Regional water resources analysis

B. RYDZ

Mr Rydz:

When the Water Resources Board was brought into being about seven years ago it was instructed in effect to secure a proper use of water resources. This phrase was not defined, but there is a good deal in the 1963 Act to indicate what a proper use of water resources is all about. There are several references to the transfer of water between river authorities if this should prove to be opportune, and there are references to the maintenance of minimum acceptable flows so as to respect the in situ needs of rivers and river users, having regard to natural beauty in what we do and how we affect our surroundings. There are the licensing and charging provisions, which seem to be designed to bring to bear on each user the net impact of his use on the water resources system, and which seem to suggest that economy in the widest sense is one of the purposes of the whole operation. We are instructed to pursue research into those matters where we can do things better with the aid of more study. On things of this sort we have built up a philosophy of what the Act is about and what we have been put there to do.

61. The particular piece of work which the Paper deals with might be regarded in a way as the centrepiece of what the Board is doing. It is an attempt at a fairly comprehensive appraisal of all the resources and all the demands in England and Wales, probably on a rather wider basis than could have been attempted before. This is intended to lead to advice to the Government on the shape of water strategy, and particularly storage strategy, which is the most troublesome and controversial problem that the powers-that-be have to deal with in this field.

62. We have so far set out the options as we see them, and hope at the end of 1972 to make recommendations on forward strategy.

63. The work described is not mine; it is the work of many of my colleagues in the planning divisions. This particular piece of analysis is not an all-purpose tool. It is something designed for a particular purpose. What we had to ask ourselves was whether it was possible to give worthwhile advice on the shape of water strategy—that is to say, on the structure of decisions as to where water should be stored, how it should be moved around, and the sequence in which developments should take place—in ignorance of many of the detailed matters that would go into the development and operation of that strategy.

64. To do this we had to make working assumptions about many things on which the timing of developments, amongst other things, will depend—population and demand growth, resource evaluation and reliability, management practices, unit costs, discount rates—and to buttress these assumptions with sensitivity tests. But all these are secondary—they are not the ends but the means of the exercise.

Mr J. G. Lloyd, Mersey and Weaver River Authority

I am glad that Mr Rydz has recorded current thinking about regional and national planning, which has been based so much on the work of bodies like the Northern Technical Working Party. The Working Party gave a set of alternative plans priced in such a way as to reveal clearly the extra costs of applying the political and social

constraints to the technical process of planning. This enables the public or their representatives to make a choice when the time comes knowing the implications on price.

66. I would like to refer to Mr Rydz's points on demand. He is right in drawing attention to the varying kinds of demand. The distinctions are fundamental. In § 12 there is reference to the offsetting of new demands by effluents resulting from increased public supplies. This is extremely important when it comes to the question of re-use of water especially the planned re-use of water in river systems.

67. I feel that Mr Rydz's suggestion that considerations of that kind can reduce problems to a matter of management as distinct from problems of providing new resources is an undue simplification, at least in respect of riparian abstractions, notably for industry. If indeed we are looking forward to planned water re-use in river systems, the problems will include not just water management problems but problems of Town and Country Planning and commercial planning. Substantial savings in capital expenditure and public disturbance on regional public water supply schemes of the type described by Mr Rydz could be achieved if only those difficult problems of planning could be solved, but they are extremely difficult.

68. Still on the matter of demand, Mr Rydz has referred to 'pseudo-consumptive demands of public water supply'. I like the term. Regional planning of water schemes gives new opportunities for some effective thought to be given to that. The general air of indecision and doubt that today surrounds population movements following proposals for new towns or city overflows, etc. or the location of new water-using industrial establishments, leads to too many and too large safety factors being introduced into computations or forecasts of demand, especially when those forecasts are related to the areas of particular statutory undertakings. This could bring the whole business of planning of water supplies into disrepute. Regional planning calls for a new and much more rational method of regional forecasting of demand, not just adding up all the individual local forecasts within the region and making a grand total. An approach of this kind calls for greater flexibility in matters of bulk distribution, with all that this implies in administrative and financial fields, but is indispensable, especially where the regional planning process itself incorporates as an essential feature the discounting of future estimated expenditures to a fixed date in order to try to get plans correct today. It seems to me that one should be equally careful about what demands will be in the immediate future.

69. If regional water planning is indeed needed, as suggested in § 6, this implies that a regional plan will in fact be produced; however much this plan may be open to modifications and extensions as events force planners to change their minds as the years pass. If there be a plan, it must be an accepted plan—indeed, an authorised plan, which supersedes free choice by the many authorities which will have to take part not only in the preparation of the plan but in its implementation. Mr Rydz has drawn attention to this but our statutory provisions for promotion of waterworks—that is, the elemental parts of the plan—are still the responsibility of autonomous authorities. This poses the question, who will authorise the plan and enforce its acceptance by the autonomous authorities?

70. Mr Rydz has rightly drawn attention to the seemingly insuperable difficulties of applying cost-benefit techniques to water supply planning to compare alternative plans on a proper basis. Yet he indicates—and I agree with him—the need for thinking along those lines. For example, in § 4 he shows the need in regard to the value of the water produced, and in § 46 in regard to the unquantifiable non-water benefits. However, he should have added a reference to the unquantifiable costs of disturbances to the community and the environment; it is those costs which tend to be ignored in the planners' sums and which are the very things that the vociferous opponents of water schemes, notably reservoirs, get most emotionally and understandably upset about. The successful introduction and implementation of regional water planning of the kind envisaged in the Paper will depend in no small measure

on the finding of acceptable solutions to the difficult problems wrapped up in these matters of valuation of almost unvaluable things.

71. Mr Rydz has perhaps given a clue to his own thinking in § 4 and later. He suggests that water is too cheap. Is it too cheap to be taken seriously? Is it too cheap to be a matter that needs planning carefully? Mr Rydz has gone so far as to talk about equalizing costs over areas. Is he perhaps suggesting that one should go further and artificially increase the cost of water, possibly by some sort of national levy on unpopular types of source, such as reservoirs, which would have the effect of altering the comparisons between the alternative choices?

Mr E. G. Reed, Metropolitan Water Board

The Paper brought out the great value and importance of regional planning for water resources. Without doubt we need to look at the problems of water resources and water as a whole on a regional if not a national basis. I think that Mr Rydz referred to the powers-that-be. I hope that they will in the near future come down firmly for this type of organization, which will serve the best interests of the consumers to the end of the century. Indeed, as I think Mr Rydz suggests, the problems of developing inter-regional links without this form of organization will be extremely difficult. From where I sit, I can well see the truth of that.

73. Fig. 4 shows a possible future development of resources based primarily on estuarial storage. Bulk supplies would be transferred to various river authority areas via national delivery routes to provide extra water for abstractors. There are, of course, other possible methods of development which have been put forward from time to time. These rely to some extent on inland reservoirs. In my view these proposals place less reliance on a few major projects, like the estuarial barrages, and provide far more flexibility.

74. There are several problems in transmitting water over long distances. In my Board's experience we find that if we keep what is not particularly good water—Thames or Lee water—in a tunnel or a main for a relatively short period it de-oxygenates very quickly: the aqueduct becomes full of water which contains a considerable quantity of hydrogen sulphide, and this can prove very distasteful to the consumer.

75. Another problem associated with the development of estuarial basins is that of quality, arising from multiple use. With excessive re-use, there is a build-up of all sorts of dissolved solids such as nitrates in the water, which are not removed by the conventional water supply treatments. With increased demands for water, barrages in estuaries may be filled with water which contains increasing quantities of sewage effluent that have already made one voyage down the river. There may well be a place in the system for estuarial barrages, but inland storage securing a higher quality of water in the first instance will, I am sure, also be needed.

76. At a recent conference on river basin management, where there were a number of overseas visitors, the Americans, almost to the man, were complaining about the surfeit of planning that was going on in the USA, to the exclusion of almost any progress in real terms. We must hope that we shall not be faced with that danger.

77. The previous speaker referred to demand forecasting and the difficulties that arise through over-guessing. This is clearly a problem, particularly in the smaller authorities. I have had experience with a really big development, Thamesmead, which has probably got something like 20 000 houses. This might be expected to produce a really serious demand impact on the authority, but in fact this construction will not change our long-term demand trend, because it is pretty obvious that a major number of the people will be from within the area, and there is therefore a considerable advantage from size. Although there are about three very big housing developments going on in the MWB area, the overall demand is staying fairly closely to the trend line that we have had for many years. Obviously, with a smaller authority, a big development could cause considerable trouble.

78. From time to time there are suggestions that desalination would solve all our problems. They could be solved but at a cost far in excess of that applicable to other suggested resources schemes. If desalination were the economic best buy, the water industry would be getting its water that way already. Nevertheless, in long-term planning we should not lose sight of the possibility that improved and more efficient methods may become available.

79. Turning to the situation as it affects London, the resources are made up of the combination of surface water storage and wells. Abstraction is from the rivers Thames and Lee, and in the case of the latter the level of re-use is approaching the order of 1:1 in certain circumstances. It is becoming increasingly necessary to determine the extent to which the dry weather flow should be derived from effluent return and what percentage dilution is adequate for water supply purposes. An advantage from London's point of view is that having used the water abstracted from the rivers it is discharged for ever into the tidal section, thereby disposing of its polluted load.

80. In the past water companies supplying London were expressly prohibited from abstracting water from the tidal reaches of the Thames, but if a change is now appearing involving collection and storage on the mouth of an estuary, whereby theoretically the stored water can be returned and in effect subjected to multiple re-use, then it is essential to decide how far this process can go.

Professor P. Wolf, City University

I think we are all convinced that planning of the kind which the Board is undertaking and which has been described by Mr Rydz is absolutely vital. The questions are, 'Is it time to arrive at the kind of conclusions which have been described? Have things been rushed too much? Is there enough knowledge for first conclusions to be drawn on which certain major investments and other decisions are to be based? Is this very broad and approximate treatment which Mr Rydz has outlined justified?'

82. I believe that the broad pattern is in fact a very blurring kind of treatment. It takes little account of the variability of the resource. If the amount of resource and its variability are blurred by drawing broad contours over the area, then I suggest that the excessive margin of safety suggested by Mr Lloyd may be only an apparent safeguard. Mr Lloyd talked about excessive margins of safety because the demands of a number of people have been taken into account in various places. This may well be true, but against this there may be insufficient margin of safety—in other words, too broad a band of ignorance at this stage.

83. The answer clearly would have been to start this work before 1965. Could we not learn our lesson now, and, using the Paper as the starting point, go into a very thorough study of what will be required for 1984, 1991 or 2001, and study the national resources more carefully?

84. Could I ask is Mr Rydz being too simple, too superficial at this stage? Can he do better? I believe there must be a way of coming to grips with the question of sensitivity as well as feasibility. I question whether it is correct to write off certain quite broad demand areas, for example. He has mentioned the 'need for more refined hydrology', 'the neglect of consumptive use here and there', 'the question of industrial demand being either included or not included'. Are his assumptions too sweeping at this stage? Do we really have to make them?

85. The solid strategy question has been touched on both by Mr Rydz and by Mr Reed. The transfer problem is a national one, and Mr Rydz is right in saying that the regional approach is just a convenient first step. The national approach ultimately must emerge from the analyses. Cannot this be stated boldly at this stage and be agreed? I feel even less knowledgeable on the question of national machinery than on the other matters. This is probably a matter that exercises the Board very

much. Could we hear a little about that? It seems to me that the machinery must be interlinked with the scientific and engineering aspects—feasibility in another sense.

Mr D. L. Walker, Electricity Council

My initial training and experience were in the field of water resources. For the last seven years I have worked on the economic side of the electricity supply industry, but I should make it clear that I am not speaking as their representative.

87. I should like to make three points based on my experience in the water and the electricity industries and also on my interest in what the Author may regard as the dismal science of economics.

88. First, I am afraid I disagree with Mr Reed's comments on § 4, which seemed to me to be slightly lacking in rigour. The real point is not whether consumers value an unrestricted supply at more than its marginal cost but whether they value additional supplies water at more than their marginal cost. The paradox in both the electricity and the water industries is that consumers make it very clear to us when their supply is interrupted that they value it very highly indeed, but that does not stop those same consumers reducing their consumption of electricity if the price is increased, and I suggest that the same may be true of water. The real issue is whether the present value of the net social costs of manufacturing, installing and reading water meters exceeds or is less than the cost of providing and disposing of the water which would otherwise be required.

89. It is by no means obvious that in some parts of England, and in some circumstances such as new housing, where it would be relatively cheap to install water meters, water metering is wrong. Is the Board now prepared to examine this question seriously? If it does not, I suggest it will be in trouble with the environmental lobby, because that lobby will.

90. In § 43 there is a very proper emphasis on discounting costs and benefits in the future. But the subsequent sensitivity analysis does not go quite far enough. As well as the risks mentioned in the Paper, the big schemes are very vulnerable to changes in the rate of growth of demand, because such changes will affect the optimal sequence of schemes, and in the case of water supply future forecasts are vulnerable to changes in the economic growth rate, changes in population expansion and perhaps changes in pricing policy. There are other problems, particularly biological problems. There are a number of uncertainties which can crop up which may not matter very much in one small scheme but matter very much when it comes to a big scheme.

91. When engineers are working at the frontiers of technology, design problems come up and schemes are delayed, and these problems lead to increased costs. Economic analysis is not very good at dealing with risk and uncertainty, so it reduces to the simple point that it is dangerous to put too many eggs in one basket.

92. My third point is that in § 57 the situation is postulated in which there is a national or regional plan which is said to be of overall benefit, and yet there are some potential participants who remain unwilling. It follows from some fairly simple analysis that there must be a cost related to the marginal cost of including the extra undertaking in the scheme, which will make it attractive for them to participate. If they are still unwilling, it means that someone is doing his sums wrong, and the best solution is to thrash out the mistakes in the assumptions, instead of attempting to impose a solution on the local undertaking. It is very tempting for those of us who are employed by centralized agencies to think that we know a bit more than the chap in the field. It seems that in Britain people do respond more easily to responsibility than to instructions, and the prospect for which one hopes is that of strong regional authorities buying and selling water freely from each other under the very expert guidance which we can rely on from the Board.

93. Mr Rydz has mentioned mathematical optimization programmes. The cost coefficients which emerge from these programmes are very little different from market prices which would come about if a market solution for water could be obtained. A

market solution is expected for other necessities of life, such as bread. The prospect for which one hopes is that the same solution can be obtained for water.

94. Like one or two of the previous speakers, I suspect that water is under-priced. The opportunity cost of many existing reservoirs is far above the cost at which they appear in the books. This is one of the reasons why the Board has such difficulty in obtaining flexibility in the use of resources. It is to be hoped that in the future the Board will not overlook the local schemes, the local initiatives to produce more water or use a bit less, and will not be too much attracted by the very big schemes which may be more popular but are also exposed to the inevitable uncertainty of the future.

Mr M. J. Featherstone, Wye River Authority

The following remarks arise mainly from my experience with the work of the Wales and Midlands Study over the last three years. The views are not necessarily those of the Wye River Authority.

96. The first point concerns flexibility. A resource giving flexibility in that it can be used to regulate three main rivers may be more expensive than several smaller sources restricted to each river. Engineering judgment may favour the more flexible solution whereas the self-optimizing computer programme will earmark the cheaper solution. Sensitivity tests are mentioned in the Paper but may well not highlight the more flexible solution. Is it possible to put a price on flexibility?

97. The second point concerns relative price changes. Significant relative price changes could alter the ranking of various solutions. For example if the price of pipelines rises faster than the price for tunnels, then the ranking of various transfer routes might change. The cost of water transport accounts for a large proportion of total capital expenditure. Is there any indication at present of likely significant relative price changes? Are there any technological changes on the horizon that might affect the solution of inter-regional links, pipes of new material or low cost tunnelling?

98. There are two points regarding the assessment of yields. The straight line approach is a useful tool. However there are certain situations where it is wise to be aware of its limitations. In regulating two rivers to a relatively low level of regulation actual yields can be considerably greater than in regulating one river to a high level.

99. The straight approach gives the same yield for a particular amount of storage and supporting catchment wherever the abstraction point is on the river system. A paper¹ to the annual conference of River Authorities in 1970 stated 'with a uniform catchment and a given storage the rate of maintainable increments at any two points on the river system is roughly equal to the square root of the ratio of the average natural flows at the two points . . . the theoretical approach gives a reasonable indication of the order of advantage in maintainable flow to be gained by regulating a river to an abstraction point near its mouth, and determination of maintainable flows by detailed analysis in specific cases supports this . . .'. This point has some bearing on abstractions from the River Wye. Fig. 5 shows an enlargement of Fig. 4 for the lower portion of the River Wye. The average daily flow for the River Wye at abstraction point (1) is approximately 1150 m.g.d. The average daily flow in the lower reaches is approximately 1400 m.g.d. The difference of 250 m.g.d. is nearly half the average daily flow of the River Usk. The yield of a given amount of storage based on the above argument would be greater for an abstraction in the lower reaches. This point is considered relevant as there is a route to the River Thames from the lower reaches of the River Wye which is not unattractive. The route has been marked as a full line on Fig. 5. Fig. 6 gives further details of the route. The route is 33 to 39 miles long depending on the discharge point selected; 5 miles of tunnel are required. After an initial pumping lift over the first two miles of 600 ft, water would gravitate to the discharge point.

100. The final point concerns demand shedding. As the level of river regulation increases the critical period for most reservoirs will be three seasons, 18 months maximum depletions occurring in the second summer. An agreed predetermined

Fig. 5

Fig. 6

system of demand shedding working on a six month advance warning might be possible to cover a design 18 months critical period should the drought occur on full demand. This would enable higher yields to be obtained from the storage. As an illustration, electrical generating capacity is low during the summer months and it might be possible with advance warning to switch to a power station with a lower net use of water.

Mr W. J. F. Ray, Metropolitan Water Board

With reference to §§ 19–21 the maintenance of a residual flow of 170 m.g.d. at Teddington Weir has been a requirement since the 1920s, and has had to be taken into account by the MWB in the planning of new resources to meet demand. In the past the MWB has pursued a programme of progressive construction of a number of storage reservoirs in the Thames and Lee Valleys, culminating in the Datchet and Wraysbury reservoir scheme.

102. The Wraysbury reservoir has recently been completed, and on completion of the Datchet reservoir the residual flow at Teddington would in effect be maintained with a reliability of about 98%, if it were not for other increasing demands on the river which are anticipated in the future. Accordingly, in order to meet all demands, more resources are undoubtedly required.

103. The Author has outlined the purposes for which a residual flow may be required. In the lower Thames it is questionable whether the flow of 170 m.g.d. at Teddington contributes very much to the maintenance of the outfall channel. It may be thought that the average flow of over 1000 m.g.d. and the much larger flood flows are the major factors in maintaining the estuary channel.

104. The residual flow dilutes polluting estuary discharges, such as sewage works effluents. Since the sum of the discharges of the sewage works at Mogden, Beckton and Crossness are in excess of about 400 m.g.d., the amount of dilution provided by a flow of 170 m.g.d. at Teddington is not very great.

105. The pollution of the tidal Thames has been studied by a committee under the chairmanship of Professor A. J. S. Pippard² and the effects of pollution have been studied by the Department of Scientific and Industrial Research.³ The investigations showed that with flows of less than 500 m.g.d. at Teddington it is the polluting load of sewage effluents which controls the condition of the river. The improvement in quality of the effluents from the various sewage works has resulted in an improvement in the tidal Thames in recent years.

106. The intakes of the Thames Valley works of the Metropolitan Water Board are situated upstream of Teddington Weir. The Mogden sewage works, located downstream of Teddington, discharges into the river below the weir. Despite the high quality of the effluent from the Mogden works, a polluting load is nevertheless imposed on the river.

107. I would like to know if it would be possible by providing a high level of tertiary treatment of Mogden effluent and higher grade treatment of the other sewage effluents discharging into the lower Thames, to effectively transform these effluents into non-polluting discharges such that, by recirculation or otherwise, the flow in the Thames below the MWB intakes could be virtually all reclaimed effluent; a greater proportion of the natural dry weather flow, including the present 170 m.g.d. reservation, might thereby be available for abstraction for water supply purposes in drought periods.

Mr R. G. Sharp, Water Resources Board

The fundamentals of a regional or national water resource development strategy are, I suggest, an amalgam of

- (a) technical feasibility to meet quantity and quality requirements wherever and whenever arising;
- (b) economic justification;
- (c) general acceptability, by the water industry, by enlightened public opinion, and by no means least, by the Government who should then back their acceptance by appropriate support of the promotion of the favoured programme.

109. Technical feasibility alone gives a very large number of alternative possibilities, some of which can be eliminated on a *prima facie* examination for the other two conditions. Economic justification narrows the field considerably, especially with the aid of mathematical modelling. The use of this technique is being developed and applied considerably in the National Resource Study. General acceptability is the real eliminator and by far the biggest uncertainty. The most practical approach, and the one which Mr Lloyd said he favoured in the Northern Report, is to examine feasible solutions for different strategies and compare the costs for the various levels of constraint and types of sources.

Alternative Regulation and Abstraction Conditions : R. Severn

Co-ordinated Use of Storage and Transfers : R. Thames

Figs 7 (top) and 8 (bottom).

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110. There may well be a considerable number of common ingredients for programmes in meeting these three basic requirements:

- (a) a relatively small number of large sources, always provided that they are favourably situated for water conservation and conveyance to centres of demand (the number should not be so small as to risk having too many eggs in one basket);
- (b) abstractions from the lower reaches of rivers preferably as near the tidal limit as possible (this has an advantage as it both increases yield from the larger catchment and also allows the river to benefit from the water being left in it for most of its course);
- (c) river-to-river transfers and links to allow the limited number of sources to be used to the greatest advantage and to enable rivers to be used for conveying water, for ultimate abstraction, from areas of surplus to areas of high demand and scarcity of resources.

I wish to comment further on the last two of these factors.

Abstraction conditions

111. Comparison of Figs 2 and 3 help to bring out the point I wish to make. There is clearly much scope for influencing the abstractable yield in relation to a given storage according to the rules set for determining the 'takeaway' yield in relation to the quantity left in the river or for augmenting residual flows. Once a comparison is made on a common basis it is important that this is right because much is at stake, especially on the larger rivers. Fig. 7 shows three alternative rules for the Severn at Gloucester for 15 months (October 1948–December 1949).

Condition 1 implies the need for substantially supplementing what nature provides in dry periods below the abstraction point;

Condition 2 implies that lowest flows can occur below the abstraction point for much longer than they would naturally;

Condition 3 is a possible half way house which, whilst protecting the lowest flows from depletion, would enable nearly 100 m.g.d. to be taken for supply with the same storage.

112. It is just as important not to overdo the amount of storage required as it is to ensure that the in situ interests of the river are properly safeguarded.

River-to-river transfers

113. These would figure extensively in any major strategic resources development programme whatever the eventual choice of sources because:

- (a) they enable the small number of large sources to be used to the maximum advantage both hydrologically and for conveyance to abstraction points near demand centres remote from the source without the need for *continuous* transmission by pipeline;
- (b) they provide for flexibility in source/demand allocation by providing a partly natural interlinking of sources and demands of advantage both in implementation and for efficient operation.

114. Fig. 8 illustrates what might be involved if water were transferred from the Severn to Thames to give an extra 180 m.g.d. net yield without increasing indigenous Thames storage, but using the existing storage in conjunction with the transfers. The assumption is that one would use existing storage first by over-drawing until 25% of storage had been withdrawn before transfer is begun. This allows time to gauge magnitude of drought and avoid needless transfers.

115. Transfers could be introduced at a gradually increasing rate of up to say 50% in excess of extra yield required. It would be necessary to have the potential to transfer at an excess rate to compensate for the overdrawing of storage initially before the augmentation starts. The transfer could be continued after the end of the critical

period if there were an advantage in doing so to speed refill. On this basis for the five years shown (1946–1950), when average six month summer flows in the Thames were only 86% of long average, the quantity transferred would be about 11.5% of the continuous yield it would support.

116. This suggests that even with the high degree of development implied (45% of ADF) transfer load factors of the order of 10% are about right if they can be used in this conjunctive and controlled manner.

Mr A. E. Drew, Middle Lee Regional Drainage Scheme

I would like to take issue with Mr Rydz on the question of reclamation of water and planned re-use of sewage effluents. The Paper suggests that the Water Resources Board still considers that sewage effluents are second-quality resources.

118. Mr Rydz has also said that in the Thames the dilution may already have reached its limit. I understand that at present at the lowest point of abstraction from the Thames, which supplies 70% of London's water supply, the average annual dilution of fresh water to sewage effluent is 8½:1. On the Lee, which has a very small catchment area, 2 000 000 population and a river length of 57 miles, and from which the Metropolitan Water Board takes 20% of its supply, the average annual dilution is only 3.5:1. These are average annual dilutions and not peaks or minima.

119. Finally I understand from the Metropolitan Water Board that the Lee water has, for some years, consistently been of a better quality than that of the Thames. So I would ask Mr Rydz to consider what has been done, what is being done and what must be done for the future.

Mr F. Law, Chief Engineer, Fylde Water Board

The first point of note upon which I would like to cross swords with Mr Rydz is the question of demand assessment (§§ 9–14). This is a very fair representation of the situation as found in the Northern Study, namely, that water conservation works are only required by the statutory water undertakings. It is doubtful however whether the Proudman Committee or the drafters of the 1963 Water Resources Act had the same picture in mind, particularly relating to the charging schemes of the river authorities and the execution of major works. Does Mr Rydz think that the pendulum will swing back again? The Proudman Committee and the 1963 Act put the job of doing conservation work onto the river authorities. In view of the findings of the Northern Working Party being that the works are required for the statutory water undertakers, will the water undertakers now be told to carry out these works, and at their own expense, and not come on the charging scheme?

121. Looking back, there seems to be no doubt that the regional investigations have made Section 14 surveys redundant. The regional surveys have covered the same ground but with a wider field. Other things in the 1963 Act that have gone by the board are minimum acceptable flows. We never hear anything about those nowadays.

122. I thoroughly agree with Mr Rydz's remarks (§§ 57–59) concerning water prices and the promotion of schemes. These matters are now coming to the forefront as the schemes being developed go ahead, albeit somewhat haltingly.

123. The most important point is possibly in § 59, where Mr Rydz suggests that the ideal to aim at in the promotion of schemes is that all participants act just as they would if they were part of one large unit. With this object in view the Central Advisory Water Committee recommended the setting up of regional water authorities, although they jibbed at specifying how large the regions should be. It would seem that as the studies develop and the date for a decision about strategies draws near, the only sensible size for the unit is the whole of England and Wales. Mr Rydz should have changed his title from 'regional' to 'countrywide' water resources analysis. The really large schemes which are being talked about in the North are needed really not for the North of England but for export to the Midlands and still

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further into the South East, or to permit water from the Midlands to go into the South East.

124. Water resources must be planned nationally and not just regionally. We may not like central dictation, but central planning is the only way which will make sense with these major transfers of water.

125. One thing which I think went wrong on the technical side in the Northern Study is highlighted by Fig. 2, the yield storage diagram. In §§ 28 and 29 Mr Rydz describes how because of the deficiencies of flow data for individual rivers, ruthless simplifications were made. The common curve which he has shown was a very good idea, but it must be clearly understood that to make it a common curve the origin must represent a minimum flow of some unspecified probability.

126. It is easy to have hindsight, but I feel it is a pity that the straight line was adopted as a simplification. That line represents, as Mr Rydz sets out in § 35, a storage yield relationship of 172 days. This, in conjunction with first year releases reckoned as 85% of the total storage, gives a uniform gross storage figure of 200 days' supply. It would have been far better to carry out the analysis of the resources in two stages—first expressing the river basin yields in progressive increments of, say 5000 million gallons storage, assuming the abstraction to be at the tidal limit, and then to list the storages which were practicable in ascending order of price per unit of storage provided.

127. As mentioned by Mr Rydz in § 36, the difference between the yield storage curve and the straight line was expressed in the report as a tidal barrier bonus, but the correct apportionment of that bonus was not set out. On a river like the Lune in North Lancashire, with an average flow of 700 m.g.d., the yields obtained with successive 5000 million gallon increments of storage would have been 75, 45, 38, 32 and 27 m.g.d. That compares with the straight line relationship of 25 m.g.d. for each increment. In other words, the first is three times as much as the straight line shows. The total bonus is 92 m.g.d., but in the report you will find the bonus is only 55 m.g.d. Where the 37 m.g.d. has got lost, I do not know.

128. For direct supply reservoirs the turning point on the yield storage graph represents something like 600 days' supply. In other words, when at the critical time for depletion of a reservoir is 18 to 20 months, increments of storage are only giving daily increments of yield of 1/600 of that storage.

129. If the figures in the report had been presented in the form I suggest, more accent would have been placed in the Northern report on the change of use of part of each of the big direct supply reservoirs, and a lot of the grandiose schemes could have been deferred until, possibly, 1990 instead of 1981.

130. I hope that it is not too late for Mr Rydz to look back at the Northern Technical Working Party report and see what could have been done with those storages with change of use of large reservoirs in the North of England, rather than building fresh ones.

131. Mr Walker has raised the question of metering water. We have been been metering 500 consumers for the past two years and from 1 October, 1971, we have put them on a new basis. If they use less water than is represented by the rateable value payment, they will get a rebate, and we hope in another two years' time to have a good picture of whether it makes any difference whether they pay by measure or by rateable value. We may then perhaps come up with some good suggestions.

Mr R. O. Meek

Several references are made in the Paper to sewage effluents: §§ 12–14 show that their re-use in various ways forms a consideration in the present and future sources of water supply. Again in § 21 it is stated that 'the recovery of effluents from sea outfalls for industrial supply, perhaps at some time for more general use, might also make a major contribution to resources.'

133. The report of the Working Party on Sewage Disposal (The Jeger Report)

makes much adverse comment on the present position as regards the discharge of sewage to the sea or to estuaries or tidal rivers. For instance it is stated that, in reference to sewage disposal to the sea, 70 parishes replied to a questionnaire saying that there was already pollution of their beaches and that nearly 200 have been listed about which the public had complained on this score in the last ten years.

134. Again in § 187 of the Jeger Report it is stated that 'on the Welsh Coast of the Severn Estuary there are 90 outfalls discharging sewage or trade waste from 1.1 million people'. This represents a total discharge of some 0.38 million m³/day (dry weather flow). The report also states that of the 90 discharges only seven are fully treated and only nine are partially treated.

135. The discharge of untreated sewage to the sea in such quantities as are quoted raises the question of how much sewage can be so discharged in such a locality as the Welsh Coast of the Severn Estuary without detriment to the amenities, however carefully the matter of any particular discharge has been studied in the design stage.

136. Considering the broader front of the whole coastline of England and Wales it appears that the remark in the Paper that the recovery of effluents from sea outfalls might make a major contribution to resources is fully justified. According to the Jeger Report it would also make a valuable contribution to the coastal amenities. The only question is the financial balance of the value of the water recovered and the improvement of amenities against the capital cost of the recovery and the capitalized running costs of the necessary treatment works. In fact there are already instances up and down Britain where sewage effluents are treated and are re-used for various purposes.

Mr P. G. O'Neill, Water Resources Board

I would like to add a few comments to what the Author has written on the problem of reliability in water supply systems.

138. There is no general agreement on whether the return period of failure should be 50 or 100 years, and indeed the available hydrology data are seldom adequate to discriminate between these two levels of security with any degree of confidence. Further, there is no accepted view as to whether reliability should be defined so that a 100 year return period means 'failure to meet demand without restriction one year in 100' or '100 year mean recurrence interval between failure events', since in a system with substantial pumped storage a failure event typically extends over more than one year. There is an added complication in that complete failure is virtually unknown and unacceptable, so the criterion becomes that of the need to introduce some abnormal degree of restriction on consumption, for which a recurrence interval of the order of 20 years might well be acceptable.

139. The use of artificial design hydrographs has a number of familiar shortcomings, one of which is the difficulty of defining a duration for the critical drought sequence. The observed pattern of failure events will show lengths varying between one and perhaps five years, so no single critical duration of droughts will in general lead to identity between return periods of failure event and of drought event, especially in the case of the conjunctive use of sources differing in character.

140. These problems, added to that mentioned by the Author of the need to take account of the severity of failures, are leading to the recognition that the yields of complex resource systems can only be studied adequately by simulating operation over a period of several hundred years. This requires the use of synthetic hydrology reproducing the main statistical properties of the historic record, with the added advantage of using the full information content of the recorded hydrological sequence. The output of such models includes a distribution of frequency and severity of failures, which can guide the selection of rules for introduction of rationing as well as for optimal system management. Models of this type are used by the Board.

141. A knowledge of consumers' demand curves, applied jointly with this knowledge of failure events and of the cost implications of varying the standard of relia-

bility, would enable us to determine the optimal level of reliability to maximize net social benefit to consumers; and Mr Law's metering experiments in the Fylde will add to the meagre data already available for this purpose. Mr Walker may be assured that the Water Resources Board is aware of the importance of the use of the price mechanism, although it has no statutory responsibility for pricing policy. Although net social benefit is the customary basis for public sector pricing theory, there are inevitably complications. Present rating methods induce considerable income redistribution, and a change in policy would cause loss to some members of society. Consumers may prefer stability or gradual rises in rates, although an allocative optimum might involve sharp fluctuations by raising price to a 'rationing' level before major new investment. The determination of an optimal level of security is further bedevilled by the difficulty of imposing an equitable rationing procedure when supplies are threatened by drought, since the application of exhortation, local orders, disconnection or pressure reduction will affect users unevenly. Raising the price at the start of what seemed likely to be a critical season would be effective, but difficult in an area where most consumption was unmetered; universal metering could facilitate both this approach and that of seasonal variations in charges. Pricing policies departing from an average-cost philosophy—that revenue and expenditure should balance, at least in the long run—would raise problems in either the distribution of surplus revenue or the basis of subsidy.

142. It is fairly safe to say both that there are areas of Britain where the relationship between the costs of metering and of new supplies render domestic metering unattractive, and that there are others where the converse is true. It is likely that the absence of domestic pricing leads to some investment being undertaken at a cost greater than the value of the water to consumers; where this excess is greater than the cost of metering, the latter may be preferable to new resource development.

143. Finally, it is recognized by those in the water industry that the major problem in deciding public policy in this sphere is that of land use. Water consumers are also consumers of food, recreation and amenity, and governments are likely therefore to require that existing resources are so managed as to produce the maximum yield attainable at reasonable cost, before they will willingly approve the construction of major new surface reservoirs.

Mr Rydz

I explained in my introductory remarks that the work described here was an attempt to sketch out a water conservation strategy with a broad brush, leaving many relevant problems unexplored. I hope in the course of this reply to touch on several of these which are being investigated in depth, particularly by our technology divisions, and thus to set this Paper in the broader context of the Board's work. I have been selective, omitting a number of points made by contributors in which I concur.

145. Mr Lloyd referred to the somewhat tenuous connexion between strategic plans of the kind evolved by the Water Resources Board and the promotion of works in the field, and I can only endorse his comments. The Board has no procedure for giving these framework plans any formal status, except insofar as they may be reflected in the Section 14 surveys of river authorities. If planning of this kind is to be taken seriously it must be brought to the attention of the public and become the subject of debate before individual projects come up for authorization. Can a two-stage procedure be evolved so that projects come up for final authorization and appropriation of funds with a history of debate behind them and with some presumption in their favour?

146. Referring to § 71, I have never said that water is too cheap. I have heard it said, but I am at a loss to understand how any commodity we need can be too cheap. I see no case for taxing water to raise revenue or to discourage its use. The suggestion that interference with landscape should be made more expensive raises wider issues of our balance of values, and the choice of strategy referred to in § 5 is an

attempt to reflect this balance. To set an artificial price level and select our sources to conform would be doing things the wrong way round.

147. **Mr Reed** mentions the operational problems of users, and particularly people who are getting very long distance supplies, maybe on an intermittent basis. This is an important point. There are considerable virtues in a degree of local storage, and this is something to take into account.

148. **Mr Reed** hoped that there will not be a surfeit of planning leading to no action. I only hope he is right, and do not know what grounds he has for his confidence.

149. **Mr Reed** referred to the important question of deciding how far water re-use for potable purposes can go. Study is being made of the possibilities of greater re-use—for instance on the Trent—but elsewhere one hears fears expressed that proposals for re-use may already have gone too far in relation to the ability to control river quality. There are pressures for the limitation of per capita water use which may in some cases exacerbate this problem. It must be accepted that delay is likely, at least for some time, between what can be proved in the laboratory and what will be accepted as sensible policy. Nevertheless reasonably consistent decisions must be made although the computer results will be far from simple. **Mr Drew** also calls attention to some of the complexities of this issue.

150. In § 81, **Professor Wolf** asks if planning is over hasty. Others, I imagine, may find the processes of planners tedious. Decision making and development must go on, although the pace varies. How soon can these processes be illuminated by some kind of coherent strategy, leaving much to be tidied up and refined later? Merely attempting to plan produces something of a hiatus in decision making and this must not be prolonged. I believe that the processes described here are a worthwhile beginning and offer some basic choices which are worth serious consideration. Every consideration to be as economical as possible has been suggested here and there, pending some major choices which must be taken by 1972-73.

151. The Board's advice on these choices will be given in national terms, as **Professor Wolf** suggests.

152. Any difference I have with **Mr Walker** on his point in § 88 is only one of semantics. By 'an unrestricted supply' I did not mean an uninterrupted supply but one free of any charge or restriction related to the amount used by the individual consumer. I suggest it is this freedom which consumers will consider worth buying at any cost they are likely to be asked to pay in the foreseeable future. The freedom is in a sense equivalent to the additional supply.

153. **Mr Law** referred to a further experiment in metering, although not in a very high price area. Although it would be interesting to see the results of carefully conducted experiments I do not think that it is for the Water Resources Board to urge these upon water undertakings in present circumstances.

154. I agree with **Mr Walker** that the range of our sensitivity tests to date has not been very great and these should be extended, in particular to include changes in the gradient of demand growth. In the northern study this was done indirectly for certain localities, as a result of a geographical switch of demand.

155. One of the broadest assumptions that had to be made—and I did not have time to refer to it in detail—was that the great mass of industrial use will be met by picking up sewage effluents arising from water provided for the public supply. We have allowed for about 100% growth of public water supply sources. For the amounts now licensed for abstraction for industrial use the corresponding allowance for growth in primary resources amounts to about 5%. Had it been dealt with on the same basis as the public supply about five times as much storage would be needed in the country by 2000 as there is now. Even so I think the advice on storage strategy was worth giving, but the enormity of some of these assumptions must be remembered.

156. Referring to § 90, biological problems of river transfers are being examined.

157. There are reservations about having too much storage in one place, although

there is little likelihood of the frontiers of technology hindering in this case. The cost of advantages of an interlinked system of large storage works have been understated by our conservative (implicit) assumptions about the coincidence of failure conditions in various areas and the necessary load factors on intermittent transfers.

158. I do not understand Mr Walker's third point in § 92. Collecting every party's marginal costs as the last participant does not suffice to pay for a project and is certainly not the approach usually adopted, even with a reluctant party.

159. Perhaps Mr Walker would permit me to amend one of his sentences in § 93 to, 'A market solution is expected for *some* other necessities of life, such as bread'. There are others for which such a solution is rarely, if ever, suggested.

160. The point mentioned by Mr Featherstone about putting a value on flexibility is interesting, and one to which some thought was given at an early stage of the attempts to model the choice of strategy. Flexibility, in the sense of the number of strategies or events to which a project will accommodate itself, has in practice been weighed at the post-model stage.

161. Relative price movements are an important facet of sensitivity testing, which have not been covered very well up to now. The cost of pipelines has risen surprisingly recently in comparison with earthworks and certain other items.

162. The straight line yield-storage relationship can be used only for choosing storage strategy, and then with care. Once a project is chosen its design and use require more realistic appraisal. The point is made at greater length by Mr Law. No one would deny that the straight line is a monstrosity. It was adopted as the only convenient means of presentation, bearing in mind that there were many opinions as to how gross maintained flow should be converted to permissible abstraction from a regulated river. Suggestions to enable the reader to slide his storage sequences around on a convex curve were reluctantly discharged.

163. With his point about the difficulty of regulating at higher flows perhaps Mr Featherstone was hinting that a growing allowance should have been made for regulation loss with increasing regulation, i.e. a point that is new to me, though perhaps not to some of my colleagues. Possibly this should be given consideration, because clearly under drought conditions one does get a persistence of low flows that will minimize the problems of effective and non-wasteful regulation.

164. Mr Featherstone also commented on the relationship between effective yield and abstraction point, and I think he was saying that where abstraction points are far apart, a common yield storage relationship should not be applied to both those places, even at this stage of analysis. This is a fair point and applies particularly where storage near the head of one river is to be used, by transfer, to regulate another. Perhaps the most convenient thing is to make effective releases a smaller percentage of gross storage.

165. I entirely agree with the point about demand shedding. This comes back to the point of knowing more about the reliabilities that people need and why they need them. If one can offer different users services of different reliabilities one can nest the lower reliability inside the higher, by making releases for the former in wetter years and thus getting a higher load factor on the storage.

166. Mr Ray emphasizes the need for a more methodical examination of residual flow needs in estuaries.

167. Mr Sharp referred to a number of possibilities of inter-river transfer and regulation, and I agree with most of his points. They are well worth considering. One particular point, that one might decide to over-use local storage to minimize the cost of transfer, is analogous with the point made in the Water Research Assoc. paper, TP 60⁴ about conjunctive use of desalination; that is to say, when the source of last resort has a heavy operating cost it is worthwhile installing some excess capacity at the source to lengthen the odds against using it. There is an important optimization possibility there.

168. Mr Sharp also referred to some of the load factors he has been evolving

recently. Up to now it has been necessary to work on assumed load factors for filling reservoirs and for transferring between rivers, often of about 25%. If it proves that the typical load factors might be 10% or less, then the apparent benefits of long-distance transfer would be more marked than they now appear.

169. Mr Law draws the conclusion from the work of the Northern Technical Working Party that water conservation works are required only by the statutory water undertakings. But although the necessary new primary sources can be closely related to these requirements much of the water has important second uses, as described earlier, and it seems right that the basis of management and payment should account for this. I believe we need organizations which can think in terms of the economics of the entire water cycle, clean and dirty. This calls for a new type of integrated authority.

170. On the value of central planning of water conservation strategy I agree with Mr Law. The pursuit of self-sufficient regions at this stage would be an anachronism.

171. The changed use of reservoirs will be a feature of our forthcoming Wales and Midlands report. In the North there were not equal opportunities, although the changed use of Thirlmere and Derwent and the enlargement of Haweswater were important suggestions.

172. The discrepancy of 37 m.g.d. referred to by Mr Law in § 127 arises because he has apparently obtained the tidal barrier yield increments by applying gross storage increments of 5000 mg to the maintained flow curve instead of applying net release increments to the lower tidal barrier abstraction curve. The 25 m.g.d. yield increments on the straight line correspond with net release increments of 5000 mg minus 15%. Moreover he has postulated a higher mean flow for the Lune (700 m.g.d. versus 655 m.g.d.) and a lower total of applied storage (25 000 mg versus 39 000 mg) than were used in the report. All these contribute to the discrepancy. Most of the apparent gain in yield by converting reservoirs for regulation to a Lune tidal barrier (and identified in the report as the Lune tidal barrier increment) is now likely to be realized through conjunctive use schemes with which Mr Law is concerned. A change in the presentation of these relationships would certainly not have led to any different pattern of recommendations at this stage, as Mr Law seems to infer!

173. In all, the regional studies have identified sufficient storage to sustain about 37 million m³/day of new primary yield—an amount exceeding to the present typical dry weather output of our water system, natural and artificial, and capable of bringing this regulated output to between a third and a half of the mean run-off of the country, which is the outer envelope of its fresh water resource.

174. About half these new storage opportunities have been listed in Water Resources Board reports for investigation and detailed comparison, and more than 75% of these investigations have now been completed or are under way. Of those listed for investigation, however, not much more than a half will be needed within the next 30 years, assuming that a very considerable extension of the superstructure of recirculatory or sequential riparian use can be based on this limited extension of primary output.

175. Thus there is a considerable array of choices, involving various degrees of inter-regional transfer and quite a range of new management problems and opportunities.

176. Among the problems being looked into are the re-assessment of storage–yield–reliability relationships, including the development of more meaningful indices of system adequacy or reliability, and the opportunities for more effective operation of regulating reservoirs in groups, of which the most important examples are in Wales. The management of regulating releases to meet a variety of needs has been the subject of a major joint study on the Dee. The uses of regulation releases to sustain abstractions and augment river flows, both above and below the abstraction point and in both critical and non-critical seasons, the optimum use of inter-river transfer capacity and on-line storage and the load factors on local and remote storage, raise a number of

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interesting problems, some of which were mentioned by Mr Sharp. The need for residual flows to estuaries and the possibilities of sea-water circulation in lieu can be regarded as part of the same package of problems.

177. The questions of river water re-use, the relationship of the re-use super-structure to primary resource augmentation and the general planning and management of sequential uses on industrial rivers pose a further set of problems for future management agencies exemplified, among current studies, by the joint Trent Economic Model exercise.

178. Reference has already been made to the problems of reconciling a theoretically optimum resource strategy with what is practicable and manageable at the retailing end of the water system, including both the physical problems of treatment and distribution and any limitations imposed by the pattern of organization.

179. Finally, I should mention the continuing problems of new types of source works—estuary schemes, desalination, aquifer management and recharge, effluent renovation and so on, about which there is still a great deal to learn.

180. I mention all these to emphasize that the use of the strategic conservation patterns described in the Paper must be envisaged against this evolving background of technology and methods of river management and that the momentum of these studies must be maintained if the most is to be made of the opportunities. The planning studies described enable some initial decisions to be taken with a broad awareness what the opportunities are—they are not a once-for-all operation.

181. In order to clarify one point, in § 14 it should have been made clear that only demands on the public water supply have been presented in the traditional additive form, and where a second use is probable, as on the Thames, the used water has been regarded as an additional source. In the case of re-use by riparian industry it has been found more convenient to delete the demand, thus avoiding the chore of estimating net demand over most of this speculative field.

Corrigenda

- p. 141, line 2, for: 'substantial overlap of water and non-water costs.'
read 'substantial overlap of non-water and water costs.'

In Fig. 4 the amounts are to a scale of 10^5 m³/day.

References

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