Design and construction of a submarine sea outfall at Hastings

E. W. CRISP, H. M. STEWART & S. J. N. FLETCHER

The above Paper was discussed at Brighton on 12 November, 1970, and at London on 1 December, 1970. The report covers both meetings.

Mr Crisp

The problems which beset all seaside towns concerning sewage disposal were only too apparent at Hastings. Should the sewage be discharged to sea and, if so, with what degree of preliminary treatment and how far out? Alternatively should a sewage disposal works be established and, if so, what standard of effluent should be achieved; should it be discharged to a watercourse or to the sea?

79. It is just conceivable that a sewage disposal works could have been located in the area between St Leonards and Bexhill, but it is improbable that this would have been approved. However, in 1960 it was assumed that such a site could be obtained, and the cost of a full treatment plant discharging effluent down to low water mark was compared with the cost of a long sea outfall discharging partially treated effluent about two miles out to sea. The financial implications were not surprisingly overwhelmingly in favour of the sea outfall and in view of the unlikelihood of an agreement on the sewage disposal works site, the investigations for a sea outfall went ahead.

80. Whilst it was likely that the pipeline would be laid by the bottom tow method, contractors tendering were asked to put forward any alternative proposals which they might have. Two interesting variations were submitted; one was to assemble the pipes in short lengths of about 60 yd between the railway and the Bexhill Road, thus avoiding the complications of crossing the road. Another was to attach a plough to the leading end of the pipeline and in one operation pull the pipeline and excavate the trench. In the event the Contract was awarded to William Press & Son Ltd to carry out as initially designed.

Mr Fletcher

Tenders for long sea outfalls which ask for alternative proposals allow contractors to take possible advantage of the sophisticated equipment and methods that are constantly being developed for the exploration and production of gas and oil offshore. For example, in some circumstances, it is far easier to pull a pipeline on the sea bed and lower it afterwards to give the required cover. In fact the suction dredging and jetting equipment on the *Wm Allpress* did exactly this when it removed from under the pipe compacted sand and dense silt which had accumulated in the dredged trench. Also there is available now compact equipment developed for burying submarine gas and oil pipelines which can cope with the hardest clays, and can, if necessary, be operated remotely from shore.

82. It follows that with the development of construction methods offshore have come new techniques in diving, the submersible work chamber, for instance. Unfortunately, the new techniques developed so far do not appear to have much economical application in the relatively shallow waters where long sea outfalls are sited. Most of the underwater construction work on this Contract, such as building the diffusers, was carried out by divers in standard gear, swim divers taking care of inspection work.

83. Although there are many excellent divers about, there is a shortage of professional engineer divers. Such men are more likely to be better informed about

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every aspect of a project and to know the relative importance of each diving operation, and if problems are encountered in design or construction, they are more able to put forward possible solutions, or at least report accurately on what they have seen or done. Certainly, if young civil engineers were to train as divers, in years to come they would be in great demand. On this Contract, the Resident Engineer and his assistant had attended diving courses and were able to make inspection dives, accompanied by an experienced diver.

84. Of course, progress on all marine operations was governed by the weather. Consequently, great use was made of the Meteorological Office weather forecasting services. The forecasters had been told the nature of the work at sea and were very helpful and usually accurate with their forecasts. When preparing the tender an attempt was made to calculate how much time would be lost due to unfavourable conditions, in other words 'down time'. From the Meteorological Office records summaries were obtained of wind forces, wave heights and visibilities recorded in the area, and from these it was estimated that during the period from April to the end of September, about one third would be 'down time'. This proved to be a fairly accurate figure. Because from time to time on marine operations there are sure to be delays due to bad weather, there is not a lot of point in bemoaning the fact, and time is better spent in preparing to make the most of the good weather when it returns.

85. As far as the construction work on land is concerned, it can be said that the Bexhill Road with the Bailey Bridge, the coast railway with the thrust bore and the narrow gap between the houses for the launchway created considerable problems of access, not least for the family who had the pipe immobile immediately outside their front entrance for ten months.

Mr Stewart

The Paper refers to the winch breakdown and the consequent delays in launching. Although all was well at the end of the day, this conceals the very considerable anxiety which all on the project shared at the time concerning the safety of the pipe during storms and the likelihood of being able to move it again after a winter's hibernation.

87. Towards the end of the twelve months' maintenance period it was possible to carry out a final inspection of the pipeline. Fortunately the weather conditions were ideal and divers were able to inspect the whole line of the trench and the diffuser assembly under exceptionally clear conditions. They found the trench was adequately backfilled over most of its length (indeed to a large extent it was no longer visible) and the diffusers were operating effectively. The divers reported on the text-book appearance of the plumes of sewage being discharged from the diffusers and remarked how it quickly dispersed and disappeared before reaching the water's surface. As expected there were no deposits of sludge or solids round the diffusers or the domes.

Brighton meeting

Mr M. Milne

I found the Paper most interesting and would like to know whether the method will be used again, on the south coast in particular.

89. I should also like to know, in general terms, the cause of breakdown on the winch.

90. Mr Fletcher has expressed the opinion that engineers with diving experience will be in great demand with the increase in marine activities. Where could engineers receive suitable instruction?

Mr Smith

What is the range of velocities of sewage discharging from the diffuser? Is the sea bed sufficiently stable to be sure that diffusers will not be either overexposed or covered?

Mr J. C. Brown, Chief Engineer, County Borough of Hastings

The sewer is performing satisfactorily to date and pollution of beaches is much reduced even though older outfalls remain in use. I congratulate the Consultants and Contractors.

Mr Marlow

Are the beaches stable? Could the sewer be exposed within the tidal range?

Mr Pullin

What was the fill depth over the outfall? Is this sufficient to prevent damage from anchors, etc.?

95. Are the sacrificial anodes used in connexion with cathodic protection to be regularly inspected?

Mr C. G. Trimmer

Were any measures taken to ensure uniformity of the trench bottom, with particular reference to the presence of rock outcrops?

97. Why was sewage not pretreated by maceration?

Mr Hunt

What pretreatment is given to sewage at the pumping station?

98. What were the limits placed on wind force and wave heights when pulling the pipe?

Mr Devlin

What was the batter of the submerged trench?

Mr Milton

I understand that the outfall will carry $6 \times$ dwf and any excess goes to the storm water sump.

101. How is the storm water sump drained?

Mr Gale

Why was the pipe protected internally with cement mortar? Was this effective only temporarily, i.e. during the construction period?

103. I would like clarification of the method used to protect the area exposed at the joints after welding. Would not a fish plate welded over the field joints be more reliable than the butt welds used?

104. What is the designed pumping rate, and was it considered economical to store at peak flows, thereby reducing overall pumping rate and possibly the size of the discharge pipe?

Mr J. R. A. Garland

Were the meteorological records used found to be reliable in estimating the safe working periods?

Mr A. Allnutt

As the float tests showed that sewage discharged at less than 9500 ft from shore might reach beaches, why were some of the diffusers sited within this distance?

107. Is the pumping carried out continually or only during selective tidal periods?

Mr Webber

Were wind force variations analysed over monthly periods as well as annually?

DISCUSSION

Mr Maple

Is the main a true pumping main over its entire length or is it part gravity drain?

Mr Hook

What was the purpose of the 'cofferdam' at the thrust bores under the railway embankment?

Mr Boocock

Would there be any additional problems in pulling a pipe 42 in. in diameter by the bottom tow method?

London meeting

Mr C. R. Cowlin, Borough Surveyor, County Borough of Hastings

I congratulate the Authors on a very informative paper. I have been involved with the project since the possibility of a long sea outfall was first mooted 10 years ago. Before I enlarge on why I consider it to be the correct solution to the Hastings problem, I would like to pose two points to the Authors.

113. The use of steel under salt water conditions introduces the need for a variety of techniques to ensure protection over a long life, and these processes are costly. The use of coal tar enamel with Fibreglass wrapping, internal linings of cement mortar and cathodic protection are all necessary to guarantee the anticipated life.

114. It therefore raises the question in my mind whether, for example, the recent developments of large diameter unplasticized PVC piping, which were unknown at the design stage of the project, could be used on future projects of this type. I realize that with the launching method used the tensile strength of the pipe is a very important consideration, but there may be ways of overcoming this. In fact, there may be other materials which could, perhaps, be used for the pipe manufacture.

115. My second point concerns the 15 diffusers or outlets over the last 750 ft of pipe. It is obviously important that a good intermixing of the sewage with the sea is achieved. Certainly, from experience gained during 1970, the design has proved successful in that there is little evidence of sewage at the discharge point at sea. I wonder whether the Authors could tell us a little more of the basic thinking behind the number of outlets provided.

116. I should like to enlarge upon the decision taken by Hastings Corporation when the adoption of either a long sea outfall or a sewage disposal works was in the balance. We all know that the running costs of a long sea outfall are much lower than for a sewage disposal works, and this is a great advantage in itself, but it is my opinion that if a sewage disposal works had been decided upon, the difficulties from both an environmental and an engineering point of view would have been very costly to solve. The only site available, at Bulverhythe, was in close proximity to housing developments. The only other alternative would have been to pump to higher ground further inland with some arrangements for gravitation back to sea.

117. With the experience of operation over the first year, I am convinced that the long sea outfall as constructed was the best possible solution in overcoming Hastings' problem of pollution on the beaches in the western part of the borough. It is interesting to note that the annual running costs projected forward from working costs of the present financial year will be approximately £4000.

Mr R. C. H. Russell, Hydraulics Research Station

I should like to amplify §§ 17 and 18 concerning the work of the Hydraulics Research Station in estimating how deeply a pipe would have to be trenched into the sea bed in order to ensure that there would be no subsequent movement. Two types of study had to be made.

119. In the first place it was necessary to determine how far the pipe would go down naturally into the sea bed if scour holes that formed on both sides of the pipe were allowed to grow indefinitely and if the pipe were free to settle under its weight into the depression so formed. It was found that the largest scours were obtained with the pipe oriented so that wave direction was normal to the pipe alignment, and this was the situation studied most intensively. The study showed that the settlement increased with wave height: in small waves the bottom of the pipe settled to a level of 0·3 dia. below the level of the sea bed, in large waves to 0·5 dia., and in very large unbroken waves to 1·0 dia. below the level of the sea bed. If the outside diameter of the pipe was 33 in. and the period of the wave was 8 s, the small, large and very large waves reproduced in the laboratory could be looked upon as having a variety of heights depending upon the local depth of water as given in Table 1. Rather surprisingly, when the waves were of extreme height and the waves were breaking, settlement of the pipe stopped at 0·4 dia.

120. At first sight one might think that if one were to dredge a channel and ensure that the bottom of the pipe were depressed 1·0 dia. into the sea bed the pipe would be safe, but this is not necessarily so. It is possible that if the pipe were held up above the bottom of a scour hole so that water could pulsate to and fro beneath it, the hole might go even deeper than 1·0 dia. The second set of studies investigated this matter by determining the stable size of the gap x beneath the bottom of pipes depressed various distances D into the sea bed. In particular the value of D at which the gap x became zero was noted. The same waves were employed as in earlier tests. Data relating to breaking waves 7·3 ft high in 9·4 ft of water are shown in Fig. 18. This reveals that gaps under the pipe can grow unless the bottom of the pipe is depressed 1·43 dia. (in this case 46 in.) below sea bed level.

121. Figure 18 also contains data from a test in the same breaking waves when the pipe was oriented at 45° to the waves. It reveals that under this more likely condition scour is less pronounced. Holes beneath the pipe in these circumstances fail to grow if the bottom of the pipe is 0·25 dia. below sea bed level.

122. Scour due to steady currents is probably less dangerous than that due to waves moving normal to the pipes. Evidence is available from an extensive study

Table 1

	Water depth, *ft*	Wave height, *ft*
Small waves . . .	12	2·5
	15	2·8
	20	3·5
	30	4·6
	40	5·7
Large waves . . .	12	5·1
	15	5·8
	20	7·1
	20	9·4
	40	11·7
Very large waves . .	12	8·8
	15	10·0
	20	12·1
	30	16·1
	40	20·0

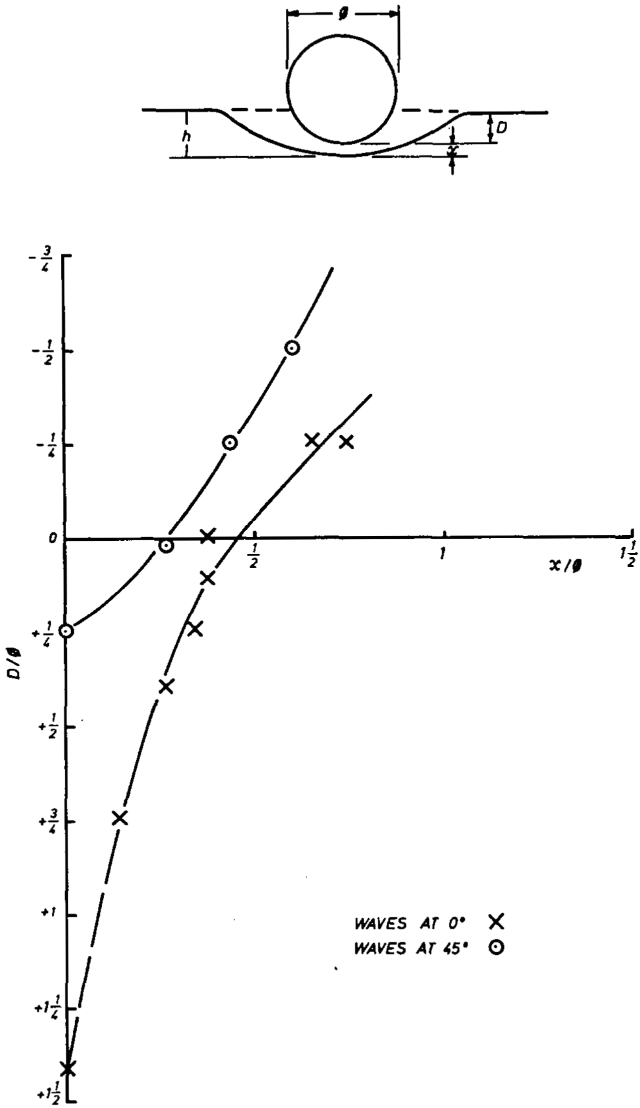

Fig. 18. Scour around pipelines : breaking waves

conducted by the Organizacion Submarina Mexicana, SA.[1] Fig. 2 of that report suggests that under conditions of steady currents scour does not develop beneath pipes if D is greater than 0·4.

Mr A. D. W. Mattin, MB Dredging Company

I would like to describe some of the problems that my company met in dredging the trench for the sea outfall at Hastings. These problems can broadly be split into two main areas: those which occurred at the tender stage, and those which occurred while the work was in progress.

124. The main work on the preparation of the tender was carried out during October 1966 when the sea was particularly calm. The information supplied to us on the nature of the sea bed was, we understand, produced by using a high-pressure water probe. While we would have preferred more detailed information on the shear strength of the material to be dredged, it was nevertheless adequate. Considerable information was also available from a number of sources on the average weather conditions that could be expected, and it was noted that moderate to severe gales from the SW could be expected during the contract period, and that these could arise very quickly.

125. The decision to use a grab dredger was made at the tender stage because of a number of factors, the most important of which were the location of the work in the open sea with no possibility of getting to a sheltered harbour before a storm occurred and the anticipated cohesive nature of the material to be dredged.

126. Given these conditions, a grab dredger will almost always prove to be the most economic unit as it can generally ride out quite severe gales on a storm mooring system, and it also removes the minimum quantity of material to form the trench. In sand or similar material a trailing suction hopper dredger could be used. It is worth noting that bucket dredgers are rarely used in the open sea as these would come up against severe stability problems in stormy weather.

127. We began work at Hastings in March 1968, and soon found that there could be a considerable difference between actual and average storm conditions. During the course of the Contract we lost somewhere between 27% and 30% of time due to this. We allowed, however, for a loss of time of 25% at tender stage and in the end, therefore, it worked out reasonably well. Nevertheless there were times, particularly when the programme completion date for the trench was approaching, when we had to make maximum efforts in even marginal weather conditions to achieve a satisfactory completion.

128. During the progress of the Contract most of the dredged material was loaded into bottom-dumping hopper barges for transportation well away from the line of the trench, as we found that if we temporarily placed material to one side of the trench, excessive quantities were washed back in, due to tidal and storm action. The only other major problem that we encountered during the actual dredging was in an area relatively close to the shore where it was necessary to employ divers to blast approximately 400 linear ft of trench because of an outcrop of rock.

129. May I suggest on behalf of dredging contractors that the area in which the greatest improvement could still be made in this type of work is that in which the client provides the contractor with the maximum information on the types, natures and shear strengths of the material to be dredged. While I appreciate that this information will be expensive to provide, I feel that in the end it could show large financial benefits to the client because of the very large reduction in the risk carried by the dredging contractor. I would suggest that the results of limited information will clearly be shown in the number of qualifications attached to tenders and the prices given.

Mr A. Caswall, British Ropes

I have been involved in eight or nine contracts of this nature and I have observed with a certain amount of interest the changes which have taken place. It is only fair to say that the wire rope industry has had to change many of its preconceived ideas, and we have been faced with some very new and interesting challenges.

131. The major problems on this type of contract are the high loads, the very low factors of safety and the very low torque characteristics which are required. The factor of safety normally demanded on general engineering requirements is 5:1, which in practice is rarely attained in submarine pipelining. Even with the very good factor of safety envisaged, there may be delays and it is a very brave agent indeed who is prepared to stop pulling because he feels that the factor of safety may be getting a little low.

132. Torque becomes a major problem because very often a contractor will ask for a high tensile wire rope which will not impart any turn to his pipe, for obvious reasons: if he has to put diffusers on top, he does not want them the wrong way up. Secondly, contractors sometimes find it necessary to function on a two-part line, which may cable up, one on top of the other, again turning the pendants which are attached to the pipeline.

133. Therefore, we have endeavoured to evolve a rope which gives a robust construction coupled with some non-rotating properties. This in itself is a problem, because when we manufacture a piece of wire rope there is a spinning loss to contend with which, with a six-stranded rope, is about 6%, but on this type of rope can be anything up to 30%. In fact, this particular rope, which was the longest of its type we have ever made, involved a loss of about 25%. Unfortunately, these ropes can be used only on capstan winches, because we have not yet had a chance to evaluate exactly how they will behave if they are crushed on a conventional drum winch.

134. Again, handling is a problem. These are very sophisticated ropes, very expensive, and it is all too easy to damage them. By virtue of the fact that the rope is on the bottom of the sea, it is extremely difficult to see that one has damaged it.

135. When we supply these ropes nowadays, we insist that the terminations are to our specification. Bulldog grips and splices have gone for ever. In fact, we cannot even resort to British Standard sockets any longer because they would certainly distort, if not break, at these loads. We have, therefore, developed very long basket sockets similar to those used by the coal-mining industry.

136. Most contractors use ropes of between 52 and 66 mm dia. for these contracts. If possible they use a non-rotating rope, or a six-stranded rope, allied to a non-rotating type of pendant. We have now been asked to manufacture some of these ropes up to 77 mm dia. and the pulling rope length has varied between 3000 ft and the Hastings length of 11 500 ft.

137. We are very interested in the lengths that these ropes are now reaching. It is not the length or size that bothers us, but the weight of the completed item. At the moment we can put 60 tons into a machine, which is quite a weight to turn around on itself.

138. Is it feasible that in the future we shall be asked to produce anything bigger and longer? If it is, we should like to know about it soon.

Mr M. T. Shilston, Sir William Halcrow & Partners

Mr Mattin referred to the exposed nature of the coastline. All too frequently tenderers inspected the foreshore site when the weather was benign with a quiet northerly wind, whereas when the Contractor started work he found that the sea could be anything but kindly.

140. Our own experience on the initial four week float survey bore this out. Of the 20 working days available to us, 5½ were lost through bad weather or high seas, with the survey launch having to shelter in Newhaven harbour. The Contractor for the detailed sea bed examination on the finalized pipe alignment had intended a programme occupying 8 weeks: in the event, he was there for 11 months. William Press & Son Ltd spent two seasons constructing the outfall.

141. This leads to the basic problem of working off an exposed beach such as at Hastings, with no harbour of refuge nearer than 35 miles. Having assessed the time required and the cost of the work, by what factor should these be increased to allow for stress of weather? Surely this is a situation in which the employer, by himself bearing the allowance for such risk, may ensure a minimum cost for the completed project.

142. Turning to two questions on reading this interesting Paper: would the Authors enlarge on, first, the failure or partial failure of the winch on two occasions, in spite of thorough testing, and secondly, the thinking that led to the bottom tow of the pipe; in this case would, in hindsight, another method have been preferable?

143. The float survey to determine the minimum distance from the shore for the pipe outlet embodied the plotted tracks obtained throughout the range of spring and neap tides from a selection of release points. Ballasted 10 ft and 5 ft spars, weighted beach balls and small flat boards were dropped in the sea, one of each type being included at one release, and then positions were noted at about half hourly intervals by Decca Navigator on board the launch. Drawings were prepared for the track of floats released within a two-hourly interval in the tidal cycle, and the simplified diagrams (Figs 19–22) give an indication of some of the survey results.

144. Figure 19 shows a float group launched at about 4000 ft from the low water mark, on a proposed outfall alignment very close to that finally decided upon. The tide is ebbing against a force 4 SW wind. The floats move with the tide, then turn northabout and, on the flood, come ashore all the way along the beaches. It was evident that 4000 ft was too close for the discharge point of the outfall.

145. Figure 20 indicates floats dropped between 5000 and 9000 ft from the shore on the flood tide. With force 5 SW winds the floats again turn northabout and, on the ebb, run closer in shore even though the tide is ebbing. At 9000 ft with a NE wind the floats are moved at slack water away from the shore and the ebb stream carries them further seaward. At these distances the wind direction has a greater effect on the surface movement at slack water.

146. Figure 21 shows a pattern of float movements 10 000 ft out from the shore. This is the position selected for the terminal of the outfall. With a northerly wind there is a very considerable spread of surface water to the southward at slack high water. When the wind is SW the floats travel close together with the wind and the flood tide up-channel and diverge when the ebb sets in.

147. Figure 22 shows what I would consider to be normal conditions, with the predominant SW winds at a slight angle onto the shoreline, but the floats indicating the movement of surface waters remaining at least a mile offshore. We found nowhere closer than about 6 miles seaward at which the tidal streams would carry the floats truly out to sea, but at this 10 000 ft discharge point the surface waters travelled 5–6 miles in a single tide, gradually dispersing and moving up-channel in an oscillatory manner.

Mr F. L. Terrett, Lewis & Duvivier

I have selected from the Paper three topics for comment, the first being in the section dealing with the investigations. Mr Shilston has already amplified the information given in the Paper on float surveys, but I think they are worthy of still further comment.

149. I imagine that the Authors would not have been surprised to find that on the flood tide their floats tended to drift towards the shore, since as the tide rises and the waterline moves in across the beaches there clearly must be a component of the tidal current in towards the shore, as there will also be a component away from the shore on the ebb tide. It is perhaps surprising that these components normal to the shore should have been detectable as far out as 10 000 ft.

150. We are told that during the investigations the wind was predominantly from the SW and it would therefore set up a surface current towards the shore. Since the investigation was for a sewage disposal scheme, floats were relatively shallow ones

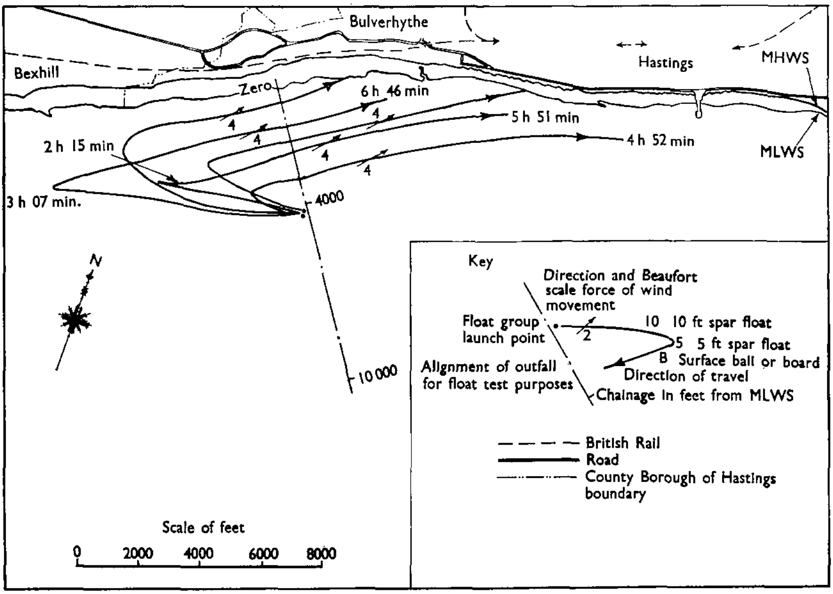

Fig. 19. Typical movement of floats 4 h after high water: 4000 ft

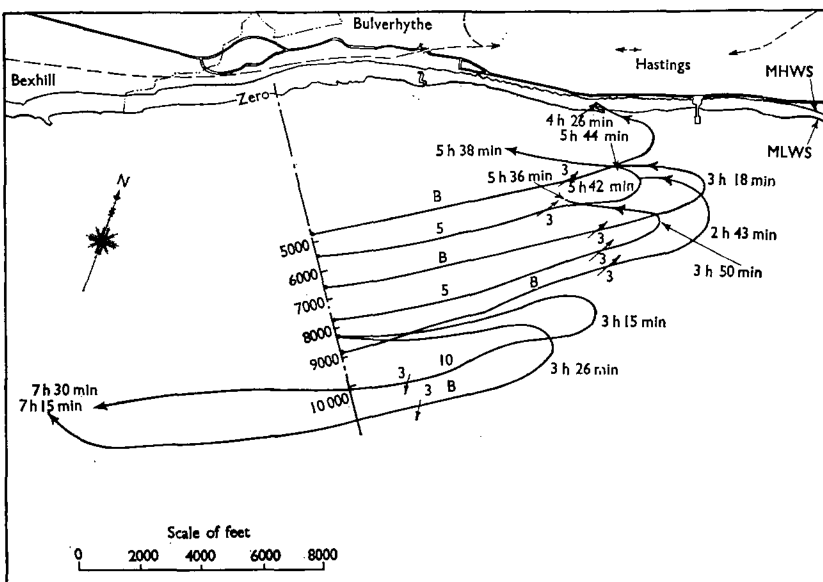

Fig. 20. Typical movement of floats 2 h after low water: 5000–9000 ft

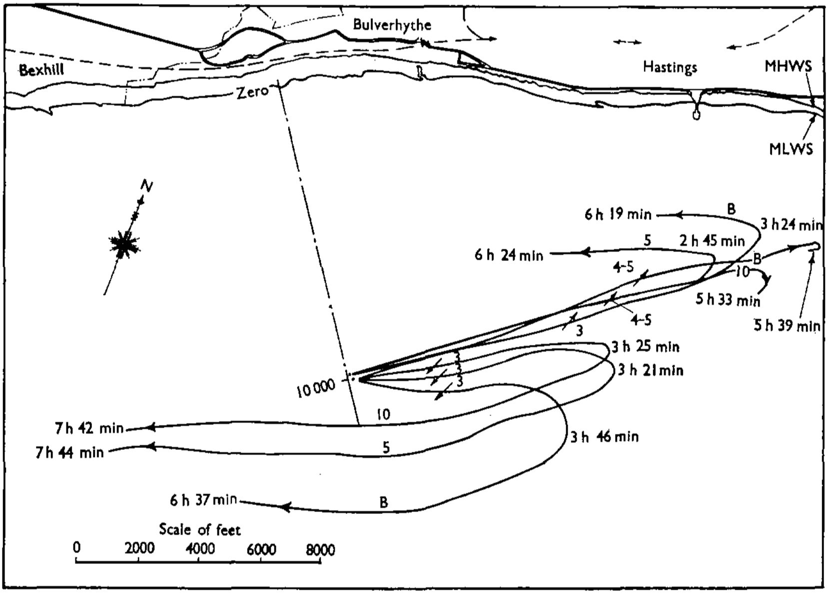

Fig. 21. Typical movements of floats released 2 h after low water : 10 000 ft

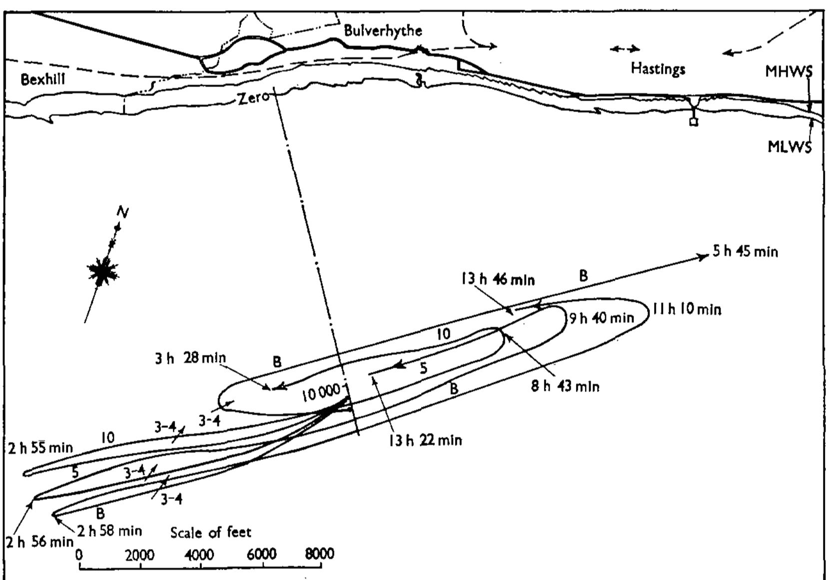

Fig. 22. Typical movements of floats released 4 h after high water : normal conditions

and would be affected by this wind-induced surface current. If, however, there is an onshore current there clearly must also be offshore compensating currents, either at depth or in the form of rip currents. In my view these countercurrents will result in increased dispersion of sewage from an outfall. One cannot therefore make a decision directly from the float test results as to how far out to sea the discharge point should be located.

151. This view is supported by work which was done by the Water Pollution Research Laboratory at a site where my firm built an outfall some years ago; they were unable to find any correlation between the degree of pollution at the shore and the direction of the wind. I think I am right in saying that with onshore winds pollution at the shore was less than at other times.

152. I should like to ask the Authors how much weight they attach to the results they obtained with their light surface floats. These, like any other floating matter, would be driven ashore by onshore winds much faster than the currents which are induced by the wind. It seems to me that in a scheme which incorporates disintegrators, comminutors or screens to remove floating material and, in addition, a diffuser to give dispersion and dilution, the problem of floating matter is very largely eliminated.

153. I raise these points because, in the absence of standards for the discharge of sewage into the sea, engineers are forced to rely on their own judgement and experience. The result is that outfalls in areas which appear to be sensibly similar vary greatly in length, depending on the engineer who has designed the work. It is my own feeling that there is a tendency to take outfalls further out to sea than is really necessary.

154. I should like to refer also to dredging. At the time the Authors were carrying out the work at Hastings, I was concerned with a similar scheme 9 miles to the west at Eastbourne. The outfall there was 2500 ft long and, as at Hastings, was laid in a trench dredged across the sea bed. By an unfortunate coincidence, we also hoped to put the pipe at Eastbourne into the sea in the summer of 1968 but did not do so until July 1969. This delay enabled us to keep the behaviour of the trench under observation during the autumn, winter and spring of 1968 to 1969, with some interesting results.

155. The trench was first completed in August 1968, and had taken about 12 weeks to excavate using a trailer suction dredger to start with and then a 2 cu. yd grab dredger. The trailer dredger removed 20 000–25 000 cu. yd of sand, which was approximately 40% of the total which had to be dredged, in three days. My only comment on that is that it was found difficult to keep the trailer dredger on line close inshore, so that the trench which it produced was rather irregular. The deepest part of it did not follow the required line very well, but nevertheless this piece of plant was very effective in reducing the total time that was required to excavate the trench.

156. Various problems prevented the pipe being laid in August but we were ready again in September, when the trench was resurveyed, and it was found that there had been about 12 in. of silting in the trench in a period of 6 weeks, during which there had been unsettled weather, including three periods of several days when there were strong SW winds and rough seas.

157. September was a better month, although it also included one period of three days with an onshore gale and rough seas which again prevented the launching of the pipe. A survey in October showed that in a period of about four weeks there had been a further 12 in. of infilling in the bottom of the trench.

158. It was in the light of these observations that it was decided to try to launch the pipe later that year. The grab dredger was brought back in November to clean up the trench, which had been surveyed again, and found not to have deteriorated to any great extent.

159. Although these rates of siltation are quite modest, particularly in view of the weather conditions, when the dredger started work in November (the weather

conditions were reasonably good and the dredger was able to work) it was found that it could barely keep pace with the rate at which the trench was filling in, and it soon became clear that it was quite impossible for a machine of that capacity to dredge the trench at all under the prevailing conditions. The work therefore had to be abandoned until the following year.

160. When the trench was surveyed yet again in April 1969, it was found that it had completely filled in from the shore to about 1400 ft out. Beyond that, there was only a slight depression in the sea bed. On this occasion the trench was redredged with a ladder bucket dredger, which completed the whole operation in 10 days, again illustrating the need to employ large capacity plant on work of this kind.

161. I have mentioned these experiences at Eastbourne because information about the excavation and maintenance of trenches across a sandy sea bed in the open sea is scarce, and I hope that the Authors may be able to include in their reply to the discussion similar information in connexion with the Hastings trench.

162. I should like briefly to refer to the section of the Paper on diffusers. I am interested to read that the construction of the diffusers proved to be straightforward. However, there is a qualification to this: we are told that calm sea conditions were necessary and Mr Fletcher has mentioned 30% lost time. Does this apply specifically to this operation, which obviously involved a lot of divers' time, or to the marine operations as a whole?

163. At Eastbourne, the diffusers were constructed on the pipeline before it was launched, and when the pipe was eventually pulled to sea, which took only 4 hours from start to finish, the only diving work involved thereafter was the unshackling of the pulling sheave, the release of the buoyancy tanks and the unplugging of the diffuser ports which had been sealed with glass fibre plugs.

Mr W. B. Harris, C. H. Dobbie & Partners

I should like to reinforce what Mr Cowlin has said. I think that the Authors have perhaps undersold the viability of disposal by submarine outfall pipe as compared with a full treatment works. They are correct in saying that the tender in this case was very close indeed to the probable cost of a full treatment works for a population of 32 000, but the point was made that a treatment works could not be on the sea front and would probably have to be a mile or two away, so that there would be a great deal of sewerage in addition!

165. I notice from § 27 that the diffuser at the end of the pipe was 12 in. in diameter compared with 6 in. dia. diffusers set further back. What were the merits of this? As I understand it, the amount of dilution obtainable over a diffuser system depends very much upon the diameter of the orifice of the diffuser. It would seem to me, therefore, that the critical part of the design would be the diameter of the largest diffuser.

166. Location of the end of the outfall was probably fixed at 10 000 ft because it was found that there was little tendency for the floats to come ashore from that point. Have any calculations been made of the probable dilution or bacteria count at the shore line? Have all the diffuser ports been opened?

167. Comminutors were used at the pumping station. I wonder whether consideration was given to the use of screens and high-speed disintegrators, which, I am told, produce a much finer macerated product which would be more readily attacked by the natural resources in sea water, marine bacteria, etc.

168. A great deal of trouble was experienced with the filling of the trench. I wonder whether, instead of dredging a trench first and expecting it to remain open while pulling the pipe into it, it might not have been preferable to excavate a narrow trench on the line of the outfall, to prove the ground physically, and then pull the pipe on that line and lower it by suction dredger, jetting, or some other method through what would then be only relatively soft material?

DISCUSSION

Mr G. E. Broadhead, George Wimpey & Co. Ltd, Central Laboratory

There is a strong case based on the large volume of the sea and the rapid dilution and oxidation afforded by it, to dispose of coastal sewage by long sea outfalls. Support is given to this by the recent Jeger Report,[2] which suggests that, provided a number of safeguards are afforded, this is the only practical method of economically disposing of sewage from coastal towns. The suggested safeguards include:

(*a*) legal controls for the discharge of coastal sewage;
(*b*) the screening and comminution of all sewage before discharge;
(*c*) a long sea outfall, and not as in many cases one finishing just below the low water mark;
(*d*) extensive investigations and tests before a new outfall design is approved, which should acquire all available knowledge of the quality and quantity of the sewage and the engineering, physical and other environmental factors which could influence the discharge.

170. To determine these factors, it is recognized that an extensive and detailed hydrographic survey must be undertaken. At present, to obtain Ministerial loan approval, scheme proposals should include, amongst many other details, hydrographic and float tests. However, the Jeger Report states clearly that 'mere float tests are not sufficient alone because of the effects of wind and because they do not give an indication of the pollution concentration'. The Report recommends, in addition to floats, the use of dye and/or radio tracer tests together with, if necessary, a hydraulic model.

171. In the light of those recommendations, it seems probable that Ministry approval in the future could be made conditional on the use of tracers in the form of either radio tracer such as Bromine 82, dye such as the fluorescent dye Rhodamine B, or bacterial tracer such as *Serratia indica*, which has been put forward for many years by the Water Pollution Research Laboratory. Research has been undertaken into their use, and we have also carried out some tests ourselves.

172. The tracking and monitoring of these tracers need care and special equipment and the results require analysis and interpretation if the survey is to be meaningful. Furthermore, the proximity of populated beaches needs to be considered if there is the likelihood of the tracers, particularly radio tracer or the red dye, reaching the shore in significant concentrations.

173. Using a bacterial tracer such as *Serratia indica*, the mortality rate of which responds to time and ambient conditions in a similar manner to the coliform bacteria in sewage, has certain advantages. By injecting the bacteria at the proposed site of the outfall and sampling along the beach at regular intervals a measure of the bacterial pollution can be obtained. This may not necessarily reflect the possible pollution caused by pathogens whose life may be different from coliform, but in general terms this tracer seems more likely to provide, from the standpoint of health, a more realistic comparison with the performance of a comminuted sewage effluent than either of the other tracers or floats.

174. Such tracers should preferably be injected in a continuous stream to provide a satisfactory simulation of the sewage discharge and should also be capable of being injected and sampled during storms. The use of normal inshore hydrographic survey vessels is impracticable for sampling in such conditions, whereas sampling along the beach is generally quite feasible. If, therefore, a vessel equipped with a device for storing, metering and injecting a tracer at a steady rate could be moored economically at the discharge point, a comprehensive set of data would become available to confirm the proposed location.

175. The hydrographic survey conducted to determine the minimum offshore distance of the Hastings outfall to avoid pollution of the foreshore and recreational waters was extensive and comprised a large number of float tracks. This culminated in the conclusion that a 10 000 ft outfall was required. The Authors have drawn

attention to the need to make allowance for windage in their analysis of the float tracks in view of the worse than average onshore winds during the survey. A more difficult assessment would be that of comparing the movement of the floats with that of comminuted sewage; this might result in a built-in factor of safety when wind and tide are complementary, but the reverse might arise under other conditions.

176. If the Authors were presented with a similar problem today, when the techniques of using tracers are being more widely proposed, would they consider it advantageous to use them to supplement the data from float tracks, for example, by providing confirmation of the design location before finally going out to tender? If so, would they have a preference for either radio, bacterial or dye tracers for revealing the necessary information, bearing in mind the long distance of the outfall from the shore?

177. My next question, which has been partly answered, is whether there has been any feedback from tests which may have been carried out since the outfall has been in position, and whether the location has been found to be perfectly satisfactory along the beach.

Mr M. Pettifer, Corby UDC, Formerly Assistant Resident Engineer, D. Balfour & Sons

The Authors are to be commended on the account of the job they have given and on the scheme which showed original thought and a great deal of hard work. Nevertheless, the breadth of some of the difficulties is not really apparent.

179. If the string joint is taken as an example, this underwent a vast amount of research and testing before a good design was evolved. Even after the design conditions were found to be adequate, it was still not clear whether the tolerance on a $\frac{3}{16}$ in. weld gap could be produced when joining two 1500 ft long, 350 ton strings. In the event it proved quite simple: Press's used a hydraulic clamp and with the use of jacks under the ends of the line before the clamp was placed on the pipe, everything went very smoothly indeed.

180. I should like to refer to the Combe Haven pumping station, which contains single stage tide flaps on the stormwater overflow chamber and the by-pass pipe in the screen chamber. When the job was being constructed there was trouble from the Sussex River Authority's tide flaps on the stream jamming open. These would admittedly have been jammed open by debris coming down from the construction, but nevertheless it was not unknown for a second tide flap about 100 yd upstream to be simultaneously jammed, which meant that the high tide rushed through beyond the construction. I wonder whether, under the operation of the scheme as it is at the moment, there have been any similar difficulties in the Combe Haven pumping station?

181. Sussex River Authority hoped that the stormwater placed in the culvert would help with the problem of shingle build-up on the beach end of the twin outfall at Combe Haven. I should be interested to hear whether this, and also the removal of the old sewer down the beach, has helped at all.

182. With regard to the outfall, I should be interested to know if in the Authors' opinion it is now possible to discount the problem of twist in the pipeline under pulling operations. Mr Caswall has outlined the difficulties involved in producing a rope which does not impart twist to the line, and it has been suggested to me that one reason why pipes twist is roller misalignment.

183. The first string was pulled on its own, by the 25 ton land winch, and from memory it turned 60–90° in its own length. The rollers were examined and found to be as correct as a theodolyte could prove them. Then pulling was repeated, and the same thing happened. In fact, the Contractor installed a small device, which has not been described, which gave them complete and fine control over the pipeline. Could the Authors describe this device?

184. There was mention of residual water in the pipeline after flooding during the winter. I would like to know whether the Contractor is satisfied with the present method used to expel the water. It is reasonable to expect that longer pipelines will be laid; and if they need to be flooded, it is obviously important that the maximum amount of water can be expelled. At Hastings, compressed air was used to try to get rid of the water, but it was not completely successful and a pair of foam rubber pigs which were blown through the pipeline almost jeopardized the whole scheme by getting stuck.

185. In the original specification the Resident Engineer had the authority to ask the Contractor to flood the line during pulling operations if he felt that weather conditions warranted it. I understand that the Contractor made representations, and I think quite rightly, that the Consulting Engineers should allow them to take full authority for the line. I would like to know from the Engineers whether this will continue on future schemes.

186. My last question relates to the standby winch at Hastings. Now that William Press have had time to evaluate this, I should be interested to know whether it will be used as a No. 1 winch elsewhere, or whether they intend to continue with the capstan winch and allow capstans completely to dominate the future scene.

Mr P. A. Banks, John Taylor & Sons

I should like to ask three brief questions. How did the Authors determine the strength and thickness of steel pipe which they used for the outfall? What were the criteria which were applied? Was the likely winch pull alone taken into account or were stresses arising from possible curvatures in the pipe as laid or during pulling also calculated?

188. Cement mortar was used to line the pipe internally. I should like to know whether this was ordinary Portland cement and whether there is any evidence that it is still intact on the inside of the pipe after the pulling operation.

189. Mr Crisp told us something of the inspection of the pipeline by divers after it was in commission. It would be interesting to know whether the diffusers appeared to be performing as they were designed to perform, with sewage discharging from each one. Was there any noticeable tendency for more to come from the inshore diffusers or was it impossible to distinguish?

Mr R. J. Taylor, Senior Engineer, Ward, Ashcroft and Parkman

There are a number of points on which I would like to comment, particularly on the design side.

191. The Authors state that it was decided to construct by the bottom tow method without giving any background to this decision. What other methods of construction, if any, were considered and why were these rejected in favour of the bottom tow method? Have British contractors generally more experience with this method than with others?

192. It is a pity that the Authors do not give more details of the investigations because the design of a sea outfall falls into two categories; the feasibility design and the construction design. From the Paper it would appear that float tests were virtually the sole means of determining the best position for the end of the outfall, but I feel sure that there were many other reasons; it is stated that floats released at the 5000 ft mark *tended* to drift towards the shore on flood tide conditions; did they actually reach the shore and if so in what time—hours or days? It would have been interesting to see a profile of the pipeline and sea bed so that water depths along the pipeline could be judged.

193. The Authors do not make mention of the main criteria in the design of a sea outfall, namely:

(*a*) no visible boil;
(*b*) no visual pollution;
(*c*) no stable sewage field (slick);
(*d*) an acceptable degree of bacteriological pollution.

It is known that under certain conditions of dilution dispersion and adequate time intervals the above conditions can be achieved; the methods of calculation can, however, be questioned. However, in so far as bacterial pollution is concerned it is known that bacteria mortality is rapid in sea water, and that within 1–6 hours of immersion there will be 90% mortality of coliform bacteria. Would the Authors care to comment on this aspect of the design of the Hastings outfall and enlarge on the reasons why an outfall to 5000 ft was not considered suitable? Construction costs are extremely high and in my opinion a reduction in length, and hence in cost, can probably be achieved with little, if any, increase in risks of pollution. Did the Authors calculate the probable maximum beach coliform count arising from this outfall, and were any background tests made of the existing beaches for future comparison purposes?

194. It is not clear whether sewage is pumped to a break tank at the landward end of the outfall; that is, does the outfall act as a gravity line or extension of the pumping main? What sort of minimum velocities are achieved through the outfall and diffusers? Presumably there are no arrangements for closing any of the outlets, and in the event of any of these becoming blocked would the protection provided by the precast concrete dome cause any difficulties in maintenance?

195. The description of the construction is most interesting and it is apparent that considerable co-ordination and co-operation was necessary between the many Authorities involved. All those concerned in the organization are to be congratulated.

196. I note that the Authors refer to tender figures only and no reference is made to final costs. In a contract of this nature I would expect contractor's claims for many reasons; without going into detail, would the Authors care to make any comment on this point, say in comparison with a contract of equivalent value for a sewage treatment plant?

Mr M. Landsell, Torbay CBC

The Authors are to be congratulated for producing what may well be the first paper published in the *Proceedings* on the design and construction of submarine outfalls by other than traditional methods. We also owe much to the oil industry which has advanced sea-bed pipeline technology immensely.

198. I was pleased to see that local medical opinion did not influence the Authority away from a sea outfall in favour of an inland treatment works with its sludge problem and 'low water mark outfall'. Although the effluent would have been aesthetically acceptable, coliform levels at the shore would probably have been little different from those at a short crude sewage outfall. Have any *E. coli* tests been undertaken to confirm that the length of the outfall is satisfactory? There seems to be no bacterial standard for bathing waters in Britain. Australian Coastal Authorities and the US Public Health Service have adopted a figure of 1000 coliforms/100 ml as the limit for waters suitable for bathing and aquatic sport in general.

199. Had the whole of the flow been discharged at the end of the outfall there would probably have been a surface slick. Is there any slick with the diffuser? Does the flow tend to come out of one or two of the points only? Do sea gulls give the position of the outfall away?

200. Turning to the pumping station, have any surge problems arisen? In long flat rising mains where the head is nearly all frictional, rapid velocity changes due to power cuts have resulted in excessive surge pressures. The greatest danger is from parting of the water column and pieces have been blown out of reflux valve bodies, joints sprung and so on, when the column reunites. In this case the main is about

14 000 ft long, with a wave velocity of about 3500 ft/s so the 'period' of the main is about 8 s. If the output of the two duty pumps was reduced to zero in this 'period' or less, a pressure surge of about 125 times the velocity change, or in this case 500 ft, would occur. I would therefore like to hear of any surge protection measures which have been installed. All types are used, including tall vent/surge columns, air vessels, reflux valves with a hole in the clock, large snifting valves, power operated delivery valves, flywheels on the shafting, etc., all with some degree of success.

201. Have there been any operating problems with the comminutors, e.g. comb damage or balling up of rag into a rope in the outlet syphon? I imagine that the grit trap does much to prevent cage wear. It is a pity that screw pumps were only in the early stages of acceptance in Britain when the storm sewage pumping machinery was at the design stage. Would the Authors agree that they economize on space in cases where the lift is small and the volume of flow considerable? In a recent article on the scheme[3] it was stated that when the flow into the station reached 12 dwf, the dwf pumps would be isolated and the whole flow discharged to the beach. Is this still the case?

202. Regarding the outfall Contract, was there any form of 'target' agreement in the form of tender whereby the risk could be shared between Contractor and Employer? I have found this sort of arrangement leads to far greater harmony between site staff on both sides than is all too often the case with 'fixed price' jobs.

Mr C. R. Neill, Research Council of Alberta, Edmonton

It is stated that estimated capital costs were closely similar for two alternatives: first, full treatment, and second, preliminary treatment plus a long sea outfall. In view of increasing international concern over pollution of the seas, was the decision to adopt the second alternative not an irresponsible one? In 1960, when the decision was taken, such concern was perhaps not widespread, but by the time construction began in 1968 the need for a change in criteria might have been apparent.

204. In the context of the 1970 global situation, I do not think much credit is due for the execution of an engineering project that removes polluting waste from the client's backyard and dumps it into international waters. It should now be evident that the use of the oceans and atmosphere as free dumping-grounds can no longer be tolerated if life on earth is to survive. It may well be that the consequences of this particular case are of negligible significance, but the Authors make no reference to these broader aspects of their disposal method.

Mr W. Fyffe, retd., formerly Ministry of Housing and Locol Government

From a study of that part of the Paper dealing with 'Investigations' it appears to me that the floats used were of the drogue type, immersed to a depth of 3 ft or more in the sea. Flat cards in waterproof envelopes do not appear to have been used.

206. The velocity of the tidal stream on most of the Sussex Coast is very low and may be likened to a broad river flowing gently eastwards on a zig-zag course along the coast. In my opinion the most important currents on the Sussex coast are those set up by the winds.

207. At Lancing, where I have owned a house for nearly 40 years, the sewage emerging from the Worthing outfall is clearly seen from the Down as a widening plume of oily slick, resembling smoke from a factory chimney. The film of oil is strong enough to smooth the waves it passes over. When the wind is light the plume flows with the ebb tide past Worthing Pier, miles to the westward, but when there is more than a light breeze from the SW the plume flows eastwards along the Lancing beach. The outfall is ¼ mile long. Before World War II the sewage was not macerated and I have seen large quantities of solid excreta drifting eastwards close inshore with the surface current while the outgoing tidal stream flowed to the SW

underneath the point of observation which was at Shopsdam, approximately 1 mile E of the outfall.

208. After the comminutors were installed the plume of slick could still be seen. This is an oily film on the surface of the water which is unpleasant to encounter when one is swimming. It is only when an offshore wind is blowing and the contaminated water is blown out to sea that the water is clean, because bottom water comes along the sea bed and rises near the beach to replace it.

209. Worthing now partially treats its sewage with settling and sludge digestion tanks.

210. Two very thorough investigations into surface currents have been carried out in recent years, one at Tynemouth in connexion with a proposed sea outfall three miles long, and the other into the currents of the North Atlantic Drift and their effect upon oil slicks. In both investigations brightly coloured flat cards enclosed in waterproof envelopes were used. The first has been described by Oakley and Dyer[4] and the other by Deacon.[5]

211. In the Tynemouth investigation it was found that with a strong onshore wind, floating matter discharged three miles offshore would reach the beach within 2 h: the speed of the current was approximately 3½% of the wind speed.

212. In the second investigation, carried out in 1954 with the help of Coastal Command RAF, 6400 brightly coloured flat cards were dropped in bundles of ten at ten mile intervals along an arc between the Faroes and Northern Spain. This was done three times, in May, September and December, 1954. Of the 6400 cards dropped, 2670 were returned within about a year. They came ashore on the shores of western Europe between Portugal and Northern Russia; 1000 came ashore on the west coast and islands of Britain; none came ashore on the east coast of England, south of Berwick. The speed of drift was approximately 3½% of the wind speed as taken from the daily weather reports.

213. The Paper states that oil and sewage consist of a very thin surface film. When drift experiments are made with drogues and weighted piles over 5 ft below the surface, the drift is affected more by the tidal stream as the effect of wind-driven surface currents diminishes rapidly with depth.

214. At the Bognor Regis inquiry in 1966 it was stated that the design of the outfall proposed to be constructed was based upon similar outfalls in California, which were functioning satisfactorily. However, conditions are quite different in California from those prevailing in the English Channel. The prevailing winds in the Channel are westerly and onshore, whereas California is in the region of the Pacific NE trade winds and the prevailing wind there is offshore and blows floating matter out to sea. There the outfalls are carried four or five miles out to sea, where they discharge into water 250–300 ft deep and where the offshore wind is well established outside the lee of the lofty mountains which line the coast. In the Channel along the coast of Sussex the sea two miles offshore is about 30–40 ft deep at low water.

215. I am of the opinion that in all float experiments of this kind both flat float cards and drogues should be used.

Mr R. H. Pilcher, Scott Wilson Kirkpatrick & Partners

In § 5 the Authors state that it 'was decided that the outfall should be constructed by the bottom tow method, and the choice of location was, therefore, influenced by the need for an assembly and launching area suitable for the purpose'. I should like to know what the reasons were that led to the taking of this initial decision, and whether a sea outfall made of any other material (such as some of the thermoplastics) was ever considered. A pipeline constructed of a different material and laid by a different method might have made it possible to construct the outfall at a different location, which in turn might have influenced the cost of other aspects of the scheme.

217. I paid a visit to the site during the construction of the scheme and noticed

that the pumping main from the Combe Haven Pumping Station, in following a line more or less parallel to the coast, reached a high point before descending and turning out to sea. I should be interested to hear what measures were taken to admit or expel air at this point and also whether it was considered necessary to take any protective action with regard to surge on the pumping main. In installations of this kind where operation of the pumps is intermittent, problems arise when the pumps start after a period during which the tide level has dropped. The water level in the pipe being the same as that of the tide, it may be well below and some distance away from the high point in the pumping main, leaving a length of air-filled pipe. It is not always easy to ensure that this air is expelled quickly when the pumps restart, and that large bubbles of air are not carried along the main, giving rise to possible locks and pressure fluctuations.

218. The failure of the main winch caused a long delay in the completion of the project. Could the Authors state whether the Contract included a provision for liquidated damages in the event of delay, and whether these damages were exacted?

219. Mr Mattin has said that the dig was harder than his Company had expected and that this resulted in the trenching operation taking longer than had been anticipated. Apart from the air and water probes referred to in § 14, were any other investigations made into the nature of the bottom? I should also like to know whether the actual variation in the anticipated nature of the bottom was sufficient to give rise to a Clause 12 claim.

Mr H. C. Williams, City Engineer, Gisborne, NZ

Some similarities seem to exist between the experiences recorded by the Authors and a submarine sewer installation carried out by the Gisborne City Council, New Zealand, in December 1964. As one who has designed a submarine sewer outfall of that type and encountered the anguish that goes with building and launching it, may I compliment them on achieving in the end what at times must have appeared a doubtful prospect for success. The absence of previous technical papers revealing the more intimate detail of submarine pipeline laying using the bottom tow method no doubt has struck the Authors also. On that account they have made a brave attempt to bring to the fore some experience and misfortunes which could well be of material assistance to those following.

221. The use of float tests cast into the sea in sufficient numbers to show up evidence of a set of absolute rules for tidal movement is generally accepted as open to question. The Gisborne counterpart to the Hastings sea movement investigation developed a technique for anchoring at a particular location a pair of flagged buoys rigged up to serve as a fixed current measurement and orientation device. One buoy was moored in the conventional way but the other, outfitted with a large drogue sea anchor, was moored to the first buoy by a light mooring line fitted with a heavy weight at the mooring line centre point. The relative positions of the two buoys thus represented a measure of the sea current velocity at that location and at that depth. The details of the system are enlarged on in Williams[6] but they did give a continuous indication of sea movement in all weathers. Perhaps the Authors would care to comment on the real faith they had in the Hastings float tests and the alternative of keeping the floats captive as outlined above.

222. No mention is made by the Authors of the question of pipe stresses, both during the transverse and longitudinal launching process and during the exposure on the sea bed prior to burial. The Gisborne pipe, 6000 ft long by 30 in. i.d., was claimed in 1964 to be the first fully prestressed concrete pipe launched into the open sea by the bottom tow method under discussion. Prestressed concrete was chosen instead of the more traditional concrete ballasted steel pipe because the evidence seemed to point to the distinct possibility of the external reinforced concrete around a steel pipe being shattered during the launching processes. It has been suggested

that more concrete has spalled off concrete ballasted steel submarine pipe than engineers care to admit. The issue in that respect seems to be the relative degree of loss to the finished structure should mischance temporarily compel the pipeline to bend *in extremis* during installation. Perhaps the Authors could indicate to what degree they have since satisfied themselves that the concrete stayed put, either by subsequent underwater inspection or by interpretation from the cathodic protection power drain.

223. Against much of the experience so far reported, the Hastings installation chose a design negative buoyancy for the pipeline of 90 lb/lin. ft. Gisborne adopted 9 lb/lin. ft in sea circumstances apparently similar to the Hastings site. Was this selection made because of the designers' doubts about being able to manufacture pipes to such a nice weight control or was it a manifestation of the model tests? Prestressed concrete pipe has, as one of its major advantages the pipe jointing sequence, where epoxy resin jointing of plain butt joints is involved, which leads to a precise site determination of the negative buoyancy of the pipeline.

224. The Hastings installation appears, on our experience, to be over-conservative in its provision for holding the pipe in place in the vicinity of the diffusers. At a depth of 60 ft, the same as at Gisborne, the effects of wave-induced sea bed movement seem to be minimal. A pipe 39·20 in. o.d. weighing 550 lb/lin. ft, half-buried in the sea bed silts, has been found to be stationary since installation; that is with sand piled up high on one side and low on the other.

225. Are the Authors satisfied that the diffuser arrangement adopted lends itself to adequate underwater maintenance? Gisborne provided 22 5½ in. dia. holes in the wall of the outfall, spaced over 600 ft at the seaward end, and has found this to work exceptionally well. Subsequent diver inspection reveals that the growth of barnacles is the thing which needs paramount consideration. Luckily the simplicity of the Gisborne arrangement has kept barnacle encroachment back from the waterway at each diffuser port because the jet of fresh water is neat and unmolested. Is it not probable that the precast concrete domes nesting over the diffusers at Hastings will foul up with sea bed materials, and then harbour obstructive barnacle growth?

226. Unlike the Hastings designers, the Gisborne City Council deliberately refrained from pretreatment grit removal. So far the decision seems sound but only because the length of the diffuser port section is substantially less than the wavelength of the big ocean swells moving onto the coast. At dry weather gravitational flow through the outfall, velocities are as low as 1·1 ft/s, with consequent depositions of grit in the submarine pipe system, but at the other extreme negative velocities do occur when a big sea is running, even with mean velocities of up to 2 ft/s. The net effect is instantaneous velocities of more than twice the average under certain conditions of wet weather flow, outfall pumping and heavy seas. That effect purges the grit from the submarine pipeline, although in the process it calls for a calculable increase in pump duty to provide the extra motive power to meet the additional pipe friction losses. The point made is that the length of the diffuser section needs to be limited if self-purging is to be taken advantage of. The Hastings length of 750 ft at a depth of 60 ft is a little more than Gisborne experience would reckon was prudent on that account. Its designers might be prepared to comment on this, in that it appears not to be mentioned in literature so far devoted to sewage disposal in submarine circumstances.

227. The natural die away or dilution of organisms downstream of the outfall area so far appears to be much faster in Gisborne than research papers and other practical reports would account for. Could the Authors report the outcome in Hastings in that respect?

228. Reference to the tendered price at £480 000, in the light of the account given of the misfortunes encountered and overcome, suggests to this reader that the actual cost could well have been different to the tendered price. It would help if the Authors could enlarge on the items of cost to see to what degree, if any, the tendered price

was unreal. To this reader it appears that the use of epoxy resin jointed longitudinally prestressed concrete pipe could have produced a cheaper pipeline requiring less haulage gear.

Messrs Crisp, Stewart and Fletcher

Mr Cowlin and **Mr Pilcher** ask the reason for the use of steel pipes and whether, in another instance, the use of plastic pipes would be considered. At the time the pipeline was designed, the maximum diameter available for plastic pipes was quite small. Now plastic pipes are manufactured in Britain up to 24 in. in dia., and larger diameters can be obtained from the Continent. Plastic pipes certainly have the advantage of inherent corrosion resistance and the problems of placing them in position can obviously be overcome, but there is concern about the anchoring of a plastic pipeline and it should certainly be well and truly anchored in the sea bed, even if it is already buried in a trench. It is doubtful if there would be any significant difference in the costs of the two materials, and on present showing a steel pipeline, protected and installed as at Hastings, would still be preferred.

230. One of the Authors has, however, been involved in the construction of two outfalls from PVC tube. Individual pipes were joined on the sea bed by divers, then weight coated by means of nylon bags filled with grout round the pipe. Certain difficulties were experienced which are worth mentioning. Joints between pipes were difficult and slow to make under water, whether flanged or 'push-fit'. Because pipe laying was slow the trench had to be kept open for a long period, which involved extensive redredging. From the beginning progress was governed by sea conditions, especially in shallow water near shore, where diving work was hindered by swell much of the time.

231. Taking into account these difficulties, the method remains competitive on short outfalls. On longer plastic outfall schemes tenders have been submitted based on the bottom tow method. PVC tubes would have been fusion welded, together within a thin walled welded steel tube designed to take the pulling load. Another method of construction which has been used is the floating of long lengths of extruded polythene tube from the point of manufacture to the outfall site where they are sunk into position.

232. **Mr Shilston, Mr Taylor** and Mr Pilcher wish to know how the bottom tow method of construction came to be adopted instead of some other method. Construction by lay barge or 'floating and sinking' are the obvious alternatives to constructing a long sea outfall in steel and concrete by the bottom tow method. Towing long lengths of floating pipe, to be sunk and joined on the sea bed, has been carried out in Britain with varying degrees of success in steel, in aluminium and in plastic. The main problem usually occurs when the pipe is floating on the surface of the sea and is vulnerable to the effects of wind, waves and mishandling. Consequently the bottom tow method is preferred by many engineers and, although there remain some pitfalls with this form of construction, the method is usually adopted by British contractors, where possible.

233. All submarine pipelines laid in the North Sea for natural gas have been carried out by lay barges operated by overseas contractors. Certainly a 2 mile long sea outfall could be constructed by lay barge but, taking into account the high mobilization and demobilization costs (usually spread over many miles of pipeline in the North Sea), it is doubtful whether the method would be viable.

234. Mr Cowlin, **Mr Harris** and **Mr Smith** also ask about the basic thinking behind the adoption of 15 diffuser outlets, and why the diffuser length should be 750 ft. First, it was required of the diffuser that it should occupy a sizeable length of the outfall in order to achieve a large degree of dilution. It was also decided to have small diffuser upstand pipes for the same reason, although these were limited to a minimum of 6 in. in diameter so as to be less susceptible to blockage. The sewage

being conveyed along the diffuser length of the outfall is reduced in quantity as each diffuser outlet in turn discharges its proportion of the flow. This could result in low velocities in the more seaward parts of the outfall, so as a corrective, the diameter was reduced to 22 in. for the last 320 ft, and the terminal outlet was made larger than the others. The design procedure adopted was to assume a size for the terminal outlet and then to carry the hydraulic calculations successively upstream, dealing with each diffuser port in turn and adding its discharge to the running total until the design quantity was reached.

235. It was also considered that the discharge should preferably be uniform over the diffuser length. Since the outlets discharge less at the seaward end and more at the landward end, the requirement of uniform overall discharge could be met either by varying the diameters of the upstand pipes or keeping to a constant size and varying the spacing. All these variables result in a somewhat protracted trial and error process and the end result in this case was that the terminal diffuser discharges about 10–15% of the total flow, the remainder being discharged through 15 diffuser outlets spaced at 35 ft centres at the seaward end, increasing to 80 ft centres at the landward end, with corresponding velocities at maximum flow of 3 ft/s and 8 ft/s. The required number of diffuser outlets gradually emerged as the calculations progressed. The only part of the diffuser assembly above the sea bed is the concrete dome and this should ensure that fishermen's trawling gear should not damage the diffuser pipe.

236. **Mr Terrett** has remarked about the advantages of pulling a pipeline with the diffusers in place and queried the lost time during construction. Usually wave heights in excess of 4 ft stopped or slowed progress on most marine operations, and during construction of the diffusers the lost time due to weather was about 25% compared to 30% overall. As it happened, diffuser construction was also hindered by the untimely arrival of a minute form of marine life which clouded the water badly and reduced diving visibility to almost nil.

237. In the event of the pipe partially rotating during pulling, diffusers on the Hastings pattern could be modified to bring the discharge pipes back to the vertical, whereas diffusers constructed on the pipeline before launching could end up buried. The simple device referred to by **Mr Pettifer** which solved the problem of the pipe twisting on the rollers during pulling consisted of one or more adjustable rollers so aligned as to counteract the tendency to turn.

238. **Mr Pullin** has expressed concern about the possibility of anchors damaging the pipe, but the outfall is clear of the main shipping lanes and the chances of difficulties arising from anchors should be slight. The depth of fill is nowhere less than 2·5 ft and extra protection is afforded by the concrete surround to the pipeline.

239. With regard to the sacrificial anodes, it is intended that these should be inspected from time to time, but an easier means of assessing their condition and effectiveness has been provided by installing a testing point at the head of the beach so that the potential can be measured at any time. Similar testing points have been installed at the seaward end of the outfall, although here, of course, it will be necessary to employ a diver to make the necessary test connexion.

240. In reply to **Mr Milne**, briefly a capstan winch consists of two drums in line both of which are driven. Rope is moved by the friction of several turns around both drums and is then collected on a storage reel. This has a spooling device and variable speeds for winding on the many layers of rope properly. For pulling heavy loads with long lengths of rope the capstan winch has considerable advantages over a conventional winch, which would require a very large drum indeed and a variety of speeds and pulls depending on the amount of rope on the drum. Also the rope would tend to damage itself under heavy load by pulling into the previously spooled layers.

241. The capstan winch which was used on this Contract is one of the largest of its kind in the world. It is driven through a complex gear box (some other large capstan winches use chain drives) and is designed for 150 tons continuous pull.

Although an inspection of the winch after breakdown revealed damaged bearings and gears stripped of teeth, the cause of failure is not known for certain. Minor faults in assembly possibly contributed to the breakdown, and the high, uneven horizontal loading created by tension in the turns of cable around the drum could have caused excessive deflexion in the drum shafts. This in turn could cause overloading and deflexion on gear shafts and bearings and loss of clearance on gear assemblies, which would lead to eventual breakdown.

242. Mr Shilston wishes to know more about the testing of the winch. It will be appreciated that a test which simulates a winch working on board a floating pontoon at sea (pulling with a rope possessing considerable elasticity on a pipe which tends to move spasmodically) is impossible to set up, and the only real test is to use the winch on an actual contract. However, the test rig used, basically a system of ropes and pulleys, worked very well and a fault with lubrication was revealed and put right. Unfortunately, the tests were concluded before the major trouble showed. Of course this is a risk that must be taken when any one-off item of equipment is being tested. Unless the engine, gear box or instrument can be tested to destruction and then rebuilt, what constitutes a complete test?

243. Mr Pettifer was interested to know whether the winch would be used again. The breakdown of the capstan winch on the Contract and the problems in consequence were very unfortunate. However, since the modifications, the winch has worked well and has demonstrated the advantages over a conventional winch. Accordingly, the capstan winch will be used in future as the main pulling winch, with the standby winch adapted for high load general purposes but retaining the capacity to take over the pulling operations in the event of a capstan winch failure.

244. **Mr Marlow** has expressed concern about the stability of the beaches. The coastal waters of St Leonards are sheltered from the worst effects of SW storms by the Royal Sovereign shoals and Beachy Head, and from easterly storms by the promontory of Dungeness. Records of Admiralty soundings over a period extending back to 1878 were examined and no evidence was found in the several surveys of migrating sandbanks or shoals, or of sustained erosion or deposition. The bottom of the trench was in fact excavated to a level of at least 5 ft below the lowest points recorded for the sea bed over the last 90 years.

245. **Mr Trimmer** and **Mr Devlin** both ask about the trench excavation. Generally the trench was excavated to two grab bucket widths at the top and one at the bottom. In the clay areas the stepped sides of the trench stood, but through the sand the sides collapsed to a saucer shape conforming approximately to a 1 in 2½ batter. Any unevenness in the bottom of the dredged trench tended to be levelled by fall-in and siltation. Where rock occurred the trench was blasted and then grabbed to well below the required level, then left to silt up. The trench line as a whole was over-dredged by about 1 ft, so that when the pipe was eventually jetted down through the accumulated silt and sand to its correct level it was cushioned from any hard material encountered in the dredging.

246. On Mr Trimmer's other point, the sewage is in fact macerated and the grit removed.

247. In reply to **Mr Hunt**, during pulling operations the winch barge was held on very secure moorings and was able to continue working in a force 5–6 wind and wave heights up to 8 or 9 ft. The only difficulty was experienced by the tug and small boats. If a severe gale had been forecast during pulling, then the tug and boats would have run for shelter and possibly the pipe would have been flooded for safety.

248. Mr Pettifer has a question concerning the expelling of water from a flooded pipe. If pipelines are to have a provision for flooding, the only certain way of expelling all the water is by means of a swabbing pig. This means that the outfall must be designed with pigging in mind.

249. Concerning the internal protection of the pipe, further information on which is requested by **Mr Gale**, the mortar lining of the pipe is designed to give permanent

protection against the corrosive effects of sewage and sea water. A number of alternative methods was considered but mortar was chosen because of the relatively well known characteristics of this material. There are many instances of the method being successfully used previously, for example in Tema, West Africa, when exhaustive tests were carried out with particular reference to the effects of pipe flexure on the mortar; cracks appeared but these closed again without damage when the loading was removed.

250. Among the alternative materials advocated was epoxy resin, and certainly the characteristics as to smoothness, hardness and resistance to wear are good. It is being used with increasing success in a variety of applications, but it was felt that the near laboratory conditions required for the use of this material as conventionally applied would be unlikely to be achieved on site. This and the thinness of the coating would jeopardize the whole scheme if the protection proved unreliable.

251. From the observations made previously it was anticipated that the behaviour of the cement mortar lining under the effect of the flexural stresses of the pipe during launching would be the opening of cracks and their subsequent closing up again. The lining was therefore given two applications of bituminous emulsion as a final membrane, not only for the protection of the surface as a whole but also as a flexible means of maintaining the protection across any cracks.

252. One or two speakers have requested some further information on the development of the special joint between pipe strings (Fig. 2). With the pipe fabricated in lengths of 1500 ft or so, it was first required that each length, or pipe string, should be complete in all respects including the inner and outer protections. Secondly it was desired of the pipe string joint that it could be made quickly, that it would ensure the continuity of the internal and external protections, that it would achieve this without the need for anybody to enter the pipe to complete any missing or damaged internal protection (and hence also without the need for anybody else to inspect what the first man had done), and that the completed joint should not disturb in any way the uniform cylindrical shape of the pipeline as a whole.

253. The design which eventually took shape is the one illustrated. A special pipe end is involved, resembling a somewhat distorted socket; these are welded on to each end of the pipe string so that the internal lining can be fully completed from end to end. Before one string is drawn into the welding position relative to the previous one, a sealing strip, $\frac{3}{8}$ in. thick and $\frac{1}{2}$ in. wide, is placed around the end of one pipe centrally over the combined thickness of the pipe wall and the mortar lining. When the pipe ends are drawn together so that the welding gap between them is $\frac{3}{16}$ in., the sealing strip has then been compressed to half its former thickness and twice its former width so that it completely covers the end of both pipe wall and mortar lining. Asbestos string is then fed through the welding gap so as to cover the sealing strip and thus protect it from the heat of the subsequent welding. The thickening of the pipe end provides extra metal as a heat sink to help prevent a local concentration of heat and it also allows an annular groove to be machined out of the thickened part to give added insulation by means of an air gap. After the welding has been completed and ultrasonically tested the annular air gap is grouted solid and then the coal tar enamel and glass fibre to the outside of the joint is made good by hand in the same way as on all the other joints.

254. The whole of the jointing procedure was rehearsed in the laboratory so as to ensure its feasibility and to check the temperatures attained during welding. Laboratory tests were also carried out on the use of epoxy resin as the final protective coat in substitution for concrete. Eventually a mix was formulated which was amenable to being placed in bulk and which had acceptable characteristics of curing and strength, and it was concluded that this application of the material would be acceptable. The whole string joint system assured continuity of strength and of the protective measures, each without detriment to the other and also without the need for anyone to work within the pipe. The joint could be completed in a few hours and it therefore permitted the launching of pipe strings at successive high tides if necessary.

255. In answer to **Mr Allnutt's** and **Mr Maple's** points, any floats released at about 10 000 ft which actually reached the shore took eight or nine hours to do so, and it was considered that if sewage took this time dilution would be such that no pollution could occur.

256. Pumping periods were dependent only upon the level of effluent in the sump, storage being limited by the size of the sump.

257. Mr Maple, Mr Taylor and Mr Pilcher inquire about the functioning of the pumping main. Sewage is pumped across the Combe Haven to the highest point in the main on the west bank, whence it gravitates to the sea when both tide level and pumping station output are low. For any other combination of tide level and pumping station output the pumping main acts as a true pumping main, except that it has been designed so as always to fill from the downstream end, and thus air trapping is avoided. The pumping main is vented by a standpipe sited at the high point and its size has been increased to 48 in. locally to act as a buffer against surge.

258. Storage of sewage during peak flow periods was impracticable due to the considerable volume required and the lack of space available at the pumping station.

259. **Mr Hook** mentioned the 'cofferdam'. No cofferdam in the true sense was employed, but steel sheet piling was driven to support the embankment where it had been excavated at each end of the thrust bore.

260. **Mr Boocock** asks about bigger pipes and **Mr Caswall** about bigger and longer ones. Both bigger and longer pipes have already been launched in various parts of the world, and a pipeline of diameter greater than that at Hastings is in fact being towed at Bognor Regis where the Authors' firms are again involved. However, there must be a limit to the length of an outfall constructed by the bottom tow method, and this will probably be determined by the power of winches available rather than the length or size of rope required. Apart from the extra weight of a larger pipe which has to be handled on site by cranes, rollers, etc., the main problem is that during the pulling operation the submerged weight is more critical.

261. With the bottom tow method of construction, the pulling capacity of the winch and the length of pipeline, together with any consideration of resistance to lift and drag forces from waves and currents, determine the operational submerged weight. On longer pulls the submerged weight may have to be reduced to about 10 or 20 lb/ft. This always imposes demands on the control of the pipe coatings, but especially so on larger pipes. For example, an increase of $\frac{1}{8}$ in. on the 4 in. concrete coating to a 42 in. pipe would add about 18 lb/ft to the immersed weight, which represents an 80% increase if 10 lb/ft is the designed weight for pulling. Similar variations could occur due to change in density of concrete, water absorption by the concrete or even change in density of the sea, because of silt or fresh water from a river estuary. All these factors must be taken into account; otherwise there is the danger of the pulling load becoming so large that the winch will be unable to complete the pull or, alternatively, the pipe could become so light that it would float. The greater weight of a larger pipe is not necessarily a disadvantage but it does mean that for a similar type of construction and similar working stresses the restriction on the radius to which the pipe can be curved is more severe for the larger pipe.

262. The Authors were glad to have **Mr Russell's** more detailed description of the part played by the Hydraulics Research Station during the design stages of the scheme, which was a most useful contribution.

263. **Mr Mattin** deserves sympathy for his difficulties in formulating a dredging tender on the basis of the information from earlier site investigations. The investigations at Hastings were quite extensive, but it seems that one can never have too much information on site conditions, especially where the sea bed is concerned. Indeed, dredging being the expensive operation that it is, a paucity of information about the material to be dredged could possibly result in quotations for dredging being so loaded as to produce tenders for an outfall scheme apparently comparing unfavourably with alternatives. In most cases the results of a Sparker Boomer

survey and a number of drilled bore holes will provide sufficient information to enable a dredging contractor to give a lower price with fewer qualifications. A cost of such a survey, on another contract similar to the Hastings outfall, amounted to about 1% of the total contract price.

264. Mr Shilston was personally involved in the hydrographic survey and it was particularly appropriate therefore that he was able to show some of the results of some of the float tracking which could not be included in the Paper.

265. Mr Terrett suggests that the outfall may be too long and asks whether a shorter one would have sufficed. This, of course, is a very difficult problem which recurs from time to time. It was felt that on the basis of the float experiments, interpreting the results as well as one can, 10 000 ft was the right length, and nothing has transpired since to suggest otherwise. A quarter of a mile shorter would certainly have been cheaper, but not proportionately so. On the other hand, although the worst conditions found during the tests might be exceeded on other occasions in the future, it was felt that 10 000 ft in the case of Hastings was long enough.

266. A contractor who tenders for underwater pipelines has the opportunity of studying most outfall schemes currently being constructed. Although the contractor may not be aware of all the background information influencing the design of each outfall, there is such enormous variation in length, depth of burial, material of construction, etc., that there must be widely differing views on what makes a satisfactory scheme. In the description of the contract at Eastbourne, Mr Terrett places emphasis on the need for large capacity plant on dredging a trench. Certainly there can be considerable advantages in completing a dredging operation in short time by using a large dredger, but there are other considerations as mentioned by Mr Mattin. Also a large dredger is a very expensive item of equipment to risk on a relatively small dredging contract such as dredging a trench for a long sea outfall.

267. Mr Terrett has requested some information about siltation in the Hastings trench. During the period when the winch had broken down the rate of siltation was known from regular echo sounding surveys and diving inspection. The inshore section of trench affected by wave action soon filled in and buried the pipe in many places. Also the deeper sections through sandy material filled in very quickly. Elsewhere siltation was more gradual but was made worse by the effects of rough seas. Although the trench filling in caused difficulties, the rate of siltation, unlike the similar situation referred to at Eastbourne, never exceeded the capacity of the plant on site.

268. With the difficulties of keeping a trench open in mind the policy suggested by Mr Harris of dredging a trench which is left to fill in has in some circumstances been adopted. The pipe is pulled (much later if necessary) into what remains of the trench, and is then lowered to the correct level by suction dredging. A proving trench of narrow width, however, would not suffice in hard material and may miss boulders in soft.

269. Mr Harris asks about the dilution to be expected. It was found that floats released at various points inshore of the 10 000 ft mark tended to gain the shore, with some floats approaching the recreational waters within 4 h of being released. Floats released at 10 000 ft, however, had much less tendency to move shoreward and those that did so took 6 h or more to enter the recreational waters and 8–9 h to reach the shore itself. Calculations suggest that dilution at the shore line should not be less than about 1500 times, even under the least favourable conditions, and that the coliform count would then be about 1000/100 ml.

270. It is agreed that fine screens and high speed disintegrators will produce a greater degree of maceration of sewage than comminutors, but with comminutors alone the installation is simpler and cheaper and it was felt that the degree of treatment imparted was sufficient. No complaints have been received, and **Mr Landsell** and **Mr Broadhead** may be interested to know that there are no sea gulls giving away

the position of the outfall, and no signs of any surface slick nor of any contamination of the foreshore.

271. Mr Broadhead also mentions some of the alternative methods available for hydrographic work, such as the use of dyes, radioactive tracers or cultures of bacteria, instead of or as well as float testing. Much valuable work on the use of these other methods has been carried out by the Water Pollution Research Laboratory and also by others both in Britain and abroad. It is to be hoped that the development of the more refined techniques to make them simple of application and reliable in interpretation will be vigorously pursued, so that a rapid and dependable method of assessing the dilutions obtainable and hence the length required of outfalls will be forthcoming before long.

272. Meanwhile, however, the use of these methods usually requires the mounting of a not inconsiderable exercise, requiring additional organization, time and money. The effects of changes in the weather are more disrupting than is the case with floats and if, in the present state of knowledge, it is not possible to be certain even that the discharge from an existing outfall is being correctly demonstrated, the chances of completely predicting the behaviour of a hypothetical outfall are even lower. It now appears, for instance, that *Serratia indica* do not necessarily have die-off characteristics similar to coliform bacteria after all. For the time being it is felt that floats continue to represent the simplest, most economical and most straightforward way of predicting the movement of sewage discharged into the sea. The float tests must, of course, be fully comprehensive, covering all states of the tidal cycle and periods when adverse winds are blowing.

273. Mr Broadhead asks how a similar problem would be viewed today, and it is considered that reliance would still be placed on a comprehensive series of float tests, but that these could usefully be supplemented by occasional use of Rhodamine B.

274. Mr Pettifer has recalled occasions when the tide flaps on the Combe Haven stream were jammed open and were therefore unable to protect the works against the ensuing high tide. It would seem that this malfunctioning must have been due to constructional debris, because no incidents of a similar kind have been reported since the works were completed. Concerning the build-up of beach material at the end of the twin outfalls of the Combe Haven stream, the degree to which this occurs is still fluctuating. Although the profile of the beach has not yet settled into a steady state, the removal of the old Bo-Peep outfall (and the discharge from it) has greatly enhanced the appearance of the beach, to which its increased popularity testifies.

275. In reply to **Mr Banks,** the stresses in the steel pipe were considered from two aspects, the maximum pulling load and the stresses arising from pipeline curvature. The least radius of curvature which the pipe was ever called upon to negotiate was during the launching on its passage from the fabrication area into the sea. Once clear of the foreshore, curvature was virtually non-existent. On the other hand the greatest pulling load occurred at the seaward end of the pipe when the major part of the pipe had already been launched.

276. Sulphate resisting cement was used for both the mortar lining and the external concrete protection.

277. The inspection of the diffusers in operation did not extend to measurements of variation in the rate of discharge, neither, to reply to **Mr Williams,** were there any signs of barnacle growth.

278. Among the points raised by Mr Taylor and Mr Williams one which has not already been dealt with refers to the comparison between the tender figure quoted of £480 000 and the figure contained in the Final Account. It is felt that in this respect many people will be interested to know that, in spite of all the difficulties encountered, these resulted in virtually no extra payment being made to the Contractor.

279. Assuming the information supplied to the contractor at tender stage is accurate and not misleading, then the likelihood of claims is no greater than for any other form of construction. If the contractor takes the weather risk and allows for

dredging in any material the major variables are covered. Apart from fabricating the pipe and diffusers, the construction work is of a temporary nature and becomes the responsibility of the contractor, subject to the engineer's approval.

280. This does not mean to say the Contractor was happy with the final cost. Indeed, on work of this nature, if the contract has been won in competitive tender and a major problem occurs which is the contractor's own responsibility, money is almost sure to be lost. Although the tender price contained a built-in risk element, a mishap which would extend the contract period from one to nearly two years was obviously not considered.

281. The figure finally agreed was £485 000. In reply to Mr Landsell's point on this matter, the Contract was of the conventional type and no form of target agreement was employed. Most contractors would be naturally interested in 'target' forms of contract. From the employer's point of view the idea is worth serious consideration, especially when a particularly difficult outfall is to be constructed and the risk element is high.

282. Mr Pilcher refers to liquidated damages and to the question of Clause 12 claims arising out of the trench excavation encountering material harder than expected. The Contract did include the normal liquidated damages clause, but this was not applied.

283. The suggestion from Mr Shilston that the employer should bear the weather risk can be discussed here. Although there appear to be considerable savings to be made if the employer takes the weather risk, in practice the arrangement can lead to difficulties. If the 'down time' allowed for proves to be wrong because the weather during the contract is unusually bad or the method of construction requires calmer sea conditions than expected, disputes tend to occur between contractor and employer, which will be aggravated if, in the employer's opinion, the contract is prolonged because of the contractor's own shortcomings. As contractors gain more experience in the construction of long sea outfalls they become more able to make accurate allowances for the effects of weather and this will be reflected in the prices of competitive tenders. If an employer were to take the risk of dredging when information about the sea bed was inadequate, then a potential saving is more likely.

284. As stated by Mr Landsell screw pumps do have their advantages but it is doubtful if their installation in the Combe Haven Pumping Station would have been a practicable proposition. It is confirmed that the operation of the pumping station is such that when the inflow reaches 12 dwf the whole of the flow is discharged to the beach via the storm water culvert where it mixes with the flow from the Combe Haven stream. It is felt that with dilution of this order and in weather so unattractive as to promote flows of this size, there is nothing to be gained by pumping a proportion of the flow two miles out to sea.

285. **Mr Neill** raised the philosophical point of the contribution of the Hastings scheme to international thinking on the question of pollution on the global scale, a matter which is of course of the greatest importance and concern to everybody, but which was purposely omitted from the Paper since the scope of the subject of pollution is sufficient for a paper in itself, and indeed complete symposia are devoted to it. Clearly the protection of the environment from misuse is paramount, and the indiscriminate disposal of noxious, toxic, or otherwise objectionable matter by dumping on land, in the sea or in the air is to be deplored and prevented. However, the discharge of macerated domestic sewage into the English Channel in the manner described in the Paper (which was intended to cover only the design and construction of the outfall) is in no way detrimental. This is not to maintain that it is sufficient to base approval of a course of action merely on the premise that it does no harm, and the pros and cons of any sea outfall proposal must be carefully weighed. Suffice it to say in the present context that at Hastings the balance of advantage lay clearly with the long sea outfall.

286. **Mr Fyffe** is mistaken in thinking that the hydrographic survey was carried out

using floats of the drogue type only. Spars 5 ft and 10 ft in length were employed, weighted so as to float completely submerged in the vertical position, and on each occasion that these were released 9 × 9 in. flat boards were released at the same time so as to obtain information on the movement of the actual surface of the sea as well as of the surface layers.

287. Mr Williams's paper on the Gisborne, New Zealand, submarine sewer outfall has been read with great interest. Mr Williams asked about faith in the float tests and it is felt that these tests were sufficiently numerous and comprehensive in their coverage of state of the tide, wind directions and sea conditions to give a fair indication of the movements of the sea and hence of any sewage discharged into it.

288. Direct and bending stresses in the walls of the pipe have been referred to previously although Mr Williams takes the point a stage further by referring to the fate of steel pipes from which much concrete surround has surreptitiously spalled off. One of the Authors has actually witnessed this phenomenon (not on any of the schemes for which he is responsible !), and a very sobering sight it is. In the case of Hastings the radius of curvature to which the pipe could be curved was limited to 4000 ft, and this was sufficient to restrict the stresses in the steel and the concrete to acceptable limits. Certainly no concrete spalled off the Hastings pipe in the region at the head of the beach where the curvature was greatest, and there is therefore no reason to suppose that any spalling has occurred elsewhere where there is virtually no curvature at all.

289. Mr Williams is under a slight misapprehension in considering that the Hastings pipe was designed for an immersed weight of 90 lb/lin. ft. The design resulted in an immersed weight of 90 lb/ft and the requirement to reduce this to about 20 lb/ft dictated the type and spacing of additional buoyancy to be provided by the buoyancy bags. No tests have been carried out at Hastings on the numbers of bacteria or other organisms present in the sea either before or after the discharge of sewage. The die off rate of *B. coli* seems to be held to vary between 20 min and several hours, depending upon temperature, daylight and several other factors. A die-off of 90% in 3–4 h seems to be a generally accepted average rate and this was used in this case in arriving at a calculated coliform count of about 1000/100 ml at the shore under the least favourable conditions.

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