Water Resources Planning and Management in Developing Countries

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Dr P Bolton
Overseas Development Unit
HR Wallingford

for

Engineering Division
Overseas Development Administration
94 Victoria Street
London SW1E 5JL

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HR Wallingford

Registered Office: HR Wallingford Limited, Howbery Park, Wallingford, Oxfordshire OX10 8BA, UK
Telephone: 0491 35381 International + 44 491 35381 Telex: 848552 HRSWAL G.
Facsimile: 0491 32233 International + 44 491 32233 Registered in England No. 1622174

Abstract

This report presents the results of a short consultancy undertaken for the Overseas Development Administration, London, in which the processes of water resources planning and management in developing countries were studied in the light of increasing competition for available resources and increasing concern over environmental degradation. The study took the form of an overview of current practices and future needs based around case studies from Zimbabwe and Pakistan. These studies served to focus thinking on the technical, administrative and political issues as well as enabling the implications of ODA's current policies and practices to be examined in relation to the water sector in these countries.

The principal conclusion of the study is that a new approach to the planning and management of water is needed to address the problems of the complex linkages between water development and other human activities and resources, the environmental factors and resource constraints which determine sustainability and the complex social and political interactions which affect decision-making. In particular, an imminent water resource crisis is foreseen in many developing countries which must be addressed by strategic planning of water resource utilisation over a 25-year horizon.

In the short-term the report recommends concerted international action to highlight the need for improved planning and management of water, to develop a new analytical framework and techniques for prediction and control and to relate these to policy decisions. As a first step towards this it is proposed that an international symposium on the subject be held in 1993 to consider the results of some detailed preparatory studies and consultations.

Executive summary

Water Resources Planning and Management in Developing Countries

1. This report presents the results of a short consultancy undertaken for the Overseas Development Administration (ODA), London in which the processes of water resources planning and management in developing countries were studied in the light of increasing competition for available resources and increasing concern over environmental degradation. (See Terms of Reference, Appendix 1).

2. The work centred on two case studies of national water management issues one taken from Africa (Zimbabwe) and the other from Asia (Pakistan). In selecting these two case studies it was recognised that no countries will be entirely representative. However, these two had the advantages that there is a fairly high level of ODA bilateral support to them, that water is a fairly high priority for them in terms of national and regional policies and that a large body of relevant information is available from them in the UK. (See Sections 7 and 8).

3. The Pakistan case study provides a good example of a country whose political interests both nationally and internationally are heavily influenced by water. The Indus River, shared with India under an accord in 1961, is regulated for power production and irrigation by one of the largest and most complex systems in the world. It dominates Pakistan's food production and economic development and, as a result, it also dominates its water management activities. The study demonstrates an urgent need for strategic planning to avert impending crises of water quality and quantity and to speed up the universal provision of adequate domestic water. Such planning must take account of significant regional variations and potential conflicts within the country and be supported by adequate research into, and monitoring of the interaction of the surface water and groundwater systems and the processes of soil salinisation and reservoir sedimentation (see Section 7.2 and Appendix 2).

4. The Zimbabwe case study differs from that at Pakistan in that, in most years, substantial rainfed production is possible and that the irrigation which exists relies on dispersed, relatively small systems rather than a single complex network of supply. By contrast, hydropower generation has been central to the development of Zimbabwe's economy and this is provided by a large and complex infrastructure centred on the Zambezi basin which, despite its size, has remained, in other respects, rather marginal to Zimbabwe's water planning. The case study identifies the main problems of water resource planning in Zimbabwe as: the highly variable nature of rainfall, temporally and spatially; the degradation of catchments; inequalities in land ownership and population distribution; the allocation of scarce resources of capital and skilled personnel; and competition between different agencies over the planning of water resources. In the future, international co-operation over the management of shared resources will become increasingly important (see Section 7.3 and Appendix 3).

5. Study of both Zimbabwe and Pakistan reveals the importance of water as a policy issue in international relations. Whilst recognising the importance of international politics, this study was constrained to limit itself largely to the processes of water planning and management at a national level. (See Section 9.1).

6. The conclusions and recommendations presented in this Executive Summary were developed after careful consideration of the assembled case study material and incorporate ideas and comments provided by various people who studied an earlier draft (see Acknowledgements). Lack of time has prevented a substantial restructuring of the earlier draft with the result that some of the conclusions could have been drawn in more logical manner from the chapters of the report had time allowed. Although developed prior to, and independently from the Dublin Statement of January 1992, they are in close accord with it (see Appendix 4).

Principal conclusions regarding the process of water planning and management

7. **Water is a vital resource** on which all human societies and biological systems and a large number of physical processes depend. The various roles and functions of water within these societies, systems and processes are complex and the interactions between these functions are also complex. (See Sections 2 and 6).

8. Throughout history the availability of water, especially reliable freshwater supplies, as well as human responses to the effects of climate, floods and tides have had a profound effect on the nature and location of human societies and on their political structures and relationships. **Water continues to have a dominant social and political influence** both nationally and internationally in many regions of the world. With an increasing number of countries facing critical water shortages in the next 25 years, water's strategic importance is growing. (See Section 4).

9. Until the present century, human activity had a small or negligible effect on the nature and abundance of global water except in some fairly restricted cases. Now, **human activities**, such as population growth, the widespread manufacture and use of many persistent and toxic chemicals and the release of increasing quantities of carbon dioxide and other gases into the atmosphere **are introducing large-scale and long-term changes in the global water cycle** affecting hydrological processes within water catchments, pollution of surface water and groundwater and even the world's climate. **These changes**, in turn, **have the potential to cause profound changes in human societies and biological communities**. (See Section 5).

10. The conventional approach to improving our understanding and *regulation of the human/water relationship has been a 'managerial' one* in which surface water and accessible groundwater have been regarded as resources to be managed and exploited in order to supply human needs, principally for domestic, industrial and agricultural water. Major engineering and institutional interventions have been undertaken to

meet the demand for this 'supplied' water. Thus, **water management in the past has largely been governed by 'supply side' planning**; the manipulation of the resource to meet the level of projected, and largely unregulated, demand. This is one of several forms of 'simplification' which have been made to ease water management decision-making. (See Section 3).

11. **A new approach to planning the conservation and utilisation of water is required** (see Section 9.1) which can enable critical water shortages, political conflicts and environmental damage to be avoided. It differs from the model described above in that:

a) the finite nature of the resource is given greater prominence by developing **the concept of 'carrying capacity'** under different systems of land and water use.

b) the need not only for prediction but also for **control of demand** is recognised and alternative methods to achieve this are explored.

c) the **concept of the 'resource' is broadened** to include not only such physical components as rainfall, runoff and water quality but also economic, social, political and environmental characteristics on which water activities depend.

d) likewise the **concept of 'demand' is broadened** to include, in particular, the water needed to ensure sustainability of environmental and social systems; and due weight is given to hitherto neglected sectors such as rural water supply.

e) the **institutions and processes** by which water is allocated, regulated and controlled **are properly studied** and steps taken to improve their ability to resolve complex water planning and management issues particularly in relation to identifying and addressing existing or potential conflicts and disbenefits (such as population relocation, impaired health and increased risk of floods or drought).

f) a **more comprehensive and long-term approach to water planning, conservation and utilisation** in adopted based on a realistic projection of the implications of current water related activities over a 25-year horizon.

g) the economic and social value of water and the social and political implications of current planning decisions and management procedures are adequately considered with a view to ensuring the **widest possible involvement and support of all sectors of the community,** including the poorest, and to guide decision-makers in the choice of priorities.

h) **adequate methods of monitoring** and early-warning are devised and consistently applied to safeguard against resource depletion, environmental degradation and conflicts of resource use or allocation.

12. The development and introduction of appropriate policies, procedures and institutions to achieve comprehensive, long-term, strategic planning as outlined above requires a complete reappraisal of current practice

with the possible creation of **high level planning and co-ordinating agencies in countries where water is scarce.**

13. **New methods of interdisciplinary collaboration must be developed.** On the one hand, a high level of scientific and technical expertise is required to achieve reliable predictions and choice of techniques. On the other hand social, economic, environmental and political expertise is required to ensure that decisions are made in the widest possible context in order to avoid short-term political or inter-sectoral conflicts; to provide the basis for environmentally sustainable development; and to prepare, adequately, for long-term restructuring in response to demographic, political, economic or environmental changes.

14. The training and introduction of a **new professional group** should be considered which builds on the strengths and impetus of the action-orientated, problem-solving approach of the current engineering profession whilst exploring new ways of addressing the problems taking full account of social, environmental, political and economic considerations within this complex and strategic decision-making area.

15. **New technical tools** are required to assist the decision-making process since suitable techniques are lacking in many key aspects of strategic water planning and management. They must be appropriate to the data and resources available and neither over-complex nor time consuming to use.

16. In view of the significant effects which global warming may have on water resources, particular effort must be devoted to the problem of **predicting future effects related to uncertainty over climatic change**, a difficulty which is exacerbated by the inadequacy of much of the historic data available.

Conclusions relating to the role of ODA and other donor agencies

17. **Currently water is not a priority issue for the ODA** although each of the ODA's strategic priorities (poverty, urbanisations, women, environment, population and good government) has implications for, or is influenced by, the planning and management of water. (See Section 9.2).

18. On the basis of the two studies there appears to be **no evidence of a coherent strategy within the ODA concerning water** and in some respects their current vetting procedures appear to introduce a negative bias against complex multi-sectoral water projects because of the large number of individual advisers who must be consulted. (See Section 8).

19. As a first step towards a more coherent approach to water resource development, and assuming that aid allocation decisions continue to be made by geographical departments, there is a need for **new methods** to be developed, within the ODA and other donors, **to enable levels of priority to be assigned to water planning and management within each recipient country** and to provide **guidance on the preparation and assessment of projects** in line with these priority levels.

General agenda for action

20. The following are put forward as the overall objectives which the ODA and other agencies should consider to enable practical steps to be taken towards developing a new approach to water resources planning and management.

a) **Highlight the issues**. This may take the form of country papers, and regional or global assessments to alert the relevant groups or agencies.

b) **Help to develop an appropriate general methodology**. This is required before countries can undertake strategic planning and control and will require inputs from a wide range of disciplines.

c) **Assist countries to apply the methodology to their situation.**

d) **Work with other aid agencies**. This will enable the burden of the above to be shared.

e) **Tie aid to appropriate analysis and policy decisions.**

Specific recommendations

21. As a starting point, the ODA may choose to **organise an international symposium in late 1993** with the following objectives:

a) to highlight the problem;
b) to share with other aid agencies the tasks ahead and develop a programme of action;
c) to identify existing human and institutional resources to carry out the tasks and evolve new ones if relevant.

22. In preparation for the symposium, the ODA may sponsor the **preparation of a number of general and country papers**. It may also identify the particular skills and experience which UK specialists can offer and assess how the inter-disciplinary collaboration necessary for a programme of action could best be achieved between them by forming **a small inter-disciplinary working group to prepare a review paper for the conference.**

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Appendices

1. Introduction

This report has been prepared for the Engineering Division of the UK Overseas Development Administration (ODA) as a first step towards assisting the ODA towards a clearer understanding of the changing role of water resources management policies in development and of the implications of such changes for the ODA's policies and procedures.

The report is preliminary in nature having been prepared on the basis of a short consultancy during which the author collected information for the two case studies presented and spoke to officials from various Divisions and Departments within the ODA. The terms of reference and preliminary briefing document on which the work is based are reproduced in Appendix 1.

The findings and conclusions of this study are incomplete due to the short time available. This report is therefore intended principally for discussion purposes. For this reason, and due to the fact that some items of information are taken from restricted documents, the report cannot be quoted without written permission from the Chief Engineering Adviser, ODA.

This report should be read in the context of the preparations for the United Nations Conference on Environment and Development due to take place in Rio de Janeiro in June 1992. The work it presents was largely undertaken before the closing statement of the International Conference on Water and the Environment in Dublin, January 1992, was published. Nevertheless the main conclusions of this report are in close accord with the Dublin Statement which called for 'fundamental new approaches to the assessment, development and management of freshwater resources' based on the following guiding principles:

1. 'Freshwater is a finite vulnerable resource, essential to sustain life, development and the environment;

2. 'Water development and management should be based on a participatory approach, linking social and economic development with protection of natural ecosystems;

3 'Women play a central part in the provision management and safeguarding of water;

4. 'Water has an economic value in all its competing uses and should be recognised as a economic good'.

The full text of the Dublin Statement is contained in Appendix 4.

2. The complexity of water resources management

Water is a vital and unique resource in relation to human societies and economies and in the management of and protection the world's natural and ecological resources. Not only is it impossible to substitute another substance to fulfil water's vital biological functions within living organisms, including human beings, but its complex multi-faceted multi-functional characteristics set it apart from any other natural resource and place it beyond the scope of most of the established approaches for planning and managing the rational utilisation of these resources. Quite simply, we do not currently have the tools or means to plan and manage the utilisation of water in the precise fashion in which, for example, we could quantify the main components of the 'energy economy' of a region or identify and quantify the sources and sinks of phosphorus within the environment. It is even debatable whether water should be regarded as an entirely 'manageable' resource or whether its quantification will ever be achievable in a comprehensive and precise manner.

The main reasons why the 'water economy' cannot be analysed in the same way as the economies of other natural resources are discussed below.

2.1 The resource base

Global estimates of the availability of water indicate that the total volume of fresh water in the atmosphere, in the biosphere and in surface water reserves amounts to less than 0.02% of the planet's water balance. A further 4% is present in groundwater (most of which is fresh water), 2% as icecaps and glaciers (also fresh) and 94% as oceans and seas, see Table 1 preproduced from Kruseman and Naqavi (1988) after Nace (1971). It is the 0.02% comprising atmospheric, biospheric and surface waters on which human life primarily depends and which is the focus of most water resources management activities. With unlimited energy resources, greater human use could be made of the water from deep groundwater, ice caps and oceans and seas but in the immediate future water resources management must continue to centre around the 2% together with whatever groundwater resources are readily accessible.

In seeking to assess the resource base a number of important characteristics distinguish water from other types of natural resource.

2.1.1 Its stochastic nature:

Rainfall, the primary source of all fresh surface water is unpredictable, in location, timing and quantity, except in probalistic terms. Even then, the existence of long-term cycles and trends may invalidate predictions made from the relatively short-term records available.

2.1.2 Its three phase existence under natural conditions:

Water may be in the form of liquid, vapour or ice and the extent to which transformation occurs between phases can be strongly influenced by human activity; for example increased evaporation which results from cultivation or increased snow melt which may occur due to atmospheric pollution.

2.1.3 The importance of water quality:

The significance of water as a resource cannot be measured solely in terms of its quantity; the quality of the water which includes not only dissolved solids, liquids and gases but also sediments and biological organisms as well as temperature, are important in defining the ways in which the resource can be used. The need to control water quality also imposes appreciable constraints on its use in terms of the need to organise how 'used' water is to be removed.

Table 1: Estimate of the water balance of the world

Parameter	Surface area $(km^2)x10^6$	Volume $(km^3)x10^6$	Volume (%)	Equivalent depth (m)*	Resident time
Oceans and seas	361	1370	94	2500	c 4000 yr
Lakes and reservoirs	1.55	0.13	<0.01	0.25	c 10 yr
Swamps	<0.1	<0.01	<0.01	0.007	1-10 yr
River channels	<0.1	<0.01	<0.01	0.003	c 2 weeks
Soil moisture	130	0.07	0.01	0.13	2 w-1 yr
Groundwater	130	60	4	120	2 w-10,000yr
Icecaps and glaciers	17.8	30	2	60	10-1000yr
Atmospheric water	504	0.01	<0.01	0.025	c 10 days
Biospheric	<0.1	<0.01	<0.01	0.001	c 1 week

* Computed as though storage were uniformly distributed over the entire surface of the earth

2.1.4 The influence of landform:

The value of water as a resource is strongly influenced by the landforms of a particular region: for example changes in elevation which enable hydroelectricity to be generated; the existence of natural lakes which provide storage; the existence of rich and accessible groundwater aquifers for storage and distribution; and the influence of coastal landforms and processes in exposing fresh water to saline contamination.

2.1.5 The influence of catchment land use:

The amount of water entering rivers, lakes and aquifers following rainfall is strongly influenced by land use in the catchment area; deforestation, cultivation, urbanisation and other changes relating to human activity have a profound effect on catchment behaviour and hence on the characteristics of the available water resource.

2.1.6 The problem of double counting:

Certain uses of water, for example hydroelectric generation and a range of washing, leaching and diluting processes, may not prevent subsequent re-use of the resource for other purposes; and other uses, such as irrigation, have a high 'loss' component which may also be re-used. Allowance must be made for such re-use in analysing water budgets.

2.1.7 The need for infrastructure and other supporting resources:

Although not unique to the utilisation of water, the value of the resource at a particular place and time is heavily dependent on the prior existence of, or future ability of society to develop and maintain, infrastructure, investments and skills for the purpose of exploiting the resource (storage conveyance, abstraction, treatment and disposal works). What makes water unique in this respect is the large number of facilities and skills which must be considered, the variety of their functions and their complex interrelationships with characteristics of the water resource.

2.2 Water uses

If assessment of the nature and extent of the resource is difficult, assessment of the demand arising due to various categories of water use is equally problematic. Conventional water resources planning considers only the quantities of supplied fresh water: that is, water which has been abstracted, stored, treated and delivered to meet a specific need. In some cases this is limited only to surface water, in others an element of groundwater use is included. Estimates of global uses of supplied water are of the order of 73% for irrigation, 21% for industrial purposes and 6% for public (including domestic) use, El-Hinnawi and Hashmi (1987). However in developing countries, the overwhelming proportion is used for irrigation whilst the industrial demand is still very low in most cases.

It is extremely difficult to devise a rational way of categorising types of water use. The problem of assessing demand is, however, readily demonstrated under the following headings:

2.2.1 Uses involving chemical change:

The total volume of water which is converted to other compounds in industrial processes (both chemical and electrolytic) is very small. However, this category should also include that proportion of the consumptive use of plants and animals (including humans) which is bonded or used to produce new substances within the biosphere. In reality biological demand is never split in this way; for example, crop water demand is taken as a single item comprising elements described here under sections 2.2.1, 2.2.2 and 2.2.6.

2.2.2 Uses involving a change of phase:

Under this category the largest item is the water which is changed to vapour by plants through the process of transpiration. For irrigation this demand can be estimated using standard procedures but for an overall assessment of the 'water economy', evapotranspiration from rain-fed vegetation must also be considered. Evaporation losses from storage reservoirs and conveyance canals also fall within this category.

2.2.3 Use of water as a solvent:

Water's properties as a solvent are widely exploited not only in industry but also in various domestic and municipal 'cleaning' tasks as well as agriculturally in the application of agro-chemicals and, more importantly, in the control of salts in the soil profile through leaching. Water's ability to remove soluble waste products is also a significant characteristic with regard to its use within animal organisms. In assessing the level of demand it is not easy to find a quantitative procedure since in each situation the volume of water required will depend on its quality before use and the maximum allowable concentration of specified solutes in the wastewater produced.

2.2.4 Use of water in transporting solids:

The transport of particulate matter (including bacteria and other organisms) is exploited for cleaning purposes, as in 2.2.3 above, for sewage disposal and for certain industrial and mineral extraction purposes. Assessment of the level of demand poses similar problems to those discussed under 2.2.3 except that waste-water containing particulate matter is more readily cleaned for re-use than water containing dissolved substances.

2.2.5 Water as fluid matter:

Certain uses exploit water's mass (the generation of hydroelectricity) or its ability to support objects floating in suspension (for navigation, fishing or recreational swimming and water sports). At first sight these uses need not imply a 'consumptive' demand for water since they do not modify its characteristics in any way which would prejudice its use for other purposes. However, on closer examination such uses may preclude others because the passage of water through turbines or to maintain a minimum depth of water for navigation require the flow to be regulated thereby affecting where water is located (in a reservoir, in a river channel etc) and hence its accessibility or availability for alternative uses.

2.2.6 Water losses:

Even piped water distribution systems suffer losses due to leakage but these are generally small compared to the losses associated with irrigation. A significant proportion of water allocated for surface irrigation in developing countries is lost through direct evaporation, surface runoff and percolation into the ground. Evaporation has already been discussed under section 2.2.2 and part of the percolation loss may be considered as a leaching demand (section 2.2.3) but the remainder of the losses are available for re-use provided that the solute load has not increased significantly or the water has not flowed into an inaccessible location. Many of the irrigation systems in South-East Asia are indeed organised in such a way that the losses from one irrigated field or system become the supply to another. In addition, water lost to a fresh groundwater aquifer may act as recharge which allows a high level of groundwater abstraction to be sustained. In view of these complexities it is difficult to assess how losses should be treated in overall water budgets or to assess the benefits which would accrue from reducing the losses.

2.2.7 Social, cultural, religious and aesthetic demands:

Demands for water under these categories are diverse and difficult to quantify. The aesthetic demand, arising from water's role in sustaining various types of landscape is of increasing importance in industrialised countries and is linked with 2.2.8 below.

2.2.8 The needs of the natural environment:

Recent concern for protection of the natural environment has introduced a new factor to the assessment of water requirements: the water needed to sustain ecological systems. Although this could be included in several of the previous categories, separate assessment of the demand serves to emphasise the need. This may take the form of controlled releases or abstractions of water, for example to augment low flows in a river; as an evaporation loss from a preserved area of lake or wetland; or as restrictions on the operating regimes of hydraulic works in order to achieve particular environmental conditions upstream or downstream. The exact water requirements to meet specific ecological objectives are difficult to quantify.

2.2.9 Negative effects of water:

In addition to the positive uses to which water may be put, account must be taken of negative effects which result from the presence of excessive water (flooding and waterlogging) or poor quality water (eutrophication, toxicity to plants, animals and humans and disease transmission). Water resources management must include provision for avoidance or mitigation of such negative effects.

2.3 Allocation and control of the resource

The formal and informal means by which water resources are controlled, both politically and economically are complex and varied. In most instances the current systems are unsuited to resolve the conflicts of interest or priority which arise and may even exacerbate them. They have also been criticised because they lead to inefficient use of resources and fail to protect the resource base and the environment. Although some people have argued the need for a method of evaluation and control based on monetary values as a prerequisite to efficient resource management, it is questionable whether this can be universally applied in the case of water.

The question of resource allocation and control is important both in a national and international context. Where river basins or groundwater aquifiers lie within more than one country, resource allocation decisions, which in other circumstances would have been within the domain of national planning, become international concerns. Likewise international conflicts, whatever their origins, may give rise to non-cooperation over water allocation and control.

In this report the focus has been on the methods used at a national level to plan and manage water but the importance of the international dimension should not be over looked. The most distinctive types of control currently exercised singly or in combination in different regions include:

2.3.1 Free upstream access and use of surface water:

This is the *de facto* water allocation principle in many regions in which no legislation, agreements or effective means of control have been introduced. The more varied and sophisticated the types of water use exercised upstream, the more urgent the need to regulate them in order to prevent conflicts developing with established and potential users downstream. The conflicts of interest are most acute in the following situations:

- where the river basin flows through several countries (few African rivers are governed by international agreements a situation shared even by some important European rivers); and

- where unrestricted water consumption, land use or effluent discharge are having a significant impact on the quantity and quality of the water downstream, particularly where downstream areas are heavily populated.

Unless the resource is plentiful and diverse, free upstream access is unlikely to be tolerable as a long-term management strategy. The question of how to modify or regulate a situation in which upstream access has previously been free may, however, pose a serious problem.

2.3.2 Free access to groundwater:

This is the situation in many regions of the world and is to some extent self regulatory since over- exploitation of an aquifer will deter further investment in wells and boreholes. However there are a number of important facts which complicate the situation:

- self-regulation will only begin to apply after the water table has been drawn down to a considerable depth at which point an equilibrium of abstraction and recharge may be achieved but at a far higher energy cost than if the equilibrium had been imposed by Government controls when the water table was much nearer the surface;

- control of the resource will inevitably pass to the individual or agency which has access to the 'best' technology (deep tubewells and large pumps) in which case the situation becomes akin to 2.3.4 below;

- there will be considerable pressure to prevent lowering of the water table, due to over- exploitation, from those with existing investments in shallow tubewell technology which would thereby become inoperative and obsolete; and

- a variety of dispersed activities will affect recharge and water quality and without control of such activities, control over abstractions will provide only a partial solution.

2.3.3 Urban needs take precedence over rural needs:

Since most urban areas require centralised water supplies (and waste-water disposal) and politicians are, generally, keen to please an articulate urban electorate, heavy priority is generally given to urban areas in the allocation of investment funds and in the drafting of legislation regarding water rights and priorities. Resettlement of river-side dwellers to more arid land following construction of a hydroelectric or urban supply dam is another example of this urban precedence.

2.3.4 Technologies and access are controlled by powerful and wealthy individuals:

It is not always as obvious in the case of water as with other natural resources how this control is achieved but closer scrutiny reveals that this is the case in many regions. The means may be through individual purchase of capital equipment (see 2.3.2), through acquiring property which commands access to water or through influencing politicians to provide the necessary infrastructure to bring water to a particular location (see 2.3.3). In water-short regions, poorer people are rarely allowed to live in locations which have ready access to good water unless there are significant disadvantages to living in such locations (for example areas prone to flooding).

2.3.5 Powerful interest groups or nations exert control:

This is a collective expression of the principle set out in section 2.3.4 above.

The principle can be seen in the international agreements governing certain river basins; for example in the Nile basin Egypt, as downstream user, has been able to have a strong influence over water management because of its political and economic power.

2.3.6 Religious or cultural principles are applied:

The management of many ancient irrigation systems is achieved by applying cultural or religious principles and traditions. In addition, the whole ethos of water management in Moslem countries is strongly influenced by the belief that water should be available free of charge to everyone.

2.3.7 Establish a free market for water:

This has been suggested by economists increasingly over the last few years as the solution to water allocation difficulties. Few examples already exist of 'free' markets with the possible exception of water sellers in some urban slums. It is unclear how a single price can reflect the cost of capital investment and of the delivery service costs whilst at the same time reflecting the scarcity or value to society of the resource and the cost of pollution and environmental damage.

2.3.8 Control by bureaucratic institutions and technical specialists:

Although professional influence is never total, a number of countries have established influential groups of technical specialists whose existence tends to promote particular forms of water management which accord with their particular professional skills. In some cases the bias may be consciously adopted but in other cases their specialist backgrounds may blind them to broader considerations.

3. Managing complexity through simplification

In facing the complex issues set out above, it is not surprising that Governments and professionals have drawn back from addressing water management in a comprehensive manner. In most cases, they have concluded that it is sufficient to specialise in a small part of the overall water economy in order to meet specific short-term needs.

In the 19th Century, for example, when little irrigation infrastructure existed, the desire to irrigate large parts of the Indus plain, in the interests of food security, called for the development of a vast body of specialist engineering skill in order to construct and operate large barrages and lengthy canals according to exacting hydraulic and structural specifications. That the engineers, for the most part, understood little about soil science or agronomy was probably neither necessary nor desirable in this context whereas such multi-disciplinary neglect would be deplorable in the same region today.

Likewise, planners in many developing regions in the second half of the 20th Century have concentrated particularly on the efficient deployment of available financial capital believing that the main constraint to efficient water management is the lack of infrastructure constrained by lack of capital. Many 'Master Plan' studies of water resources development, including recent studies in the Indus basin, have started from the premise of a finite financial resource whose significance is equal to or greater than the constraints imposed by the water resource. Until recently, however, in this particular approach towards simplification, environmental and social concerns have not featured sufficiently strongly.

Another way in which planners and managers have sought to achieve a simplification of the complex task they face has been to limit the time-scale of their planning. Ostensibly this has been justified on financial and economic grounds due to the fact that discounted rates of return on project investments place minimal value on long-term benefits or costs. In many cases this justification may have served to cover political motives arising from the relatively short time horizon over which most Governments are constrained to operate. Standard procedures for preparing national five-year economic plans have also placed the principal focus of national planning activity within short time-horizons.

The complexity of the multiple demands now being made upon the world's fresh water resources and the far-reaching impacts which many water use activities are having are forcing planners to consider water management in a fully comprehensive manner for the first time. However, it is not yet clear how this can be achieved in practical terms.

4. The possibility of an impending water crisis

Before looking in more detail at the ways in which water management planning is undertaken and the weaknesses of these approaches it is useful to consider why such a study is now a matter of urgency in many countries. The need to conserve and manage water resources is not new, although in the past most countries could meet their requirements for domestic, industrial and agricultural supplies well within the water resources available to them. As population numbers increase, coupled with demands for high per capita domestic and industrial consumption resulting from improved standards of living, the sustainable upper limit or 'carrying capacity' of water resource utilisation will be approached very rapidly over the next two to three decades in many countries. The situation is most acute in countries which are already heavily dependent on irrigation to meet their domestic food needs or which are rapidly approaching the limit of their rainfed agricultural outputs under current farming practices.

Falkenmark (1987) attempted to identify those countries in Africa which face problems in meeting domestic food needs and which, at the same time, have limited capacity to expand irrigation due to heavy competition for the available surface water resources. Surprisingly the list she produces does not place the western Sahel countries, nor Sudan and Ethiopia, which are widely believed to be the areas suffering the most acute water shortages, in the categories of most severe need. This is presumably because of their low population densities. In fact her analysis suggests that Burundi, Kenya and Rwanda are already facing severe water problems, and that Malawi, Tunisia, Lesotho and Somalia are likely to face critical conditions in the near future.

If Falkenmark's analysis is correct, and there are certainly aspects of her analysis which can be improved, there are a number of African countries which may, even unknowingly, be facing an absolute scarcity of food and water in the near future (possibly around the turn of the century) as their populations continue to grow.

The impending crisis is not confined to Africa. Significant areas of Asia and the Middle East as well as limited parts of Latin America cannot support their present population solely on rainfed agriculture. In many cases, the shortfall in agricultural production is amply supplied by means of irrigation but competing demands for available surface water and growing populations are likely to create a critical water shortage in particular regions, if not in entire countires, before long. Analysis of the situation in Asia is, however, more complex than that in Africa because of the greater reliance on irrigation and the large size and geographical variability of certain key Asian countries.

The impending crisis is unlikely to be recognised as an absolute resource constraint unless planning methods are adopted which are designed to investigate water resources constraints in a comprehensive manner. A more likely scenario is that, with the normal stochastic variability of rainfall, a series of dry years will occur resulting in significant national food deficits in the critical countries. The initial perception will be that the problem is due to 'drought' caused by the variability of rainfall or the effects of greenhouse gases on global climate. The fact that the underlying cause is the growth of the national population to a level approaching or exceeding the carrying capacity of the national water resources may only gradually be realised.

In addition to the water crisis which is faced by such countries as those discussed above, due to an absolute shortage of water within their national borders, there are a number of countries whose ability to meet national demand is dependent on the good will of other countries which share a common fresh water resource, most notably the riparian countries within an international river basin. For them the possibility that any one country is approaching an absolute water shortage will give rise to growing international tensions and the possibility of confrontation between the countries which share the common resource.

Access to water resources is already a significant factor in the geo-politics of Middle-Eastern countries and competition for water is becoming an important issue in international politics in a number of other regions. For them, 'strategic' planning implies not only the planning of water in a comprehensive and long-term manner but also its planning in relation to the highest political and even military priorities (reflecting the original meaning of the word).

5. The notion of substainability

It is not possible to review the global state of water resources management without referring to the notion of sustainability. The word 'notion' has been used in preference to 'concept' since the latter implies a degree of rigour or consensus in the definition of sustainability which is at present lacking. Despite this lack of clarity in meaning, there is still value in retaining the word 'sustainable' in the vocabulary since its use prompts those planning or undertaking activities within or affecting the environment to ask themselves two important questions:

- Is the activity likely to change the environment in such a way that the natural productivity and regenerative capacity of biological systems is permanently impaired? (for example the damage to aquatic ecosystems caused by water pollution);

- Is the activity likely to impose problems of natural resource availability, allocation or utilisation upon future generations for which the current generation can see no practicable solutions? (for example the gradual loss of reservoir storage capacity through sedimentation).

In reality the two questions are interrelated. They are also, in the final analysis, unanswerable since we do not now have, nor are likely to have, the ability to make comprehensive precise predictions of environmental change over long time spans. That does not excuse developers and resource managers from attempting to address the questions in a partial manner using the knowledge and skills currently available. The scandal of so called 'environmental disasters' caused by engineering works in developing countries is not that certain impacts were not foreseen on the first occasion when particular types of works were introduced but that 'mistakes' have often been repeated with little indication that experience has been gained and transferred (Goldsmith and Hildyard, 1984).

The notion of sustainability was brought to the fore as a result of the work of the Brundtland Commission (1987). With respect to water resources their report was disappointing since it failed to give water issues adequate consideration. However, the most important feature of the report was the emphasis which it placed on the close link between environmental protection and economic development. In effect, the Commission concluded that talk of the environmentally sustainable development was inappropriate without, at the same time, addressing problems of social and economic deprivation. The links between poverty and a degraded environment act in both directions. The poor are most vulnerable to the effects of a degraded environment (for example they are more likely to be exposed to polluted and disease carrying water); and poverty is also a factor leading to environmental degradation (for example pollution by untreated human wastes and degradation as a result of overstocking and unsustainable levels of cultivation or fuelwood collection). On the other hand it should be remembered that affluence also has major environmental consequences in terms of over-exploitation of non-renewable resources, diverse forms of chemical pollution and the release of greenhouse gases.

In practical terms the notion of sustainable development can only be addressed if planners are prepared to ask the following questions of their planning approach:

a) Is the choice of time scale appropriate?

b) Is the choice of spatial scale appropriate?

c) Are both the process of change and the intended result sustainable?

d) Has the sustainability of a 'do nothing' strategy been assessed?

e) Has the notion of 'carrying capacity' been adequately examined and what options are available if it is likely to be exceeded?

f) To what extent have the methods used to predict future changes covered the comprehensive range of possible environmental effects?

g) Have the attributes of the existing social systems and their relationship with the planned development been adequately studied?

h) What underlying assumptions about social, economic and political conditions are necessary for the planned development to be sustained?

i) What effects do current institutional arrangements have on the achievement of sustainable development and what changes can be made to improve sustainability?

j) How are the problems of managing non-renewable resources and monotonic changes (eg sedimentation) being addressed?

k) Have the resilience, fragility and adaptive potential of the biological systems affected by the planned development been adequately assessed?

l) How has the effect of uncertainty been addressed (for example, hydrological variability)?

m) To what extent does the chosen method of economic justification or financing predispose developers towards the selection of unsustainable options?

None of the above questions has easy solutions and the challenge to professionals over the next few years is to develop practical ways of ensuring that such questions are adequately addressed without imposing such heavy burdens on developers that necessary economic and social development becomes stifled.

6. The need for a new framework for water resources assessment

6.1 General

With reference to water resources the case has already been made that levels of complexity in resource assessment, water use assessment and control, are greater than for any other natural resource. In view of this complexity current water resources planning and management procedures are inadequate to address either the problems of impending critical water shortages or current concerns about sustainability. The most apparent short-coming is in relation to question a) above; the time scale of planning. If water crises are to be averted in many nations, there is an immediate need for strategic planning over horizons of at least 25 years so that potentially severe water shortage problems can be identified sufficiently in advance for appropriate responses to be formulated. Such strategic planning is rarely undertaken at present. It may be structured according to various levels of detail beginning with a fairly superficial level in which major problem areas are identified (as Falkenmark, 1987, has done) through to the most detailed level, to be undertaken in those areas where the risk of shortages is greatest.

Passing to question b) above, the choice of spatial scale, an immediate difficulty becomes apparent: in relation to surface water resources the most appropriate planning unit is the river basin; but in relation to water use, economic and political planning is undertaken within political boundaries which may either be much bigger or much smaller than particular river basins, and only rarely coincide.

The planning and management of most natural resources requires an analysis both of the availability of the resource and of the projected demand under different end-use categories. In many cases a 'supply side' approach is adopted in which it is assumed that the level of demand is independent of control, at least in the short-term, and that the purpose of resource planning and management is to develop supplies of the resource to meet this demand. By contrast, with rare resources, such as 'strategic' minerals, the level of supply may be taken as fixed and the object of resource management is to allocate that supply to areas of priority demand. With water resources management, the complexity of the inter-relationships between the two make it necessary to consider simultaneously both the characteristics of the resource and the characteristics of the demand and, in addition to consider comprehensively the linkages with other sectors and the means by which allocation and control are achieved.

To address the complexities of water planning and management in the context of the current critical shortages requires a fundamental reassessment of the methods of analysis and water management adopted and the development of a new framework and new techniques. Such a reassessment may take time. In the interim, the problem may, at least partially, be addressed by broadening the definitions of 'resource base' and 'end-uses' so that a more comprehensive treatment is achieved in line with several of the questions posed in Section 5 above. Frameworks for these new broader definitions are proposed in Tables 2 and 6 and discussed in more detail below.

6.2 Assessment of the resource

Table 2 presents a proposed list of resource components which could form the basis for studying water resources planning and management in a comprehensive manner. The table includes many more categories than would normally be considered as comprising the 'resource base' but each has a significant bearing on the degree to which specific water related objectives may be achieved.

Items A, B and C of Table 2 are the **standard water resource categories** of precipitation, runoff and groundwater with B sub-divided to provide mean, flood and low flow assessments in recognition of the importance of floods and low flows in water management. Item D recognises the importance of **storage works** as a resource (they provide the ability to control natural patterns of flow variability). Items E to I are **other infrastructure resources** needed for the control and distribution of water. Item J recognises the **quality of water** as an important characteristic of the resource. Items K and L are included in recognition of the fact that the existence and preservation of certain **species and habitats**, dependent on the water environment, is an important resource attribute without which diverse and productive ecosystems cannot be established. A rather intangible attribute of the resource base is item M, the **aesthetic and religious value** which is attached to water or particular water dependent environments. It is counted as a resource attribute since motivation for resource management may derive from it. Items N, O and P include the **skills and social, economic or political conditions** which are necessary to support particular water management activities.

Table 2: Water resources management: Resource components

A	Rainfall, snow, etc	:
B1	Runoff* - mean	:
B2	- flood	:
B3	- low flow	:
C	Groundwater	:
D	Storage works	:
E	Abstraction and diversion works	:
F	Conveyance and distribution systems	:
G	Drainage and disposal systems	:
H	Treatment facilities	:
I	Flood control works	:
J	Water quality (including sediment)	:
K	Special habitats**	:
L	Important species**	:
M	Aesthetic and religious value**	:
N	Individual knowledge and skills**	:
O	Social/institutional organisation**	:
P	Political/economic/ legal environment**	:

* includes water received from outside the country/region
** specific to water

Table 2, may be used in a number of different ways. For example, Table 3 has been adapted from it to highlight the problems which are faced in attempting to quantify or assess the existing resource components under these categories. Some of the problems which are highlighted relate to the lack of essential data. Others arise due to the absence of a methodology and parameters for undertaking such assessments.

Table 3: Assessment of the existing resource

(including temporal and spacial variations)

A	Rainfall, snow, etc		: Long rainfall records exist for most countries but remote (often high or low rainfall) areas are poorly covered.
B1	Runoff*	- mean	: Long, reliable records at a fixed gauging site are rare. Resource assessment is complicated by upstream developments modifying flows.
B2		- flood	: Data notoriously unreliable because of difficulty of river gauging in floods.
B3		- low flow	: Data fairly reliable except that gaps in low flow records are more frequent. Analytical techniques somewhat neglected.
C	Groundwater		: Significant regional differences in data availability and quality. Current rates of abstraction often unknown.
D	Storage works		: Design data widely used ignoring effects of sedimentation, but surveys becoming more common except for small reservoirs.
E	Abstraction and diversion works		: Design data for major works available but details of small informal surface and groundwater abstraction works are poor.
F	Conveyance and distribution systems		: Design data widely used with inadequate consideration of effects of obstructions (sediment, aquatic plants) and losses.
G	Drainage and disposal systems		: Only major systems are adequately recorded. System performance neglected as in (F) above
H	Treatment facilities		: Data generally available except for low technology rural works.
I	Flood control works		: Location of major works recorded but extent of protection may be unknown : linked to (B2) above.

Table 3 (cont'd)

J	Water quality	: Data generally lacking. Sediment discharges (including sediment) may be measured but data quality highly unreliable
K	Special habitats**	: Local knowledge may be poor. Increasing international interest provides additional dispersed sources of information.
L	Important species**	: As for (K).
M	Aesthetic and religious value	: Relates to local inhabitants so can only be assessed by community involvement. Characterising attributes is difficult.
N	Individual knowledge and skills**	: Professional, technical and other skills rarely assessed on a sectoral basis. User skills not recognised.
O	Social/institutional organisation**	: Descriptions of frameworks generally available but their performance is difficult to assess.
P	Political/economic/ legal environment	: Information is probably available if essential attributes can be defined.

* *includes water received from outside the country/region*
** specific to water

Table 4 considers a further important need for water resources planning: the ability to predict how the available resource will change with time. Prediction is made difficult by poor existing data, inability to predict the effects of climatic change, inability to predict how changes in human population will affect runoff and insufficient knowledge about the resilience of particular biological, social and economic systems.

In Table 5 each resource component is examined to determine what management activities are necessary in order to protect the resource from degradation and to facilitate its continued development and control. Many of the items relate to the need for adequate planning and financing of maintenance but in certain cases monitoring the effectiveness of such maintenance is difficult.

It may be seen from Tables 3, 4 and 5 that the basic building blocks needed for comprehensive planning and management of water resources are in many respects rather weak. Not all of the resource components can be adequately quantified or assessed, future changes which may affect many of the resource components cannot be adequately predicted and, in the majority of cases, the means by which control over the resource could be achieved have not been adequately established or tested under practical conditions.

Table 4: Prediction of the future resource

(including changes due to physical processes such as erosion; deterioration of facilities; effects of new projects planned; and climate change)

A	Rainfall, snow, etc	: Predictions of effects of climate change are unreliable.
B1	Runoff* - mean	: Impacts of land use changes are likely to be significant and are difficult to predict; climatic change will have an uncertain effect; influence of new works is generally predictable.
B2	- flood	: As for (B1)
B3	- low flow	: As for (B1). See also (C) affecting baseflow.
C	Groundwater	: Safe level of exploitation to avoid 'mining' aquifers inadequately known. Prediction of effects of land use on infiltration rates is poor.
D	Storage works	: Current rates of sedimentation are inadequately known and the effects of future land use changes generally ignored.
E	Abstraction and diversion works	: Depends on investment in new works and the maintenance of existing ones. Flexibility to meet future changes may significantly affect utilisation.
F	Conveyance and distribution systems	: As for (E).
G	Drainage and disposal systems	: As for (E). Assessing the potential for reuse of sewage and drainage water is becoming increasingly important.
H	Treatment facilities	: As for (G).
I	Flood control works	: As for (E). Sea level changes and modified floods may have unpredictable effects on the level of protection provided.
J	Water quality (including sediment)	: If current data are poor, prediction of future changes is unwise. See also (B1). Groundwater quality is particularly difficult to predict due to time lags.
K	Special habitats**	: The resilience of many ecological systems to change is largely unknown. An empirical approach may lead to permanent damage.

Table 4 (cont'd)

L	Important species**	: Closely related to (K). Construction of physical barriers, direct control or exploitation and the effects of introduced species are also important.
M	Aesthetic and religious value	: Aesthetic value ascribed by a community is likely to change with their level of development.
N	Individual knowledge and skills**	: Development of skills can be planned but "leakage" to other sectors unpredictable. New skills needed for future technologies are also unknown.
O	Social/institutional organisation**	: The resilience of particular systems and institutions to change is largely unknown.
P	Political/economic/ legal environment**	: As for (O).

* includes water received from outside the country/region
** specific to water

Table 5: Requirements for protection, development and control of the resource

A	Rainfall, snow, etc	: Long-term control of greenhouse gases and global vegetation may affect the resource but unproven.
B1	Runoff* - mean	: Comprehensive catchment management, including control of water and land use, has economic, social, political and legal implications.
B2	- flood	: With extensive storage, controlled releases are possible at the expense of other potential users.
B3	- low flow	: As for (B2).
C	Groundwater	: As for (B1).
D	Storage works	: New projects affected by large capital investments and diminishing numbers of suitable locations. Practicable methods to protect against sedimentation unknown except in specific cases.
E	Abstraction and divesion works	: Adequate planning for, and financing of maintenance is a major need. Deferred

Table 5 (cont'd)

		maintenance often translates into the need for new investment.
F	Conveyance and distribution systems	: As for (E). Monitoring the effectiveness of maintenance is difficult.
G	Drainage and disposal systems	: As for (F).
H	Treatment facilities	: As for (E). Also the financing of consumables (eg chemical reagents) is important and may need foreign currency.
I	Flood control works	: As for (F). The incentive for maintenance declines as the time from the last flood disaster increases.
J	Water quality (including sediment)	: Ideally development and pollution control should go together but this requires considerable finance and strong political/legal controls.
K	Special habitats**	: Protection is physically possible in many cases but clear policies are required on how to put economic value on the resource and who pays.
L	Important species**	: As for (K).
M	Aesthetic and religious value	: Protection can only be achieved by active community participation.
N	Individual knowledge and skills**	: Investments in training, institution building and community mobilisation must be planned.
O	Social/institutional organisation**	: As for (N).
P	Political/economic/ legal environment**	: External factors largely dominate.

* includes water received from outside the country/region

** specific to water

6.3 Assessment of end-uses

Table 6 sets out a list of the principal water end-use categories which should be considered. The list does not follow the rather theoretical classification of section 2.2 because of the difficulty of applying such a classification in practice, but approaches the demand for water from a human activity/needs basis.

Table 6:	Water resources management: End-use categories
1	Rain-fed production*
2	Irrigated production*
3	Hydro-electric energy
4	Domestic needs
5	Community/municipal needs
6	Industrial needs
7	Livestock needs
8	Aquaculture
9	Natural fisheries
10	Navigation
11	Waste and heat disposal
12	Access and inhabitability
13	Soil fertility
14	Terrestrial ecosystems
15	Aquatic ecosystems
16	Shoreline ecosystems
17	Floodplains and wetlands
18	Animal/fish migration
19	Cultural and Recreational
20	External water transfers
*	Includes arable, pasture and forestry basis.

As with the resource components in Table 2, the list is broad and encompases items which are not generally included as end-uses for water management and planning purposes but which represent demands on the resource which may be in competition with each other.

Item 1 is included both to stress the fact that **rainfed production** is an important component of water resource use even though the supply is largely outside human control (apart from the possible use of cloud seeding techniques); and to emphasise the fact that rainfed production may compete for resources with other uses through its influence on catchment yield and groundwater infiltration. Items 2 to 6 are the **standard water use categories** currently considered in water resources management. Items 7 and 8 **livestock and aquaculture**, have important requirements in certain, fairly restricted, circumstances. Items 9 and 10, **fisheries and navigation**, are activities which depend on preserving the quantity (and quality) of the natural rivers and lakes rather than in achieving a particular level of supply. Only occasionally are decisions made to regulate river flows specifically to enhance these uses. The more normal situation is for other uses to be restricted if they begin to seriously affect them. Item 11, **waste and heat disposal**, covers the human activities which result in water pollution. Society has a need to dispose of wastes but the manner of their disposal must be carefully controlled to prevent adverse effects on other water uses. Item 12, **access and inhabitability**, is a human need which is met by land drainage and flood protection or control. Again, there are potentially adverse effects on other uses unless such activities are carefully managed. Item 13, **sustaining soil fertility**, is a need in all agriculture and may be influenced by activities under items 1,2 and 12 or may be treated as a separate item in regions where land reclamation is in progress. Items 14 to 17 treat the **preservation of particular types of ecosystem** as an identifiable need or water end-use. As with item 9 their main demand on the resource relates to the regime of river discharges, the quality of water and the types of aquatic habitat which must be preserved. By contrast, item 18, which is also of ecological significance, relates to the physical barriers which water management activities may create impeding **animal or fish migrations.** Increasingly item 19, **the cultural and recreational needs** of society, is becoming a significant end-use requirement, including not only recreational swimming, boating and fishing but also the preservation of landscape and the provision of access for various traditional cultural activities. Finally, item 20 recognises that in international river basins, national governments must meet agreed **water release or transfer demands of neighbouring countries** as part of their water resources management obligations. The agreement may cover not only the quantity but also the quality and the timing of such releases.

In the above discussion of end-use categories it may have become apparent that different uses relate in different ways to the various resource components listed in Table 2. The complexity of these linkages is demonstrated in Table 7 which shows some of the principal ways in which the resource components relate to the end uses. For example, the productivity of rain-fed production (end-use item 1) depends on rainfall (resource item A), drainage infrastructure (resource item G), sometimes on flood protection (resource item 1) and on the skills, organisation and other socio/economic conditions of society (resource items N, O and P). In addition, of course, other inputs are required which are not directly related to the water resource but on which other end-uses also depend. These inputs, shown in the final three columns of Table 7 are energy inputs; financial and capital resources; and land and soil resources. Inclusion of these linkages demonstrates a further complexity in water resources management which will be discussed further in Section 6.4 : that water resources planning cannot be undertaken comprehensively unless it is also considered in parallel with energy planning, financial and economic planning and physical and land use planning.

Table 7: Resource components necessary to meet particular end uses

(key to other inputs : E = energy, C = capital, L = land/soil)
(linkages in brackets () are partially or indirectly important)

		Primary Linkages	Nature of the primary linkages	Other Inputs E C L
1	Rain-fed production*	A,G,(I),N,O,P	a) Crop water requirements b) Prevention of waterlogging	/ / /
2	Irrigated production*	A,B1,B3,C,D,E,F, G,(H),I,J,N,O,P	a) Crop water requirements b) Prevention of waterlogging	/ / /
3	Hydro-electric energy	B1,B3,D,(E),(F), J,N,O,P	a) Controlled flow b) Hydraulic head	x /
4	Domestic needs	(A),B1,B3,C,D,E, F,H,J,N,O,P	a) Drinking b) Washing	/ /
5	Community/municipal needs	B1,B3,C,D,E,F,H, J,N,O,P	a) Consumptive use b) Washing	/ /
6	Industrial needs	B1,B3,C,D,E,F,H, J,N,O,P	a) Consumptive use b) Washing	/ /
7	Livestock needs	A,B1,B3,C,D,E,F, J,N,O,P	a) Drinking	/ /
8	Aquaculture	A,B1,B3,C,D,E,F, J,N,O,P	a) Pond filling	/ /
9	Natural fisheries	B2,B3,D,F,G,H,I, J,K,L,N,O,P	a) Ecosystem (see 15) b) Techniques	(/) /
10	Navigation	B2,B3,D,E,F,(G), N,O,P	a) Minimum flow depth b) Minimum flow velocity	(/) /
11	Waste and heat disposal	B3,C,D,F,G,H,J, N,O,P	a) Dilution b) Physical transport	/ / (/)
12	Access and inhabitability	A,B2,C,D,G,I,N, O,P	a) Flood protection b) Drainage	/ / /
13	Soil fertility	A,B1,B2,C,G,I,J, N,O,P	a) Leaching flows	/ / x
14	Terrestrial ecosystems	A,C,G,I,K,L,M	a) Habitat preservation	/
15	Aquatic ecosystems	B2,B3,D,F,G,H,I, J,K,L,M	a) Habitat preservation	(/)
16	Shoreline ecosystems	B2,B3,D,F,G,J,K, L,M	a) Habitat preservation	/
17	Floodplains and wetlands	B2,B3,C,D,G,I,J, K,L,M	a) Habitat preservation	/
18	Animal/fish migration	B2,D,E,F,G,I	a) Preserving migration routes	/
19	Cultural and recreational	B2,B3,D,F,J,K,L, M	a) Various	(/) / /
20	External water transfers	B1,D,E,F,G,(H), J,O,P	a) Agreed flows	(/)

* Includes arable, pasture and forestry

As with the resource components, a number of data and methodological shortcomings limit the ability of planners to estimate future demand under each of the end-use categories over, say, the next 25 years. Table 8 lists some of the difficulties which arise in assessing both the current and future levels of demand. A key variable in various categories is the rate of poulation growth which becomes increasingly difficult to predict as the time-span increases. In many of the categories an accurate estimate of future demand would require considerably better data and simulation techniques that are currently available.

Table 8: Physical factors affecting assessment and prediction of demand

(see also policy factors listed in Table 9)

1	Rain-fed production*	A key variable is population growth. More information on the agricultural productivity of water is also required
2	Irrigated production*	As for (1). Irrigation efficiencies are also key parameters.
3	Hydro-electric energy	Detailed hydrological simulations are generally required to determine how releases for energy affect other potential users.
4	Domestic needs	Key variables are water quality, population growth rates and per capita demand (linked to income, health goals, type of supply/ sanitation).
5	Community/municipal needs	Generally a small proportion of urban supplies (cleaning, fire fighting, offices) but significant where large numbers of tourists visit remote regions.
6	Industrial needs	Detailed estimates are only possible in relation to known processes particularly with regard to water quality and pollution control.
7	Livestock needs	Generally related to rural population numbers but availability of grazing is also important. Needs often met from natural waters.
8	Aquaculture	Consumptive demand is low but water quality is important.
9	Natural fisheries	Assessing 'demand' is complex. Depending on how biological productivity relates to water management practices in given ecosystems, reservoir releases etc may be modified. See also 10.
10	Navigation	Demand has 2 components: releases to provide minimum channel depths and control of minimum drawdown levels of reservoirs for boat access.

Table 8 (cont'd)

11	Waste and heat disposal	Minuimum discharges may be controlled to ensure adequate effluent dilution depending on the initial quality of the water.Future effluent types/rates not readily predicted.
12	Access and inhabitability	Land reclamation and flood protection require large investments. Impacts on flood hydrology and groundwater levels may be significant.
13	Soil fertility	Investment in land drainage and irrigation water management practices are important factors. Prediction is difficult.
14	Terrestrial ecosystems	As for (9). Modification of groundwater abstraction rates may be significant.
15	Aquatic ecosystems	As for (9).
16	Shoreline ecosystems	As for (9).
17	Floodplains and wetlands	As for (14).
18	Animal/fish migration	There is a need to recognise that dams, large canals, etc, may form barriers to wildlife which may be overcome if suitable passes/bridges can be built.
19	Cultural and recreational	No major consumptive uses: for hotels see (5). Main needs are water quality, landscape and access.
20	External water transfers	Formal agreements may be complex involving water quality and seasonal distribution of flows. Releases to control saline intrusion should also be included.

* Includes arable, pasture and forestry

While Table 8 concentrated on the physical factors which must be considered in assessing current and future levels of demand, there are also a number of policy issues which may have a significant effect on future water resource utilisation. The most common of these are considered in Table 9 where the following national planning objectives are considered in relation to the impact they may have on predicting each end-use category

- basic needs provision/poverty alleviation (B)
- energy self-sufficiency (E)
- food self-sufficiency (F)
- growth in the economy (G)

- international considerations (I)
- protection of the environment (P)
- regional equity within the country (R)
- social equity and individual rights (S)
- urbanisation and industrial growth (U)

In reality a government may embrace policies which include verbal assent to most of those listed above to various degrees. The planner may have the difficult task of deciding which order of priority will, in practice, be assigned to different political objectives and how these may change with time. Clearly the most fundamental difference between societies, with regard to the planning of future demand, is the extent to which the economy is either centrally planned and regulated or based on free and open markets. This question in itself may be a highly complex one for the professional to address with unpredictable changes occurring, as witnessed recently in Eastern Europe, and with political rhetoric at variance with actual practice.

Table 9: Government policies which may have a direct impact on levels of demand

(see text for key)

	B	E	F	G	I	P	R	S	U
1 Rain-fed production*	√	√	√	√		√	√	√	√
2 Irrigated production*	√	√	√	√		√	√	√	√
3 Hydro-electric energy	√	√		√		√	√	√	√
4 Domestic needs	√			√				√	√
5 Community/municipal needs				√			√		√
6 Industrial needs				√		√	√		√
7 Livestock needs	√		√			√		√	√
8 Aquaculture	√		√					√	√
9 Natural fisheries	√		√			√		√	√
10 Navigation				√	√		√		√
11 Waste and heat disposal		√		√	√	√			√
12 Access and inhabitability	√			√		√	√		√
13 Soil fertility	√		√	√		√		√	
14 Terrestrial ecosystems	√	√				√			
15 Aquatic ecosystems	√					√			
16 Shoreline ecosystems	√					√			
17 Floodplains and wetlands	√					√			
18 Animal/fish migration	√					√			
19 Cultural and Recreational								√	√
20 External water transfers					√	√			

* Includes arable, pasture and forestry

6.4 Linkages with other planning spheres

In the foregoing discussion of Table 7 it was noted that other spheres of planning have an important bearing on the management of water resources, notably energy planning, economic planning and physical planning. The significance of each of these spheres will be considered separately.

With regard to energy planning the interdependence with water management goes far beyond the generation of hydroelectric power. Many water uses carry direct demands for energy, particularly where the source of the supply is groundwater. On the other hand, energy consumption may significantly affect water resources since agriculture and forestry are primary sources of energy in many rural communities in developing countries, with excessive fuel-wood collection being an important contributing factor to the degradation of river catchments leading to flash floods and high sediment concentrations. Similarly, in certain countries, including Zimbabwe, ethanol distillation from irrigated agricultural crops is providing an important substitute for part of the nation's petroleum requirement. Finally, the desire to optimise agricultural output per unit of water supplied brings increasing demands for fertilisers which frequently require energy inputs for their manufacture.

With regard to financial and economic planning the primary linkage with water is through the need for capital investment and ongoing finance to meet maintenance and running costs without which few of the end-use demands can be met. The relationship is not wholly one-sided, however, since investment in water resource dependent activities, notably agriculture, is often seen as a means by which developing countries can achieve economic growth. In addition, agricultural produce often provide important sources of foreign exchange earnings albeit at the expense of increased imports of agro-chemicals and farm machinery.

The need to consider physical planning is readily apparent with regard to rainfed production, irrigation, access and inhabitability (flood control and protection) and soil fertility (principally with regard to soil salinisation and waterlogging). The two spheres are also closely related through catchment and groundwater hydrological processes whereby land use can have a profound effect on runoff, erosion and water quality. Finally in order for 'carrying capacity' to be evaluated, land capability classifications must be developed and studied.

The environmental or ecological sphere has not been included as a separate item in the above discussion of linkages partly because current practice rarely considers it as a separate planning domain, but also because ecological considerations have been included in the categorisation both of the resource components and the end-uses. This approach recognises both the inherent value of the biosphere in relation to water management and the important constraints which must be imposed on water management if damage to the biosphere is to be avoided. Although this approach has certain practical advantages it may obscure the important overall motives for environmental protection. The principal motives can be summarised as follows:

- to protect natural resources from over-exploitation and degradation so that sustainable levels of resource utilisation are not exceeded;
- to protect 'economic' activities which are directly dependent on the biosphere (eg fisheries);
- to protect species and ecosystems as having value in their own right (biodiversity); and
- to ensure that life-support systems are not polluted or disrupted (air, water, temperature, radiation levels, chemical cycles).

6.5 Mechanisms of allocation and control

Table 7 presents, in tabular form, the complex matrix of interlinkages between different resource components, end-users and other planning spheres. In order to undertake comprehensive planning and management of water and water-related activities, it is necessary to study the formal and informal mechanisms by which the allocation and control of water is achieved. A suitable method for doing this is not readily available and further work is required in this area. Nevertheless, a number of tentative ideas are proposed in the following paragraphs although it has not been possible to develop them to a level which allows them to be systematically applied in the case studies.

One approach to studying mechanisms of water allocation and control might be to study the links between individual resource components and end-users shown in Table 7. For example, how does a particular society regulate the use of groundwater for irrigation or the flood regime of a river for the benefit of aquatic ecosystems? The analysis in each case is a complex one and involves consideration of the legislative, administrative and informal processes which affect allocation and control. A list of some of the factors which should be considered in relation to this are presented in Table 10.

If such an analysis were to be undertaken rigorously the result would be a large number of copies of Table 10 corresponding to each element in the matrix linking resource components and end-uses. The contents of these tables would be extremely repetitive since in most regions a single agency has multiple responsibilities. The analysis would also be unsatisfactory in the following important respects:

- concentration on individual components detracts from the principal reason why current procedures must be improved which is to enable water planning and management to be created in a more comprehensive manner;

- the analysis of individual linkages does not allow linkages with other planning spheres to be readily studied;

- the analysis would have to be repeated at a number of levels to provide a complete picture of the relevant mechanisms of allocation and control: global, international, national, regional and local;

- if planning is to be undertaken on a 25-year horizon, an assessment must be made not only of the existing situation but also of various potential changes which could be introduced during the next 25 years.

In view of these difficulties it may be preferable to develop a procedure which centres the analysis around the agencies and mechanisms of allocation rather than beginning from individual resource components and end-uses. Even then, some grouping together of functions would provide a useful framework.

For example, a distinction can be drawn between those procedures which relate largely to allocation of a quantifiable resource (including not only 'supplied water' but also such things as finance); those procedures which are aimed at the protection and management of the resource base (of which the most important are catchment management and pollution control); those procedures which relate to the management and control of demand; and those which relate to the protection of 'intangibles' (including amenity and ecological attributes).

Table 10: Analysis of methods of allocation and control

Resource component: **End use:**

a. Degree of allocation/control, if any

b. Mechanism for allocation/control (formal and informal)

c. Relevant legislation

d. Agencies responsible for enactment

e. Competence of agencies to enact with respect to

  (i) finance
  (ii) personnel
  (iii) internal organisation
  (iv) conflicts with other agencies
  (v) political influence

f. Public participation/consultation in allocation/control

  (i) formal mechanisms
  (ii) informal mechanisms
  (iii) degree of public awareness/concern

g. Nature of any conflicts or potential disbenefits associated with allocation/control

h. Mechanisms available for identifying disbenefits and resolving conflicts

  (i) formal mechanisms
  (ii) informal mechanisms

One final approach to the analysis of water allocation and control options is to focus on three fundamental questions:

- what is desirable? - what are the goals and priorities, who sets them and how?

- what is achievable? - what is feasible not only physically but also economically and politically?

- what is most efficient? - what is least wasteful of various resource components and also easiest to manage?

Although these are important issues to consider, it is not readily apparent how they can provide the basis for a systematic analysis procedure although they may usefully be incorporated within other analytical approaches.

7. *Case studies of water resources management*

7.1 Introduction

The terms of reference specify that the study of water resources management strategies and needs will be undertaken with particular reference to two case studies to be agreed with the ODA. The two countries selected were Pakistan and Zimbabwe. The choice of these countries was made because it was believed that sufficient data and information about them could be collected to make a worthwhile study in the short time available rather than because they were believed to be typical of a large number of other countries or to be facing particularly serious or immediate water resources management constraints.

The method by which the case studies were undertaken was to collect whatever documents were readily available on water resources management in these countries and to use these as the basis for assessing what methods of water planning and management are currently used; whether there are gaps in these approaches; and what particular water resources management issues are likely to be important for the countries over the next 25 years. Because of the fact that key documents may have been missed in such a short review exercise, the conclusions are to be treated with caution with respect to specific conclusions concerning the two countries studied. Their principal role was to focus the author's attention on practical constraints and considerations so that general conclusions, including the framework already discussed in Section 6, would be closely related to practical reality.

Due to the shortage of time and incomplete information it was not possible to follow through the assessment of resource components and end-use categories as set out in Section 6 but this framework provided a valuable basis for the studies. Before undertaking any kind of analysis, however, it was necessary to collect some key facts about each country. These facts have been summarised on two sets of data sheet: Table 11 was developed to record key facts about water resources availability and use; and Table 12 was developed to include information about water planning and management activities in the country concerned.

It should be stressed that Tables 11 and 12 have been applied in the current study on a national basis. However, because of regional variations there are advantages in studying water resources management on a regional (preferably river catchment) basis. This is particularly true with respect to certain data required for Table 11.

Table 11: Water resources key fact sheet

1. **Country or region**:

2. **Population**: total (year:)

2.1 Urban % Rural %
2.2 Population growth rate % yr^{-1}
2.3 Urban growth % yr^{-1} Rural growth % yr^{-1}
2.4 Life expectancy at birth years
2.5 Daily per capita calorie supply kcal
2.6 Illiteracy in adult population %

3. **Land**

	Category	Area (km^2)	%of total
3.1	Agricultural - irrigated		
3.2	- good rainfed, >180 growing days		
3.3	- poor uncertain rainfed, <180 growing days		
3.4	Total agricultural		
3.5	Forests and reserves		
3.6	Open water and wetlands		
3.7	Urban and built		
3.8	Other		
3.9	**Total land area**		

3.10 Cultivated land per capita ha
3.11 Irrigated land per capita ha
3.12 Intensity of irrigation (3.11/3.10) = %
3.13 Comment on regional variations in the distribution of population and cultivated/irrigated land :

3.14 Population supporting capacity of rain fed agriculture under low inputs M; medium inputs M; high inputs M

4. **Economy**

4.1 Gross national product (US$ x 10^6) (year :)
4.2 GNP product per capita (US$)
4.3 Real growth rate in GNP per capita %
4.4 Agriculture's share in GDP %
4.5 Contribution to exports - primary agricultural products %
4.6 - processed agricultural products %
4.7 Main agriculture based export commodities :

Table 11 (cont'd)

5. **Water resources** : Overall balance for country/region

		$m^3 \times 10^9$	mm	% of P
5.1	Annual precipitation (P)			100
5.2	Mean annual unregulated runoff from region (R_1)			
5.3	Mean annual runoff received from outside region (R_2)		-	
5.4	Minimum value of R_2 fixed by agreement/convention (R_2')		-	
5.5	Net increase in groundwater storage (ΔS_1)*			
5.6	Net increase in surface storage (Lakes, reservoirs, swamps, ice etc) (ΔS_2)*			
5.7	Mean annual runoff passing to adjacent regions (R_3)		-	
5.8	Maximum value of R_3 required by agreement/convention (R_3')		-	
5.9	Mean annual runoff to sea (R_4)			
5.10	Evaporation/consumption (E) $= P+R_2-R_3-R_4-\Delta S_1-\Delta S_2$			
5.11	Available runoff (R_5) $= R_1+R_2'-R_3'$			

(* Normally zero unless long-term change occurring. Indicate a net decrease as a negative value).

5.12 Available runoff per person = m^3cap^{-1}

5.13 Available runoff per unit cultivated land = m^3ha^{-1}

5.14 Comment on regional variations in water resources providing ranges of values for 5.1, 5.12 and 5.13 if available

5.15 Comment on the seasonal distribution of P and R_5 indicating months and ranges of values

5.16 Comment on the inter-annual variability of P and R_5 and estimate their 1 in 20 year extreme values

5.17 Describe important surface water quality characteristics giving, if available, typical mean and extreme values of sediment concentrations, dissolved solids concentrations, etc, at key locations, now and historically

Table 11 (cont'd)

5.18 Describe the main groundwater systems in the region

Name	Location(s)	Area (km^2)	Water Resource Potential and Quality

6. **Water resources development**

6.1 Annual water supplied to

	m^3 x 10^9	% of total
agriculture		
industry		
urban/other		
Total		

6.2 Source of supplied water

	m^3 x 10^9	% of total
surface water		
groundwater		

6.3 Live reservoir storage capacity available m^3 x 10^9

6.4 Domestic water/sanitation

	Rural	**Urban**
Population served by 'safe' supply (%)		
Average per capita daily consumption (l)		
Population served by adequate sanitation (%)		

6.5 Principal urban water supply systems :

Location(s)	Water Source	Type of Service	Population Served

6.6 Main types and extent of irrigation systems :

Type	Water Source	Location(s)	Crop(s)	Area (km^2)

6.7 Main types and extent of drainage systems :

Type	Disposal Method	Location(s)	Area Drained (km^2)

6.8 Total installed electrical generating capacity MW
Contribution of hydroelectricity to the above MW (%)

Names of main hydroelectric stations	Installed capacity (MW)

Table 11 (cont'd)

6.9 Annual fish production from fresh waters t yr^{-1}
Describe the main locations :

6.10 Describe locations and significance of any inland navigation routes :

6.11 Describe any significant causes of surface or groundwater pollution

7. **Environmental characteristics**

7.1 **Locations prone to flooding** **Typical area flooded (km^2)** **Frequency**

7.2 **Locations protected from natural flooding** **Area (km^2)**

7.3 **Locations reclaimed by drainage** **Area (km^2)**

7.4 Irrigated land seriously affected by
waterlogging (%)
salinsation (%)

7.5 Important natural ecosystems
Description **Area (km^2)**

(a) Terrestrial :

(b) Aquatic :

(c) Shoreline :

(d) Floodplain/wetland :

Table 12 provides a basis for recording significant features of the current water resources management and planning activities in the country or region under study. Questions 4 and 5 provide key elements in this information since they record details of specific planning or water management activities which have been studied. Multiple copies of these sheets are used, one for each activity.

Table 12: Current watert planning and management information sheet

1. **Country or region :**

2. **Agencies** involved in water planning and management

Name	Abbrev Name	Agency Type	Areas of Responsibility Sector(s)	Region(s)

3. **Hierarchy of responsibilities** between agencies
Sketch of describe inter-relationships and means of coordination

4(...) **Available water planning strategy documents** (complete question 4 separately for each document)

4.1 Title : Date :

4.2 Purpose :

4.3 Planning approach (end use, etc) :

4.4 Components of plan :

4.5 Sectors included :

4.6 Geographical regions :

4.7 Time Horizon :

Table 12 (cont'd)

4.8 Planning methods and tools :
(a) Physical system
(b) Economic evaluation
(c) Environmental assessment

4.9 Plan prepared by :

4.10 Plan prepared for :

4.11 Procedure for authorisation prior to implementation :

4.12 Extent of public participation :

4.13 Extent of inter-agency consultation :

4.14 Time and resources needed to prepare plan :

4.15 Professional involvement in preparation of plan :

5(...) **Operational water management activities** (complete question 5 separately for each activity/function)

5.1 Title :

5.2 Purpose :

5.3 Scope :

5.4 Sectors included :

5.5 Geographical regions :

5.6 Time horizon :

5.7 Methods and tools used for identifying options :

5.8 Method of public consultation/involvement :

5.9 Operating agency :

5.10 Source of agency's authority :

5.11 Actual or potential areas of conflict :

5.12 Method of conflict resolution :

5.13 Time and resources required for operation :

Table 12 (cont'd)

5.14 Professional involvement in operation :

6. **Hydrometric network** : Number of operational stations in regions which have been functioning for five years or more

Type	Number in region	Number per $10^4 km^2$
Precipitation		
Evaporation		
Stage (water level)		
River discharge		
Sediment discharge		
Surface water quality		
Groundwater level		
Groundwater quality		

(For recommended minimum standards see UNESCO/WMO 1988)

7. **Specialist institutions** for training and research in water

Name of institution	Type	Functions and specialisation

8. **Describe sources of funding** and procedures for water resources development

9. **Describe environmental control procedures** and list agencies responsible

10. **Describe significant international water issues** in the region

Copies of Tables 11 and 12 completed with the information collected for Pakistan and Zimbabwe are contained in Appendices 2 and 3 respectively. Also included in these Appendices are Bibliographies of material studied during the current research and lists of projects in the water sector funded by ODA and other bilateral and multilateral funding agencies in these countries over the last 10 years. The format in which the project data are presented is given in Table 13.

Table 13: Bilateral and multilateral funded projects related to water resources management in ....

Project Title	Type	Purpose	Funded by	Implemented by for	Start	End	Cost

7.2 Pakistan Case Study

The basic information and data on water resources management in Pakistan, collected during the course of this study, are summarised in Appendix 2 and important features of the available resources and end-use demands are listed in Tables 14 and 15. The following notes highlight the main issues.

To a large extent water resources management already dominates much of the economic, political and social activity in Pakistan. The country is heavily dependent on agriculture and more than 90% of its agricultural production is from irrigation. The Indus Irrigation System (IIS) is the largest interconnected system in the world and the Indus Basin covers much of the country. Its catchment extends beyond Pakistan's northern borders (about 44% being outside Pakistan) and continued development of the system is only possible as a result of the Indus Water Treaty agreed with India in 1961.

Because of its importance it is worth providing the following detailed introduction to the IIS based on World Bank (1988b). The 2 900 km long Indus River with its six major tributaries (Kabal, Jhelum, Chenab, Ravi, Beas and Sutlej) drain an area of 960 000 km² and provide a permanent source of surface water. The rivers are snow fed, drawing their supplies from perpetual Himalayan glaciers. In the summer, the flow increases; beginning in April from snow melt and, between July and September, from monsoons. The volume of flow in the summer season is often more than 10 to 20 times the winter discharge.

Before the development of irrigation systems, the Indus flooded a vast area of about 1300 km long and 240 km wide. For thousands of years the flooding deposited large amounts of alluvium which has gradually built up on the Indus plain. Today, an extensive system of canals and barrages helps prevent flooding and allows for irrigation. Nevertheless, flood warning remains an important function of water resources management in Pakistan and occasionally flood damage is severe.

The two other minor river systems of Pakistan are largely ephemeral being both scarce in rainfall and high in evaporation. They drain the Kachi Plains and the coastal streams west of Karachi.

Irrigated agriculture began perhaps five thousand years ago in the Indus valley and has been closely linked to the many civilisations that have since flourished there. Of the Indus Basin's 200 000 km², 70% is cultivable and 50% is under irrigation served by 60 000 km of canals. This represents the largest *contiguous block of irrigated land in the world.*

The importance of the IIS has meant that water resources planning has become synonomous with irrigation planning as demonstrated by the Water Sector Investment Planning Study (WSIP) just completed (MacDonald et al, 1991) which does not consider domestic, urban and industrial consumption nor hydroelectric power generation. In recent years irrigation planning has included an increasingly significant drainage component by virtue of the high groundwater and salinity levels which have built up in more than 10% (possibly as much as 25%) of the lands of the Indus Plain with detrimental effects on output. At the same time, groundwater has become a significant source of irrigation spurred on by World Bank and other donors' policies which favour the decentralisation of control.

The interactions between the surface water, groundwater and soil systems and the quality of both surface and groundwater involve complex relationships which have an important influence over predicted water availability within the IIS in the future. Summary data such as produced in Appendix 2 appear inadequate as indicators of levels of long-term sustainable yields from groundwater and of the influence of current policies on recharge and water quality.

Legislation has established the Water and Power Development Authority (WAPDA) as responsible for river basin development and management of surface water flows. No provision is made in the legislation for ground water management or the prevention of groundwater pollution.

Table 14: Significant features of the resources in Pakistan

A	**Rainfall, snow, etc**	: Falls mainly on non-arable land (mountains)
B1	**Runoff*- mean**	: Substantial proportion (40%) received from outside Pakistan
B2	**- flood**	: Partially controlled, frequency of floodplain inundation greatly reduced by reservoirs and irrigation
B3	**- low flow**	: Totally controlled by reservoirs
C	**Groundwater**	: Already over-exploited in Baluchistan. Salinity affects utilisation of rich aquifer in parts of Indus plain
D	**Storage works**	: Tarbela filling with silt at 1-2% yr^{-1}. Echo surveys conducted regularly. Storage is vital to the Indus System but questions raised over new investment
E	**Abstraction and diversion works**	: Indus System has 22 barrages/dams. Rehabilitation of Sukkur and Kotri has been necessary recently
F	**Conveyance and distribution systems**	: Karachi depends on a 240km supply canal and Faisalabad 50km. Indus System has 57000km of canals. Big watercourse lining programme
G	**Drainage and disposal systems**	: SCARP and private tubewells irrigate and control groundwater level. LBOD and evaporation pans used for disposal. Some tile drainage
H	**Treatment facilities**	: Large urban centres have treatment. Most use groundwater
I	**Flood control works**	: Flood warning has national priority. Extensive flood embankments in need of maintenance
J	**Water quality (including sediment)**	: Some routine sediment measurements u/s Tarbela. Few water quality data available. Mapping groundwater salinity is vital
K	**Special habitats****	: Mangrove swamps and various types of wetland and floodplain
L	**Important species****	: An important bird migration route depends on wetlands

Table 14 (cont'd)

M	**Aesthetic and religious value**	: Religious beliefs govern attitudes to water charges and women's participation
N	**Individual knowledge and skills****	: Strong professional group in some agencies but others (eg LGRDDs) badly understaffed. Farmer skills well developed
O	**Social/institutional organisation****	: Farmer organisations relatively new. Inter-agency links often weak
P	**Political/economic/ legal environment****	: Water management well supported but environmental protection weak.

* includes water received from outside the country/region
** specific to water

Table 15: Significant features of the demand in Pakistan

1	**Rain-fed production***	Production small
2	**Irrigated production***	Important for food and exports. Dominated by the Indus system and tubewells but smaller schemes also locally important
3	**Hydro-electric energy**	About 40% of electricity. Generating capacity lags demand leading to load shedding
4	**Domestic needs**	Rural water supplies poor but improving. Urban supplies better but suffer high losses
5	**Community/municipal needs**	Small compared to agriculture
6	**Industrial needs**	Small but likely to increase
7	**Livestock needs**	55M animals at present
8	**Aquaculture**	No information
9	**Natural fisheries**	80 000 t yr^{-1} produced. Marine fisheries also important
10	**Navigation**	Virtually none except on pools between barrages
11	**Waste and heat disposal**	Increasing disposal of wastes is poorly repulated
12	**Access and inhabitability**	PIDs responsible for flood control. Elaborate flood warning exists

Table 15 (cont'd)

13	**Soil fertility**	Major soil salinity and waterlogging problems
14	**Terrestrial ecosystems**	Irrigation has brought major changes to a previously arid region
15	**Aquatic ecosystems**	Many new canals and reservoirs created but their ecological value unknown
16	**Shoreline ecosystems**	Riverain forests declining due to control of floods
17	**Floodplains and wetlands**	Minimum releases below Kotri to prevent further damage to mangroves unknown.
18	**Animal/fish migration**	Bird migration significant. Depends on wetlands
19	**Cultural and**	No information
20	**External water transfers**	Indus Water Agreement transfers water to India before it enters Pakistan. No other agreements

* Includes arable, pasture and forestry

Future planning in relation to the IIS has tended to focus on the optimal use of investments over a 5-10 year horizon (WSIP spans 12 years). No coherent strategy appears to have been formulated to address the implications of resource constraints over longer periods. This now appears to be necessary since it is clear that within the next 15 to 20 years food production will no longer be able to keep pace with a population growth of over 3% (the second highest in South Asia) and the current policy of food self-sufficiency will have to be abandoned. Unlike Egypt, however, (see Abu Zeid and Rady, 1991) there is no immediate prospect of urban or industrial demand making a major encroachment into the water available for irrigation although this will also be important in the longer-term. Global warming may well reduce the available water and increase inter-annual variability as well as causing increased flood risk particularly if mean sea level rises.

Pakistan's irrigation managers and planners face problems of water quantity and quality which will probably reach crisis proportions in the next 25 years. At present they are focusing on two specific issues: how to make a given volume of water more productive (particularly by reducing distribution losses) and how to prevent salinisation from affecting soil fertility and the quality of current groundwater sources. The two questions are linked in an intricate and insufficiently understood manner since seepage losses provide the major source of groundwater recharge. The planning of future water strategies must, therefore, be undertaken comprehensively but the ability to provide comprehensive solutions to these difficult questions is limited by the organisational and legislative structures which are directed towards the management of surface water to the neglect of groundwater.

With regard to domestic water, there is no immediate likelihood that there will be a lack of suitable sources except in some arid regions away from the Indus Plain (eg. the highlands of Baluchistan) and in parts of the Plain where saline groundwater occurs. At present the main constraints to improving the low numbers of people served by a safe supply in rural areas (where only 40% the population are served) are low levels of investment and insufficient numbers of technical staff. The World Bank has started a major project in this sector.

The low level of rural water supply is indicative of a number of other important social and health concerns which have been voiced with regard to Pakistan's path to economic development; including an infant mortality rate of 100 per 1000 live births. Of particular concern is the low level of literacy, particularly among rural women (less than 10% in many areas). Programmes directed towards improving rural water and sanitation, spreading rural electrification and increasing the sustainable levels of agricultural production, whilst not specifically addressing such problems, are (particularly in the mountainous regions) likely to improve Pakistan's performance on these and other social indicators. Although such activities will have a fairly minor impact on water resources, they do compete for available skills and investments against other types of project.

Apart from the question of soil salinisation, which has already been discussed in relation to sustaining agricultural production, the most immediate environmental issues listed by WSIP are the possible effect on the Indus delta and its associated fisheries of further reductions in system outflows; the impact in the delta and elsewhere of changes in water quality from inputs of saline drainage water and unregulated industrial and sewage effluents; the management and preservation of wetlands and riverain areas particularly in respect of large populations of migrating birds; and the control of erosion in hilly catchments particularly upstream of Tarbela Dam. Like salinisation, most of these issues are being addressed more from the point of view of their effects on future water resources management than as purely ecological questions. Indeed, there appears to be little detailed ecological information available but this may reflect the sparseness of the biosphere in this arid region.

Water resource development has brought a number of social disbenefits in the past and is likely to continue doing so. Prominent amongst these are population displacement by reservoirs, negative health impacts (particularly in relation to malaria) and loss of inland fishers. Although the latter two are not clear-cut, the need to avoid serious disbenefits must be recognised in the method of water planning and management adopted in future.

Reservoir sedimentation is likely to be a major water resource issue in the future. The storage capacity at Tarbela is reducing at about 1.5% per year (rather less than the rate predicted during its design). At the time it was built, engineers were confident that new storage reservoirs would have been built with a total far in excess of Tarbela's capacity long before the loss of storage began to affect output. This has not happened and even the most advanced proposals for new dams are repeatedly shelved for various reasons including the vast overspends and repairs needed for Tarbela. Watershed management has reportedly reduced sedimentation rates in Mangla substantially but the largely glacial sediment entering Tarbela is unlikely to be controllable by such an approach. With seasonal storage a key feature of irrigation on the Indus plain and continued dependence on hydroelectricity for about 42% of electrical energy, the issue of long-term sustainability of the 'storage works' component of the water resource requires further strategic examination.

Water management in Pakistan is heavily dependent on existing major investments in infrastructure. These impose constraints on the flexibility of future water management options in two ways. First, there is the physical constraint which is imposed by the difficulty and cost of modifying the location and maximum capacities of major canals and diversion structures. Secondly, the infrastructure requires large numbers of skilled professionals for its maintenance and operation. The thinking and training of these people exerts a strong constraint over the ability to plan and introduce innovative approaches to water management. This influence is institutionalised in the prominence given to WAPDA in national water resources planning and management. The cost of providing the operation and maintenance services for this vast infrastructure is also an important issue since cost recovery from farmers is partial and inadequate at present and there is some resistance to the concept of charging for water.

Until recently, the question of water quality has been overlooked except with respect to saline groundwater zones. A major challenge which water managers face in Pakistan is to improve the monitoring of surface water quality and to ensure that adequate controls exist for the regulation of pollution from industrial and other sources.

Politically the major water resources allocation question has, for the last decade or more, centred around the apportionment of water from the Indus to the different Provinces. A new agreement on this has now been reached (see Mulk and Mohtadullh, 1991) and a new agency has been created to implement it but its effectiveness is yet to be established and already problems are foreseen in the allocation of supplies during years of shortage.

International conflict over water sharing has for thirty years been avoided by means of the agreement which was reached with India in 1961 and the subsequent injection of large amounts of capital by the World Bank. However, potential conflicts may yet arise as growing demand affects both the quality and quantity of available water. In particular, the rivers flowing from Afganistan and the disputed territories of Kashmir are not covered by formal agreement although, with limited land available for irrigation in the upper basins of these rivers, Pakistan is unlikely to lose significant amounts of surface flow unless major inter-basin transfers are undertaken.

International concern over possible water related conflicts and environmental degradation is being voiced by many South Asian countries who are seeking to work within the auspices of the South Asian Association for Regional Cooperation to establish a mechanism for future planning and cooperation.

Pakistan itself has recognised the need for improved planning of water resources development. The Sixth Five-Year Plan (Planning Commission, 1983) envisages the establishment of a Master Planning Unit attached to the Water Resources Section of the Commission. It is unknown whether this Unit was established but, given a sufficiently broad terms of reference, such a Unit could form the basis for long-term strategic planning as advocated in this report.

It is clear that substantial research will be needed to support the future water management activities of Pakistan in view of the complex inter-related issues of surface and groundwater use and the various social, economic, environmental and political expectations and influences which must be considered in managing them. Even the basic collection of hydrometric data appears to be at a fairly rudimentary level in the country and is in need of a detailed review. The current investment in irrigation and drainage research is low in relation to the high levels of investment in these sectors. (Only 3 out of 16 World Bank projects since 1974 had a research component although the total funds this represents is large due to the size of the projects; see Safadi and Plusquellec, 1991). Better coordination and direction of research will be required for the future.

Finally, in any study of Pakistan's water resources there are significant regional variations which must be considered. The upland areas of North West Frontier Province and the Punjab have plentiful rainfall and surface water resources but restricted areas in which cultivation can be undertaken. The highlands of Baluchistan face similar shortages of good land but without the perennial surface water and rain. Already there are indications that the meagre groundwater resources there are being overexploited. The rich irrigation-dependent agriculture of the Indus plain contrasts strongly with this. Any study of water resources based on a carrying capacity concept must, therefore, be at a regional rather than national level.

7.3 Zimbabwe Case Study

Details collected for the Zimbabwe case study are presented in Appendix 3 while the principal features of the resource base and end-use demands are summarised in Tables 16 and 17.

In contrast to Pakistan, the most agriculturally productive regions at Zimbabwe lie along a central watershed rather than in an alluvial plain. In the past this land was concentrated in the hands of a few European settlers. Since Independence, the desire to redistribute land ownership without jeopardising agricultural production has been one of Zimbabwe's chief political issues.

Zimbabwe receives no surface water from beyond its borders except in the Zambezi River which is never fully within Zimbabwe, always forming the border with Zambia. Because of its international status and its remoteness from major centres of industrial and agricultural development the Zambezi river has, in fact, been regarded as totally separate from the country's other surface water resources and has played little part in meeting growing demand for agricultural, industrial and urban supplies. By contrast it plays a vital role in meeting the country's electrical-energy needs through the generation of hydropower at Kariba Dam. This situation seemed unlikely to change substantially with planning studies concentrating solely on the further exploitation of hydropower and no interest shown in major irrigation development in the Zambezi valley due to lack of suitable irrigable land. Furthermore, the large amounts of energy which would be needed to pump the Zambezi water to centres of high demand elsewhere in Zimbabwe, until recently, excluded this option; but the recent severe drought has caused the public authorities and businesses around Bulawayo to co-operate in proposals to build a 400km long pipeline, although the amounts it could carry are likely to be small compared to the mean annual discharge of the river.

For all other surface waters, Zimbabwe has assumed the right to exercise total control over the available resources irrespective of the needs of the various downstream nations (Mozambique, Botswana and the Republic of South Africa) through whose lands the rivers subsequently flow. Considerable effort has been devoted to measuring and apportioning these resources: national legislation to control abstractions and water quality has been in place for many years and there is an extensive hydrometric data collection network; but no international agreements on water use exist apart from those which govern the construction and operation of Kariba Dam.

Another contrast with Pakistan is the relatively high rainfall over much of the country which allows a single rainfed crop to be cultivated on the major part of the arable land most years. Although shortage of time prevented access to the key reference (FAO et al, 1983) it is believed that the estimated rainfed food production potential of Zimbabwe is well in excess of the present population, suggesting that, in absolute terms, the country's carrying capacity is unlikely to be exceeded for several decades. Thus, at first sight, there does not appear to be an imminent water crisis for the country as a whole.

Nevertheless, due to the spatial and temporal variability of surface water, rainfed production has been shown to be inadequate. Many over-populated arid regions already exceed their carrying capacity; and disastrous crop failures occur when rains fail as has happened with increasing frequency in the last 20 years. This has resulted in the introduction of supplementary irrigation even to some of the highest rainfall areas. Irrigation has also been introduced to overcome problems of drought and food shortages in the poorer, more arid regions to which large numbers of African farmers had earlier been displaced by European settlers. Irrigation also allows cash crops, notably sugar and cotton, to be grown in estates in the south and east of the country. However, in the current drought, lack of inflow to reservoirs has meant that even irrigated production has sufferered. If the current situation is indicative of the long-term effects of climate change on Zimbabwe's rainfall, a water crisis may be much closer than previously thought.

Water resources management has been seen as the key to increased agricultural production and to overcomiong economic and social inequities associated with regional variations in land and water resources. However, since suitable soils tend to be dispersed, except in the south of the country, irrigation has developed as a series of small systems the largest being no bigger than 10-20 000 ha. Water resources engineers have seen their principal role as locating and building suitable storage sites to enable the seasonal river flows to be stored and used for double season cropping. The main constraint on water development is seen by them to be the lack of funds and local expertise to continue an ambitious dam construction programme which, until recent years, had been largely staffed and financed from the country's own resources. Water engineering has been amongst the most prestigious and well-staffed activities in the country for much of this century to the benefit both of agricultural and urban water supplies but the impetus has not been maintained in the last decade with the result that skill shortage is becoming and increasingly acute problem.

Table 16: ***Significant features of the resources in Zimbabwe***

A	**Rainfall, snow, etc**	:	Varies from wet east to drier west and south. Single wet season
B1	**Runoff*- mean**	:	Highly variable in time and space. The Zambezi borders Zimbabwe and is treated totally separately
B2	**- flood**	:	Larger rivers now mostly dammed
B3	**- low flow**	:	Headwater swamps (dambos) provide some perennial flow to larger rivers
C	**Groundwater**	:	Some areas of good alluvial aquifers but mostly poor yielding crystalline rocks
D	**Storage works**	:	A critical resource steadily increasing. Sedimentation not yet a major problem in most reservoirs
E	**Abstraction and diversion works**	:	Not much investment except in small schemes
F	**Conveyance and distribution systems**	:	The largest systems are in the Sabi Valley and in the south
G	**Drainage and disposal systems**	:	Not of major importance
H	**Treatment facilities**	:	Urban centres have adequate treatment
I	**Flood control works**	:	Few
J	**Water quality (including sediment)**	:	Fairly good. Sediment loads variable and in need of more data.
K	**Special habitats****	:	National parks mainly in woodland/savana. The Zambezi floodplains are important
L	**Important species****	:	Black rhino endangered. Some antelopes provide meat
M	**Aesthetic and religious value**	:	The Zambezi has religious value for the Barotse
N	**Individual knowledge and skills**	:	Irrigation skills are restricted. Previous professional expertise in hydrology now declining
O	**Social/institutional organisation****	:	Various important institutions but co-ordination often poor

Table 16 (cont'd)

P	**Political/economic/ legal/environment****	: Well developed legal framework for water control. Economy static at present

* includes water received from outside the country/region
** specific to water

Table 17: Significant features of the demand in Zimbabwe

1	**Rain-fed production***	Very important resource which has potential to feed expanding population
2	**Irrigated production***	Mainly introduced for cash crops, to prevent mid-season crop failure or to provide famine relief to arid areas
3	**Hydro-electric energy**	Zambezi hydropower has been crucial in Zimbabwe's development although coal is available
4	**Domestic needs**	Rural water demand previously neglected now being met from boreholes
5	**Community/municipal needs**	Urban centres well supplied
6	**Industrial needs**	Important industrial base requires water but amounts unknown
7	**Livestock needs**	5.6M cattle supplied by small tanks, groundwater and natural rivers
8	**Aquaculture**	Virtually unknown
9	**Natural fisheries**	Reservoirs of all sizes are fished but total unknown
10	**Navigation**	None
11	**Waste and heat disposal**	Will become more important as industry and mining develop
12	**Access and inhabitability**	Flood control and land reclamation are not significant
13	**Soil fertility**	Salinity thought to be fairly insignificant
14	**Terrestrial ecosystems**	Woodland and savana important. Major threat is wood cutting for fuel

Table 17 (cont'd)

15	**Aquatic ecosystems**	Reservoirs and ponds carry fish. Drawdown may be disruptive
16	**Shoreline ecosystems**	Ecological potential of reservoir shorelines unknown
17	**Floodplains and wetlands**	Zambezi floodplain and dambos important
18	**Animal/fish migration**	No significant problems recorded except eels in the Zambezi
19	**Cultural and recreational**	Some important water-based tourist attractions as well as hunting and fishing
20	**External water transfers**	Zimbabwe is the upstream country in all except the Zambezi River basin. There are no international agreements

* Includes arable, pasture and forestry

As in Pakistan the rural water sector has been relatively neglected until fairly recently but, ironically, the only comprehensive water resources Master Plan prepared for Zimbabwe relates to this sector and was prepared under Norweigan aid in the mid 1980's. Again capital and skills are the main constraints currently faced in improving the coverage of safe supplies from the current level of 33%. The main technology used is communal handpumps with up to 30 000 boreholes at present installed. However, because of the dominance of crystalline rocks, the costs are high and yields variable in many areas.

Rural poverty is a significant problem in Zimbabwe as in most developing countries and water-related diseases are common although significant progress has been made, through the work of the Blair Research Laboratory, in controlling schistosomiasis and malaria and in developing low cost, appropriate water supply and sanitation technologies.

Prompted by the NORAD-funded study there have been moves recently within the country to improve the coordination between different Ministries and agencies in the planning of water resources development. It has been recognised that this can no longer be left mainly in the hands of the engineers of the Ministry of Energy and Water Resources and Development (MEWRD) but must encompass the Ministries of Lands and Agriculture, Local Government, Natural Resources and Tourism, Health and of course, Economic Planning. As a result a number of coordinating committees and planning units have been established but, from an outsider's initial glance, these do not yet appear to have clarified or simplified the procedures and responsibilities. It is believed that MEWRD still has responsibility under the Water Act, to prepare outline plans for the development of water resources in each of the country's eight river systems but staff shortages have prevented the production of any of these beyond draft status.

Planning responsibilities are probably still in a state of flux as local and regional agencies are gradually given more power, initiative and responsibility to formulate development plans in consultation with local people. The environmental conditions being so different across the country, it is advantageous to plan development at a regional level but whether this will also provide for a rational use of the nation's limited financial and manpower resources remains to be seen. Contradictions are already apparent in the politically expedient, but technically and economically questionable, decision that one new medium-sized reservoir should be constructed in each province every year.

Development of water and energy resources are closely linked in Zimbabwe due to the importance of the Zambezi hydroelectric power generation. Despite the fact that Zimbabwe has large coal reserves, hydropower remains an important resource with plans to build further dams on the Zambezi constantly under review. However, an important linkage between the two sectors, which in the long-term may be of greater significance to water-related development in Zimbabwe, has not been given sufficient prominence: the effect that rural fuelwood collection is having on river catchment erosion and hydrology. Hosier (1986) estimates that there will be an increasing deficit in fuelwood availability from 1990 onwards and that even if immediate steps are taken to plant more trees the deficit will continue to increase until well into the next century with major consequences for soil erosion. A further link between the sectors is provided by the production of ethanol from irrigated sugar. Its use in vehicles allows a 20% reduction in petrol imports.

Both fuelwood collection and hydroelectric dam construction create significant environmental changes and these are being increasingly recognised within Zimbabwe. Plans for one proposed Zambezi dam, at Mupata Gorge, have already been shelved due to the impact it would have on the wetlands at Mana Pools downstream of Kariba. Other proposed dams are also being closely scrutinised. Apart from these issues, the environmental concerns which are likely to be of greatest significance in water resources development in Zimbabwe are the need to protect the delicate balance of headwater swamps (dambos); and to remain vigilant to prevent major industrial, agricultural or wastewater pollution of the rivers and groundwater. However, it is the possible effects on large mammals which are most likely to attract public concern because Zimbabwe has a long history of wildlife protection, through its National Parks on which the tourist industry depends.

An attempt has been made by the UNEP to coordinate environmentally sound management of the whole Zambezi basin (encompassing approximately half of Zimbabwe's land surface) in order to prevent degradation of the catchment and ensure that basin states co-operate to optimise the use of resources. A Zambezi Action Plan (ZACPLAN) was formulated and a co-ordination centre established through the SADCC in Lesotho (which is not a basin state). But the initiative seems to have fallen from the prominence with which it was launched and its current status is unknown. In future, greater prominence must be given to water resources planning on a bilateral or regional basis and effective co-operation arrangements be created not only for the Zambezi but also for the Limpopo, Sabi and other international rivers.

Economic justification for dam construction and other water resources development in Zimbabwe has, in the past, been secondary to other considerations. Even today, political considerations and efficiency of water use may be more significant in defining investment priorities. Nevertheless, cost recovery has been attempted, albeit on an unsound financial basis which has tied unit costs of water to a non-discounted contribution towards capital costs plus partial operational costs. Furthermore, problems have been faced in gaining political acceptance for the idea of charging small-holder farmers for irrigation water.

As with Pakistan, water resources development is closely tied to national economic growth in the eyes of the government: with the urban population growing at over 5.5% per annum, before the effects of the recent drought, and with 25% urban unemployment, the pressure to stimulate employment opportunities is considerable. However, unlike Pakistan the major constraint at present is not the finite nature of the resource but the skills and capital needed to develop it. In addition, social and political questions concerning access and control over the resource, particularly in the more arid rural areas are prominent. To some extent, however, these are only part of the larger political issue of land ownership and distribution. In the future the integrated planning of land and water development will become increasingly important since degradation of catchments poses a major threat to the sustainable development of water resources.

Research activity in the water sector in the country has been relatively high although the value in cost terms is unknown. This activity has largely been focused towards enabling the rural poor to achieve more efficient use of available water, improved agricultural income and productivity, improved access to reliable and safe water supplies and protection from human and animal diseases. Given the unequal distribution of resources such research will continue to be necessary but it must also be extended into studies of the impact on water resources of significant changes in land-use practice under, for example, an accelerated programme of resettlement. In addition, because of the high variability of rainfall in this region, the future planning of Zimbabwe's water will depend heavily on the success of research on global circulation models in predicting future climatic changes.

8. The role of the ODA and other bilateral and multilateral agencies in water management in Pakistan and Zimbabwe since 1980

Difficulties were encountered in collecting the data for this part of the study. First, it proved very difficult to obtain information about aid projects relating to a specific sector, particularly in view of the wide range of projects which might be considered as being relevant to water resources management. Secondly, there appears to be no easy way of collecting data about the activities of different donors short of approaching each in turn. Thirdly, there were some projects which were jointly funded and records were often unclear as to whether the total cost was for one or all of the donors. Fourthly, it was difficult to distinguish grants and loans: in the end no distinction has been made between them. Fifthly, the costs of projects were sometimes given at project start and sometimes at project end (with appropriate allowances for inflation and project modifications). Lastly, it was not always possible to discover when particular projects began or ended, with some having been extended several times. The collected data presented in Tables A2.3 and A3.3 must, therefore, be read with caution and be regarded as at best a partial, and in places incorrect, record of major aid projects in the water sector in the two countries since 1980.

Turning first to Pakistan, very large aid funded investments in the water sector have been made since the country's independence. This has continued over the last ten years with the World Bank taking a lead in such projects as the various phases of SCARP (Salinity Control and Reclamation Project), Left Bank Outfall Drain, On-farm Water Management, Command Water Management and Irrigation System Rehabilitation. Each of these has been directed towards the needs of the existing irrigation and drainage system in the Indus plain with the major emphasis being on drainage, salinity control, system rehabilitation, reduction of irrigation losses and increased farmer participation. The ODA has contributed large sums to several of these projects over the years and has a continuing commitment to such activities, for example the rehabilitation of Kotri Barrage and the maintenance of Tarbela Dam.

At the same time, the World Bank has recognised the bias in Pakistan's water management and has begun supporting programmes of rural water supply and sanitation. Other donors, including the ODA, have again contributed to this initiative although the overall sums appear to be smaller. The ODA has also retained an interest in assisting Pakistan in the maintenance of its urban water supply and sewerage systems through provision of equipment and training.

A third area of activity by donors, including the ODA, is in providing assistance with water resources planning. The World Bank's involvement dates from the early 1960s when major storage works were planned following the Indus Waters Treaty. More recently there has been a Water Sector Investment Planning Study and a Right Bank Master Plan (still in progress) both of which consider the future investment needs of the Indus Irrigation System in a broad, but basically investment-orientated, fashion.

A growing area of donor activity has been in supporting rural development (including both water supply and small irrigation schemes) in the mountainous regions of Baluchistan, northern Punjab and the North West Frontier Province. In many cases Non-Governmental Organisations have taken the lead supported by bilateral and multilateral funds. The ODA has recently made further commitments to part-fund the Aga Khan Rural Support Programme in this type of work.

Finally, there have been commitments to undertake research. Since 1974, the World Bank has made provisions for amounts in excess of US $14.0M in support of such projects as the On-Farm Water Management Project and the Private Tubewell Development Project. The ODA has made a number of modest contributions to research in the water sector including recent studies of snow and ice hydrology and tannery effluents.

Turning now to Zimbabwe, the overall level of donor funding in the water sector appears to have been substantially less than in Pakistan, even in relation to the smaller population size, with no significant World Bank projects undertaken except in the hydropower sector. The most prominent donor in the water sector has been Norway whose support for rural water and sanitation development and funding of a Master Plan study in rural water and sanitation have had far-reaching effects both on the development of this sector and in influencing the method by which such activities are planned. Other donors, such as SIDA and GTZ, have also contributed.

In the development of small irrigation, it is known that GTZ and Italy have been active and that a Japanese project is underway but further details could not be obtained. The ODA provided funds for new pumps for the Nyanyadzi Irrigation Scheme.

In the past, major investments were made in the Kariba Dam and continued donor inputs have been made over the years to maintain and upgrade its facilities and also to provide planning expertise for the assessment and design of further hydroelectric installations. Both the World Bank and the ODA have been active in this area.

One of the ODA's main areas of activity in the water sector in Zimbabwe has been in the support of the MEWRD. This has been through consultancy services for new dams, provision of Technical Co-operation Officers and in support of the groundwater development section. Other areas of assistance have included forestry, fisheries and pest control all of which impinge on water resources management. Finally, there has been strong ODA support for various research projects related to groundwater development and irrigation. It must be said, however, that water has not been a major priority for ODA's activity in Zimbabwe and that, in comparison to the funds made available for structural adjustment, resettlement and poverty alleviation the amounts involved have been small.

9. *Discussion*

9.1 Water resources management needs in developing countries

Two factors are readily apparent from the general introductory work for this report and the two case studies: that water resources management is an extremely complex and far reaching activity within developing countries; and that the needs and current approaches of different countries are quite diverse. It has been difficult, even for someone with a broad multi-disciplinary training in water resources research, to identify the main strengths and weaknesses of the current approach to water resources management in Pakistan and Zimbabwe and to pin-point particular needs within the short span of this consultancy. It is likely to be still more difficult for non-technical personnel, who often have the responsibility to formulate national policies, to select water resource management priorities. Strangely, familiarity with a country was not found to be particularly advantageous: the author's prior knowledge of Zimbabwe did not help clarify the issues although it enabled a number of information gaps to be filled.

One over-riding need identified was the need for strategic thinking about future water resources planning and management. The word 'strategic' is used to imply both the time-scale and the breadth of the thinking required but also carries the political scientist's meaning of addressing issues which are of the highest national priority. A comprehensive view of needs and resource constraints over, say, a twenty-five year span or longer has, to my knowledge, rarely been attempted for individual developing countries. Even over 25 years the populations of Pakistan and Zimbabwe will have more than doubled if they continue at current rates and this will present a massive challenge to those seeking to provide food, water and other basic needs. Of course, demographers expect that population growth rates will reduce but the urgency remains.

In terms of the breadth of thinking required, the study has illustrated many of the linkages which must be considered not only between the end-use needs and water resource components but also with other sectors: energy planning, economic planning and physical planning. In addition the study has touched on some national and international political issues which are important in water resources management concerning access and control over the resource, the influence of institutional arrangements in determining current management practices and the widespread lack of public involvement in the formulation of plans (although new initiatives in Zimbabwe may be changing this).

The new approach to water resources planning and management advocated above requires a radical rethink of the analytical methods used and of administrative and political considerations. To illustrate the need for a new analytical approach a framework was developed in this study, based on comprehensive lists of resource components and end-use categories. Such lists may form a useful basis for ensuring that important considerations are not overlooked in strategic thinking although the contents of the lists and their manner of use need further discussion and development. Even within this study, various short-comings and inconsistencies have arisen in setting up data sheets for the case studies. In particular, the complexities which arise in analysing the existing and potential methods of allocation and control demonstrated the need for further detailed study of this crucial area.

Although the formulation of the above lists did not result in a coherent new analytical framework an important result of their use has been to illustrate the many weaknesses which exist in our ability to assess and predict current and future levels of resource availability and demand even as individual items; far less so when linkages between them are also considered. Predictive methods, scientific understanding and basic data are all in need of further development. It is clear, however, that for strategic overviews to be produced there is need to develop an analytical procedure which is not over-complex or time consuming. To this end a number of key indicators must be investigated which can be used to assess the significance of various resource components and end-uses from data which should be readily available.

A key consideration in strategic thinking is the population supporting capacity of a country's land and water resources in terms of food production, since agricultural demand far exceeds all other per capita water uses. In temperate countries we are fortunate that this demand is largely met from rainfall and even in many semi-arid and arid countries there is significant potential to use rainfall to meet at least part of crop water requirements. The work reported in FAO (1983) must be re-examined and extended if a realistic assessment of carrying capacity is to be acheved. Even in the case of Pakistan, where rainfall is adequate for crop production only in the northern hills, the suggestion has been made that the rainfall on arid rangelands could be made more productive if more research were undertaken into wider use of tree crops.

One factor which has not been adequately discussed in this report is the possible effect on water resources management of climatic change. Information on this question is still rather meagre but below-average rainfall in Zimbabwe over the last 15 to 20 years has been shown to correlate closely with anomalies in sea surface temperatures which, in turn, are part of the database on which theories of global warming depend. Such studies must be continued and their implications for water resources management assessed. Whether the cause of climatic anomalies is a gradual global change or within the range of stochastic variability, it is clear that the ranges of expected maximum of minimum rainfall, the degree of inter-annual variability and, in the case of Pakistan, the possible changes in the mean sea level, must be better predicted and proper account taken of them in strategic water resources planning.

The case of Pakistan illustrates the heavy dependence of several countries on irrigation. The number of such countries is expected to increase as populations grow. However, with a finite resource, countries such as Egypt are already finding that available water for irrigation is declining as growing demands for urban and industrial supplies take precedence. In this situation, total independence in national food production is unlikely to be feasible. Long-term solutions to complex resource allocation problems of this nature will reach to the centre of political and economic life. It is vital that they are supported by adequate technical knowledge about the effects that different policies will have on the quantity and quality of the available resource and the limits which can be expected to the productivity of the water. Ensuring that environmental degradation does not occur in the process will provide a considerable challenge.

The above discussion of strategic planning has implied that it will be undertaken at a national level. This is not necessarily the ideal situation although it is important for it to link with national economic planning. The case studies have illustrated the large variations which may occur in access to water resources within different regions of a country. Already there are areas within both Pakistan and Zimbabwe where the population carrying capacity of the water and land resources has been, or soon will be exceeded. Such regional disparities need to be recognised since they are a significant factor underlying many social, economic and political disparities which exist and, therefore, an increasingly likely cause of conflict. Unless the concept of carrying capacity is applied to appropriate planning units, considerable effort is likely to be expended in treating the symptoms rather than the causes of the social, political and economic problems which water resource constraints create. At the same time, the actual processes by which the allocation and control of water are achieved and conflicts resolved will become increasingly influential in ensuring the long-term acceptance and sustainability of water development activities.

The main focus of this report has been the planning and management of water as a national resource and the resolution of intra-national problems of allocation and control. What has been discussed at a national level is equally significant at an international level where conflicts over access to and control over water may fuel, or provide weapons for, serious bilateral and regional confrontations. In the case of Pakistan, water is already high on the political agenda in its relations with India and may also feature strongly in future relations with Afghanistan. With Zimbabwe the lack of any bilateral of regional agreements over the management of its various river basins, all of which are shared with at least one other country, provides a potential source of future conflict although the SADCC is beginning to examine how the issues can be addressed co-operatively.

The notion of sustainability has been discussed in the report in relation both to the protection of life-support systems from degradation and to the need to prevent current generations from 'solving' their short-term problems by passing even greater problems to future generations. A number of key questions have been identified in relation to the practical application of the sustainability notion to development planning. Some of these relate to considerations which are included within environmental impact assessments but others are more far-reaching including the resilience of social and biological systems to change and the flexibility of technology to adapt to new needs and constraints. It is clear that professionals face a considerable challenge in relation to meeting the political and economic expectations of rapidly expanding populations from available national resources if the notions of sustainability and environmental protection are to be adequately applied. Not only are new techniques of technical and economic analysis required but new methods of inter-disciplinary collaboration and of political participation must be developed.

9.2 ODA's policies and activities

At present the ODA does not appear to identify water management as an issue requiring priority consideration. For the most part the discussions concerning aid to particular countries are made by the geographical desks in response to perceived needs and political considerations. Professional advisers scrutinise proposed projects and activities which are relevant to their disciplines. This means that, in the case of water resources projects, advisers from the Engineering, Natural Resources, Health and Population and Social and Economic Divisions are all likely to have an influence over the form of the project. Having so many 'hurdles' to cross it is likely that water projects take longer and have less chance of being accepted for funding than more straight-forward single-sector initiatives such as those, for example, in primary health care. This is not necessarily to argue that the vetting procedure for water projects should be simplified, since the complexity of water resources management demands that it be given careful examination, but that the ODA must recognise and overcome the negative bias of the current vetting procedure if greater emphasis is to be given to assistance in water resources management.

The ODA currently has a number of strategic priorities to guide their aid initiatives. These include:

- poverty alleviation;
- the problems of urbanisation;
- the role of women in development;
- environmental protection;
- population planning (reproductive health); and
- good government.

Projects which accord with the ODA's policies in these areas are particularly favoured. It is noteworthy that each of these strategic priorities has implications for water resource planning and management and, in some cases, appropriate water management policies are central to achieving the

ODA's objectives. For example poverty alleviation, in many regions, is allied to agricultural productivity, which in turn is related to the provision of irrigation water and the proper protection and management of river catchments. At the same time, poverty alleviation is also related to individual and communal access to resources, rights and independence of choice (Chambers et al, 1989); issues which must also be addressed in relation to improved water resources management. One could continue through each of the other strategic priorities identifying similar linkages. In particular, much has been written, especially in World Bank project documents, about the importance of water management policies and practices in relation to the role of women. The extent to which the ODA has applied the priorities in relation to their aid programmes to Pakistan and Zimbabwe could not be adequately studied for this report with the incomplete data available but it is clear that recent apparent trends away from capital projects towards technical co-operation and assistance to NGO's in rural development are in line with the ODA's strategic priorities.

With reference to the two countries studied, Pakistan and Zimbabwe, the ODA's involvement in water resources management has been very different. In both countries water has long been recognised as a key resource. In Pakistan, the management of this resource has centred around the Indus Irrigation System and to a lesser degree hydro-electric power generation from the Indus both of which have been the subject of vast capital, operational and rehabilitation expenditure over the past thirty years. The ODA has accepted that water is a national priority sector but, because of the importance and complexity of the Indus System, has tended to support projects which are part of wider World Bank led investments. In Zimbabwe, by contrast, the main needs perceived by the government are more fragmented and relate to dispersed storage reservoirs, rural water and sanitation and hydro-electric power. The British aid programme in Zimbabwe has been constrained by heavy commitments in other areas, particularly in support of the resettlement programme, with assistance to the water sector being itself fragmentary, largely unrelated to other aid donors and centred around technical co-operation and research. The differing extents of the ODA's support for water activities in the two countries may, to some extent, be due to the institutional differences between Pakistan and Zimbabwe: the former having a strong and influential agency responsible for planning and implementing the major projects undertaken (WAPDA); the latter having a formerly strong department which is now under-resourced and understaffed with its role and responsibilities being questioned and adapted.

One of the particular emphases of the ODA's current policies is its support for forestry as part of the overall strategy of environmental protection. This is not very evident in the two countries selected for the case studies but in other countries, such as India and Sri Lanka, comprises a significant part of the aid programme. Both Pakistan and Zimbabwe would benefit from additional aid to their forestry and tree crop sectors and the importance of forestry on a global scale should not be ignored. Nevertheless, in relation to an overall strategy of water resources management, there is a danger that over-emphasis on forestry may link the ODA too closely with particular methods of treating specific symptoms of environmental degradation rather than basing its programmes on an assessment of the underlying causes. In particular, forestry must be undertaken within the context of knowledge about its effects on the carrying capacity of the region and the influence which land-use changes will have on hydrological and erosion processes and thereby on other water resources activities.

If the ODA is to take seriously the challenge of a possible impending water crisis and resulting water conflicts in many developing countries there is a real need to develop procedures which will assist its staff to decide whether water should be accorded priority status in particular countries and to relate the impacts of all activities in such countries to the multi-faceted nature of the water resource base. Such procedures must be sufficiently simple for them to be applied without the need for vast analytical resources yet sufficiently sophisticated to cope with the complexities of the issues. In addition, in countries where water management is regarded as having priority, the project funding mechanisms should be capable of responding swiftly to areas of priority need through more streamlined vetting or project identification procedures.

10. Preliminary recommendations

The principal recommendation arising from this short study is that the planning and management of water as a vital and strategic resource should be accorded a higher level of priority than at present and that the issues raised and the methods available should be studied and discussed more widely in the search for appropriate techniques, institutions and policies with particular emphasis on a 25 year planning horizon. With this in mind the following are put forward as preliminary recommendations for discussion within the ODA by the disciplines and departments concerned in water resources management.

a) **Recognise the importance of water resources planning and management**: The special significance of water resources planning and management needs to be recognised in the formulation of aid policies for developing countries both with regard to the possibility of an impending water resources crisis in several regions and the complexity of the inter-relationships which affect many aspects of human life, health and well-being.

b) **Support the establishment of active and relevant water resources planning and management processes in developing countries**: A process is required which should be capable of identifying strategic needs and priorities, address comprehensively the resource constraints and needs of the region, include public participation and the ability to interact with political, social and economic considerations, consider the need for long-term sustainability and work from a basis of resource-defined planning units (eg river basins).

c) **Establish international and regional research initiatives in support of strategic planning**: Such research is necessary not only to develop appropriate techniques and procedures to support national water resources plannning and management activities but also to investigate a number of major resource issues which are significant for the optimum utilisation of water resources: eg. climatic change, soil salinisation, catchment erosion and reservoir sedimentation, productivity of irrigation water, hydrological processes affecting water quality, costs recovery mechanisms and appropriate evaluation procedures.

d) **Development of a simple procedure to enable the ODA and other donors to assess the countries which will face critical water resource constraints over the next 25 years**: This must form one of the initial priorities for the research effort (see, c) and will require specific technical back-up to determine the appropriate choice of indicators, to develop procedures, to gather data and to undertake research, for example into the assessment of carrying capacity.

e) **Promotion of greater international co-operation in regions where shared water resources are significant**: Continued lack of international treaties, particularly in Africa, will make national long-term water resources management difficult and hazardous.

f) **Provision of special help to meet the needs of water-short regions**: A number of nations will undergo severe and repeated drought-crises over the next few decades unless rapid and appropriate assistance can be provided. Help is needed both to enable them to apply an appropriate planning procedure and to re-structure their demands on the available water resources or to develop alternative resources.

g) **Encourage professional groups and disciplines to develop new ways of working together both within the ODA and outside**: The demands for improved water resources management cannot be met by existing professional groups working in isolation or competing as to which is most appropriate. New ways of interacting and new agreements over disciplinary responsibilities are needed so that on the one hand the technical complexities are adequately addressed and on the other hand adequate consideration is given to social, political, economic and environmental factors.

In the light of the above general recommendations the following short-term agenda for action is proposed to enable practical steps to be taken towards developing a new approach to water resources planning and management.

i) **Highlight the issues**. This may take the form of country papers, and regional or global assessments to alert the relevant groups or agencies.

ii) **Help to develop an appropriate general methodology**. This is required before countries can undertake strategic planning and control and will require inputs from a wide range of disciplines.

iii) **Assist countries to apply the methodology to their situation.**

iv) **Work with other aid agencies**. This will enable the burden of the above to be shared.

v) **Tie aid to appropriate analysis and policy decisions.**

As a starting point, ODA may choose to **organise an international symposium in late 1993** with the following objectives:

a) to highlight the problem;
b) to share with other aid agencies the tasks ahead and develop a programme of action;

c) to identify existing human and institutional resources to carry out the tasks and evolve new ones if relevant.

In preparation for the symposium, the ODA may sponsor the preparation of a number of general and country papers. It may also identify the particular skills and experience which UK specialists can offer and assess how the inter-disciplinary collaboration necessary for a programme of action could best be achieved between them by forming a small inter-disciplinary working group to prepare a review paper for the conference.

11. Further work needed

Since one of the principal recommendations of this report is that active inter-disciplinary discussion and research is needed it follows that there is much that could be listed under the heading of 'further work needed'. Approaching the subject from the engineering/professional view-point the author has been particularly conscious of the lack of methods and techniques which address the practical problems now faced. However, before research is undertaken to develop such techniques there is a need to set the objectives more closely within the context of multi-disciplinary debate: hence, the recommendation that a special conference should take place preceded by a period of preparation and discussion. A particular objective will be to elaborate what 'strategic' planning entails and to establish a framework for how it should be undertaken.

One of the weaknesses of the current report has been the relative neglect of international issues. The planning and management of water has implications at many levels: global, regional (multi-lateral), bilateral, national, provincial and local. It also has implications in the context of aid and the relationship between industrialised and developing countries (not only in terms of the targeting of aid but also in terms of the perception of developing countries concerning the impact of water related activities within the industrialised countries themselves). The extent to which linkages exist between these various spheres and their effect on the planning and management of water requires further study.

Finally, from the perspective of the ODA, it is necessary to ask what particular activities can best be supported with UK expertise so that Britain's aid can be directed towards areas where it will be most effective. In broad terms, the UK has considerable expertise and established links exist with developing countries which are relevant to the promotion of new approaches to water planning and management. It will be beneficial if a brief review of this expertise and these links can be undertaken so that any future UK initiatives can build on existing strengths.

12 Acknowledgements

The preparation of this report would not have been possible without the assistance of Mr T D Pike and advisers from the Engineering and Natural Resources Divisions in ODA, the ODA desk officers for Pakistan and Zimbabwe, the aid section of the British High Commission, Harare and the staff of the ODA Library. In addition, Mott MacDonald International gave me access to their considerable library of water resources literature for southern Africa, and valuable references were provided by the International Food Policy

Research Institute and the World Bank. To all of these I am most grateful. My thanks also go to Dr K Sanmuganathan and my colleagues in the Overseas Development Unit of HR Wallingford for their advice and support and to Karen Robson who typed the report.

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13 *Annotated list of general references*

(for specific references see Appendices 2 & 3)

1. Abate Z (1991). Planning national water policy: a proposed case for Ethiopia. Paper presented for World Bank Workshop, "Comprehensive Water Resources Management Policies". (Contains a useful framework for developing water policies based on river basin master plans and raises some important issues).

2. Abu-Zeid M A and Rady M A (1991). Egypt's water resources management policies. Paper presented to World Bank Workshop, "Comprehensive Water Resources Management Policies". (Detailed consideration of strategies and policies over a 35 year period in the face of severe water resource and political constraints).

3. Ambroggi R P (1980). Water. Scientfic American v.243 no. 3 p91-104. (Although dated, this still provides one of the best introductions to a global understanding of water issues).

4. Brundtland Commission (World Commission on Environment and Development) (1987) Our Common Future. Oxford University Press. (Stresses the link between environmental protection and economic development).

5. Chambers R, Saxena N C and Shah T (1989). To the hands of the poor: Water and Trees. Intermediate Technology Publications, London. (Argues that lift irrigation and trees address the needs of the rural poor not only in terms of income and subsistence but also to counter seasonal fluctuations and improve security).

6. Chen Zhi-Kai (1991). Water resources development policy in China. Paper presented to World Bank Workshop, "Comprehensive Water Resources Management Policies". (Useful source for general indicator used in assessing the resource base. Proposes several policy changes in the face of increasing conflicts in the demand for food, energy and water and difficulties in protecting the environment).

7. El Hinnawi E and Hashmi M (1987). The State of the Environment. Butterworths, London for UNEP. (A useful overview of global parameters and global issues).

8. Falkenmark M (1987). Water-related constraints to African development in the next few decades. In 'Water for the Future'. IAHS Publication 164, p439-453. (Provides an overview of man-vegetation-water-soil relationships and identifies five strategic water resources issues affecting future development).

9. Falkenmark M (1989). The massive water scarcity in Africa? Why isn't it being addressed? Ambio v.18 no 2 p112-118. (Takes an overall view of water scarcity but has a rather static idea of the "water scarcity barrier" and the role of technology. Arguments based on general national statistics would carry more weight if supported by more detailed case studies).

• 10. Falkenmark M (1990). Global water issues confronting humanity. Jl. Peace Research 27(2) p177-190. (Considers why the follow-up to the UN Conference at Mar del Plata has been disappointing and concludes, amongst other factors, that responses are based on simplistic reaction to perceived rather than predicted problems).

11. FAO/UNEP/IIASA (1983). Potential population supporting capacities of lands in the developing world. Land Resources for Populations in the Future. FAO Tech. Report of Project FPA/INT/513. (This key reference provides estimates of population carrying capacities of each country under rain-fed production with different levels of mechanisation. It is the basis of Falkenmark's work).

12. Goldsmith E and Hildyard N (1984). Social and Environmental Effects of Large Dams. Vol 1 Overview, Vol 2 Case Studies. Wadebridge Ecological Centre, UK. (A comprehensive review of the literature and the issues which is flawed by a lack of objectivity in some parts).

13. Pearce F (1991). Africa at a watershed. New Scientist (22 March). (Argues that small-scale irrigation and micro-harvesting of water offer a better hope for Africa's future than grandiose water transfer schemes).

14. Safadi R and Plusquellec H (1991). Research on Irrigation and Drainage Technologies: 15 years of World Bank Experience. World Bank Discussion Paper No. 128, Washington DC. (A useful survey of the extent and distribution of research investments world-wide linked to World Bank projects).

15. Sassin W (1980). Energy. Scientific American v.243 no.3 p107-117. (The method presented for predicting national energy requirements over periods of 50 to 100 years merits close study in the context of strategic water planning).

• 16. UN/ESCAP (1991). Experiences in water resources management in Asia and the Pacific. Paper to 8th Afro-Asia Regional Conf. of ICID, Bangkok. (A very useful review of the types of planning and co-ordination currently being practiced in the region).

• 17. UNESCO/World Meteorological Organisation (1988). Water Resources Assessment Activities. Handbook for National Evaluation. (Sets out guidelines for minimum coverage by hydrometric networks as well as levels of staffing and other resources).

18. The World Bank (1990). The World Bank Atlas 1990. Washington DC. (Source of population and economic statistics).

Appendices

Appendix 1

Terms of Reference

Terms of reference for the water resources management committee

Objective

To assist ODA to develop its strategy with regard to fresh water resources management in developing countries, in response to concerns over increasing competition for limited water resources.

Scope of work

The initial task is to draft a working paper which, inter alia:-

i) Reviews methods of national/regional water resource management, in two countries to be agreed with the ODA, beginning with a review of available water resources management strategic documents prepared by the two countries, or for them by key international agencies such as the World Bank.

ii) Develop a general framework for assessing the strengths and shortcomings of such strategies, and for relating them to their needs for health, food security and economic development, and the ODA's current strategic priorities and wish to promote development. The development of such a framework, should consider not only technical/engineering aspects, but also wider issues such as institutional constraints and underlying causes and effects (socio-economic implication, for example).

iii) Compiles details of ODA's activities in the chosen countries, and those of other bilateral and multi-lateral agencies where these are readily available. This should cover work within the past ten years which has implication for the selection and implementation of water resource management policies, and include comment on its relevance to the priority needs.

iv) Identifies the key areas whose assistance is required in these countries in order to improve water resource management against a background of finite resources, population growth, the need for economic and social development, international relations and possible climatic change. This should also include recognition that such management issues relate to both water quantity and quality.

v) Explores possible ways in which ODA's activity and by implication those of other agencies, might be adapted or enhanced in order to:-

    a) Better identify the priorities and improve current practices, in order to take more account of water-related needs and constraints, and

    b) Include new initiatives which address the key water resource management issues identified.

Methodology

The Consultant is expected to exchange views widely with a range of disciplines, using an initial draft which will be prepared in consultation with a steering group comprising the Chief Natural Resources Adviser, the Chief Health Adviser, the Chief Engineering Adviser, and a Senior Environmental Adviser. It is expected that this will require an input of some 21 man-days, based on a three day week of two days in London and one in Wallingford.

Timing

The study will commence on 5 August, and the draft report is expected before the end of September.

Administration

This work is being commissioned with HR Wallingford by Engineering Division, who will be responsible for its administration and for the costs of consultancy. Dr Peter Bolton has been nominated for the task.

Engineering Division
2 August 1991

Appendix 2

Information and Data Collected for The Pakistan Case Study

Table A2.1: Water resources key facts sheet: Pakistan

1. **Country or region :** Pakistan

2. **Population**: total 110.0M (year: 1989)

2.1 Urban 30% Rural 70%
2.2 Population growth rate 3.2% yr^{-1}
2.3 Urban growth 4.5% yr^{-1} Rural growth % yr^{-1}
2.4 Life expectancy at birth 55 years
2.5 Daily per capita calorie supply 2200kcal
2.6 Illiteracy in adult population 70%

3. **Land**

	Category	Area (km²)	% of Total
3.1	Agricultural - irrigated	162 000	20
3.2	- good rainfed, >180 growing days		
3.3	- poor uncertain rainfed, <180 growing days	46 000	6
3.4	Total agricultural	208 000	26
3.5	Forests and reserves	94 000	12
3.6	Open water and wetlands	45 000	6
3.7	Urban and built	42 000	5
3.8	Other ... mountains and deserts	415 000	51
3.9	**Total land area**	804 000	100

3.10 Cultivated land per capita 0.19ha
3.11 Irrigated land per capita 0.15ha
3.12 Intensity of irrigation (3.11/3.10) = 79%
3.13 Comment on regional variations in the distribution of population and cultivated/irrigated land :

The bulk of the cultivable land is in the Indus plain where the bulk of the people also live. Water not land is the main constraint to agriculture there. In upland areas water sources and land are meagre and dispersed; eg. in NWFP the cultivated land per capita is less than half the national average.

3.14 Population supporting capacity of rainfed agriculture under low inputs 2.4 M; medium inputs 7.1 M; high inputs M

4. **Economy**

4.1 Gross national product (US$ x 10^6) 40 134 (year : 1989)
4.2 GNP product per capita (US$) 365
4.3 Real growth rate in GNP per capita 2.9%
4.4 Agriculture's share in GDP 27%
4.5 Contribution to exports - primary agricultural product 26%
4.6 - processed agricultural products 60+%

Table A2.1 (cont'd)

4.7 Main agriculture based export commodities : Rice, cotton, cotton based manufactured, leather and leather based, carpets

5. **Water resources** : Overall balance for country/region

		$m^3 \times 10^9$	mm	% of P
5.1	Annual precipitation (P)	480?	600?	100
5.2	Mean annual unregulated runoff from region (R_1)	97 (Indus) 8 (other)	184))	
5.3	Mean annual runoff received from outside region (R_2)	76	184)	
5.4	Minimum value of R_2 fixed by agreement/convention (R_2')	(76)?	-	
5.5	Net increase in groundwater storage (ΔS_1)*	0?		
5.6	Net increase in surface storage (ΔS_2)* (Lakes, reservoirs, swamps, ice etc)	0		
5.7	Mean annual runoff passing to adjacent regions (R_3)	0	-	
5.8	Maximum value of R required by agreement/convention (R_3')	0	-	
5.9	Mean annual runoff to sea (R_4)	25 (since 1979)		
5.10	Evaporation/consumption (E) $= P+R_2-R_3-R_4-\Delta S_1-\Delta S_2$	?		
5.11	Available runoff (R) $= R_1+R_2'-R_3'$	181		

(*Normally zero unless long-term change occurring
Indicate a net decrease as a negative value)

5.12 Available runoff per person = 1645 m^3cap^{-1}

5.13 Available runoff per unit cultivated land = 8700 m^3ha^{-1}

5.14 Comment on regional variations in water resources providing ranges of values for 5.1, 5.12 and 5.13 if available

P:>1500mm in Himalayas; 800mm at their foot; falling to <100mm in Upper Sindh. P is not a very useful parameter because 2/3 falls on the mountains where it cannot be directly used. Only 230mm falls on the plain.

5.15 Comment on the seasonal distribution of P and R_5 indicating months and ranges of values

P : mostly falls in monsoon July to September

R_5: Indus Basin 40 x 10^9m^3 (June), 3.2 x 10^9m^3 (Jan); 1922-63 mean

5.16 Comment on the inter-annual variability of P and R_5 and estimate their 1 in 20 year extreme values

P is low and erratic over most lowland areas but R_5 is fairly uniform.

R_5: Indus and Jhehum varied ± 25% (1922-63).

Table A2.1 (cont'd)

5.17 Describe important surface water quality characteristics giving, if available, typical mean and extreme values of sediment concentrations, dissolved solids concentrations, etc, at key locations, now and historically

Dissolved mineral content of Indus, Jhelum & Chenals = 150 to 250ppm rising to 300 ppm near mouth. Western tributaries = 140 to 250ppm. U/s of Tarbela sediment concentrations of 4000mgl^{-1} are common and may exceed 18 000mgl^{-1}.

5.18 Describe the main groundwater systems in the region

Name	Location(s)	Area (km^2)	Water Resource Potential and Quality
Plains	Indus Valley	310 000	High yielding thick alluvium (300m). Salinity serious in parts
Valleys	Peshawar/Mardan	?	Good close to rivers
Valleys	Potwar Plateau	180 000	Scarce and at depth
Deserts	Cholistan & Thar	?	Generally saline except in local depressions
Highlands	Baluchistan	155 000	Variable depth and yield. Already over-exploited in parts

6. **Water resources development**

6.1 Annual water supplied to

	m^3 x 10^9	% of total
agriculture		96
industry		1
urban/other		3
Total	186	

6.2 Source of supplied water

	m^3 x 10^9	% of total
surface water	130	70
groundwater	56	30

6.3 Live reservoir storage capacity available 15.1 m^3 x 10^9

6.4 Domestic water/sanitation

	Rural	Urban
Population served by 'safe' supply (%)	40	80
Average per capita daily consumption (l)	45(target)	220(Lahore)
Population served by adequate sanitation (%)	10	52

6.5 Principal urban water supply systems :

Location(s)	Water Source	Type of Service	Population Served
Karachi	Surface +250km canal		
Lahore	Groundwater		2.5M
Gujranwala			0.25M
Multan			0.5M

Table A2.1 (cont'd)

6.6 Main types and extent of irrigation systems :

Type	Water Source	Location(s)	Crop(s)	Area (km²)
Surface & g/w	Indus	Indus plain	Rice, cotton	200 000
Hill & flood		Baluchistan & NWFP	Friut etc	1 000?
Small dams		Punjab, Bal & NWFP		Small
Flood	Indus	Along river		12 300

6.7 Main types and extent of drainage systems :

Type	Disposal Method	Location(s)	Area Drained (km²)
Vertical & Horizontal	To sea (LBOD) & evap. ponds	Indus plain	

(264 000 private tubewells, 67% diesel)

6.8 Total installed electrical generating capacity 6700 MW
Contribution of hydroelectricity to the above 2900 MW (43%)

Names of main hydroelectric stations	Installed capacity (MW)
Tarbela (Indus R)	1750
Mangla (Jhelum R)	800
Warsak (Kabul R)	240

6.9 Annual fish production from fresh waters 80 000 t yr^{-1}
Describe the main locations :

6.10 Describe locations and significance of any inland navigation routes:

Navigation is not of major significance. There is some traffic on pools between the Indus barrages. Possible development of routes from Port Qasim to Kalabagh & Lahore by river/canal being studied in 7th Plan (1988-93).

6.11 Describe any significant causes of surface or groundwate pollution

Discharge of domestic, agricultural and industrial effluent is largely uncontrolled. Many fish have high toxin levels and are inedible.

7. Environmental characteristics

7.1

Locations prone to flooding	Typical area flooded (km²)	Frequency
Lower Indus (Sindh) and Punjab	37 000	2-3 years

7.2

Locations protected from natural flooding	Area (km²)
Indus floodplain prior to irrigation	200 000

Table A2.1 (cont'd)

7.3 **Locations reclaimed by drainageArea (km²)**

7.4 Irrigated land seriously affected by

	waterlogging	10*(%)
	salinisation	10*(%)

*some areas included twice

7.5 Important natural ecosystems

	Description	**Area (km²)**
(a) Terrestrial :		
(b) Aquatic :		
(c) Shoreline :	Riverain forests	2400
(d) Floodplain/wetland :	Wetlands on Indus plain (important for bird migration) Mangroves (important for coastal fisheries)	900-2600

Table A2.2: Current water planning and management information sheet

1. **Country or region :** Pakistan

2. **Agencies** involved in water planning and management

Name	Abbrev Name	Agency Type	Areas of Responsibility Sector(s)	Region(s)
Water & Power Dev. Auth.	WAPDA	Parastatal	Irrigation, hep, water supply, nav floods, drainage	National/ Water-Provincial
Provincial Irrig. Dept.	PIDs	Government	Irrigation (surface & glw)	In each province
Rural Works Prog.	RWP	Parastatal	Village supplies	
Water & Sanitation Agencies	WSA		Urban supplies & sanitation	Big cities
Publ. Health. Eng. Dept.	PHEDs		Urban supplies &	Provincial Dept. towns
Land Water Dev. Board	LWDB	Co-ordinating	Tubewells etc	Provincial
Indus Riverl System Auth.	RSA	Government	Newly created to monitor water accord	Inter-Provincial
Local Gov. & Rural Dev.Dept.	LGRDDs		Local infrastrucure	Local union councils

3. **Hierarchy of responsibilities** between agencies
Sketch or describe inter-relationships and means of co-ordination:

Further clarification needed.

Council of Common Interest resolves inter-provincial questions

Federal Departments: Ministry of Water and Power (responsible for WAPDA). Ministry of Food and Agriculture, Federal Flood Commission, etc.

Provincial Departments: (Provinces are fairly autonomous in Pakistan) PIDs etc.

Local Government and Urban Departments: LGRDDs, PHEDs, WSAs

Table A2.2 (cont'd)

4(.1.) Available water planning strategy documents (1)

4.1 Title : Water & Power Resources of West Pakistan Date :1968

4.2 Purpose : Clarify development potential and identify investment priorities following Indus Waters Treaty, especially with respect to Tarbela Dam.

4.3 Planning approach (end use, etc) : Maximise outputs and investment returns within available resources and Government priorities

4.4 *Components of plan* : Reports on irrigation and agriculture (23 vols), reservoir storage (6 vols), power (2 vols) & review of information on Tarbela

4.5 Sectors included : Agriculture, irrigation, energy

4.6 Geographical regions : Indus Basin

4.7 Time Horizon : 1965 to 2000, including annual plans for 10 years and 5 year plans for a further 15 years

4.8 Planning methods and tools :

(a) Physical system: Aerial survey to identify dam sites. Simulation of water needs in 61 canal commands. Irrigation system simulation linked to storage and energy simulations. Electricity distribution simulation

(b) Economic evaluation: Detailed observations of irrigated farming on 2400ha. Economic analysis of various project options and programmes (linear programming)

(c) Environmental assessment: No assessment made. Allowance made for leaching water to control salinisation. Tarbela sedimentation assessed at 2% yr^{1} but ignored in simulations of operation over a 20yr horizon

4.9 Plan prepared by : Consultants liaising with WAPDA

4.10 Plan prepared for : World Bank and GOP

4.11 Procedure for authorisation prior to implementation :
Separate projects executed by WAPDA following GOP approval

4.12 Extent of public participation : None apart from questionnaires concerning agriculture.

4.13 Extent of inter-agency consultation : Mainly WAPDA but also PIDs & LWDBs.

4.14 Time and resources needed to prepare plan : At least 20 senior professionals supported by over 100 (mostly field staff) during 4 years

Table A2.2 (cont'd)

4.15 Professional involvement in preparation of plan : Largely engineers with inputs from economists, agronomists etc.

4(.2.) **Available water planning strategy documents** (2)

4.1 Title : Water Sector Investment Planning Study Date :1991

4.2 Purpose : Develop: a) 10yr investment plan; b) procedures and criteria for planning; c) proposals for institution building

4.3 Planning approach (end use, etc) : Aimed to address future food shortages and stimulate economy within the resource base and available investments.

4.4 Components of plan : Studies of existing development, future demand, resource constraints and detailed plans for candidate investments.

4.5 Sectors included : Irrigation, drainage, flood control, environment

4.6 Geographical regions : Mainly Indus Basin but also other agricultural regions

4.7 Time Horizon : 1990 to 2000

4.8 Planning methods and tools :

(a) Physical system: Linked reservoir, surface supply system and groundwater simulation

(b) Economic evaluation: Procedure for updating plans for particular regions and the Indus Basin Model Revised (IBMR) implemented.

(c) Environmental assessment: Considerable thought given to salinity and some given to sediment. A single consultant used to assess other impacts.

4.9 Plan prepared by : Engineering Consultants (MacDonald et al)

4.10 Plan prepared for : GOP/WAPDA/UNDP/World Bank

4.11 Procedure for authorisation prior to implementation : Through GOP National Plans and funding agencies

4.12 Extent of public participation : None

4.13 Extent of inter-agency consultation : Close consultation with WAPDA and PIDs through National and Provincial Planning Cells.

4.14 Time and resources needed to prepare plan : 44 consultants and 22 local officials over 17 months plus 6 months finalisation.

Table A2.2 (cont'd)

4.15 Professional involvement in preparation of plan : Mainly engineers and economists

4(.3.) **Available water planning strategy documents** (3)

4.1 Title : Water Resources Management Policies Date :1991

4.2 Purpose : Review of policies and current development for presentation at International Workshop, Washington.

4.3 Planning approach (end use, etc) : Not strictly a plan but includes some strategic thinking

4.4 Components of plan : Considers policies, uses, technical issues and future scenarios before making policy recommendations.

4.5 Sectors included : Comprehensive

4.6 Geographical regions : All

4.7 Time Horizon : 1990 to 2000

4.8 Planning methods and tools :

(a) Physical system: Draws on earlier studies

(b) Economic evaluation: Draws on earlier studies

(c) Environmental assessment: Draws on earlier studies

4.9 Plan prepared by : WAPDA

4.10 Plan prepared for : World Bank Workshop

4.11 Procedure for authorisation prior to implementation : N/A

4.12 Extent of public participation : No specific consultation

4.13 Extent of inter-agency consultation : No specific consultation

4.14 Time and resources needed to prepare plan : Unknown

4.15 Professional involvement in preparation of plan : Senior engineers in WAPDA

4(.4.) **Available water planning strategy documents** (4)

4.1 Title : Hydroelectricity Inventory, Ranking and Feasibility Studies Date :1984

4.2 Purpose : To rank candidate projects in order of highest economic returns

Table A2.2 (cont'd)

4.3 Planning approach (end use, etc) : 'Resource potential' study based on hydrological and topographical information

4.4 Components of plan : Assessment of potential made with little reference to other water users

4.5 Sectors included : Hydroelectricity

4.6 Geographical regions : Upper Indus System

4.7 Time Horizon : Undefined

4.8 Planning methods and tools :

(a) Physical system: Basic engineering design approach. Sediment largely ignored apart from desilting around draft tubes.

(b) Economic evaluation: Comparisons made on the basis of index cost - unit cost of energy produced

(c) Environmental assessment: Very poor study. Resettlement and fisheries were mentioned. The impact overall of dams would be beneficial it is maintained.

4.9 Plan prepared by : Montreal Engineering

4.10 Plan prepared for : WAPDA/CIDA

4.11 Procedure for authorisation prior to implementation : Individual projects to be presented for funding.

4.12 Extent of public participation : None.

4.13 Extent of inter-agency consultation : Little - It is not even clear how much WAPDA (Water) was involved.

4.14 Time and resources needed to prepare plan : Approximately 25 specialists over a 3 year period

4.15 Professional involvement in preparation of plan : Mostly engineers

4(.5.) **Available water planning strategy documents** (5)

4.1 Title : Indus Basin Model Revised Date :1990

4.2 Purpose : This is a tool rather than a planning document but it was developed to assist plan formulation.

4.3 Planning approach (end use, etc) : Specified user activities are modelled to assess overall behaviour and the impact of various policies/ investments

Table A2.2 (cont'd)

4.4 Components of plan : Crop needs and production, surface water hydrology, groundwater, economic behaviour of farming systems

4.5 Sectors included : Irrigation/agriculture. Energy partly considered

4.6 Geographical regions : Indus Irrigation System

4.7 Time Horizon : -

4.8 Planning methods and tools :

(a) Physical system: Physical interdependence of the distribution system g/w system and crop water use are modelled in detail

(b) Economic evaluation: Very detailed study of farmer inputs and behaviour in response to price incentives etc

(c) Environmental assessment: G/w level and salinity only considered. Model aims for situation of no change in g/w level i.e. sustainability.

4.9 Plan prepared by : World Bank

4.10 Plan prepared for : World Bank/GOP

4.11 Procedure for authorisation prior to implementation : N/A

4.12 Extent of public participation : N/A

4.13 Extent of inter-agency consultation : N/A

4.14 Time and resources needed to prepare plan : Initial development 1976 to 1982. Revised 1986. Updated and transferred 1990. Number of man-years unknown but large team involved.

4.15 Professional involvement in preparation of plan : Thought to be mainly computer scientists and economists

5(.1.) Operational water management activities (1)

5.1 Title : Operation of Mangala and Tarbela Dams

5.2 Purpose : Setting daily releases for hydropower and irrigation (details not found)

5.3 Scope :

5.4 Sectors included :

5.5 Geographical regions :

5.6 Time horizon :

Table A2.2 (cont'd)

5.7 Methods and tools used for identifying options : Snow cover is measured by satellite but no prediction made of inflow

5.8 Method of public consultation/involvement :

5.9 Operating agency :

5.10 Source of agency's authority :

5.11 Actual or potential areas of conflict :

5.12 Method of conflict resolution :

5.13 Time and resources required for operation :

5.14 Professional involvement in operation :

5(.2.) **Operational water management activities** (2)

5.1 Title : Division of Waters of Indus between provinces

5.2 Purpose : Division of water according to agreed principles between the provinces

5.3 Scope : To set a framework within which provinces are free to develop irrigation independently

5.4 Sectors included : Irrigation only

5.5 Geographical regions : All Indus Basin waters

5.6 Time horizon : Allocations on ten-day and annual basis

5.7 Methods and tools used for identifying options : Fixed quota system agreed on a ten-day basis. A further pro-rata distribution quota agreed for any additional water above the nominal quota

5.8 Method of public consultation/involvement : Not appropriate for this inter-provincial sharing

5.9 Operating agency : Indus River System Authority

5.10 Source of agency's authority : Accord signed in 1991 by the four provinces

5.11 Actual or potential areas of conflict : No framework for dividing water in times of shortage. Unless new dams are built, quota will also have to be reduced due to sedimentation. No agreement on control of groundwater use and drainage.

5.12 Method of conflict resolution : Unknown

Table A2.2 (cont'd)

5.13 Time and resources required for operation : Unknown

5.14 Professional involvement in operation : Unknown

6. **Hydrometric network** : Number of operational stations in regions which have been functioning for five years or more

Type	Number in region	Number per $10^4 km^2$
Precipitation		
Evaporation		
Stage (water level)		
River discharge	22+ in Upper Indus	<0.5?
Sediment discharge	Several	
Surface water quality	Probaly none	
Groundwater level		
Groundwater quality		

(For recommended minimum standards see UNESCO/WMO 1988)

7. **Specialist institutions** for training and research in water

USAID as part of Irrigation Systems Management project listed training institutions in the water sector in Project Note 2 (PRC/Checchi 1985). This includes 8 in the Punjab, 5 in Sindh, 4 in NWFP and 2 in Baluchistan.

8. **Describe sources of funding** and procedures for water resources development

Substantial investments made in Agriculture and Water in National Plans (30% of total to 1975 falling to 12% by 1988). Private investment now being sought especially for tubewells.

9. **Describe environmental control procedures** and list agencies responsible

There is a Federal Env. Protection Agency and Provincial EPAs are being established; also an Environmental Cell in WAPDA. A National Conservation Strategy Secretariat exists (post-Brundtland)

10. **Describe significant international water issues** in the region.

The 1961 agreement with India appears to be holding. No agreements have been reached with Afghanistan over the Karbul River. The disputed territory of Kashmir is also significant.

Table A2.3 Bilateral and multilateral funded projects related to water resources management in: Pakistan

Project Title	Type	Purpose	Funded by	Implemented by	Implemented for	Start	End	Cost
Snow & ice hydrology	Re-search	Improve estimates of inflows to Tarbela	ODA	M'chester Univ.	WAPDA		1992	£0.1M
Reservoir maintenance	Tech		World Bank/ ODA				1994	$42.0M £9.0M
Small irrigation schemes	Capital	46 dams in NWFP to irrigate 52 000ha	ODA				1992	£0.9M
Drainage project 4	Capital	Tile drains in Punjab	World Bank/ ODA			1983	1994	$101.4M £11.4M
SCARP 6	Capital	Salinity control using tubewells linked to evaporation ponds	ODA				1992	£15.9M
Left bank outfall drain (LBOD)	Capital	To take drainage from Indus L.B. to sea	World Bank/ ODA			1985		$635.0M £34.0M
Right bank master plan	Plan	To investigate options & investment priorities	ODA	Mott McDonald	WAPDA		1992	£2.6M
Waterlogging and salinity control	Re-search	Technology research under IPTRID	?			1991+	-	$79.0M (with Egypt)
Tanneries effluent study	Re-search		ODA				1991	£0.1M
Lahore wastewater treatment	Cons-ulting		ODA	Balfours		1987		
Lahore water supply	Equip Tech	37600 new meters, sewage treatment etc	ODA			1987	1991	£12.4M
Punjab urban dev. project	Equip Tech	Water and sanitation in cities	World Bank			1987	1991	$145.0M
Rural electrification	Tech Train	6700 villages (1.2m people) 27000 tubewells etc	World Bank			1989	1995	$160.0M
Private tubewell dev.	Equip	Electrify 8000 TWs	World Bank			1990	1994	$40.4M
Irrigation sys. rehab	Works/ TA Equip	Repair 14000km canals and 3500km surface to drains benefit, $3.8x10^6$ha, 700 000 families	World Bank USAID			1983	1989	$164.0M

Table A2.3 (cont'd)

Project Title	Type	Purpose	Funded by	Implemented by	Implemented for	Start	End	Cost
Barani master plan	Plan	Rural water and sanitation	ADB-					
Baluchistan int. area	T.A.		CIDA					$1.5M
BIAD I + II (water)	T.A.		EEC					$12.3M
Baluchistan self help	T.A.		Germany					$3.0M
NWFP, sanitation			Germany					$7.0M
Punjab rural water study			ODA					$0.2M
Sindh rural water study			Switz.					$2.7M
Water & sanitation			UNICEF					$19.4M
Rural water supply		Rural water and sanitation	CIDA					$3.1M
Community Water/San			WHO					$0.2M
NWFP Rural Dev. Programme			World Food					$15.5M
Rural Water Supply & Sanitation Project	Capital Tech	2400 supply schemes, 1000 wells/TWs, 50 000 latrines	World Bank			1992	2000	$194.0M
Thar Arid Zone water supply		Wells for water supply irrigation	ODA	Ground-water Dev. Consult		1988?		
Lahore water supply sewage & drainage	TC		ODA	National Water Council		1980	1985	
On-farm water management		Renovation of water courses	World Bank			1981		$111.6M
Command water management		Formation of water user groups	World Bank			1984		$81.9M
2nd On-farm water management		Renovation of water courses	World Bank			1985		$57.8M
SCARP Transition			World Bank			1986		$21.8M
2nd Irr. Sys. Rehab.			World Bank			1988		$220.0M
1988 Flood damage restoration			World Bank			1989		$55.6M

Table A2.3 (cont'd)

Project Title	Type	Purpose	Funded by	Implemented		Start	End	Cost
				by	for			
Sukkur Barrage		Rehabilitation	ODA				1994	$16.9M
Kotri Barrage		Rehabilitation	ODA				1992	$12.7M
Chitra Rural Support	50/50 grant	Funding to Aga Khan Rural Support Programme for rural development and health including some irrigation	ODA/ Aga Khan				1996	£6.0M+
BIAD		Rural water/sanitation	Netherlands					$14.2M
NWFP Groundwater		Resource study	Netherlands				1988	$3.8M

A2.4 References specific to Pakistan

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World Bank (1989b). Pakistan Rural Electrification Project, Staff Appraisal Report. [Supplies to 6700 new villages and 27000 tubewells]

World Bank (1990). Pakistan Irrigation Systems Rehabilitation Project. Completion Report M90-864 [A massive technical input - 224 reports generated - but questions raised over appropriateness of techniques and lack of baseline data to establish agro-economic impacts].

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World Bank (1991b). Third On-farm Water Management Project. Staff Appraisal Report. [Reviews previous work in this area and sets out a new 4 year project costing US$ 155.5M].

Appendix 3

Information and data collected for the Zimbabwe case study

Table A3.1 Water resources key facts shets: Zimbabwe

1 **Country or region:** Zimbabwe

2 **Population:** total 9.6M (year: 1989)

2.1 Urban26% Rural 74%
2.2 Population growth rate 3.6 % yr^{-1}
2.3 Urban growth 5.7% yr^{-1} Rural growth % yr^{-1}
2.4 Life expectancy at birth63years
2.5 Daily per capita calorie supply 2232 kcal
2.6 Illiteracy in adult population 26%

3 **Land**

	Category	Area (km^2)	%of Total
3.1	Agricultural - irrigated	1300	0.3
3.2	- good rainfed, >180 growing days	65000	17
3.3	- poor uncertain rainfed, <180 growing days	265000	68
3.4	Total agricultural	321300	82
3.5	Forests and reserves	56000	14
3.6	Open water and wetlands	?	
3.7	Urban and built	2200	0.6
3.8	Other	?	
3.9	**Total land area**	390 000	

3.10 Cultivated land per capita 3.35 ha
3.11 Irrigated land per capita 0.01 ha
3.12 Intensity of irrigation (3.11/3.10) = 0.3%
3.13 Comment on regional variations in the distribution of population and cultivated/irrigated land:

Historically the best agricultural land especially along the central watershed was owned by European settlers while the African population was crowded into remoter areas with poorer land. Some redistribution is now taking place under the resettlement programme.

3.14 Population supporting capacity of rainfed agriculture under low inputs M; medium inputs M; high inputs M

4 **Economy**

4.1 Gross national product (US$ x 106) 6 076 (year : 1989)
4.2 GNP product per capita (US$) 640 (heavily skewed)
4.3 Real growth rate in GNP per capita 3.0% (1987-1989)
4.4 Agriculture's share in GDP 13%
4.5 Contribution to exports - primary agricultural product 25%
4.6 - processed agricultural products 41%
4.7 Main agriculture based export commodities : Tobacco, sugar, cotton, maize(?), cattle products

Table A3.1 Cont'd)

5 **Water resources**: Overall balance for country/region

		$m^3 \times 10^9$	mm	% of P
5.1	Annual precipitation (P)	280	700	100
5.2	Mean annual unregulated runoff from region (R_1)	20	50	7
5.3	Mean annual runoff received from outside region (R_2)	40	-	14
5.4	Minimum value of R_2 fixed by agreement/convention (R_2')	(40)?	-	
5.5	Net increase in groundwater storage (ΔS_1)*	0		
5.6	Net increase in surface storage (ΔS_2)* (Lakes, reservoirs, swamps, ice etc)	0		
5.7	Mean annual runoff passing to adjacent regions (R_3)	58	-	
5.8	Maximum value of R_3 required by agreement/convention (R_3')	?	-	
5.9	Mean annual runoff to sea (R_4)	0		
5.10	Evaporation/consumption (E) $= P+R_2-R_3-R_4-\Delta S_1-\Delta S_2$	262		
5.11	Available runoff (R_5) $= R_1+R_2'-R_3'$	20?		

(* Normally zero unless long-term change occurring indicate a net decrease as a negative value)

5.12 Available runoff per person = 2083 m^3cap^{-1}

5.13 Available runoff per unit cultivated land = 622 m^3ha^{-1}

5.14 Comment on regional variations in water resources providing ranges of values for 5.1, 5.12 and 5.13 if available

P varies from 400m in the lowveld to 900m over the watershed and 1200m in the Eastern Highlands. R_1 varies from 5mm in Matabeleland to 300mm in the East.

5.15 Comment on the seasonal distribution of P and R_5 indicating months and ranges of values

There is a single wet season of approximately 5 months from November with very little rain at other times. Larger rivers maintain perennial flow due to groundwater (dambos).

5.16 Comment on the inter-annual variability of P and R_5 and estimate their 1 in 20 year extreme values

Variability is high with persistence in dry and wet years. Values of C_v (=1 in 3 year extremes) vary from ± 45% to ± 160% across the country.

5.17 Describe important surface water quality characteristics giving, if available, typical mean and extreme values of sediment concentrations, dissolved solids concentrations, etc, at key locations, now and historically

Table A3.1 (cont'd)

Surface and groundwater quality is good with few causes of industrial pollution. Organic pollution of Lake McIlwaine has been controlled. Estimates of sediment yields vary widely from 10 to 700 t $km^{-2}yr^{-1}$

5.18 Describe the main groundwater systems in the region

Name	Location(s)	Area (km^2)	Water Resource Potential and Quality
Crystalline	75% of country		Limited yields
Non-crystalline	25% of country		Good in places

6. **Water resources development**

6.1 Annual water supplied to

	$m^3 \times 10^9$	% of total
agriculture	1.8	78
industry	0.55	
urban/other		
TOTAL	2.3	

6.2 Source of supplied water

	$m^3 \times 10^9$	% of total
surface water		
groundwater		

6.3 Live reservoir storage capacity available $4.9m^3 \times 10^9$
(plus Kariba shared with Zambia,44 x 10^9m^3)

6.4

Domestic water/sanitation	Rural	Urban
Population served by 'safe' supply (%)	33	80
Average per capita daily consumption (l)	30	600
Population served by adequate sanitation (%)		

6.5 Principal urban water supply systems:

Location(s)	Water Source	Type of Service	Population Served
Harare	Surface		
Bulawayo	Surface		

6.6 Main types and extent of irrigation systems:

Type	Water Source	Location(s)	Crop(s)	Area (km^2)
Surface/ sprinkler	Surface	Chiredzi	Sugar	250?
Surface	Surface	Sabi Valley	Cotton/wheat	50?

6.7 Main types and extent of drainage systems:

Type	Disposal Method	Location(s)	Area Drained (km^2)

6.8 Total installed electrical generating capacity MW
Contribution of hydroelectricity to the above MW (38* %)

Table A3.1 (cont'd)

Names of main hydroelectric stations	Installed capacity (MW)
Kariba South	600

* (In 1986 Kariba S provided 38% of energy but a further 37% was imported from Zambia which was also generated from hydropower)

6.9 Annual fish production from fresh waters t yr^{-1}
Describe the main locations:
Reservoirs particularly Kariba

6.10 Describe locations and significance of any inland navigation routes :
Limited to boats on larger reservoirs

6.11 Describe any significant causes of surface or groundwater pollution

Not very serious at present but problems have been reported due to sewage/eutrophication, industrial effluents (paper mills, fertilisers, textiles) and mine wastes

7. **Environmental characteristics**

7.1 **Locations prone to**

flooding	**Typical area flooded (km²)**	**Frequency**
Downstream of Kariba		Annual

7.2 **Locations protected from natural flooding** **Area (km²)**
Small

7.3 **Locations reclaimed by drainage** **Area (km²)**
Small

7.4 Irrigated land seriously affected by

waterlogging	0?(%)
salinisation	0?(%)

7.5 Important natural ecosystems

	Description	**Area (km²)**
(a) Terrestrial :	The natural savanna and woodland is important for many large mammals	
(b) Aquatic :	There are no large natural lakes. The reservoirs have some important species	
(c) Shoreline :	Shoreline ecosystems are affected by the large and unpredictable drawdowns of many reservoirs	
(d) Floodplain/wetland :	There has been considerable concern over the Mana Pools area downstream of Kariba Dam. Black rhino are a particular concern. Headwater dambos are also important.	

Table A3.2: Current water planning and management information sheet

1. **Country or region** : Zimbabwe

2. **Agencies** involved in water planning and management

Name	Abbrev Name	Agency Type	Areas of Responsibility Sector(s)	Region(s)
Natural Resources Board	NRB			
Dep. Agric. Technical & Extension Services	AGRITEX			
Min Local Gov, Rural & Urban Dev.	MLGRUD			
Min Energy & Water Resources & Dev.	MEWRD			
Parliamentary Select Comm. on Environment				
Min. Finance, Economic Planning & Dev.	MFEDP			
Inter-ministerial Comm. on the environment			Co-ordinates between ministries	
Environmental Monitoring Unit				
National Planning Agency			National Plans	
Min. Lands, Resettlement & Rural Dev	MLRRD			

3. **Hierarchy of responsibilities** between agencies
   Sketch of describe inter-relationships and means of co-ordination

   These are rather complex and some are not fully resolved. MFEPD has overall responsibility for all planning. The Conservation Strategy envisages the co-ordinating responsibility be held by an Inter-Ministerial Committee on the Environment and administered by NRB (within Min.

Table A3.2 (cont'd)

of Nat. Res. and Tourism). The Rural Water Supply and Sanitation Master Plan envisages a National Co-ordinating Unit within MLGRUD administering the discussions of a National Action Committee which co-ordinates between ministeries. MEWRD issues water rights and has diverse functions.

4(.1.) **Available water planning strategy documents** (1)

4.1 Title : National Master Plan for Rural Water Supply and Sanitation — Date :1985

4.2 *Purpose* : To prepare a cost-effective plan of investment in rural water/ sanitation to lift burden from women and limit disease

4.3 Planning approach (end use, etc) : Resources and methods assessed to meet goal of adequate water and sanitation for all

4.4 Components of plan : Resource studies, policies, strategies, technology selection, implementation methods, manpower dev., organisation, finance

4.5 Sectors included : Water, sanitation, health, environment

4.6 Geographical regions : National

4.7 Time Horizon : Complete provision of safe facilities by 2005

4.8 *Planning methods and tools* :

(a) Physical system: Very detailed resources study including hydrology, sedimentation, g/water

(b) Economic evaluation: Costing of investments and support programme at current prices

(c) Environmental assessment: Erosion and livestock effects considered in detail. Water quality measured and guidelines proposed: Ecology not discussed.

4.9 Plan prepared by : Interconsult (Norway)

4.10 Plan prepared for : MEWRD/NORAD

4.11 *Procedure for authorisation prior to implementation* : Recommendations discussed by NAC. Full plan not yet agreed by Cabinet

4.12 Extent of public participation : Integrated plans at local level recommended through Village Dev. Committees.

Table A3.2 (cont'd)

4.13 Extent of inter-agency consultation : Inter-departmental National Action Committee (NAC) established but disputes have arisen (eg. MEWRD/DDF on drilling). National Co-ordination Unit (NCU) established in MLGRUD as Secretariat.

4.14 Time and resources needed to prepare plan : NOK 20M over 4 years involving a large consultancy team.

4.15 Professional involvement in preparation of plan : Extensive team of consultants from various disciplines. A Master Plan Office within MEWRD was recommended.

4(.2.) **Available water planning strategy documents** (2)

4.1 Title : National Conservation Strategy Date :1987

4.2 Purpose : To set targets and objectives for the protection, sustained utilisation and development of Zimbabwe's natural resources

4.3 Planning approach (end use, etc) : Based on UNEPs World Conservation Strategy and seeking to apply it within Zimbabwe

4.4 Components of plan : Strategy, implementation targets/objectives (in various sectors), organisational considerations

4.5 Sectors included : Agriculture, forestry, energy, mining, conservation

4.6 Geographical regions : National

4.7 Time Horizon : Unbounded but water needs studied to 2030

4.8 Planning methods and tools :

(a) Physical system: Studied with respect to need for reservoir storage

(b) Economic evaluation: Cost of reservoir storage evaluated

(c) Environmental assessment: Various environmental linkages highlighted but others neglected

4.9 Plan prepared by : National Resources Board

4.10 Plan prepared for : Inter-Ministerial Committee under Min. Nat. Res & Tourism

4.11 Procedure for authorisation prior to implementation :
Cabinet has approved

4.12 Extent of public participation : The Village Development Committees are given central role in preparing local dev. plans

Table A3.2 (cont'd)

4.13 Extent of inter-agency consultation : Involves many dept's and agencies to be co-ordinated under the National Resources Board of Min. Nat. Res. and Tourism responsible to an Inter-Ministerial Committee

4.14 Time and resources needed to prepare plan : Many technical and other submissions to Inter-Ministerial Committee over 3 years

4.15 Professional involvement in preparation of plan : Unknown but substantial

4(.3.) **Available water planning strategy** documents (3)

4.1 Title : Irrigation Options and Investment Priorities   Date :1987

4.2 Purpose : To review current irrigation and future potential and identify investment priorities

4.3 Planning approach (end use, etc) : Single sector study based on resource potential

4.4 Components of plan : Land capability, potential reservoir yield (MEWRD data) and project characteristics

4.5 Sectors included : Irrigation

4.6 Geographical regions : National

4.7 Time Horizon : Unbounded

4.8 Planning methods and tools :

(a) Physical system: Water and soil resources assessments by standard methods

(b) Economic evaluation: Project viability

(c) Environmental assessment: None

4.9 Plan prepared by : Euroconsult et al

4.10 Plan prepared for : World Bank/Netherlands Gov.

4.11 Procedure for authorisation prior to implementation :

4.12 Extent of public participation :

4.13 Extent of inter-agency consultation :

4.14 Time and resources needed to prepare plan :

Table A3.2 (cont'd)

4.15 Professional involvement in preparation of plan :

4(.4.) Available water planning strategy documents (4)

4.1 Title : Dam Construction Programme Date :

4.2 Purpose : To identify needs and priorities for dam construction

4.3 Planning approach (end use, etc) : Resource potential, projected demand and implementation constraints

4.4 Components of plan :

4.5 Sectors included : Water storage works

4.6 Geographical regions : National

4.7 Time Horizon : 25 years

4.8 Planning methods and tools :

(a) Physical system: Resource assessment procedures developed locally

(b) Economic evaluation: None

(c) Environmental assessment: None

4.9 Plan prepared by : MEWRD

4.10 Plan prepared for : MFEPD?

4.11 Procedure for authorisation prior to implementation : Through the National Plan

4.12 Extent of public participation : None

4.13 Extent of inter-agency consultation :

4.14 Time and resources needed to prepare plan :

4.15 Professional involvement in preparation of plan : Engineers in the MEWRD

5(.1.) Operational water management activities (1)

5.1 Title : Operation of Kariba Dam

5.2 Purpose : Daily operating decision for Kariba Dam

5.3 Scope : Planning the seasonal pattern of releases each year and evaluating potential from alternative operating procedures

Table A3.2 (cont'd)

5.4 Sectors included : Hydropower

5.5 Geographical regions : Whole Zambezi Basin

5.6 Time horizon : Various

5.7 Methods and tools used for identifying options : Various models used to predict inflows and to simulate operation so that options can be assessed including joint operation with other projects in the Zambezi

5.8 Method of public consultation/involvement : None

5.9 Operating agency : Zambezi River Authority

5.10 Source of agency's authority : Inter-governmental Agreement

5.11 Actual or potential areas of conflict : No agreements have been made about guaranteed inflows from Angola and Zambia or guaranteed outflows to Mozambique. Also ecological conflicts and lake-shore impacts due to varying drawdown and releases

5.12 Method of conflict resolution : None

5.13 Time and resources required for operation :

5.14 Professional involvement in operation :

5(.2.) **Operational water management activities** (2)

5.1 Title : Operation of other reservoirs

5.2 Purpose : To provide releases to meet demand

5.3 Scope :

5.4 Sectors included : Irrigation and Urban Water

5.5 Geographical regions : Various

5.6 Time horizon : 1 year max

5.7 Methods and tools used for identifying options : Rudimentary forecasting of yield and demand

5.8 Method of public consultation/involvement : Operation is tailored to the demands of customers

5.9 Operating agency : MEWRD

5.10 Source of agency's authority : Central Government

Table A3.2 (cont'd)

5.11 Actual or potential areas of conflict : a) whether MEWRD or consumer bears responsibility for risk decisions b) conflict between urban and agricultural demand at some dams

5.12 Method of conflict resolution : Priorities defined by statute

5.13 Time and resources required for operation : At least one water bailiff plus a maintenance team at each dam

5.14 Professional involvement in operation : Supervised by a Provincial Water Engineer

6. **Hydrometric network** : Number of operational stations in regions which have been functioning for five years or more

Type		Number in region	Number per $10^4 km^2$
Precipitation		1200	30.7
Evaporation		53	
Stage (water level)	(	310	28.8
River discharge	(		9.6
Sediment discharge		21	
Surface water quality		96	
Groundwater level			
Groundwater quality			

(For recommended minimum standards see UNESCO/WMO 1988)

7. **Specialist institutions** for training and research in water

Name of institution **Type** ***Functions and Specialisations***

Univ. of Zimbabwe BSc courses and research
Various specialist research and training centres under the Ministry of Agriculture

8. **Describe sources of funding** and procedures for water resources development

Mostly through central government investment programme but some NGO involvement

9. **Describe environmental control procedures** and list agencies responsible

Water Pollution Control section of MEWRD has wide powers but is understaffed

10. **Describe significant international water issues** in the region.

Kariba dam is shared with Zambia. There is no agreement governing the Zambezi or other international rivers. Zimbabwe is mainly an upstream user

Table A3.3 Bilateral and multilateral funded projects related to water resources management in: Pakistan

Project Title	Type	Purpose	Funded by	Implemented by	Implemented for	Start	End	Cost
Collector Wells	Re-search	To develop and field-test large diameter collector well techniques	ODA	BGS	MEWRD			
Collector Wells	Capital	Implement above	ODA			1991	1994	£0.52M
Drilling rigs	Capital		ODA			1991	1993	£0.28M
Mayfair and Claw	Capital		ODA			1988	1992	£3.60M
Dams	TC		ODA					£0.74M
Nyanyadzi irrigation	Capital		ODA				1991	£0.18M
Save Valley Exp. Stn	Capital		ODA				1993	£1.06M
Data processing	TC	Meteorological data	ODA		Met. Dep.	1989	1992	£0.27M
Agric. Sector Strategy	TC	Consultants in food strategy and planning	ODA			1989	1991	£0.34M
Rusitu resettlement	TC	Options study	ODA	Mott McDonald		1991	1992	£0.05M
Institutional strengthening to Forestry Comm.	TC		ODA			1990	1996	£1.06M
Fisheries assistance	TC		ODA			1988	1994	£0.02M
Groundwater assistance	TC	Institutional support	ODA		MEWRD	1987	1992	£0.72M
Waterflow measurement	TC	Research in low-cost method	ODA	HR	MEWRD	1987	1990	£0.11M
Water quality lab. implementation	TC	Consultancy and	ODA		MEWRD	1990	1993	£0.62M
Gokwe Town water	TC	Options study and implementation	ODA		MEWRD	1991	1994	£2.52M
Lecturer in water	TC		ODA		UZ			£0.05M
Strategic planners development	TC	Planning rural	ODA		DERUDE	1991	1994	£0.45M
Malaria control	TC	Support for research	ODA		Blair	1991	1994	£0.25M
Rural water rehab.	TC	Rehabilitation of rural water	NORAD		MEWRD	1981	1987	NOK £160M

Table A3.3 (cont'd)

Project Title	Type	Purpose	Funded by	Implemented by	Implemented for	Start	End	Cost
National Master Plan	TC	Master Plan for Rural water supply and sanitation	NORAD		MEWRD	1983	1986	NOK £20M
Mashonaland Crash Prog	TC	320 boreholes in 9.5 months for drought relief	NORAD		MEWRD		1985	NOK 49M
Manicaland water/sanit planned using Master Plan (500 wells/TW + 850 latrines)	TC	Rural water/sanitation	NORAD		MEWRD	1984	1987	
Rural planning	TC	Sector support	NORAD		MLGRUD	1987	1990	NOK 180M
Rural water supply	T	12 Rural Service Centres	Belgium					
Planning rural water	TC		DANIDA					
Rural water/sanit.	TC		DANIDA		MOH			
Handpump rehab.	TC	Community based rehab.	DANIDA		DDF			
Support to water sector	TC		GTZ SIDA		MEWRD			
Rural sanitation	TC		SIDA					
Pilot training prog.	TC	For water supply/ sanitation	SIDA					
Integrated sector prog	TC		Dutch		NAC			
Boreholes, wells, toilets			EEC					
Well/pump rehab.			UNICEF					
Sanitation			UNICEF					
Support to rural health			UNDP		MOH			
Sanitation adviser			WHO		MOH			
Rural water supplies		Mainly at growth points	ADB			1985	1988	Z$20M
Small-holder design procedures	Re-search	Monitoring and new	ODA	HR	AGRITEX	1982	1992	
Schistosomiasis Control	Re-search	Pilot tests for measures	ODA	HR	AGRITEX	1984	1992	
Micro Irrigation	Re-search		ODA	IOH	AGRITEX			

Table A3.3 (cont'd)

Project Title	Type	Purpose	Funded by	Implemented by	Implemented for	Start	End	Cost
Use of dambos	Re-search		ODA	L'borough				
Alluvial aquifers	Re-search	Pilot test for measures small irrigation	ODA	S'hampton & U of Z	AGRITEX			
Hand pumps for irrigation	Re-search		ODA	L'borough	AGRITEX			
Power II Project		Kariba South rehab & transmission network improvement	World Bank etc		ZESA	1989	1993	US $224.1
Hydrological assess-ment		Review of SADCC countries	World Bank					
Small Irrigation Schemes			GTZ					
Small Irrigation Schemes			Italy					
Small Irrigation Schemes			Japan					

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Appendix 4

The Dublin Statement

Communiqué from the International Conference on Water and Environment, Dublin, 26-31 January 1992

THE DUBLIN STATEMENT
ON WATER AND SUSTAINABLE DEVELOPMENT

Scarcity and misuse of freshwater pose a serious and growing threat to sustainable development and protection of the environment. Human health and welfare, food security, industrial development and the ecosystems on which they depend, are all at risk, unless water and land resources are managed more effectively in the present decade and beyond than they have been in the past.

Five hundred participants, including government-designated experts from a hundred countries and representatives of eighty international, intergovernmental and non-governmental organizations attended the International Conference on Water and the Environment (ICWE) in Dublin, Ireland, on 26-31 January 1992. The experts saw the emerging global water resources picture as critical. At its closing session, the Conference adopted this Dublin Statement and the Conference Report. The problems highlighted are not speculative in nature; nor are they likely to affect our planet only in the distant future. They are here and they affect humanity now. The future survival of many millions of people demands immediate and effective action.

The Conference participants call for fundamental new approaches to the assessment, development and management of freshwater resources, which can only be brought about through political commitment and involvement from the highest levels of government to the smallest communities. Commitment will need to be backed by substantial and immediate investments, public awareness campaigns, legislative and institutional changes, technology development, and capacity building programmes. Underlying all these must be a greater recognition of the interdependence of all peoples, and of their place in the natural world.

In commending this Dublin Statement to the world leaders assembled at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992, the Conference participants urge all governments to study carefully the specific activities and means of implementation recommended in the Conference Report, and to translate those recommendations into urgent action programmes for WATER AND SUSTAINABLE DEVELOPMENT.

GUIDING PRINCIPLES

Concerted action is needed to reverse the present trends of overconsumption, pollution, and rising threats from drought and floods. The Conference Report sets out recommendations for action at local, national and international levels, based on four guiding principles.

Principle No. 1 – Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment

Since water sustains life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems. Effective management links land and water uses across the whole of a catchment area or groundwater aquifer.

Principle No. 2 – Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels

The participatory approach involves raising awareness of the importance of water among policy-makers and the general public. It means that decisions are taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects.

Principle No. 3 – Women play a central part in the provision, management and safeguarding of water

This pivotal role of women as providers and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources. Acceptance and implementation of this principle requires positive policies to address women's specific needs and to equip and empower women to participate at all levels in water resources programmes, including decision-making and implementation, in ways defined by them.

Principle No. 4 – Water has an economic value in all its competing uses and should be recognized as an economic good.

Within this principle, it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.

THE ACTION AGENDA

Based on these four guiding principles, the Conference participants developed recommendations which enable countries to tackle their water resources problems on a wide range of fronts. The major benefits to come from implementation of the Dublin recommendations will be:

Alleviation of Poverty and Disease

At the start of the 1990s, more than a quarter of the world's population still lack the basic human needs of enough food to eat, a clean water supply and hygienic means of sanitation. The Conference recommends that priority be given in water resources development and management to the accelerated provision of food, water and sanitation to these unserved millions.

Protection against natural disasters

Lack of preparedness, often aggravated by lack of data, means that droughts and floods take a huge toll in deaths, misery and economic loss. Economic losses from natural disasters, including floods and droughts, increased three-fold between the 1960s and the 1980s. Development is being set back for years in some developing countries, because investments have not been made in basic data collection and disaster preparedness. Projected climate change and rising sea levels will intensify the risk for some, while also threatening the apparent security of existing water resources.

Damages and loss of life from floods and droughts can be drastically reduced by the disaster preparedness actions recommended in the Dublin Conference Report.

Water Conservation and Reuse

Current patterns of water use involve excessive waste. There is great scope for water savings in agriculture, in industry and in domestic water supplies.

Irrigated agriculture accounts for about 80% of water withdrawals in the world. In many irrigation schemes, up to 60% of this water is lost on its way from the source to the plant. More efficient irrigation practices will lead to substantial freshwater savings.

Recycling could reduce the consumption of many industrial consumers by 50% or more, with the additional benefit of reduced pollution. Application of the "polluter pays" principle and realistic water pricing will encourage conservation and reuse. On average, 36% of the water produced by urban water utilities in developing countries is "unaccounted for". Better management could reduce these costly losses.

Combined savings in agriculture, industry and domestic water supplies could significantly defer investment in costly new water resource development and have enormous impact on the sustainability of future supplies. More savings will come from multiple use of water. Compliance with effective discharge standards, based on new water protection objectives, will enable successive downstream consumers to reuse water which presently is too contaminated after the first use.

Sustainable Urban Development

The sustainability of urban growth is threatened by curtailment of the copious supplies of cheap water, as a result of the depletion and degradation caused by past profligacy. After a generation or more of excessive water use and reckless discharge of municipal and industrial wastes, the situation in the majority of the world's major cities is appalling and getting worse. As water scarcity and pollution force development of ever more distant sources, marginal costs of meeting fresh demands are growing rapidly. Future guaranteed supplies must be based on appropriate water charges and discharge controls. Residual contamination of land and water can no longer be seen as a reasonable trade-off for the jobs and prosperity brought by industrial growth.

Agricultural Production and Rural Water Supply

Achieving food security is a high priority in many countries, and agriculture must not only provide food for rising populations, but also save water for other uses. The challenge is to develop and apply water-saving technology and management methods, and, through capacity building, enable communities to introduce institutions and incentives for the rural population to adopt new approaches, for both rainfed and irrigated agriculture. The rural population must also have better access to a potable water supply and to sanitation services. It is an immense task, but not an impossible one, provided appropriate policies and programmes are adopted at all levels - local, national and international.

Protecting Aquatic Ecosystems

Water is a vital part of the environment and a home for many forms of life on which the well-being of humans ultimately depends. Disruption of flows has reduced the productivity of many such ecosystems, devastated fisheries, agriculture and grazing, and marginalized the rural communities which rely on these. Various kinds of pollution, including transboundary pollution, exacerbate these problems, degrade water supplies, require more expensive water treatment, destroy aquatic fauna, and deny recreation opportunities.

Integrated management of river basins provides the opportunity to safeguard aquatic ecosystems, and make their benefits available to society on a sustainable basis.

Resolving Water Conflicts

The most appropriate geographical entity for the planning and management of water resources is the river basin, including surface and groundwater. Ideally, the effective integrated planning and development of transboundary river or lake basins has similar institutional requirements to a basin entirely within one country. The essential function of existing international basin organizations is one of reconciling and harmonizing the interests of riparian countries, monitoring water quantity and quality, development of concerted action programmes, exchange of information, and enforcing agreements.

In the coming decades, management of international watersheds will greatly increase in importance. A high priority should therefore be given to the preparation and implementation of integrated management plans, endorsed by all affected governments and backed by international agreements.

THE ENABLING ENVIRONMENT

Implementation of action programmes for Water and Sustainable Development will require a substantial investment, not only in the capital projects concerned, but, crucially, in building the capacity of people and institutions to plan and implement those projects.

The Knowledge Base

Measurement of components of the water cycle, in quantity and quality, and of other characterisitics of the environment affecting water are an essential basis for undertaking effective water management. Research and analysis techniques, applied on an interdisciplinary basis, permit the understanding of these data and their application to many uses.

With the threat of global warming due to increasing greenhouse gas concentrations in the atmosphere, the need for measurements and data exchange on the hydrological cycle on a global scale is evident. The data are required to understand both the world's climate system and the potential impacts on water resources of climate change and sea level rise. All countries must participate and, where necessary, be assisted to take part in the global monitoring, the study of the effects and the development of appropriate response strategies.

Capacity Building

All actions identified in the Dublin Conference Report require well-trained and qualified personnel. Countries should identify, as part of national development plans, training needs for water resources assessment and management, and take steps internally and, if necessary with technical co-operation agencies, to provide the required training, and working conditions which help to retain the trained personnel.

Governments must also assess their capacity to equip their water and other specialists to implement the full range of activities for integrated water resources management. This requires provision of an enabling environment in terms of institutional and legal arrangements, including those for effective water demand management.

Awareness raising is a vital part of a participatory approach to water resources management. Information, education and communication support programmes must be an integral part of the development process.

FOLLOW-UP

Experience has shown that progress towards implementing the actions and achieving the goals of water programmes requires follow-up mechanisms for periodic assessments at national and international levels.

In the framework of the follow-up procedures developed by UNCED for Agenda 21, all Governments should initiate periodic assessments of progress. At the international level, United Nations institutions concerned with water should be strengthened to undertake the assessment and follow-up process. In addition, to involve private institutions, regional and non-governmental organisations along with all interested governments in the assessment and follow-up, the Conference proposes, for consideration by UNCED, a world water forum or council to which all such groups could adhere.

It is proposed that the first full assessment on implementation of the recommended programme should be undertaken by the year 2000.

UNCED is urged to consider the financial requirements for water-related programmes, in accordance with the above principles, in the funding for implementation of Agenda 21. Such considerations must include realistic targets for the timeframe for implementation of the programmes, the internal and external resources needed, and the means of mobilizing these.

The International Conference on Water and the Environment began with a Water Ceremony in which children from all parts of the world made a moving plea to the assembled experts to play their part in preserving precious water resources for future generations.
In transmitting this Dublin Statement to a world audience, the Conference participants urge all those involved in the development and management of our water resources to allow the message of those children to direct their future actions.

Address: **Hydraulics Research Ltd,** Wallingford, Oxfordshire OX10 8BA, United Kingd
Telephone: 0491 35381 International + 44 491 35381 Telex: 848552 HRSWAL G.
Facsimile : 0491 32233 International + 44 491 32233 Registered in England No. 162217