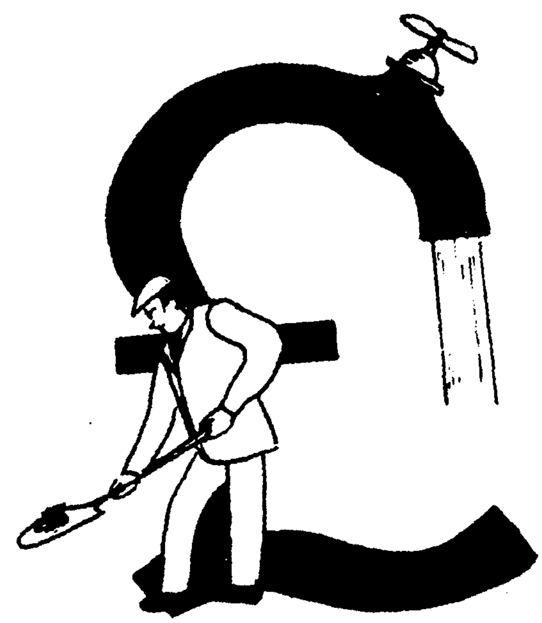
fifth public health engineering conference

held in the Department of Civil Engineering
Loughborough University of Technology
JANUARY 1972



ECONOMICS AND MANAGEMENT IN PUBLIC HEALTH ENGINEERING

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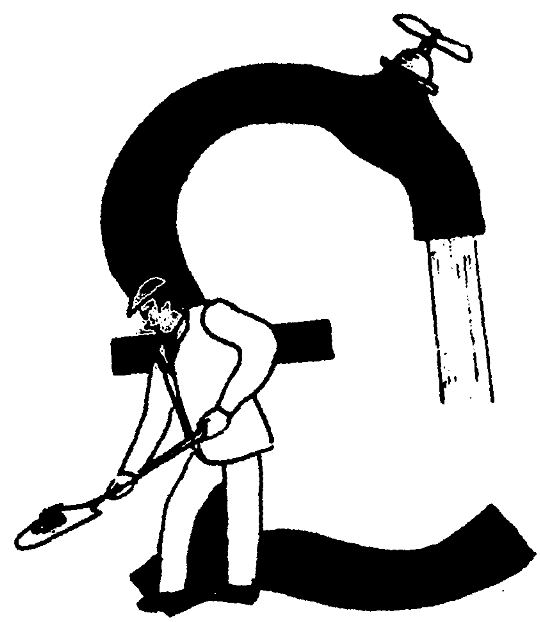

ECONOMICS AND MANAGEMENT IN PUBLIC HEALTH ENGINEERING

P R O C E E D I N G S
edited by John Pickford

contents

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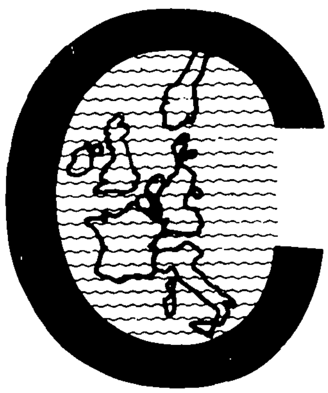
introduction

The Loughborough Public Health Engineering Conference now seems well-established as an annual event to which many engineers and others look forward. The fifth Conference followed the lines of those held previously, which dealt with the following topics:

1967 Surface water and storm sewage
1969 Tertiary sewage treatment and water reuse
1970 Industrial waste water
1971 Sludge treatment and disposal

In preparing these Proceedings I have greatly appreciated the advice of those who took part in the discussion, and the painstaking care of Mrs Pauline James, whose diligence has carried the work from tape recordings through several drafts to the final form in record time.

The 6th Conference will be held on the 8th and 9th January 1973 and will have as its theme BRITISH AND CONTINENTAL PROGRESS IN WATER POLLUTION CONTROL. There will be, as usual, four papers; two will be by British authors and two will come from Continental Europe.



JOHN PICKFORD
Department of Civil Engineering
University of Technology
LOUGHBOROUGH, Leics.

May 1972

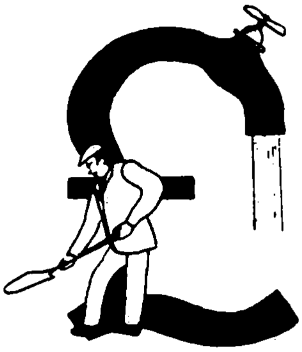
opening address

by Professor G.C. BROCK, PhD, FICE
Head of the Department of Civil Engineering
Dean of the School of Engineering.

Professor Brock opened the Conference by welcoming the participants. While many had attended previous Loughborough Public Health Engineering Conferences, some were attending for the first time and he was pleased to note that they included a number of final year under-graduate members of the Civil Engineering Department.

The choice of the theme of the Conference was also welcomed as especially timely. Financial considerations relating to water supply and treatment, as in other projects, are of paramount importance in deciding which works and processes are actually put into operation. About one hundred years have passed since that enterprising Frenchman Dupuit first published his papers on the "Utility of Public Works". When we consider the additional work which has been done since Dupuit we must count it small in comparison with that devoted during the same period to devising and constructing the works themselves. Yet the whole trend of events is leading to an increasing demand that Civil Engineers should be able to justify the utility of their works to the communities within which they are constructed.

Professor Brock continued by saying that the Conference would face problems whose intrinsic difficulty was undoubtedly responsible for our comparative lack of understanding. The members might well find themselves needing to "quantify the unquantifiable". He was, therefore, looking forward to an unusually interesting meeting.



H.R. OAKLEY

cost effectiveness in the design of waste treatment schemes

INTRODUCTION

Engineers are always concerned explicitly or implicitly in the economy of the works for which they are responsible. In exercising their privilege of harnessing the great sources of power in nature for the use and convenience of man they carry much of the responsibility for the wise use of these natural resources which provide the material basis of an expanding civilisation.

Water is one of the most important and fundamental of natural resources and economic analysis as applied to water and waste water engineering is concerned with assessing the real cost for using that resource in the best possible way, so as to provide the means of judging the relative merits of alternative schemes, as an aid to decision making. This paper is not concerned with the wider aspects of water resource management (see for instance the report of the I.C.E. informal discussion on Cost Benefit Analysis in River Basin Management(1) but only with aspects of waste water treatment.

Cost Benefit Analysis

The general aim of economic evaluation is to secure the greatest benefit from the resources available. In particular, the financial aim of an organisation in the public sector may be said to be to maximise the value of the nett benefits which it is expected to provide for the community. Relating cost to benefit in this way is a process called 'cost benefit analysis', but since the benefits will depend on the effectiveness of the works, the alternative term 'cost effectiveness' is sometimes used.

Formal definition of these terms is not easy to follow; a definition given by the Institute of Cost and Works Accountants is "a quantitative examination of alternative prospective systems as to potential trade offs with regard to the benefits or effectiveness to be gained and the cost to be incurred among the alternatives for the purpose of identifying the preferred system and its associated equipment or products". This may be less precisely but more simply put as the process of determining which alternative gives the best value for money.

Evaluations of this nature require two steps:

a) an estimate of the cost of the scheme

b) a quantitative expression of the benefits conferred

Assessment of the effectiveness of the operation of waste treatment works is relatively easy, but there are problems in taking the next step of evaluating the benefits conferred by works of differing effectiveness and the success of attempts to quantify benefits is open to debate. If all the costs and benefits of a public investment can be expressed as a cash flow, alternative projects can be evaluated on a comparable basis. However, it is often difficult to attach a monetary value to all costs and benefits, particularly benefits of a kind which cannot be bought or sold in the market. The method of assessing benefit for the Trent study has been described(2) and readers must judge for themselves the conviction which it carries. In spite of these difficulties, a cash flow analysis can play an important role in decisions on such projects by identifying as many as possible of those facets of the problem which can be reduced in a meaningful way to money values.

Since resources in general are limited, it is seldom possible to undertake all projects which appear desirable. At the national level, the Government may not be able to obtain enough resources to build all the new roads, schools, hospitals, water treatment and waste treatment facilities that are desired by the community, and cost benefit analysis is of value in assisting in the selection of those projects which should have priority.

Further consideration of cost benefit analysis is outside of the scope of this paper, which will retreat from discussion of the benefits of alternative arrangements for disposal into the more tangible and safer subject of the cost effectiveness of treatment works.

Economic Evaluation

There is of course no magic in cost effectiveness. We make loose judgements of this nature every day in our lives, but rigorous or formal treatment necessarily introduces technical terms which are not always clearly understood.

Basically, the cost of schemes can be compared either on a capitalised basis or in terms of a total annual cost. Complications arise from the necessity for fixing the period over which capital expenditure should be written off, calculating the interest which is payable on loans, and assessing the effects of inflation or deflation.

In order to compare schemes on a capitalised basis, the actual expenditure and income over a period of time are converted into equivalent capital sums as measured at a single point of time - that is, into the capital sum which would yield the required annual value during that period. It is usually convenient to use the present time as the reference point, i.e., to calculate the Present Value of the total financial transactions. Assuming that the relevant annual rate of interest expressed as a decimal is r and is compounded with annual rests (that is to say, one years interest is added at the end of each year), then the sum of $£C_0$ arising at time 0 would have a value of $£C_0(1 + r)^n$ in n years time; similarly the sum C_n arising in n years time has a Present Value of $\frac{C_n}{(1+r)^n}$

The process of calculating a Present Value in this way is known as 'discounting', and the terms 'interest rate' and 'discount rate' are used interchangeably. Methods which involve the use of compound interest formula are referred to as 'discounted cash flow' methods.

The alternative of converting initial cost and subsequent expenditure or income into total annual costs involves the reverse procedure of annuitising the capital expenditure using similar and standard formulae. The two methods are arithmetically equivalent, and comparisons based on them give the same answer, but in the majority of cases the Present Value method is easier to apply, particularly if the annual costs vary with time, because of increasing maintenance or operational costs, or because the time period for capital repayment varies for different parts of the work.

Alternative methods are sometimes used, expressing the same data in different form. For example, in his report on Tyneside Sewage Disposal in 1964, the City Engineer Newcastle showed the estimated total annual costs of the alternatives of sea outfall and full treatment schemes in graphical form together with the culminative differences in costs between the two schemes over a one hundred year period, which showed that the aggregated costs equated after eighty-five years. Interest rates were taken as 5½% and no account was taken of price increases; it would be of interest to re-work the comparison on current conditions. When a further report on methods of sludge disposal was made in 1969, an interest rate of 8% was used, future costs were estimated assuming a 3½% p.a. increase (except that electricity costs were taken at 2% p.a. increase) and the aggregated expenditure for fifteen alternative schemes were compared for a 60 years period; the more rapid inflation experienced in the two years following that report underlines the problems of basing selection on total costs over such a long time period.

Assuming, however, that a Present Value or discounted cash flow comparison is acceptable (if only for want of a better guide) then economic evaluations proceed in the following stages:

1. Define the problem
2. Set out the data, state the assumptions and assess the reliability which should be attached to the assumptions
3. Make the calculations
4. Interpret the results and modify them on the basis of judgement to allow for factors not taken into account.

The validity of any conclusions will depend on the reliability and completeness of the data and the assumptions made. As has been shown this is seldom exact, and even in the best conditions different people will attach different weight to particular factors. Consequently, in most situations it is not meaningful to speak of a 'correct' or 'true' solution. Where significant uncertainties arise it is useful to list the range of results thought to be likely and to attach to each an estimate of this probability.
Main detailed discussion of the topic will be found in the ICE publication 'An introduction to engineering economics'.

Provision of Capital

Most (but not all) waste water treatment works are constructed by Local Authorities: it is worth while giving brief consideration to the sources of local authority finance, which may be provided by grant from Central Government funds, or raised by the Local Authority's own borrowing or taxation facilities.

In general, Local Authorities meet current expenses out of taxation, but borrow money for capital investment by issuing securities in the ordinary market at the current rate of interest or by borrowing (in the U.K.) from the Public Works Loan Board. Whereas the Public Works Loan Board may lend money at a fixed rate of interest, the alternative practice of raising loans on the open market from time to time as may be necessary to meet all financial needs (including repayment of earlier loans) divorces the total cost of servicing such loans from any particular project, and gives rise to the concept of a consolidated interest rate which represents a weighted average notionally attached to the whole of the outstanding debt at any particular date, calculated from the different rates of interest at which the money has been borrowed over a long period.

It is general knowledge that interest rates vary from time to time and that the general trend has been upwards: for example, the interest on loans from the Public Works Loan Board moved from between 2 and 3% (depending on the loan period) in 1952 to over 7% in 1957 and whereas 20 years ago it was common to think in terms of interest rates from 3 or 4% it would now be proper to consider interest rates of the order of 8 to 10%. The effect of high interest rates on the present value or the annual cost of the project is dramatic, particularly for long loan periods. Thus, at an interest rate of 3%, the amortisation (interest and repayment) reduces from 6.6% on a 20 year period to 4.3% over a depreciation period of 40 years, a relative decrease of over 50%; but with an interest rate of 8% the amortisation decreases from 10.2% in 20 years to 8.4% in 40 years, a relative decrease of less than 20%. The financial attractiveness of long depreciation periods thus diminishes as the rate of interest rises, so that high interest rates give preference to relatively cheap designs which can be written off in a short period. Put in another way, as the discount rate increases, the Present Values of benefits and costs decrease faster the more distant they are in time, but the more distant the time, the more unreliable the forecast, so that undue weight should not be given to effects of this nature. The wrong choice of discount rate can lead to erroneous conclusions, and it is probably advisable to show the effect of different discount rates and let the Client exercise his judgement as to which is the more appropriate.

Where the factors involved are subject to uncertainty a process called sensitivity analysis, to which further reference will be made later, is a valuable aid to decision making. In this approach, the appraisal is based on the use of what is judged to be the most likely values of the data or assumptions, and calculations made in terms of the change in value necessary to reduce the nett costs or benefits by a specified amount. Taking each of the principal factors or combination of factors in turn, the analysis may reveal critical factors in which fairly small errors seriously effect the judgement on the project. Particular attention can then be devoted to the study of these sensitive areas.

All cash flows should be expressed in terms of money having a common purchasing power and inflation is another important aspect of project appraisal. For some years an assumption of increase in cost of 4% per annum was reasonable(3), but it is well known that over the past two or three years this rate of increase has doubled or trebled. It has been argued(4) that inflationary trends can be disregarded in calculation as long as inflation does not overtake the rate of progress of the national income. This is perhaps a confusion in terms, as inflation could be defined as a rate of increase in the general price level in excess to the rate of increase in national productivity. It is correct that in so far as the general price level reflects an increase in productivity the real cost remains constant in terms of its relation to the national income, and only excessive increase in price levels need to be taken into account in an economic appraisal.

Loan Period

Annual costs and Present Value sums are significantly affected by the period of amortisation, which may be determined by:

a) the period of need

b) the effective life of the structure

c) obsolescence of the process

d) policy considerations related to the provision of finance, or administrative or political considerations of wide variety.

Life as determined by physical deterioration of the structure is relatively easy to assess, but obsolescence, as a loss of economic value as a result in changes in circumstances is difficult enough to judge at any present time, let alone forecast. Policy considerations are even more difficult for the engineer to take into account; with Local Authority work, a legitimate factor open to debate is the extent to which future generations should be asked to pay for capital investments made now.

In practice, three categories can be defined:

a) Land purchase, and pipelines and heavy civil engineering works which can be kept in good condition for a long term of years and are likely to serve a useful purpose indefinitely.

b) Civil engineering works related to a particular process which might be supplanted by more efficient alternatives.

c) Steel structures, and mechanical and electrical equipment exposed to physical deterioration and in some instances, rapid obsolescence.

Currently accepted loan periods for public works vary from as much as 60 years for some items in the first category, to as little as 5 years for new and experimental plant.

Provision for depreciation over the period of amortisation is usually made by taking the original cost and spreading the sum uniformally over the life assigned to it, that is, a straight line method of depreciation. It is evident that with changing (usually rising) prices, the sum of such annual amounts will be less than the value of the original asset when corrected for the rise in price level, and this may need some correction. Some authorities suggest that in these circumstances the annual depreciation should be based on the estimated replacement cost of the asset in question rather than on the historic cost, but this can only provide a rough guide as it is highly unlikely that any replacement would be an exact duplicate of the original asset.

The incidence of construction where phasing is required to meet increasing demand is also of interest, and requires some financial computation. It is often the case that the cost of constructing two smaller units is greater than the cost of one larger unit, and it may not be immediately evident whether or not staged construction is desirable. A simple approach based on World Bank figures has been described(5) which relates the period of staging to the discount rate and shows that as the discount rate increases so the staging period decreases. Inflationary trends may also have to be taken into account.

Capital Costs

A good deal has been published about the estimation of the capital costs of waste water treatment plants, which seems mainly to underline the difficulty of making accurate estimates of cost short of pricing detailed designs. The reasons are apparent - physical circumstances are variable, but significant; external influences such as the availability of alternative works, labour, materials and so on affect contractors costs; and even tenders for a particular works may show wide variations which reflect contractors estimates of the risks and costs involved(5)(6). When making comparisons of costs in different locations, further problems arise; figures given in the ASCE publication 'Civil Engineering' in 1970 show area varients in USA from 0.90 to 1.65 (taking prices in Washington D.C. as 1); and 0.7 (Formosa) to 4.0 (Greenland) elsewhere.

Useful guides as to the relative costs of works of different sizes have been given by Townsend(7) and Logen(6) and for smaller works by Bradley and Isaac(8), and show that the cost and size relationship is generally in the form $\text{Log}_{10}C = a\text{Log}_{10}V + b$

when C = Cost

V = DWF

a & b = constants

There is still less certainty in assessing the proportion of cost due to individual treatment stages, as can be seen from Table 1:

	Capital (per cent Total)	
Stages	Isaac & Bradley	Herriot(9)
Inlet	1 - 6)	20 - 30)
Primary Treatment	2 - 16)	)
Biological Treatment	5 - 35	45 - 60
Sludge Disposal	10 - 25	12 - 35
Storm Sewage Treatment	3 - 9	-
Miscellaneous Site Works	20 - 45	-

To obtain meaningful costs of individual units, estimate should be made for standard design on unit sizes(3); and for non-standard units, on outline design and rough quantities(10).

Annual Costs

Apart from the interest and repayment of capital, the annual costs of operation and maintenance of works are important in determining the right choice of scheme, and may be assessed either in terms of annual cost or as the equivalent Present Value.

Operating costs are made up of the labour, material and power. In some instances, such as in the assessment of the economic value of an automatic control scheme or in the assessment of alternative pump tenders, comparisons of one of these elements may be adequate as a basis of comparison; but in the appreciation of the overall merits of alternative schemes, the total operational cost may have to be assessed, and again a wide range of figures have been quoted (6)(7)(8) although there is general agreement that there is a general cost/size relationship of logarithmetic form.

These uncertainties in cost estimation suggest that over-sophistication of economic evaluation of different schemes is not always warranted; but in particular instances, and for the purpose of comparison, meaningful and reliable data can be obtained(11).

Performance

If the estimates of cost of alternative schemes of waste treatment works presents uncertainties, assessment of the likely effectiveness is even more subject to difficulty. Rarely is one in the happy position of being able to forecast results from the factual evidence provided by the operation of existing works or pilot plants. In many cases the character as well as the rate of the incoming flow is subject to variation and the performance of individual works units can rarely be predicted with any degree of certainty.

Reference has already been made to the difficulty of determining the effluent quality which would achieve the objectives of pollution control, and to assessing the objectives in beneficial terms; alternative courses of action may well exist(12)(13), but their consideration is outside the scope of the paper and for the present purposes it is assumed that the desired effluent quality has been defined; but definition is itself open to debate, and it is not clear what importance one should attach to the reliability of results. A statistical approach to this on the basis of daily averages was discussed by Porter and Boon(11), but further examination of variability in terms of shorter periods and in relation to different stages of treatment may be a fruitful field(14). It is sufficient for the present purpose to note that works yielding effluent of the same average quality, but one more consistant than another, are not necessarily equally "effective" in terms of pollution control.

Considerable research on the design of sedimentation tanks has not identified satisfactory relationships between efficiency and the many parameters, but the design of biological systems is more susceptible to a theoretical approach and is probably sufficiently accurate for the purpose of cost-efficiency analysis. Reasonable relationships are also found between the design and performance of mechanical straining processes in tertiary treatment applications, but the performance of land treatment areas is of a more indeterminate character. Combine the uncertainties of performance of individual units, and it will be appreciated that the assessment of the effectiveness of convential treatment works is necessarily subject to wide error, and it is for this reason that design engineers are loath to guarantee results or to adopt the approach suggested by Bradley(15).

Nevertheless provided the uncertainties are recognised, meaningful comparisons can be made between alternative methods designed to achieve the same result, and comparisons made of the cost of systems giving similar results; see for example papers by Eden(16), the Indian Institute of Public Health(17), Isaac and Hibberd(18) and Cohen(19). If such relationships can be established, then the tools are available for optimising design to achieve stated objectives in the most economical manner.

Optimisation of Design

In any system there is a feed back from one stage of the process to another; that is, the output of one stage becomes the input to the next, so that variations in efficiency of one unit effect the performance of the following units, and of the whole system. It is therefore possible if reliable data is available to optimise a system with relation to the efficiency of the individual units; it is also possible, if alternative arrangements of systems are conceivable each producing the same overall effect, to find the most efficient arrangement.

Many examples of a simple optimisation approach can be quoted (see for example Oakley and Cripps(20)), but with the development of the electronic computer the facility for the manipulation of figures widened the potential scope of optimisation studies.

There is a considerable literature on the systems used for optimisation in various fields and it is not the purpose of this paper to describe the general approach, but to outline the particular application to the problem of waste treatment processes.

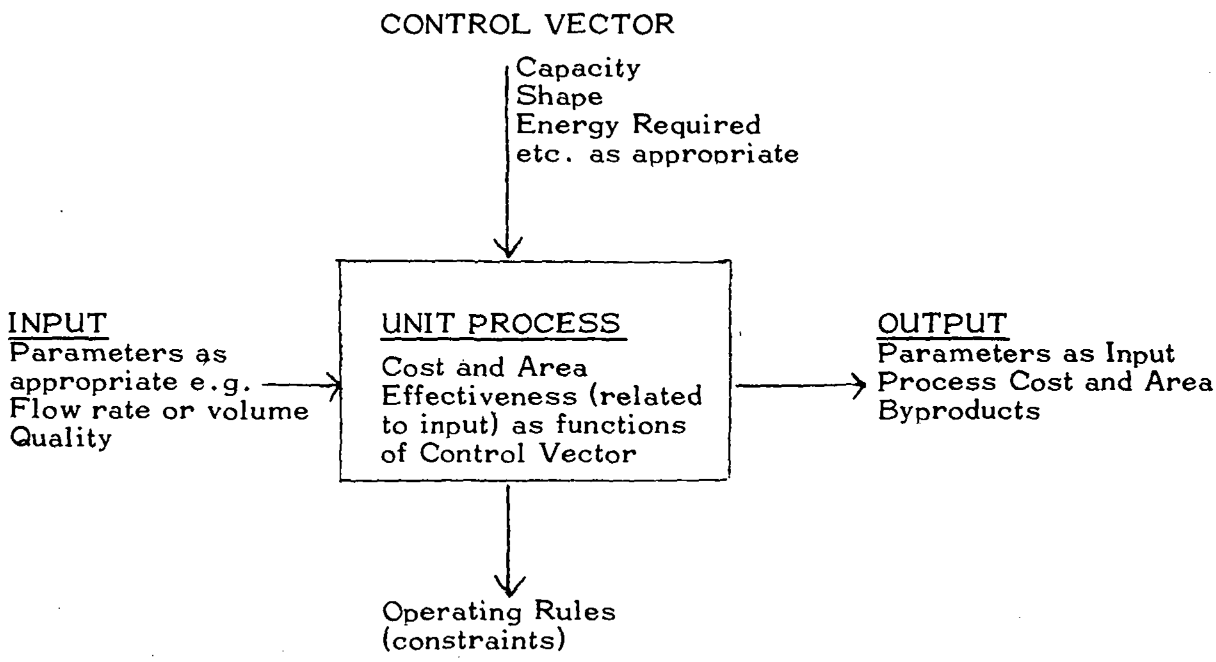
A number of theoretical studies have been made which are of interest. An early paper by Logan(6) reviewed the construction and operational cost of the unit processes in 61 works and attempted to withdraw meaningful conclusions from the observed relationships. Because of inconsistencies in field data and the resulting difficulties involved in establishing parameters from the actual cost of existing plants, capital and operating cost estimates were made of a series of theoretical designs, and tabulated figures given for 34 different combinations from which it was suggested that the most economical solution could be selected for any particular circumstances.

A more detailed analysis, also on a theoretical basis, was attempted by McBeath and Eliassen(21) for the activated sludge process where the relationships between the various parameters are reasonably well defined, and is a good example of the way in which sensitivity analysis can be used to identify the significant parameters.

With waste treatment plants however the effect of unit performance cannot usually be isolated, as the cost of dealing with the sludge produced will be a major item in optimising the system.

The technique used in this instance is to plot relationships between two parameters (one being cost) in line form, and between three, as a surface; the slopes on the surface indicate areas where variations, on the value of each parameter significantly affects others.

A feasibility study now being undertaken by CIRIA proposes to construct a series of modules which represent the unit processes of sewage treatment, and to outline the cost-performance characteristics of each. The schematic diagram of one module is shown below and it will be seen that in most instances there will be immediate difficulties in obtaining the necessary information. In any system, the selected modules would be linked together by pipelines, channels etc., which can also be treated as modules and costed according to the length and



size of the link. Computer programming techniques are then available to enable a search to be made for the combination which gives the least cost or the least land area or other parameter for the required overall performance; and in its final form, the model would be capable of testing the cost effectiveness of alternative systems e.g. activated sludge treatment, biological filtration or physical-chemical processes.

In formulating the model, some of the basic problems are to prepare an acceptable terminology; to select significant process stages out of the many alternatives available and to agree on quality parameters which are relevant. When that has been done, the information relevant to those quality parameters and process stages has to be collected, and only then will it be possible to see whether a full study is possible at the present time, since it is clear that success in designing and operating an optimisation process of this nature depends on the accuracy and availability of the information available, and it may be that at the present time many assumptions will have to be made which will be difficult to validate. But even a simple choice between alternative systems involves some prediction as to the behaviour of the component parts and of the cost of construction and operation, and an optimisation model which assists in formalising this process will be of value; if the present attempt proves to have data limitations, it will at the least outline those areas where further data must be obtained.

Socio-Economic Factors

It is well to remind ourselves in a largely material age that money is not the be all and end all of the evaluation which should take place, and reference has already been made to the inherent difficulty of quantifying benefits for abstract or subjective factors. Some aspects of waste treatment plant design have implications of a general economic nature which are difficult to assess, and in so far as they have a social content are perhaps impossible to evaluate in monetary terms. Thus, the type and number of men employed can be evaluated in terms of the wages paid but other considerations such as availability, the effect on labour migration, and the desirability of use in more productive areas may also be of relevance; similarly, in a given situation, the amount and nature of the materials used may have some bearing on wider questions of the productivity and economy of the country. To take another example, conservation of water is obviously relevant, but conservation of mineral matter or of energy may also be of some importance. Again, the capital investment policy of the country may be of overriding significance at any particular time. Considerations of this nature are of particular importance in developing countries, and are carefully considered by international agencies when evaluating projects.

Cost Effectiveness in the Design Office

It might be appropriate to give brief consideration to cost effectiveness in the design office.

The cost of design is not often publicised but, if the standard fee scales applied by consulting engineers can be taken as a guide, (and it is perhaps relevant that U.K., U.S.A., South African and Australian scales are broadly equivalent), then the cost of design can be taken as varying from 15 to under 4% of the capital cost, according to the size and complexity of the works. It is reasonable to suppose that economy in design is false, but the cost of design is not always expended to best advantage. The care taken and the completeness of the design may vary from one office to another, and are intangible factors, difficult to assess, although reflected in the reputation enjoyed by the authority or firm. External frustrations also affect efficiency.

Thus the effectiveness of a design office in terms of the quality as distinct from the quantity of output is difficult to gauge, and unless detailed costings are available the efficiency of an office is also problematical. Most design offices in private practice will have their own cost control systems and conscious efforts will be made to produce cost-effective working, although, as always, there is a difficult balance to be struck on the proportion of total effort given to analysis and introspection. There is little doubt that design efficiency depends on skilled and experienced leadership, a balanced team of competent engineers and technicians, and an infrastructure of supporting and specialised services which may include mechanical, electrical and architectural services, structural design, quantities and contract account sections, computer facilities, and so on. There is little doubt that large teams which can pool and collate a varied experience are potentially more effective than smaller and less experienced teams, but there will be a communication difficulty to be overcome. A good information service is essential; the successes and failures on completed works must be appraised objectively, and the lessons so learnt disseminated in technical committees, internal literature, and informal discussion of colleagues problems.

Conclusion

This review of the economic evaluation of waste treatment plant design does not offer any new concepts or original thinking, but it will have served its purpose if it brings out areas of ignorance or uncertainty. It is suggested that the following merit discussion:

1. What period should be considered in making an economic comparison having regard to plant life, obsolescence of process or other changing circumstances?
2. What discount rate should be taken during this period?
3. What is the effect of inflation?
4. What is the sensitivity in cost terms of the many design parameters?
5. What importance is attached to developing formal processes for optimising system design?
6. What information is required for optimisation purposes and how can it be obtained?
7. How can reliability and consistency of performance be evaluated?
8. Can amenity values be satisfactorily quantified?
9. How can socio-economic factors be taken into account?

Until satisfactory answers can be given to all of these questions, cost effectiveness might be considered a desirable principle without fully meaningful application; but uncertainties should not prevent the attempt and even the most tentative conclusions will have value if the limitations are realised.

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discussion

CHAIRMAN: J. H. J. WATSON, FICE, FIPHE, MIWE
President, Institution of Public Health Engineers

The CHAIRMAN thanked Professor Brock and the Conference Organiser, John Pickford, for inviting him, representing the Institution of Public Health Engineers, to take the Chair at the first Session of the 5th Public Health Engineering Conference.

2. Local authorities were soon to be put in the melting pot and recast; the Government had proposed the reorganisation of water and sewerage services into ten pyramids of massive power and perhaps bureaucratic management dealing with a resource - water - which largely escaped measurement in terms of commodity or market value; and there was public demand for improved effluent necessitating an expanding capital expenditure. Economy with improved design had become a pressing need and it was timely that the Conference was concerned with Economics and Management in Public Health Engineering.

3. Mr WATSON introduced Mr Oakley, a partner in the firm of J.D. and D.M. Watson - with whom the CHAIRMAN had no family connection.

4. Mr H.R. OAKLEY introducing his paper said that although consideration of the efficiency of design offices and of cost benefit analyses of alternative schemes would be warranted by the title of the paper, he had chosen to concentrate on the relationship between cost and effect in the design of treatment works. Even with this limitation, discussion might deal with a wide range of topics from alternative materials to reinforced concrete, and the protection of steel from corrosion, to the selection of pumps and the use of automatic control systems. He thought, however, that the most important question was that of process design and the paper was drafted to introduce the subject of optimisation of treatment works.

5. Because of the variety of disciplines and range of experience of participants in the Conference, it seemed desirable to outline the principles of economic evaluation in the public sector and to underline the uncertainties of forecasting and estimating and the consequent need to consider the assumptions made as to loan period, interest rates, and the effect of inflation.

6. The current high interest rates encouraged a short-term view. One simple example of the effect of interest rates had been given in a recent paper and was reproduced as figure 1.

7. A guide to the conditions in which staging of works was financially attractive could be found in a graph originating with I.B.R.D. quoted in reference 4 and reproduced as figure 2; Is and Ia were the costs of a small and an additional unit respectively, which together served the same function as a single larger unit costing I1. The graph of the functions showed the critical time period for different interest rates beyond which phasing would be financially attractive.

8. Regarding the provision of capital, Mr OAKLEY said that in the United States engineers had to persuade the authorities of the attractiveness of schemes, most of which were financed by bond sales, but these were obtained at favourable interest rates because the interest was exempt from Federal Tax.

9. A recent World Bank leaflet expressed the view that treatment works should be, and could be, justified economically and should be linked to the overall use of water. This might eventually be the view taken in this country following the formation of the new Regional Water Authorities.

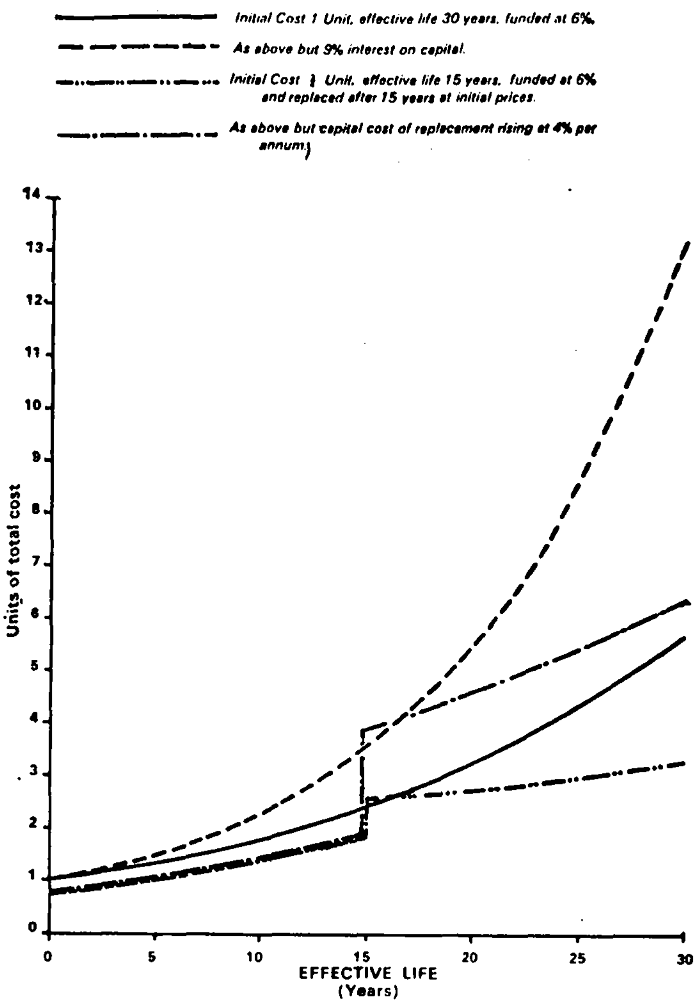


Fig. 1. Effect of interest rates and inflation on outfall costs

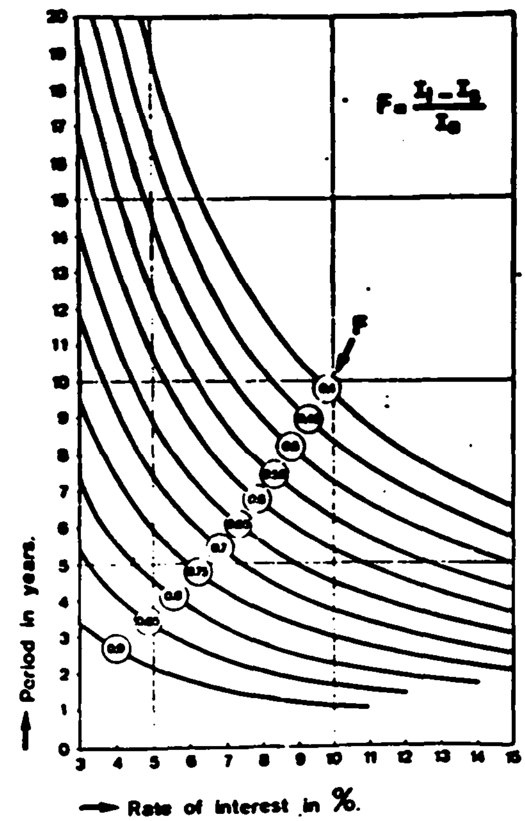


Fig.2

10. The accuracy of estimated capital costs might be as low as plus or minus 20 or 25% at the outline scheme stage, and estimates of annual costs for operation and maintenance were even less certain. A uniform system of costing would be a great help in arriving at reliable comparisons.

11. The need for minimising the ratio of cost to effort was evident and had long been recognised, and Mr OAKLEY suggested that a logical system, even with uncertain data, was better than a haphazard method based on hunches or experience.

12. Very simple illustrations of how treatment works design could be optimised had been given in the discussion of Townend's paper(7) and were reproduced as figures 3 and 4. The complication of taking account of all the relevant factors was considerable and complete studies were not feasible prior to the advent of the electronic computer.

13. On the socio-economic side to the question the minimum cost was not the only important factor. Also to be considered were aesthetics, politics, and the local employment situation.

14. It now seemed timely for the question to be examined in detail, and Mr OAKLEY hoped that Dr Wright who was to open the discussion would outline the important optimisation study which CIRIA had initiated.

15. Dr D.E. WRIGHT oulined the general principles of economic evaluation. He pointed out that the phrase 'cost-benefit analysis' was used in three distinct senses: as a general description of any form of economic analysis of capital projects; as a description of economic appraisal in which special allowance for semi-quantified social costs was made; and to mean a particular discounted cash flow technique in which the criterion for investment was expressed as a ratio of costs to benefits. To save confusion we should be clear about the particular sense we intended.

16. Investment could be made either to earn cash revenues (and so achieve a required return on the capital employed) or to meet a stated need. Although it could be argued that effluent treatment resulted in benefits as tangible as other cash revenue, it was more usual to consider investment in treat-

Fig. 3

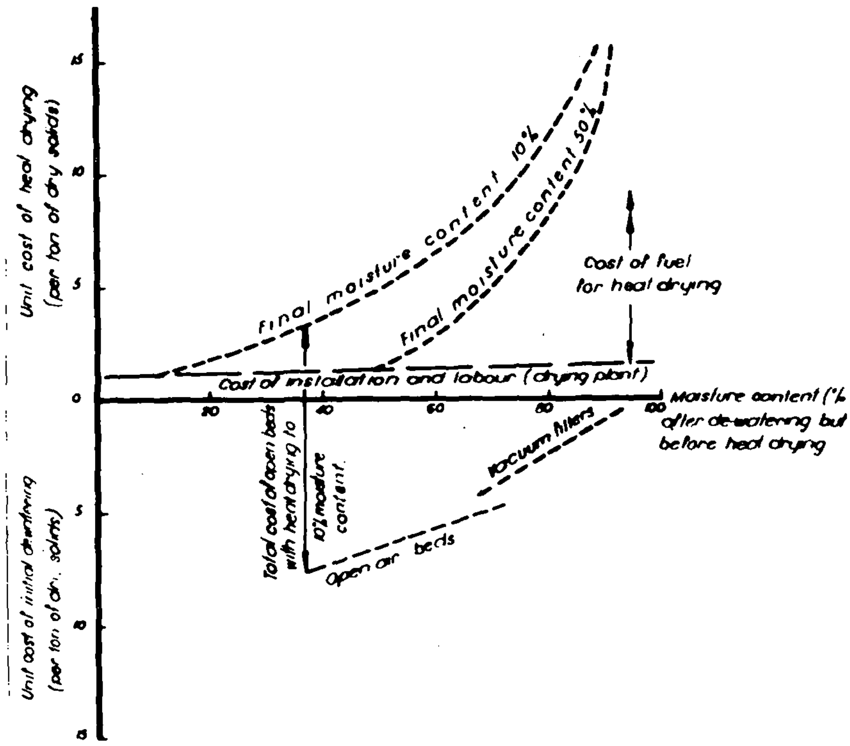
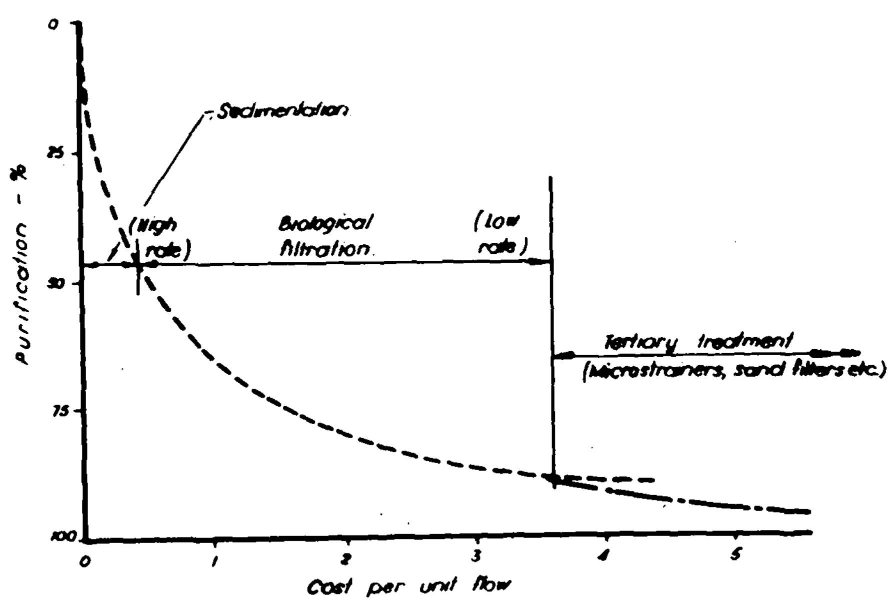


Fig. 4



COMPARISON OF CAPITAL COSTS OF WASTE-WATER TREATMENT.

ment facilities to be in the second category and to assume that economy was served when the present value of the capital costs plus operating costs was a minimum.

17. Dr WRIGHT read extracts from the ICE publication "An introduction to engineering economics"(22) to emphasise the distinction between economic evaluation and financial planning. Economic evaluation should be used to select the preferred project from the choices available, after which financial planning was necessary to arrange for raising and repaying the capital required and providing for operating expenses.

18. Economic evaluation was used to secure the greatest benefit from the available resources using money only as a yardstick. It was wrong in economic evaluation to make any special allowance for inflation. Quoting from Beesley(22) inflation was only important when some of the terms contributing to the cash flow were varying at different rates.

19. Depreciation was of interest to accountants looking at the past, but not to engineers looking at the future. The manner chosen to measure depreciation was entirely irrelevant to economic analysis. Depreciation only came in where the economic analysis included some tax allowance factor linked to depreciation.

20. Dr WRIGHT said that behind all their technical expertise and economic analyses, engineers had a professional responsibility to the community they served as stewards of the resources of the natural world. We should also state the engineering alternatives clearly and give the costs of each.

21. Mr J.D. STOREY agreed that depreciation had no part in the economic analyses of a project. Inflation had no part in public works, but the private industrialist was concerned with tax allowances which were very seriously eroded by inflation.

22. Mr G.F.G. CLOUGH said that an unchanging standard was needed to replace cash, which was a yardstick continually varying. Man-hours, suitably weighted, might be an acceptable alternative, but a great deal of tedious calculation would be involved.

23. In comparing activated sludge with biological filters the result of excess capacity should be taken into account. The cost of power used for aeration could be saved, but filter medium might lie unused. The selection of the design basis was critical for optimised design since there would be less surplus capacity and the result of errors would be more serious. Mr CLOUGH suggested that a cost effective design was one which required the least total expenditure of resources (including feasibility studies and design effort) to meet the specified objectives.

24. Mr OAKLEY agreed that money was a shrinking yardstick, but a man-hours basis might also prove variable, and would not mean much to the average client.

25. The CHAIRMAN wondered whether the use of long periods for cost comparison (like the hundred years for the 1964 Tyneside scheme) were of value or nothing more than an academic exercise.

26. Mr G.L. ACKERS pointed out that the longer the loan period and the higher the discount rate, the lower the present worth of the end-value. An economic appraisal must at least extend over the loan period and should take into account the end-value, whether positive or negative.

27. Mr E.V. FINN said that following a feasibility study a new estimate would be required after three years or so. Simple year-by-year adjustment did not allow for the greater rate of inflation of labour costs compared with material costs.

28. Mr R.P. BOYD JAMES pointed out that costs in real terms varied. For example mechanical sludge dewatering costs had dropped whereas the cost of development of water resources had increased in recent years. He found the present value concept difficult and preferred the more realistic annual basis. It was reasonable for future generations to pay for schemes from which they would benefit (paragraph 1.5 of the paper).

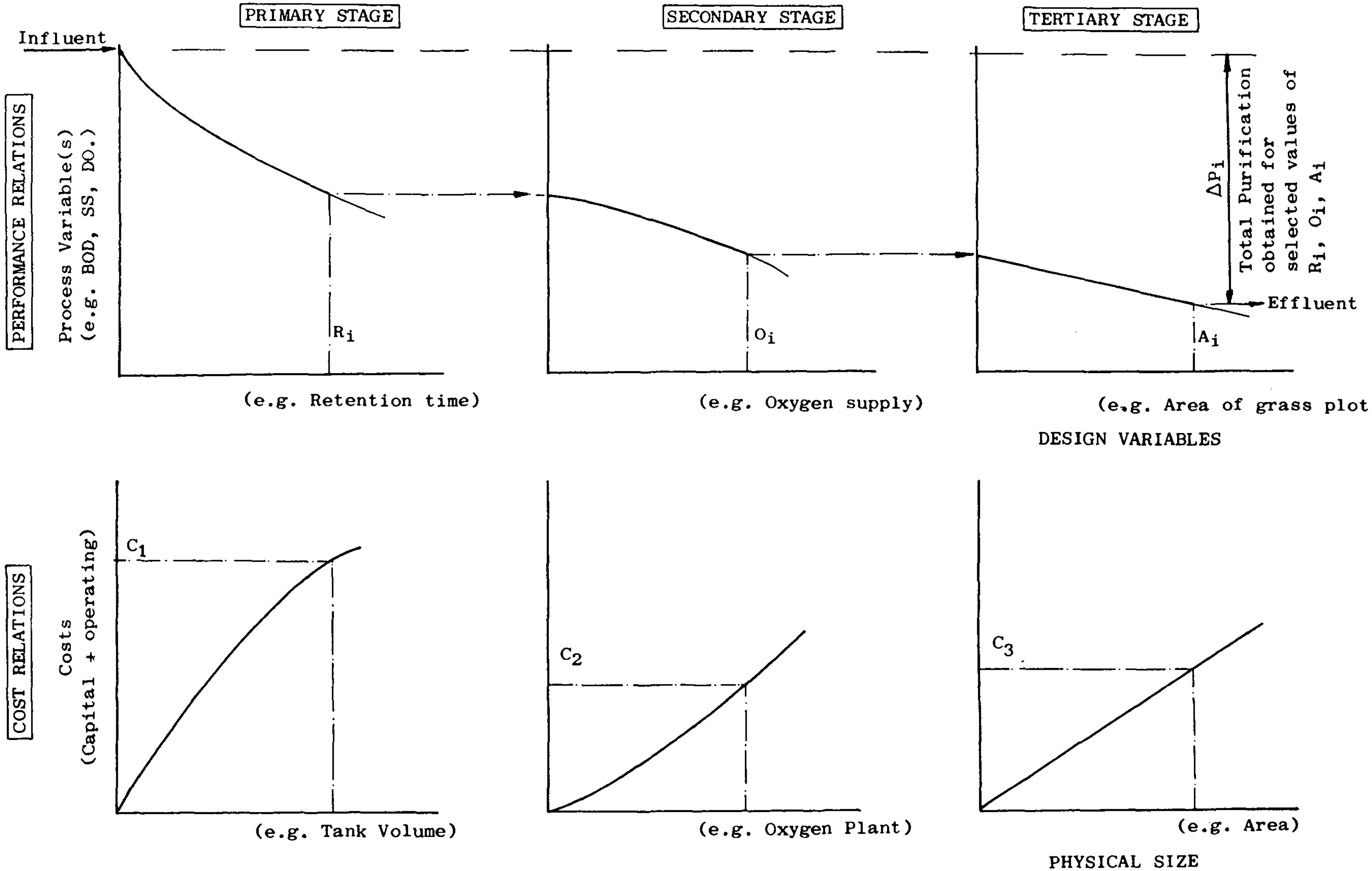
29. There were not enough resources to deal with all desirable projects at once, and overloading the industry could result in higher costs. An example of this had been the motorway programme; a rapid rate of progress had been followed by a lull with specialist plant standing idle.

30. Mr OAKLEY said that the choice between present value or annual costs depended on the loan period; a single capital figure made it easier to compare schemes with fluctuating loan repayments. He suggested that it should not be assumed that future generations would want all the benefits with which they are burdened, so that excessively long loan or amortisation periods were inappropriate.

31. Mr D. ANDERSON stressed that design could not be started until the engineer knew what he was designing. Different cost-effectiveness criteria applied to the engineer and the client. Mr OAKLEY said that there was a need for ad hoc feasibility studies: consultants were concerned with a profit margin, and local authorities had an overheads margin.

32. Mr ANDERSON did not accept the suggested error of ± 25%. He thought that consultants should take on a job on a fixed fee basis; there would then be better cost-effectiveness. The CHAIRMAN defended a 20-25% factor in the context of a broad estimate of alternatives at the time of a preliminary feasibility study, and Mr OAKLEY said that even with detailed designs contractors' tenders varied by more than ± 10%. Payment to consultants

Fig. 5. Sketch to Illustrate Principle behind CIRIA Optimisation Study of Sewage Treatment (drawn with reference to effluent stream only).



For selected values of the design variables R_i O_i and A_i, a reduction in the influent pollution (measured in terms of BOD, SS, etc) of ΔP_i is achieved for a cost of $(C_1 + C_2 + C_3)_i$. Various combinations of R O and A can be tried to find the minimum total cost.

N.B. The curves shown are for illustration only and have no technical or economic significance.

of a fixed fee was acceptable, given protection against inflation, changes in requirements and other contingencies. An attractive arrangement would be to fix the fee in relation to the estimated cost and divide any saving between the client and the designer.

33. Mr J.R. HUGGETT said it was often cheaper to extend an existing facility rather than provide a completely new process. This might give an unfair picture and could be a real bar to progress and in this context socio-economic factors became important.

34. Dr D.E. WRIGHT described the CIRIA Optimisation Study of Sewage Treatment, whose object was to examine the best performance and cost data available to see if this was sufficient to construct a mathematical model of the sewage treatment process. The 18-month feasibility study was being done under contract to CIRIA by the Local Government Operational Research Unit and was being carried out in close consultation with engineers from the Department of the Environment, consultants and local authorities and research workers in WPRL and the universitites.

35. Dr WRIGHT showed, in a very simple manner (fig. 5), the type of performance and cost relationships which were being formulated. It was hoped to relate some seven or eight process variables to the design and cost of selected process stages. The model should help the designer to find that combination of process stages which gave the minimum overall cost (capital plus operating). Sludge treatment was included in the study.

36. Mr T.H. CARTER was sceptical about the value of this comparison of construction and treatment costs. The variation of flows and process loads and the effect of a particular site of a works were such that the project might not get much beyond a 'hunch' or 'feel of things'. Foundation costs and the nature of existing works were important considerations.

37. Mr R.W. BAYLEY did not think a rigid solution would be obtained, but understanding of the cost/performance relationship would allow for a better solution at a given site. Dr WRIGHT confirmed that the model would require the insertion of information appropriate to particular conditions. Mr OAKLEY said that available data might prove inadequate and it might be ten years before the model could be really useful.

38. Mr CLOUGH said that an optimum design did what was required with the minimum effective effort.

39. Mr C.H. SPENS said that models and computers were wonderful tools, but the ultimate decision must be taken by a man.

40. Mr R.S. ANDERSON suggested that a great cost-benefit might be obtained by reviewing methods of financing projects. With a loan over 40 years at 8%, 320% of the capital sum had to be repaid. After reorganisation the new Water Authorities would not be saddled with capital debts and capital programmes could be financed from revenue. Mr OAKLEY said that the World Bank view was that with revenue from the sale of water and disposal of waste this could be done. Mr S.F. WHITE said that the new Authorities would presumably take over loan debts of existing authorities.

41. The CHAIRMAN said there were many complexities and uncertainties yet to be unravelled. Engineering judgement and experience was still of vital importance, but should be strengthened by common-sense use of new methods and approaches. Mr WATSON thanked Mr Oakley for speaking on his paper which had engendered so lively a discussion and for replying so adequately to the many points raised.

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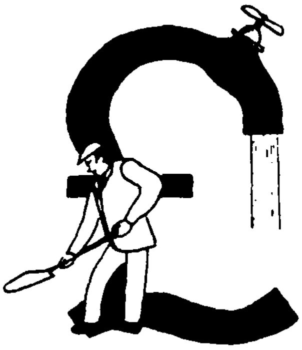


S.F. WHITE

economic aspects of water management

Any views expressed in this paper are those of the author and not necessarily those of the Department of the Environment.

Wherever the word 'water' appears in the paper in inverted commas it is meant to signify all aspect of water in the river, in public water supply, in sewage, in industrial effluents etc.

1. INTRODUCTION AND SYNOPSIS

1.1 At the time of writing (October 1971) the Central Advisory Water Committee have reported upon the future management of water in England and Wales but the Government have not yet issued a White Paper declaring their intentions.

1.2 The Committee were able to agree on several important points of principle. They recommended that the relationship between the various authorities in a river basin should be changed so that comprehensive 'water' management plans for each river basin could be drawn up and once such plans had been agreed the system of financial arrangements should be such as to put no obstacle in the way of their implementation.

1.3 It cannot be denied that the financial arrangements imposed on any future re-organisation is one of the key factors, if not the key factor, in determining the efficiency and effectiveness of the organisation. It is also true that the present system is far from satisfactory and concentrates attention on individual interests as opposed to those of the river basin as a whole.

1.4 For these reasons it is timely that some of the principles of financing the 'water' services should be examined and discussed. The paper sets out some of the relevant economic factors with the aim of provoking discussion. No attempt has been made to set out a 'recommended' financial system but some conclusions are given at the end of each section.

1.5 The paper views the problems in the context of the river basin throughout. This is the smallest unit from which 'water' problems can be viewed as a whole. If a larger unit such as a region or the country as a whole is taken the issues become blurred and the river basin is adopted for the sake of simplifying the issues.

1.6 The view of the Central Advisory Water Committee quoted in 1.2 above implies a considerable degree of control of local authority expenditure in the interests of the river basin. For this reason local priorities and competition by the 'water' services for local funds is not dealt with in this paper although at the present time such influences are strong.

1.7 The theme of the paper, if indeed there is a theme, is that 'water' is quite unlike any other service or commodity and that the normal laws governing trading transactions cannot be made to apply except in certain relatively unimportant respects.

1.8 Section 2 deals with the ownership of water and shows that until water is legitimately taken out of a source it is not in 'ownership' and rights tc use can only be enjoyed if they do not conflict with other rights.

1.9 Section 3 discusses the value of water and draws the conclusion that nc objective or commercial value can be placed on it.

1.10 Section 4 shows that the costs involved in the provision of any public 'water' service are interrelated with the costs of almost every other public 'water' service. Any attempt to apportion costs between one service and another is bound to be arbitrary.

A further difficulty is that the costs of private abstraction and discharges are also interrelated with each other and with the public costs yet are extremely difficult to bring into the account.

1.11 Section 5 sets out some of the factors affecting the apportionment of costs between one consumer and another.

1.12 Section 6 mentions three possible charging systems ranging from a system in which consumer pays separately for each individual service to a single charge for the use of the multiple services provided.

The former is by no means as precise or equitable as may seem and suffers from the disadvantage of inefficiency and complication.

The latter is apparently simple, relatively cheap to operate, but can lead to loss of accountability.

1.13 Section 7 deals with accountability. It shows that the 'water' services have a dual and sometimes conflicting responsibility to the consumer and to the community respectively. The most suitable system of finance can depend on whether the interests of the former or the latter are to predominate. It is doubtful whether in the future, with even larger 'water' authorities, consumer interest can practicably have a significant voice and the views of the community however arbitrarily aroused and expressed may come to predominate.

1.14 The final section gives some views of the factors determining investment in 'water'. So long as a policy is maintained of meeting the growing demand for water as it arises the largest block of investment in 'water' is pre-determined by the programme of works to meet that demand. External influences on expenditure are tending to increase and in some cases produce a conflict with optimum investment programmes.

Some consideration is given to the choice of investment programmes.

2. THE OWNERSHIP OF WATER

2.1 For centuries people have been concerned with water rights such as riparian, navigation and fishing rights. The law is complex, uncertain and inconsistent. Nevertheless one principle has been established, that water in a stream must ordinarily be passed on unaffected in quality and quantity to the next riparian owner.

2.2 In legislating Parliament has been careful to interfere as little as possible with those rights unless the owner thereof has agreed to their derogation. As an example the Rivers (Prevention of Pollution) Acts have made it an offence for anyone to discharge a polluting effluent to a stream without the consent of the river authority. The Act in no way implies that the giving of such consent hampers anyone with private rights who might be injuriously affected by that discharge from taking action under common law; indeed it specifically states that nothing in it shall affect the law relating to nuisance.

2.3 Particularly during Victorian times traditional water rights became eroded partly through indifference both on the part of the public and on the part of the holders of the rights, partly by the purchase of those rights by statutory water undertakers and it is understood by dischargers of effluent.

2.4 One is not aware of any instance where an enactment is concerned specifically with 'ownership' of water in a source. But what has been established is that, speaking generally, rights can be owned provided they are exercised without detriment to the rights of others.

The Water Resources Act 1963, though providing that no person should abstract water from a source except under licence, has not materially affected the position. (The Act makes exceptions to the requirement for a licence but these affect only small quantities of water.)

2.5 It is perhaps as well to emphasise that the Act does not confer ownership of water in a source on the river authority, a common misapprehension. The river authority itself cannot abstract without a licence.

(Here again it is a common misconception that when a stream is impounded in a reservoir the water comes into the undertaker's ownership as that expression is ordinarily understood. Even pumped storage reservoirs may have small natural catchments and the owners require a licence to abstract water from them.)

2.6 In these respects water is quite unlike any other commodity and this distinction adds to the difficulty of any attempt to deal with it by monetary practices applying to commercial products and services.

2.7 When water has been abstracted it passes through several stages of ownership and use and, except for an abstraction charge adjusted according to a broad category of use, there are no restrictions on that use nor upon the point of return to source (see below). This factor may lead to difficulties in the future; certain rivers may come to depend on the return of good quality effluent for common use. Sewage and trade effluents dischargers are under no obligation and in practice are in a position to dispose of their effluent to whatever water course they choose, provided they meet the standard of effluent required by the river authority, perhaps eventually to another river basin or to the sea where it is lost altogether. It might become necessary for the disposal point and quantity of effluents discharged to be prescribed.

Conclusion

2.8 Until water has been removed from a source it cannot be considered to be in ownership and there are some misconceptions on the subject.

Rights to water can only be enjoyed if they do not conflict with the rights of others.

3. THE VALUE OF WATER

Value in Source

3.1 As has been indicated, because flowing water is in principle free for all to use difficulties arise in determining an objective value for water in source.

3.2 Let us suppose that a stream and the adjoining land could be wholly owned by a company. The directors would use their judgement to decide whether to develop the stream for recreational purposes or to offer the water for sale to a water undertaker or to invest money in a reservoir to enable them to do both. The competing users would, as it were, bid against each other to establish a market value for the use of the stream and the water in it. Or, taking it one stage further, the market value would determine the amount of capital that could profitably be invested in the reservoir.

3.3 In the present situation this could not happen, the concept of right to use is ingrained and is unlikely to change. Nor is the community likely to look with favour on such an approach where such a vital commodity is concerned.

3.4 The value of a stream for recreational uses such as fishing or boating is determined in relation to the suitability and availability of other fishing and boating waters in the area. Any revenue raised from these interests derives from the established rights to exclusive or shared use of the stream and has little to do with the intrinsic value of the water itself.

3.5 The 1963 Water Resources Act established charging schemes whereby a river authority can levy a charge on the quantities of water an abstractor is authorised to take.
A very small charge is levied on a mill owner who passes on the water undiminished in quality and quantity to the next user and a relatively heavy charge is levied on an abstractor who does not return water at all.

This is a reflection of the effect one user has upon another; the money raised is spent on improving and augmenting resources to the benefit of all users. In no sense can the charges be considered as establishing a "market value" for water in a source.

3.6 Some economists have attempted to distinguish between flow or non-consumptive uses, such as recreational uses, and withdrawal or consumptive uses to arrive at a 'market' conception for each group of use separately.

3.7 In the author's opinion such attempts are bound to fail for the reason that both types of use depend on a right to a flow of water and clearly are competing for the same basic article. Unless free rein can be given to such competition, and it does not seem that it can, neither concept of a market value for water in a source is realistic.

What is the consumer prepared to pay for?

3.8 When water has been abstracted by a water undertaker it cannot be sold on a 'market' basis nor is it ever likely to be. There is an absolute need for water to support life and to promote health. The community will always insist that essential water is supplied as a right and at a reasonable cost. For this reason and because it is impracticable that water could be supplied other than as a monopoly service the charges and profits made by a water undertaker are carefully regulated in relation to the cost of affording the supply. More and more there is a tendency to equalise charges between different classes of consumers and between areas with scarce supplies and those with plentiful supplies.

3.9 However laudable these policies may be, they have the effect of further limiting the application of the normal market systems whereby the consumer can be given choice and an opportunity of showing what he is prepared to pay for.

3.10 Hitherto water has been so cheap and plentiful that this has not mattered. Variations in the price of water from one area to another amounting to several hundred per cent have affected few consumers to the extent that they have deliberately moved to cheaper water areas.

3.11 There are plenty of signs that this happy state of affairs is drawing to a close. New resources are becoming increasingly difficult to develop and increasingly expensive. The competing uses for resources tends to restrict their exclusive use for particular purposes. At the same time water demand continues to rise at a never diminishing rate.

3.12 In these circumstances charging policies must be re-examined to see whether the consumer can be given any choice to determine the amount of money that is spent on the development of new sources and so express his view about the value of water to him.

3.13 The first point to make is that every consumer has "essential" uses for water and "marginal" uses. A domestic consumer must have water to drink but he, or perhaps his children, may not be so particular about the amount of water they require for washing purposes or for cleaning the car. An industrial consumer may need water for an essential process but he may be able to restrict his demand for other purposes such as for cooling, or for washing down of floors.

3.14 Because of the absolute need for water the community will no doubt insist that no one should pay more than a limited amount for "essential" water and the value in monetary terms is artificially low. This may partly explain why the community does not appreciate the importance of the water services and will not accord them the priority in terms of land and finance that they deserve.

3.15 On the other hand the value of marginal water could conceivably be determined to some extent by the consumer through the medium of marginal pricing. He might for instance decide that he was prepared to do without marginal water or to take less. His decision would affect the revenue obtainable for developing additional sources and the need to develop such sources.

3.16 A second point is that every consumer values water according to different criteria, chiefly varying in practice in respect of quality and season.

3.17 The domestic consumer requires water from a source that can be made potable i.e. water that is sufficiently free from toxic elements and is reasonably attractive to the senses. He is not very interested in the dissolved solids content and, since the advent of detergents, less concerned with hardness than he used to be. An industrial consumer may not be the slightest bit interested in the toxic content but may be very concerned with total mineral content. The value of the water is determined by different criteria in each case.

3.18 As a further example the seasonal user such as a spray irrigator may value water very highly in a dry season but has no need for any in a wet season. An industrialist may take a uniform supply day and night throughout the year.

3.19 These differing requirements have given rise to ideas of supplying water in different ways. Dual supply systems whereby different qualities of water can be offered are being examined. Suggestions are being made that certain highly polluted rivers can be cleaned up and developed as sources of cheap industrial water. Charging schemes are being suggested so that the seasonal user can help himself by storing water to limit his demand when water is scarce.

In these ways the consumer can be given some choice and to express his view about the value of water but again it must be made clear that in no way is a 'market' being established.

3.20 A third point is that the value of

water depends on the reliability of the supply. A domestic consumer can tolerate a break in supply for periods of up to a day or two but he would value less highly a supply that was not available for longer periods in certain dry years. Spray irrigators feel strongly about the provisions in the Water Resources Act whereby their abstraction may be reduced or stopped in a dry season, a time when they may need the water most. On the other hand an industrial consumer may be able to do without water for weeks at a time.

3.21 The need for reliability clearly has an effect both on the essential and on the marginal values of water. Rivers and boreholes rarely dry up completely and resources in the driest years are adequate to meet "essential" uses. At other times there is ample water to meet all demands if it can be distributed.

3.22 An alternative therefore to marginal pricing or of giving a consumer a limited choice in the quality or season of the water he receives is to introduce the element of unreliability to his marginal water and to lower the price to reflect the lower value to the consumer of water supplied at all times except in a dry season.
(See also para 5.21)

The value of returned water

3.23 There are strongly held but opposing views about the value of returned water. One school of thought maintains that anything returned to a stream other than water unchanged in quantity and quality derogates and a penalty should be applied according to the effect on the stream.

3.24 The other school insists that water returned is a valuable addition to resources and quoted the undoubted success of authorities, such as those in the Lee Valley, in promoting the re-use of large quantities of water. The Water Resources Act leans to this point of view; abstraction charges are abated according to the quantity and quality of return.

3.25 The author feels there are dangers in an unqualified adoption of the latter view. For example, we are not sure that certain waters containing high proportions of industrial and sewage effluents can be made wholly safe except at prohibitive expense. It cannot be assumed that a return of water is always of intrinsic benefit and every case has to be treated on its merits.

3.26 It may therefore be advisable to assume that returned water has no intrinsic value but neither does it derogate from the value of the receiving water if it meets prescribed standards. In this way it is possible to avoid the difficulty that value of water returned must be related to the value of water in a source which cannot be determined objectively.

Value of Water Services

3.27 Almost as a footnote it can be mentioned that, apart from any value that water supplied may have, the provision of 'water' services has a "value" of its own. Property values are enhanced when main drainage is provided or a reservoir is built nearby. The potential availability of water can attract a manufacturer, uncertain of his future development and water needs, to an area.

This "value" cannot effectively be brought into the account but it may justify higher expenditure on services than would otherwise be considered economical.

Conclusion

3.28 There seems to be no way in which water in a source can be given an objective value, neither can the normal 'market' forces be made to operate. On the other hand there may be ways in which the individual consumer can be given an opportunity to express his views about the value he attaches to water and the amount he is prepared to pay.

4. COSTS INVOLVED IN DEALING WITH WATER

Source Costs

4.1 Until comparatively recently 'water' costs were dealt with in neatly isolated packets. A water undertaking might build a reservoir or sink a borehole, abstract the water and charge the whole cost to those taking the supply. A sewerage authority might build a disposal works and debit the cost to the general rate fund. A river or catchment board could precept for the cost of a land drainage scheme. Each authority would carry out its project without reference to any other authority and each would charge the cost to a separate account.

4.2 There have been exceptions. For many years the Thames and Lee Conservancies have been receiving substantial payments from the Metropolitan Water Board in respect of their prevention of pollution functions in the Thames and Lee Catchments. There is a case of a water undertaking making a direct payment to a sewerage authority for the improvement of a disposal works.

4.3 It is now generally realised that the costs of the various 'water' services are interrelated and cannot be packaged in a convenient way. Abstraction by a water undertaker from a stream can affect the standards of effluent that a sewage disposal authority has to achieve and so affect costs. Discharges of sewage effluent may reduce stream water quality and thereby increase a water undertaker's costs. Water conservation works, particularly river regulating schemes, may have several purposes and affect many interests. Hardly any source work can now be constructed without affecting the costs of other water users in some way or other.

4.4 The 1963 Water Resources Act recognised this complication and went some way to dealing with it by giving river authorities power to enter into an agreement with a statutory water undertaker or a local authority in connection with any works which the river authority considered necessary to enable it to carry out its new functions under the Act.

4.5 Nevertheless the Act perhaps did not go far enough. It failed to deal adequately with the financial arrangements whereby those who had constructed or were prepared to construct new source works could be compensated for their contribution to the development of the water resources of the area. An arbitrary separation of costs between the owners of such works and other abstractors has to be made.

4.6 In making their decisions on water resources and pollution control river authorities do not have to take into account the effect those decisions have on the costs of sewage disposal authorities and those discharging trade effluents.

4.7 Resources can be developed in several ways. For instance it is possible to improve sewage and trade effluents so that they could be re-used for other purposes; the cost would fall wholly on the sewerage authority and on the industrialist. The same effect could be achieved if a water undertaker built a direct supply reservoir or a river authority constructed a regulating reservoir. In the latter case the cost would fall on the water undertaker and on the river authority.

4.8 In the majority of cases the optimum overall scheme might be achieved by a combination of several of the developments mentioned in the preceding paragraph. The optimum scheme it should be noted is not that which causes the least expenditure to fall on a particular authority.

4.9 When we examine the benefit side of any scheme we may find that many interests may have gained. A water undertaker may be able to increase abstraction, an industry may have received added dilution for its trade effluent, better fisheries may be promoted, amenity is improved. But in the absence of a common measure of benefit there is no objective way in which costs can be apportioned. Also the point must be made that the optimum scheme is unlikely to produce the highest benefit/cost ratio for each interest, if for any.

4.10 Therefore, in so far as any particular "water" interest is concerned apportionment to it of a substantial proportion of costs within an ideal planned river basin is almost certain to be arbitrary, perhaps in some cases not less so than the determination of its costs in the past.

Public Utility Costs

4.11 Some costs are determined by considerations of water resource development on a river basin basis as indicated above. These can amount of as much as 50% of the total expenditure of water and sewerage authorities.

4.12 Other user costs can usually be allocated to the specific utility more precisely. The distribution system of a water undertaker is undoubtedly for the purpose of supplying water to a consumer, a sewer is laid for the purpose of draining away foul or surface water.

4.13 Nevertheless difficulties arise. The most frequently encountered are those that can arise out of the apportionment of cost to different consumers. For example an industrial water consumer considers that he is entitled to a reduction in the unit cost of the water he receives because of the large quantity he takes. Similarly a single person living in a highly rated house objects to paying for his water at many times the unit cost that a large family living in a lowly rated house pays.

These types of difficulties can be resolved (not solved) as in the past by firm policy decisions but it may be found in the future that, as water prices rise, there may be increasing dissatisfaction with those decisions.

Industrial Costs

4.14 Industrial "water" costs cannot readily be related to the costs of other users. The water quality requirements of industry vary to a tremendous extent. Often an industry taking a public water supply has to re-treat the water at a cost several times that of the supply. Some industrial effluents are extremely difficult to treat and require very sophisticated plants. It is of course unlikely that the combined cost of water supply and effluent treatment is more than a small fraction of the cost of a product but there may be cases where it has a considerable effect on profits.

4.15 Some water resource decisions can have a very material effect on the permissible standards of industrial effluent. An effluent containing a toxic metal might receive sufficient dilution in a stream for the toxic content to be tolerated. An abstraction from the stream could cause a reduction in flow so that the safe level of metal was exceeded and a new and expensive treatment plant would become necessary.

4.16 Means must be found of bringing industrial costs into the economic assessment of river basin schemes. This is by no means easy for several reasons:-

(a) Industrialists are notoriously reluctant to disclose their costs.

(b) The costs relate to different criteria from those of other consumers. For instance one cannot directly compare the benefits to a river of removing chrome content from a trade waste to that of reducing the biological oxygen demand of a sewage effluent.

(c) The control of industrial processes gives a manufacturer far greater flexibility than a sewage disposal works manager. He has the possibility of changing his process to produce a different effluent or perhaps to eliminate it altogether. This may make it easier for him but it complicates an assessment of the cost effect that revised standards of effluent would have.

4.17 Various proposals have been put forward to deal with this question of industrial 'water' costs. They range from one extreme that public authorities should take over full responsibility for the provision of industrial water and treatment of industrial wastes to the other extreme of ignoring these costs altogether.

4.18 Neither course is acceptable and the ultimate solution will no doubt lie between the two extremes.

For instance cost factors to be taken into account could be limited to a few criteria of quality and quantity particularly those common to the operations of public authorities. All other cost factors would be dealt with arbitrarily but it cannot be pretended that this would be very satisfactory.

"Social" costs

4.19 It is worth repeating the distinction made elsewhere in this paper, between those costs determined on "social" grounds such as amenity, recreation, general public health interest, and those determined by "technical" considerations arising out of the provision of services such as water supply, provision of main drainage, flood alleviation etc.

4.20 Technical costs can often be related to particular revenues and the consumer can be given some scope for choice in the scale of expenditure incurred. Social costs are determined by the community at large and the consumer cannot be given a preference.

Conclusions

4.21 "Water" costs arise out of a multitude of purposes and interrelated uses. In the absence of a determining factor such as a 'market' value for water the apportionment of costs between the various interests is bound to be arbitrary.

4.22 One solution would be to amalgamate all costs arising out of the public interests involved into one account. (See also Section 5.9) The main argument in favour of this solution is that at present the burden falls on the general rate and taxpayer anyway and in a quite haphazard fashion so that the simplication would not be any more arbitrary. The chief arguments against such a solution arise out of the difficulties of dealing with private interests such as private abstractors of water and dischargers of trade effluent direct to source.

5. PAYING FOR WATER SERVICES

The existing system

5.1 Sufficient revenue has to be raised to meet expenditure i.e. capital charges plus day to day costs plus a margin to cover administration costs, allocations to reserve funds and profit (if any).

5.2 The following figures are estimates of gross total annual expenditure (revenue plus capital expenditure) on the "water" services in England and Wales for the year 1970:-

		£M
Water Supply		230
Sewerage and Sewage Disposal (excluding "on site" drains & sewers)		225
Water Resource work	(River Authorities)	7
Pollution Control	(River Authorities)	1
Land Drainage		20
Fisheries	(River Authorities)	1
Navigation (including expenditure by B.W.B.)		5

5.3 At present water supply expenditure is met by a charge related to water consumption; most sewerage and sewage disposal expenditure is met from the general rate fund; water resource expenditure is met by a charge on abstractors of water; water pollution control and land drainage expenditure is met by a precept on local authorities or by means of a drainage rate. The relatively small expenditure on fisheries and navigation is partly met by charges on those benefitting.

5.4 Capital expenditure on land drainage works attracts generous grants from central government and thus from the general taxpayer. Relatively small grants are made in respect of certain types of capital expenditure on water and sewerage. Expenditure on sewerage and sewage disposal, financed from general rate funds, is supported by the general taxpayer through the medium of the rate support grant.

5.5 It can be seen that with the exception of water supply and water resource expenditure, the revenue raised to meet "water" costs in general is raised as a tax on the general rate and tax payers. Even in the case of water supply, revenue raised from the domestic consumer is levied as a water rate and only in the aggregate do domestic consumers pay for water in proportion to their consumption.

5.6 An industrialist with a large factory producing a small trade effluent can find himself paying for "water" services, some of which he may not use at all, through the medium of general taxation, the general rate fund, a precept on the general rate fund, a drainage rate, a direct metered charge for his water supply, and a charge made by the local authority for the reception and disposal of his waste.

Re-organisation

5.7 This mixture of charge and tax has arisen because 'water' services have been regarded as public health services. It cannot as a charging system be defended on grounds of logic and equity but it is accepted by the majority of those who pay. For instance, because a supply of water is a public health necessity some take the view that it should not be limited or charged for by metering.

Change is likely to be resisted and must be fully justified but the pending re-organisation of 'water' services has created an opportunity for looking afresh at methods of paying for them.

5.8 It is clear that revenue raising schemes must be related to the type of organisation that is created. It is difficult to visualise for instance an organisation based upon a company structure being financed through the medium of taxation. Nevertheless there are certain factors that must be taken into account in devising the 'ideal' charging system and some of these are dealt with below.

Simplification

5.9 Expenditure on water supply and sewerage services amounts to well over 90% of the total. It would make only a small difference to those at present paying for these services if their rates and/or charges were increased to cover all the other 'water' service expenditure.

In any case they pay a large proportion of the balance of expenditure through their general rates and taxes.

5.10 This simplification would have the merit that water resource expenditure, which is likely to become substantial in the future, would be raised on a common account with expenditure on water supply. Water supply accounts will in any case bear the brunt of expenditure on water resources through the payment of charges for abstraction of water.

Arrangements would have to be made however to ensure that private abstractors continued to pay their share.

Equalisation

5.11 There are two basic types of "inequity":-

(a) that between one consumer and another in the same area, one paying in total for the 'water' services more than another and making less use of those services.

(b) that between consumers in different areas paying different amounts for the same service. To some extent this reflects the community's choice in the standard of service and in the method of paying for the service provided but to a larger extent it reflects accidents of geography such as the distribution and location of population in relation to the availability of water.

5.12 Therefore, before any charging system can be established, two important questions must be answered:-

- should charges for "water" service be firmly based on the use made of them?
- should charges be related as nearly as possible to the actual cost of providing the services in each locality or should they be equalised over wider areas such as river basins, regions, or even nationally?

5.13 Should the answer be that charges should be equalised irrespective of the benefit gained or the cost of providing the service, means other than a charging scheme must be devised to prevent the services being abused and to prevent excessive expenditure in certain "expensive" areas.

Public and Private Interest

5.14 Because of the vital public health and amenity interests of the community in the 'water' services, 'water' authorities have been given statutory regulatory and control functions. Among these are the Rivers (Prevention of Pollution) Acts, the Water Resources Acts, byelaw powers etc.

5.15 Through the medium of these powers 'water' authorities have a direct effect on private interests such as private water abstractors and private dischargers of effluent. They can indirectly affect the financial decisions of such interests. In some cases the latter can be influenced to make use of services such as water supplies or effluent disposal facilities provided by water authorities.

5.16 If therefore a 'water' authority is given such powers, and can also levy a charge for the service provided, the charging scheme must be devised so as to be reasonably equitable to the private interest: it should not discourage the private interest from making use of the service if it is in the general interest that it should do so.

5.17 Such a charging scheme could well conflict in principle with a policy decision about equalisation of charges as between one consumer and another.

Economy

5.18 One of the objectives of a charging system should be to promote economy in the use of services and in the use of water generally. Because water has been so cheap in the past there has been little incentive to economise in its use, but this state of affairs cannot last for ever. In recent years there has been some discussion about the possibility of restricting the growth of demand by financial means, for example by marginal charging. Almost all these systems depend on the universal metering of water supplies.

5.19 In the author's opinion metering of domestic water supplies cannot be justified on economic grounds until the stage is reached when the cost of installing, maintaining and reading meters is balanced by an actual and/or potential reduction in expenditure on the provision of water services. There is little evidence to indicate whether or not this stage has in fact been reached at the present time.

5.20 If water supply and sewerage services are included on one account and charged for in proportion to water consumption metering would govern much larger expenditure and the incentive to reduce consumption would be increased. Care must be taken however not to confuse the reduction in proportional cost of metering with actual or potential reduction in expenditure on water services.

5.21 In section 3 certain systems have been touched upon whereby a consumer can be given a measure of choice in his decisions about his consumption of what, which for want of a better word, has been called 'marginal' water. The most attractive of these systems is that whereby a consumer is made to reduce his marginal consumption only in a dry season. At all other times sources can supply all his needs without restriction. Water undertakers could be given powers to charge consumers penal sums for water taken in excess of certain prescribed amounts under drought conditions. Such a system, as has already been stated, would require universal metering for which the time may not be ripe.

Conclusion

5.22 Expenditure on water supply and sewerage amounts to well over 90% of 'water' expenditure as a whole. If all public 'water' expenditure were charged to these accounts it would make little overall difference to the average water consumer.

Before a charging system can be established political decisions have to be taken concerning (a) equity as between groups of consumers and (b) the way in which private interests are dealt with.

Promotion of economy in the use of services by charging systems is unlikely to be feasible until universal metering becomes economically justified.

6. CHARGING SYSTEMS

Range of practicable systems

6.1 It was stated above that charging systems should be designed to fit the organisation of 'water' services. This statement is only partially true. Methods of raising money to finance services can be considered independently of the way in which the money is distributed to meet the expenditure on those services. Nevertheless for reasons of tradition, acceptability, economy and public accountability the financing of the 'water' services wholly from general taxation or by a tax unrelated to the benefits gained can be discounted. However attractive the idea may seem, to consider financing 'water' services by a tax on beer, for instance, would be unrealistic.

6.2 Practicable methods of raising revenue range from the present system of a mixture of taxes, rates and charges, to an out and out charge for all services based on a single revenue account. Three examples are discussed below.

Revenue raised on an account for each individual service

6.3 This system would approximate to that in England and Wales before 1963. Separate accounts would be kept for expenditure on each of the individual services, water supply, sewerage and sewage disposal, land drainage, fisheries, navigation etc. Charges would be levied separately to meet the expenditure on each account; water consumers would pay for water supply expenditure by way of a charge, perhaps based on rateable value, dischargers of effluent would pay for the drainage services in the same way, those benefitting from land drainage works would pay in proportion to the benefit gained etc.

6.4 Additional expenditure such as that incurred in respect of regulatory and planning functions could be met by a percentage levy on each of the accounts, approximately in proportion to the benefit gained from those functions.

This system would be cumbersome and would be expensive to administer. A "consumer" could be presented with bills for charges raised on as many as five or six accounts.

6.5 Neither would the system be as precise or as equitable as might at first sight appear. The following are some examples of the difficulties that might develop:-

(a) Proper river basin management would ensure that the greater proportion of expenditure on water resources, e.g. river regulation works and river water quality improvement works would tend to be of general benefit and a quite arbitrary apportionment of cost between the various interests would have to be made.
Expenditure on water supply accounts would for very many years reflect past expenditure on water resource work.

(b) Private interests such as abstractors, dischargers of effluent, owners of fishing and navigation rights cannot readily be brought into the account. They may benefit from water resources works and they may incur expenditure to meet control requirements.

In the absence of an objective value for water in sources to provide a common yardstick (see section 2 above) there can only be an arbitrary allocation of costs to them and expenditure on their own services cannot be allowed for.

(c) Expenditure on sewage disposal is determined by standards imposed on the discharges of treated effluent. On grounds of equity there is a tendency to promote uniform standards throughout a river basin e.g. Royal Commission standards. Sometimes this is contrary to the true interests of river basin management. Isolating sewage disposal expenditure would tend to perpetuate uniformity and inhibit proper management of resources.

(d) By accident of geography, in certain river basins sewage disposal authorities have to produce a very high standard of effluent and substantially contribute to water resources. In other areas e.g. coastal districts, disposal authorities have only to meet nominal standards. It is extremely difficult satisfactorily to allow for this disparity when devising an equitable charging scheme to meet water resource expenditure.

(e) Considerable expenditure is incurred solely to meet existing amenity requirements or to provide added amenity. The apportionment of such expenditure to a particular account must needs be by rule of thumb.

Revenue raised on a limited number of accounts

6.6 This would be a modification of the present system.

The present river authority water resources account includes, expenditure on a number of diverse 'water' functions such as hydrometry, licensing of abstraction, expenditure on new works of all kinds. In principle this is an example of a grouping of accounts.

A charging system could be devised whereby expenditure could be divided between three accounts related to the three major expenditure items, water supply, sewerage and sewage disposal and the provision and control of water resources. The last named could include all items related to river work such as flood alleviation, fisheries and navigation.

6.7 As in the previous system revenue could be raised for water supply and sewerage services by means of rates or charges. Revenue for the water resources account could be raised by a system of charging for abstraction of water and giving a rebate for the beneficial return of effluent. The present river authority charging schemes achieve this in a rough and ready way but they could be substantially improved and refined given the necessary powers. Charges could be made for fishing and navigation services to produce the optimum revenue. The spread of land drainage costs amongst abstractors and dischargers on the water resource account might be sufficiently close to the present spread not to arouse considerable dissatisfaction.

6.8 Expenditure on regulatory or planning functions could either be divided between all the accounts in proportion to expenditure on each account or charged wholly to the water resource account. The former might be more equitable.

This system would be much simpler to administer than that mentioned above and few consumers would be charged on more than two accounts.

It escapes none of the disadvantages listed in 6.5(a) to (e) above.

Revenue raised on a single account

6.9 On the basis that every water consumer has some interest in promoting water resources, land drainage and amenity, all 'water' revenue could be raised in principle as a charge or rate on water consumers in relation to the quantity of water taken. There would have to be a varying scale of charges to differentiate between a private consumer who provides his own works of water supply and the consumer taking a public supply.

6.10 Because the charge would include for the reception, transmission and disposal of effluents, abatements would have to be made for those not requiring such a service. Additional charges might have to be made for the receipt and disposal of certain trade wastes if they proved more difficult to treat than the norm. As in the example above services such as fisheries, navigation etc could be charged so as to produce optimum revenue.

6.11 The schedules of charges would obviously not reflect the cost of the service to the particular consumer and the basis of revenue would in fact be as near to a tax as to a charge for the sale of water. Charges would be adjusted for such reasons as to promote optimum revenue or to promote the best use of available resources; not for such reasons as to reflect the cost of individual components of expenditure.

6.12 A single account presupposes a single financial authority for the purpose of collection and disposal of revenue; it does not necessarily mean one water authority. The French "Agences Financieres de Bassins" have such a function in a more limited context.

6.13 If however a single river basin authority were established a single account would have several advantages. It would make possible the optimisation of "water" expenditure to give the best benefit to all water interests in return for the least expenditure. It would avoid the difficulties mentioned in 6.5 (a), (c) and (d). It would have to recognise that the complications caused by the private abstractor and discharger and by amenity interests can only be dealt with arbitrarily.

6.14 The system would however make it much more difficult to determine the proper balance of expenditure between one function and another and, internally, separate accounts would have to be kept if only as a management tool. So the gain of simplicity may perhaps not be as much as is at first sight apparent. Real difficulties may arise in respect of accountability (see the following section).

Conclusion

6.15 None of the systems mentioned above is perfect and an ideal system will never be devised. The difficulty arises from the fact that water services, because of their nature, must in essence be paid for by a combination of charging for a commodity and of taxation. Charges are therefore bound to be arbitrary to a greater or lesser extent. When a scheme such as that set out in 6.3 above is examined in detail it becomes clear that in essence it is not less arbitrary than that set out in 6.9 above.

7. ACCOUNTABILITY

Dual accountability

7.1 Unlike most other services or commodities the "water" services have a direct effect both on public health and amenity. More than any other factor, pure water supplies and efficient main drainage have contributed to public health. Standards are being continually raised.

The public is no longer as prepared as before to tolerate unclean rivers, sewage filled ditches, continual flooding of low lying areas, excessive depletion of river flows, or the reservation of lakes and reservoirs solely for water supply purposes.

7.2 At the same time as public demands on the services are increasing, public concern about the actions of "water" authorities is growing. In other words "water" authorities have become accountable in the true sense of the word to the community at large as well as to their "consumers".

7.3 This dual role is reflected in the expenditure of 'water' authorities an increasing proportion of which is determined from outside their jurisdiction and on other than technical considerations such as those appropriate to the provision of a service.

There can be, and often is, a genuine conflict of interest between the two.

Accountability to the community as a whole

7.4 It was mentioned above that a considerable proportion of expenditure on "water" is undertaken for the benefit of the community at large. For instance the community may wish to see a river "cleaned up". To do this may involve expenditure under many headings including:-

River regulation works

Cessation of water abstractions

Sewage Disposal works

Trade effluent diversion works

River water quality improvement works

River channel improvement works.

7.5 In a 'perfect' system the cost of meeting the objective of clearing up the river would be presented to the community as a single estimate so that it would be weighed against estimates of cost of meeting other objectives such as the provision of new schools, hospitals, roads etc and a decision taken according to priorities for each. The existing system does not provide for a presentation of cost to the community in this way.

7.6 At the present time an individual interest such as a sewerage authority or a water undertaker tries to obtain powers to proceed with a scheme which will best serve the interests of its consumers. The scheme is considered in relation to the cost of similarly devised projects and to achieve objectives not directly related to the economics of the river basin as a whole.

Quite clearly charging and accounting schemes such as those mentioned in Section 6.9 above have a marked advantage as far as the community interest is concerned because it enables the best overall scheme to be put forward.

Accountability to the consumer

7.7 The consumer has a legitimate interest in the individual service that is provided. He is concerned that expenditure is kept to a minimum and that the standard of the service provided is no higher or lower than he requires. His interests do not extend beyond the provision of the service itself. For instance, if he is a discharger of effluent he has no financial interest in seeing the standard improved, quite the contrary; if he is a fisherman he will press for the highest possible standard of effluent with no thought for the cost.

7.8 In so far as the consumer is concerned with an individual service, systems such as that mentioned in section 6.3 may serve him best. He can see what money is being spent and have some influence on it. He can resist pressure by external interests to make him pay more.

7.9 To some extent this is an over simplification because everyone is a "water-consumer" of one kind or another and yet is involved in the community as a whole. But the 'local' financial interest is there nevertheless.

7.10 In the commercial field pricing mechanisms and competition between similar products allow for the expression of such interest. In the 'water' field, a true monopoly where a substantial proportion of the expenditure is determined by other than consumer criteria, there seems to be little hope of such mechanisms being of any benefit. (It should however be stated that they may have other uses, such as determining total expenditure, or the allocation of costs between different classes of consumer.)

7.11 At the present time the Secretary of State for the Environment has some powers to guard consumer interest in respect of water undertakers and the water resources work of river authorities. For instance rates and charges can only be levied within ceilings set by orders made by him. Nevertheless his freedom of action is constrained by the duty of water authorities to provide adequate supplies and their right to revenue to support that duty.

Conclusion

7.12 'Water' authorities have a dual accountability to the community as a whole and to the individual consumer. Depending on the view taken of their responsibilities the selection of charging and accounting system can be adjusted.

The consumer is already remote from some of the larger authorities but there is no prospect of pricing mechanisms being devised to enable him to influence the efficiency of the services offered.

8. INVESTMENT IN WATER

Internally determined expenditure directly related to services.

8.1 The greatest proportion of 'water' investment arises from the growing demand for water. The projects involved include works of water supply, source and distribution, as well as works to carry away and dispose of increased flows of effluent.

8.2 Until recent times no difficulty has been experienced in meeting these demands but as easily developed sources have become scarcer and pressure is being exerted to improve standards of effluents consideration is being given to ways of dealing with the situation other than by the provision of new source and effluent disposal works.

8.3 Some methods whereby demand can be restricted are mentioned in Sections 3 and 5 above. All involve universal metering which would be expensive to introduce and the implied controls on consumption would be generally unpopular.

8.4 Much can be done by way of improved techniques of operation of sewage disposal works, acceptance of rather higher probability of failure of water supply than hitherto, conjunctive use of diverse sources, improved systems of flood forecasting, promoting re-use of water within industry, reduction of waste within the water industry etc.

8.5 In the above ways the investment programme could be cut but probably not substantially and eventually an irreducible minimum would be reached.

8.6 There is less flexibility in another large block of investment for water mains, sewerage, and drainage works required to supply the needs of new development and redevelopment. Planning and investment decisions concerning such development are rarely affected significantly by water and sewerage considerations and the investment in the water and sewerage services must follow such decisions without fail. There may be limited scope for timing, for instance some surcharge could be permitted in existing sewers, rather less than satisfactory water pressure can be tolerated, limited flooding of low value areas can be accepted for a time. Nevertheless a time is reached when a programme of works has to be settled and the investment must be made.

8.7 Repair, maintenance and renewal works are primarily determined by the need to keep up the value of capital assets. Average expenditure in the long term must be maintained at a sufficiently high level to achieve this objective. In the short term there is considerable flexibility.

8.8 Spending departments have a duty to justify every item of expenditure with hard costings. Provision for the future must be sensibly assessed on the basis of the known facts and not on the whims of an individual. Wherever possible investment should be programmed to give flexibility. Capital investment to reduce labour or material costs must be fairly weighed not against arbitrary "capital per man" figure, but by means of careful estimates of total cost with or without that investment. Expenditure to maintain special waterworks standards must be properly weighed against actual financial benefits in public relations, improved labour reliability etc.

8.9 However, all these considerations and duties are internal to the investment decisions of individual "water" authorities and to their consumers. The investment programmes are mainly determined by technical and economic considerations.

Externally determined expenditure

8.10 An increasingly large proportion of investment in "water" is determined by factors outside the direct control of the individual 'water' authorities within a river basin.

River water quality standards are imposed in many cases to meet amenity requirements, or by non-revenue producing recreational demands, or by a combination of the two.

Cheaper sources of water supply are denied to water undertakers because of pressure by conservationists and water supply schemes are having to be amended at additional expense to include amenity or recreational features that bring no added revenue.

8.11 National and regional policies play an increasing role. At the national level Parliament and Government may press for action to clean up a particular estuary, or may exclude new reservoirs from certain areas, or may impose restrictions on certain types of expenditure.

At river basin level planning and local authorities increasingly take in interest in "water" and influence important investment decisions.

8.12 As mentioned earlier, these external influences often conflict directly with optimum investment decisions. For instance the location of a sewage works cannot be chosen to best "water" advantage or an exceptional standard of effluent may be required because of amenity considerations. A local authority may proceed with rural housing improvement or development in an area where it would be quite uneconomic to provide "water" or indeed any public utility service.

Alternative investment programmes

8.13 Almost all commercial investments are made as a result of selection from a choice of possible programmes of expenditure by the weighing of cost against financial benefit. It may not be generally appreciated that in a monopoly situation there is no purely profit making incentive to carrying out such an exercise because the benefit (revenue) automatically matches the cost. In some cases, where the profit is fixed in proportion to expenditure, most benefit can be gained by highest expenditure.

8.14 It is therefore necessary to "externalise", but how far should this go? Do we simply include benefits to those who, by means of rates, charges, licence fees etc, finance the 'water' services? Should the national interest be given a financial weight? For example should capital intensive schemes be preferred at times when unemployment is high in the construction industry; should high standards of effluent be produced to permit game fishing when lower standards of effluent would be amply sufficient for coarse fishing; should a financial weighting be given to the preservation of a rare colony of plants at a suitable reservoir site.

8.15 A river basin authority could take the view that essentially the optimum investment should be that which increases present and future total revenue requirement least. In comparing programmes of works the only external benefits that should be applied would be those which could be measured in terms of potential revenue. In this way a true picture could be obtained of the actual cost to the authority of any investment decision.

8.16 An alternative approach would be for the authority to attempt to set out all the investment programmes available to it and to ask the community to decide which suited it best. Each programme would include an evaluation in financial terms of the external costs and benefits.

8.17 In practice the course taken must include elements of each approach. Authorities must take into account the acceptability and possible external benefits to the community of any investment decisions yet they cannot abrogate responsibility for those decisions.

The art of evaluating external benefits cannot be claimed to have reached any degree of precision and taking such benefits into account will, at least for the foreseeable future, remain a 'social' rather than an 'economic' choice.

8.18 Nevertheless every effort must be made to achieve a system whereby the cost to an authority of its alternative investment programmes and, separately, externally imposed costs are presented and examined before the final choice is made. In this way the community could best be made to appreciate the true cost of imposed restrictions. The separation of 'water' costs into individual service accounts prevents 'water' authorities from doing this at the present time.

8.19 The analysis of costs may lead to the selection of a 'best' programme in which excessive fluctuations of expenditure would occur from year to year. It might be possible to phase expenditure more efficiently or an alternative is to amend the objectives of the programme and make a fresh analysis of alternative programmes. An example could be a large scheme which only becomes feasible when the area to be served by the scheme is extended to cover whole regions. The effect of scale is to reduce the relative size of increments of expenditure and to bring forward the date when the full benefits of each increment materialises. Another way of achieving spread is to consider all river basin 'water' expenditure in one programme.

8.20 It is fashionable and also government policy that in comparing programmes of investment the expenditure should be discounted to present values. It is undeniable that £100 spent in ten years time costs less than £100 spent today. Such discounting must be applied both to expenditure and to any "external" benefits that may be included in the account (see paras 8.15 and 8.16 above).

8.21 The fundamental difficulty is to decide on a true discount rate and the effect of this is crucial. For instance the present cost of a sum of money discounted fifteen years at 5% is approximately double that of the same sum discounted for the same period at 10%.

One school of thought refuses to take inflation into account on the grounds that current long term interest rates already allow for prospective inflation. Those who adjust the rate to allow for inflation deny this because of the influence world interest rates, political decisions concerning cheap money and other factors can have on present interest rates. In any case they claim that the operation of loans pools make nonsense of the use of current interest rates.

A related controversy concerns the financing of capital expenditure from revenue rather than by loan.

8.22 All the layman can do is to realise that at best comparison of present values can only give a general indication of the relative financial merits of alternative programmes of works.

Several discount rates should be tried out and only those programmes that consistently seem best should be included on a short list. The final decision could then be made using hitherto unquantified criteria such as potential amenity or political factors or perhaps applying plain prejudice. The result is not likely to be far wrong.

Conclusion

8.23 It is necessary to distinguish between internally determined and externally determined investment. Some way must be found of presenting to the community the cost of alternative investment programmes and the cost of external limitations affecting those programmes. The present system cannot satisfactorily achieve this.

discussion

CHAIRMAN: C. H. SPENS, CB, FICE, HonFIPHE, FIWPC, FIWE, FGS
Consultant, Rofe Kennard and Lapworth

The CHAIRMAN said it was a pleasure to be in the Chair for the paper introduced by a former colleague, Mr S.F. White. Mr White had worked for nine years with consulting engineers, followed by six years as resident engineer responsible for two major water supply schemes. Mr SPENS as Chief Engineer with the Ministry of Housing and Local Government had recruited Mr White as an engineering inspector. He had risen to the rank of Senior Engineering Inspector and had now changed his title, although not entirely his work, to "assistant director (Water Engineering) in the Department of the Environment".

2. Mr White wrote his paper in October 1971 before the Government announced its intentions for the future of the Water Industry, as disclosed in the circular 92/71 of the Department of the Environment issued in December, by which after April 1974 water will be a commodity to be sold, to be acquired and disposed of at an economic price with finance raised by the Regional Water Authority without loan or grant from Central Government.

3. Mr S.F. WHITE commented on the title of the paper. The words 'economics' and the 'economist' meant all things to all men. He had many economist colleagues and friends and had a great respect for them, but took exception to the statement made in Session 1 that engineers did not want to get involved in economics and finance and subjects which were not strictly engineering. In fact engineers must get involved with all aspects of water management or they would find themselves to be tools of other people. Public health engineering included water supply, sewage disposal and river authority work; and there were several representatives of all these functions at the Conference. The future would show the need for a multi-purpose engineer to go with multi-purpose water authorities.

4. The paper was concerned with the principals of financing of water services and of methods of achieving overall economy and would enable the Conference to discuss how the provision of finance for the water and sewage services fitted in with that of public services in general. The determining of priorities for water expenditure in the broad sense of the word in relation to all other expenditure was of interest at the present time when the organisation of water services was in prospect. Any opinions expressed were strictly personal and not necessarily those of the Department.

5. Mr WHITE was interested in attempts that had been made in several countries to design systems of finance whereby water services could be brought into the fold of standard commercial management and practice. So far he had seen no convincing evidence of success. Historically water had been treated by the community as a public service such as education. Water was a true monopoly. The urban consumer at least was fully dependent on a piped supply and on main drainage. His health was a matter of general interest and it was in the interests of the community that he was provided with these services. Other public utilities were in an entirely different position: gas, electricity and transport services were desirable but there were alternatives, and again no harm came to the community as a whole if an individual was not provided with these services. Water was analogous to the education and medical services in each of which expenditure was determined by social factors. He asked the Conference whether it was agreed that water was quite unlike any other commodity and it would be unrealistic to think of it as a consumer product. To some extent this question was tied up with the determination of the value of water which must be related in some way with the value of the water in source.

6. Mr WHITE referred to the determination of expenditure. How was the level of expenditure to be determined in a situation where much of the expenditure was external to strictly consumer considerations? It was possible to keep overall expenditure (i.e. total expenditure by the average user of water services) down to a minimum having regard to the accepted standard of service. This might mean that the person taking a supply of water may have to pay less wile a person discharging effluent may have to pay more, but only when internally determined expenditure was concerned. Such an approach would not help to decide how much or when money should be spent in, for example, cleaning up a river or an estuary for amenity reasons.

7. A further problem touched on in the paper was the difficulty of introducing into the balance sheet costs incurred other than by public water authorities. The public authority could for example reserve for itself cheap sources of water, leaving the more expensive resources to be developed by private users. Cleaning up a river could perhaps be achieved by imposing excessively high standards of effluent on private industry without corresponding expenditure on sewage treatment works.

8. It was probably accepted that maximising profits was not likely ever to be the purpose of changing policy. This apart there were a number of possible objectives some of which could be initially opposed, for example:-

- economy in the provision of services
- economy in the use of services
- equality as between one type of consumer and another
- equality as between consumers in different areas
- consumer choice in the standard of service provided
- ensuring that private interests (e.g. abstractors or dischargers) played their part and made the best use of resources.

Some of these objectives would be set by purely social and not consumer considerations and apportionment of cost brought about by the charging system must necessarily be arbitrary. Nothing would be gained by complication in an attempt to reach precision.

9. Charging systems were allied to accountability: how should water authorities strike a balance between their duties to the consumer and the community as a whole? Such a balance was unlikely to be achieved by an adjustment of the composition of authorities. It was, however, probable that the financial system could be designed to help. It was highly unlikely that pricing systems could be devised which would enable a consumer to influence the overall efficiency of a monopoly water authority.

10. Mr WHITE quoted from the explanatory memorandum on the Government's proposals:

"Paragraph 35: The Government agree in principle that apart from Exchequor grants for specific purposes the revenue to enable the new Authority to discharge their main functions should come from charges for the services they provide. They also consider that the idea of a combined charge to cover all functions carried out by the Regional Water Authorities deserves to be explored further. The Department will carry out consultations on the manner in which progress can best be made towards these objectives. It will be necessary to take account of the financing of new Authorities in the discussions on the future financing of local government." That was a clear statement of intention that the Department of the Environment wished to consult on these matters: the views of engineering associations should be clearly heard.

"Paragraph 37: The administrative costs of pollution control at present met from a precept levied on local authorities will in future be treated as part of the overall cost of providing and reclaiming water. The charges levied under the Water Resources Act 1963 on abstractors of water from surface and underground sources will be retained alongside the charges for piped water. Those categories of abstractor who are exempt from charges under the 1963 Act will continue to be exempt." That meant that in effect pollution control expenditure of River Authorities would be taken as part of the general expenditure of the Regional Water Authority, but otherwise the methods of financing the Authorities in these respects would remain much as at the present.

"Paragraph 39: It is intended there should be statutory safeguards to ensure the costs of the Regional Water Authorities' operations are distributed equitably between different categories of water user. The Government do not however think it appropriate that Ministers should concern themselves with detailed levels of charges." The latter sentence was a declaration of intention to abandon the controls that were at present exercised on charges levied.

11. The wording of paragraph 39 was significant because the cost of Regional Water Authority operations were to be distributed equitably between different categories of water user, e.g. the discharger of sewage effluent and the trade waste discharger, who would be a private person, and this could present difficulties.

Clearly much remained to be settled, and Mr WHITE hoped the discussion would highlight matters where engineering advice would be of value.

12. Mr R.L. KLEIN said Mr White's excellent paper gave a very comprehensive and wide ranging view of water management in its widest sense. The problems involved were varied and complex with no easy answer.

13. Mr KLEIN was surprised to see in the paper that present worth or discounted cash flow techniques were described as 'fashionable' which suggested something illogical or whimsical, liable to rapid and unpredictable change. However it was the logical nature of these techniques which made them particularly valuable both to engineers and planners. Any economic study involved gazing into numerous crystal balls such as the future demand for the particular product and future interest rates. Although the selection of the appropriate discount rate was difficult, this could be overcome up to a point by the comparison of alternatives over a range of discount rates. A realistic decision could then be made.

14. It had been suggested that economic analysis was not concerned with pounds or dollars but with units of constant purchasing power, and that therefore inflation was irrelevant. Certain components of cost, such as labour, tended to increase in real terms whilst others (electricity for example) decreased, but in practice it was difficult to take all these opposing trends into consideration. Capital investment in water supply was particularly high in relation to revenues and it was essential to treat capital expenditure realistically in any analysis. Water had been cheap in this country, largely because our forefathers were generous in provision for the future, and there had been little need in recent years for really large capital investment in water supplies. This situation was very rapidly changing. The need for major capital works involved looking further afield for water which would be more expensive. The cost of money was increasing alarmingly, and consequently the capital element in water cost was becoming the major rather than the minor constituent. Even in England water rates approaching 50 pence per thousand gallons were being introduced in certain areas which were short of water such as Suffolk, Norfolk and Essex.

15. With this in mind Mr KLEIN felt that the need for universal metering in this country was not far off. Nobody complained about the metering of electricity, gas or telephone, and although these particular services had not the same social elements of benefit to the community at large, in the modern world they were almost as essential as water. In the past the annual bill for water had been small in comparison with bills for other utilities, and the cost of metering would have been disproportionately high, but it would not be long before the water bill approached that of other utilities. Water supplies were universally metered in the United States and in other parts of the world, and the restraining effect of metering was well known. It was not difficult to imagine the increased use of electricity, gas and the telephone if these services were not metered. Malta was a good, if rather exaggerated, example of the logical application of a system of metering. In this country, where natural water supplies were very limited and had to be supplemented by the use of very expensive desalted seawater, the first ten gallons per head per day was supplied at a rate of 10 pence per thousand gallons and water above this was charged at 75 pence per thousand gallons. This showed that metering could be used to serve three purposes: to reflect realistically the actual cost of providing increasing supplies of water: to give the consumer a choice of using water for marginal (or non-essential) purposes: and to ensure that the poorer section of the community were supplied with their essential needs at modest costs.

16. Mr G.L. ACKERS said the paper was wide ranging and stimulating but had two principal drawbacks: it accepted that the interests of a river basin could best be served otherwise than by competition of the several interests, and it assumed that it was not possible to place a value on water. Management on the basis of these two assumptions leads to all the dangers associated with autocracy or bureaucracy. The autocrat or bureaucrat might be right or wrong, and without the conflict in real terms of opposing interests and without being able to ascribe real money values to the water in its different uses and different appropriations it would be a matter of opinion only as to whether he was right or wrong. Mr ACKERS quoted Adam Smith and said that it was essential that the judgements of technical advisors and policy-makers were put to the test of competition. It was difficult but nevertheless essential to provide adequate safeguards and to do so without stultifying progress or perpetuating mistaken ideas.

17. Mr White proposed that the water management service be paid for partly by selling water as a market commodity and partly by taxation, which raised the spectre of part being used for general revenue in much the same way as motor tax. Mr White

had emphasised that water had no intrinsic value in money terms. The question of ownership seemed to be a red herring in the context of cost for purposes of economic appraisal, and it was necessary to avoid confusing value with cost. The value of water of a given quality in a given situation was like the value of any other commodity, namely what it would realise in money terms, but this if known, would not be of much use if costs were not separately accounted. Mr ACKERS thought there were very few areas where cost could not be assessed at least within a reasonable tolerance. One way of looking at the limiting cost of water at a given location was the cost of desalting seawater at the nearest appropriate spot and then transporting it to that location.

18. A great deal of thought was given to the treatment of sewage. Little was given to the necessity for water-borne sanitation in the form now adopted, which mixed everything together and then tried to treat or separate it. There was a need to examine methods of conveying waste and the degree to which it should be separated at source.

19. In reply to Mr Klein, Mr WHITE said that discounted cash flow techniques were being used as standard practice of the Ministry, but he had meant to imply that they were being used in ways they were not meant to be used.

20. Mr WHITE had learned to avoid, wherever possible, committing long term future expenditure because of the uncertainties involved. In many cases it was possible to phase capital projects and programmes of expenditure in such a way that decisions need only be taken affecting the immediate programme of works.

21. Universal metering was a very vexed question and Mr WHITE repeated that he thought metering of domestic water supplies could not be justified on economic grounds until the cost of installing and maintaining meters was balanced by an actual or potential reduction in expenditure on the provision of water services. There was a possibility that water consumption in Malvern was of the order of 15% less than similar places elsewhere. In this case the equivalent saving did not justify metering, but the Department had persuaded the Water Board to maintain the system as a research exercise. The annual cost of installing a meter would be of the order of £2 per house, and the Department had no evidence to suggest that there were any cases where this expenditure would be economic.

22. In reply to Mr Ackers, Mr WHITE asked how competition could be introduced in a situation where there was an absolute monopoly.

23. Mr G.F.G. CLOUGH agreed that it was difficult to get estimates of industrial waste disposal costs. By rough estimating procedures he had found that in individual companies this cost varied from less than 0.1% of production costs to more than 12%. If manufacturers in the latter group were obliged to pay for full effluent treatment, the selling price would have to go up correspondingly. In a market competing with imports, the product might then be too expensive to survive. Should the country accept that the industry would die, subsidise it or put a tariff on imports equivalent to the cost of treating the effluent?

24. Mr CLOUGH suggested that it would be possible for a contractor to operate water supplies on a concessional basis annually and to make profit out of the difference between the charge for the water and what he paid for the concession. He was not in favour of this possibility.

25. Mr WHITE agreed that there were industries where the waste treatment costs were particularly crucial. The community could say 'we want this industry; we are going to subsidise you'. Rolls Royce was rescued in exactly this same situation. In his view if there was to be a subsidy it should be direct but in any case the effluent should be treated to the required standard. In reply to another query from Mr Clough, Mr WHITE said research and development was essential but it was not easy to determine the best balance between basic research and development.

26. Mr R. WOOD argued that charges for the treatment of industrial waste waters should be quite separate from water supply. The most powerful weapon to control trade effluent discharge was economic. If the community were willing to subsidise the trader because this charge was high, the community should do this by taking complete charge of the pre-treatment plant at the factory.

27. The CHAIRMAN said that there were very few industries where the cost of water had any material effect on the cost of the product as compared with other establishment charges. Examples were railway industry, one or two paper manufacturers and a few chemical works. How would Mr Wood deal with a factory which was discharging a filthy effluent to his sewers? Mr WOOD said that if the community in one way or another must subsidise this factory, then the local authority should take over the responsibility for the treatment of the waste at the factory. Mr WHITE

considered that the factories should be made to treat their effluent to the required standard, but if the factory would become bankrupt and the community decided it should be kept going, the factory should still pay for treating the effluent and putting the requisite works in, but the community should subsidise it in other ways.

28. The CHAIRMAN asked for opinions about the value of crediting an industry or a local authority for the return of used water to the river and debiting if it was not up to the standard of the river. Would charging for water, which was an extremely complicated issue if the sewerage charge was included with the water charge, be made easier by having a multi-purpose authority as against single purpose authorities? There was room for discussion as to whether it was possible and right in this country to sell water as a commodity or whether it was so linked with public health that it should not be sold at an economic price.

29. Mr F.J. MACHON said that research should lead to better ways of doing things, and the solution of new problems. The Rothschild Report suggested that in research there should be a relationship similar to that between a supplier and a customer, and concluded that this meant that the customer must say what he wanted. Mr MACHON thought this was the wrong conclusion. In commerce it was the supplier who decided what the consumer wanted, and offered it to the consumer; if the supplier was right the consumer bought it and the supplier prospered; and if the supplier was wrong the consumer did not buy it and the supplier must learn or go out of business. That was the kind of relationship which should be maintained in research.

30. The purpose of metering domestic consumers was said to be to curtail the consumption of water. It might do this, although there was little evidence that the consumption of water was elastic with price. The total amount paid for water rates was so small that few people knew how much they paid per year, and would not in practice vary their consumption in response to a small price change even if the payment were related to the amount consumed. To reduce the consumption of water other ploys would generally be found much more effective against cost than the introduction of meters: for example, systematic control of wastage from the distribution system, and modest public relations programmes. The major effect of introducing domestic metering might well be to establish a relationship between consumer and water undertaking much more like that between retailer and customer. Such a change would probably tend to accelerate, rather than reduce, the increase in consumer demand. Domestic metering should not be introduced without first defining its purpose and deciding whether it was the best way of achieving that purpose.

31. Mr WHITE said that he had dealt with metering as a mechanism for determining charges rather than as a means of reducing consumption. In one possible system for instance metered charges could be low in a year when water was plentiful, and in dry summers charges could be high. If such a system reduced consumption it would be an indication that people did not wish to spend any more on new sources to tide them over a dry summer. If on the other hand it did not reduce consumption, it would be an expression of opinion by the consumer that he was prepared to have more money spent on new sources.

32. Mr J. VAN WELY referred to one of the few industries where the cost of water and effluent was severely affected, paper making. There were 285 paper mills in this country and the average cost of providing plant for effluent treatment was in the region of £150 000 to £200 000. The Swedish Government recently subsidised the effluent treatment plants in Sweden to around 75%. Consequently the cost of the product had to be increased in this country while they could stabilise the price in Sweden. As a result there was an enormous import of paper into this country, and consequently the closing down of paper mills and redundancies. The Government should look into this and subsidise certain industries. The CHAIRMAN commented that it was quite clear that the paper industry here was obviously working in unfair competition with Sweden. Perhaps when we entered the Common Market this would sort itself out. In reply to a question from Mr White, Mr VAN WELY said the legislation was new and he thought the Swedish Government made a direct subsidy to the firm.

33. Mr P. RAMSDEN had noted that in paragraph 5.2 of the paper no figure was included for trade effluents as such, although no doubt the cost of reception and treatment of trade effluents into sewers was taken into account in the figure of £225 million. What was the cost of trade effluent plant installation including maintenance and operation, either for pre-treatment for sewer reception or pre-treatment for river reception? Mr White appeared to consider that industry in this country had a raw deal as far as water was concerned, and the Conference had already discussed whether a community ought to subscribe to trade effluent treatment costs to keep a factory in operation. Industry

already in many instances paid for more than it received. Industry as a whole paid higher rates than the domestic rate which was reduced by 10% to 15% through Government subsidy, and an industrial concern received no direct benefit from substantial factors in the genera rate such as education, welfare and housing. In the River Trent, which served heavily industrialised areas, at Trent Bridge, Nottingham, there was about eight times as much effluent from sewage works as there was industrial effluent (if cooling water was disregarded). If the industrial proportion of the sewage flow was 40% there was about a 50-50 balance between domestic water usage and industrial water usage. There was a case for investigating some means of recovering more money from the domestic water consumer.

34. Mr WHITE said the figures in his paper were only approximate and were included to show the variation in the overall cost of services. He had not meant to imply that he thought that industry in general was unfairly treated. In some cases the opposite applied; a large industrial effluent discharged under an agreement many years old had been an undue burden on the sewage disposal account of a small town. The sums of £230 million, £225 million and so on, did not reflect in any way who paid for the expenditure: it could be private individuals, or industrialists through general rate.

35. Mr T.H. CARTER suggested that the method adopted for charges would to some extent be resolved by the internal structure of the Regional Water Authorities. If they were sectionalised, each individual section would be accountable for its expenditure, and the total for the section could be collected separately. On the question of debiting or crediting the dirty water, there was a need for a system within the new Authorities for appeals against charges. Mr WHITE saw no reason why a similar system to that dealing with charges for abstraction should not be set up. An abstractor could object to the proposals for charging under the Water Resources Act and the Minister could amend the charging scheme.

36. Mr P.J. COWIE suggested that competition came into this, for when an industrialist wished to set up a new factory or extend his factory, he would consider the availability of water if that was one of the things which he needed. He would check the likely cost for his water and waste disposal and if he found that one authority seemed to be charging too much for his water, he could explain to them that he would go elsewhere or not expand his factory. In effect he would either ask and obtain a subsidy or go to a cheaper authority. In this way competition would be maintained.

37. Mr D. SAUNDERS said there would be a certain amount of inequity because the regions with the main problems of pollution were in the main the old industrial areas. Had priorities for expenditure in those areas been studied? The Regional Water Authorities would be very powerful. Who would determine the priorities within a region? For example, if several towns within the region wished to expand, which town would get priority and who would determine this priority? Mr WHITE replied that in the past water services had had only a small influence on major planning decisions; the attitude had been that water was a service that had to be provided regardless. The CHAIRMAN said that for water the final arbitrator would be the Regional Water Authority. There might well be appeal to the Department of the Environment in certain cases. Before main planning decisions were taken an approach would be made to the Regional Water Authority as to whether water could be provided, because there might be certain industries needing a great deal of water which could not be supplied economically.

38. Professor G.C. BROCK referring to the previous speakers' concern about the fairness of pricing, said that taxation was seldom intended to be equitable between the people from whom money was taken and the objects on which money was spent. Taxation was raised from those people who would give it with the least objection. The same principle applied to water, since the supply of water was a monopoly, and the people who sold water (if we came to the stage of having it sold as a commodity) would devise tariffs which would maximise the money that they received. The tariffs would not be based on equity, but to bring in most money.

39. The CHAIRMAN said that because we had an inequitable tax situation, there was no need to perpetuate it. It was usual under the Water Resources Act 1963 to spread the charge for development of resources and abstraction over the whole area irrespective of whether one particular part of that area be developed or not. This would presumably be continued throughout the very large Regional Water Authority. Over a short period much of the charging was inequitable, but over a long period it generally worked out about all square.

40. Dr D.E. WRIGHT referred to paragraph 3.11 of the paper and suggested that eventually the cost of supplying water had to be increased. All 'essential' water could be supplied at a 'nominal' price, but above that level there must be some sort of differential charging policy. Mr WHITE said there were other possibilities. For instance drinking water could be delivered with the

milk, and the water in the mains could be returned sewage, treated to an acceptable non-potable standard. This would keep the cost down almost indefinitely and there would always be plenty of water. Whether this would be acceptable to the community was open to debate. Mr WHITE did not think a marginal system need be introduced before the end of this century. Supplies of water would be sufficient well into the next century at a reasonable cost and still probably cheaper than the cost of distilling seawater at that time.

41. Mr D.A.D. REEVE wanted the new Regional Water Authorities to be fully consulted on planning matters, but would be unhappy if these Authorities sought to exercise constraints on planning in any widespread sort of way, as this was not their function.

42. On the question of charging for water, Mr REEVE said that discounting Central Government sources, there were only three ways of collecting money for this sort of purpose from the public: directly from the rates, indirectly from the rates by precept, and directly from the client or customer. The first of these was presumably unacceptable because the Regional Authorities would not be sufficiently closely associated with district councils. Precepting authorities were unpopular even now many have a fairly large representation from the local authority membership. In some cases they had 100% membership from local authorities, and were still unpopular; there was a degree of remoteness that members did not always like. The direct charge to the customer was really the only sensible way of raising the necessary income for these Authorities. Even if the functions were distributed among single-purpose bodies, then the single-purpose bodies should combine for the purpose of obtaining their income.

43. Regarding charges to industry, the suggestion of a penalty and a bonus system was very attractive. There was no reason why the present trade effluent charging scheme should not be adapted to this sort of formula; it might be a first class and very attractive idea. The CHAIRMAN said this proposal was discussed by the C.A.W.C. before the Water Resources Act in 1963 in relation to return to the river, although not with regard to returns to sewers. It was rejected purely for administrative reasons.

44. Mr WHITE quoted from the Department of the Environment Circular 92/71:

"The revenues to enable new Authorities to discharge their main functions should come from charges for the service they provide."

45. Mr WHITE thought it would be difficult automatically to take out of industry's hand the right to treat direct discharges to meet an approved standard because industry had so much more flexibility than a public sewage disposal authority. Industry could change its process and eliminate its trade waste altogether, it could re-use water; it could treat partially or wholly, it might be able to discharge a proportion of almost untreated waste to a stream without harm and thereby promote economy in sewers and sewage treatment works.

46. Once such a right had been established the question arose as to the control required. The control could not be purely financial otherwise industry might consider itself justified in severely polluting a stream and paying "compensation" for doing so. Nevertheless there might be scope for a limited penalty-bonus scheme of a somewhat different character to that of the present schemes governing discharges of trade effluent to sewers. Mr REEVE and Mr WHITE agreed that it might be possible to pay a discharger who returned water to a source and who benefitted the source in doing so.

47. Mr E.P. ISZATT referred to the reported subsidy in the Swedish paper industry in respect of effluent treatment, and the significance of industrial wastes and the costs of processing water in industrial development. In relation to the viability of British Industry and our forthcoming entry into the Common Market, what was the Continental practice generally in relation to costs of processing industrial water, and was the practice of hidden subsidy on the Swedish pattern more widespread than was generally recognised in Britain?

48. Mr WHITE knew about German practice which varied from region to region. As an example he quoted two public authorities that had been set up to deal with specific catchments. The membership of the Boards consisted of industrialists and sewage disposal authorities in proportion to the volume of effluent discharged and consequently in proportion to the apportionment of costs. The authorities took over responsibility for transmission of the effluents, built treatment works, and apportioned charges according to the relative cost of dealing with each discharge. The system worked well and industrialists felt they had proper representation. It had snags because it was solely "discharge" and not "resource" orientated, and it had the disadvantage that certain watercourses were set aside as "sewers".

49. Mr R.S. ANDERSON suggested that Malta's two-part charging system would unnecessarily

discriminate against the lower-paid group in that it would take away perhaps the one single thing where he could still equate himself with somebody richer. Mr ANDERSON was opposed to government subsidies to industry because ratepayers and taxpayers were not willing to subsidise shareholders. Shareholders could choose whether to put their money into an industry or not, but taxpayers could not choose whether to pay taxes or not.

50. Mr WHITE said that with two-part charging the rich man would not benefit more than the other. The purpose would be to provide the poor man with essential water at a minimum, perhaps a subsidised, cost, but anything more than that he would have to pay for.

51. Mr V.H. LEWIN said that some 50% of the flow to sewage works was derived from water used by industry. Industry also lost water by evaporation as steam and discharged slightly sullied water, thermally polluted, direct to streams. They should be charged a proper price for all such waters. If this were done it would provide the incentive for industry to make further substantial economies on water usage. This could readily be done using presently available technologies. The CHAIRMAN pointed out that since the Water Resources Act, industry had made tremendous strides throughout the country to re-use and re-cycle their water, partly on account of cost but also by exultation of the C.B.I. who had worked tirelessly to persuade industry not to put water down the drain.

52. Mr D.J. ATKIN thought that the indiscriminate use of the word 'consumption' contributed to the dilemna on the question of equitable charging. Strictly only a proportion of domestic and industrial usage was actual consumption. Water was a medium of transportation, not a commodity. Consumptive use in the strict sense only applied where the water was evaporated. It was important to charge for the use of water as a transportation medium. Then the alteration in the condition of that medium could be studied; the concept of debit and credit aimed at this. The CHAIRMAN could not see what difference was made by considering water as a transportation medium. Mr ATKIN said that as regards the domestic consumer, metering would measure the amount of the commodity and it would be reasonably equitable to assume that the condition in which he returned it into the cycle would not differ significantly from consumer to consumer. The only variant would be in the amount used. As regards the industrial consumer the concept of charging for water as a transportation medium avoided the difficulty of charging for a large abstraction in terms of volume when all that industry might do was to put it back in as good a state as it began. It also left industry its own freedom of action to determine the condition in which to return its water. The CHAIRMAN thought this was quite sensible from the point of view of industries, and of course all industry was metered anyway.

53. Mr J.H.J. WATSON said that the new multi-purpose Authority would be responsible for the whole of the water cycling, and as such would be judge and jury of everything it did. Therefore, there was no real reason why it should attempt to economise other than from public pressure. In the last ten years or so the River Authorities had been able to force local authorities to improve sewage treatment works.

54. Mr WATSON next dealt with the use of water. The use of meters had been put on one side because of economics, yet in Malvern there was a 15% reduction in water. It had been suggested that loss from mains ran into not just 10% but probably to 50%. Water supplies increased by 3% per year, and it was important to discover how to use water more economically without loss of amenity or value to the consumer. If only metering were to reduce water supply by 15%, there was five years of the increase provided for. Industry used two-thirds of the total water supply, and Mr WATSON's own experience was that once tackled over trade effluents the first thing industrialists looked at was how much water they used. With re-cycling and so on industry had made a great contribution to water reduction, but he would like to see more attention paid to reducing the use of water which would bring about economies in capital expenditure for a number of years.

55. Mr WHITE had no doubt that water could be used better. The figure for wastage generally used in the Water Industry was 15% on average, but this had to be related to the cost of saving that water. Many water undertakings had spent a great deal on waste detection and prevention, and found that the cost did not justify the saving they had achieved. It might have been better to have spent the money on new resources.

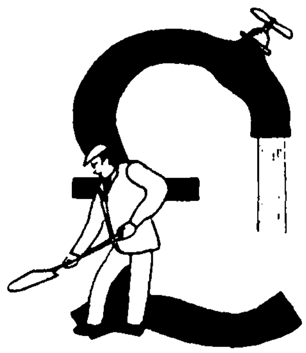
56. An objection to multi-purpose authorities was the combination of the control function with the spending function. This argument could equally be used in favour of multi-purpose authorities: the best value for money could not be produced without a combination of the two functions.

57. Mr R.J. AXTELL referred to the debit and credit system. If an industrial concern put into a sewer the same standard of water that it had obtained, theoretically the credit would be equal to debit, but the authority had still to provide hydraulic capacity at the treatment works.

58. The CHAIRMAN thought Mr Axtell had over-simplified the situation. Nobody had suggested that because water was returned in the same state as it was taken out then nothing should be paid, although this was very nearly so in the meaning of the Water Resources Act charging scheme. Administrative charges, and the hydraulic costs and any other costs would have to be met. Nobody had suggested that 100% be cast off the charge because the water was put back clean. The CHAIRMAN favoured Mr Reeve's plan, relating to the standard of the water in a river as decided by the Regional Water Authority. Above that standard an effluent would benefit the water authority; below that it would reduce the quality. On the one hand a credit was due and on the other hand a debit, but it would not be 100% credit.

59. Councillor F.D. BURT said that his water bill was twice that of his contribution to sewage disposal on the rates. He remarked that No. 3 Authority would extend from Bristol to the Humber, and many of the members would have to travel at least 100 miles to get to a meeting. Would this involve erosion of democracy or greater efficiency?

60. The CHAIRMAN thanked Mr White for his paper and closed the Session.



D. ANDERSON & M.W. ASKEW

some economic aspects of industrial waste treatment plant design

1. INTRODUCTION

The sole motivation of industrial management is to ensure that a company is profitable. In this, the second half of the twentieth century, profits have to be achieved with humanity and a social conscience. Thus it is that a production complex has to be considered in its entirety, from raw material in, to product and waste out. The contributing costs from all variables have to be managed to yield the optimum results for the company. In the past this has not always been achieved, with the unfortunate result that some companies have neglected to meet statutory obligations on quasi-economic grounds.

We are not concerned in this paper with the technical bases for process or plant selection other than to draw attention to the importance of systems analysis. Rather, we have attempted to outline the basis and practical implications of those considerations we have found of importance in arriving at optimum designs. Neither the technical nor economic merits of alternative approaches can be evaluated in isolation and mistakes can easily be made by non-specialist management in both areas.

2. Problem Classification

Problems of industrial waste management are at once more complex and capable of more flexible approach than are those of sewage treatment. The essential difference is that the nature, composition, volume, manner, location and timing of wastes production are all to some extent controllable by the producer, who is therefore in a position to optimise the problem itself in terms of production economics. Moreover, the producer is able in many cases to exercise some degree of selection both as to the wastes to be treated and the treatment standards to be met. Thus he may elect to discharge the whole of his wastes to sewers for treatment in a municipal plant; to carry out some pretreatment before discharge; to selectively treat some waste streams and discharge others untreated; to treat part or all of his wastes for discharge to a watercourse, or to treat some or all of his wastes to standards suitable for his own re-use combined with ultimate disposal to either sewer or watercourse.

The selection of a particular course of action in given circumstances is therefore a highly specific matter. Specific not only to the type of effluent and its manner of production, but to the circumstances of the production and the influence of additional factors as a function of overall production economics.

3. Treatment Standards

In assessing the viability of alternative courses of action, it is important to be able to relate them to defined end results, in this case the standards to be met. Such standards may be externally imposed by statutory bodies or internally imposed by the requirements of process considerations where water is needed for re-use. They are inflexible in the former case, but not necessarily so in the latter where economic optimisation may require internal compensation for the use of water less than the highest quality.

Whatever the detail of the case, however, it behoves everyone who has responsibility for establishing treatment standards to understand clearly what the imposed limitations mean, for they can affect not only the well-being of river and water management regimes, but also the profitability of industry. By the same token, industry must appreciate that good management requires the provision of correctly designed and costed plants to deal with optimised effluent conditions.

One can do no better than quote Klein (1) on the requirements for treatment standards applied to rivers but of general validity :-

(i) The standards must be capable of precise definition.

(ii) Reliable methods of analysis must be available for determining whether the effluent or test sample infringes the standard.

(iii) The standard should be neither too lenient nor too stringent since in the former case some pollution of the river may occur and in the latter unnecessary expenditure may be incurred by the traders or local authority.

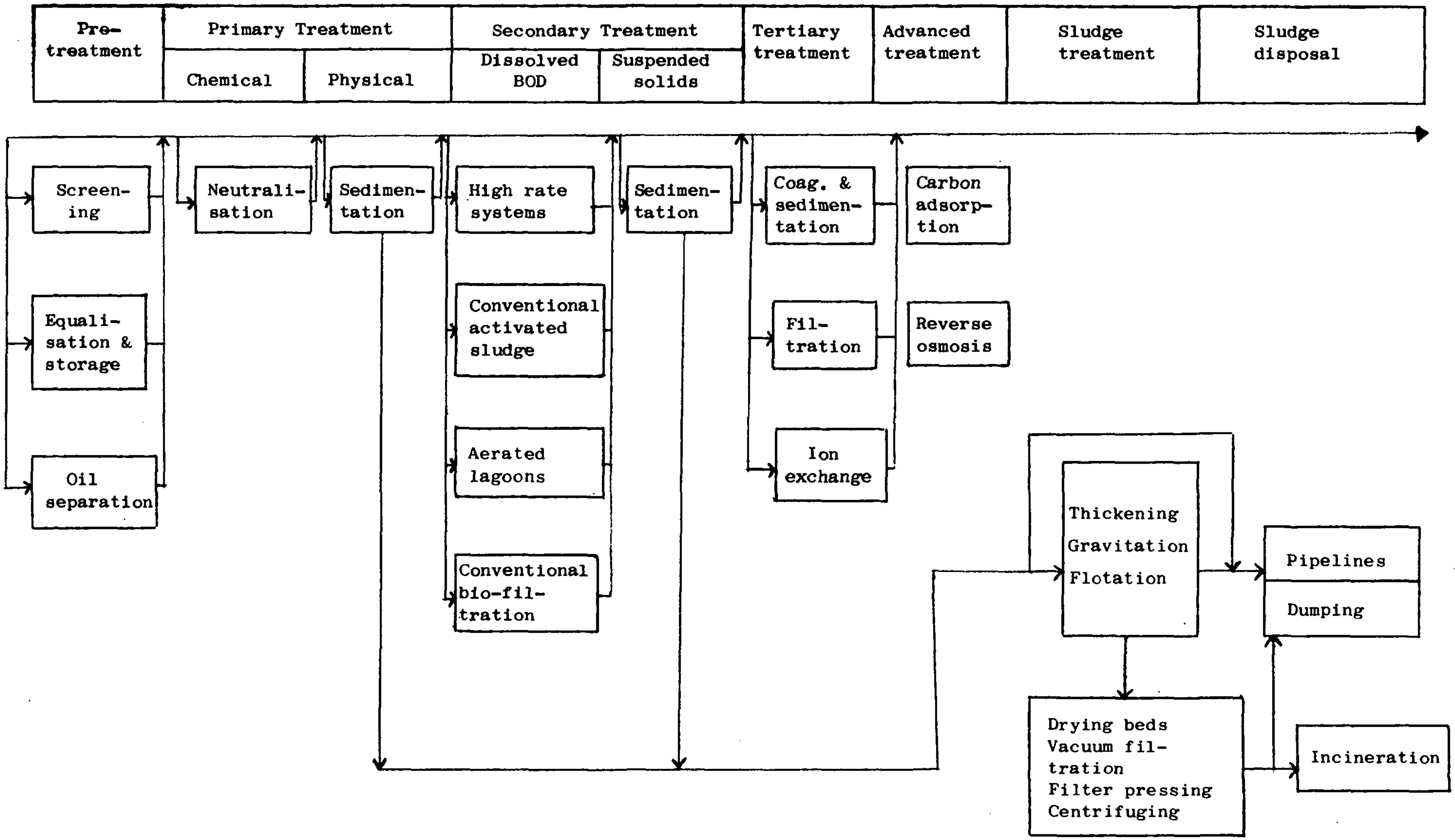
(iv) The standards should be practicable, that is, possible to attain by reasonable means.

4. Treatment Standard - Cost Function

Although the actual cost of any waste treatment system is dependent upon a variety of factors, including flow, composition, method of treatment and method of disposal of treated concentrates, including sludges, the controlling cost parameter is the quality requirement of the treated water, since this provides the constraints within which all subsequent process and engineering evaluations must operate.

Most industrial wastes lend themselves to selected process sequences, although each total system is specific to the waste being treated. Fig. 1 represents a general waste water treatment sequence. The operations shown are capable of utilisation in a variety of

FIGURE 1. WASTE WATER TREATMENT SEQUENCE

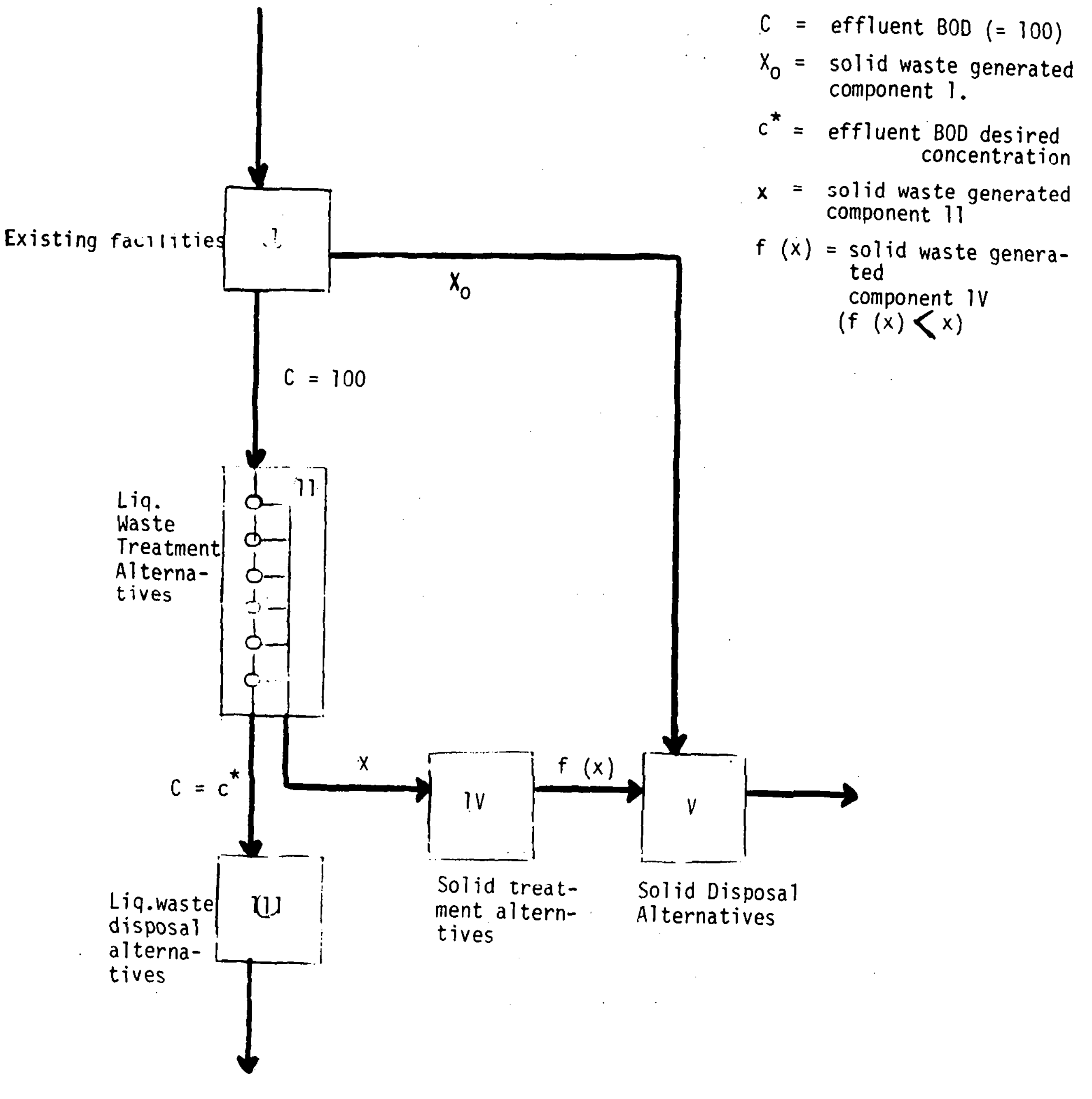


combinations, but for any waste stream there is normally only one optimum technical treatment regime suitable for the standard required. The optimum regimes defined for the same waste management problem may differ almost as widely as may the treatment standards applicable to it. Whether this optimum is approached is dependent upon such diverse factors as problem identification, technical design competence and capital availability. However, except in rare instances, the predominant constraint is economic and this means that a number of possible process systems must be evaluated on a techno-economic basis and the results optimised in terms of a treatment system.

A typical waste treatment system can be considered, at least initially, to have five basic components, viz. (Fig. 2)

1. Existing facilities (or alternative sites)
2. Liquid waste treatment alternatives
3. Liquid waste disposal alternatives
4. Solids treatment alternatives
5. Solids disposal alternatives

FIGURE 2. TYPICAL WASTE TREATMENT SYSTEM



The number of alternative processes available for consideration can be many as is shown in Table 1, which depicts processes for the removal of BOD from cannery wastes.

Table 1   *BOD removal processes: cannery wastes*

Unit processes	BOD removal (%) Lower	Upper
Sedimentation	0	10
Chemical Precipitation	25	45
High Rate Filtration	55	95
Mineral Media Filtration	40	80
Activated Sludge	65	90
Aerated lagoons	15	90

Each one of these processes will have a specific cost effectiveness on the basis of load removed per unit of load applied, and each will produce solids of specific quantity and type for disposal, thus influencing the overall system, a point of particular importance in the food industry where the technical problems of waste solids disposal can be considerable (2). It is vitally important, however, that not only is a total treatment system costed, which is more than a summation of prime plant cost items, but that the impact of each alternative upon total production economics, including the cost of any disposal to sewers, is correctly reflected in cost evaluations. As a result, the correct establishment of effluent treatment costs will always benefit from a total systems approach which facilitates and is formulated by proper problem definition.

5. Problem Definition

Assuming, for the purposes of this paper, that Utopia has been achieved, and that, in a given situation relevant externally and internally imposed treatment standards can be set, it is clear that the problem of industrial waste management is not, as is so often supposed, the application of a rigid series of process operations to an immutable combination of waste streams. It is to meet these presented standards, now and in the future, whatever the nature of in-plant process operations or the wastes themselves, and to do so as economically as possible.

While the standards applied to the given situation can be considered inflexible with regard to quality of effluent discharged or water re-used, the problem to which they are applied is not. Intelligent selection can be applied in order to optimise the problem itself before proceeding to process selection and capital investment. The important factors to be considered include :-

5.1 That in-plant production methods, whilst being optimised to yield maximum profitability, should take cognisance of waste management problems. There have been occasions when comparatively minor process changes have significantly affected the volume, nature, strength of waste streams and increased production profitability.

5.2 That minimisation of product wastage can have a marked effect upon the effluent problem. While such minimisation may not be economically viable in terms of product loss, it can often be so in terms of overall profitability.

5.3 That it is not essential to include all waste streams in the feed to a treatment plant. Especially where water recovery and re-use is contemplated exceptionally strong wastes, often of small volume, can advantageously be disposed of separately.

5.4 That some process operations may not require water of very high quality; slightly contaminated wastes from other processes may prove adequate for direct re-use or may need only minimal treatment for such re-use.

5.5 That where long or short-term operational changes may be contemplated, e.g. raw material supply, product, product scheduling, scale of operation, the effect on waste management economics should be evaluated as early as possible. Provision can most economically be made for the effects of such changes in the initial planning. Conversely the economics of waste management may militate against certain process operations at a given site.

5.6 That effluent discharge standards are always subject to modification, although changes are subject to discussion and negotiation. The extent and effect of possible future changes should be explained, but should not be allowed to become the cause of overdesign.

5.7 That external disposal costs rarely reduce and, being less readily subject to internal control. tend to increase faster than internal costs. The same is true of fresh water supply costs. Consideration of future costs of water management (supply and disposal) can indicate preferred courses of action alternative to those based on present costs.

5.8 That the effect of rising costs can often be contained by planning, from inception, for a degree of process effluent recovery and re-use even in those increasingly uncommon cases where immediate economics seem to justify no more than the crudest effluent disposal arrangements.

Of these factors, 5.8, which incorporates the effect of 5.1 - 5.4, is becoming increasingly common as a logical extension of improved in-process water utilisation.

6. Process Selection

Given a problem definition which incorporates the effects of treatment standard requirements and essentially those of early comparative economic evaluations, actual process and plant selection can be considered. While generalised guide-lines for such selection are of limited value, the following points, although seemingly self-evident, are often neglected :-

6.1 The unit operations shown in Fig. 1 are not mandatory. For example, simple segregation of a single, low-volume effluent stream can eliminate the need for both preliminary and primary treatment in some industries; production scheduling and flow equalisation can make it possible to dispense with external pH and nutrient regulation while some solids separated as sludges can be reworked, sold or dumped to advantage.

6.2 Land area requirements of types of equipment should be estimated at an early stage. It can prove poor economics to devote land to water management plant which could profitably be used for production expansion; it is pointless to cost systems which cannot be accommodated at a given site.

6.3 Not all types of biological treatment plant are equally applicable to every type of biodegradable effluent. It can prove wise to pay scant attention to proposals made by manufacturers on the basis of a superficial appraisal.

6.4 Process and systems designs which are essentially simple tend to be the more reliable in operation.

6.5 Where labour costs are likely to prove a significant item in comparative costings, it is often possible to select systems which lend themselves to automation at the expense of but a modest increase in capital costs. In the same situation systems capable of construction in ways and materials involving low maintenance charges can be preferred.

6.6 The disposal of sludges, whether primarily or biologically derived, represents an unavoidable element of capital and operating costs which can prove a significant factor in economic comparisons. Not all sludges are equally treatable in terms of thickening or susceptibility to deliberate (or inadvertent) anaerobic degradation. It is unwise to opt for a system which incorporates different methods of dealing with sludges of different origin. Forecasts of sludge production in terms of weight of dry solids per day can be misleading as to the costs of transport, storage vessels, chemicals and processing equipment in the absence of information about sludge concentrations and behaviour.

6.7 Industrial treatment plant should be designed for flexibility in operation under a variation of loads and flows often more marked than that encountered in sewage treatment. Especially where water recovery is contemplated designs should be against a minimum defined quality standard under 'worst condition' operation; design for average performance will not suffice.

6.8 Where production expansion may need to be catered for on a scale not yet defined, plant design in modular units can facilitate the addition of further capacity without interruption of operation. Pipeline capacities and layouts can advantageously be designed from the outset with such expansion in mind.

6.9 Where water recovery is proposed, it is especially important to design systems to be fail-safe; adequate quality monitoring must be provided as must emergency sources of supply. The cost of these provisions must form part of comparative design estimates.

7. Economic Comparisons

Whether as technologists we like it or not, the function of management is predominantly decision making on the basis of economic and financial data. It is a function of good technical management to ensure that the appropriate financial functions are included in the equation and this can only be achieved by economic evaluations of a series of technically based propositions.

Some such economic comparisons are inevitably involved at the problem definition stage in selecting the preferred alternatives from a number of courses of action, while the more precise comparisons which can be carried out at the process selection stage are often found to provide a feedback, resulting in improved problem selection.

There are many technical methods of estimating the costs of services and plant items, and each accepted method can be developed to fit the accounting and financial structure requirements of individual companies. It is worthy of note, however, that such self-imposed restrictions can limit the flexibility of decision making essential to this type of evaluation. We describe here only the estimating techniques we have found practical, and of course these too reflect the nuance of our own company.

8. Predesign Estimating

Predesign estimating is estimating which is performed without the aid of detailed design drawings and specification. In reality it is a misnomer, for even the sketchiest estimates require some degree of design, e.g. capacity estimates, physical scope of project etc. Indeed predesign estimates of varying quality, based upon design information of varying degrees of completeness are required during successive phases of a project for :

Economic study estimates

Comparative design estimates

Defined estimates

8.1 Economic Study Estimates:

It is necessary when considering new treatment facilities to establish the approximate costs at the outset. This cost can only be determined precisely by building the plant - an impractical solution. Next best, from an estimate accuracy viewpoint, would be a complete definitive design. From this engineering detail take-off quantities are multiplied by unit costs and the resulting estimate is fairly accurate. These detailed design engineering and estimating are too expensive and too time-consuming to be used in planning studies. It is necessary to devise estimating methods of reasonable accuracy which can be applied with a very minimum of design engineering and which produce adequate estimates well in advance of design completion. The cheapest and simplest method of estimating capital cost is from curves of loading v. cost. These are plotted from experience with plants of various capacities and preferably of identical type. These capacity cost curves must be corrected to a base price level representing conditions in a given year in order to compensate for annual inflationary effects. It is this curve which corresponds to the well-known exponential curve of the form $C = kQ^n$....... (i)

where C = cost of plant as of the base year

Q = plant capacity

K = constant coefficient, typical of the treatment method

n = constant exponent about 0.6-0.7

The correct factoring of this exponent is important and its true significance must be appreciated. Woddier & Woolcock (3) in an excellent review of the significance of this factor illustrate the necessity of understanding the component parts of process plant. Thus, it must be appreciated that
Total Equipment Cost = Equipment Class A + Equipment Class B +..............(ii)
and each class may have a different exponent value. This means that resorting to a blanket use of one exponent value reduces the accuracy of the estimate accordingly.
Analysis of capital cost of various plants usually shows that items may be allocated into groups.
A general first approximation is as follows :

Group A : items, the cost of which are nearly proportional to scale. In this group the exponent is usually between 0.8 and 1.0.

Group B : items, the size of which can vary as required, and therefore independent of plant size. The exponent is usually between 0.4 - 0.8.

Group C : items unaffected by scale. The exponent is usually 0.0 - 0.4.

8.2 Comparative Design Estimates:

Plant capacity - cost curves can seldom be used for the estimates made during project definition to determine the difference in capital cost between one process or design and another. For such comparisons, it would be desirable, from the standpoint of accuracy, to prepare and price two complete detailed designs. But this is much too expensive and it is necessary to prepare these comparative estimates from approximate partial designs. There are two general methods for preparing approximate estimates based upon partial design. The first is to sketch the design completely enough to take off quantities and price them as if they were based on a complete design. For some work this approach is economical and accurate - comparing two sedimentation systems for example. For more complex comparisons, however, there is a danger of going into too much detail, at considerable expense, without commensurate accuracy. The design effort is spread over a large number of items, sometimes with little attention to their relative cost importance.

The second method concentrates design effort on a few key items, determining all other costs by a statistical relationship between these key items and the other elements of the project cost. These key items not only represent a substantial percentage of the total cost of the treatment plant, but also by their presence, establish requirements for most of the other elements of plant cost.

The statistical approach can be used for comparative estimates when the effect of changes in major treatment equipment or plant location (i.e. discharge requirements) are in question. The sketch design method can be used to investigate problems, such as piping layouts, drainage, foundations etc. In both cases a knowledge of the technology of the treatment involved is implicit.

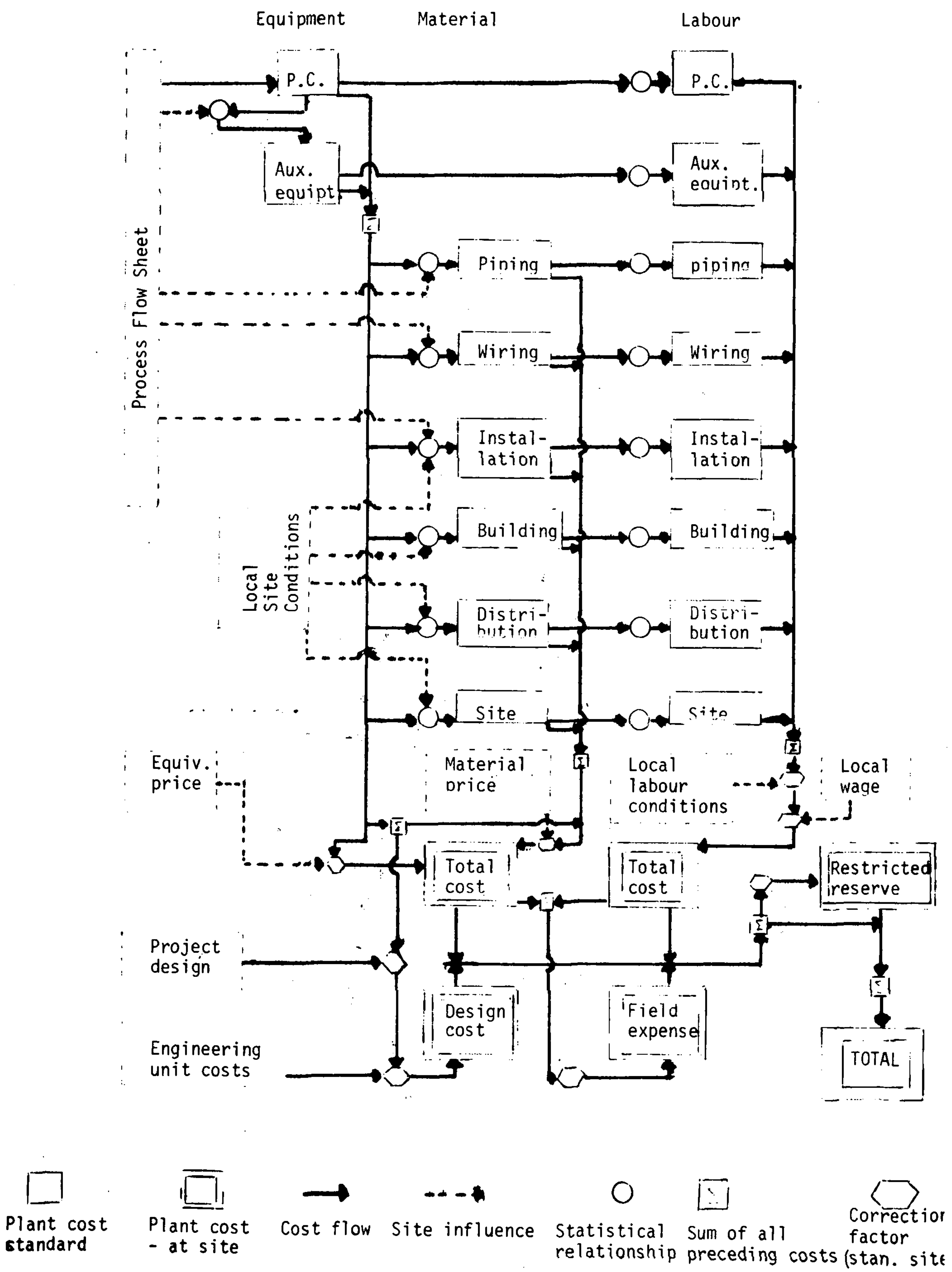
There comes a time, even in effluent control, when industry having made a decision institutes an engineering project. At the outset an accurate cost for the proposed installation is necessary, and this should be produced in such a way as to take cognisance of final costs as well as enable the effect of price changes operating during the project to be immediately available.

9. Cost Relationships

It is possible to draw up a systems diagram of cost relationships for treatment plants and Fig. 3 is such a diagram in simplified form. The basic determinant of plant cost is the process flow sheet which sets out the design conditions. It establishes the major equipment requirement which, in turn, through a cascade of relationships determines the total plant cost.

Solid single line rectangles on the diagram indicate elements of plant cost at standard conditions and prices. Double line rectangles indicate elements of plant cost under the conditions and at the prices, at which the project will be performed. Solid line arrows indicate the flow of costs and circles which interrupt these arrows represent the statistical relationship between one item and another. Squares with sigma signs indicate the sum of all preceding costs, and hexagons indicate correction factors which convert values at standard conditions and prices to the actual conditions and price levels forecast for the project.

FIGURE 3. COST RELATIONSHIP SYSTEM DIAGRAM



The diagram highlights the dominant position of the process flowsheet, and the vital role of process and planning engineers in determining what a plant will cost. If equipment is added, or taken away, the associated bulk material, labour, overhead and design cost go with it. Process conditions, such as biological loadings, hydrogen ion concentration, flows, pressure drops, recycle ratios, materials of construction, flexibility, are likewise the discipline of these engineers and strongly influence cost.

Another important factor the diagram highlights is the difficulties created by basic design changes made after estimating has begun. Such changes flow through the entire system, making it necessary to alter many figures, with resultant duplication of work, extra cost, and potentialities for error.

10. Predicting Operating Costs

Operating costs are a key element in determining treatment plant value. Only general guidelines can be given in this paper. Essentially two modes of operating costs are applicable, namely fixed and variable costs. The former are company specific but usually comprise, essentially, depreciation, amortisation, loan repayments. Depreciation is an annual non-cash charge geared to recover the invested capital during the life of the plant. Whilst amortisation is another non-cash item with an annual charge geared to the plant life, start-up costs, development costs, initial project charges etc. may, in some cases, be capitalised first and then amortised over a period, thus avoiding heavy book losses during the initial years.

Variable costs include such items as labour, utilities, maintenance, treatment chemicals etc., and as such will usually be dependent upon size, throughput and effluent standards.

When attempting to estimate such costs the company's cost records can prove an invaluable source of information allowing incremental costs to be computed, providing due cognisance is taken of the base load tariffs.

The best means of establishing operating labour requirements is to prepare a complete manning schedule including labour rates, overtime rates and supervisory increments. Since, usually, labour costs are the largest single item some care is warranted in this computation. The costs of chemicals etc., can be obtained from the process flow sheet. Perhaps the most difficult function to estimate is that of annual maintenance cost. It appears that scant attention can be paid to equipment manufacturers' claims and in any event a great deal rests on the quality of the operating labour. Experience suggests that the simpler the treatment plant, the lower the maintenance costs, and, furthermore, there appears to be little to be gained in assessing this annual charge at x% of the capital cost without taking the operating life of the plant into account. Very little usable data have been published, but a useful formula has been found to be

$$M = (0.009 \text{ to } 0.035)(In \times tu/Lu) \quad \ldots \text{(iii)}$$

where M = annual maintenance cost

In = Investment cost

tu = years the unit has been installed

Lu = estimated life of the unit

The factor (0.009 to 0.035) is very much company dependant.

Conclusion

We have attempted to outline a formal procedure necessary for the requesting and approving of funds to be used for capital projects. These procedures for controlling the commitment of capital can be summarised as :

Concise and complete project description

Factual justification for expenditure

Provision of check lists for estimating operating cost, total investment, project timing etc.

Financial planning

Control of capital expenditure

By definition this is a management function, but it can only be achieved correctly if all the constraints of the problem have been appreciated. We are finding that major capital projects for industries located as far afield as the U.K., South Africa, South America and Japan require, on average, 15 per cent of the capital to be allocated against water and waste-water management. This level of expenditure warrants formal management recognition.

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discussion

CHAIRMAN: T. R. RICHARDSON, FICE, FIMunE
President, Institution of Municipal Engineers

The CHAIRMAN introduced the authors of the paper and said that waste treatment was a matter of great importance, especially in view of the recent announcement by the Secretary of State for the Department of the Environment that a major expansion in capital expenditure in this field would take place.

2. Mr D. ANDERSON said he would look more closely at the estimating section in the paper. The paper presented the rudiments of an estimating system which was commonly used in the petro-chemical industries, but not always applied in the waste treatment field. The paper was geared to industrial waste treatment plant, but the basic philosophy applied equally to municipal treatment plants, although there were certain nuances in that particular problem that might change certain emphases in the costing procedure.

3. It was necessary to define systems engineering; it seemed to mean a different thing to different people, and it certainly meant different things on each side of the Atlantic. Most of Mr ANDERSON's experience and training in this field occurred on the other side of the Atlantic and there might be a certain difference to U.K. accepted terminology. Fig. 1 was a diagramatic representation of systems engineering applied to this particular field; it was not an actual treatment sequence. Implicit in this were all ancillary processes, which were accepted as part of the particular treatment system; for implicit in chemical neutralisation were controlling equipment, storage tanks etc. In systems engineering the total system was broken down into systems and sub-systems. It was an application of logic. Systems engineering was a term which had been coined to describe the thinking necessary to create a commercial processing system. The effectiveness of capital utilisation depended upon the skill by which the technique was applied.

4. A waste treatment system was a collection of equipment which effected the transformation of materials through biological or a chemical reaction, and the systems engineer was required to combine the most suitable unit process and unit operations to obtain the best economic advantage. The accuracy of the design data was important. Design involved the application of technology; there was nothing new about it, but it was operating within economic constraints.

5. The modular structure of any process system was its most obvious feature. Large systems consisted of a number of easily identifiable components, in which there were interactions. The performance of each component was strongly dependent upon the other components, and the performance of the system as a whole was more than the sum of the performance of these component parts. These interactions could prove difficult if logic were not applied to the total system design, and the haphazard approach to the optimisation of any inter-reactive system could completely overwhelm any design engineer.

6. Fig. 2 was a static representation of a system showing the interactions which occur between the sub-systems I and II. Instead of BOD any other variable could be used, and within sub-system II there could be any number of operations which would reduce BOD in a liquid waste. Each operation would have an effect on the solids waste for disposal, the liquid waste for disposal and the way in which the liquid wastes and solid wastes could be disposed. Invariably more than one treatment process would be technically feasible. Selection would depend on both technical and economical considerations. There would therefore be a need to compare the various alternatives so that those exhibiting the better effective use of capital could be examined more fully.

Reasonably accurate methods would be required for estimating. Costs were available to companies, but since cost data was not specific to the problem under investigation, considerable skill and care was required to ensure the changed position of these costs from one regime to another.

7. When the treatment process had been selected, the next step could be to cost the plant using published cost figures. This approach was frought with dangers since most published figures in the U.K. were estimates. Certain journals published cost indices which enabled the updating of previous cost to be made. Publications in the U.S. journals often contained costs, and these could be extrapolated to the U.K. provided they were adjusted to the U.K. conditions by employing an investment factor, which could only be computed from the analyses of a large number of cost estimates. It should always be remembered that cost indices were based upon published list prices rather than actual prices and exhibited a lack of sensitivity. In some instances equipment suppliers were asked to provide budget prices against ill-defined and sometimes ill-conceived process specifications. Whilst this was an easy approach for the organisation with a waste disposal problem, the contractor had to spend time and money and provide what could only be in this instance an ineffective service.

8. Capacity-cost curves for various equipment in the literature were often presented as straight lines on log-log plots of size versus cost. The size was usually related to the capacity of the equipment, and in general the cost curve for a specific item of equipment had a slope more or less characteristic of its class. This usually pertained only to a very limited range, and extrapolation beyond this range introduced inaccuracies, but despite this the approach had some merits if handled with circumspection. The authors viewed plant costings in the light of the systems diagram, Fig. 3, which illustrated the logic that should be applied with cost estimation. A definitive costing necessitated the application of all the steps and the inclusion of very accurate data. Preliminary estimates could be obtained by using shortcut methods and introducing blanket costs, but the procedure and logic should be the same. Capacity-cost curve took the data contained within a simple flow sheet and transferred it to a final plant cost using a single adjustment and introducing a correctional index for expected price level of equipment. Other estimating methods might be similarly analysed with the aid of this cost system diagram.

9. The first thing to notice in the diagram was the predominant position of the process flow sheet; this applied whatever the industry. The system was broken into three vertical sections: equipment, material and labour, and there was cascade effect going through to the final plant cost. A single line through it was in effect the movement of costs through the system, with the single square being the sum of all the preceeding costs. The final definitive price for the installed plant depended on when it was going to be built and where it was going to be built and this information was fed in at a later stage. The circles represented ratios which might be calculated from previous data, the ratios being applied to all projects of a similar nature. Reliability increased with experience. The equivalent ratio method of estimating was a fairly straightforward method of operation, and gave fairly accurate plant estimates. It was necessary to ensure that equipment was classified correctly and one such general classification would be major process equipment, auxilliary process equipment and utilities off site. However, greater refinement was needed in the classification than this in practice.

10. In the early stages the process equipment had to be reasonably well established as to type, number, size, etc, and could be reasonably accurately priced from previous data. Analysis of previous records could often establish the ratio that existed between the major process equipment and the probable auxilliary process equipment, and the approximate cost of the auxilliary process equipment could be determined without expending time or money on detailed engineering, listing and pricing of the auxilliary equipment etc. The auxilliary equipment ratio was usually between 0 and 2, and common values were from about 0.3 to 0.5.

11. Ratio estimating was affected by price changes which occurred throughout the life of a scheme from its inception to construction, and it was necessary to keep all estimates to some fixed or standard cost and then index these to existing conditions by use of an appropriate factor, which was represented by a hexagon in fig. 3, to give the final design cost. This was the discounting technique referred to in an earlier paper. Using this technique necessitated a substantial degree of project design, which should be concentrated on the features of the project which had the strongest influence on the total project cost. Little design time should be spent on standard items, the cost of which could be approximated satisfactorily by statistical relationship.

Defined estimates should be accurate enough that deviations of actual from estimated values would not substantially affect financial planning.

12. Whilst it was necessary to develop costs for new treatment facilities under standard or basic conditions, it was usually necessary to adjust these to conditions at the designated site, and to conditions to be expected during construction. During study estimates these corrections were often made in approximate and arbitrary ways since the site might not be known and the time of execution was conjectural. In the definitive stage, however, timing and site would become principal subjects.

13. The process definition stages was followed by a technical and cost evaluation which should result in a recommended process and reasonably accurate cost estimates. Engineering design was really the creation and description by drawing and specifications of a unified physical system which would perform the operations called for by the project definition, and had two principal phases. Phase one was the basic design to ensure proper functioning as a whole and the preparation of a detailed project design study; it contained all the essential engineering information relating to the project, process details, equipment, etc. Phase two defined the necessary structures and equipment so that the whole worked satisfactorily. The relative sizes of the two phases varied according to the size of the project, type of system, degree of novelty and most important of all - accuracy of project definition. Bearing in mind all that had gone before, no reason was apparent why design fees should be other than on a fixed fee basis against clearly defined terms of reference.

14. This approach necessitated discipline being exercised by the client as well as the engineer, and should ensure maximum utilisation of capital. However, what could not always be achieved was the effective completion of construction on a fixed price basis. Very commonly contract prices in excess of those estimated could be largely attributed to inadequate design criteria, inadequate project management, poor site supervision, and external factors such as wage rates and labour productivity. If the first two factors were adequately controlled escalations of contract prices would be reduced.

15. Vast amounts of money were necessary to combat pollution, but the authors contended that estimates of cost had been made against false premises. It was not known how effectively money had been used in the past and if, as was suspected, it had been used ineffectively on the basis of required results against optimum cost, then extrapolation of poor economic return on investment could only result in poor estimating. Whilst it was appreciated that perfect accuracy could not be obtained, systems engineering went some way towards establishing the true nature of a problem, and thereby providing a true measure of cost. Government expenditure, consultants' fees, contractors' services and plant costs were reflected in pollution abatement programmes, and all required a rationalisation of capital utilisation, or the application of logic.

16. Mr I.J. COTTRELL only knew one economic law, Gresham's law, which stated that bad currency drove good out of circulation. In this Conference on Economics and Management in Public Health Engineering there had been a great deal of economics and very little management, and this might be an application of Gresham's law: the somewhat dubious currency of economic theory had driven out the honest coinage of management. Mr COTTRELL congratulated the authors of this paper for the clarity of their presentations.

17. The maintenance cost formula in Section 10 of the paper indicated that maintenance costs were to be assumed to be proportional to the age of the plant, and Mr COTTRELL wondered whether this was true of the plant used for waste treatment. For example, pumps needed fairly frequent attention to their glands and bearings but otherwise needed very little in the way of maintenance; vacuum filters probably needed de-scaling every year or so, but otherwise did not call for much maintenance. Maintenance costs could often be taken as more or less constant during the life of the plant.

18. The authors had pointed out that producers of trade effluent had a considerable degree of control over the timing of their discharge. Mr COTTRELL was glad to have this confirmed; those on the receiving end of trade effluent sometimes got the impression that the worst effluents were produced at the time when sampling was least likely. The degree of control which could be exercised complicated the process of arriving at a logical solution. The process of "intelligent selection" necessary made the final design of such plants "consultant specific".

19. Most of the factors listed in the paper (points 5.1 to 5.8 and 6.1 to 6.9) were of equal application to municipal sewage works and were useful check lists for the designer.

20. Point 5.7 implied that external disposal costs increased more rapidly than fresh water supply costs, but the opposite had been true, in some areas at least, for many years.

21. The heart of the paper was the estimating techniques to be applied between the preliminary appraisal and the final design. All the techniques which the authors described were interesting, but depended on the amount of data available. Mr Anderson had said that a good deal of this data ought always to be available, but Mr COTTRELL had found that it was not available when it was most required.

22. The authors had mentioned that a number of projects required on average 15% of the capital to be allocated against water and waste-water management. This seemed a very high figure, and Mr COTTRELL asked which types of industry spent so much.

23. Mr G.F.G. CLOUGH thanked Messrs Askew and Anderson for their stimulating paper. Fig. 3 could be used as a method of progress control, and for keeping track of expenditure on every item so that the total commitment was known before the job was finished. These costs could be used to check the accuracy of the estimated figures first used, and for succeeding estimates. This had particular value when one organisation was responsible for a series of jobs, and was a strong argument for employing specialist firms to control contract costs. Fig. 3 did not show land costs. Land did not depreciate in the same way as industrial plant and therefore the cost should be dealt with separately.

24. Mr ANDERSON said that maintenance was company dependent because some companies provided very good maintenance of all their process equipment, whereas others only maintained plant occasionally. The maintenance cost figure had been used with success on some occasions and failed miserably on others. No matter how good staff were, maintenance costs increased after a period of time. In industry treatment plants normally had a ten to fifteen year life period. The factor 0.009 to 0.035 was very wide, and was a measure of company efficiency.

25. Mr M.W. ASKEW said that the manufacturers' choice as to whether he produced a particular kind of effluent was important. A simple example was in the milk industry, where in former years it was common practice at the end of a production run to remove the few hundred gallons of milk remaining in the vessels by flushing them with fairly large quantities of clean and sometimes quite expensive water. This was regarded as the cheapest way of cleansing and returned the vessel to the production line quickly. In terms of production alone, it was probably the most effective way to deal with waste. However water cost as much as 25 pence per thousand gallons, waste treatment costs were additional, and a hundred gallons of milk represented 100 pounds BOD, and an industrialist should have second thoughts.

26. Another example was in a fruit canning line. The system was such that the cans were filled with fruit, passed along the production line and were filled with syrup until they brimmed over and then the lid was put on. The syrup cost very little and so was not worth worrying about, until Mr ASKEW had considered the effect it had on the total effluent treatment costs in terms of BOD. Such matters could not always be resolved completely satisfactorily, but there was often a case for looking at them.

27. Expenditure on water and waste-water management up to 15% of the total capital outlay was becoming fairly common in some sectors of the petro-chemical industry. It was particularly common overseas in the food industries where water of good quality was in very short supply. In some cases the industrialist had to purify poor quality water for the purposes for which he wanted to use it. In other cases water as a commodity was in very short supply, but of good quality, and a very high standard of effluent treatment had to be reached.

28. Mr Clough had mentioned land costs. It was not good industrial economics to devote large areas of land to no profit by effluent management operations when that same land could be better devoted in profit terms to additional manufacturing capacity, but land costs should be kept separate.

29. Dr D.E. WRIGHT agreed with the authors' attempt at a more rigorous and logical estimation of costs, and thought it significant that this system had been adapted from petro-chemical practice. He wondered how significant it was that in the structures used in that industry a larger proportion of the total costs was in above-ground units, in comparison with the more conventional local authority municipal sewage works where a great proportion of the cost was in holes in the ground and concrete. The techniques and cost estimation used should certainly be applied more widely, but it would be interesting to know the authors' experience in applying these techniques to more typical civil engineering situations, where site conditions played a dominant part in the total cost of works.

30. Mr ANDERSON thought this technique was developed in the petro-chemical industry because it was a comparatively new industry with a very rapid growth rate and a high technically orientated basis. Some of the authors' work had been in jobs with a high civil engineering content, but applying the techniques required civil engineering expertise and background.

31. Mr R. McCAFFER said that it was the function of management to make decisions based on economical and financial data, and the authors' approach was a formalised version of the common one of producing approximate estimates followed by a halving of these estimates as more information became available. The initial estimates were approximate, because the information was not available. The decision-maker should be given more information as to how approximate the estimates were in the form of probability distributions, which would not be too difficult to deduce from past data. Mr ANDERSON agreed that the beauty of the system was that estimating could be up-dated by a continuing record of actual cost.

32. Mr ASKEW hoped the authors had not failed and given the impression that this was simple; it was quite the converse. Starting with approximations, the problem had to be studied and available possible solutions discovered. In the more complicated situations feedback set the designer back to the original problem to see if it could be modified to better suit the purposes.

33. Mr ANDERSON referred again to the 15% of capital cost devoted to water and waste-water cost. The figures had been computed from surveys in Asia (including Japan), the United States, South America and South Africa. Virtually everywhere the iron and steel industries and the petro-chemical group were the industries committed to the largest expenditure on water and waste-water treatment, including treatment of cooling water and boiler feed water. The cost included schemes for water re-use. In the United States, a treatment plant receiving typically American sewage used chemical precipitation as primary treatment, activated carbon, sludge incineration, and regeneration of activated carbon. It was the American idea of the sewage treatment plant of the future.

34. Mr J. VAN WELY thought the authors had assumed two points: the availability of space and the availability of capital. Most complete effluent treatment plants included biological treatment. A complete treatment plant could be devised in two parts: sedimentation and dewatering of primary sludge; and biological removal of BOD with an external filter area to deal with the excess activated sludge. Mr VAN WELY thought it would often be a good idea to provide primary treatment for the effluent on the site and treat the BOD in a sewage works. This would be difficult when the sewage works was overloaded, but there could be some sort of agreement for the industry to share in the cost of the extension of the sewage treatment plant. This scheme was of particular value as industry was often acquainted with removal of suspended solids, but ignorant of the biological side of the effluent treatment.

35. Mr ASKEW said that this depended on the particular circumstances. He did not think that industrialists found it much more difficult to operate biological treatment processes than physical or chemical treatment processes. Biological treatment was not as sophisticated or as difficult to cope with as many of the industrial production processes which were carried on at the same site. The primary consideration was the economics of the situation from the point of view of the industrial producer. His first move in many cases was to install some sort of pre-treatment plant on site for a variety of reasons, perhaps because the local sewage works was overloaded. He then often came to the conclusion that in any event he was paying for the treatment of his waste right through from the condition in which it started to the fully treated state, and wondered whether he could not with better cost effectiveness treat the effluent and re-use it. It was becoming commonly recognised that much of the water used for industrial purposes did not require a very high quality. In a particular case where a manufacturer of potato products wanted to have his effluent purified so that he could re-use it in part of the process, he insisted it must have a BOD of less than 10 mg/l and be bacteriologically sterile. On inquiry it was found that he was going to wash the dirty potatoes with it!

36. Mr E.V. FINN said that the authors had gone into quite sophisticated techniques for producing an estimate. Having produced an estimate for say scheme A, it was necessary to add the running costs and maintenance costs over a given number of years. Another estimate, for scheme B, was then prepared and the running and maintenance costs added. Then financial techniques (the discounted cash flow etc) were used for a comparison over a number of years. Maybe after 25 years the cost of scheme A would cross over the cost of scheme B, taking into consideration all factors. Had the authors any suggestions or sophisticated techniques for going that one stage further? Mr ANDERSON said that D.C.F.

and N.P.W. were implicit in the system suggested. The use of these techniques was the only way of bringing cost data up to a required value. Mr FINN added that method of producing the finance might make difficulties; for example the capital might be obtained one way, but the maintenance and running costs could be financed another way.

37. Mr R.W. BAYLEY referred to Mr Askew's account of the potato processing works where water was re-used. An industrialist would show the greatest interest in waste-water treatment schemes if he would reap some direct benefit from it. The presence of 10mg/l of BOD in reclaimed water did not make it unfit for washing potatoes provided the trade waste was kept quite separate from all the domestic sewage. A BOD of 10 mg/l derived solely from potatoes was one thing, but a BOD of 0.1 mg/l derived from domestic sewage was another. Mr ASKEW said that in any of the food processing industries which may use reclaimed water, domestic sewage should be separated at source.

38. Mr D.O. DOWDESWELL asked the authors whether sufficient consideration was given by industrialists to the problems of waste disposal, particularly at source. It would be of great benefit to the industrialists themselves and to the environment if they gave more consideration to the problem. Mr ASKEW agreed.

39. Mr P.J. COWIE suggested that the method suggested by the authors was logical, but might take out the human factor. Where and how could the ease of operation of a plant be assessed, and how could it be accounted for economically? He also asked whether the authors, when they had finished a cost relationship diagram, stood back and looked at the feel of it. Mr ASKEW said that labour costs were becoming a very important factor in more industrial production and there was increasing attention to operators' comfort as far as possible. A number of plants could use more automation; others may have too much, because it had been assumed that a machine was looking after everything, but no machine was infallible. Some sort of compromise was needed: the operator must feel that he was doing a reasonable job and that his status matched his responsibility. For example in some food production factories expenditure of something like £60 000 per year might be involved.

40. Mr C.R. COOMBS suggested that terms that had been used like 'value analysis', 'cost effectiveness', 'cost benefits', and 'planning engineering' were just terms for 'engineering'. They were terms used by accountants. He could see nothing wrong with accountants running an engineering business, providing accountants accepted that an engineer could run an accountant's business! In fact they were complementary to each other in each other's fields. Engineers must be cost conscious by definition. Engineering was in its broadest sense the commercial application of scientific principles. The CHAIRMAN suggested that an engineer could do for 25p what any fool could do for £1.

41. Mr COOMBS queried the upper BOD percentage removal for activated sludge given in Table 1. With reasonably strong domestic sewages 97.5% removal had been achieved on diffused air plants.

42. Mr V.H. LEWIN thought the paper had been written on the premise that industrialists would put up a certain size factory for known production capacity and knew precisely what quality and quantity of water was wanted, moreover, and could calculate nicely the economics of treating the waste or discharging to municipal sewers. In his experience this was not so; only when the waste was produced did they think of the problem and even if they did produce an estimate it was likely to be changed by other considerations or directives at the next board meeting. Normally municipal sewage works were designed by consulting engineers with spare capacity for future development for housing and/or industry. Mr ANDERSON said that the only reason for having consultants was that they could provide the service or knowledge or technique that was not available at any other source.

43. Mr ASKEW agreed with Mr Lewin that industrialists often did not know what they were doing in terms of their effluent problem, because they had not bothered to find out. They had to be educated and made to bother about it, not just in their own interests in terms of the profitability of their own organisation, but in the interests of everyone who used the water as a resource.

44. Mr R. WOOD got the impression from the paper that processes could be very precisely tailored particularly for industrial effluent treatment plants for exact volumes of known quantity wastes, but there were two problems. One was the need to deal with the accident within the factory. An accident could be a leak from, say, a nickel plating plant which could be of disastrous proportion. Very often they were just a nuisance, but could easily affect the quality of the effluent discharged from the treatment or pre-treatment plant. The other arose from a manufacturer buying raw materials for a particular process without necessarily

knowing the full content of what he bought. As an example a firm carrying out etching bought hydrochloric acid and found to their horror that their effluent proved to be unsatisfactory, because the hydrochloric acid had 2000 mg/l of zinc in it. What sort of precaution could be built into plants which were specifically designed so that the manufacturer would feel fairly safe, particularly if he were discharging to a river?

45. Mr ASKEW suggested that the precision of design was not as great as Mr Wood suggested. It was rather the other way round, that in selecting particular types of unit processes unsuitable members among the apparent total number of possibilities could often be rejected at an early stage, and after that it was a question of carrying out judgements on the remaining unit processes as part of an integrated total system. It was suggested in the paper that a water reclamation plant for industry should be designed on a worst condition basis. The difficulty was knowing what the worst conditions might be; it was not possible to take account of everything that could possibly happen any more in industry than in municipal works.

46. Mr J.M. DYSON suggested that every sewage treatment works in this country should keep proper financial records to enable the sewage treatment charges to be calculated on a 'Mogden' basis. (n.b. this apportions cost of handling flow, BOD removal and sludge treatment and thus given flow, BOD and suspended solids the cost of treatment of a new effluent could be estimated). These figures could be made available to a Planning Authority so that when an application for planning approval was made the answer from the Authority could give the basis of sewage treatment costs. The manufacturer would then know the likely cost of treating his effluent at the local treatment works. This would give him feasibility study A and he could follow on with studies B, C, D etc. for individual treatment units installed on his own premises from as many specialist manufacturers as were prepared to quote him.

47. Mr CLOUGH thought manufacturers often did not know the nature of their effluent through no fault of their own. Two typical cases were the sudden popularity of leather coats resulting in a big increase in effluents from tanneries, and the popularity of the maxi coat which produced additional effluent from the manufacturers of a particular type of felt. There were also trends of fashion in the chemical industry. In the industrial field, skill was involved in designing a plant which was sufficiently flexible to take into account these variations. It was one of the reasons for the preference in industry for plants which were low in capital cost. If the effluent production fell to half in the case of activated sludge, the rate of aeration was reduced, but this could not be done with biological filters. He did not agree with Mr Lewin's argument that a large number of effluent and sewage plants were grossly over-capacity; his personal experience was rather the opposite.

48. Mr LEWIN said that a very large number of sewers were running under capacity. Moreover a large number of small sewage works were over capacity in some sections, particularly primary sedimentation units, and under capacity in others. Mr COOMBS suggested that under-utilisation of sewers was like the under-utilisation of a fire brigade.

49. The CHAIRMAN thought it was necessary to educate industry because there was little doubt that the general approach of an industrialist, unless he had a specific financial problem, was that there was a sewer, probably over-sized, able to receive the drainage from his premises. It was also necessary to educate works designers, architects and probably local authority building control staff.

50. Mr J.D. HUNTER said that Section 2 of the paper mentioned a number of alternatives for the disposal of waste. Mr HUNTER thought River Authorities were pressing for industrialists to put their wastes into sewers and wondered whether this was because manufacturers generally did not know how to treat to the standards required.

51. Mr ASKEW said there had been a tendency towards industrialists installing their own treatment plant for one of a number of reasons, but in the final count because they found it cheaper. Once they began to think about water, they found they could use less, could create less polluting material, and could use the water again. It was perhaps desirable that industry should discharge its wastes to municipal sewers because municipal authorities were best qualified to treat those wastes, but industry could acquire the 'know-how'.

52. Mr J.H.J. WATSON suggested that the matter should be kept in perspective. The authors were talking about large industries, but there were thousands of very small industries producing very small wastes. They were often too small to provide their own treatment plant, and would really be in trouble if they were unable to discharge them to the sewer. He had experience of dealing with industrial wastes, agreeing proposals

and then months later finding some of the product had been changed.

53. Mr ASKEW agreed that these considerations were most relevant to sizeable industries. However, there was not always a sewer and a sewage treatment plant nearby, particularly for the dairy industry where there could be a very large factory in the countryside near a small village with a small or no sewage works at all. If there was a choice industry should make up its mind in terms of the cost involved.

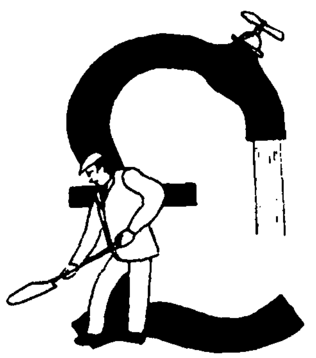
54. Mr WOOD did not think that industrialists always had the choice of discharging fully treated effluent to the river or a partially treated effluent to the sewer. The industrialist might not be near a river. Mr WOOD doubted if the Regional Water Authorities would be happy at having a large number of direct discharges to river as they required supervision and control. The manufacturers' choices were really much more limited than was usually imagined. Mr COOMBS added that the convenience to the industrialist was finally cost effectiveness. For a factory to do its own trade waste treatment there would have to be some fairly senior post in management to look after it, with consequent increased overheads.

55. Mr C.H. SPENS said it was impossible to generalise; every industry had a different character of effluent. Industry was beginning to realise that the protection of the environment was a duty for them. Also if industry treated its own effluent to a reasonable standard it could in many cases recycle it, and with industries using a great deal of water this meant a large saving on the product. Following the passing of the Rivers Pollution Prevention Act and the 1961 Public Health Act, authorities were instructed to be lenient and eventually this had been tightened up. Mr SPENS thought that the future Regional Water Authorities would not be content with many very small discharges which could not be supervised, and would prefer them to be concentrated into sewers for treatment at sewage treatment works.

56. Mr J.R. MURLEY asked the authors to comment on the value of surveys carried out for industrial plants, particularly in the food processing industries, where throughout the year the discharge could vary enormously. It was essential for the treatment plant to be designed to treat all these wastes.

57. Mr ASKEW said the essential starting point was to find out what was to be treated. The authors had been dealing with an organisation where the products were seasonal - fruits and vegetables in season - and the quantity and the quality of the effluent to be dealt with could vary greatly over the year. In addition, the treatability of the effluent in terms of the ease of removal of the polluting constituent could vary very considerably.

58. The CHAIRMAN thanked the authors for preparing their excellent paper. The discussion had been very stimulating, and he thanked all who had taken part.



V. H. LEWIN

trade effluent control economics

INTRODUCTION

The economics of industrial effluent disposal are complex. Availability of reliable data is scarce, scattered and largely outdated. Industry appears to have an inherent reluctance to publish details of such costs particularly in highly competitive fields. The spiralling inflation of costs of water and effluent disposal has caused more thought to be given to the whole question in recent years. Economy in use of water, improved methods of reclamation and utilisation and reduction in wastage of specific constituents of waste have been the subject of numerous cost benefit exercises. There is little doubt that there is still room for considerable reduction in water consumption in some industries. Publicity of the potential shortage of water to meet all demands by the year 2000, at least in some regions of the UK has raised concern that some system of rationing may become necessary. That such a system is likely to be apportioned on a basis related to current consumption - a quota system - may well have influenced some establishments not to have fully implemented all the economies known to be practically possible at the present time.

The imposition of more stringent effluent standards by River Authorities on discharges to certain stretches of some rivers has a marked effect on the cost of effluent treatment and disposal. The more stringent implementation of clean air requirements also plays a part.

In short the cumulative influence of many factors are tending to require all industries to re-examine their water supply and disposal policies. The proposed re-organisation of water resources into ten

Regional Water Authorities(1) with responsibilities for sewage disposal river management and water supply will undoubtedly have an impact on the whole economy in future years. It is appropriate that at this juncture we should endeavour to take stock assess the present in order to be better prepared for the future.

In the past many, if not all, the 1500 Local Authorities responsible for domestic sewage disposal have provided a service to industry for the cheap, efficient and worry free disposal of their waste waters. Much indeed was done long before the Public Health (Drainage of Trade Premises) Act 1937 provided the legal framework for such facility. The war years prevented maximum exploitation of these provisions. In the event a common or National policy on the subject failed to emerge. Differing interpretations of specific clauses hindered realisation of the full benefits that had been intended. The differences in methods of treatment, ultimate disposal and size of the various installations markedly affected specific costs. Part V of the Public Health Act 1961 corrected a number of anomalies and there is little doubt that some future legislation will further amend and rectify remaining faults. N. Fisher(2) discusses the legal aspects very fully in his paper to the recent I.W.P.C. National Symposium on the Discharge of Industrial Effluent to Municipal Sewerage Systems. In fact, the collection of nine papers presented at that conference fully cover the many facets of the disposal problem. Simpson & Truesdale(3) put forward one concept of charges and my own paper(4) discussed in some detail, the more commonly employed, volume and strength system. The differences in systems of attempting to recoup the costs incurred by Local Authorities in undertaking this service to Industry are however very wide indeed. Many still use a simple fixed sum, calculated as approximately correct many years ago. There are also simple scales of charges and there are many instances where for one reason or another no attempt is made to recover costs. The unit costs of sewage treatment also vary enormously and generally speaking are lower in the larger installations and highest at the tiny works(5).

The very recent decision of the Minister for the Environment(1) to transfer responsibilities for sewage and industrial waste treatment and disposal away from Local Authorities to ten new gigantic Water Resources Authorities will have widespread economic repurcussions. The principal object is of course the more efficient control and integration of the whole water cycle of supply, usage, treatment and re-cycle. It is essential to ensure that there will be adequate supplies in those locations when it will be required in future years. It is one of the schemes put forward in the CAWC Report(6). Inevitably it will entail a re-appraisal of charges which will need to be made for this service. Clearly there will be a greater degree of uniformity, though not necessarily identical charges, for similar waste, and less influenced by geographical location.

The present system of financing the capital construction and maintenance of municipal sewage treatment facilities is a charge on the Local Rates. Capital is normally borrowed from the Government and its repayment included as 'loan charges' in the annual running costs of the undertaking.

It is estimated that at the present time, up to 50% of the volume and pollutional load dealt with by these units is derived from Industrial Effluents. The proportion naturally varies from unit to unit; many rural plants receiving no industrial wastes. Oxford(4) for example copes with the domestic sewage of a resident population of 110 000, a commuter population around 25 000 and industrial effluents respresent 12% of the flow. Oxford and many other towns recover the costs of industrial effluent reception with Trade Effluent charges. The new organisations will need finance and if they are to improve upon the present position they will require much more finance. One way or another Industry will be committed to its full share. Industry will not find it practical to avoid these costs. It may find it profitable to undertake a much closer look - a realistic cost benefit study of the water it presently uses. The question of effluent treatment costs will become inseparable from water supply charges and no doubt will one day be integrated.

Water Supply

Many industries in the UK are favourably situated and may at present even have a choice of water supply. Abstraction rights from rivers, canals and/or underground sources account for much of the water presently used. Mains water, normally of a single high quality standard - drinking water quality - is the alternative. The cost of mains water has in the last decade increased dramatically. The increase has not been uniform over the country. It can be attributed to many causes but principally the inflational spiral of wages and materials. When it only cost 5p per 1000 gallon (1.1p/m^3) or less, no one worried about quantity. The present price of 15 to 25p/1000 gallons (3.3 to 5.5p/m^3) has already caused striking economy measures. That the price may rise to £0.4 or £0.5 per 1000 gallon (8.8 or 11.0p/m^3) within the next decade or so, will cause it to be classified as a valuable commodity and to be treated with appropriate respect.

Those industries with abstraction rights are not however avoiding the increasing cost of water. Hitherto it was a straight forward cost benefit approach, pumping costs and perhaps some limited treatment costs, compared with purchase from the mains. Those pumping costs and the labour and materials of pretreatment will have increased a little. Since the Water Resources Act 1963 the then reformed River Authorities had a right to make a charge for such abstraction privilege and to control the volume abstracted.

Those rights will be transferred to the new Water Resource Authorities, and will constitute one of the sources of income offsetting the increased expenditure we predict. There is likely to be less economic advantage, than has hitherto been obtained, in having such choice of water supply. According to G. Lines(7) abstraction charges have been based on differential rates depending on the quality of intake, use to which it is to be put and whether it is a seasonal or all year requirement. Thus summertime requirement for industrial purpose might average 0.7p/1000 gallon whereas all year round requirement could vary from 0.5 to 1.50p/1000 g. When the surveys of rivers which the River Authorities were charged to undertake are completed the need for more treatment is likely to be shown to be substantial in many cases(8). Abstraction charges are a potentially viable source of some of this additional finance.

Quality of Water Supply

The quality of water required by industry varies considerably and is dependant upon the purpose for which it is used or the processing to be carried out. Much need not be of the high bacterialogically sterile quality essential for drinking water supply. On the other hand it is often required of much higher quality than normal tap water in respect of dissolved constituents. It is said that processing of tap water for boiler feed purposes of modern high pressure efficiency units costs up to £2 per 1000 gallons. Electroplating, the manufacture of television tubes and transistors, are industries where de-ionised water is preferred. Phasey(9) in a paper to the Institute of Metal Finishing Effluent Symposium at Southampton in October 1971, quoted production costs of ion exchange processing for the years 1959 and 1970. The latter value is 29.58p/1000 gallons compared with 60.19p in 1959, the reduction is largely as a result of improved technique, longer life between regeneration and in spite of labour charges more than doubling in that period. He also quotes effluent pretreatment costs before discharge into the City sewers of 4.88 and 10.00p/1000 gallon in the respective years and states that it is never the less cheaper than mains water. For this particular effluent the Local Authority charged 9.0p/1000 gallons for reception and treatment which represented 0.49p/1000 gallon of de-ionised water produced.

A number of industries in the Bristol area purchase sewage effluent of Royal Commission quality i.e., BOD less than 20 mg/l and suspended solids content less than 30 mg/l for industrial purposes, mainly as cooling water. The price paid is the cost of such treatment and this will be dependant on the size of the treatment plant. Current costs vary widely as seen from the statistics produced by the Association of Municipal Treasurers(5). Water used for cooling may become polluted in a number of ways and allowance may need to be made to rectify this before discharge as an effluent. In addition to thermal pollution (it is well known that it is undesirable to raise the temperature of receiving waters) additives such as anti-fouling compounds may have been employed. Oxygen may have been stripped from the water and in the event of evaporation losses, the organic and inorganic constituents will have been concentrated.

Quantities of Water Required

Predictions of future water requirements have been authoritively made, and elsewhere from time to time. Experience with water consumption for domestic purposes rising from 10 g.h.d. in rural areas at the beginning of the century to over 50 g.h.d. in large UK cities and 120 g.h.d. in affluent American Cities at the present time provides some evidence for such forecasts. Industrial usage is also rising and can be related to new techniques and increasing production. It has been said that the Alcohol Fermentation industry uses 100 times the weight of product produced(7), and a similar ratio for the paper makers, while man-made fibres require 150 times and the Chemical Industry 1000 times the weight of product. One of the arguments in favour of entry into the European Economic Community is the potential market and scope for expansion of production. Line(5) has indicated abstraction costs alone of water, per ton of product for various industries as follows:-

Steel	5.3p
Alcohol	10.5p
Paper	10.5p
Cellulose Fibre	16p
Chemicals	90p

To these abstraction costs must be added any water treatment costs that are necessary, distribution costs within the factory and effluent disposal costs. Whereas in some industries these additional costs may only double or treble the initial cost, in others it may be much more substantial. Cost of effluent treatment not only vary from one authority to another but with the degree of pollution they contain. At Oxford(4) where sewage treatment costs for 1970/71 averaged 14.16p/1000 g (3.11p/m^3) the charge for reception and treatment of different industrial effluents varied from 0.03p/1000 gallons for waste from printing to 24.58p/1000 gallons for waste from slaughtering. Spent liquors from the fermentation industry may cost up to £17.50 per ton of product(7). Nevertheless it would be reasonable and logical that such costs should be passed on to the consumer. In the case of alcohol it would seem a trivial sum compared with the excise duty on a bottle of Scotch but it can hardly be ignored as a slice from the profit margin on the far greater volume of duty free alcohol produced for other purposes: particularly if the competitor in this market does not have to bear similar costs. Since few continental countries treat sewage and effluents to the high standards we have found essential in the UK it can be presumed that their costs are much lower than ours.

Treatment Costs

Published treatment costs are likely to prove unrealistic and low since few take into full consideration all the factors. Most sewage works are designed for a limited life and few make provision in the annual running costs for amortisation. Most rely on borrowing the capital for the extensions or renewed works and recovering that loan in future charges. The cost of replacement increases annually. Normally sewage works are originally sited some distance from developed areas, the land being appropriated from agriculture at the low agricultural value, for this specific purpose. Housing development later reaches this area and the value of the sewage works site escalates but rarely is consideration given to the loss of revenue to the owners - the Local Authority - were they free to develop the site for some alternative purpose.

A typical case of this is the use of substantial areas as sludge farms. An economic and effective disposal of sludge by agricultural dispersal and utilisation. Costs are currently less than £10 per ton of dry solids. The land was probably purchased years before at less than present agricultural land values of £300 per acre. If some alternative method of disposal say incineration plus a suitable ash tip can be provided the sludge farm can be realised for development at land values of upwards of £5000 per acre.

Sewage treatment was developed for domestic sewage and hence largely as a biological process. It has been adapted to accommodate various industrial wastes whereas it is quite probable that chemical or other techniques might prove equally effective. Undoubtedly, large units would be less costly to operate than small individual plants at each factory. There has been a move in this direction in some cases in the States utilising polyelectrolyte flocculents and activated carbon to extend an existing activated sludge plant. This unconventional approach is stated to cost less than traditional alternatives(10). Stander(11) in South Africa has shown that chemical engineering techniques can provide a satisfactory answer where the re-cycle of effluent for potable supply is essential. There is clearly scope for development of such ideas in this country. Although proven biological methods have been good and faithful servants they are highly susceptable to many toxics and biocides. Some give rise to fly nuisance when wrongly located and few can avoid the accusing finger of suspicion when hot warm air carries offensive effluvia to neighbouring residences, a trouble likely to become more commonplace as anti-pollution legislation cleans up the air and removes the smoke particles that conveniently adsorbed these traces of odiferous substances in the past.

Purely on financial grounds chemical engineering techniques could offer enormous savings in capital investment. Conventional plants utilising massive concrete structures and necessarily large capacity for the long retention periods for biological reaction, cost £15 to £40 per capita served to construct. Of these costs some 75% will be civil engineering excavation and concrete. Only 10% of the total costs will be spent on mechanical equipments. Techniques to accelerate solids separation could be developed to replace conventional sedimentation units. There appears to be no logical reason why a series of screens should not affect such removal. Micro scrainers might similarly replace final separation tanks.

Ammonia requires an enormous amount of oxygen to be biologically oxidised to nitrate and even so the river and water supply chemists are uncertain whether they like it anyway. Many residual constituents of modern 'domestic' sewage are biologically non biodegradable or give rise to non biodegradable residual COD currently around 30-50 mg/l. Activated carbon, ozone, reverse osmosis and no doubt other techniques might prove more efficient.

CONCLUSION

The general need for closer consideration of water requirement by industry is indicated. Greater economy in use will be financially essential. A variety of techniques of reclamation and recycle already abound while realistic cost benefit studies bearing in mind the inevitable rise in cost of water supply - effluent treatment, may indicate that alternative non-aqueous systems can in some cases be substituted.

The scarcity of cost data hinders progress in developing more efficient and less costly pre-treatment and treatment techniques. The conservative adhesion to traditional civil engineering techniques for joint municipal and industrial treatment works is unrealistic. The probable cause may be largely due to preferential loan terms on civil work.

The departure from Local Authority responsibility to gigantic Water Resource Authorities with responsibilities for the whole of the water cycle may provide the opportunity for a fresh approach; finance arrangements will be the key. Integration may take time and eventually will produce rationalisation and at least geographical standardisation of cost. Initially the need to provide more plant must lead to increased costs. The form in which these will be levied is problematical.

The present system of part in rate levies, separate charges for water supply or abstraction and part in water treatment or effluent pre-treatment at the industrial plant and for effluent disposal charges, is confused. Tax concession also impinges on the problem: it is an economist's nightmare, the true and apparent costs being virtually impossible to ascertain.

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discussion

CHAIRMAN: D. A. D. REEVE, BSc, MICE, AMIWPC
Engineer, Upper Tame Main Drainage Authority

The CHAIRMAN introduced Mr Valentine Lewin who could always be relied upon to inject life into a discussion. For many years he had been the manager of the Oxford Sewage Works where the trade effluent problem was very evident. The cost of public health engineering was reflected in the cost to industry of treatment of industrial waste waters. There was closer contact between industry and public health engineers than in the past. Even at the capital works stage industry was consulted when schemes were put forward for approval, and it was usual for the Confederation of British Industries to be represented at formal inquiries or technical investigations. Industry was becoming increasingly aware of the cost to them of treating trade effluent.

2. Mr V.H. LEWIN said he could emulate Professor Beckerman, the political economist at London University and a member of the Royal Commission of Environmental Pollution, who prefaced a lecture on the economics of pollution with the claim that "he deplored his own weakness in having agreed to speak on the subject on which economists so far knew very little." The position had not changed; there was an urgent need for data upon which a real national economic cost-effective study could be based. Mr LEWIN gave details of some further papers (refs. 11 - 14) which were relevent.

3. Mr LEWIN said that on page 2 of the paper he stated that the new Regional Water Authorities would have an impact on economy. This was a gross understatement: they would put up the cost to the consumer, water requirements would drop, rivers would be improved, and the money available on loan (£1300 million over the next five years) would just about keep pace with inflation and be equivalent in purchasing power to the £860 million the Industry spent in the last five years. Unless the Thames received some priority because it flowed past the House, coastal resorts and the industrial Midlands and the North would get the lion's share of that quota. The less fortunate authorities would have to do a good deal out of revenue. Perhaps this was a good thing, because if they were wise it would be with machinery and plant, not concrete. Reduction in pollution could be expedited by new legislation to amend out-dated trade effluent agreements. The price of water would perhaps be higher for those who lost it as steam, and others like brewers, mineral water bottlers and apothecaries, who sold water at fat profits. Domestic users also could afford a small increase in cost but Mr LEWIN deprecated the suggestion that a separate drinking water supply should be brought round in bottles. People in the refuse collection field would also object: they already had enough trouble with non-returnable bottles and plastics, and if returnable it would take five to ten times as much water to clean the receptacle for safe re-use.

4. Mr R. WOOD said that there were two distinct aspects of trade effluent control economics: that of the trader and that of the sewerage authority. The trader was dealing with a near monopoly and soon would be dealing with a complete monopoly. The monopolist for his part was dealing with a unique product, which all his customers needed to live and which some of his customers needed to thrive. Mr Lewin had said that one result of the monopoly would be that effluent treatment costs and water supply charges would be integrated. Mr WOOD hoped they would not be. The control of trade effluent discharges relied to a great extent upon its economic armoury, and any trader ought to be able to see immediately by reduced charges the result of more

efficient water re-usage, better pre-treatment, or capital expenditure on pre-treatment of his effluent. There had been a reference earlier in the Conference to the industrialist having the choice of fully treating his effluent to a standard suitable for discharge to the river direct, or having it done for him in some degree by the sewerage authority, and if he had this choice he could be faced with rather a nice problem.

5. About a year ago Mr WOOD obtained some costs of actual plants for full treatment of industrial effluents. All were full treatment plants but in each case some existing equipment was available. Textile effluents would cost £7.4 per thousand cubic metres; and his Drainage Authority would charge about twice as much for full treatment. A dye waste at £4.5 per thousand cubic metres would be charged about the same. A poultry processing plant on the other hand with a charge of £45.4 per thousand cubic metres to do it themselves would get away at half price if they discharged to the Authority, whereas paper mill wastes ranging from £7.8 to £2.1 per thousand cubic metres would pay rather more if the effluent were treated by the Authority. In each case allowance should be made for the existing plant. In fact the manufacturers did not have this choice and land costs alone could often rule out on-site treatment. Usually it was in their interests to install some sort of pre-treatment plant. It was usual that each stage of waste treatment cost more than the previous one, so logically it would pay the trader to do more than the bare minimum in pre-treatment. The industrialist establishing a new process or building new premises could usually do a neat sum to decide how much more than the minimum he should attempt, the minimum being that set out in the agreement or consent which laid down the precise limits of individual constituents.

6. The Mogden three part tariff was useful. For example, in 1971 effluents discharged to the sewers of the West Hertfordshire Main Drainage Authority were charged according to a formula as follows:

$$C = 2.32 + M_t/158.8 + S_t/36.3$$

where C was in £ per thousand cubic metres.

There were two fixed unit charges: the charge for the preliminary treatment of £2.32 and the factor $M_t/158.8$ which was subject to a minimum of £1.99 per thousand cubic metres, so the minimum chargeable value of M_t was 316 (say 320). Thus any manufacturer was committed to a cost of £4.31 per thousand cubic metres whatever he discharged. If he considered that the cost of effluent disposal must not be more than £5 per thousand cubic metres as far as he was concerned, then the maximum solids concentration that he could permit in his effluent was 25 mg/l, or if he had no solids, the maximum McGowan strength was 425. If on the other hand his permitted expenditure was £15 per thousand cubic metres, then the maximum solids concentration he could afford would go to 400 mg/l, or if he had no solids he could have a strength figure of just over 1100 parts per million.

7. Examination of the sewage purification and disposal statistics of the I.M.T.A. for 1968/69 indicated that the average trade effluent income per thousand cubic metres ranged from rural districts at 7.96p to the G.L.C. at 15.98p. The average at 10.7 were the country boroughs, and Mr WOOD thought it was likely that the costs of the new Regional Authorities would be in that mid-range. However, out of the 470 rural district councils only 34 submitted figures, and only nine of them had trade effluents.

8. The maps in the recently published River Survey suggested that industrialists in the Midlands and the North would have to pay more for their trade effluent treatment because the bulk of the money would have to be spent there in the next few years.

9. Although there was the possibility of charging for water as a form of transport rather than as a commodity, the industrialist rarely paid more than a nominal charge for the sewers, which were expensive. An industrialist to be safe often put in a trade effluent request giving the maximum volume as twice that which he discharged. When any calculations for duplication or relaying of sewers was made this had to be taken into account. Mr WOOD asked the author how authorities should charge the industrialist for the use of the sewers. Should the charge be related to the dry weather sewage flow, to the total flow, to the volume he actually discharged or to the maximum amount he wished to discharge?

10. Mr LEWIN said that a common invoice for abstraction, water usage, sewage and effluent charges was inevitable sometime after the formation of the Regional Water Authorities. He agreed that there would be advantage in itemising these on the bill separately. The Regional Water Authorities would obviously unify charges over a district or the region and so it was probable that present high operating costs of some small works and low running costs of large works would tend to level out. This might mean a lower charge to industrial effluents presently discharging to small rural works. He agreed that capital investment necessary in the Midlands and the North would necessarily increase charges in those areas. Mr Wood's costs and charges

data was interesting and applying it to Oxford Sewage, McGowan Strength 105 Suspended solids 354 mg/l would mean that West Herts could treat it at a charge of £14.06 per 1000m^3 whereas Oxford costs or charge using their own formula would be £29.00 per 1000m^3. This illustrated it was more economic to treat sewage (and trade effluent) at very large works. Similarly Mr Wood quoted paper mill waste charges from £2.8 to £7.8 per 1000m^3 whereas paper mills discharging settled waste to Oxford were charged from £13.9 to £24.00 per 1000m^3.

11. Mr Wood's point regarding charging for sewer capacity was pertinent, and as local sewers were likely to be the responsibility of one authority while trunk sewers and treatment plant another's, it was clear that tripartite agreements or consents would be necessary, and needed to include equitable sharing of income. In Johannesburg following major resewering, property was charged for the cost of the sewer, whether it was used or not. In this country, however, many sewers had been put in a long time ago, in many cases substantially oversized, in anticipation of potential future development. It would thus seem unfair to charge on sewer capacity. Indeed, such a course might lead to excessive caution in sewer design and restriction of designers "safety margins" and capacity for potential development. Excess capacity within the limits was less embarassing or costly than under capacity. Charges should be based on total sewage flow rather than hypothetical dwf and for incentive potential and equity, on actual volume discharged.

12. Mr C.H. SPENS asked the Chairman to mention the difficulties that Birmingham Corporation had over the knotty problem of acceptance of trade effluents. The CHAIRMAN said the problem was complicated because his Authority had no direct trade effluent function although it acted as agent to most of the constituent authorities. Two of these authorities, Birmingham and Wolverhampton, exercised their own trade waste control directly and collected the whole of the sum that was due to them and his Authority on an agreed basis. The trade waste charging basis was uniform throughout the Authority's area. His Authority made the calculations on the basis of analysis and informed the constituent authorities, who collected the charge, retaining an agreed amount for carriage. Mr REEVE's Authority took the rest for treatment and carriage purposes in respect of the main sewers which they operated. The constituent authority initiated any prosecution that was necessary. The scheme worked extraordinarily smoothly.

13. Mr J.M. WALKEY said that Mr Wood had spoken of the industrialist reserving sewer capacity in his agreement or consent with the authority, and suggested that he also reserved works capacity and that little account was taken of that reservation in the charges which were made on him. Mr LEWIN did not think that the industrialist reserved any capacity either in the sewers or in the plant. The municipal authority designed the plant with excess capacity to take care of future developments. Providing that reserve was still in operation and the plant was producing a satisfactory effluent, the management of the plant gave consent to accepting some volume of trade waste. In Oxford the works was designed with reserve capacity and industry had reduced its effluent discharge by 50%; the capacity was there but not fully used. If the factory were told 'you reserve one tenth the capacity so your costs are £X per year whether you use it or not' the incentive of the factory to economise would be destroyed. The real value of trade effluent charges in the last fifteen years had been the incentive to industry to realise the value of water.

14. Mr T.H. CARTER asked Mr Lewin whether he anticipated that with the re-organisation of the Water Authorities, conditions for the mandatory charges of trade effluent would be incorporated, since some authorities did not charge for trade effluent for one reason or another. What transitional arrangements for changeover would be made for the existing discharge which was not charged for.

15. Mr LEWIN said that the Government, being a democratic organisation, was bound to modify the ideas first put forward for the Regional Water Authorities. However, the Regional Authorities would have an obligation to recover the costs wherever they could, and therefore one of their first tasks would be to ensure that all the trade effluents that were escaping charge because local authorities had been dilitary, would be picked up. He did not know whether the legislation could be changed to cover those industries who had been long-sighted in the 1910-30's and obtained agreement without clauses for termination or change. Almost certainly each Regional Water Authority would determine some uniform policy for itself. It was quite possible that COD rather than BOD or McGowan would come into greater prominence, because it was easier to do. It would probably be three or four years before a scheme was settled and in the interim they might well delegate the work to the existing authorities, or districts within their region.

16. The CHAIRMAN asked Mr Lewin's views on the extent to which local authorities, sewage treatment authorities and their successors should offer an advice service to industrialists when the question of new plants or trade effluent controls arose. Mr LEWIN thought advice should not be given, although it was reasonable to indicate the alternatives, the economic advantage of the alternatives, make reference to other factories that used the alternatives, and give the names of reputable plant manufacturers or consultants. Mr LEWIN mentioned a factory that discharged ¼ million gallons per day to the sewers, and wanted to expand. The drains were not big enough and Mr LEWIN had suggested the use of ion exchange. An ion exchange system was adopted and reduced the volume of discharge to 10 000 gallons per day, and the chromium, nickel and copper were reduced to the prescribed limits. However, the effluent from the regeneration of the plant was high in sulphates and could have caused trouble. Mr LEWIN's Authority would have been in difficulty had his advice to the firm been unqualified.

17. Dr D.E. WRIGHT referred to the statement in the paper that the present price of 15 to 25p/1000 gallons for water had already caused striking economy measures. This suggested that one approach to the problem of pollution from industrial sources would be to charge the industrialist a high price for water. Those industries which used a great deal of water would be forced economically to re-cycle that water and so reduce their chargeable 'consumptive' use. Then if they put elements into it which were unsatisfactory for their own processes they would be forced to treat the re-cycled water on their own premises.

18. Mr LEWIN said this re-introduced the question of integration of water charges. He was convinced that trade effluent charges would increase on economic grounds. He hoped they would be kept separate from water charges. The Public Health Act laid down that the trader could only be charged what it cost to treat the sewage, and this was a weak point. Had it allowed a charge which would be an incentive for the factory to reduce its water we would not be worrying so much about water shortage. In 1956 when Mr LEWIN started to clean up the trade effluent discharges in Oxford, the then Water Engineer complained about the loss of profits. After the Water Industry was semi-nationalised water prices rocketed and made industry economise. The graph of flow of trade effluent in Oxford since that date had taken a downward trend, and the trend could be extended by again putting up the price of water. On the other hand, a limit would soon be reached due to residual COD. It was all very well for economists to say 'make these people re-use this water 20 times; this is the best answer', but the waste they then discharged would contain a great deal more residual COD non-biodegradable pollution and dissolved solids. For this reason in 15 years time more physico-chemical treatment would be used to supplement biological methods.

19. Mr P. RAMSDEN said that when the 1937 Drainage of Trade Premises Act was brought in, and perhaps even when the 1961 Public Health Act was introduced, complexity of discharges to public sewers was not appreciated. The chemical industry in particular discharged an increasing number of complex and intractible effluents, whereas in 1936 sewage works were generally capable of dealing with those by the conventional treatment. More research ought to be done in this field. Mr LEWIN agreed and said that the new Authorities would be able to collate data which was now missing.

20. Mr WOOD suggested that the charge for trade effluent under the 1937 Act could be made 'having a regard for the additional costs incurred or likely to be incurred'. The charges must be related to the nature and composition of the material discharged. The CHAIRMAN suggested that a way of testing this was by way of appeal, and Mr WOOD said it had been held on appeal that matters not related in any way at all to the treatment of sewage, such as street lighting on the sewage works, were a charge on the trader.

21. Mr LEWIN had some experiences of this. Fortunately the Department of the Environment, who held the enquiries, often gave decisions in favour of the local government side. During the evidence the authority had to show what it cost to treat and to substantiate that the figures were reasonable. Unfortunately the Department treated this information as private, and did not publish the results. If the proceedings of appeals were more freely available it might dissuade industrialists from rushing into appeal.

22. Mr R.W. BAYLEY noted that Mr Lewin anticipated that the Regional Water Authorities would have a uniform system for costing over their whole area. He wondered how this would affect future industrial development. It would be preferable to encourage industries to move towards the estuaries and away from streams, and one way to do that would be to have a weighted charge in accordance with local conditions.
Mr LEWIN replied that the new Authorities would wish to make their accounting simple

and would want a uniform rational cost over the whole community. He thought they might later integrate the present four charges, water consumption, water abstraction, sewage and trade effluent.

23. The CHAIRMAN said that earlier in the Conference he had expressed his opinion that precepting would not be an acceptable answer for the financing of the new Authorities. He doubted whether the cost of trade effluent treatment, unless it changed very substantially, would be a substantial factor in bringing about the re-location of industry.

24. Mr SPENS asked why Mr Lewin thought that the water charges would be increased by the new Regional Water Authorities? The cost of sewerage and sewerage disposal was likely to be equalised over the whole of the Regional Water Authorities, which would hit some manufacturing firms. When the consultative paper from the Department of the Environment was considered by the I.W.P.C., considerable thought should be given to the charging for sewerage, sewage disposal and trade effluents.

25. Mr LEWIN agreed that a great deal of thought must go into it. His own view was that even with a large organisation, improvement of the efficiency of sewage works and reduction of river pollution would cost more than had been spent in the past. The Government had said that loans for this would only be of the same order as they were ten years ago, and so money must be raised in some other way. Precepting was likely to be disfavoured by the new Authorities, and the obvious alternative was to raise the charge for water.

26. Mr J.L. THOMPSON said that there had been a lot of talk about concentrating industrial wastes to get smaller volumes. His firm was handling a case where the concentrate could be so small and so offensive that it could not be received in the sewers. In another case they had advised the industrialist to dilute his effluent before discharge. Mr LEWIN had always deprecated the idea of using water to dilute effluent. It was usually possible to treat a more concentrated waste more easily than a dilute waste. Physico-chemical methods might be more appropriate, disposing of the residual as a sludge, or by evaporation and incineration.

27. The CHAIRMAN queried Mr Lewin's assumption in his paper that the adoption of chemical engineering techniques could offer enormous savings in cash and investment. Physico-chemical or chemical engineering methods involved large aggregations of steel structures, and avoided (to quote Mr Lewin) a vast expenditure on massive concrete structures. The CHAIRMAN was not sure that any saving in cost could be assumed to arise from the adoption of chemical engineering techniques.

28. Mr LEWIN said that the traditional method of building a sewage plant was with concrete and reinforcement, with a 40 years' life, because of the preferential terms of such a loan period. Yet all the evidence was that most sewage works built 40 years ago were obsolete and needed substantial alteration or modification. Steel structures were usually given a 10 year loan period yet it need not have a limited life, because modern cladding would make it more durable. There were also alternative fabrics to steel. If the financial arrangements for borrowing the money were readjusted, there would be a greater use of the quicker and lighter chemical engineering approach to the job, and a saving in loan interest payment. Dr WRIGHT said that CIRIA were considering a new research project on this question.

29. In reply to a query from Mr Spens, Mr LEWIN said that loan charges were a cause of expensive design. For example, many small rural district authorities wanted to put up a small sewage works where packet plants could be installed in a few months, would work perfectly satisfactorily given the right operators, and would be cheaper on overall cost than the traditional structure. Nine times out of ten the traditional structure was built because the annual repayment sum was less, even though cost plus interest were greater. The CHAIRMAN said that recommended loan periods were maxima and there was no objection to authorities adopting shorter loan periods.

30. Mr R.P. COPPEARD represented a small rural authority with many small works, and thought Mr Lewin was wrong because of the difficulty in getting good operators to run the more sophisticated package-deal units. Operators understood small traditional works which they visited once every three or four days, but could not cope with the more sophisticated package deal unless there was a sewage works manager. Many rural districts had no manager.

31. Mr LEWIN never accepted that plant was too complicated for personnel to operate. When he went to Oxford in 1951 he had twenty five farm labourers who for 20 years had been pushing sewage around a sludge farm. When a modern mechanical plant with power generators was installed, all of those men were employed. They had to be personally re-trained, and they did the job well. The

CHAIRMAN had been astonished to find the extraordinarily quick and efficient way in which men who had been doing menial jobs adapted to quite sophisticated plant.

32. Mr J.D. HUNTER said that another point in rural authorities was distance and the number of small works which required supervision. Mr LEWIN thought this would be one of the advantages of the Water Resources Authorities: they could provide mobile teams.

33. The CHAIRMAN said that some package-deal units were rather capricious in their operation and required a fair amount of maintenance.

34. Mr G.F.G. CLOUGH had been personally involved in the application of chemical engineering techniques in waste treatment. Package plants in which the process was operated intensively required a higher degree of supervision, and were often constructed of steel. In the chemical industry the write-off period was often three to five years, and therefore a low capital cost was required. If the steel were made more durable by one of the various coating techniques possible, the price approached that of concrete, which also insulated well, which was important for waste treatment. Furthermore, most chemical plants closed down for a week a year or so, when any major maintenance could be carried out. Without a complete spare unit, that could not be done with the sewage works. Mr CLOUGH was not against using chemical engineering techniques, but they should be applied within the framework of sewage treatment requirements. Chemical methods had to be judged on the capital cost/running cost basis. An extreme example was a strong industrial effluent which could be treated by activated sludge having a capital cost of about £100 000. The alternative was chlorine injection, at a capital cost of about £50. The operating cost using chlorine was about 25 times that of the activated sludge system, but because it was only required for a very short period in a purely temporary situation, it was in fact more economical to use chlorine.

35. Mention had been made of the choice facing industrialists; in practice in the case of a new plant the industrialist had a choice. Where the plant had already been built and the capital already laid out in one particular direction, he had very little choice.

36. Mr G.L. ACKERS said that D.C.F. techniques were devised to deal with decisions like those between the various uses of materials and potential durability plants. A previous speaker mentioned that concentrates were easy to treat, and generally speaking this was true By avoiding water in the sewers in the first place, a great deal of trouble would be saved. A lot of effort was involved in mixing things together and then trying to separate them. Finally, Mr ACKERS hoped the Regional Water Authorities would differentiate costs where such differentiation was of significance, so that it would be these costs which would influence planning decisions and policy as water became more scarce rather than the Regional Water Authority itself acting as a quasi planning authority.

37. Mr LEWIN said that an alternative transport for sewage had been mentioned in the Jeger Report. The vacuum system had potential for new towns and blocks of flats, but in this country about £500 million was already invested in sewers and drains and it would cost £1000 million to remove them. Another point was that such systems used power and in the end used more water because much of the cooling water used for electricity generation was lost as steam. As far as planning was concerned, Mr LEWIN thought it was the job of all service authorities to respond to situations rather than to seek to control them in any major way.

38. The CHAIRMAN thanked Mr Lewin very much for presenting his paper and for dealing with the discussion in such a lively way.