CHAPTER 1

THE NATURE OF WATER MANAGEMENT

In 1969 a geographer could write: 'Perhaps the best tribute to the water supply industry in Britain has been the lack of interest which has been aroused in its activities. For most of us the supply of unlimited water of excellent quality at the turn of a tap has been taken for granted' (Jackson 1969: xiii). This lack of interest did not persist far into the 1970s. At the beginning of the decade a government advisory committee was devising a new management structure for the water industry, and the Water Act 1973, implemented the following year, wrought tremendous changes in the industry's organisation. Then came increases in the charges for water services, variable from place to place but many greatly in excess of general rates of inflation. Public alarm at the reorganisation and at the seemingly associated price rises led to a government review of the working of the 1973 Act and a promise of early amendment.

At the time of writing we are recovering from a severe drought. In August and September 1976 domestic supplies in south east Wales were cut off for part of the day and in areas of Devon the only water was from street stand-pipes. The government's legislative programme was rearranged to make room for an emergency Drought Act (August 1976), and the water industry, scarcely settled down after the upheavals of reorganisation, had to face the possibility that reservoirs and aquifers would not refill adequately during the winter. Relief has come with an unusually wet winter, but the memory of the drought is still vivid.

The drought was exceptional, unlike anything since rainfall records began in 1727, and it could be a mere aberration, although a serious disruption for agriculture, industry and domestic consumers of no lasting significance. More worrying is the suggestion that it may be evidence of a climatic change over Britain and north west Europe, which could give many years of lower rainfall. It is too early to know for sure. What is certain is that unlimited, cheap water supplies cannot be taken for granted.

But this book is not about crisis in the water industry, disturbing though the last few years have been. Rather it is about change in the water industry, and in particular the institutional and management changes that have helped the industry adapt itself to the task of giving the nation the water services it wants at costs it is prepared to pay. Indeed, it is thanks to recent changes that the worst drought for several centuries has not been a greater calamity. The drought has confirmed the success of many of the post-Water Act arrangements – and has emphasised certain deficiencies too. Further change is now inevitable.

Water management has been accepted as a public responsibility for a very long time. The ancient 'hydraulic civilisations' of Egypt, Babylonia, India and China depended on large scale engineering works for irrigation and flood prevention, and through the maintenance of the river works their governments were able to maintain a monopoly of social and political power. In the New World, pre-Columbian Peru and Mexico had elements of hydraulic civilisation, with strongly centralised government (Hall and Dracup 1970: 11; Smith 1969: 107–9). Britain never possessed a hydraulic civilisation in these terms – society was not organised around water management – but even here water management always seems to have had social and political dimensions.

It is obvious that the complexity of the water management problem increases when the demands for water services outstrip easily developable new resources. The first function of water management is the development of new resources, but when relatively low-cost possibilities have been exhausted and demand continues to rise, management has to assume a second function. This is the allocation of available resources among potential users, a 'rationing' of water services which may be effected by price, by administrative means or by a combination of the two. A third function, recycling, is necessary when new water is insufficient even with careful allocation. To some extent recycling occurs whenever sewage or other watery wastes are put into rivers upstream of abstraction points, but many modern water resource systems require recycling on a much greater scale than this. The regulation of effluent discharges and their integration with other water services becomes a major management task.

Our water management institutions have, over the years, taken upon themselves these three functions of development, allocation and recycling. The most recent changes, following the Water Act 1973, have been in the integration of effluent disposal. A decade earlier the Water Resources Act 1963 concentrated on water allocation.

This chapter goes on to explore the nature of the water management task, and especially those characteristics of the hydrologic system and of man's demands on it which determine the type of management needed. Following Craine's example in his study of the Water Resources Act 1963 (Craine 1969) and the water industry's deliberations both before and after the Water Act 1973 (Department of the Environment and Welsh Office 1970: 50–1; Central Advisory Water Committee 1971; Department of the Environment 1973a; Department of the Environment 1974a; Department of the Environment, Welsh Office, Ministry of Agriculture, Fisheries and Food 1976), we suggest institutional conditions which seem to favour good management.

Chapter 2 is a short review of the growth of water management legislation, emphasising the gradual convergence of responsibility for different water services upon the regional Water Authorities, and the problems of co-ordinating the work of regional units into a national water policy.

Then follows a series of case studies of different water services – public water supply, spray irrigation supply, flood damage reduction and effluent disposal. This is not intended to be a comprehensive list. Rather each service is chosen because it reveals a substantially different set of management problems. Present policies are shown in historical perspective, for most of the problems being tackled now with new weapons have been around for some years. Partial solutions have accumulated with time. Questions now are whether the management structure allows more complete solutions and whether it is flexible enough to tackle the different problems which are certain to be generated to replace those solved. As well as considering individual water services, we include a chapter on the contribution of groundwater to total resources, to complement the many references to surface sources and to draw out the special problems of controlling the exploitation of an invisible asset. Chapter 8 discusses aspects of water policy which transcend the boundaries of the regional Water Authorities and involve the whole nation. Finally we examine the water industry against the criteria of good management here set up.

The water management system

Water management can be considered as a man–environment system which transforms inputs of physical resources into desired outputs of water services. Man intervenes in the natural hydrologic system to increase the quantity of usable water and to modify its patterns of occurrence. However, man's control of the system is incomplete. Some inputs, rainfall for instance, are largely free of his influence; and some outputs, such as severe flood damage, are not what he desires.

Figure 1 illustrates this concept of water management. The management system at the centre of the figure uses structural and non-structural measures, first to develop and modify inputs and then to allocate and recycle the transformed resources among the potential users to give the desired outputs of services. As well as being linked to each other via the management system, the inputs and outputs are themselves inter-linked. Reservoir and groundwater abstractions may be increased or decreased in order to regulate river flow; and river flow controls the replenishment of groundwater resources and of many surface reservoirs. The outputs of water services are inter-linked in that some can be had simultaneously and are thus complementary, such as recreation, amenity and navigation, while some are incompatible or conflicting, an increase in one resulting in a decrease in another. For example, if water is drawn out cf a river for irrigation, a char-

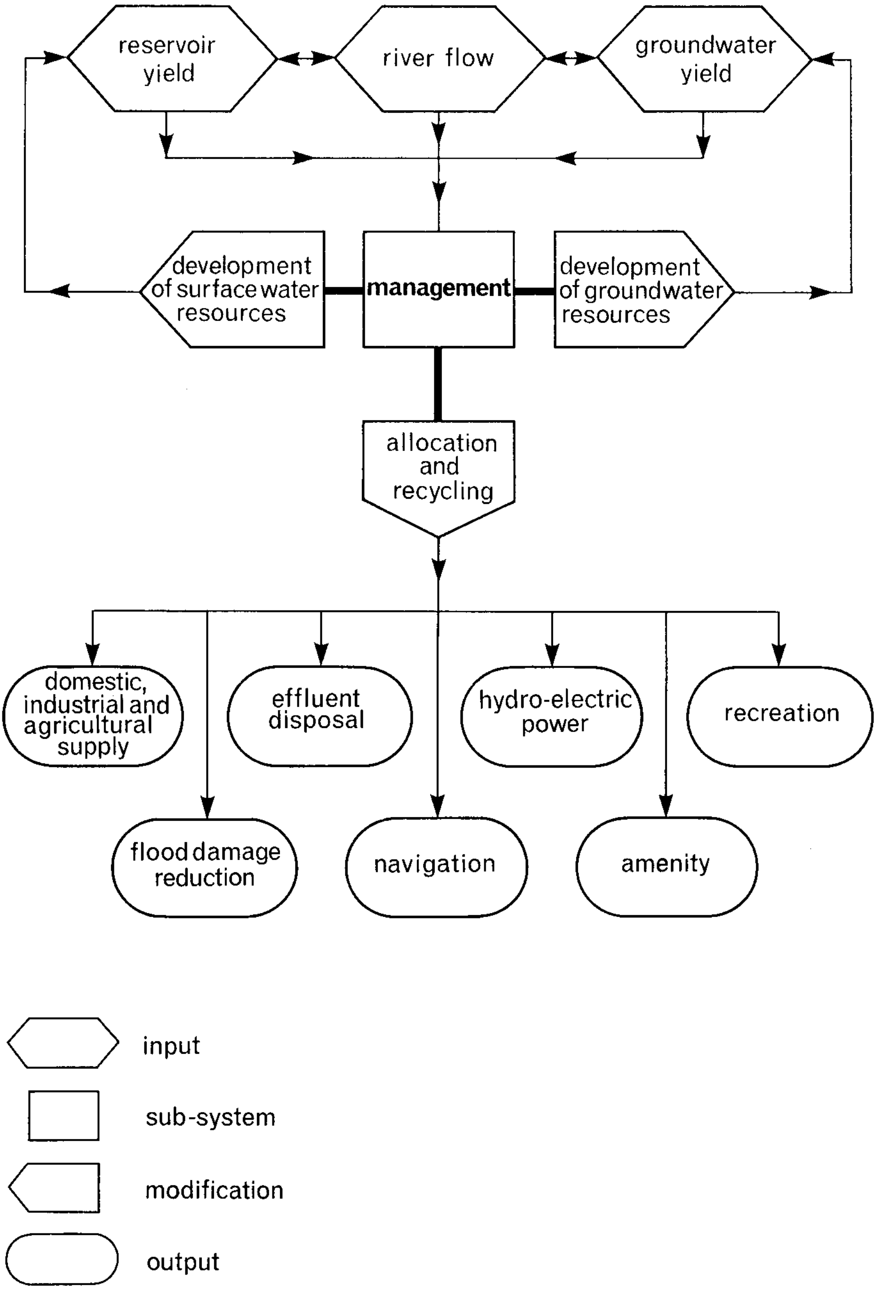

Figure 1 The water management system.

acteristically consumptive use, the river level may fall, restricting all those services with higher water level requirements. The central elements of the system, the water management techniques, are determined by the inputs and the desired outputs. They are there to create the one from the other.

System inputs – some characteristics of water resources

Figure 2 is a block diagram of a river basin, showing the main components of the basin hydrologic system. Figure 3 shows schematically the interrelations of these same components. Precipitation in the form of rain, snow, hail or dew falls directly into river channels and bodies of standing water and also onto vegetation and the land surface below it. Some of this water evaporates or is transpired to the atmosphere, but much of that falling on the land is transferred over and through the soil to contribute to river flow or downwards to contribute to groundwater.

In the natural state, without the interference of man, evapotranspiration and river flow are the main outputs derived from precipitation, with water held in a number of storages or moving between them, *en route* through the system. These natural storages include the river channel, vegetation surfaces and irregularities of the land surface retaining water usually only for a very short time, storage in the soil, and groundwater storage.

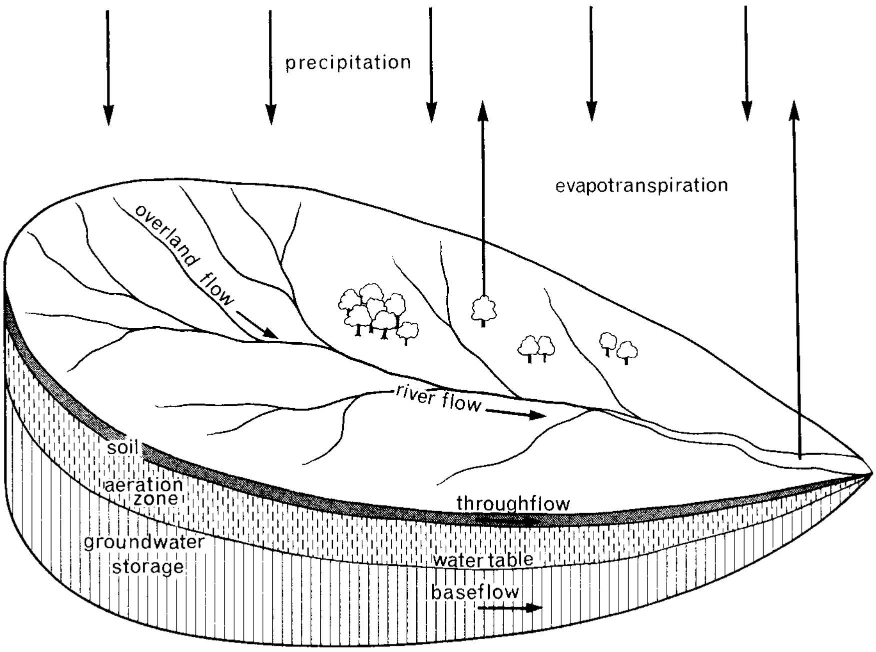

Figure 2 Block diagram of a river basin.

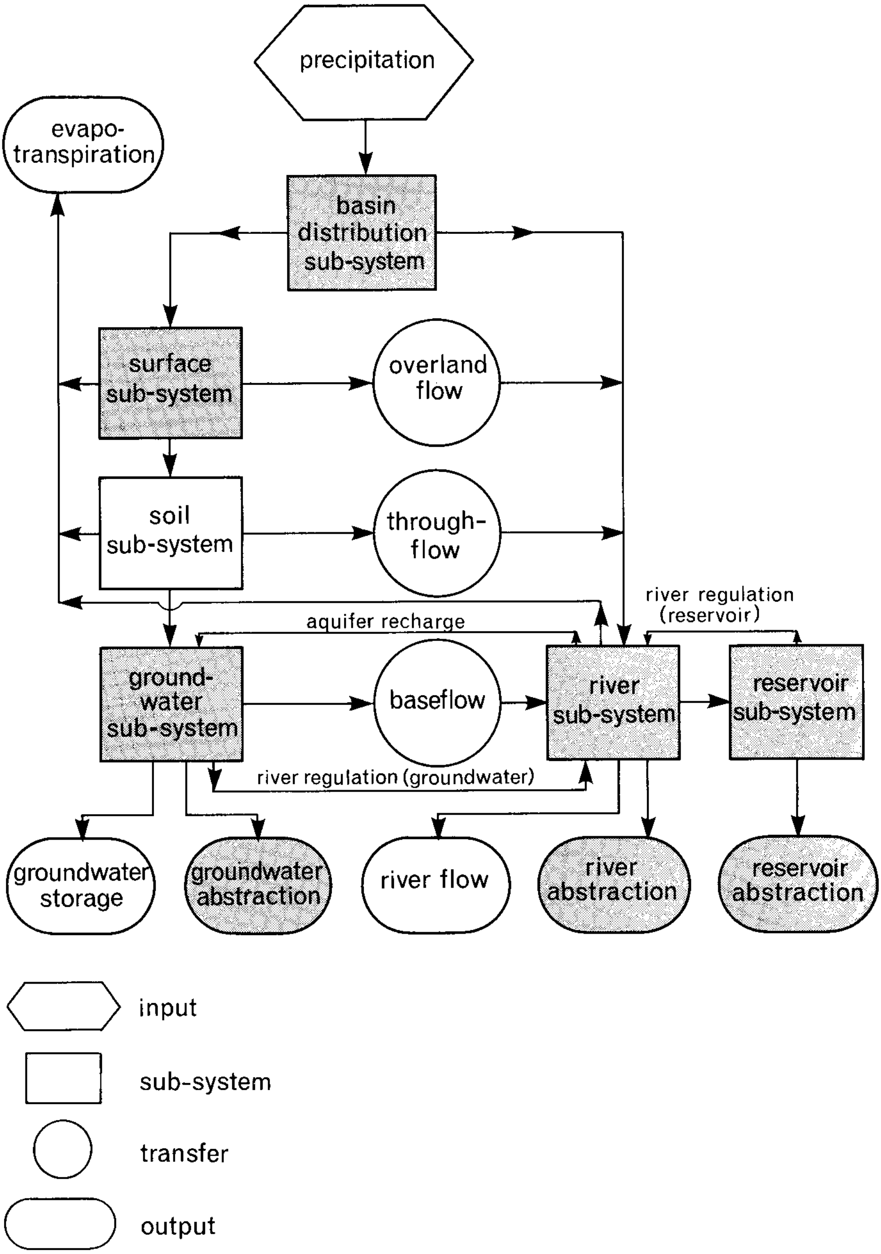

Figure 3 The river basin system: points of intervention.

Man's intervention in the hydrologic system has been concerned mainly with modifying the natural storages, although Chorley and More (1969: 157) have pointed out that no part has been entirely free of his experiments. Weather modification in general and induced precipitation and storm mitigation in particular could come to have an important influence in the future, but at present in Britain we may take the fundamental water input as given. Figure 3 shows, in the shaded sections, those points at which man has concentrated his efforts in water management.

By regulating the passage of water through the different storages, especially by diverting water from one to another and increasing the retention time in storage, man has gained partial control over his water resources. The first point of regulation is the basin distribution sub-system. Here incoming precipitation is divided between that going directly to river flow and that going through the various surface and soil storages. Alterations of the river network, drainage of wetlands or creation of new lakes and ponds will affect this division. The surface sub-system offers another opportunity to alter the amount of water going into the river, for instance by erosion control measures which reduce the overland flow of water during storms.

Some of the water percolating into the soil goes into groundwater storage in the aquifer where, under natural conditions, it contributes baseflow to the river when surface-derived flows are low and is itself recharged from the river when river levels are high. The hydrologic connection between groundwater and river flow has often been ignored by water engineers who have tended to treat the two sources quite separately. Traditionally the groundwater sub-system has been drawn upon for abstraction with little thought for the effects upon other groundwater users, let alone for the effects upon the river.

Direct abstraction from the river is the oldest form of water resource development, though it was soon found to be unsatisfactory because of natural fluctuations in flow. The off-stream storage of water in tanks, basins or reservoirs, to even out flow fluctuations, was a feature of the early hydraulic civilisations, and even today to many people water resource development means quite simply reservoir construction. Indeed it is arguable that the introduction of this extra, artificial storage element *is* the most influential of man's many interferences in the hydrologic system.

These traditional manipulations of the groundwater and river sub-systems give rise to three controlled outputs: groundwater abstraction, river abstraction and reservoir abstraction. Recently a greater understanding of the natural inter-relations between the components has led to more complex development measures, moving water to and fro between aquifer, river and reservoir. Of course these give the same type of outputs, but their interdependence and their efficiency are increased and more usable water is produced from the same physical resources.

Formerly, most of our reservoirs were used for direct supply, water being collected, stored and conveyed to consumers by pipe. The connection with the river was one way only: water was taken out of the river, or the headwaters were stopped off, and thereafter the water was distributed artificially, returning to the natural system again only as effluent after use. Recent changes in the operation of the same reservoirs gives a two way connection. Water is put into artificial storage as before, but in place of some of the direct, piped abstraction there are releases of water back to the river, to regulate flows for the benefit of river users. This is shown in figure 3 as 'river regulation'. A second form of river regulation is through controlled releases of groundwater into the river, to supplement its natural baseflow.

The final man-made connection between aquifer, river and reservoir subsystems is the artificial recharge of the aquifer, when the aquifer is dewatered but there is surplus surface water. In effect this is the converse of groundwater abstraction for river regulation, water being taken from river (or reservoir) when supplies are in excess of demand and put into groundwater storage.

This outline of the hydrologic system shows two natural characteristics which have implications for good management. First is the flow characteristic of water. This gives opportunities for successive downstream uses of the same water, and also causes upstream abstractions or discharges to have downstream effects. No management system can afford to overlook this most basic feature. Second is the natural association of groundwater and river flow, which demands that the two types of source be managed with close reference to each other, even if fully integrated development is not possible.

A third resource characteristic not mentioned so far is the uneven spatial distribution of precipitation and of water-bearing rocks which gives an uneven distribution of physical resources. In England and Wales the areas of maximum precipitation are in the north and west, while the main aquifers underlie central and south east England. Groundwater is more important in the centre and south east, although it does not fully compensate for the region's deficiency in comparison with the rainier parts of the country. To compound the problem, it happens that some of the heaviest water demands are concentrated in areas of relatively meagre local resources.

The uneven distribution of water resources, together with the non-congruence of resource and demand patterns, means that some areas are not self-sufficient in water. They need to import it, perhaps from a few miles, perhaps from a hundred miles distant. This raises the question of appropriate size of the water management unit. If it is small there will be many transfers across its boundaries, involving negotiations with other units. As size increases the number of negotiated transfers decreases, but other management problems occur as local interest declines and centralised decision-making takes over. The ideal size of unit may be illusive, but the search for a practicable solution must take some account of the hydrologic base of resource distribution.

System outputs – the end products of water management

The desired results of water management may include water supplies for domestic, industrial and agricultural purposes, effluent disposal, reduction of flood damage, hydro-electric power, navigation, fisheries, recreation and amenity. To some extent what is desired is conditioned by what it is possible to attain. Hydro-electric power, an important product of water management in Canada and the United States, is ignored altogether in English water management, terrain and river flow precluding its development. In Scotland and to a lesser degree in Wales hydro-electric power *is* a possible and hence a desired output (Smith 1972: 145, 160).

In addition to the desired outputs there are those which come, whether desired or not, and reflect the incompleteness of man's control. Flood damage is in this category, a result of natural fluctuations in river flow. Then there are instances of man's intervention which have had unfortunate consequences. Water pollution comes to mind immediately. This is effluent disposal in excess, a reasonable use exaggerated until positive harm is done to other water services.

The various water services desired of the system are commonly classified in two ways. One classification separates those uses which take water out of the river (or aquifer) – abstractive uses – from those which utilise water *in situ* – in-channel uses. The difference is a fundamental one: in one case water is lost to the system, if only for a short time; in the other case it is always present. Abstractive uses include all domestic, industrial and agricultural supplies, and power station cooling. In-channel uses are sometimes further divided into flow and on-site uses (Sewell and Bower 1968: 12). Flow uses are those which require water to move in a designated channel, and among these are generation of hydro-electric power, reduction of flood damage, navigation and effluent disposal. On-site uses use water where it occurs naturally, the principal examples being wildlife and amenity.

The second classification separates consumptive from non-consumptive water uses, and to some extent it overlaps the abstractive/in-channel classification above. In the main, in-channel uses do not consume water, but nor are all abstractive uses consumptive. By consumptive we mean permanently lost to the system, that part of the abstraction that is not returned to the original or some other watercourse for reuse. Irrigation water evaporated, transpired and taken up by plant tissues is consumed in this sense, although of course the atmospheric water is eventually recycled as precipitation. Irrigation is a highly consumptive use, different authorities rating water loss at between 70 and 100 percent. On the other hand, consumption of water in domestic and industrial uses may be less than 10 percent, at least 90 percent being returned after use.

The water returned may, however, be sufficiently different from unused water to limit its further utility. Deterioration in quality and increases in temperature are very common. Both may adversely affect wildlife and, while increases in temperature do not usually in themselves bother abstractors other than those hoping to use the water for cooling purposes, quality deterioration can impose such additional costs on potential users that reuse is restricted or even abandoned. Temperature has an influence on water quality, affecting the amount of dissolved oxygen held in the water. Dissolved oxygen is an indicator of good water quality, and dissolved oxygen concentrations decrease as temperature increases. Temperature and quality must therefore be considered together as limits on water reuse.

This serves to amplify the idea that some water uses are complementary while others are conflicting. Figure 4 shows the links between different water uses. The in-channel uses (flood damage reduction, hydro-electric power, effluent disposal and recreation) are largely complementary, although complementarity or conflict between effluent disposal and recreation depends on water quality. In general the abstractive and consumptive uses (irrigation, domestic and industrial water supplies) are in conflict with in-channel uses. An exception is flood damage reduction. This often requires a degree of regulation of river flow by reservoir storage and so is rendered complementary to water supply which also benefits from river regulation.

Here we need to define more closely the concept of multiple use of the water resource. It has two distinct aspects, one the reuse potential of any given unit of water and the other the several purposes that water control structures may serve. Each has implications for water management. The reuse potential, so easily reduced by consumptive abstraction and quality deterioration, forces upon management a concern for resource allocation and recycling. An appropriation of water by highly consumptive or polluting uses will certainly restrict its use for other purposes, and it is a management task to decide if such an appropriation is justified. Maximum diversity of use is not necessarily the correct answer.

The second aspect of multiple use is the multi-purpose potential of water control structures, particularly reservoirs. The English and Welsh reservoirs now operated partly for river regulation act to hold back flood flows, augment low summer flows, give direct supplies to consumers and provide recreation opportunities. Not surprisingly there are both complementarities and conflicts here, in initial design and in operating procedures. An example that can be observed nearly every year is the late summer drawdown of the reservoirs resulting from direct abstraction and river regulation releases. This creates storage for anticipated high winter runoff but inconveniences those using the reservoir for recreation. Again management is involved in