. The material was as sticky as that and not at all easy to deal with.

128. The Authors referred to underpinning existing bridges. Different methods had had to be employed in almost every case according to the circumstances. Some had been dealt with in dry weather by damming the streams completely, and others had to be flumed. If the water rose to a dangerous level, it had been necessary to release the dams and flood the works, and that was why they had invented the special release dam, so that all the watchman had to do was to bang a handle; but they had had to do the work in stages, so that no more damage to the work was done by flooding than necessary, and in any case this had been laid down in the specification.

129. The arrival of a gang to start underpinning operations on a bridge often led to farmers claiming that the operation caused damage and flooding upstream. On one or two occasions it may have done so, but generally it had not. Sometimes the farm was very far up the system and there they were having flooding at +10 O.D.

while Mr Hunt had been concerned with +2. Had it not been for the records over the years, he might have been persuaded that floods had never occurred before, but then there would have been no reason for the scheme.

130. With regard to piling, they had used precast piles, sheet piles and box piles, and steam and diesel hammers. The only calculation he could be certain of was that with a drop hammer of, say, 4 tons dropping 2 ft, he knew what would happen. Calculations could be made for both steam and diesel hammers. There was a formula for diesel hammers which he did not understand, and if he did, he might not believe it. They had used different hammers with different types of pile and kept records of the results for comparisons in practice rather than theory.

131. He had no comments on the technical details, and only one criticism; he did not like the exhaust pipes on the back of the pumping station. Whatever the architect's view, it did not look pretty.

132. On behalf of his firm he thanked the authorities and the consulting engineers for the co-operative way in which they had dealt with the contract.

Mr T. A. D. Farran (Consulting Engineer) asked for more information on what he understood to be Mr Harris's part of the Paper, information which he appreciated could not have been incorporated in the Paper. In § 43, reference was made to some V.C.B. engines, and he would be interested to know whether or not they were pressure charged. He imagined from the rated horse-power given that they would be pressure charged. His reason for asking that question was that in a pumping station which his firm had recently installed, they had had to fit one pump with a capacity 50% more than that of the next one; to maintain uniformity they had put in a 6 V.C.B. engine with normal aspiration and a 6 V.C.B.X. pressure-charged engine with 50% more horse-power but occupying exactly the same floor space and with most spares interchangeable. Although it gave 50% more horse-power, it cost only 30% more. He thought that there was a great future for the pressure-charged version of these engines. A secondary consideration was that it was far quieter; one could hear oneself talk when close to it, which was not possible alongside the normally aspirated engines.

134. In § 44 it was stated that the air receivers were charged by a small compressor driven by a diesel engine. Presumably there was more than one compressor set, or the whole station would depend on the starting capacity of that one small compressor engine; there must be some electrical or other alternative.

135. A small point, although a large one from the point of view of cost, arose from § 53. Were these oil-storage tanks really required to hold a six months' supply of fuel? It would be more normal to provide a supply adequate for three weeks' continuous running of the engines. He questioned the need to install storage tanks for a six months' supply of fuel when there was a good hard road leading to the station. Possibly what was meant was six months' normal use.

136. It was nice to employ architects to help with buildings, but was it right to allow them to surround storage tanks, which were an engineering feature, with brick walls? It might improve the aesthetics, but why was it necessary to hide an engineering detail?

137. Mr Farran was interested in the remarks about thrust-boring, because the very pipes which the subcontractor had been unable to drive, as stated in § 65, had been sold to one of his Boards, and the same firm had driven them successfully. What tolerance had the Authors specified for the thrust-bore? In his own case, on a 90-ft bore under six railway tracks, a tolerance had been specified in all directions of 6 in., and the subcontractor had kept just within that 6 in. What tolerance had the Authors obtained for their various crossings? With the form of dead-man anchorage used, it would be interesting to know how stable it had been possible to make it in the very poor materials in which the work had to be done.

138. On the question of rainfall, 0·715 in. of run-off in 24 hours had been catered for by the Authors. With an area as large as 25 000 acres, was not that a question of wearing braces and a belt as well? In the eastern part of England a number of pumping stations with which he was familiar had not been overmastered provided the overall capacity including standby did not exceed 0·5 in. of run-off. In analysing the run-off he had found it better to take the worst case of a two- or three-day storm rather than a 24-hour storm. He had had access to pumping station records together with rainfall records for the last 75 years, and it had been found that the occasions on which the pumping station had been most heavily loaded had been following a two- or three-day rainfall rather than a 24-hour rainfall. Possibly the reason was that the former took note of whether or not the catchment was initially wet when the storm came, and the three-day rainfall provided the worst case of an initial wetting.

139. He agreed that the Bilham formula for land drainage purposes gave results almost twice those with which one would have to work. He had gone into this rather closely some years ago and agreed with that and with the actual incidence of rain per 24 hours.

140. He congratulated the Authors on their Paper which was the first that he had seen to cover almost every aspect of the subject with which a land drainage engineer was faced.

Mr W. E. Doran (retired) said that this was the first land drainage Paper presented to the Institution for nine years. There had been previous Papers in 1936, 1945, and 1954, so that in each case the interval had been nine years. A number of land drainage engineers were present that evening and he hoped that another nine years would not have to pass before there was another Paper on the subject.

142. In § 22 it was stated that after the reconstruction of 1947, the power station had housed five pumps with a total capacity of 150 cusecs, or 30 cusecs per pump. It seemed extraordinary that such a multiplicity of small pumps seemed to be favoured.

143. On the subject of peat shrinkage, Mr Doran did not know that he could go the whole way with the Polish formula. He was dubious about the effect of the depth of the peat. In his experience in the Fens, when an area which had previously been undrained was drained, a very rapid shrinkage occurred in the first 12–18 months; a shrinkage of 12 in. in less than 18 months, for example. As Mr Hunt had mentioned, it could be very rapid indeed in only a few months. The shrinkage was divided, as Dr Prus-Chacinski had said, into the consolidation of the peat underneath when the water was removed, and the surface wastage. In their calculations, the Authors had mentioned the Polish method in § 32 and said that assuming the same order of wastage, the total lowering would be so-much. There was no basis in the Paper for the assumption made about the wastage. In the Great Ouse area, it was thought that the wastage varied between 1 and 2 in. a year and was related very much to the amount of cultivation. It had been found that the wastage slowed up when it got to within 12–18 in. of an impervious soil such as clay, but not much if there was sand underneath.

144. Mr Doran could not agree with the statement in § 31 where the Authors had said:

> 'The total lowering of land surface in Crossens was therefore much smaller than that observed in the Fens, because in the deepest spots the lowering was only about 30% of the original depth of peat, whereas in the Fens it was often more than 50%.'

In the Fens it was up to 100%. A large area of the Fens had lost all the peat. The surface wasting went on, and the more efficient the drainage the more rapid was the wastage.

145. Mr Ashton had mentioned the reason for the number of pumps in the pumping station. There were 13 pumps, three in each of the wings and seven in the low-level floor, and Mr Ashton explained that there had been five pumps available.

Mr Doran wondered what the economic position was. The five pumps had already given some service, and in view of the cost of the foundations for 13 pumps for work which could have been done by less than half that number, one wondered whether it paid to go to that expense in order to use the old pumps.

146. In § 37 it was stated that 'All main structures have been prepared to receive future run-off increased by 40% in the future'. Why was this? Later, in the same paragraph, it was stated that 'No special provision for increased run-off has been provided, as the area is purely rural'. These statements appeared to conflict.

Mr J. R. A. Garland (Chief Engineer, West Sussex River Board) asked whether the quick release device on the cofferdams had been entirely successful and had resulted in virtually no silty material being left in the excavation. At the moment he was dealing with a claim where a contractor was endeavouring to establish the contention that the extra work which had to be done in cleaning the excavation was due to the presence of silty material in the banks of a stream.

148. With regard to the use of timber stakes and brushwood, how was it envisaged that maintenance would be carried out? This seemed to preclude the use of a drag-line excavator. Had the Authors considered the use of the inverted filter mentioned in § 72? As this could be laid to the 1:1½ slopes of the banks, it might make future maintenance simpler. What type of timber was used for the stakes and what life were they expected to have?

149. In § 76 the mixture given for the grass used to seed the slopes of the excavated channels appeared to be rather an expensive one, more suited to pastures. Why had the Authors used it for the channel slopes? He could understand its use to re-seed spread soil on grass fields, but for the banks it seemed unnecessarily complicated, particularly with the inclusion of clover. Had any difficulty been experienced in establishing grass on the 1:1½ slopes?

The following contributions were received in writing:

Mr A. R. B. Edgecombe (Project Manager, Kafue Basin Survey, Northern Rhodesia) wrote that the Authors compared English and Northern European drainage standards and pointed out that the English standards were not specifically related to the mean annual rainfall, whereas the European standards were. English standards were understandable since high floods were independent of annual rainfall.

151. It was interesting and informative to bring India into the comparison as there were large irrigation works in that country, and irrigation went hand in hand with land drainage. Indian drainage standards were not related to the annual rainfall.

152. In Bengal in the flat areas usually growing paddy, a run-off of ¾ in./d was generally assumed for large catchment basins in designing surface drainage channels. On the Godavri delta in Madras, a run-off equivalent to a depth of 2 in. in 24 hours was taken.

153. The English standard quoted in the paper under discussion of ⅛ in. to ⅜ in. in 24 hours was equivalent to drainage factors of 3·4 and 10 cusecs/sq. mile. In the United Provinces, India, the factor adopted was from 2 to 10 cusecs/sq. mile.

154. A most important aspect of Indian drainage, and one to which Mr Edgecombe saw no reference in the paper, was that of the time factor. Indian practice of land drainage did not provide sufficient drain capacity to carry off high floods, but did enable the storm water to be removed before the standing crops were drowned.

155. In the United Provinces, the criterion of design was the removal of storm water within ten days. On the Godavri temporary flooding was allowed up to one week.

Mr E. L. Barron (Job Engineer, Bechtel International Ltd) wrote asking the Authors how the blinding layer of high alumina cement concrete, surfaced with rubber-bitumen jointing compound (§ 47), functioned in protecting the concrete foundation raft from the crystalline gypsum in the Triassic marl. Was the blinding layer considered to insulate the concrete structure, with the jointing compound to ensure bonding of the two, or was the compound used as a waterproof layer for 'tanking' the structure? In the former case it would have appeared difficult to ensure that the blinding layer was really impervious, while in the latter case a thick coating of hot-applied asphalt was usually considered essential.[2] High alumina cement concrete would not have appeared worthwhile for the blinding layer because the long-term deterioration of this layer would have had no adverse effect upon the structure. The Authors made no mention of protection for any part of the vertical faces of the structure, nor of sulphate in solution. The corrosion problem could be better visualized if the Authors would give the test results for sulphate concentration in the groundwater and/or the marl.

157. It must be gratifying to many engineers to find that architectural treatment of exhausts would result in the most crudely economical arrangement shown in Fig. 14. In view of the enclosure of the relatively inoffensive oil tanks in a brick structure, it was surprising that the exhausts were not grouped together and enclosed in brick shafts, which at the same time would obviate the architect's desire to paint the exposed steel.

Mr A. W. Shilston (J. D. and D. M. Watson, Consulting Engineers) commented that there was little information in the readily-available engineering literature on the problems associated with constructional works in peat lands, and the Authors had shed light on the perverse nature of the qualities of peat.

159. Dealing with lowland peats, he wondered whether the Authors could make any generalized comments on points that engineers should look for when works in peat lands were under contemplation. Were there prima facie grounds, for example, in suspecting that groundwater would tend to be aggressive to normal Portland cement concrete; that fairly high sulphate concentrations were distinctly possible; that anaerobic corrosion of steel and cast iron might well take place, and that deep excavations could yield gases which in sufficient concentrations could affect workmen? Mr Shilston had recently met such an episode in the latter category, where the groundwater was polluted with sewage and dangerous concentrations of H_2S were met in the excavations. The presence of peat deposits in the vicinity might have had no bearing on the matter, but it allowed scope for reflexion.

160. On the subject of peat shrinkage, he had come across the case of a tunnel driven through soft ground within which deposits of lowland peat overlay the crown of the tunnel, which was built with the assistance of compressed air. A certain amount of ground settlement soon became apparent at the surface, and this, in part, might have been attributable to the presence of the peat. Air lost from the tunnel would probably find a ready path through the reeds in the structure of the peat, and it seemed reasonable to assume that accelerated drainage by virtue of the expulsion of water, through this unnatural agency, would cause a very rapid rate of shrinkage within the peat layers, resulting in ground settlement. Did the Authors consider this to be a feasible explanation of what might have taken place?

161. Mr Shilston said he was intrigued by § 52 of the Paper relating to the design of the pumping station. Presumably the transverse dimension of the building would have required to be increased to permit the accommodation of the exhausts within the building. That undoubtedly helped the internal appearance of the pumping station but spoilt the rear elevation; he imagined there must have been some conflict with the Town Planning Authority on this point. Had the decision been taken on cost grounds alone?

The Authors, in reply, agreed with Mr Ashton's suggestion that excavation of new channels in unstable or badly draining material should be carried out in two stages.

163. Sudden and spectacular slips had occurred where attempts had been made to excavate completely new channels through the deep peat areas. However, it had been found that, provided the initial excavation was restricted to a depth of 6 ft, a further 2–3 ft could be removed after a period of four months without slipping or uplift. The disadvantage of a general application of this principle was that the excavated spoil made subsequent access difficult, and that compensation for an additional year's cropping might have to be paid.

164. Mr Nixon referred to the delta works in Holland and seemed to be in agreement with the Authors that some definition of the minimum standards for flood alleviation schemes would be useful. With regard to his question on standards for the Crossens Scheme, the storages quoted by the Authors were not directly additive to the capacity of the pumping station; these storages compensated for the comparatively fast run-off from the built-up areas of Southport, from higher ground around Ormskirk in the Western Area, and from around Tarleton in the Eastern Area.

165. The capacity of the gravity culvert could be used only at very high levels when large areas of land were already flooded, so this culvert was only an emergency safety valve at high discharges. At present, there was some margin over the capacity of the pumping station in the storages stated by the Authors, but during the course of years, that margin would disappear due to the shrinkage of peat. Before the main channel overflowed, large areas of land would already have to be flooded, and these areas provided a very large amount of storage. Therefore, in the Authors' opinion, the real standards of the Scheme were equivalent to the capacity of the pumping station if average conditions were considered, say, over the next 30 years, unless major reconstruction of the Scheme was undertaken before this period ended. Underdrains were designed for the future lowering of channel beds by 2 ft, but most of the inverts of the bridges were lowered by only 1 ft, as it was found that this was sufficient to avoid a significant afflux after future lowering of the bed.

166. Mr Wolf commented on the drainage standards, and also criticized the Authors' methods in their hydrological study. Unfortunately, it had been impossible to convey all the accumulated information in a comprehensive paper, and perhaps the very condensed Appendix on hydrology, which was only a précis, proved not to be clear enough, even when supported by verbal discussion. This might be the reason for many inaccuracies which slipped into Mr Wolf's contribution. The Authors would try to comment on these as far as it was possible in a necessarily short reply.

167. The Paper on 'Surface Water Drainage' mentioned by Mr Wolf had no connexion with land drainage, and indeed did not discuss rainfall intensity. The Ministry of Health's formula, or design storm, provided a minimum standard for storm water sewers, but would not normally be helpful as a minimum standard for urban flood alleviation schemes in any larger catchments.

168. Fig. 20 showed floods in Taunton, Somerset, in the autumn of 1960. This flood appeared to have a frequency of about once in 50 years, so that protection against this sort of flood would be a minimum standard according to continental ideas.

169. Dutch standards related to a comparatively small zone where the climate and elevation were almost uniform and, although Dutch standards were very similar to those for British lowlands, particularly on the eastern side of the Pennines, they did not prove or disprove that there was a connexion between storm intensity and annual rainfall.

170. The Authors were pleased to note that Mr Wolf did not disagree with the possibility of an indirect connexion mentioned by them. It was rather unfortunate that Mr Wolf was under the impression that the Bilham formula had been used for Crossens. In fact, Dr Prus-Chacinski used the results of his own study of rainfall intensities in the Southport area. The Bilham formula was quoted in § 93 only as

FIG. 20: FLOOD IN TAUNTON, SOMERSET, IN OCTOBER, 1960

an illustration, which might have misled Mr Wolf. As mentioned in Appendix 2, the floods of 1954 were studied in great detail, and although it was not mentioned, the Authors obtained their rainfall data from the Meteorological Office.

171. Fig. 21 illustrated the 12-hour rainfall and the frequency of that rainfall. For a low elevation the line was much below one calculated from the Bilham formula, whereas one at 1000 ft was very similar to the Bilham formula.

172. Fig. 22 was the same story for 24 hours. The uppermost line was from the Bilham formula. Of the two lower lines, one was for Southport and the other for Taunton in Somerset. It seemed that the intensity of rainfall at low elevations was lower than that at high elevations.

173. The Authors appreciated the deficiencies of the Bilham formula in its present form, but they were of the opinion that regionalized formulae should be produced and would be immensely helpful in this country.

174. The Authors appreciated Mr Wolf's comment on one-day rainfalls, but this factor did not seem to alter the general conclusions about rainfall intensity at high and low elevations. Also, in the case of Crossens, rainfall over a period of several days was studied and taken into account. With reference to the area factor, this was studied for rainfalls during the autumn of 1954, applying data from three to four rainfall gauges in and around the area, and the area coefficient was found to be similar to that quoted by Richards. The Exmoor storms quoted by Mr Wolf belonged to quite a different category. The Authors were not certain whether the expression 'run-off coefficient' should be dropped. Perhaps a re-definition was all that was really needed.

175. The Authors would be very happy if they could agree with Mr Wolf's estimate of the capacity of the Crossens Scheme as approaching 1 in. per 24 hours, which would mean that they could produce additional safety for literally nothing. This point had already been mentioned in the reply to Mr Nixon, and unfortunately the capacity of the Scheme was not significantly larger than the capacity of the pumping station, although there was a margin necessary for conditions of this kind. Incidentally, the positive margin of discharge provided by a battery of axial pumps was very small, when the outlet channel was relatively narrow.

176. Mr Wolf expressed the rather strong opinion that the Authors could have produced a much better hydrological study. No doubt practically any project could be carried out in a better way, but the Authors would suggest that a study of 18 years' rainfall and run-off records, together with the detailed study of floods and of the dominant soil characteristics, provided quite a satisfactory background for the design of a land drainage scheme. It was doubtful whether the continuous recorders suggested by Mr Wolf would, in this case, contribute materially to the practical design. Moreover, as Mr Wolf was no doubt aware, hydrological records were normally most misleading when they related to a short period of observation.

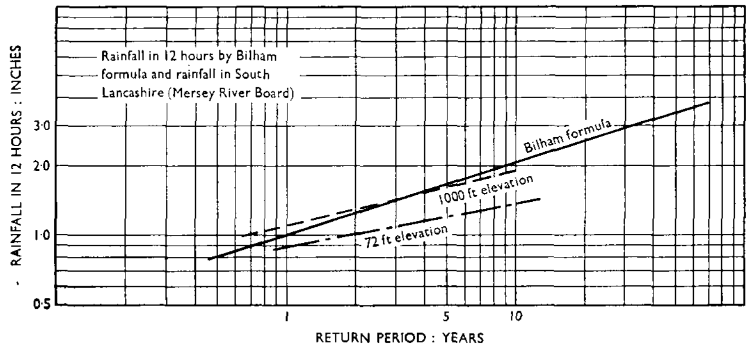

FIG. 21

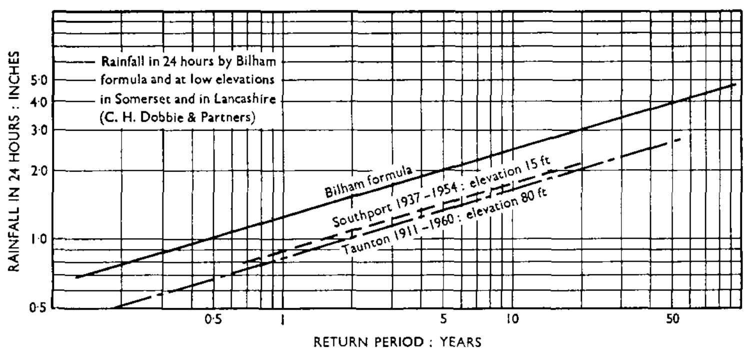

FIG. 22

177. Mr Wolf seemed to imply that the Authors did not carry out the best of hydrological site investigations. What was the best, however, was a matter of opinion and particularly in hydrology. Often, methods which seem to be rather pedestrian gave most satisfactory results, and it was not very practical to crack a nut with a steam-roller when a hammer would do.

178. Referring to points raised by Mr Garland, most of the channels were excavated in Downholland silt, and fairly general erosion and face slipping of the bank had been experienced. In the worst areas, a dwarf revetment of stakes and brushwood had been placed at water level or at the toe of the bank, to contain the movement of material. Fir trimmings had been used for stakes and a variety of

material for the brushwood. It was hoped that the life of these materials would allow the vegetation on the batters to become fully established. Following completion of the job, it had been necessary to re-excavate some of the channels to remove material washed in from the banks, or brought in from the side streams and ditches, and the presence of the dwarf revetment had, in fact, not unduly interfered with the operation of the dragline excavators.

179. The cost of providing the grass seed had worked out to be ½*d.*/sq. yd, and the cultivation costs varied from 1½*d.*–4*d.*/sq. yd. Occasional bare patches persisted on both peat and raw silt areas, but on the whole the grass mixture had taken well. The function of the clover was to provide shade for the roots of the finer grasses.

180. Mr Firth mentioned that he disliked the idea of a uniform standard. The Authors had in mind only the very minimum standard for urban flood alleviation schemes. This would vary, of course, but the Authors felt that there was always a minimum below which the law of diminishing returns operated, and perhaps it would be helpful to have a broad agreement on such a minimum.

181. Both Mr Firth and Mr Ashton had referred to the gravity outfall. This had three possible functions. First, under extreme flood conditions, the water levels might reach 9·0 O.D., and when the tide was out, it would be possible for the relative levels to permit gravity discharges to supplement the pumps, so decreasing the frequency or duration of flooding. Secondly, during the summer when a retention level of 6·5 O.D. was maintained, the tidal doors would allow normal discharges to take place at low water, since the bed level of the outfall had been as low as 4·5 O.D. There would be little risk of higher levels occurring temporarily in the main drainage channels, as the whole pumping capacity of the station would be available as a standby. Thirdly, the doors must be retained for emergency use should some calamity overtake the pumps.

182. Mr Dalkins had had levels taken in the estuary channel from time to time, and, so far, the results indicated that there had been an improvement in bed levels as a result of pumping for about a mile downstream from the station.

183. With reference to the off-shore conditions, Fig. 23 was an aerial view of the Crossens Tidal Channel as it had been in 1955. The foreshore was accreting quite fast, and a large area of saltings could be reclaimed without difficulty. The level of saltings was between +16 and +17 O.D. A good part of the saltings had been reclaimed at the beginning of the last century, but there was an additional area which could be reclaimed now that accretion was going on rather faster than before.

184. In reply to Mr Firth's point about costs, the value of flood damage in 1954, 1956, and 1957 had been estimated to total £380 000. Divided into the total area benefiting by the Scheme, this was equivalent to a cost of £13 10*s.* 0*d.*/acre. However, the saving in costs of cultivating the better-drained ground, together with the increase of productivity, must exceed this figure many times over, especially if a period equivalent to the effective life of the Scheme was considered.

185. With reference to the points mentioned by Mr Farran, the line and level of the underdrains placed by thrust-boring had been quite satisfactory.

186. Work on the thrust-bore for the Three Pools underdrain had ceased from 4 p.m. on 2nd November to 7.30 a.m. on 3rd November, 1958.

187. An initial penetration of 40 ft had been achieved easily, but after the period of 15½ hours it was impossible to move the pipe, although 50-ton jacks were used to supplement the winch and auger. Had the delay been confined to a period of an hour or so for welding on the extension, the Authors doubt whether, in that particular ground, driving the pipe could have been resumed. The silt or fine sand had very peculiar surface tension properties as, although it slumped like a jelly, with care it was possible to stand on the surface dry-shod. Mr Harris had personally tried the shovel test mentioned by Mr Hunt and had been unable to withdraw the blade.

188. Mr Hunt had also referred to the danger of the dammed-off bridge sites causing real or alleged flooding. As mentioned in § 60 and illustrated in Fig. 16,

quick-release mechanisms and flumes had been used to deal with actual flows. When the work had had to be flooded, the silt and mud could be brushed out. The layman found it difficult to understand the principle of fluming, and the use of properly-levelled stick gauges sited upstream and downstream from the works restored confidence and also provided reliable data to refute claims of alleged flooding.

FIG. 23: AERIAL VIEW OF CROSSENS TIDAL CHANNEL IN 1955
(The arrow indicates the position of the old pumping station)

189. There had been several references to the architectural aspects of the pumping station, and while recognizing that individuals held personal preferences in matters of this kind, the Authors felt that the result was a functional building having a pleasing appearance. The exposed exhaust pipes blended with the vertical lines of the slender window mullions, and as Mr Shilston pointed out, the solution had cheapness to commend it.

190. Mr Farran mentioned that in eastern England the usual standard was 0·5 in. run-off including standby, and he seemed to think that the Crossens capacity was high by comparison. In the Authors' opinion, 0·5 in. excluding standby was about the same on the west side of the Pennines as 0·5 in. including standby on the east side, and this was the capacity of the high level pumping station at Crossens; 0·715 in. including standby, quoted by Mr Farran, was only in low-level pumping stations where the catchment area was most vulnerable to flooding, and where there was a leakage from the high systems. The Authors were in complete agreement with Mr Farran as to the effect of prolonged rains, even if they were not of very high intensity. They were pleased to note that Mr Farran supported the Authors' opinion on the Bilham formula.

191. Mr Farran had made several apposite enquiries about the pumping station plant. The five V.C.B. engines had not been pressure-charged, but the Authors agreed that there was a great future for pressure-charged engines irrespective of cost. However, the Crossens engines, although not pressure-charged, ran very quietly.

If the future capacity of the pumping station was to be increased, pressure-charged engines might be installed.

192. Electric power was normally used to charge the air receivers, and the diesel engine mentioned in the Paper was a standby for use in case of mains failure. The capacity of the fuel oil storage tanks was equivalent to an estimated six-months normal winter use, i.e. about 17 days' requirement with all the engines in continuous operation for 24 hours each day.

193. Mr Doran commented on the small size of the pumps in the low-level pumping station. The Authors agreed that they were small, and this was due to the historical development of the old pumping station over many years. On the other hand, small pumps were convenient for channels of this kind. At low discharges one pump could run conveniently for a reasonable period, but a larger unit would have to stop and start very frequently. The main structures were prepared for a 40% larger future run-off only on both high systems. This was because the probable development of housing estates in Ormskirk, Southport, and Tarleton in future years would no doubt increase the run-off. As major reconstruction was expected in about 30 years' time, due to the shrinkage of peat, it might then be necessary to increase the capacity of the design run-off in both high systems. In the Middle System standards were higher now, and it was not necessary to make similar provisions for this area which was expected to remain purely rural.

194. Fig. 24 was a sketch which showed that if the shrinkage was taken into account, the line of the drain could be designed in such a way that after shrinkage there would be no kinks. That was very helpful and this sort of design would certainly prolong the useful life of a drain.

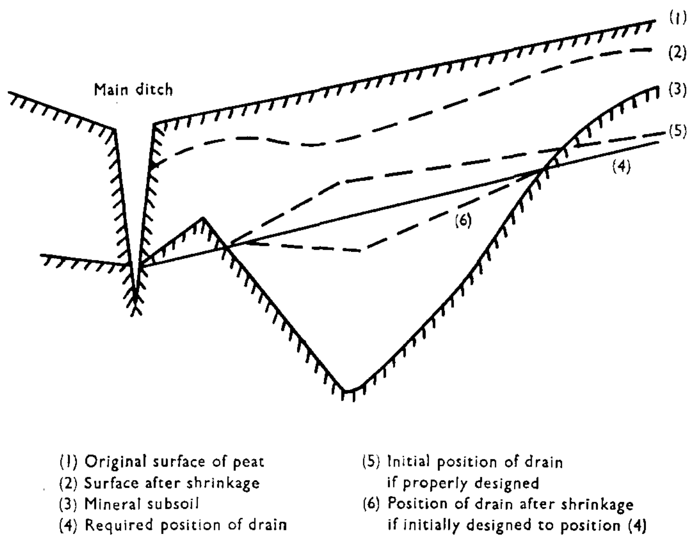

FIG. 24: DRAINS AND SMALL DITCHES IN PEAT

195. Regarding the shrinkage of peat due to drainage, there were two independent phenomena: (*i*) wastage of peat surface due to several causes, and (*ii*) shrinkage proper due to the collapse of the peat fabric. Fig. 25 showed that peat shrank not only above the water table but below the water table. It was often difficult to convince people of this, but unfortunately it was true. The explanation was that when

a ditch or drain was dug, water drained out of the top layers, which then slowly collapsed and pressed on the lower layers, squeezing water into the ditch, so that there was shrinkage below the water table.

196. Dr Prus-Chacinski agreed with Mr Doran that the Polish formula for peat shrinkage should be treated with caution. However, it was a step in the right direction, and future research would no doubt improve on this method or find a better one.

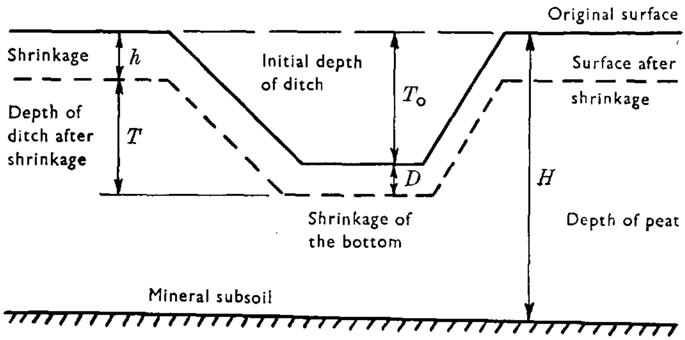

FIG. 25: SHRINKAGE OF PEAT DUE TO DRAINAGE

197. With regard to wastage, the total lowering of the Crossens land surface in the past was estimated by the historical method; this lowering includes both shrinkage proper and wastage, and indeed was very much smaller than in the Fens. The Polish method was only tried later and seemed to fit very well. Incidentally, 100% was more than 50%, so § 31 quoted by Mr Doran did agree with the observed facts that the total lowering in the Fens was up to 100% of the depth of the peat.

198. Wastage in Crossens was clearly very much smaller than in the Fens, and the figures quoted by Mr Doran for the Fens were in the right proportion, considering the total lowering of the surface in Crossens and in the Fens. The whole subject of wastage was rather involved. It certainly depended on the type of husbandry, but also depended on climate. Indeed, the lowering of the land surface in the Fens was very great. Dr Prus-Chacinski has personal knowledge of many hundreds of thousands of acres of peat lands in many parts of Europe, but as far as he knew, nowhere had the lowering been as great as in the Fens, which might be due to local peculiarities in climate. In the Fens, winters were comparatively frosty, but snow cover was poor. Therefore, frost exerted a crumbling action on the peat and blowing then followed. In Europe, snow cover was normally much better, so the crumbling action on the peat might be smaller. In Crossens there was much less frost, and therefore not so much blowing. The whole subject might be of great interest, and certainly deserved careful study. There were large areas of high-moor peat in this country, which some day could be reclaimed, and there were, of course, enormous areas of peat in Canada which might become important fairly soon.

199. Replying to Mr Barron's enquiries regarding the protection of the concrete foundations against sulphate attack, the Authors wished to enlarge on the brief description given in § 47. The pumping station was founded approximately on the surface of the massive Triassic marl strata, and the raft was enclosed within a wall of steel sheet piling. Boreholes had revealed the presence of isolated crystals of gypsum some feet below foundation level, but at a level that would be reached by the piles. It was thought that ground water might follow the line of piling, and it was decided to protect the underside of the concrete slab with a screed of fondu. This was placed

in panels immediately after excavation, and it also prevented the surface of the marl from turning into a slurry. The rubber bitumen compound over this acted as an impermeable membrane and was itself protected by a further 2 in. of fondu screed. The sides of the structure were protected to water level by a skin of engineering bricks jointed in fondu mortar, and this skin also served as outside shuttering.

200. Mr Edgecombe mentioned Indian standards, which seemed to be similar in concept to standards applied in many parts of continental Europe in the nineteenth century. Then, winter or early spring flooding was allowed, and it had to be evacuated during a certain period of time. This normally would not do much harm to winter cereals. This practice had now largely fallen into disuse because of the widespread application of chemical fertilizers, and because root crops were now more common than cereals on lowlands.

201. Mr Shilston mentioned the corrosive properties of water in peats. Water flowing from peat should not be used for making concrete unless it had been found to be free from harmful acid, which might sometimes have happened. Peat water, if very acid, might have a corrosive action on concrete or steel, but Dr Prus-Chacinski had never observed concentrations of H_2S during more than 30 years' experience of dealing with peats. Methane, on the other hand, was quite common although he had not observed it in this country. Local shrinkage of peat could occur quite rapidly if the peat was loose, and the case quoted by Mr Shilston might perhaps be explained by the rapid local shrinkage. It should be observed, however, that the area covered by rapid local shrinkage depended on the permeability of the peat, and this varied very considerably with the peat type.

Reference

1. L. H. Watkins. Surface water drainage. *Proc. Instn civ. Engrs*, vol. 24, March 1963, pp. 305–330.
2. P. E. Halstead. The effects of sulphates on Portland cement concrete and other products. Tech. Rep. TRA/145, p. 11. Cement and Concrete Association, London, April 1954.

Corrigendum

In Table 2 of the Paper, in the third column relating to Type 2: for '2 hours' read '24 hours'.