WORKING PAPER 490

THE STRATEGIC IMPLICATIONS OF UNITED KINGDOM CATCHMENT RESEARCH: PROBLEMS AND SOLUTIONS

ADRIAN McDONALD AND DAVID KAY

School of Geography
University of Leeds
Leeds LS2 9JT

May 1987

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Adrian McDonald and David Kay

The University, Leeds, U.K.

St. David's University College, Lampeter, Dyfed, U.K.

INTRODUCTION

In many small countries with a high population density the use of land as an agent in the production of food has dominated over other strategic uses of land for example for the gathering of water. The United Kingdom is typical of many European countries and indeed of many structurally isolated units in coastal regions. The travel time of waters in the relatively short rivers is brief and the inherently variable flows create a need for storage. The "water estate", land primarily used for gathering water, is a significant part of the U.K. land holdings. About 1% of the U.K. land surface collects water that drains into direct supply reservoirs whilst almost half the land contributes to rivers above potable supply abstraction points.

It has long been recognised that vegetation must be of significance in the transformation of rainfall to streamflow. However, in recent years there has been a growing concern that the direct and indirect effects of land management have generally been detrimental to the water industry. A number of piecemeal economic assertions have been made. These have been neither national nor subject to the normal scrutiny of other researchers but have received much acceptance in part due to the position of the U.K. water industry as one of the major, most united land management organisation in the U.K.

In this paper the authors propose to outline the claimed influences of land management on water interests. Some of the influences are well supported by research findings whilst others are both contentious and local. In the second part of the paper we suggest a variety of approaches that might alleviate some of the proven problems. To structure the analysis of solutions they have been gathered under three headings; institutional, structural and economic solutions.

PROBLEMS

Quantity Problems

The cheapest source of potable water is from direct supply reservoirs. Although the specific cost depends upon the particular source, works and treatment provision, the normal cost is approximately £5 per megalitre. Since few sites for new reservoirs are being permitted in the U.K., new water supplies are more generally from groundwater or from river abstraction points. Costs for these sources are more variable but the normal range is from £20 to £50 per megalitre. Thus any reduction in quantity from an upland reservoir will, if replaced, have a unit cost of approximately 4-10 times that of the original supply.

In the late 1950 work started on the effects of afforestation on water yield in upland supply catchments. The work was carried out at Stock's reservoir, a site typical of many Victorian upland reservoirs. The results reported in Law (1957) indicated that over 40% of the usable yield of the catchment was lost due to the forest. Although Law was much criticised both for his site and his conclusions from the data, subsequent work by IOH comparing the yield from a major grassland catchment(R. Wye) with a largely, 70%, forested catchment (R. Severn) has demonstrated that the increased interception of the forest and the increased aerodynamic roughness have caused a reduction in streamflow of some 15% (IOH, 1984). Since streamflow consists of two components, a minimum flow, needed to maintain adequate flow levels in the lower river, and the remaining yield which can be used by the water industry, it is clear that a 15% overall reduction in streamflow will represent a much larger component of loss in yield to the water industry.

Changes in yield as the result of afforestation are not in doubt. There is doubt over the claim of the water industry that they should be permitted to maximise the water yield from areas of land. In addition the comparison made by the IOH between a grassland and a forest catchment may not be valid for the sites where the major Forestry Commission planting is planned, in Scotland. Here the change is between bracken, heather, bare ground and forest with a significant proportion of the precipitation as snowfall. Early results for bracken catchments (Lockwood et al, 1985) suggest that aerodynamic resistance in such crops may be much higher than grass and so differences with forest may be diminished.

Quality Problems

The claims of changes in water quality are much more contentious and are supported by much weaker data. The changes fall into three groups, microbiological, physical and chemical and in the latter two groups changes are claimed to be detrimental to water interests. Only the problem groups will be considered in detail here. A change from grazing to forest greatly reduces the concentration of enteric bacteria in the water. Since this measure is internationally recognised as the prime means of assesssing the quality of potable supply, afforestation may have a most significant advantage for the water industry. This water quality improvement stems from the reduction in input bacteria and from the reduction in physical energy within the system due to the limited response of runoff to rainfall (McDonald, Kay and Jenkins, 1984).

Chemical

The reduction in water quality is claimed to be significant in two areas. The first, nutrient enrichment, the second, acidification. Nutrient enrichment is caused by the addition of fertilisers for plant growth. It is not restricted solely to forest operations, improvement of upland grazing requires fertiliser additions. However, the majority of the concern over nutrient enrichment has focussed on forestry. Warn (1984) and Ginocchio (1985) have both indicated the dangers of increased nitrates in water supply. Nitrate has been associated with cancer of the stomach and with cyanosis especially in young children

Workers at the water research centre (Youngman and Lack, 1981) have claimed that over 260 catchments are at risk of algal problems stemming from nutrient enrichment if the proposed afforestation of 1.8 million hectares proceeds. They suggest that increased treatment requirements would have capital costs of £31-87 million with annual operating costs of £3.5 - 6.9 million.

Anthropogenic modification of rainfall chemistry has given rise to concern in a wide range of circumstances. Such modification lies outwith the realm of the land manager. However there is growing evidence that the rainfall chemistry is further modified as it passes through the canopy of the forest. Increases in concentration of elements in throughfall and stemflow may result from the following mechanisms.

1. Simple concentration increase through interception, dynamic roughness and evaporative loss.
2. Negative interception of highly charged occult precipitation or interception of dry deposition.
3. Addition of acidic leachates from coniferous vegetation.

The likely sites of forest development in the U.K. will exacerbate chemical problems because of the low buffering capacity of the soil and their inability to hold nutrients in the clay poor soils. Forests might also be responsible for a decline in base cations by uptake and the reduction in watertable by both the forest and drainage may increase oxidation of Sulphur and Nitrate resulting in increased SO_4 and NO_3 within the soil. Stoner (1985) has shown that for sites in Wales receiving similar, weakly acidified precipitation the effects on the streams having a forested catchment are more severe. Summary results are given in Table 1. Although there are cost estimates for the general effects of acidification, there are as yet no costs for enhanced acidity.

Physical

Changes occur in the physical properties of water as a result of land management. Two changes appear to be of cost significance to the water industry, namely sedimentation and discolouration. Sedimentation is largely due to forest operations rather than to the ecological effects of the forest itself. Sedimentation will reduce the operating life of an impoundment and the significance of this effect will be a function of load increase, trap efficiency and dead storage capacity.

Currently more concern arises through the turbidity effect of sedimentation and the associated treatment costs. Stretton (1983) notes that new treatment facilities costing £1.8 million are required at the Cray reservoir in South Wales following serious sedimentation. At a smaller scale Holmestyes reservoir in West Yorkshire had to be removed from operation following sedimentation from new afforestation in 1980. Additional costs were in the order of £34,600 during the 11 months out of service period. Capital costs of new equipment to deal with the residual load are £143,000 and additional running costs are in the order of £20,000 per annum (Edwards, 1985).

Water provided for potable supply should be colourless. Burt and Oldham (1985) note the increase in colour in recent years in

Table 1 Acidity associated differences between pasture and forest catchments

	PASTURE (3 sites)	CONIFEROUS FOREST (2 sites)
Range of mean		
pH	5.0 - 6.0	4.5 - 5.5
Mean Soil Al. Meq/l	20	25 - 50
No. of Insect Taxa	46 - 70	30 - 36
Gill Al. Accumulation Ratio	1:1 - 7:1	36:1 - 57:1
Fisheries Status	Generally abundant	Absent

upland supplies. Because of the high number of complaints (currently some 12,000 per year) the Monopolies and Mergers Commission drew the attention of Yorkshire Water Authority to the unsatisfactory colour of supplies. To reduce the problem a capital expenditure of over £30 million is currently underway. Again land management is seen as a major cause of change. Between 1979 and 1983, ditching of moorland in Upper Nidderdale, North Yorkshire was blamed for an increase in colour from 3.75 AU m^{-1} to 4.90 AU m^{-1} (AU = absorption unit, 1 AU is approximately equal to 15 Hazen units) at an increased treatment cost of £34,000 per year in 1983/1984 prices. In the same region quality deterioration in response to land use change is documented for Blackmoorfoot Reservoir. Here land improvement and liming between 1976 and 1983 raised pH levels and despite a 20% reduction in the water treated, chemical requirements doubled and unit treatment costs increased five-fold. The trends are shown in Figure 1.

SOLUTIONS

Three sets of solutions are presented:

1. Institutional solutions Involving both the water industry and the forestry commission
2. Structural solutions which involve the modification of operation by both the water and forest industries particularly at a local level.
3. Economic options in which the status quo is maintained and reparation is made through some agreed procedure.

Institutional

Information

In the United Kingdom there is no formal mechanism by which information can be exchanged between the forest and water industries. The Forestry Commission which has direct control of about half of the current afforestation in the U.K., is limited by budgetary and planning constraints through the Ministry of Agriculture. The water industry enjoys an apparently freer, but in practise more complex, form of control largely through the Department of the Environment. There is therefore a need to establish

1. The precise nature of the information needed by both industries to permit damage limitation.
2. Procedures by which the information might be transferred and acted upon.
3. Arbitration procedures to resolve conflicts.

The basic information needed includes the location, extent, and timing of proposed afforestation and the procedures to be used in the ground preparation. The information would be needed at least three gathering seasons in advance. Since the bulk of Forestry Commission planting is in Scotland and since that country does not have multi-purpose semi-autonomous water authorities, exchange of information would most satisfactorily take place at Forest Conservancy - Regional Council level. In England, at Conservancy - Water Authority level.

Partition

The water resources of different regions of the U.K. are shown in Table 2. Those areas most highly stressed are outwith the areas

Table 2 Water resources availability and catchment change in the U.K. Region

Region	Runoff	Net Resource (Runoff - Baseflow Requirements)	Population 000s	Total abstraction Ml/d	Gross Resource availability (Runoff/ abstraction)	Net Resource availability (Net Resource/ abstraction)	New Forest Plantings ha x 10^3
North West	33,200	19.900	7,052	6,107	5.4	3.3	
Northumbrian	12,800	7,700	2,672	1,058	12.1	7.3	
Severn Trent	19,000	11,400	8,189	8,427	2.2	1.4	
Yorkshire	17,700	10,600	4,534	5,408	3.3	2.0	
Anglian	9,200	5,500	4.636	2,200	4.2	2.5	England
Thames	8,300	5,000	11,775	4,090	2.1	1.2	1.9
Southern	9,300	5,600	3,760	1,482	6.3	3.8	
Wessex	10,800	6,500	2,230	882	12.2	7.4	
South West	21,500	12,900	1,347	693	31.0	18.6	
Welsh	49,600	29,800	3,000	8,419	5.9	3.5	1.4
Scotland	200,000	120,000	5,217	4,236	47.2	28.3	22.0

where the bulk of afforestation is planned. In Scotland, the ratio of resources to demand exceeds 40 with the bulk of supply from low cost reservoir sites and with the prospect of further available sites. In England, however, resources available are close to parity with demand when river baseflow requirements are taken into account. At the simplest level then, priority to forestry might be given in Scotland with water supply priority in England. Within each region smaller areas could be designated in contradiction to the broad priority classification, for example the Central Scotland Water Supply Area.

Structural

Modified management

The Forestry Commission has already produced information on the management of forest streams (Mills, 1980). However, this focussed largely on the biological well being of the streams and reduction of the erosive potential. From the viewpoint of the problems outlined earlier it is important to remove coniferous forest from the dynamic contributing areas of the forest. The contributing area (CA) is a variable area of land that is close to saturation and which provides the bulk of the river flow through saturated overland flow. Acidic or nutrient rich flows from these areas will reach the streams quickly and without the possibility of cation exchange or buffering. The contributing areas form a corridor along the streams often becoming proportionally more significant in the upper parts of the catchment. The CA expands during winter and during individual storms.

To define the CA exactly might not be feasible despite the careful land evaluation studies that precede afforestation. However the non-planting of a 75 m corridor on each side of forest stream would encompass much of the CA. It would also increase light and decrease organic fall to the streams as suggested by Mills (1980). Such an area of non-planting is likely to be significant in the overall economics of afforestation. Test cases in some forests of Southern Scotland, Glentress, Elibank and Traquair Forests, indicate that 15-20% of the forest could be lost in CA protection. Glentress for example is almost 10 km^2 and has 12.5 km of streams. Corridors would use more than 1.8 km^2. The calculated loss percentage is 19.05. Trap efficiencies of ponds that might be introduced into the drain systems are low and at any feasible size are not likely to remove more than 20% of sediment load. To reduce sedimentation drain lines should end before the stream,within the CA. Drains would also generate less sediment if they were not allowed to penetrate the mineral horizons of the soils. However the most effective management would be the rescheduling of operations. Spring ditching for example, would allow the revegetation of the ditches before autumn and winter erosive floods.

Sensitivity Analysis

While the term sensitivity analysis is most commonly applied in a modelling sense, it is in every respect appropriate to use it on the ground. Different land areas have a differing sensitivity to change in land use. It would be possible to map catchment to identify sensitive and less sensitive areas. In this way proposed developments for forestry could be screened and examined in more depth in sensitive regions. There are a number of causes of sensitivity in water catchments which provide a basis for classification:

1. Supply sensitive type I. In this class would fall any reservoir and supply system where the demand and reliable yield was close to parity. Loss of supplies would lead to a demand for new resources. Within this class it would be valuable to (a) identify systems with a critical period close to or greater than one and (b) the costs or type of alternative supplies.
2. Supply sensitive type II. This type would be identified by the nature of the treatment facilities available. Where lowered water quality could not be contained within the existing treatment system the catchment would be designated supply sensitive. Again within this class it would be valuable to define the nature of treatment limitation.
3. Environmentally sensitive type I. Catchments from regions with high erosive characteristics determined from bed load characteristics, other afforestation sites or soil survey. In the U.K. experience any area having a humus layer thinner than a feasible furrow depth and thus penetrating the mineral layer would fall into this class.

4. Environmentally sensitive type II. Catchments having a low base status or naturally acidic flows from which chemically enriched flows would issue unmodified. There is a case for designating such catchments on the basis of river/lake sensitivity to include catchments supplying sensitive fisheries and oligotrophic lakes.

Economic considerations

Each of the industries discussed in this paper are highly cost conscious. Almost all of the solutions outlined have economic implications. It could be argued that the forest industry should make financial reparations to the water industry for loss of supply and quality. This of course assumes a prior right to water on the part of one industry. Similarly, if the forestry interests do modify their land management patterns to accommodate outside bodies one might expect that they should receive a payment in respect of the "sub-optional" land-use being practised. On the other hand it may be time to recognise that the era of cheap water, based in the U.K. on a Victorian legacy, is now over and that consumers should pay the full economic costs of supplies as they are developed today. Revenue from higher costs could be used to reduce the estimated 20-30% of supply lost by leakage in the distribution system. There is certainly a moral argument that the water industry should attend to its internal losses before raising questions about yield loss through outside agencies.

CONCLUSIONS

Forestry has an effect on water interests. Few of the studies are sufficient to be scientifically acceptable on a national basis. Claims about the economic effects range from a few thousand pounds in individual cases to hundreds of millions of pounds nationally. The economic basis of many of these claims is dubious. There are paths that might alleviate some of the problems but as yet the very different administrative spheres of the two industries hinders progress. Upland agricultural improvement will also cause water supply deterioration. This is carried out by individual farmers and will be more difficult to control.

Finally over the last ten years there has been a change in the nature of forest development in the U.K. Almost half the new planting is now carried out by private companies, again much more difficult to control. Forestry Commission planting is now focussed very much on replanting existing forested areas and so the question here concerns the effects of second rotation afforestation and deforestation.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the help of the Welsh and Yorkshire Water Authorities. The Natural Environment Research Council provided a grant from which much of the material on problems was developed. The Countryside Commission encouraged the development of solutions. The paper was typed and made readable by Margaret Hodgson to whom we are again grateful.

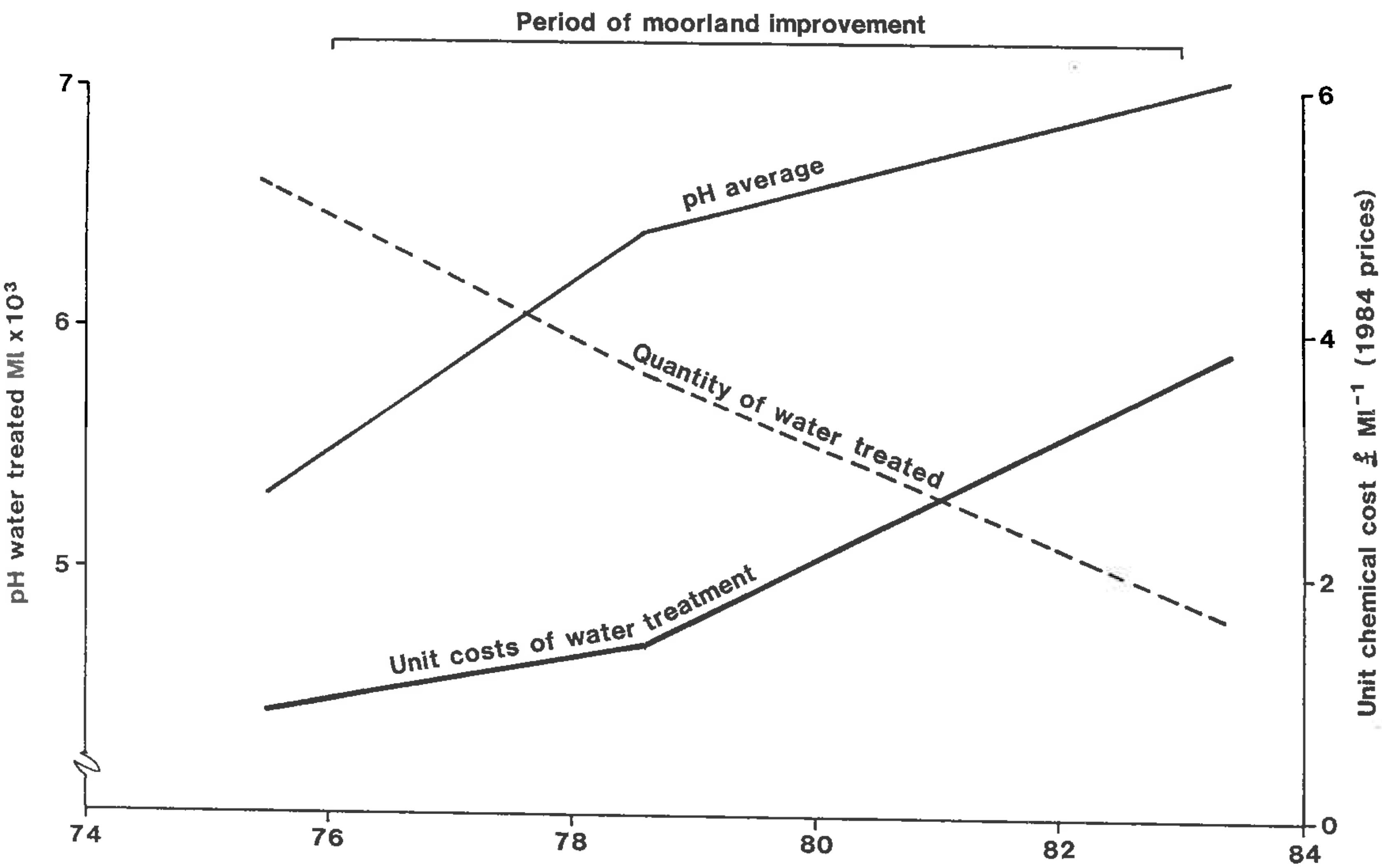
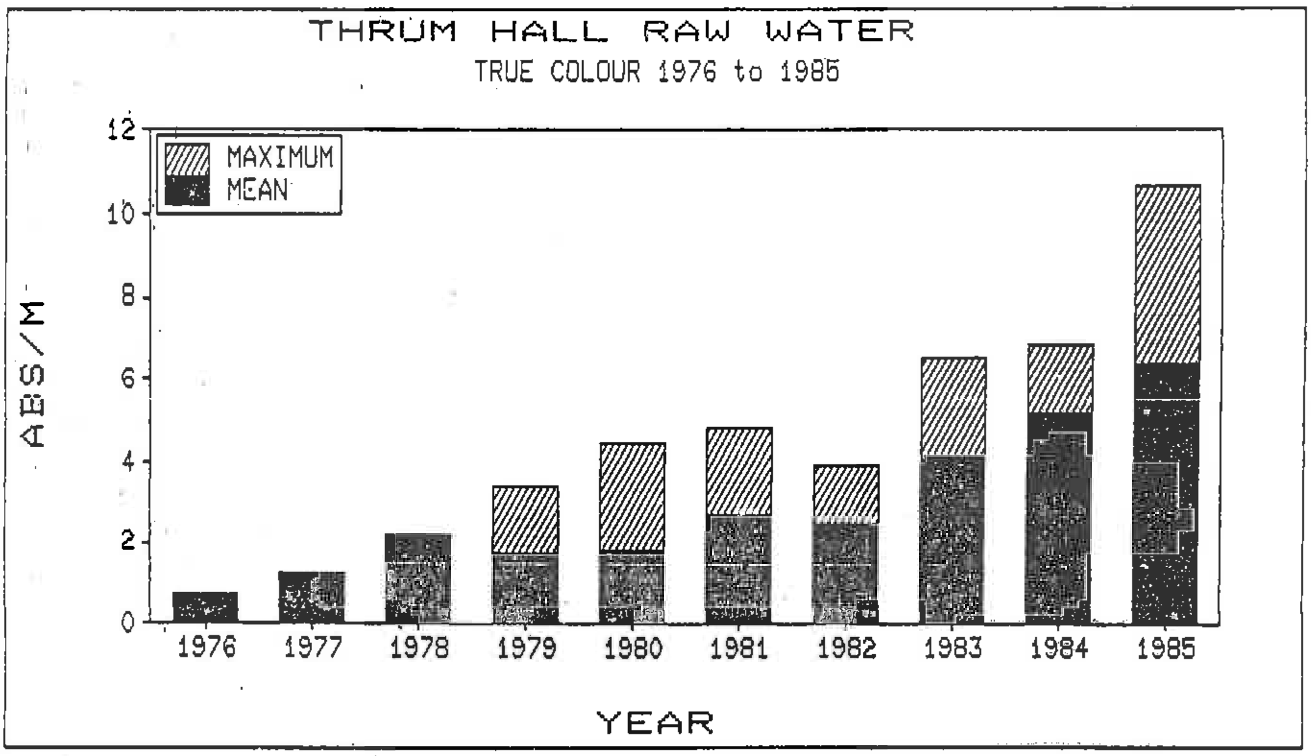


Figure 1. Cost and quality trends in an improved catchment in Yorkshire.



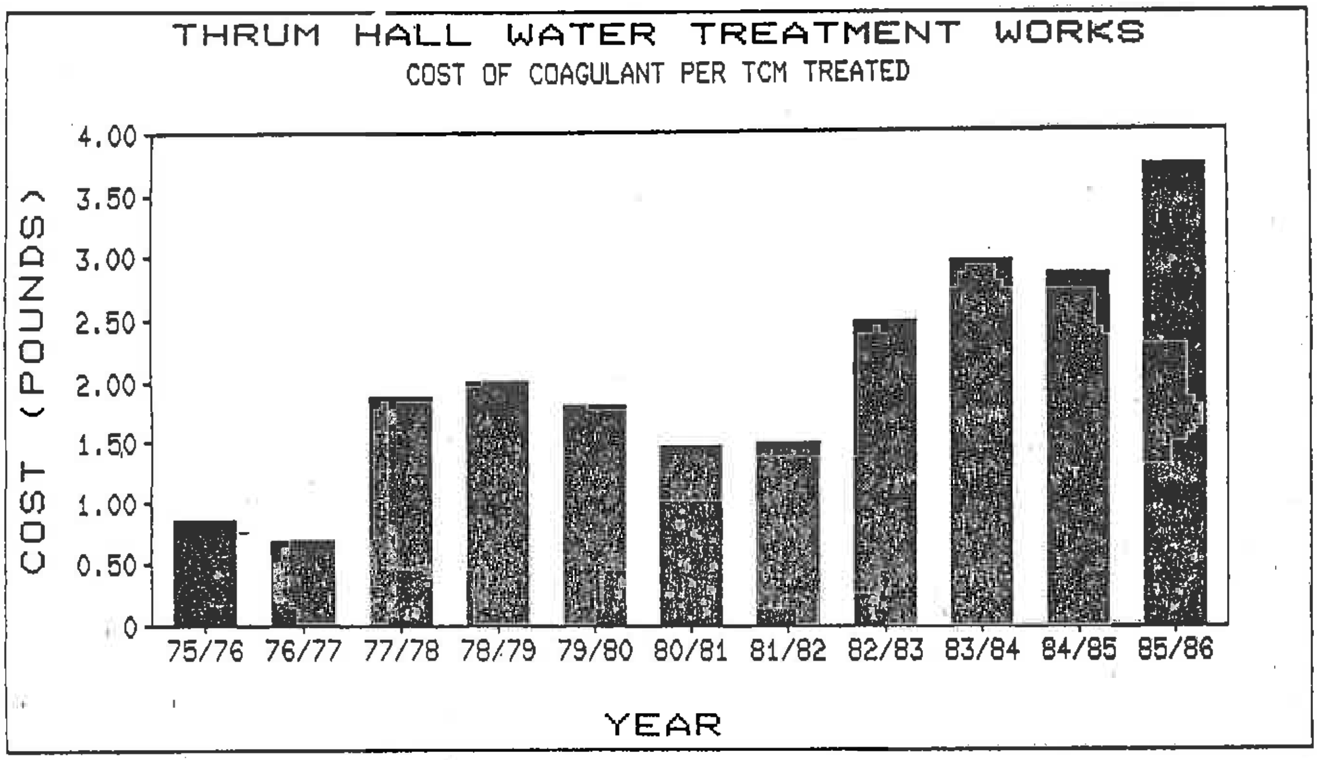
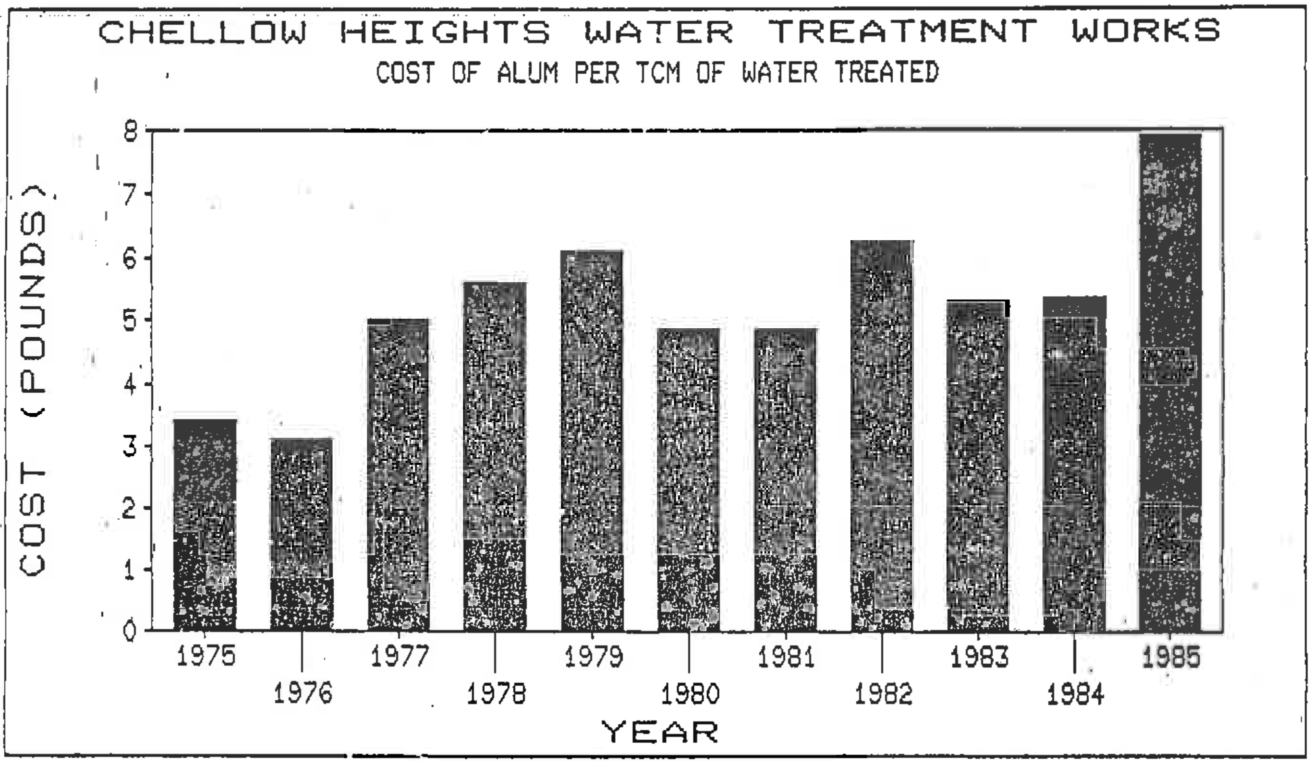


Figure 2. Trends in raw water colour and associated coagulant cost increases at Trhum Hall treatment plant. All costs constant at 1986 prices.
(Source: E. Haworth, paper on coloured waters presented to the Institute of Water Engineers and Scientists, 15th April, 1987).



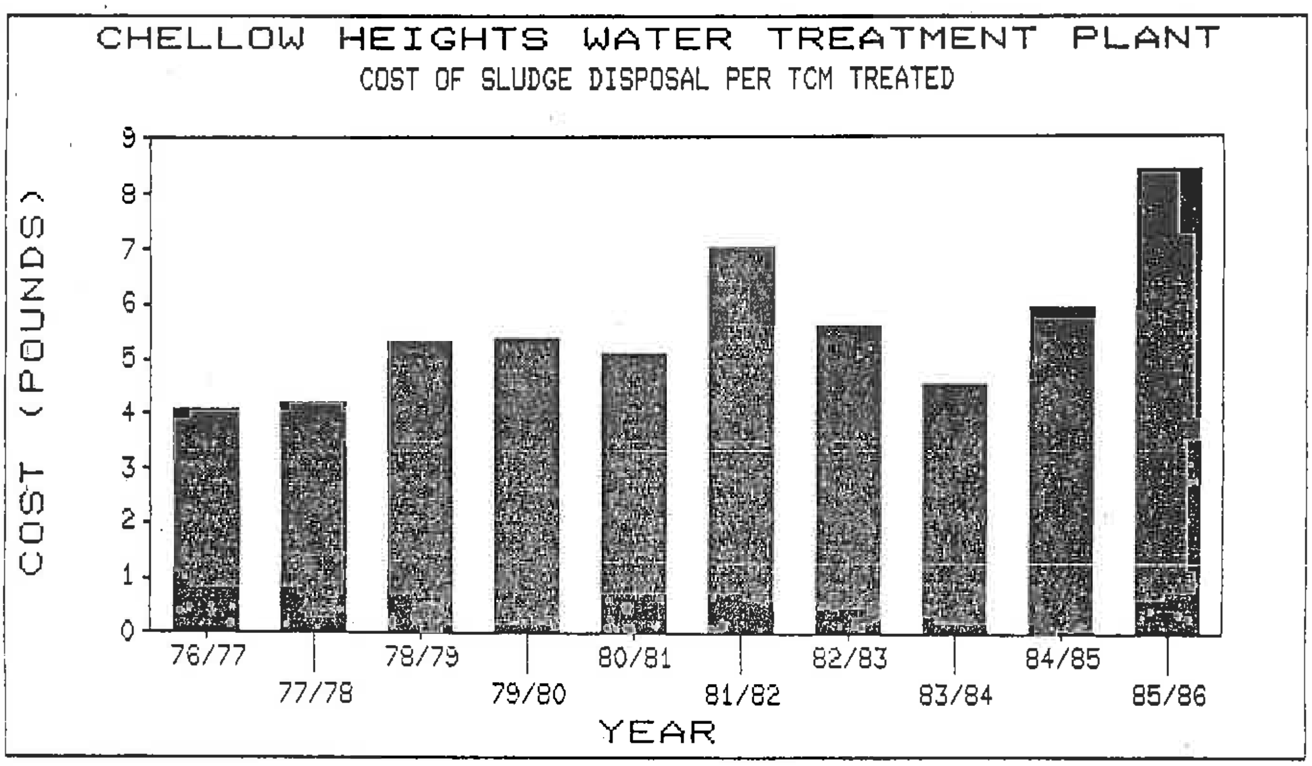


Figure 3. Trends in costs of alum applied per TCM at 1986 prices and subsequent trends in sludge disposal costs for Chellow Heights at Esholt.

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