Estuarine pollution control: objectives and priorities

K. D. STAPLES

Mr Staples

The use of predictive modelling techniques, referred to rather briefly, requires further explanation. The relationship with the selection of priorities is best illustrated by a number of examples in which the modelling results cited principally relate to dissolved oxygen levels. Although this is not the only parameter modelled it is the one most easily interpreted.

58. The improvement in conditions in the River Thames is well known, but recent monitoring shows that 'success' is associated with a mean summer dissolved oxygen sag level to under 25% saturation in the third quarter of the year. It is understood that drought conditions in 1976 have led to flow being pumped back from the tidal river rather than the normal fresh water river flow over Teddington Weir, effectively achieving reuse of sewage effluent from the estuary. Contrary to first expectation, these conditions were associated with maintained and even improved conditions in the river quality, largely, it is suggested, because the events coincided with the commissioning of additional sewage treatment facilities. Prediction modelling by the University of Newcastle of dissolved oxygen levels suggests that for the River Tyne further treatment of the larger downstream discharge from Howdon may have advantage over extended treatment upstream, a reversal of the normal expectation expressed in the Paper. Nevertheless, the first priority of reducing gross visible pollutants properly overrides consideration of dissolved oxygen in implementing the Tyneside scheme, and demonstrates the need to balance objectives in according priorities.

59. Similarly, the Mersey modelling by the Water Research Centre showed that long-term objectives can only be fully realized by adopting a high degree of treatment for effluents from the upstream catchment embracing the Manchester conurbation. Again, however, real and apparent progress in the lower estuary is more dependent on the interception and partial treatment of crude waste discharges from the lower estuary development.

The Chairman (Professor A. L. L. Baker)

I would be glad if Mr Staples could say a little more about the table of costs. The costs of Mersey, Tyneside, Teesside, etc. vary from £28 to £53, presumably per head of population in the area. Compared with average rates, this is not very high as long as it happens only once. Would it not be considerably reduced if industrialists—who seem to be putting most of their waste into the rivers—were made to stop? After all, it is a public river, and does not belong to them. They are simply using it as a means of disposing of noxious waste material.

61. Engineers can not in my view be satisfied with the situation until rivers are so

civilized that, for example, on Westminster Bridge one would see nets hanging over the water just as they do in Stockholm, with fish being caught regularly. After all, that is the natural original condition. It is difficult now to press for anti-pollution treatment, which is expensive, but I think that ultimately this sort of standard should be the aim.

Mr W. B. Norgrove, Northumbrian Water Authority

Since the implementation of the Public Health Act of 1875 it has been incumbent on every town to provide an adequate sewerage system. It is with regret that four of the five estuaries referred to in the Paper—and which, unfortunately, are all situated north of Potters Bar—are still directly receiving crude sewage and industrial pollutants from their respective catchment areas.

63. Mr Staples has clearly indicated the complexities not only of the estuary regime but of the polluting elements and their points of contribution. He has also advocated that the first objective should be the elimination of visual offence and freedom from odour, with which I fully concur.

64. Referring to §§ 21 and 22, dealing with mathematical modelling, it would seem to me that the simplest modelling techniques, compatible with providing a credible answer should be adopted and therefore such techniques should always be the least complicated. A mathematical model is merely a device for representing the physical characteristics of the estuary, and the accuracy and reliability of its predictions can be no better than the available data from the estuary.

65. There are few absolute values in the assessment of pollution, and a final decision on a course of action is often made on subjective grounds. The widespread development along the banks of these estuaries during the 19th and early part of the 20th centuries has produced in planning terms fully developed land use areas. Therefore there is a minimum of flexibility in the layout and siting of any new sewerage and sewage treatment facility.

66. Mr Staples may care to comment on the cost/benefit of attempting to develop a two-dimensional model, bearing in mind that his Paper refers principally to heavily polluted and fully developed estuaries which, in the first instance, require the establishment of a basic sewerage and sewage treatment system. How sensitive does one need to be in establishing the equation between the pollutant input and dilution and transportation?

67. Turning now to priorities of environmental capital works schemes, where so often vociferous pressure groups dictate policy, there may be something to be learned from the development of the Tyneside sewerage scheme, where 20 public authorities got together to overcome a major environmental problem.

68. Management of the water cycle has not, up to now, been analysed in a cost/benefit sense on a national scale in the UK. There is obviously a need for some form of standardization of the measurement of appropriate values so that expenditure patterns can be compared on an equivalent basis. In this connection the assessment of other values outside the limits of the water cycle will, of course, have to be taken into account. It is also food for thought that over the next few decades the use and reuse of water will become more important, and in this context the flexibility of the Tyneside sewerage scheme, for instance, could provide, if need be, reusable water at the ultimate stage of development of some 1.3 million m³/day. Perhaps Mr Staples would be prepared to indicate some possible parameters that could be used in the development of such a cost benefit study.

69. On § 43, I would suggest that it is not necessarily appropriate for staged implementation of such major engineering works to start in the upper part of the estuary. The staged development of the Rivers Tyne and Wear, for instance, has, for various reasons, begun in the lower part of the estuary and it would seem that the Mersey, if and when this scheme gets under way, would follow a similar pattern.

70. Referring to § 47, would it be possible to develop some form of modelling technique which might indicate in a cost/benefit sense the degree of flexibility and effectiveness of shorter length sea outfalls compared with the somewhat higher degree of treatment which under such circumstances would be required on shore?

Mr H. R. Oakley, J. D. and D. M. Watson

There is little doubt that the deplorable conditions of some of Britain's estuaries is an outstanding blot on the pollution landscape, and Mr Staples' Paper is a valuable statement of the problems and method of approach in tackling the engineering tasks.

72. The Paper properly draws attention to the main objective of avoiding excessive dissolved oxygen depletion, but it should not be overlooked that the ultimate ideal is the establishment and maintenance of a near natural condition with a balanced ecology. This has been emphasized by the identification in a recent WRC publication⁹ of at least 20 research projects concerned primarily with the relationship between the ecology and the pollution of estuaries.

73. Consequently, it is necessary to give consideration to many other factors including particulate matter, nutrients, surfactants, toxins and temperature. This significantly complicates mathematical and physical models, and although attempts have been made to model biological conditions, the accuracy of such predictions is in some doubt. Thus, although models are a valuable (and perhaps invaluable) tool in the design of estuarine pollution protection schemes, they are not a complete answer to all questions of prediction, and the collection of data and the need to prove their performance makes them expensive. Consequently, there is much to be said for designing schemes which can be progressively implemented, so that with proper monitoring after each stage, the beneficial effect can be assessed before further expenditure is incurred.

74. The allocation of sites for treatment works in suitable locations on highly developed and industrialized estuaries, where the worst problems are met, is a major difficulty and led to the proposal in the Mersey investigation⁵ of siting the works on an artificial island in the estuary. Consequently, some re-ordering of the priorities set out in the Paper seem desirable; perhaps the logical progression is:

- (a) examine the present situation and development proposals, and define pollution control objectives;
- (b) identify and secure treatment works sites and interceptor sewer routes;
- (c) construct interceptor sewers and control industrial waste discharges;
- (d) construct and develop treatment works.

This emphasizes the importance of drawing up a master plan and securing sites and routes so that work can be implemented as and when resources can be diverted to this end. The work that has already been carried out to establish master plans for the Tees and Mersey will be wasted if agreed sewer routes and works sites are not protected from other development, and the already difficult problem compounded in the future, as it has been in the past.

75. It is not difficult to understand that in the present economic circumstances little significant progress can be made in cleaning up the major industrial estuaries. Industry has developed in these locations for obvious reasons, and the cost of treating industrial wastes to an adequate standard will clearly bring into question the competitiveness of the product in overseas markets. But where, as on the Tees, the industrial pollution load is greater in quantity and more difficult in character than that from municipal wastes, it is essential that industrial waste control precedes or runs parallel to the construction of works to treat and dispose of domestic sewage. It seems unlikely that the present expenditure in treating municipal wastes on the upper part of the Tees estuary¹⁰ will have beneficial results until effective measures are agreed and implemented to deal with the massive industrial waste load in the lower part of the estuary.

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Mr M. J. Kenn, Imperial College, London

I understand that at Beckton a large capital investment has been made in order to discharge a very high quality effluent into the Thames, at an average flow which is equivalent to almost half that of London's water supply.

77. Would there perhaps be a case for spending relatively a little more money and, in times of severe drought, pumping the water back to Chingford Reservoirs for recycling? Alternatively, would there be merit in pumping the effluent upstream to just below Teddington Weir in order to replace the statutory flow there, or is this statutory flow not now needed any more?

Mr M. Mallowney, Water Research Centre

Mr Norgrove mentioned that models should be as simple as possible for design purposes. I would agree with that on the whole, but another point is that in order to make suggestions about how to remedy a system, it is necessary to understand the system. This is done by comparing predictions with observation, and it may be that simple models will not work. Therefore, more complicated models have to be used.

79. Models are usually based on well-established principles of conservation of mass, volume and momentum. The estuary is subdivided into small volume elements. The changes occurring are calculated at time steps by solving the conservation equations for the elements. There are usually a number of known parameters, such as diffusion coefficients, which are worked out by fitting the observed salinities to those predicted. For dissolved oxygen it is necessary simultaneously to calculate the distributions of effective carbonaceous oxygen demand (COD) and the ammoniacal nitrogen and oxidized nitrogen. The rates of uptake of COD are fairly well established experimentally, and the only unknown parameter is the reaeration coefficient. This value can be used in comparing predictions with the observations.

Fig. 6. Comparison of salinity variations during average tidal cycle in Thames estuary, obtained from mathematical model and hydraulic model

Fig. 7. Half-tide distributions of dissolved oxygen and ammoniacal and oxidized nitrogen in four quarters of 1969. Figures are average freshwater flow at Teddington Weir. Exchange coefficient $1.3 \text{ m}^2/\text{day}$

80. Figure 6 shows the salinity variations in the Thames estuary during a time cycle at various points. This demonstrates that it is possible to get a set of diffusion coefficients which will fit the curves. Fig. 7 shows a comparison with dissolved oxygen, ammoniacal nitrogen and oxidized nitrogen during the four quarters of 1969 in the Thames estuary. Comparisons are fairly good, using a simple one-dimensional model.

Mr J. G. Lloyd, North West Water Authority

The North West Water Authority is very interested indeed in the matter of estuarial pollution, and is therefore grateful for the Paper.

82. There is a great deal in the Paper with which I agree, and which I applaud, but one statement I cannot allow to pass without comment because it is not wholly true. I refer to § 48 on national and regional priorities, where the Author says: 'but in the absence of grants from central government responsibility rests with the local regional authority and national priorities have little significance'. It is true, of course, that within their constraints the matter of priorities is one for the regional water authorities, but the constraints laid upon them are very real. One of these is the capital investment ceiling, which is directly related to the national economic processes (PESC). Therefore, anything that the regional water authority does within its ceiling for priority fixing, particularly when it comes to a large expenditure, must of necessity be related to national priorities. Indeed, the fixing of the ceiling for all or any particular authority has to be related to the government's priorities. This demands an understanding of the government's attitude towards investment in, for example, estuarial pollution reduction.

83. It has been said, quite rightly, that the regional water authorities have to cut their coats according to their cloth. But they are in the business of doing that even when

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times are very much better than at present. Therefore it is not just a matter of looking forward to the future when there may be unlimited money to spend on the control of estuarial pollution or, indeed, anything else. The same processes will be expected to operate at all times.

84. Mr Staples referred to public attitudes to floating solids but this is by no means the limit of the public's interests. Public attitudes are influenced by the water charges that flow from any investment programme of a water authority and they are also interested in the way a water authority allocates its priorities internally once the ceiling has been fixed.

85. Recently one of the metropolitan local authorities adjacent to the Mersey Estuary, incensed about the state of the estuary, sought to drum up help from other local authorities in the region to try to get the regional water authority to give higher priority to the task of cleaning it up. They approached about a dozen local authorities, but almost all told them that the water authority had more urgent things to spend money on. Local public pressures are not just to clean up estuaries but to see that money is wisely spent. That is one of the practical effects of working within a capital investment ceiling in a region.

86. My authority has a number of other estuaries to consider besides the Mersey. From a practical point of view some of these, notably the Lune, have more urgent requirements for capital investment than the Mersey, not least because the effects of investment there would show a quicker and more direct benefit to other sectors, including public water supply, fisheries and amenity.

87. It was suggested earlier that the water authority had not been active in following up the work of the Steering Committee on Pollution of the Mersey Estuary. It is true that no sites for treatment works have been purchased, but what or whether new sites are needed has been the subject of a great deal of planning effort. Much has been, and is being done behind the scenes, and it is hoped that this will result in the most effective use of such capital as becomes available from time to time for the purpose.

Mr A. D. Maskell, Howard Humphreys

Would the Author comment on the effect of stormwater flows on estuary pollution and the extent to which sewage treatment works on estuaries should incorporate storm tanks. In the Tyneside situation have the sewers been sized for 3, 4 or 6 times dry weather flows, or are they designed in accordance with the recommendations of the final report of the Technical Committee on Storm Overflows and the Disposal of Storm Sewage, thereby reducing sewer sizes and hence their cost?

89. Taking note of the salinity distributions shown in Fig. 3 of the Paper and also in Fig. 6, would the Author care to comment further on the relationship between the oxygen sag curves and salinity levels?

Mr R. L. Gouge, North West Water Authority

There have been one or two allusions, both in the Paper and the discussion to the condition of the Mersey Estuary, which is part of the North West Water Authority's 'inheritance'. If there were a book *1974 and All That*, one would have hoped that the inheritance of the water authorities would be classed as a 'good thing', but so often the inheritance has to be referred to as a 'bad thing'. Unfortunately, certain aspects of the Mersey Estuary fall into that category.

91. Mr Staples said that the work which his firm had done in the past related to the lower estuary. When the water authority started to think about this, it was in a much better position to consider the estuary as a whole and to think about the upstream catchment in addition. This is what the North West authority has been doing during the past two years or so. The water authority has taken over the mathematical model, refined it and applied it to planning the improvement of discharges to the whole of the estuary.

92. What has come out of that work so far is that the initial supposition that treatment of the discharges to the upper estuary was the key to improving the dissolved

oxygen levels there is not the whole of the story. In fact, the key may well prove to lie in the inflows to the estuary from the contributing streams, particularly the River Mersey, and from the Manchester Ship Canal. Nevertheless, there are still a number of puzzles.

93. The summer of 1976 has had one considerable advantage in that it has been a great aid to the validation of the model with low flows obtaining in the Mersey Estuary. Although Mr Mollowney has indicated quite good validation against the 1972 conditions, the conditions obtaining in 1976 are not yet fully understood. In particular, the ammonia and nitrates position, as shown by the model, differs from the actual situation which occurred. This is another justification for caution.

94. With regard to Table 1, I think that the figures which Mr Staples has given for the Mersey really refer only to the lower estuary. The pollution load stated there as 163 000 kg/day is too low. The figure of 297 000 kg/day is used at the moment for the whole estuary. Also, there is something dubious about the minimum fresh water flow of 167 000 m³/day. There are quite a large number of sewage effluent discharges in the catchment, which maintain the low flow, and a figure of 900 000 m³/day is used in the model for the low flow over Howley Weir. The figure of 40 km is given for the anaerobic length under worst annual conditions. One could reach conditions of that sort, according to our modelling, but only at a certain stage of the tide. In fact, during a tidal cycle, the length of the zone which has below 10% of dissolved oxygen, though not necessarily anaerobic, varies between about 25 km and 40 km in the very worst conditions.

95. In § 17 Mr Staples refers to objectives related to the removal of solids, which could be floating solids or deposits on beaches and foreshores, and to dissolved oxygen levels. In the case of the Mersey Estuary, where the water authority has itself adopted similar minimum objectives, the questions which arise are not only what are the most cost effective measures in relation to improved dissolved oxygen levels, but also what is the relative priority between the removal of solids and the improvement of dissolved oxygen levels?

96. When thinking about maintaining dissolved oxygen levels, the water authority's predecessors and the authority itself have adopted an objective that stipulates that a satisfactory level of dissolved oxygen shall be present at all times, which has been interpreted as 10%. But as time goes by and more modelling is done, the emphasis on 'at all times' may create a difficulty. In water supply one thinks of reliability or frequency of occurrence, and it may be that one should be trying to adopt a parallel approach with this sort of objective. 'At all times' is open to different interpretations. I should be interested to have Mr Staples' comments on this.

Mr A. W. Shilston, Consulting Engineer

I should like to make two points arising from the discussion on the Paper.

98. Searching for a further hard reason why finance might be allocated towards the mitigation of estuarine pollution, I recollect that about 16 years ago litigation was started in the High Court in London regarding the contended ill-effects of the anaerobic conditions of the Thames on the hull of a Thames vessel. I believe that the hearing never reached the stage of a judgment so that we do not have the benefit of a piece of case history. It is interesting to speculate on what contributory influence, if any, the onset of those proceedings might have had on the provision of the considerable financial resources deployed on the improvement of the biological condition of the Thames.

99. My second point carries on from what the Chairman said of the duty of the civil engineer to advocate the need for clean rivers. Some time ago the Institution made a formal statement about the wider responsibilities of the chartered civil engineer in the exercise of his professional role which could be linked both with Professor Baker's and my own related comments.

100. The chartered civil engineer in his professional advisory or consultative role

undoubtedly has a duty, as part of his 'social contract' (using that now well-known expression in its more apt context) with the lay public, to pay appropriate regard to the impact on the environment and the amenities of the proposals made or advice given in the performance of his professional function. *A fortiori*, the chartered civil engineer engaged in the field of water pollution control and the protection of river-derived raw water, the source of an ultimate potable water supply, has a particular responsibility in this respect having regard to his duty to advocate the general cause of the need for improvement in standards of public health and hygiene.

101. The responsibilities assumed by the professional civil engineer under the social contract in this particular area are sophisticated. Within the presumed framework of the discussion set by the content of the Paper, the complex nature of the social responsibility ingredient of the civil engineer's duty is illustrated, inferentially, by the observation of Mr Lloyd earlier, when he said, *inter alia*, that the professional officers of the regional water authorities had to operate in the real world of today and see that money was wisely spent on public health engineering measures right through the whole of the river system, of which the estuary forms only a part.

Mr Staples

In response to **Professor Baker's** questions, it should be noted that the figures referred to in Table 2 show the per capita costs varying between £28 and £54 for an 'equivalent population', which means with an allowance for the polluting load from industry. The same table demonstrates that for the actual population estimated costs vary from £51 to £76, and in fact under current legislation industrialists are required to pay charges based on the quantity and, in some cases, the polluting load discharged to a river or estuary. I do not agree with the Professor's view that industrialists should cease to pollute, since the proper controlled use of UK waters allows the community at large to benefit, and industry is part of the community.

103. The reference to fishing in Stockholm recalls reports that in the last century there were a series of strikes by apprentices on the Tyne, who complained that they were being fed too frequently on salmon from the river. We in Britain may look forward to a better supply of salmon in our major estuaries, but hopefully not such a supply as will encourage more strikes.

104. **Mr Norgrove** questioned the need for more complex techniques in modelling, and the cost/benefit to be associated with developing two-dimensional models. Obviously the simplest appropriate model should be adopted, but in some estuaries where there is pronounced stratification it is clearly appropriate to undertake two-dimensional modelling in order to assess some of the effects of pollution. Major costs of modelling are involved in obtaining river water and pollutant samples, analyses and collating basic data for the preparation of the model. Although sophisticated computer models are expensive to produce, generally the fieldwork accounts for more than half the cost and virtually the same fieldwork is necessary for a simple or a more complicated model. In any event the cost of modelling is small in comparison with the cost of the engineering works involved.

105. The whole question of assessing priorities for estuarine pollution control, and establishing cost/benefit study parameters is very difficult, principally because the major measurable benefits are probably related to the freehold values of land and the rateable value of properties bordering and fronting on an estuary; this, of course, is also affected by many other factors including demand.

106. The reuse of water was obviously topical in 1976 because of the drought, but in the circumstances of most UK estuaries it appears to me that the most likely method of reuse for the foreseeable future will be indirect. Possibly this might be by following the example of the Thames in reducing or terminating the flow of fresh water to the estuary from the upper river in periods of shortage, thereby allowing the whole up-river flow to be utilized and the necessary flushing of the lower estuary to be effected by discharge of the appropriately treated sewage and industrial wastes.

107. Mr Norgrove has also separately questioned the form of modelling techniques which might indicate cost/benefits associated with varying lengths of sea outfalls, as compared with higher degrees of treatment on land. Here there are so many subjective rather than objective criteria that the circumstances of each particular case must be examined in detail, and there is then little room for any formal standardized technique associated with cost/benefit studies.

108. **Mr Oakley**'s remarks about the factors to be modelled are relevant, but perhaps dissolved oxygen is modelled not only because it may be the most easily understood, but also perhaps because it is a factor of most importance in achieving the first priorities of pollution control.

109. On the question of priorities, the Paper suggests that the control of toxic or difficult wastes might be tackled first, principally because the necessary legislation is available and such control is essential regardless of the type of scheme adopted. In the present difficult economic climate, although the burden to industry must be carefully assessed it may be possible in many instances to make some progress in this area at modest expense. The need to identify and secure treatment works sites is obviously vital, and usually a key feature in establishing the engineering alternatives within a master plan.

110. **Mr Kenn** referred to the possibility that Thames estuary effluent might be pumped back for recycling and such schemes have been under consideration for some time. The drought conditions of 1976 have, as I explained resulted in the pumping back of effluent to just upstream of Teddington Weir, and no doubt when all the factors and experience of that year are fully assessed such a practice might be further developed by the Thames Water Authority.

111. The comments of **Mr Lloyd** clearly reflect the real dilemmas of water authorities in establishing priorities: There is some misunderstanding regarding §48 and the influence of national priorities on regional responsibilities. At present national government controls the overall capital expenditure of the individual water authorities and thereby limits the options, and it was my suggestion that in view of the very high cost of estuary pollution control it might be appropriate for central government to assist or adjust allocation of resources between authorities in order to permit progress to be made on perhaps one estuary at a time. The present alternative, given the economic situation, implies that it will be impossible to make significant progress with estuary pollution control for a very long time and for the Mersey it is doubtful that anyone could now suggest a date by which the first objectives could be achieved.

112. Replying to **Mr Maskell**, storm water discharges have only a small polluting effect in terms of overall dissolved oxygen etc., and although on Tyneside sewers have been sized to accept a multiple of 3.5 times dry weather flow, there is a case to be made for adopting the recommendations of the Technical Committee on Storm Overflows with the reduced dilution factor.

113. The relationship between salinity levels and oxygen sag curves for the estuaries discussed are not direct, but obviously where the high salinity reflects incoming sea water it is often associated with raised dissolved oxygen levels.

114. **Mr Gouge** has outlined some of the ongoing work of the North West Water Authority on the Mersey estuary, and the differences in figures quoted highlight the problems of obtaining and validating data for input to a model, though it appears that the overall situation and conclusions remain good. The difficulty in the case of the Mersey seems to be a possible overemphasis on raising dissolved oxygen levels by upstream treatment, whereas a reduction in gross pollution and the attainment of initial dissolved oxygen objectives rest on achieving some reduction in the gross pollution from the lower estuary.

115. The choice of the satisfactory level of dissolved oxygen to avoid nuisance which has generally been established as 10%, is, of course, arbitrary, as is the criterion that dissolved oxygen be present 'at all times'. It is evident that in sampling and monitoring it is considerably easier to assess river water conditions on average rather

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than worst conditions, since the tidal regime is changing continuously. Nevertheless, with the limitations imposed by present methods of modelling and monitoring, a dissolved oxygen criteria of 10% at all times appears to be valid, particularly since the economies likely to result from modest relaxations are unlikely to be significant.

116. Mr Shilston's comment regarding the financial implications of the ill effects of anaerobic conditions on shipping is interesting, but perhaps it should be borne in mind that there is an obverse, in that with cleaner estuaries some of the major power stations could suffer problems with the fouling of cooling water intakes due to the growth of marine organisms, and this phenomenon, although controllable, might also arise with certain ships.

117. All engineers are properly concerned with our social responsibilities, but the Institution's guidance is particularly related to the impact of an engineering project on the environment, whereas estuarine pollution control is, of course, associated with works specifically designed to improve the environment. As has been indicated, the search is much more concerned with obtaining a satisfactory solution while minimizing cost. Indeed, as the discussion has shown, unless the results can be achieved at a modest cost and the correct priorities accorded, projects for estuarial pollution control will not proceed and the environmental improvements will not be achieved.

References

9. GOULD D. J. *Ecological effects of sewage discharges to the sea: an assessment of needs*. TR 26. Water Research Centre, Stevenage, July 1976.
10. PORTER E. *Pollution in four industrialized estuaries*. HMSO, London, 1973, p. 26.

Errata

Table 1, columns 3-5: the following figures should be substituted

	Freshwater flows, 1 000 m ³ /day		
	Minimum	Average	Maximum
Tyne	275	4 000	90 000
Tees	180	2 000	36 000
Wear	115	1 350	30 000
Mersey	900	—	—

§ 15: Mileage of polluted estuaries refers only to heavily populated estuaries associated with 7 of the 30 river authority areas covered by the Department of the Environment Report.