

ODI Research Study

Hydro Logic?

Reform in Water Resources Management in Developed Countries with Major Agricultural Water Use

Lessons for Developing Nations

Hugh Turrall

Overseas Development Institute

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Acronyms

ABARE	Australian Bureau for Applied Research in Economics
ACC	Administrative Coordination Council (UN)
ACF	Australian Conservation Foundation
ACP	Agricultural Conservation Programme (Aus)
AMA	Active Management Area
CAP	Central Arizona Project (USA)
CCC	Catchment Coordinating Committees
CMG	Catchment Management Group
COAG	Council of Australasian Governments
CRBP	Colorado River Basin Project
CRP	Conservation Reserve Programme
CRSP	Colorado River Storage Project
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSO	Community Service Obligation
CVP	Central Valley Project (California)
CVPIA	Central Valley Improvement Act
DWR	Department of Water Resources (California/New South Wales)
EC	European Commission
ECU	electrical conductivity unit
EPA	Environment Protection Act (EPA)
ESA	Endangered Species Act (US)
EU	European Union
GIS	Geographic Information Systems
GMID	Gouldburn Murray Irrigation District
HDWB	Hunter District Water Board
IAP-WASAD	International Action Programme on Water and Sustainable Agricultural Development
ICM	Integrated Catchment Management
ICWE	International Conference on Water and Environment (Dublin 1992)
IFPRI	International Food Policy Research Institute
IHE	Institute of Hydraulic Engineering (Delft)
IID	Imperial Irrigation District
IIMI	International Irrigation Management Institute
ISGWR	Inter-Secretariat Group on Water Resources (UN)
KCWA	Kern County Water Authority
LA	Los Angeles
LRMC	Long Run Marginal Cost
MDB	Murray–Darling Basin

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MDBC	Murray–Darling Basin Commission
MIA	Murrumbidgee Irrigation Area
ML	Mega litre = 1 million litres = 1,000m ³
mML	million mega litres
MWD	Metropolitan Water District (California)
NFF	National Farmers’ Federation
NHP	National Hydrologic Plan (Spain)
NSW	New South Wales
NWRP	National Water Resource Programme
PWD	Public Works Department
RMC	River Murray Commission
MWC	Rural Water Corporation/Commission (Victoria)
SAG	Salinity Action Group
SJV	San Joaquin Valley
SRWSC	State Rivers and Water Supply Commission (Victoria)
SWP	State Water Project
TVA	Tennessee Valley Authority
UNCED	United Nations Conference on Environment and Development (Rio 1992)
UNDP	United Nations Development Programme
USBR	United States Bureau of Reclamation

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Introduction

From Dominion to Concern – The Development, Mobilisation and Control of Water Resources

Improved engineering knowledge, materials and techniques have rapidly accelerated water development and control projects worldwide in the 20th century. A 'frontier mentality' and a belief in man's innate superiority over nature fostered settlement and development on a large scale in arid and semi-arid regions as diverse as the United States, Australia, and South and Central Asia. The engineer stood, for a time, as the front-line soldier in the battle to control floods and mitigate drought, buoyed by his faith in the certainties of science and a philosophy of control over the natural environment.

Society's increasing demands for electric power created the impetus to regulate great rivers, construct large dam-storages and harness natural flows for human benefit. Extensive irrigation development in tandem with the 'green revolution' has resulted in more than 80% of many developing countries' water resources being allocated to agriculture, peaking as concerns mounted about global food security and regional food deficits in the 1960s and 70s.

Today much of the world's water is harnessed for multiple productive uses and the environmental values and characteristics of water systems are increasingly understood *and* appreciated. The world's population has continued to grow, urbanise and industrialise to the point that both developing and developed countries face intersectoral competition for water. In the industrialised countries of the north, water quality and restoration of degraded natural systems has become an increasingly important priority. In the south, it is anticipated that competing demands can be satisfied by making transfers from the technically and economically 'inefficient' irrigation sector which has tended, until recently, to absorb considerable proportions of state finances. At the same time, water developers must understand the environmental consequences of over-developing hydrologic systems and where possible, harness the resource in a sustainable and responsible way, learning from the hard-earned experience worldwide. Table 1 summarises the institutional, political and sustainability characteristics at different stages of water resource development (after Allan, 1994). The institutional arrangements for traditional and public irrigation systems have recently been expounded in some detail (*inter alia*, Ostrom, 1992; Ostrom and Tang,

Table 1 Historical contexts for water resources development

Phase	Water resource availability	Water resource allocation and use	Patterns of political relationships	Economic sustainability	Ecological soundness
I	In surplus	Unconstrained	Developing	Short term	Short term
II	In balance (for existing policies and technology)	Approaching limits	Inflexible interdependence of farmers and politicians addressing the principle of food self-sufficiency	Tendency to ignore principles of allocative efficiency [poor]	Tendency to ignore principles of ecological sustainability [poor]
III	In deficit	Seasonal and annual shortages (for irrigation)	Political leadership unable to adopt sound allocative principles	Unable to adopt appropriate policies [i.e. poor]	Unable to adopt appropriate policies [i.e. poor]
IV	In balance	Demand management adopting principles of allocative efficiency and use	Political leadership freed of pressure from food-producing interests	Sustainable water resource use	Sustainable ecological use

Source: Allan, 1993

1992), but a similar analysis of water resources management at large has yet to be attempted. A more pragmatic prescription for sound institutions of water management stresses that it is not a technical, but a political subject (Fredericksen, 1992) that requires continuing evaluation and dynamism. The expert role is to provide technical information to political bodies in all sectors, both public and private, while ensuring consistency in both legislation and organisational structure.

A number of developed countries have undertaken substantial water development for irrigation through the 19th and 20th centuries, and their experience highlights the importance of developing appropriate institutional arrangements to manage water wisely as its 'scarcity value' increases. It is to this accumulated experience that this study turns.

World Trends Affecting the Allocation of Water Resources

Global population continues to grow rapidly, and UNDP estimates a world population of 8 billion by 2025, or about 60% more than today. This alone requires considerable increases in food production in global and regional terms. Although the green revolution has almost removed food deficits in much of Asia on the back of irrigation and high-yield

production packages, productivity gains have been declining. Commodity prices of staple foods have steadily declined over the last 15 to 20 years, changing the pattern of agricultural growth and development (Rosegrant et al., 1995). The International Irrigation Management Institute and the International Food Policy Research Institute (IIMI/IFPRI) have estimated that 80% of the increase in future food demand will have to be met from irrigated cropping, which will require considerable finesse in management, especially as a second 'green revolution' technical-fix is not around the corner. And the 'green revolution' has by-passed most of Africa, where water resources are more precarious and offer little potential to meet food security in the long term (Field, 1995), especially considering the past performance of irrigation there.

By contrast, there are conflicting signals in world markets for agricultural produce, where the very success of US and EC state-sponsored and subsidised agricultural growth has contributed to depressed prices and restrictive trade practices. One of the major uncertainties affecting future irrigation water use will undoubtedly be how the world market changes in response to both the management of northern surplus production and the extent to which major industrialising nations (such as China) substitute imports for domestic food self-sufficiency. This in turn will have knock-on effects on the reallocation of water resources and the impact of conservation measures in irrigation. It is one thing to identify such crucial influences, but it is much harder to predict, even coarsely, what will in fact happen. It is therefore difficult to make contingency plans – an example of why water resources management is a continuing and dynamic process which needs a sound institutional framework.

The crucial demographic factor impacting on water resources management is urbanisation. At current rates of urban growth, more than 60% of the world population will reside in cities in 2025 (Seregeldin, 1994), although it is by no means certain that current trends will continue. This concentrated demand and the associated residential, industrial and amenity development will put stress on local and sometimes regional water systems. Water quality, safe potable supplies and wastewater management become increasingly interdependent, and will require enormous capital investment as well as management capacity, even if, in absolute terms, the volume of water required could be satisfied by less than a 10% reduction in irrigation usage. There are strong signals that irrigation investment will be dwarfed by these emerging requirements, which will be so large (US\$600 billion) (Seregeldin, 1994), that national governments and lending agencies are exploring all avenues to encourage private investment on a hitherto undreamed of scale. These projected costs are in part driven by the increasingly stringent standards for water quality in the industrialised countries, standards which have reshaped the water industry in Europe

and the USA.

The economics of water is a relatively new and contentious subject, born out of its recently acquired scarcity and the very real inability of governments to continue to subsidise not only the operation and maintenance of water supplies, but also their construction. Proponents of economic solutions to water provision find themselves at odds with an almost universal human belief that water is a 'gift from God', or a natural right as a fundamental prerequisite of life. They also have to contend with multiple problems associated with the recalcitrant economic characteristics of water itself (see Turrall, 1995). Nevertheless, much of the focus of recent institutional development has been on market-like initiatives to manage demand and to encourage private sector, profit-motivated activity. The market philosophy has overtaken most of the planned or 'command' economies of the world, and the role of the state in the management of water is being redefined continually.

The new roles for the state appear to be the creation of an enabling environment for private enterprise and public participation in water management; environmental care; and data collection, provision and management. It is possible, however, for the state to retreat from the *active* regulatory role that is increasingly commonplace.

In the last 10 years, environmental allocations for in-stream flows, habitat and recreation have intruded into the water developer's realm, complicating economic valuation and the breadth and depth of public involvement. Crudely put, there are now more users, each requiring more of a limited resource. This has created a complexity to which few traditional water managers, engineers, have been sensitised, or trained to understand. The process of institutional development in developed country water management has occurred over the last 30 to 50 years as various elements of this complexity have revealed themselves and in turn brought the realisation that further change and complexity lies ahead which cannot be managed exclusively by well-informed individuals and well-trained technocratic elites.

The International Agenda for Water Policy Reform

An *ideal* institutional framework for rational water resources management has been proposed (Bottrall, 1992). It shows why there are gaps between the ideal and reality. The ideal framework includes the following characteristics:

- A decentralised and accountable structure that is coherent and consistent at each layer of administration, from national through provincial/river basin levels to local.

- Self-management of independent bodies and self-financing at user and higher levels of activity, according to users' ability to pay.
- Market mechanisms are an integral part of water allocation, determining the value of water between sectors, the value to the management agency and to the user.
- Government has an enabling rather than a controlling role, with key responsibilities for capital investment, supporting legislation, data collection and processing, and support for basic technical research and development.
- A comprehensive and consistent legal code which clearly defines the water rights and responsibilities of individuals, groups, agencies and government bodies. A set of procedures for *de jure* and *extra-legal* arbitration of disputes and established enforceable penalties for misuse and degradation of water resources.

A number of contemporary concepts in water resources management, summarised in Table 2, have found their way into international policy prescriptions for developing countries, via a series of international meetings in the early 1990s and from the resulting dialogue and activities of the United Nations (UN) family of technical agencies.

These international actions go back to the 'Water and Sanitation Decade' (1980–90), following the Mar del Plata Conference and resulting action plan of 1977 and the emergence of Inter-Secretariat Group on Water Resources (ISGWR, 1990) under the Administrative Coordination Council (ACC) of the UN. The New Delhi Statement (1990) concluded that the long-term future of sustainable development lies in becoming more demand- than supply-oriented and in developing local capacity in all natural resources sub-sectors. Capacity building in the water sector became the theme of the United Nations Development Programme–Institute of Hydraulic Engineering (UNDP–IHE) conference in Delft in 1991, and was quickly followed by the International Conference on Water and the Environment (ICWE) in Dublin (1991). Three basic elements of capacity building were identified:

- the creation of an enabling environment with appropriate policy and legal frameworks;
- institutional development, including community participation; and
- human resources development and the strengthening of managerial systems.

The ICWE called for innovative approaches to the assessment, development and management of freshwater resources, and provided policy guidance for the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992. UNCED

highlighted the need for water sector reforms throughout the world. The Dublin statement reaffirmed that 'it is vital to recognise first the basic right of all human beings to have access to clean water and sanitation at an affordable price', and went on to assert the following principles:

- Water must be managed in a holistic way, taking into account interaction among users and environmental impacts.
- Water should be valued as an economic good and managed as a resource necessary to meet basic human rights.
- Institutional arrangements must be reformed so that stakeholders are fully involved with all aspects of policy formulation and implementation. Management must be devolved to the lowest appropriate level and enhance the roles for NGOs, the private sector and community groups.
- Women must play a central part in the provision, management and care of the resource.

In 1993, the World Bank issued a comprehensive policy paper defining its new objectives for the water sector. The Food and Agriculture Organisation (FAO) recently established an International Action Programme on Water and Sustainable Agricultural Development (IAP-WASAD). Likewise, the UN specialised agencies, international non-governmental organisations (NGOs) and bilateral assistance agencies are all coordinating or participating in special programmes related to water resources. The ministerial conference on drinking water and environmental sanitation (at Nordwijk, the Netherlands, March 1994) called for strategies for drinking water and sanitation to be developed in the context of broader strategies for sustainable water resources management and environmental protection.

These meetings have been at pains to stress that there are no prescriptive solutions for water management because of its complexity, arising from its many facets and interactions with other human activities and natural processes. It is evident, however, that some inherent contradictions lie even in the development of sound principles of sustainable water management when it comes to putting them into practice: what sort and *degree* of treatment of water as an economic good is appropriate and practical? What are the limits to *cost-effective* but worthwhile public participation? As the principles of good water management have largely been drawn from accumulated developed country experience in coming to terms with changing needs, it appears logical to review how they have been applied in practice in situations that more resemble those of developing countries, particularly where

irrigation is the dominant use.

A Brief Summary of Reform in Developed Countries

Worldwide, there is a dichotomy in water use, and in the resulting pressures for policy reform. The institutional arrangements reflect the dominance of either agricultural water use (typically in developing countries) or industrial use, as in northern Europe and temperate North America. The principle driving force for reform in industrialised countries has been the environmental lobby, spurred by chemical and thermal pollution of natural stream habitat, by increasingly tough environmental standards for potable water quality and by restrictions on the discharge of sewage effluent (notably the famous European Union (EU) 'Bathing Waters' Directive). The push to safeguard environmental quality has required massive injections of capital into ageing water infrastructure that was developed, in many cases, in the last century. This in turn has forced governments to look at alternative means of financing such needs and has inevitably led to interest in private sector involvement as managers, developers and even owners of water services (in the UK).

Although the water quality issue has been the major force driving reforms in temperate country water resources management, there are a number of developed countries where irrigation is a major consumer of water and urban, industrial and environmental water demands have combined to create a similar competitive environment. This problem emerged in the western USA at the end of the 1970s and continues to attract much attention at state and federal level. Continuing urban growth, especially in Southern California, an arid environment with a near fully developed water resource, could be analysed for potential application to developing countries. In the Murray–Darling Basin of Australia, and the Colorado Basin in the USA, in-stream salinity and land salinisation are consequences of irrigation development and have brought a new dimension to inter-state cooperation in river basin management and environmental allocation of water. Australia has been particularly innovative in promoting community participation in land and water management through its 'LandCare' programme. Both countries have contrasting water rights systems and a mix of government and private initiatives in developing water resources, with more corporatist history in the USA. Both countries have, in recent history, turned to economic measures and public sector reforms including privatisation to conserve and re-allocate water and manage demand, in preference to further and increasingly expensive infrastructure development. These countries have also experimented with transferable property rights to water.

Spain has a long history of irrigation development and management,

with a strong tradition of user-finance up to the end of the 19th Century, since when the state has become a major developer of water infrastructure. Spain instituted river basin management nationwide in 1928 and has worked towards the evolution of a comprehensive and integrated law to underpin a continually evolving water policy. Entry to the Common Market spurred considerable public and private investment in irrigation, and tourist development has placed localised pressure on water resources in the dry south and south-east. The environmental debate, especially in relation to natural wetlands, has been slow to develop in Spain compared with the USA and Australia. Agricultural growth remains an important national objective and fuels a large slice of the economy, compared to its more industrialised European neighbours. Spain has therefore maintained a much greater interest in supply augmentation than either the USA or Australia, although it has also pursued demand management as a complementary policy. The current National Hydrologic Plan (NHP, 1993) envisages an ambitious programme of inter-basin (and inter-provincial) water transfers from the well-endowed north and north-east to the south-east and south-west. The enduring drought that has gripped Spain since the beginning of the decade, plus the need to comply with EU directives on water quality, have brought the NHP very much into the public eye, and despite many years of institutional development and fine-tuning, it is finding increasingly vocal and potent opposition from environmental activists and northern provincial politicians.

Although public perceptions of the nature of water as a resource are changing in developed countries, it is not clear that this is so in developing ones. The international profile of water is still largely limited to reaction to the impacts of flood and drought disasters, and many developing countries have only recently adopted water policies of any description, let alone ones aimed at integrated and rational management.

Rationale for Present Study

In many developing countries, competition for limited water resources is increasing as urbanisation and industrial development accelerate, and as resources are developed to the limit for irrigation. Inter-sectoral competition to develop and appropriate water supplies is further limited by increasing environmental awareness and the need to reserve good quality in-stream flows to maintain habitats and hydrological balance.

The major obstacles to sustainable water development were identified by the World Bank (1988) and include:

- fragmented sector policies;
- weak institutional arrangements and inadequate intersectoral coordination;

- lack of adequately trained and motivated staff;
- use of inappropriate technology (especially for developing country contexts) and poor knowledge of alternatives;
- inadequate operation and maintenance;
- poor cost recovery and resource mobilisation; and
- little community involvement.

Further characteristics of policymaking and planning deficiencies in water resources *development* were identified by research based on four semi-arid case-studies (ISPAN, 1993) as an absence of:

- clear and well-understood legal principles;
- adequate data;
- public accountability;
- fair processes of appeal and adjudication; and
- adequate promotional and enforcement capabilities.

Given the limited experience with water reforms in developing countries and the preceding impediments to sustainable use, it is reasonable to examine the process and experience of institutional reform in developed country situations that have the closest similarities in resource allocation and security. Although institutional arrangements and technology are closely interlinked, it appears that there is a more significant stumbling block in institutional development than technology availability, if only because comparable problems emerged 15 to 20 years earlier and have been the subject of creative and dynamic response. This history has been documented (but only partially analysed) at different stages, and contains the only source of substantive information on economic approaches to reform and on serious attempts at full cost recovery. It is hoped that sound analysis will enable some short cuts to be taken in implementing policy in developing countries, even if it only warns of avoidable pitfalls.

Problems in Water Resources Management in Developing Countries

There are a number of factors underlying the implicit assumption that there is an inadequate framework of institutions in developing countries for the rational management and allocation of scarce water resources. The three main ones are:

- The existing institutional landscape is dominated by public works or irrigation departments which have evolved as construction and *water development* organisations, primarily concerned with large-scale *projects* in surface irrigation, flood control and hydro-power development.
- Other aspects of water resource development (urban water supply and sewage and rural water supply) have been undertaken by parallel organisations, with the result that management of water tends to be

both fragmented and centralised but with little coordination and long-term integration.

- Newly emerging Water Resources Departments tend, in the main, to be renamed Public Works Departments (PWDs) and Irrigation Departments, precisely the organisations that have fostered past distortions in allocation and use of water. Old attitudes are hard to change and there may be strong resistance to reform, particularly in terms of accepting the roles of service provision and management (in place of construction) and a wider catchment and river basin perspective in place of a project culture. The situation is compounded by a lack of donor coherence on these issues.

Consequences of the Prevailing Institutional Bias in Developing Countries

Large capital-intensive irrigation projects have been favoured at the expense of other uses. As the international profile of large-scale irrigation has become somewhat tarnished, the focus of investment has shifted to medium- and small-scale irrigation, rehabilitation and groundwater development. Now that irrigation investment appears to be declining and urbanisation heralds massive investment requirements in water supply and sanitation, a new sectoral agenda may again miss the imperatives of integrated water management. Sectoral fragmentation has resulted in monopoly control of data collection and analysis, with very limited dissemination and provision to other agencies or a wider public.

Inappropriate design and poor construction, coupled with ineffective management of large-scale water projects has generally exacerbated a poor level of accountability to water users and the general public. The provision of water at minimal cost (effectively as a free good) has resulted in wasteful use and has restricted revenue to the point that operation and maintenance budgets are usually in deficit. Pricing has not been an effective tool in allocating water between competing uses because of the artificially low cost or poor service fee collection.

The legal framework behind water resources management has been poorly articulated and is inconsistent, with limited specification of individual or group user's rights and responsibilities. Transfers of water within agriculture and between sectors have been conducted by unilateral agency fiat. Groundwater has effectively been exploited as an open-access resource, and the longer that this situation has prevailed, the more difficult any form of regulation has become. Communally organised water use in small-scale irrigation, domestic water supply and sanitation has been recognised increasingly, but its place in the wider context of allocated water rights, and the processes of management and planning,

is frequently ignored.

The most promising points of intervention in reform lie where the prevailing power brokers are weakest (Bottrall, 1992) and the developed country analysis should focus on these points where they are most relevant to the developing countries situation, in:

- peri-urban and urban allocation and water use in rapidly expanding cities;
- attempts to develop new institutions, such as River Basin Authorities, water-user groups and federations of water-users; and relations between emerging water-user groups and state agencies – innovation, inertia and resistance in the technocracy.

Focus and Objectives

The study analyses the history of water resources development and management in the western USA, Australia and Spain. It uses and refines the framework for institutional analysis in water resources management that was developed in mid-1994 (Turrall).

The study of western US experience draws mainly on the inter-state compact dividing the waters of the River Colorado and water management in Southern California. It draws on the development of federal water law and investment in infrastructure, and examines the responses to severe and prolonged drought from 1987 to 1992, which resulted in innovative solutions to manage demand and reconcile agricultural and environmental needs.

The Australian review is centred on the development of inter-state water agreements in the Murray–Darling Basin, which is the main focal point of water use and management in the country. The approach to community participation embodied in Land Care is also outlined and a more detailed analysis is made of the heavily industrialised Hunter Valley on the east coast of New South Wales.

Water development in Spain since Roman times is reviewed, culminating in nearly a century of legal consolidation and reform leading up to the present NHP. The plan is discussed in some detail and material is being collected on the emerging opposition to it. The burgeoning environmental debate is introduced in the water-stressed Guadalquivir Basin, in south-west Spain, where ecological problems are more developed and the supply augmentation proposed in the NHP is minimal.

A number of key issues provide the context for comparison and application to developing country situations. They are:

- The status of existing organisational structures and the processes of planning and management at national, regional and local levels.

- Patterns of public investment (a) between water sectors and (b) within agriculture (large-, medium- and small-scale irrigation).
- The use of market-based instruments for efficient use and allocation of water. Incentives in reform – subsidies, penalties, tariffs and taxes.
- The nature of water law and the relative powers and responsibilities of the state compared to regional and local levels of organisation.
- Sequences in the reform process: articulation of policy, provision of supporting legal framework, implementation of legislation and effective regulation, internal reform of government agencies and enablement of market and decentralising initiatives.
- Use of privatisation, corporatisation and economic instruments in service provision. The role of community-based organisations and state-led strategies for broader community participation in watershed management and water-use planning.
- The role, constitution, function and effectiveness of planning bodies in the coordination of sectoral agencies and the determination of cohesive policy at successive levels of administration. Assessment of the way of working and effectiveness of River Basin Authorities.

Subsidiary issues might include:

- The level of intensity of competition for water at sectoral and regional levels. Assessment of the level of vulnerability to water scarcity at a national and regional level.
- Assessment of the performance of water supply systems for agriculture, urban and industrial use.
- Determination of factors of system performance in the areas of design, construction and management and the relationships between technology and management.
- Management of water quality and strategies for water conservation and re-use.
- The collection, analysis and provision of hydrological, water-use and socio-economic data relevant to water resources planning. The use of computer-based management models for technical management and economic evaluation of development and operational strategy: the quantity, relevance and quality of data provision.

- An analysis of winners and losers in past and present water resources management.

Formal Hypotheses and Objectives

Despite contextual differences, the pressures to reform water resources management in the developed country case-studies are similar to those now emerging in many developing countries, and there is little room for radically new responses. This experience will yield useful insights for good practice in Idcs and provide a platform for more comprehensive and informed analysis in due course. Although it may be harder to conceive of such direct inference to Africa, there are useful lessons for water resources development within a strategy of drought coping and preparedness.

The study will:

- Examine the root causes of inadequate institutional performance and capability in the allocation, management and planning of water resources prior to reform. This requires a detailed understanding of the present impediments to rational use and the historical reasons for this situation.
- Ascertain the long-term goals for reform.
- Examine the strategies proposed to achieve the transformation, and the success of those actually used, on a step-by-step basis.
- Assess the results in terms of allocative efficiency, equity and the enabling role of government.

Although it may be difficult to address these formal objectives with absolute clarity, the study should develop and synthesise understanding in four key areas:

- In analysing the patterns of change, what are the combinations and sequences of factors that facilitate change?
- What are the socio-economic, political and ecological reasons for significant differences in patterns of change between the case-studies?
- What are the similarities and differences that developing countries experienced at various stages in the past, to the present? Where does the transition occur from an interventionist to an enabling government

involvement in water resources management?

- What hypotheses can be made about the sequential action needed to bring about lasting reform and in-built adaptability to developing countries water resources management? How do complex management structures evolve in response to changing circumstances, and how can flexibility be built into an institutional framework, understanding that the situation being managed is essentially dynamic?

The Structure of the Paper – How to Use It

The problem of allocating limited water resources, and some international background, sets the tone for the study in the Introduction (Chapter 1). The following three chapters (2 to 4) provide a brief summary of water resources development and management in the western USA, Australia and Spain respectively. Case studies are presented to illuminate the detail of water resources allocation and management problems and analyse the responses made at different times in recent history.

The issues and findings that are common to all case studies, as well as their divergent experiences, are discussed in Chapter 5, and their implications for developing countries are drawn together in Chapter 6.

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The Western United States – From Wild West to Palm Beach Sunset, via the New Deal, Pork Barrel Politics and an Unholy Alliance of Reaganomics and the Earth Mothers

Federal Water Policy and National Development

In this chapter we look in turn at federal, regional (Colorado Basin) and state (California) water management, along a scale of increasing competition. Each stage incorporates the history of development, legislation and policy reform, and notes critical impact points such as drought, which are instrumental in stimulating reform. Technological solutions have alternated with institutional reform and attempts at demand management but the increasingly influential environmental concerns of the late 20th century now press for more fundamental reallocation away from well-organised and powerful agricultural interests.

Water and Federal Policy

From 1902 until the end of the 1960s, water development, principally for agriculture and western settlement, was heavily promoted by the federal government through positive incentive programmes, increasingly involving semi-autonomous federal agencies. The Environmental Protection Act (EPA) of 1969 marks a symbolic watershed in public attitudes to water development and subsidy for irrigators. Since then the United States Bureau of Reclamation (USBR) has transformed itself slowly into an agency concerned primarily with data collection, water regulation and electricity generation, although it retains considerable managerial responsibility for major infrastructure.

In 1980, total national withdrawals were estimated at 619 cubic kilometres, representing an increase of 1.7 and 1.22 times the amounts withdrawn in 1960 and 1970 respectively. Fresh surface water accounted for 64.4% of that total, 19.5% was from groundwater and 15.8% from saline surface water. Overall, industrial demand accounted for 57.5% and irrigation 33.7% of use. Consumptive uses and conveyance losses amounted to only 171.3 cubic kilometres, 27.7% of the total, of which 85% was attributable to irrigation.

Capital subsidy and state-led investment in irrigation and drainage infrastructure has gone hand-in-hand with incentives to achieve food self-sufficiency and export-led agricultural growth. Positive incentives continue to be used in environmental legislation and are favoured over federal regulation. Recent efforts have tried to harmonize agricultural production incentives and environmental management, especially where pesticide and fertiliser use impacts on water quality. Estimates of the extent of public subsidy vary, but Devine (1995) quotes researchers at the University of Colorado who have determined that USBR projects for irrigation and hydropower alone have cost the American taxpayer close to 20 billion 1986 constant dollars over the period 1902 to 1986, and that the total federal subsidy to irrigation was US\$2.2 billion in 1989. Flood control expenditures have cost the US Treasury US\$35–40 billion from 1960 to 1987 and annual subsidies to river traffic, mainly barges, account for billions of dollars each year (Devine, 1995).

The states have relied heavily on federal support for major capital projects, but have established a tradition of local financing of local works, particularly in metropolitan water supply. Although water allocation is a state responsibility, the federal government has wielded considerable influence both through leverage attached to subsidies and through provisions in the constitution that can be interpreted as relating to water rights and interstate trade. State water legislation tends to have been more regulatory, particularly in environment and water quality, but the recent Proposition 65 environmental code in California heralds a possible new phase, where government involvement in regulation is reduced and effectively 'privatised' by shifting the burden of proof of no harm to polluters and encouraging consumers to take legal action in cases of violation.

Nationally, in view of the status of irrigation as the environmentalists' whipping boy, a surprising importance was accorded to flood protection, in terms of the numbers (although probably not stored volume) of single-purpose dams constructed, especially post-1970. More recently flood control has given way to non-structural measures such as flood damage protection insurance, following the establishment of a Federal Insurance Administration, with responsibility for flood hazard estimation and public compensation (Magura and Wood, 1980). Recently, federal flood insurance has also come in for criticism, as its subsidies have been charged with both stifling private sector insurance and encouraging inappropriate levels of settlement in the flood plains of the nation. It is also charged that nearly half a billion dollars have been paid in compensation to repeat flood victims, accounting for only 2% of all policy holders, stimulating interest in resettlement options in place of reconstruction payments.

Frederick (1991) has classified different periods of US water resources development up to 1990. This could be the beginning of a new period of

reversal of previous water policy as food production takes on subsidiary importance to environmental allocation and fiscal responsibility.

Table 3 Phases in North American water development

19th century	the conservation period
1900–20	private versus public water exploitation
1921–32	growing federal role in water development
1933–44	reshaping the nation's waters for economic development, in tandem with the New Deal
1945–69	encountering economic and environmental limits
1970–90	meeting future water needs

(after Frederick, 1991)

Historical Landmarks

An outline of some of the legislation relating to water resources development illustrates how the policy environment has changed during the 20th century:

- 1902 The Reclamation Act boosted construction, with USBR becoming responsible for all major hydroelectricity projects. Pinnacle of its expertise is the Hoover Dam (224m) on the Colorado river, commissioned in 1936.
- 1917 Flood control programme begins under direction of US Army Corps of Engineers.
- 1933 Tennessee Valley Authority (TVA) set up by Roosevelt to revitalise the rural economy of Tennessee Valley, via construction of an integrated system of 32 multi-purpose dams.
- 1935 Soil Conservation Act, authorised the Conservation Technical Assistance Programme, operated in conjunction with nearly

3,000 local soil conservation districts. Technical assistance for drainage and levelling of wetlands up to 1977.

- 1936 Flood Control Act resulted in US Army Corps of Engineers taking a more active role in dam construction, following its earlier mandate (1928) to undertake basin studies. It also made urban areas that were liable to flooding eligible for federal grants.
- 1936 Agricultural Conservation Programme (ACP), authorised as an amendment to the Soil Conservation and Domestic Allotment Act of 1935, provided direct subsidies for the adoption of soil conservation technologies. The Small Watershed Programme of 1954 emerged from this.
- 1954 Watershed Protection and Flood Prevention Act broadened provisions of the Flood Control Act to agricultural land.
- 1960 Flood Control Act recognises need for a broader approach to flood management and requires Army Corps of Engineers to make information more widely available to other federal agencies, eventually resulting in the Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973, which stressed non-structural responses to flood problems. The best dam sites had been developed by end of 1960s, which partly accounted for the decline in construction activity.

Rising environmental opposition, such as to the Glen Canyon dam in the 1960s, symbolised the sea change in public opinion that used to consider large dams as monuments to man's conquest of nature and to modernity and economic prosperity.

- 1968 Wild and Scenic Rivers Act introduced to preserve habitats and amenities from development.

Congress passes legislation for the National Flood Insurance programme (updated in 1973).

- 1969 National Environmental Policy Act requires federal agencies to give full consideration to environmental impacts of all projects and shifts the burden of proof to the developer, who must demonstrate that the environmental impacts of any project are benign, and must take steps to mitigate adverse effects accordingly. It requires all federal agencies to prepare environmental impact statements and provide assessment of

reasonable alternative solutions, including the 'do-nothing' option. Originally the legislation was not binding on federal agencies, although they were supposed to 'pay attention to their findings in the decision making process'. More stringent and binding state environmental legislation has subsequently had a greater impact.

- 1972 Clean Water Act (Federal Water Pollution Control Act Amendments) empowers states to impose minimum stream-flow requirements in order to protect water quality.
- 1973 Endangered Species Act (ESA) becomes the single most influential piece of legislation affecting water control, invoked by US Fish and Wildlife Service to halt the Animas-La Plata project in the Colorado Basin, because it might have harmed the endangered Colorado squawfish (Frederick, 1994) (*Resources* 19).
- 1974 Safe Drinking Water Act makes water quality rather than water supply the driving force behind the nation's water-related investment.
- 1977 Clean Water Act amendment introduces incentives for land-based treatment of wastewater, adopted by 1,280 communities by 1982, 80% for irrigation (Postel, 1985).

Second national water assessment completed

- 1978 US Water Resources Council creates 18 water resources regions: nine covering 31 states in the east and nine covering 18 states in the west.
- 1982 Reclamation Reform Act signals the removal of subsidies for irrigation development and initiates the slow process of transforming the USBR into a regulatory, monitoring and planning agency. Vocal opposition from west-coast irrigation groups.
- 1985 Food Security Act authorises the Conservation Reserve Programme (CRP), a multi-objective programme designed to meet goals for agriculture supply control, water quality and wildlife habitat in addition to farm income and soil erosion reduction.

- 1987 Clean Water Act amended to manage non-point source pollution and includes a 50% grant to implement state-level groundwater protection activities.
- 1988 Modifications to Central Arizona Project (CAP) to encourage tree planting in catchments and on buffer strips running alongside streams in order to improve water quality.

Federal and State Jurisdiction

Although water is a state resource, federal influence has been substantial through massive injections of federal funds, particularly in western water development and long-distance transfers. There are three important aspects of the institutional, legal and political situation which bear on water transfers and inter- and intra-state water management:

- The constitution of the United States and the division of powers it makes between the federal government and the states
- The federal system of political representation
- Environment protection legislation

Although the constitution says nothing explicitly about water, the Welfare and Commerce clauses require congressional approval for interstate agreements and the subclause that states that Congress has a duty to provide for the general welfare of the United States has been interpreted by the courts as giving it authority to authorize large-scale public works projects.

Federal Congress also has the right to regulate interstate commerce and legal opinion has held (controversially) that water, like other natural resources, is a commodity. In 1983, the US Supreme Court reaffirmed this view and found that the federal government had the right to allocate water among the states (*Sporhase and Moss vs. Nebraska*). National government has largely left the regulation of water to the states, who have developed their own codes of allocation and use, conservation and beneficial use. Wyoming and New Mexico have both passed laws prohibiting interstate transfer of water to protect their resources from depletion and degradation, although such declarations can be declared unconstitutional if they clearly discriminate against interstate commerce. The federal government could authorise interstate transfers as water resources become more limited, by citing overriding national interest.

Intra-state diversions (such as those in California) do not involve the federal authorities unless they cross federal land, make use of reserved

water rights or require substantial federal funding. Historically, individual states and regional alliances have been very successful at obtaining federal investment in water projects because of alliances and trade-offs between congressional representatives of those states (two per state) and a quid pro quo in approval of public works projects. National level subsidy has been facilitated by two major federal agencies, the USBR and the US Army Corps of Engineers, and large-scale transfer projects may take place even if they are demonstrated to be economically unsound, providing they have sufficient political momentum (such as the Central Arizona Project).

However, Just (1991) notes that multiple legal jurisdictions over agriculture and water resources policies, particularly in the west, resulted in rising uncertainty for western farmers, and that the US Supreme Court (federal) has become increasingly influential in the resolution of the administrative overlap governing agricultural to urban water transfer. One of the more curious jurisdictions is that the federal Forest Service has responsibility for national water resources assessment (Guldin, 1989).

Environmental interests have extended federal influence over the states: federal institutions arbitrate between dissenting parties within states to enforce sound water management using the Endangered Species Act (ESA) and the Environmental Protection Act (EPA). Interestingly, little comment has been made on the cost (and hence construction interests) of retro-fitting dams for improved ecosystem management, such as equipment to enable the discharge water of different temperatures from different strata of storage to match required river temperatures for aquatic insect breeding.

Environmental Legislation and Beyond

The environmental battle is not over when new laws are passed. The dam construction era was really over by 1980, but the effects of America's 5,500 large dams are increasingly apparent. Many environmental activist groups (such as the Natural Heritage Foundation, American Rivers, or the Nature Conservancy) and academic researchers are providing increasingly detailed evidence of ecological despoilation and indicators of degradation. The long-ignored federal Fish and Wildlife Service has emerged as a new power in the water resources management arena and, it is argued, the Environmental Protection Agency wields far more influence than the construction agencies ever did in their heyday. The USBR has been challenged in court to implement Environmental Impact Assessments before renewing federal irrigation contracts, which is likely to encourage further land retirement (Postel, 1989).

The main reasons that extensive river regulation by dams results in loss of habitat and ecological diversity are that:

- the natural flow regime is altered, both at low and high flows, and the timing of flows is different from the natural situation to which the ecology had adapted;
- water released from storage has lower temperatures and higher concentrations of nitrogen compounds, whilst containing less oxygen (eutrophication); and
- sediment, required for river bed and bank stabilisation and the regeneration and/or supply of nutrients to downstream habitat, is almost entirely intercepted and stored in the reservoirs.

In fact, by 1989, all western states except for New Mexico had taken steps to protect in-stream flows and quality, including the recognition of environmental allocation as a 'beneficial use' (Postel, 1989).

The US has spent more than US\$500 billion on preventing and cleaning up water pollution since 1972 (Frederick, 1994), so the environmental costs have already exceeded the costs of subsidies in infrastructure by more than a factor of 10. Opponents of dams and river regulation also point out that aging dams, like the road infrastructure, are enormous fiscal time bombs. The Clean Water Act has been the prime mover in redirecting national water financing from construction to water quality, and section 404 was invoked by the EPA to veto about a dozen water development projects on environmental grounds. The Supreme Court ruled in 1994 that this act gives broad authority to impose minimum streamflows to protect water quality.

The ESA is having its greatest impact in the Columbia Basin, where dams have produced cheap power, enhanced recreational opportunities, irrigated millions of hectares and provided inland towns with ports with ocean access. These achievements have come at the expense of the Snake River and Columbia River themselves, which have been transformed from natural wild ecosystems into successive tiers of still-water reservoirs. The natural migration of salmon has been impeded and stocks have dwindled, and while there is broad agreement that decisive action is required to protect salmon, there is no consensus on what form it might take. Smolts are at present carried upstream in barges owned by the Corps of Engineers, and at the moment all proposed alternatives have significant drawbacks: an experiment to aid upstream migration by artificial spills was terminated when the resulting increase in nitrogen levels was also found to harm the fish. Another proposal involves lowering the reservoir water levels so that the flow velocity behind the dams more closely approximates that of a natural river, to aid smolt migration at critical times. The preliminary cost estimates for modifications amount to between US\$0.6 and 1.3 billion on four dams in the lower Snake River, exclusive of lost power, navigation and recreational revenues. The most extreme and probably beneficial solution

for the salmon would be to remove the dams completely; an unlikely option, but one that is under consideration on the Elwha River in Washington State. The Department of Interior is backing a call by local congressmen, conservation groups and native American tribes to remove two large hydroelectric dams, at a cost of between US\$140 and 235 million (Divine, 1995). Some federal licences for hydroelectric operators were issued as long as 50 years ago, and many are up for renewal. The Electric Consumers Protection Act of 1986 requires the Federal Energy Regulatory Commission to give equal consideration to power and non-power benefits and to re-award licences in the broad public interest. This procedure provides a new opportunity for environmental interest groups to voice objections and make alternative proposals, and signals a new period of institutional change, seeking to balance ecological values and developmental goals in water resources management (Frederick, 1994).

Environmentally aware approaches to water management have been under development for a long time. In the 1970s the US Fish and Wildlife Service proposed local strategies for in-stream flow management in Arizona (Nelson et al., 1978) and logging controls were introduced in 1979. It has taken this long for them to be more widely adopted because of both institutional arrangements that have historically favoured irrigators and the absence of a coherent federal–state–local government view (Isaacson and Fall, 1979).

The West

Settlement of the American west was stimulated by federal sponsorship of irrigated agriculture from 1902 onwards. The low rainfall (see Map 1) and desert-like conditions were overcome by massive projects that harnessed and moved water when and to wherever it was needed. Urban settlement and growth followed, and the population growth rate in the west was 22% for the period 1975–80, double that in the east (Micklin, 1985), and the west is now the most urbanised part of the country (MacDonnell, 1990). There has also been a substantial relocation of industries (for instance military contractors) from the east, and development of the electronic and high technology industries throughout the 1970s. Agricultural development has used both surface water and groundwater extensively, accounting for 77% of supply in Texas and 49% in California in 1980. The Colorado and the Ogallala aquifer supported over one-third of the total of 21 million ha irrigated in 1980 (Micklin, 1985).

Unconstrained development has resulted in total use exceeding average streamflow in almost every western sub-region (El-Ashry, 1991), and is responsible for water quality degradation, groundwater mining and depletion of in-stream flows. In 1986, 44% of renewable supply in

the whole western region was consumed, 90% by agriculture (El Ashry and Gibbons, 1986). Much of this consumption is on the 20% of western farming land that is on federal reclamation projects, where rights of delivery and storage are defined in part by long-term contracts with federal and private bulk sellers (Ingram et al., 1984). Worse assessments (Postel 1989) revealed that more than 4 million ha of irrigated land (a fifth of the national total) was supplied by mining groundwater in California, Texas, Nebraska and Kansas.

Competition between sectors and between states has existed throughout this century, but a cycle of development, over-exploitation, adjustment and new development is a result of continually rising population and urbanisation. The use of all local surface water was followed by over-exploitation of groundwater, which (as will be illustrated) sometimes led to voluntary institutional reform to mitigate overdraft. Long-range transfers of water, both within and between states, have expanded irrigation, substituted for groundwater and even recharged aquifers, particularly near expanding towns. In turn, the river regulation and conveyance infrastructure for inter-basin transfer has resulted in many of the environmental externalities that the region now faces: localised waterlogging, salinity, groundwater pollution and habitat loss.

The fuel crisis of 1973 had only a temporary impact on water consumption, as pumping costs rose as both energy costs and lifts increased. Despite a 30% fall in irrigated area in the Texas High Plains (Postel, 1991), fuel price impacts have faded and groundwater tables have continued to recede, continuing the trend of increased pumping cost. Overall, irrigated agricultural area has been declining in the west since 1979, as farmers have intensified to higher-value production, reverted to dryland farming or abandoned agriculture altogether, although even in the mid-1980s more than 70% of irrigation was applied to low-value grain and forage crops (El-Ashry, 1986). Water use per ha declined by 28% over the period 1974–87 because of the improved technology adopted with intensification programmes (Postel, 1991), but the overall impact on declining water tables has been minimal.

The current pattern of water use and the intractability of reform and re-allocation of water is held to be a result of a now inappropriate water rights system (see Box 1), designed initially to promote water development and protect settlers from speculative monopolists. This institutional framework has created powerful brokers for irrigators' interests, such as the major Irrigation Associations, as well as the smaller 'ditch companies' (irrigation supply companies) and other private and quasi-private utilities. 'Pork-barrel' politics and the associated corruption and rent-seeking of western water development arose out of an alliance of interests between business, politicians, constructors and the more powerful irrigators associations (see *inter alia* Reisner, 1986 and Repetto,

Box 1 Water rights in the Western USA

The western states subscribe to variations of the appropriative rights doctrine. It has two basic tenets, formulated by miners, ranchers and irrigators in the pioneering days of the 19th century, principally in California. The first is that seniority of use is conferred according to the historical order of development – also known as ‘first in time, first in right’. Seniority is such that junior rights’ holders may forego water supplies in times of drought until seniors have used their accorded share. Priority could also be lost by failing to develop water resources with ‘due diligence’. However junior appropriators were protected as senior users were prevented from changing uses in ways that harmed others. Seniority is complemented by the requirement of ‘beneficial use’ of water, where beneficial use was historically taken to be productive use for drinking water and sanitation, agriculture and livestock, navigation and industry. The notion also initially preferred private over public use. It is because of this development perspective that in-stream needs for wildlife, fish and recreation were overlooked (Matthews, 1994).

By contrast, the rights to groundwater followed riparian practice, derived from water law in the eastern states, and founded in English practice. The overlying landholder initially had an unrestricted right of abstraction but this unfettered right caused problems with the evolution of technology to extract substantial quantities of groundwater. Groundwater has since been brought under various systems of licences and permits, and in states such as California restrictions and conditions have been applied which recognise the public trust doctrine and emphasis public over private rights. Most western states have traditionally been reluctant to restrict private surface and groundwater rights.

The prior rights of the indigenous Indians were established in the ‘Winters Case’ of 1908, which exempted Indians from establishing the proof of prior use. The resulting ‘reserved rights doctrine’ has been used by the federal government to prevent individuals from controlling large tracts of land by monopolising a sole water resource (Herbert and Martinez, 1981). Federal claims on water must clearly show that the federal purpose of reserving land requires a water right. It has been used to adjudicate disputes in potentially damaging state-level water developments, such as those which would de-water a major river. A landmark decision in 1978 overturned New Mexico state legislation of 1973 that excepted Pueblo Indians from the provisions of the Winters precedent. The reserved rights doctrine (Masters, 1978) will find increasing application in the maintenance and restoration of in-stream and environmental flows, and has therefore generated some uncertainty about the quantities of water that might be claimed under this doctrine. However, to date, the federal management and control of water by this means is modest, for instance only 0.18% of the total diverted volume in the Arkansas River, Colorado Basin.

Prior rights and seniority have been modified over time in a number of ways: in the past senior users would have received their complete allocation by shutting off flow to juniors until they were satisfied. As measurement and control technology have developed, it has been possible to model the apportionment and provide a wider service accordingly (Balleau, 1988).

The appropriative right is specified at the point of diversion from an identified source, limited to a maximum designated flow rate. The total annual allocation is specified volumetrically, as its place and purpose of use, including the exact area, if for irrigation. The seniority and ownership (legal title) are perhaps the most important attributes contributing to the value of the right. The appropriative system protects traditional technology and does not allow rights to return flows – it is a right of consumptive use only. Neither of these characteristics provide incentives for improved technology and water conservation (Matthews, 1994).

American water law has developed in a piecemeal fashion over the last 150 years and has been strongly influenced by other developments, notably in environmental legislation. Calls for reform cite the following shortcomings (Davis, 1994):

- The system is not uniform among the western states.
- The law does not integrate surface, underground and atmospheric water law and is not in harmony with hydrologic reality.
- It fails to promote efficient water use and conservation.
- It is poorly adapted to severe droughts and water shortages.
- Provisions for change of ownership use and reallocation are insufficiently flexible.
- Regulation through the permit system is not integrated within the whole jurisdiction of water planning.

Water quality is not specified under Californian water rights legislation (Kanazawa, 1992) which provides further complications in promoting environmentally sound management and use and undermines the potential value of water right transfers.

Box 1: continued

Much recent discussion on economic reforms in water resources management has centred on the development of tradeable water rights, and the generally low volume of transfer and trades has been attributed to the institutional and legal impediments to transfer (Rosegrant and Binswanger, 1994). In California, holders of water rights, both prior and post the Water Commission Act of 1914 (which consolidated water rights and issued permits to use state-owned water) may transfer appropriative rights without approval from the State Water Control Board, provided that no other legal water user is injured (Rosegrant, 1994), and short-term (less than one year) transfers are exempt from compliance with the Californian Environmental Quality Act.

MacDonnell (1990) notes that most states recognise the ability to make changes to most of the elements of water right without loss of priority and that restrictions on transfer of ownership can be enforced with minimal state supervision, but that the process becomes more complicated when change of use is contemplated. Nunn (1990) asserts that much of the sound and fury over water rights and transfer originates from California, which she claims to be an example of institutional eutrophication. MacDonnell clearly demonstrates that California has the least transfer activity (three) but that in Colorado, Utah and New Mexico the number of transfers involving a change of purpose or place of use over the period 1975–84 was significant, with more than 3800 in Utah. The volumes transferred were generally small and mainly involved groundwater in Utah and New Mexico in contrast to surface water in California, Wyoming and Colorado. By contrast, the volume transferred in California was nearly 500 times greater than those in any other state over the period 1982–89. A complex pattern of change of use emerged from research, varying in each state, and agriculture to urban/industrial transfer accounted for more than 50% of transfers only in Wyoming and Colorado. Approval rates for transfer varied from a minimum of 70% in Wyoming to 93% in New Mexico and required 6 to 7 months in New Mexico rising to 20 months maximum in Colorado, where a specially constituted water court deals with all cases. The opposition rate to transfer is the highest in Colorado, with challenges made on 60% of the applications, followed by 50% in California.

McDonnell identifies the provisions to limit adverse third party effects as the biggest barrier to transfers of water right, and notes that decisions concerning public interest lie with the State Engineer or Water Commission, whose engineering staff are reluctant to assert their powers, being less familiar with water quality issues attached to rights and social impacts on communities. Nunn notes that third party effects are not trivial matters in the west and that many modifications to the practice of water law have been determined by urban centres drawing in water from their hinterlands to fuel economic growth.

Many states have placed restrictions on the transfer of surface and groundwater across state boundaries, and have been challenged by the federal government under constitutional provisions for non-restriction of trade between states. An interstate wrangle occurred in 1979 when El Paso (in Texas), sought to appropriate groundwater from aquifers in New Mexico and was barred by New Mexican state law. Its appeal under federal provisions was not submitted in time and the case has lapsed since then.

In the past few years, a working group of the American Society of Civil Engineers has sought to develop a model water code, rather two model codes, one based on riparian doctrine for the eastern states and one for the appropriative rights doctrine of the west (Matthews, 1994). It seeks to consolidate all the changes and provide a consistent law across the states. It is aimed at encouraging water conservation and easing the transfer process, while shifting the burden of proof that there are no harmful effects of transfer to the applicant. Temporary transfers would be expedited more swiftly and easily, and forfeiture of water rights is envisaged after five years of non-use, except in extenuating natural circumstances such as prolonged drought. The uniformity of legislation is designed to allow out of state transfers, but subject them to the same approval process and proof of no significant impairment to other users and third parties, particularly the effects of large inter-basin transfers on the economic viability of rural areas within a basin. However, the code is still weak on the substance of jurisdictional conflict and integrated management, although its backers intend to address this with a model interstate compact. The model code recognises the hydrologic links between surface, ground and atmospheric water and as a consequence requires the specification of water quality in the water right, and grant of permits will also require the analysis of safe yield, impacts on wetlands, in-stream water quality and contamination of aquifers, in accordance with federal and state environmental regulations. Minimum in-stream flows are also exempted from appropriation. The definitions of beneficial use are broadened considerably and the idea of economic efficiency is introduced by the rather ambiguous requirement of 'reasonable' use.

1986). There are parallels with developing country irrigation development, and the history of the ensuing reforms and initiatives are instructive.

The Colorado Basin and its Client States

A full, well-written and entertaining history of the politics, patronage and development of western water, especially that of the Colorado, can be found in Carl Reisner's *Cadillac Desert* (1986), but a brief sketch will suffice here.

- 1901 Valley of the Dead renamed Imperial Valley as stream diversions from the Colorado bring irrigation water to south-eastern California, and George Chaffey establishes a private irrigation trust.
- 1922 Colorado River Compact signed between six of seven basin states – excluding Arizona. Cooperation cemented through the promise of federal funding for the All American Canal and Boulder Dam, later known as the Hoover Dam.
- 1930 Total population in the western states reaches 11 million.
- 1935 Hoover Dam completed.
- 1936 Hoover Dam electricity generation begins.
- 1939 Beginnings of water conflict between California and Arizona over the Parker Dam, and the size of the allocation implied for Arizona by the Colorado River Compact.
- 1944 Secretary of State Cordell Hunt formally promises Mexico 1.5 million acre feet (maf) (1.85 million ML) set aside for it in the Colorado River Compact.
- 1949 United Western Investigation begins to undertake an inventory of all options for western water development, which ultimately yields project proposals such as the peripheral canal around the California Delta and the Klamath diversion from northern to southern coastal states. Opposition to north-to-south transfers within California becomes manifest, based in part around political rivalry between Los Angeles and San Francisco.
- 1950 California begins to 'borrow' unallocated upper basin water for Central Valley and Coachalla Valley irrigation projects, exceeding its entitlement of 4.4 maf (5.42 million ML).
- 1952 California's diversion climbs towards 5.5 maf (6.78 mML), prompting a US Supreme Court action *Arizona vs. California*.
- 1956 Colorado River Storage Project (CRSP) bill passed to supply irrigation to upper basin on the basis of massive cross subsidy from electricity (85% of costs). Total cost of US\$1.6 billion

- represented a subsidy of around US\$2 million per farm (Reisner, 1986).
- 1963 Supreme Court uphold Arizona's case on virtually all counts and its 2.8 maf (3.45 mML) entitlement remains intact.
- 1965 Glen Canyon Dam completed, as part of CRSP.
- 1966 Legislation passed to initiate the Central Arizona Project (CAP) interbasin transfer.
- 1968 Colorado River Basin Project (CRBP) Act passed to authorize federal funding for USBR to begin the CAP and a large number of other dams and transfers. Guarantee of Mexico's Colorado allocation becomes a matter of (rather ambiguous) national responsibility.
- 1985 CAP canal fills 'a man-made river flowing uphill to a place of almost no rain' (Reisner, 1986). None of the other five major projects in the CRBP have received funding.
- 1990 Population of southern California reaches 20 million.

The Colorado basin has seven member states – Wyoming, Colorado, New Mexico, Nevada, Utah, Arizona and California – and it runs more than 2,200 km from its sources in Colorado and Wyoming to Mexico, draining an area of 619,520 km². Originally a wild and untamed river with extreme variations in flow, it is now one of the most highly regulated rivers in the world, courtesy of 20 major dams including the amazing Hoover Dam. Its proximity to California and the scale of conflicting state interests has earned it a central place in the lore and substance of western water development. Indeed, the New Deal philosophy that emerged in the USBR under Strauss in the 1920s and 1930s was partly fuelled by the sense that the state should undertake large-scale water development to provide cheap water and electricity to rural settler communities who were not supplied or were charged exorbitant rates by private utilities (Reisner, 1986). The history of water development in the Colorado Basin is also a history of ferocious competition between two major federal agencies, the USBR and the Army Corps of Engineers. The misuse of public money became so obvious in the development of less important and marginally economic projects that congress finally prevented them from undertaking their more daring and grandiose super projects.

The Colorado Basin Compact of 1922 apportions equal annual shares of about 7.5 maf each to the upper and lower basin states, plus about 1.0 maf for evaporation and 1.0 maf to Mexico, although in 1986 outflow was still of the order of 2.8 maf. The apportionment was made on the basis of only 18 years of streamflow data, however, and that happened to coincide with a wetter than average period. The 17.5 maf annual average streamflow is now acknowledged to be an overestimate, and is thought to be 14.9 maf per year (from streamflow gauging) or 13.5 maf (from tree

ring data) over a much longer period (Ingram et al., 1984). The Colorado River Compact was the forerunner and model for interstate arrangements in other large river basins throughout the country.

Hydrological science has in fact been 'adapted' by interest groups to enhance or diminish average annual flow estimates to support construction or conservation measures. Similarly, USBR estimates of energy demand in the Upper Colorado Basin turned out to be much greater than the reality (Ingram et al., 1984).

The dividing point between the upper and lower basins is at Lees Ferry on the border between California, Nevada and Arizona, with 2.8 maf per year allocated to Arizona as a junior right holder to California. Since economic development in the upper basin has lagged behind that of the lower (mainly in California), water demand has been less than the allocation, with the result that unused flow entitlements go to the next most senior rights appropriator. In practice the lower basin states have made use of the theoretically reserved rights of the upstream neighbours, who have consequently followed a path of pre-emptive water development, mainly for use in relatively low value agriculture (El-Ashry and Gibbons, 1986), such as the Central Utah Project. The benefits of unused upper basin outflows accrue to the south in the form of reduced electricity costs, better water quality, irrigation, water supply and recreational needs. The policy of pre-emptive development has been widely criticised, but few options have emerged to circumvent the problem of usufructuary right rather than ownership of water by the upper basin states. The so-called 'double-dip' of subsidising irrigators to grow subsidised crops within the upper basin, when there are incentive programmes not to produce in other (un-irrigated) states has caused noisy Congressional indignation, but one with previous precedent in the era following European reconstruction after the Second World War. In the early 1980s the Galloway group proposed interstate water marketing to sell water rights from Colorado to San Diego (El-Ashry and Gibbons, 1986), without resolution by the end of the decade (Nunn et al, 1991). The basin is very close to full use of its water and further rounds of interstate wrangling can be expected as California starts the process of reducing its use to the specified 4.4 maf per year. The dilemma of the Colorado basin is an interstate one, which mirrors and is substantially driven by the rising competition for water between agriculture and cities (El-Ashry and Gibbons, 1986), within and across the states.

Micklin (1985) reported that the federal Water Resources Commission noted that Gila River Basin was the most stressed area in the lower Colorado and that it had estimated that as much as 243,000 ha or 63% of the area irrigated in 1975, would have to be taken out of production.

Institutional Issues

Helen Ingram is a long-time observer of institutional issues related to water allocation. As long ago as 1973 she concluded that 'under most circumstances an integrated and comprehensive treatment of water resources cannot be organised within the framework of a single integrated agency', because of the plethora of values at stake, notably those of the states, governors, and federal and state agencies. She notes that resource economists who fail to account for the restraints of political viability in their organisational recommendations risk disillusionment when those arrangements fail to perform. She is categorical in saying that political considerations cannot be sidestepped by granting regional organisations more formal authority, and that institutional development requires processes of negotiation and consensus, built on a framework that prevents the regional agency itself from being captured by particular interest groups (Ingram, 1973). The summary of reforms and privatisation of irrigation systems in the Columbia Basin, based on work undertaken by IIMI in 1992, is typical of many similar examples in other states including California (Svendsen and Vermillion, 1994).

Ten years on, Ingram and her co-authors (Ingram et al., 1984) were saying much the same thing:

'Some institutions favour the creation of formal organisations without careful examination of the incentives to which officers of the organisation may be subjected. The result is formalism but little capacity to deal realistically with situations that invite imaginative change. The assessment that makes a contribution will be one that examines how human beings are likely to behave and not how we hope they would behave'

'The realistic water resources scholar and practitioner will understand that institutional analysis, because it deals with complexities and dynamics, is time consuming, intellectually challenging and costly. It cannot be done "on the cheap"; it cannot be done with inadequate tools; and it cannot be purchased in "canned" form from work done elsewhere.'

They had far more to say about what 'stakes' or interests needed to be pulled together to negotiate successful regional management of water resources. The first two statements are expanded on below:

'The realisation that institutional problems in water resources development and management are more prominent, persistent and perplexing than technical, physical or even economic problems has fostered as much frustration as insight among analysts and planners...'

'The paradox of the importance of institutions versus the paucity of useful analyses...'

- Technically based demand-projections are notoriously speculative and unreliable. Nevertheless, private organisations have often been disadvantaged compared to federal ones in terms of pools of expertise and data, except where there is disagreement among technical specialists and agencies.
- Legal rules and arrangements are not the last word in an operative sense and need to be overhauled in the light of improved knowledge and changing values (the binding Colorado Compact was based on faulty hydrological assumptions). Over reliance on rules, especially overlapping state and federal ones, can result in faulty analysis and reform agendas.
- Everyone must be clear about the nature of economic power as represented by different interests, such as cities, power producers, irrigators, rural communities and industries.
- Everyone must understand prevailing public opinion and the values that are not captured in economic analyses, such as the value of agriculture (open space farmland) as an amenity.
- That control of organisational and administrative mechanisms can be wielded in a number of ways needs to be understood. Ingram associates the closeness of irrigators and their associations to the USBR with the fact that many high-ranking officials in the Carter administration had previously held posts in environmental groups prior to 1976.
- Old conflicts between rival development agencies have given way to new, broader and more complex ones between development and conservation organisations.
- Access to the modifying forces of institutional structures (Congress and the state legislatures) was not equal amongst interest groups at any particular point in the water resources history of the Colorado river. Different courts may have different leanings, the most obvious example being the environmental sympathies of the Californian Supreme Court. Federal and state courts had made considerable improvements in access during the 1970s though, allowing the individual to take on the state, albeit within the constraints of costs, legal norms, precedent, the risk of delaying actions and the legal tradition of considering cases on as narrow a legal basis as possible.
- Public participation had largely been conducted through the ballot box, both in elections and in referenda, and well-informed and

motivated private pressure groups had established the right to force public ballots on water resources issues.

Over those ten years the regional and national water management institutions took a beating at the hands of the environmentalists (not without good cause); they were captured by a group as powerful and partisan as that which existed in the earlier construction-dominated era.

In analysing how institutions could negotiate improved water management Ingram et al. (1984) highlighted intermediate facilitating actions, such as the introduction of full-cost pricing in irrigation systems before water markets are established. Sub-rosa water transfers (private transfers carried when such transfers were not actually permitted in law) between neighbouring irrigators are one example of a difference between the statute and practice of law which can point the way to more enabling action to achieve policy objectives. New institutions can be created within old ones (such as the state-sponsored drought water banks) or agencies can be transformed, such as the regulatory reorientation of the USBR following the Reclamation Reform Act of 1982 (Wallen, 1989). Expensive legal action, lobbying and land purchases could be avoided by negotiating settlements by indemnification, as the western Colorado oil shale companies did to purchase farm water rights.

Barriers to improved institutional analysis were both substantial and understandable, including the:

- reluctance to be involved in the politically sensitive mechanisms by which society allocates scarce values;
- perception by (implementing) agencies that they have no mandate to change or manipulate institutions;
- qualitative nature of institutional analysis;
- attempts by agencies to appear (a) to be uninfluenced by institutional considerations and therefore (b) to be even-handed to enhance public image; and
- lack of familiarity with the subject.

El-Ashry and Gibbons (1986) concluded that assessment of components is inferior to assessment of the sum of the impacts of water development at a basin level, although environmental effectiveness should match economic efficiency. Limits to supply development had almost been reached, ushering in a new era of demand management, where urban conservation was likely to be cheaper than new resource development.

Supply Augmentation versus Conservation

Inter-basin transfer

Western water development relied heavily on water transfers from the early days of west coast settlement in Los Angeles (see p. XXX [2.3]), and

returned to this type of water supply many times in the middle years of this century. Aggregate western water movement in the 1960s was estimated to be 22 km³, mainly from the Colorado (12.2 km³ in the Lower Colorado water resources district where consumptive and conveyance losses were 1.8 times the average annual run-off), including 5.5 km³ diverted to southern California (Micklin, 1985).

Basin transfers supplied plenty of low-cost water for irrigation and remedied groundwater stocks in urban and industrial zones of California and to lesser extent Arizona. The halcyon days of such projects were the 1950s to the late 1970s, ending with the Central Arizona Project, itself a testimony to the perseverance and power of lobby groups (Cortner and Berry, 1977). Studies continued into the early 1980s for south-western transfers from the Columbia River, but the EPA had prevented further environmentally harmful projects. The North American Water and Power Alliance proposals were opposed by Canada, and Texas' plans for water transfers were opposed by the USBR and the Mississippi River Commission and foundered on lack of public support for a bond issue to finance the state's contribution to estimated supply costs of US\$60–200/ML.

Alternative approaches to supply augmentation include the inconclusive experiments with cloud seeding to enhance precipitation in the Upper Basin (Agnew and Anderson, 1992; Micklin, 1985) and desalination. Desalination was already happening at more than 650 municipal and industrial sites throughout the United States by 1983, but it is just too expensive for general application. It is increasingly considered for treating salt-affected fresh waters, which is cheaper than seawater treatment.

Urban water conservation

When irrigated land supplied by the Salt River Project was settled as Phoenix expanded, overall water consumption was expected to fall by 50%, but remained the same as before, largely because of excessive garden and public amenity watering (Wehmeier, 1980). Engelbert (1979) estimated that city gardens were being overwatered by 40% in the late 1970s, and called for water conservation policies.

Urban conservation technology now minimises consumption by toilets, showers and household appliances. Adoption of technology has been stimulated by water pricing tariffs (inverted block structures and attempts at marginal cost pricing) and by uprating building standards for new housing since 1980, in many of the western states. Subsidised retrofit packages and inducements and reliable automated watering equipment have had a major impact. The 'Beat the Peak' demand management campaign in Tucson, Arizona, in 1976 reduced maximum demand by 25% over May–August and resulted in a hangover reduction

of 13.3% in the following year, sufficient to defer construction of a new well-field by only three years (Ingram et al., 1982).

Gibbons (1986) outlined approaches to valuing water in different uses and summarised the limited economic intelligence on the elasticity of demand of municipal water supplies (see also Winpenny, 1992). This information and subsequent evidence indicated that 'cool' season and temperate zone water demand is used predominantly within dwellings, and it is price inelastic and not responsive to price-led demand management initiatives. There is some inconclusive evidence, however, that dry season water use for gardening exhibits price elasticities of between 5 and 8% (a reduction of 4 to 7% in demand for a 10% price increase).

Industrial water conservation

There has been a revolution in industrial water use efficiency throughout the USA over the past decade (Water and Environment, 1995), with reductions in water demands for industrial processes themselves, as well as substantial wastewater treatment and recycling. There has also been extensive re-use of cooling water and improved technology requiring lower flow rates and more controlled temperatures in return discharges.

Conservation of water in agriculture

Water conservation in agriculture is more complicated: overhead (sprinkler, rain-gun and centre-pivot) and micro-irrigation (drip and spitter) technologies can conserve water if properly managed, but usually require a change to higher value cropping systems to cover their increased capital and running (notably energy) costs. Field crop producers in some areas, (notably the Texas High Plains, Colorado and New Mexico) have adopted a range of high- performance surface irrigation technologies (Broner and Liebrock, 1994), such as surge flow, cablegation and cutback furrow irrigation, in conjunction with recycling systems, there is some evidence that surge flow is the most cost-effective option. Conservation tillage practices adopted in Texas were reported to have made beneficial impacts in both irrigated and rainfed farming (Postel, 1985). Improved scheduling, automation and more efficient on-farm conveyance all contribute to water conservation, but require high levels of management for even modest gains. Revised crop patterns using less water-intensive species and cultivars may help, but evidence is very patchy to date.

But there is no sign that on-farm water savings are translating into system- wide economies that allow transfer of water to other uses: new techniques may not reduce seasonal water use, but may ensure that a greater percentage is used, increasing productivity. There may also be benefits in reduced accessions to groundwater-mitigating salinity problems. Efficiency improvements may simply allow individual farmers

to reallocate water on-farm and either irrigate larger areas or improve the match between demand and supply and increase productivity through increased consumptive use on the same area. Savings on one farm may simply remove a source of return flows that were previously used by neighbours, both close by and further down the water system (Keller et al. 1990). Up-stream efficiency improvements in non-consumptive use also have marginal impact as the return flows are largely available to downstream users.

Substantial land retirement has occurred in California, Arizona, Kansas. In the Texas High Plains land use peaked in 1974 and declined thereafter (Postel, 1991): 14% of the gross land loss (678,000 ha) occurred between 1978 and 1982, where groundwater mining supported 40% of all US grain-fed beef production (Postel, 1985). Land retirement is one of the few clear cut ways of measurably saving water for groundwater mitigation or for re-allocation (Ervin, 1991).

Augmentation versus conservation

Curiously, the choice between supply augmentation and conservation is not a clear one, as is shown with the cities of Phoenix and Tucson in Arizona, and will be illustrated in the more detailed discussion of California later. In Arizona, rainfall averages 280mm annually, slightly higher in the Central Highlands Province, where the state's groundwater reserves are recharged. Groundwater mining has been extensive since the 1940s but the innovative Arizona Groundwater Management Act of 1980 has stipulated that there should be zero overdraft by 2025, resulting in the installation of a meter on every well head in the state (Charles, 1991).

Although the Central Arizona Project has supplied water for agriculture since the late 1980s and recently began supplies around Tucson, the water is more saline than groundwater and more expensive, due to the cost of treatment to potable standards, and despite massive federal subsidy in both construction and day-to-day pumping and operation. Although per capita demand in Tucson has been falling (9% per annum was the peak year over the past 18 years), it will still be hard pressed to meet the zero overdraft target by 2025. That groundwater reserves are still 15 times the total consumed by the city so far may have lessened the urgency of meeting the target (Charles, 1991), and the city has purchased 8900 ha of irrigated land in the Avra Valley for its water right alone since 1976.

The Active Management Area, under the control of the city council, experiments with different price rates and block structures to control demand, worked out in conjunction with a citizens' advisory committee (*Water and Environment*, July 1995). These aimed to minimise summer use whilst simplifying administration and improving fairness: because of public opposition, a two-band excess use higher rate structure has been replaced by a simpler three-block inverted rate structure which operates

throughout the year. Over the period 1975–95, however, average costs to the consumer (230–240%) have risen less than supply costs (260%) and winter consumption has increased by 2%. What proportion of these improvements can be attributed to pricing, conservation technology and changed habits is unknown. Garden watering may have diminished significantly thanks to 'xeriscaping', an alternative landscaping philosophy that makes use of indigenous xerophytes such as cacti. During 1988 alone, the two cities of Tucson and Phoenix purchased 232,800 ha of neighbouring farmland to obtain its water right to augment supplies (Postel, 1991).

Phoenix uses 25% more water per capita than Tucson – more than 800 lpcd – and has also experimented with complicated multipart water tariffs. They too have returned to simple and more uniform structures, so that now industry, residential and commercial properties all pay peak charges through the four-month summer period, off-peak rates in winter and a unit rate in the transition periods in spring and autumn. Overall monthly charges increased by 335% between 1975 and 1995 (*Water and Environment*, July 1995), whereas costs have gone up by only 260%. Average summer water consumption has declined by 30% and average winter use has also dropped by a quarter, although the early 1990s have been wetter than average and the longer term pattern may be slightly less optimistic.

Santa Fe County in New Mexico adopted a land use zoning policy, after public consultation, to set ceilings on development density according to the availability of water. However, the plan explicitly allows for the exhaustion of groundwater over the next 100 years and over 40 years in urban areas, on the assumption that there will be alternative sources, augmentation or wholesale land retirement in agriculture in the intervening years (Wilson, 1983).

The Arizona experience with price led demand management has shown that it is difficult to obtain public support for penalty rates to curtail usage except in drought periods and that gradual implementation of conservation-oriented rate structures that appear to be fair and reflect the costs of provision (*Water and Environment*, 1995).

Environmental Impacts of Surface and Groundwater Development

Surface water development, especially long-range transfers, is closely tied to the historical pattern of local development, over-use and in some cases exhaustion of groundwater. Groundwater mining is a policy of the past that was thought to be reasonable given that large surface water transfers could be effected to either stabilise aquifers or substitute for their supplies. Augmentation is no longer an option, and the environmental impacts of groundwater degradation from industrial and non-point

source agrochemical pollution prove the need for sound groundwater management. Degradation of surface water and increasing demands for environmental allocation mean that existing quantities of transfer water may decline in the long term. The interconnections between surface and subsurface hydrology are becoming increasingly well understood, often leading to more conservative water supply strategies.

Upstream environmental impacts in the Colorado Basin arise from the massive inundation behind the major dams – loss of free flowing streams and associated recreation, sediment trapping, salt concentration and thermal stratification of stored water. Downstream, flow modification has altered river morphology as well as habitat and ecosystems, due to reductions in sediment load and changed nutrient and chemical levels and temperatures of the in-stream flows. Although the sediment load downstream of Glen Canyon Dam has decreased from 140 million tonnes per year to 20, the concentration of total dissolved solids has increased, due to complex interactions between hydrochemistry, phytoplankton, diagenesis and temperature (El-Ashry and Gibbons, 1986).

The major problem is salinity: contributions from the naturally saline Glenwood Springs are greater than 500,000 tonnes/yr, or about half the average annual load to that point. Irrigation in the Grand Valley contributes about 179,000 ML of seepage to groundwater and with it, 780,000 tonnes of salt annually to the Colorado, which is equivalent to an increase of 77 mg/l at Imperial Dam. The impacts of salinity are felt predominantly in the lower basin, both from natural accession of salts due to hydrogeological continuity with naturally saline strata and aquifers, and from irrigation practice. The steady increase in upper basin water use has also resulted in reduced downstream dilution, which has enhanced concentrations and the severity of the problem (Keys, 1979). Damages per mg of salinity were estimated in the lower basin at Imperial dam over a range of concentrations from 900 to 1,400 mg/l. At 1979 prices, these costs averaged US\$33,100 per mg over the basin, rising to as much as 112,000 US\$/mg for urban damages. The estimated losses in the Imperial Valley were US\$33,100/mg falling to 11,200 in central Arizona (Anderson and Keinman, 1978). Other estimates computed total costs in 1982 to be US\$113 million and they are expected to double in real terms by 2010 without mitigation (El Ashry and Gibbons, 1986).

The USBR undertook a massive programme of civil and on-farm works designed to mitigate salinity, which attracted strong criticism from writers such as Gardner (1988), who doubted both the economic efficiency and the extent of claimed benefits. These works included diversion of rivers around naturally saline areas, construction of desalination plants, and measures to prevent canal seepage, such as lining with concrete, with a price tag estimated in 1984 to be US\$280 million. They noted that land retirement in the upper basin had the most significant impact in controlling salt loads. A sub-basin study concluded

that improved agricultural water efficiency and the adoption of dry-cooling techniques in power stations would only reduce salinity levels by 5% in the upper basin and 4% in the lower reaches (Gilliland and Fenner, 1981). Salt taxes have been proposed (Stevens and Vaux, 1990), but opposed (Gardner 1988) on the basis that it is almost impossible to quantify the contribution from any given area, and it may even be difficult to attribute this to an identified polluter. In any event, salt taxes have not transpired and the following anonymous quote summarises the current situation, little changed over the past decade: 'the upper basin is entitled to pollute, the lower basin is entitled to acceptable water quality and the federal taxpayer is entitled to pay the bill'. El Ashry and Gibbons (1986) called for concerted action by the member states, but little response has been made in the last decade. Water quality is an additional complicating factor in the development of water markets and the specification of water rights required to support intersectoral transfer.

Water Markets and Reallocation of Limited Water Supplies

The development of water markets has become a popular topic over the last 15 years (Quirk, 1979) and is currently being promoted for developing country water management on the basis of conflicting and incomplete developed country experience. Economists see water markets as a natural means of allocating an increasingly scarce resource, and environmentalists have thrown their weight behind them as a likely means of staving off more water development and dam building. Water markets are proposed as one way of overcoming the institutional complexities of water re-allocation from low value (agriculture) to high value (urban and industrial) uses and side-stepping many of the organisational impediments noted by Ingram et al. in the preceding sections. The activities that are deemed to constitute market transactions are:

Within agriculture:

- informal water swaps and one-off sales between irrigators;
- temporary seasonal transfer by sale; and
- permanent transfer by sale.

Between sectors:

- temporary seasonal sale to alternative user, utility or 'water bank'; and
- permanent transfer of water entitlement to a different use and location.

It is only the fifth form of transfer that makes any meaningful contribution to long-term water reallocation and satisfaction of rising urban and industrial demand. Much has been claimed for the potential

of market-based transfers (Rosegrant and Binswanger, 1994), and both proponents and detractors have pointed to the low number of transactions and volume of water transferred to date. Proponents have made detailed analyses of the legal and transaction cost impediments (discussed in more detail on page XX [2.3]) and of the inappropriateness of the prior appropriative rights system for market transfer. The major objection that exercises dissenters is the possibility of monopoly control of a vital and natural monopoly resource resulting in severe misallocation between the 'haves' and the 'have-nots'.

Enabling conditions for market transfer include:

- the allocation and registration of individual or group water rights, with good administrative machinery (Simpson, 1994);
- a good existing water allocation and regulatory structure;
- a clear distinction between consumptive and return flows;
- minimal attenuation in the specification of water rights;
- sufficient measurement capacity to be able to quantify savings and record transfers; and
- a suitable infrastructure for transfer and where necessary storage.

It should be evident that in any late 20th century political environment, the protection of adverse third party impacts will remain a priority on political, rural equity and ecological grounds, and therefore all transfers will be subjected to a measure of scrutiny, the costs of which will be born by the buyers and sellers. The economic characteristics of water present considerable natural barriers to development of a conventional market (see Turrall, 1995), with the result that market-like institutions are more likely than a completely unfettered, regulated and fully informed market. Young (1986) has suggested some reasons for lower than anticipated volumes of intersectoral transfer: the transaction costs of storage and conveyance, negotiation of contract and assurance of no damaging third party impact imply a differential in values of water use that is much greater than at present exist. He suggests that water values in irrigation are capitalised into land values, about which many farmers take a long-term view, and are therefore not inclined to sell at what seem to be favourable prices. There appears to be a particular problem of market intelligence and valuation of irrigation water in this sense; MacDonell (1990) noted that in studies of Colorado Basin water marketing it was easy to establish the administrative transfer costs of water, but almost impossible to determine the actual sale price of water right, even when a change of use was registered. Nunn et al. (1991) suggested that one way of improving the level of market activity might be for non-government, private and state level organisations requiring re-allocation of water for recreational, in-stream and ecological purposes to get involved in the purchase of water rights from irrigators.

California apart, there appears to be substantial if low-level water transfer throughout the Colorado Basin and its neighbouring states (as indicated in Box 1) and more investigation of the practice rather than the theory of water markets would be useful. Twenty years of market activity in the lower Rio Grande, Texas, has resulted in significant volumes sold to municipalities (Chang and Griffin, 1992) and net municipal benefits have been estimated to far exceed agricultural costs. In the seven counties making up the Arkansas River Valley in south-eastern Colorado, large transfers have occurred to urban use with minimal loss to agriculture and the economy at state level. There have been considerable uncompensated costs imposed on local economies (Howe et al., 1990), however, and other consequences include accelerated wind erosion, reduced options for land use and reduced agricultural productivity (Sutherland and Knapp, 1988).

Livingstone (1987) noted substantial secondary effects on rural employment and diversity by water market transfers in Colorado, although the sellers were compensated well. Water rights owned by distribution organisations in Colorado must allocate shares to their members, which partially protects irrigators, but if the dominant shareholders are non-agricultural, farmers must rent water. There are signs that this is causing a decline in agricultural production and Thompson (1987) cites declining irrigated areas and an increasing proportion of small farms as a percentage of total farms. Farmers remain in production if they can retain their existing water rights or shares and if they can finance costly new water conserving technologies. Livingstone (1987) suggested that sequential salvage and re-use schemes might offer a better balance in satisfying urban demand whilst preserving the agricultural economy, but that the increased costs to municipalities effecting transfers might be worthwhile in the longer term to maintain a more diverse economic base.

In certain instances fallowed land must be kept watered, even if there is no cropping, to prevent dust storms from wind erosion, as happened in Phoenix and Tucson in the early 1980s. The Arizona land rush resulted in more than 500,000 ha being purchased entirely for their water rights, and has been termed water farming. This land grab was prompted by the Arizona Water Resources Department requirement that new residential and industrial subdivisions should have secure water right for at least 100 years, if municipalities were to have any chance of growth beyond 2001 (Charney and Woodward, 1990). Water market proponents have decried land purchase for water rights as economically inefficient, but an alternative point of view is that the true value of agricultural water (its capitalization in land value) is accounted for. It is clear that some form of land stabilisation costs must be born as part of the transaction. Charney and Woodward say that because of the clustering of the sale points of rural to urban transfer, state-wide impacts on agricultural

productivity and the economy were not significant, even though localised impacts were. They argue that there is indeed a high economic return to such transfers and that this should entertain the possibility of compensation of third party effects, whilst noting that the loss of autonomy and reduced livelihood options associated with loss of water right is very hard to value. Thompson (1987) found that it was increasingly difficult for new agricultural producers in the urban periphery to obtain rights to water.

Some valuation studies do not show agriculture as being a low value use of water; trade-off analysis in Idaho valued returns to agriculture at US\$200 per acre-foot compared to only US\$8 for hydroelectricity generation (Long, 1990). Market values for water have been estimated in the states using the Ollagalla aquifer by calculating price differentials between sales of irrigated and dryland farms in New Mexico, Colorado, Kansas and Nebraska (Torrell et al., 1990). Water value accounted for 30 to 60% of the farm price, but this analysis is complicated by a trend of falling land values since 1983 and considerable variation in values ascribed to water, ranging from US\$1.09 to US\$9.5 per acre foot – low values by any standard.

California and Southern California

History

California has generated the largest amount of literature on water in the western states and represents perhaps the most complex situation. This has also resulted in a bias in the literature, however, that gives an incomplete, even distorted picture of the management of water in the west – especially with respect to water markets and enabling conditions for successful reallocation by water marketing (MacDonnell in East–West Centre project paper, 1991).

California typifies some aspects of developing country situations – rapid urban growth and industrialisation simultaneously with agricultural growth based on irrigation. Apart from Northern California, there is a widespread deficit in water availability compared to current use, which is largely supported by three sources of inter-basin transfer.

Institutional reform and innovation has received a new stimulus following severe and prolonged drought in a complex setting, now made more intricate with the rise of environmental activism supported by powerful state and federal legislation. A potted history of some landmark events in Californian water:

1870s Truckee-Carson water brought from Nevada to San Francisco – a forerunner of the Central Valley Project (CVP).

- 1904 Los Angeles City Water Company becomes the Department of Water and Power.
Work begins on the Owens Valley irrigation project and diversion on the Owens river and plans for water transfer to the city of Los Angeles.
- 1905 Chaffey's diversion channel in the Imperial Valley is silted up and not operational.
- 1907 Owens Valley Project annulled, leaving a large water allocation for the city and some residual water for a few large landholders who had taken over the land allotted for homesteaders under the reclamation project proposal (Reisner, 1986).
- 1913 Los Angeles city receives its first water supply from the sources in the Owens valley 400 km away.
- Paiute Indians seek water rights allocation in Truckee–Carson dispute in Federal Courts, especially in respect of Newlands irrigation district. Saga of claims and counter claims (eventually including urban and agricultural demand in Reno-Sparks area) begins – not resolved until 1990.
- 1914 Water Commission Act registers appropriative rights and issues permits and licences through what has now become the State Water Control. Board
- 1923–27
Drought and Owens Valley water 'war', including dynamiting of aqueducts and siphons built to take water to LA.
- 1935 LA is landlord of 95% of farmland in the Owens Valley and 85% of small town property.
- 1935 USBR begins work on the Central Valley Project (CVP) to transfer water from northern to southern California, as Depression prevents state from financing this scheme under the State Water Plan. CVP now deliver 4 million ML per year for irrigation in 1994.
- 1946 Central Valley Project (CVP) completed.
- 1949 Water master appointed to oversee legal settlement of groundwater sharing arrangements in Raymond Valley, southern California.

- 1950s California already using its entire allocation of 3.57 million ML from the Colorado.
- 1957 Department of Water Resources launches the first California Water Plan to address maldistribution of water resources, and eventually results in the State Water Project (SWP).
- 1960 SWP approved, just, by voters and leads to successful bond issue for US\$550 million in addition to US\$1.75 billion guaranteed under the Burns–Porter Act of 1959.
- 1973 State Water Project begins supplying 3.8 million ML per year to San Joaquin Valley (63%) and southern California (31%).
- 1976–7 Drought
Metropolitan Water District (in Southern California) reduces wholesale deliveries to contractors, launches an intensive media campaign to promote conservation and introduces a surcharge for water consumption that exceeds prescribed limits.
- 1979 California Water Policy specifies that water must be used for fullest beneficial use and that waste and unreasonable use and methods should be prevented.
- 1980 Water Law amended to allow right of sale of conserved and salvaged water.
- 1982 Public referendum defeats construction of the Peripheral Canal, an extension to the SWP around the Sacramento–San Joaquin Delta, the Peripheral Canal, mainly due to opposition in northern California: signals end of large-scale long-distance water transfer projects.
- 1984 Area of origin protection or ‘public trust doctrine’ granted to water sourced from eight areas including Mono Lake.
- 1985 Selenium hazard from irrigation water diagnosed at five wildlife sanctuaries and enters public debate (Postel, 1992).
- 1987–92 Drought
- 1987 California Water Plan Update
Metropolitan Water District (MWD) and Imperial Irrigation District conclude agreement to line supply canals on return for share of conserved water.

- 1989 Legal injunction prevents LA Department of Water and Power from abstracting Mono Lake water, describing it as a national environmental and scenic treasure: LA deprived of 15% of its existing water supplies.
- 1990 Truckee–Carson Settlement Act
50% reduction in water deliveries to agriculture, not expected to seriously affect state-wide crop production.
- 1991 Water Code Amendment specifies five yearly review of water plan and policy.
First emergency drought water bank.
- 1992 California Water Project Improvement Act reallocates more than 1.23 million ML of CVP water supply for fish and wildlife.
Second emergency drought water bank.
- 1993 US Fish and Wildlife Service lists Delta smelt under the ESA, resulting in moratorium on water transfer through and out of the Delta.
- 1994 Third emergency drought water bank.

Setting and Background

Most water resource replenishment in California occurs in winter, in the north of the state, whereas most of the demand is in the south in summer: 73% of the run-off occurs north of Sacramento and 75% of the state's use occurs south of this point (O'Mara, 1988). Nearly 4.1 million ha of irrigated land and extensive metropolitan settlement obscures the fact that most of the state is desert with annual rainfall ranging from 76 mm in the south-east to 483 mm in Sacramento. The population more than doubled between 1950 and 1980, reaching 20.8 million at the end of that period, with two-thirds in the south. Urban growth was accompanied by an increase of 38% in the irrigated area. Groundwater abstraction accounted for 50% of all use in 1950, but had declined to only 24% by 1980. State-wide groundwater storage is estimated to be over a billion megalitres (ML) in 450 defined basins: although this represents more than 100 times annual groundwater use, less than half is usable due to cost and quality (DWR, 1993).

Approximately 20% of the water used in southern California is generated within the area of use and long-distance transfers supply the balance: 57% from the Colorado, via the Colorado Aqueduct from the Parker and Imperial Dams, and 15% from the State Water Project. A

complex and comprehensive hydraulic infrastructure has been developed that allows water to be transferred from north to south and from east to west and has allowed the dramatic increases in population, irrigated agriculture and standards of living (Keller et al., 1992) The enormous federally funded Central Valley Project transfers northern water to the San Joaquin and Sacramento valleys, the largest single irrigated area in the USA.

The first California Water Plan was conceived by the Department of Water Resources in 1957 to move water from north to south. It resulted in the State Water Project, which was developed to transfer water to the San Joaquin Valley and southern San Francisco Bay area in the 1960s. Water deliveries extended to southern California in 1972, although by 1983 little more than half the ultimate planned delivery was covered by contract commitments, and initial deliveries were not sufficient to restore overdraft in localities such as Kern County and south San Joaquin Valley.

The 'imperial state', as Reisner dubs it (1986), has experienced several cycles of localised water development, water transfer and recharge, and repeated over-use of ground and surface water. This has been addressed in the short term by some demand management and organisational reform measures, followed by further rounds of large-scale water transfer, as is illustrated in the historical summary above. This cycle has been in part due to that fact that the state has no water policy that integrates surface and groundwater (Keller et al., 1992).

California is now entering a phase where supply augmentation is no longer a cost-effective or environmentally acceptable solution, and multiple re-use of water at a basin scale is increasingly common (what Winrock refer to as a 'closing water system' (Keller et al., 1992)). As a consequence, users are becoming increasingly interdependent and conscious of the importance of efficiency. Management improvements may have system-wide impacts but system-wide management needs flexible alternatives and the reallocation of water between uses becomes increasingly important, with inevitable consequences for established uses and their water right holders.

Water reallocation for environmental use, coupled with decreasing supplies of transfer water from the Colorado Basin (as Arizona and Nevada make full use of the remaining 740 mML/yr of their allocation) mean that agricultural and urban demand are in increasingly severe competition.

A water balance for 2020

Some consideration of the details of the present water balance and the pressing demands being made on it is essential background to the process of policy development and management reform in California. The state Department of Water Resources (DWR) estimated that the total supply for 1990, shown in Table 4, would rise to an average value of 80.4

Table 4 California water supply with existing facilities and programs

Supply	1990	
	Average	Drought
Surface:		
Local	10.1	8.2
Imports by local agencies ¹	1.0	0.7
Colorado River	5.2	5.1
CVP	7.5	5.0
Other federal	1.2	0.8
SWP ¹	2.8	2.2
Reclaimed	0.2	0.2
Groundwater	7.5	12.2
Groundwater overdraft	1.0	1.0
Dedicated natural flow	27.2	15.1
Total supplies	63.7	50.5

¹ 1990 SWP supplies are normalized and do not reflect additional supplies needed to offset reduction of supplies from the Mono and Owens basins to the South Coast hydrologic region.

million ML in 2020, somewhat less at 62.8 mML under drought conditions. The state policy continues to emphasise the decrease of groundwater overdraft state-wide, which has been making steady progress from 2.5 mML/yr in 1980, to 1.23 million in 1990 and targeted to fall between 0.577 and 0.86 million ML/yr by 2020, depending on the package of water conservation programmes implemented (DWR, 1993).

The total population is expected to rise to 40 million by 2020, most growth continuing to be in the southern part of the state, and urban demand is expected to increase by 61% in average and drought years. Net urban water demands are expected to rise by the same proportion to nearly 13 million ML in a normal year and about 4% more in a drought year.

By contrast, total irrigated area is expected to continue its gentle decline, from a net area of 3.7 million ha in 1990 to 3.56 million ha in 2020, compared with a peak historical value in 1980 of 3.85 million ha. The associated fall in irrigation demand only assumes 1990 level conservation measures, so that 2020 demand will fall by 2.5 to 2.96 million ML per year to around 36 million ML, less than three times the total urban demand. The impact of commodity price changes and world markets interactions have been factored into the prediction procedure.

The extent of increase in environmental demand is unknown in the wake of the Central Valley Project Improvement Act, but was expected to increase only marginally (1.1 mML) to 36.4 mML in an average year,

on a par with agricultural use. On the same, now optimistic, assumptions, predicted environmental allocation falls considerably to 21.33 mML in a drought year. However, the total predicted demand of more than 82 mML is very sensitive to that actual future level of increased environmental allocation, modelled by DWR in the range of 1.23 to 3.7 mML/yr.

Two packages of conservation options have been considered to meet the 2020 demand (DWR, 1993) based on detailed analysis of options with proven technology and mechanisms and a rather more speculative package of less well-tested possibilities. The first category of packages assumes *best management practice* in urban water management based on a suite of incentives to reduce demand and adopt conservation measures (see Box 3). It also envisages the adoption of efficient water management practices in agriculture.

Without any of the conservation packages, the projected deficit will be 2.7 to 9.6 mML/yr depending on the additional water allocated to the environment to a marginal surplus of 730,000 ML/yr in a normal year and more than 4 mML in a drought year. Implementation of the second level conservation options would, in theory, result in more robust margins of safety in this finely judged water balance. The point of sharpest focus for imbalance between supply and demand is in southern California, where current supplies from local and three transfer sources amount to 9.55 mML/yr, with no further signs of augmentation (Keller et al., 1992).

Local water supply and demand issues loom large in the implications of the state's water balance; for instance declining Colorado supplies are off-set by greater deliveries from enhanced flows in the SWP.

The major *uncertainty* affecting engineering (and alternative) solutions to improved water distribution and conservation centres on the limits to water exports from the Sacramento–San Joaquin Delta, from which two-thirds of the population and millions of hectares are supplied. The proceedings of the 1992 State Water Resources Control Board's (SWRBC) public hearing and subsequent EPA intentions to promulgate new standards for water quality and supply in the delta and bay area, promise more stringent limits on the export capacity of water from the delta. In 1993, CVP deliveries from Delta exports were restricted to 50% of contracted supply to federal bulk sellers from Tracy to Kettleman City. The old engineering 'solution' to enhance supplies in the southern part of the state by bypassing the Delta with the 'Peripheral Canal' must now be as extinct as the dinosaur it metaphorically resembles, even though it is claimed it could supply better quality water a judicious ecological moments and actually improve the Delta's ecology (Rosegrant, 1994).

Box 3 Water pricing initiatives in the Metropolitan Water District (MWD), California

The MWD is a public water wholesaler that currently services 27 member agencies comprising 10 bulk suppliers and approximately 250 retailers who, in turn, provide domestic and industrial supply to 15 million people living in 239 cities and the surrounding rural areas. MWD services half the population of California, in an area with a high annual population growth that averaged 200,000 through the 1970s and rose to 300,000. The number of dwellings is rising at a faster rate, with average occupancy expected to fall from 2.85 to 2.69 over the coming 20 years.

The MWD was created in 1928 by public vote in 13 Southern Californian 'founder' cities to construct and operate the Colorado River Aqueduct. Construction throughout the 1930s was financed from property taxes, since the agency had no water to sell until deliveries commenced in 1941. Even then, sales were relatively small as the bulk of water supplies were sourced locally, principally from groundwater, but MWD now provides about 60% of the needs of its service area.

US public law, 100-675 section 207, authorises the Secretary of the Interior to construct new lined canals in order to conserve 123,300 ML of Colorado River water per year, and requires all water agencies (including MWD) that have contracts with the Secretary to review pricing policy and practice, including:

- the recovery of all costs through water rates;
- marginal cost pricing;
- seasonal rate differentials;
- dry-year surcharges;
- increasing block rates.

MWD, at the outset, established a straightforward wholesale water rate structure, designed to recover capital and operational expenditures from users in an equitable manner. In 1954 service was curtailed when storage levels in Lake Matthews declined to a critical level after a period of full capacity supply, resulting in the adoption of trial seasonal pricing structure. Groundwater replenishment was encouraged by discounting deliveries over a five-month off-peak demand period, and this concession has continued and is now available year-round.

From the end of the 1970s to the early 1980s, MWD's approach to pricing changed considerably in response to the single worst drought year ever experienced in California (1977) and federal restrictions on property taxes. A cap was set limiting taxes to repayment of general bond debt service to MWD and the State Water Project (SWP) so that, in 1991-2, taxes accounted for only 9% of revenue compared to 81% from water charges (tariffs).

Wholesale pricing

It is often argued that water prices at the margin are too low (do not reflect marginal or incremental costs of supply) which discourages resource conservation efforts. MWD adopted two programmes based on marginal cost pricing, starting in 1981 with the Local Projects Programme (LPP), which makes direct payments to qualifying projects that reclaim and re-use water. In 1992 the payment was US\$125 per ML to offset supplies from MWD costing US\$212 per ML, and is equivalent to raising the marginal price of water to US\$336 per ML.

At the time demand was reduced by 112,000 ML per year and now the regional goal for 2010 is to reclaim nearly 500,000 ML per year. In 1988, the Conservation Credits Programme (CCP) was introduced to allow similar value of credits to agencies adopting effective water conservation programmes, and price at US\$336 per ML at the margin. The expected savings from this initiative are expected to reach more than 62,000 ML per year.

An acute shortage of imported water in 1981 led to the establishment of the Interruptible Water Service Program, whereby member agencies pay an additional US\$40 per ML (1992 prices) for a non-interruptible service, to have the assurance that supplies will not be curtailed during times of drought. Agencies which purchase the cheaper interruptible supplies are obliged to maintain service levels from local sources, although the MWD manager has a priority list for interrupting supply with lowest priority afforded to groundwater recharge, highest given to injection to seawater barriers, and higher value agricultural uses lying in between.

A Seasonal Storage Programme was introduced in 1989 to discount off-peak season rates (Oct 1 to April 30) by US\$75 per ML for untreated water and US\$87 per ML for treated water compared to the peak season rate. The intention is to encourage agencies to purchase and store water in the off-season to enhance flexibility in the dry summer months, and total sales in the 1989/90 financial year were 231,000 ML.

Box 3 Continued

Dry-year surcharges were adopted in the droughts of 1976–7 and 1987–91, using penalties and credits. For deliveries over 90% of the prior non-drought year of 1976, a 100% surcharge was levied, but for each ML saved below the 90% threshold, US\$20 credit was awarded. In the second drought this was simplified to an US\$81 per ML rebate for savings during the June to September period below 95% of the non-drought figure in 1989. As the drought lengthened, the Incremental Interruption and Conservation Plan introduced conservation targets for member agencies using more extreme incentives – an additional US\$320 per ML for exceeding the target, combined with an US\$80 credit for further conservation.

Retail pricing

The drought pricing approaches are a form of *increasing block rate* structure, which is generally considered to be more appropriate for retail than wholesale suppliers. However, it is economically inefficient, as marginal cost pricing applies to only a few customers in one particular block and thus the majority (51%) of retail agencies in Southern California apply a uniform rate and only 35% use an increasing block rate. Retail water rates are higher than wholesale ones due to the cost of *local* supply infrastructure and abstraction. All supplies are individually metered and billed monthly or bi-monthly and wastewater services from 12 agencies are also metered and billed accordingly. In the long term, the rate of price increase for MWD supplies will outstrip local costs, but is not anticipated to have the same impact on overall pricing due to the dominance of the local supply costs.

Consumer response to pricing has been much harder to determine, as it is difficult to separate price responses from the effects of public awareness campaigns, the adoption of conservation packages and lower water consumption in housing built since 1980. Uncorrected price elasticity of demand has been estimated to be near to zero for the winter season, compared to across-the-board summer reductions of less than 3.6% for a 10% increase in charge rate.

Estimates of corrected elasticity are more conservative at less than -0.1 overall, and when drought restrictions are in force, of -0.05. Total water savings due to price increases in 1990 were estimated at 107,000 ML which was equivalent to 4% of total municipal and industrial use.

Future MWD pricing policies will continue in this vein, with further analysis of the pros and cons of conservation-oriented rates and assisting contracted agencies in improving their rate design, whilst publicising the success of those agencies adopting innovative and effective charging systems.

Source: Water Conservation Pricing Approaches of the MWD. MWD Staff Report August 1992, PMC Ltd. Carbondale, Illinois

The 1976–7 and 1987–92 Droughts and their Impacts on Institutional Reform

Many of the San Joaquin Valley's aquifers were seriously depleted in the 1976–7 drought but subsequently recovered in the late 1970s and early 1980s when wetter than average conditions enhanced run-off and exports from the Delta region. Conjunctive use strategies developed over this time contributed to a halving of the groundwater overdraft from 1980 to 1990, so that of 10.5 mML of groundwater abstracted, 1.23 mML is still 'mined' state-wide.

Groundwater played a vital role in helping water users throughout the drought of 1987–92 as a deliberate policy of over-drafting was used to maintain water supplies, notably in the San Joaquin Valley (SJV), where longer term recharge is a proven possibility. Groundwater accounted for

more than 60% of supply over the drought compared to 40% in normal years, but although long-term recharge is possible, shorter term problems emerged: accelerated saline intrusion in the Salinas Valley; accelerated land subsidence in the San Joaquin Valley; and more rapid groundwater contamination in SJV, notably Kern County and Mendocino (DWR, 1991). Bacterial contamination of urban groundwater worsened due to drought overdraft in Santa Barbara and Montecito. Remediation of groundwater degradation is extraordinarily expensive, and more prudent drought groundwater strategies are needed in future. Enhanced water transfer has contributed to the long-term decline in overdraft and aquifer recharge has been enhanced by flow control achieved by the Hidden and Buchanan dams.

While the six years of drought stretched California's developed supplies to the limit, it stimulated innovative water management actions, water transfer, water supply interconnections, and changes in project operation to mitigate harmful effects of drought on fish and wildlife. It is also true that the drought would have had much more severe impacts in the south if Nevada and Arizona had been using the 740,000 ML of their entitlement under the Colorado Basin Compact. However, the Colorado aqueduct flowed full for most of the drought period, excepting six months of about 25% reduced flow in the first half of 1992. Over the first five years of the drought, there was minimal economic impact due to storage, but by 1990, the reservoir storage levels were 16 mML lower than in 1986. The State Water Project (SWP) stopped all agricultural water deliveries and supplied only 30% of nominal urban demand. The CVP reduced agricultural deliveries by 75% and all others by 25%, and the CVP and SWP limited joint deliveries of water to about one-third of SWRCB permitted levels. Financial losses in 1990–91 were estimated at about US\$0.5 billion from agriculture and a similar amount from hydropower and recreational income foregone (DWR, 1981).

Restrictions on flow deliveries in the drought periods stimulated pricing initiatives to penalise excessive use, but were coupled with more traditional methods of rationing (to 159 lpcd from more than 600 lpcd) and limiting supplies. The Metropolitan Water District (see Box) reduced deliveries to sub-bulk suppliers and other contractors, whilst engaged in an intensive media campaign aimed at individual users. MWD also introduced surcharges on contractors who ordered above prescribed limits. The drought stimulated the DWR into setting targets to conserve 1.85 mML of water by 2010 – 620,000 mML from agriculture and double that from urban use.

The Emergency Drought Water Bank

DWR was authorised, by the state Governor's executive order, to establish a clearing house to facilitate market-like transactions of water, principally from agriculture. Negotiations were quickly begun with both

individual irrigators and the water districts to purchase water by fallowing land, pumping groundwater, and obtaining 'excess' stored water. By the end of 1991, 350 contracts had been processed by DWR with advice from a purchasing committee made up of potential buyers, to obtain a total of 1.03 mML. Approximately half of this was obtained by fallowing land and one-third from groundwater; most of the fallowed land was located in the Delta, whereas planners had anticipated that it would come from rice-produces in the lower Sacramento Valley, who in the end demanded too high a price for their water (Keller et al., 1992). Water sellers were paid an aggregate price of US\$101/ML at that time.

In 1991, the three buyers were MWD, Kern County Water Agency and the City of San Francisco. Rosegrant (1994) shows that total volume purchased by the second drought water bank in 1992 fell to less than 25% of the previous year's transfers following unusually heavy late March rainfall. The total unit price of water fell to less than half the 1991 value of US\$142/ML. In 1991, the dominant allocation was to urban use, followed by storage in the SWP allocation, with agricultural use accounting for only 10% of the total transfer volume. By contrast, in 1992, agricultural transfers accounted for nearly half the trade, and urban use less than a quarter. Transfers in the most recent 1994 drought water bank have been similar to 1992, with slightly greater volume (around 250 mML) and a marginally lower price of US\$55/ML.

The bank took a very active role in certifying, broking, securing financial banking and acting as a public interest advocate (Keller et al., 1992). Transfers were deemed, under temporary and then permanent legal provisions, to be a beneficial use, but transfer of over-drafted groundwater was not permitted unless it could be deemed to be artificial recharge water from prior 'groundwater banking'. The amount of water retained for environmental quality in the Delta was substantial in both years (roughly 25% of purchases), although this is for some reason not recorded as a transfer. Limitations in the infrastructure became apparent when moving the purchased water through a system that was designed for irrigation and urban supplies, and there are now strict environmental constraints on the timing and quantities of water than can be moved throughout the Delta.

Interestingly, the USBR takes the view that water sales are detrimental to project service and therefore have not allowed transfers of CVP water to any of the drought water banks. The banks have been very successful in reallocating water at the margin, and in demonstrating the feasibility of market-like transfers, although it does indicate the need for strong brokerage, within the institutional constraints operating in California. Peabody (Keller et al., 1992) suggests that the groundwater supplied to the drought water banks was bought at too high a price, which stimulated uncontrolled withdrawals with third party impacts on overdraft and resulted in accelerated land subsidence, which damages

aquifer capacity in the long term. He therefore suggests a two-tier pricing structure for purchases, with substantially lower remuneration for groundwater. These state-mediated market-like transactions also need to be considered in their rightful context – the total volume traded in 1991 was less than one sixtieth of the total state-wide supply in 1990.

Supply Augmentation, Conservation and Demand Management

Historically, the serious local and state-wide groundwater overdrafts have been stabilised by long-distance transfer of water which has both substituted for pumped supplies and been used for artificial recharge (Bogle, 1989). Rural to urban water transfer has not been popular, however, due to the memory of Los Angeles' appropriation of the Owens Valley water rights in the 1930s, which resulted in the valley almost 'drying up and blowing away' (Keller et al., 1992).

The biggest impact on the state-wide overdraft of around 10 mML in the 1960s has been from the SWP transfers. Initially surface water was injected to prevent saline intrusion in coastal aquifers, but it has been such a successful technology that many areas now enhance groundwater storage in normal years in order to 'bank' it for the inevitable droughts. The idea of groundwater banking was discussed as long ago as 1977 as a strategy for the CVP (Thomas, 1978) and inaction at the time was attributed to the conflict between private rights to groundwater and the right of the re-charger to re-abstract. Groundwater injection has also been used to control degradation and contamination gradients in groundwater basins and is now being used as part of a strategy of wastewater reuse. In Orange County, southern California, population grew by 800% to 2 million over the thirty years prior to 1979, placing ever-increasing demands for water despite osmosis plants, industrial wastewater re-use and sophisticated conjunctive use strategies. The most recent innovation recycles wastewater, treated in 'Water Factory 21', which is injected into the aquifer where it undergoes further natural bacterial treatment and is mixed with good quality groundwater. The technique of mixing wastewater has been evaluated in the saline intrusion zone since 1976, and has resulted in a permit to inject 100% treated water into the aquifer for re-use.

Although the SWP is delivering considerably less water than initially planned, the California Water Plan Update (1993) does not envisage that deliveries will increase by more than about 2.75 mML per annum by 2020; opposition to financing and exporting water from northern California is the key constraint. The restriction on exports from the Delta has prompted some calls to implement the peripheral canal to improve water quality and reduce transmission losses, whilst providing enhanced flows for the ecological health of the area. Under the current funding

climate, and the need to raise substantial user-sourced finance and opposing environmental groups, it is unlikely that this or any other major transfer project will be undertaken. As noted elsewhere, the total volume of transfers from the Colorado is likely to decline by about 15% as the other riparians exercise their water rights, and recent legislation has placed restrictions on the transfer of water to Los Angeles from Mono Lake and the Owens Valley.

The California Water Plan envisages relatively modest options to augment supplies by a total of nearly 2.35 mML/yr by 2020, including:

- water reclamation by wastewater recycling and groundwater reclamation of an additional 1.23 mML, resulting in a net augmentation of 740,000 ML after accounting for re-use. Costs are in the range of US\$325–810/ML at 1992 prices;
- solutions to the Delta management problem, yielding a net increase of 370,000–620,000 ML/yr;
- conjunctive use to augment drought supplies on the model of the Kern groundwater bank – 620,000 ML/yr; and
- additional storage facilities to provide a further 620,000 ML/yr.

There are plans to provide local security and drought mitigation by more widespread use of desalination. Since 1990, at least five high-capacity reverse-osmosis seawater treatment plants have been commissioned in southern California and many more are under investigation. Desalination of brackish water is less energy-intensive and has higher yields, and is also under development. The 1992 price of US\$325 per ML is still 50% more expensive than water purchased and delivered from the drought water bank, but is in the same ballpark as current long-run marginal cost prices being adopted by MWD (see Box 3). Desalination is still two to five times more costly than surface and groundwater supplies. More than 20 programmes to enhance precipitation by cloud seeding were underway in 1991; the estimates of increase in annual precipitation (not yield) range from 2 to 15%. Research and action to enhance storage and hydroelectricity generation continues.

The current suite of strategies (DWR, 1993) for demand management to match supply in 2020 includes:

- water conservation, providing net savings of 1.1 mML/yr through adoption of best management practice packages for urban use. Gross irrigation savings of 2.1 mML are envisaged through recently improved conservation and management practice, but this will translate into only 370,000 ML/yr in net freshwater savings;
- drought land fallowing to supply 740,000 ML or more via the water bank;
- drought demand management of 10% voluntary rationing could add up to 1.2 mML/yr in savings; and
- retirement of 18,200 ha of poorly drained land in the western San Joaquin Valley will yield only 160,000 ML/yr.

Augmentation will supply 1.5 times more water than conservation in normal years but will make up only 60% of additional use in drought periods. *It is easier to achieve tangible savings through urban conservation than through agricultural measures, and this is where effort is being concentrated.*

Water conservation in the sunshine state

Conservation of urban water has largely relied on reducing the very high per capita consumption that is common in California – more than 600–800 lpcd in many districts compared to 200 lpcd in the UK. Amenity watering received 40% more water than necessary (Englebert, 1979). Xeriscaping has been widely promoted throughout California (Postel, 1985 & 1992), and one study at Novato revealed water savings of 54%. Improved water control technology has led to significant water and energy savings for municipalities (Irrig Expo, Melbourne, 1993), as have improved leak detection, and innovative repair and replacement technologies.

Industrial water conservation was dramatic in the 1980s; in San Jose conservation and recycling saved 540,000 ML – or enough to supply 9,200 homes (Postel, 1991). Savings ranged from 27 to 90% and the average investment payback time of under 12 months helped rapid adoption. The three largest water using industrial groups cut their use by two-thirds over the period 1970–90 and water savings from 640 manufacturing plants in 12 Californian counties reduced consumption by 19% from 1985 to 1989 (940,000 ML, equivalent to 150,000 households).

Best practice includes retro-fitting low-flow showers, low-flush toilets and restricted-flow taps, all of which are included in revised housing codes. Pricing approaches to water conservation are discussed in more detail in Box 3 on the MWD.

Agricultural water conservation has been partially stimulated by the energy cost of pumping – 7% of California's total generation in 1979, two-thirds of that for agriculture. This figure was expected to double by the end of the century (Roberts, 1979), but with recent pricing reforms in the CVP and other federal projects using subsidised USBR generated electricity, it is likely that further pressure is being applied. The CVP was criticised particularly (Postel, 1989) as it supplies one-quarter of all irrigated land in the state, and (prior to 1993) delivered water at a quarter of the cost of the SWP. Farmers had repaid only 5% of the estimated US\$931 million capital cost over 40 years resulting in one-third of all CVP deliveries irrigating low value pasture and commodities such as wheat and sorghum.

It is unfortunate that the new efficient irrigation technologies are more energy intensive than most surface irrigation methods. Surge flow has been widely adopted for higher value field crops and for horticultural row crops, but there is little data on net savings at the district or even

farm level (Turrall, 1993). In 1985, half the national area of trickle irrigation was in California but only covered 115,000 ha (3% of total irrigated area) (Postel, 1985); the area had trebled by 1991. Other techniques include:

- the recycling of tailwater (particularly from furrow irrigation) can contribute to 10% of water savings on farm, although management of saline run-off can introduce new problems;
- increased flexibility in water ordering and delivery times;
- automatic control of division gates in the delivery system;
- interception drainage to catch spills and leakage;
- low energy use micro- and overhead irrigation; and
- improved scheduling – controlled deficit irrigation.

Until recently the impact of this conservation on fresh groundwater supplies over the border in Mexico has been ignored, although seepage from the All American canal supports urban and agricultural needs which are now being adversely affected.

Recent innovations

A study undertaken by Winrock in 1992 (Keller et al., 1992) identified three examples of innovations in longer term water management.

Water transfer: MWD will line the delivery facilities within the Imperial Irrigation District, and in return will receive 123,000 ML/yr of the conserved water, over a thirty-year period. This market-like exchange is expected to become a model for further agriculture-urban transfers which do not have any negative impact on rural livelihoods.

Conservation: Price-driven agricultural water conservation has been achieved in Broadview Water District through two-tier pricing. There is a base rate for volumes up to 90% of the historical delivery for specific crops, and a higher rate thereafter. It was hard to distinguish savings due to drought or pricing, but farmer interest in and knowledge of conservation increased.

Water storage and exchange: MWD and the Arvin-Edison Water Storage District propose to enhance MWD supplies by increasing off-season aquifer recharge in this closed groundwater basin. MWD will pay for the increase in recharge capacity and abstract the stored water in the peak season; Arvin-Edison irrigators will use groundwater for summer irrigation saving the surcharge on surface water from the California Aqueduct and free up this surface water for MWD. This agreement is favoured by environmentalists as storage south of the Delta may reduce dry-season pumping and its impact on habitat and wildlife. Ironically, implementation of the proposal was still dependent on an EIA of the impact of off-season pumping to artificially recharge the aquifer.

Environmental Issues

Salinity

Salinity is severe problem in California. Water tables in the San Joaquin Valley are within 1.5 m of the soil surface over more than 500,000 ha, requiring pumped and surface drainage to prevent salinity impacts on long term 'sustainable' agriculture. Between 1970 and 1985, crop yields in the SJV declined by 10%, an average annual loss of US\$31.2 million at 1985 prices (El-Ashry and Gibbons, 1986). Severe salinity problems are also evident in the Imperial and Coachalla valleys, where there are heavy clay soils (vertisols). Central Valley agriculture has raised in-stream salinity by contamination with return flows, so that virgin salt contents of 51 mg/l change to more than 1320 mg/l below the confluence of the San Joaquin and Merced rivers. This is one of the reasons that dilution flows are sought to minimise habitat degradation in the Delta (*ibid*). Much of the salinity problem occurs where there is low-value fodder and grain production, and intensification has been proposed on the better land, although Ervin (1991) points out that land retirement will remove a source of water table accession, whereas changing cropping patterns will at best reduce the extent of the problem but not remove it. The California Water Plan expects the bulk of land retirement to occur on marginal lands in the south of the San Joaquin Valley, but has little to say about the salinity mitigation effects that might result.

The leaching requirement in the Imperial Valley is about 120 mm per year on about 200,000 ha., which contributes a fifth of the inflow to the Salton Sea, a natural depression adjacent to the irrigation district. Ironically, improved irrigation efficiencies and reduced seepage resulting from the MWD–IID agreement may affect the ecology of this saltwater habitat.

There is little information available about strategies and more importantly non-structural approaches to salinity management, unlike in Australia. Public domain studies of the performance of structural measures, which have dominated salinity management strategies to date, are also hard to find.

Toxicity

Another unfortunate and much publicised consequence of irrigation has been the emergence of Selenium toxicity at least 22 different wildlife sites in the state (Postel, 1989), which has resulted in bizarre deformities and population decline in fish, birds and other wildlife. The problem was discovered in Kesterson National Wildlife Refuge, which was an artificially created wetland, intended to store return flows from farms and overflow water from the CVP. Irrigation has accelerated the leaching of this essential but also toxic element, which has been further

concentrated by evaporation in ponds and wetlands. Detoxification of drainage water can be performed by soil microbes, mechanical filtration and chemical treatment, but at a cost that would not justify the irrigated agriculture. Where risk levels are high, land retirement is the most likely outcome.

Groundwater mining has caused land subsidence, damaging infrastructure and impairing aquifer storage capacity. The worst over-pumping in California has been mitigated by improved allocation and management (see below) and ultimately by inter-basin transfer (see above). Nevertheless, overdraft continues, mainly in the Central Valley where more than half of the overdraft of 1.23 mML is in Kern County. A more worrying trend has been localised groundwater contamination caused by over-drafting and possibly excess recharge. This is a much more serious problem, as aquifer remediation is very expensive. DWR audits groundwater irregularly (California Water Plan Update, 1993), however, and it is not clear that there is a continuous programme to monitor groundwater use and quality.

The importance of wildlife habitat, species diversity, in-stream water allocation and wetland conservation are all covered under the provisions of the EPA and ESA and these concerns have been instrumental in reshaping the state's water policy.

Institutional Reforms – Past History and Present Innovation

A political analysis of federal, state and local water resources management concluded that the public interest (as represented by the federal government) was subordinated to a fragmented administrative structure, dominated by powerful lobby interests (Cortner and Berry, 1977) and was characterised by long inaction, namely on groundwater management. Up to that time, there had indeed been a highly fragmented institutional framework for managing water, but there had also been some local, innovative institutional reforms to manage groundwater. The number and diversity of 'players' has increased considerably since then, and that the capacity to manage water rationally has much improved. The links between the various players have been strengthened by legislation, rising appreciation of a common interest, and a broadening mandate for key state agencies such as the Department of Water Resources. But all is not sweet: water development in California is a litany of successive conflicts over:

- development objectives and strategies;
- investments and their impacts;
- major political and economic interests; and
- water use, valuation of water, and regulatory strategy (Keller et al., 1992).

Participation is highly institutionalised and polarised representing both narrow economic interests and broader conceptions of public good (*ibid*), crystallising into three major interests groups – urban and industrial water users, agricultural water users and environmental interests. Urban and agricultural interests' dominance has waned since the mid-1970s when sophisticated environmental legislation began. Water conservation is the common ground between these interests, although conservation itself may have contrary impacts (Keller et al., 1992) – such as reduced metropolitan revenues. Farmers may be loath to reveal the full extent of efficiency improvements if they fear that mandatory restrictions may result which prevent them from benefiting from either the conserved water or its transfer. The urban and agricultural groups have each formed umbrella organisations to represent their interests, but the environmentalists are represented by a more amorphous group of private and non-governmental organisations, such as the Natural Heritage Institute and the Environmental Defence Fund.

These divisions and sympathies are mirrored in state and federal organisations, although increasingly organisations such as the State Water Resources Control Board and the Department of Water Resources have such broad mandates that they are actively concerned with satisfying the interests of all three factions.

Other players on the institutional landscape are:

- Major bulk water suppliers – CVP a heavily subsidised federal (USBR) project, SWP;
- Water Districts (also bulk suppliers, but private or parastatal) – MWD, Irrigation Districts, municipal water utilities;
- State agencies – namely environmental
- Municipal and rural water utilities (local bulk suppliers and service organisations);
- Federal agencies – USBR, USACE, EPA, USDA, Fish and Wildlife Service, Forest Service;
- Industry;
- Private commerce – agricultural commodity traders, processing industries, etc.;
- NGOs – environmental activist and lobby groups; and
- Recreational interests – such as white-water rafters.

Agricultural water districts include irrigation and drainage districts and canal or ditch companies. Municipal water utilities may include domestic water companies, special districts, municipal (publicly owned) water departments, selected industries and lower level wholesalers (DeCook et al., 1978).

A survey of more than 1000 Californian Water Districts found two systems of administration and representation on governing boards (Goodall and Sullivan, 1979). Property weighted representation was increasingly under judicial review and has progressively given way to

governing boards elected by one man-one vote. In some water districts, any resident on the electoral register is entitled to vote, which changes the balance of power away from large agricultural interests. The legal nature and autonomy of the water districts allows them to hire staff, accountable to members. They have sufficient status and clout to negotiate equally with other users and agencies, which is by and large not the case in comparable developing country situations (Keller et al., 1992).

Historical institutional responses to groundwater mining

In California, institutional responses to over-exploitation of groundwater developed early, as groundwater development began at the start of this century. Permits or licences are not required as landowners have full rights of ownership to groundwater stocks below their land, unless special water rights have been adjudicated by the court.

The state experienced the typical adverse effects of over exploitation: increased energy costs to lift water, higher costs for well-deepening, change in crop pattern to high-value or rainfed crops, land subsidence, water quality degradation, saltwater intrusion, and ultimately exclusion of some pumpers from access to useable water.

Typically, water user organisations were formed, and consultants were hired to provide advice (Coe, 1988). Often, a new public agency would arise out of the need to levy taxes, legislate to control abstraction, or contract to import substitute water. In some cases, water rights were adjudicated and the idea of correlative rights was introduced.

Santa Clara Valley (later Silicon Valley), was an agricultural area but urbanised heavily post-war; the population had reached 1.4 million by 1983. Private groundwater abstraction has been increasingly brought under public management and the overdraft has steadily decreased, although a major decline of 40 m occurred over the period 1910–50. The worst case of land subsidence was near San Jose, where the surface fell over 4 m between 1910 and 1970, and saline intrusion has been evident along the southern portion of the San Francisco bay.

A Water Conservation District was created in 1929 in the Raymond Basin to discuss and communally manage the groundwater problem (Ostrom, 1990), and 10 flood detention dams were built over the next 25 years to recharge the aquifer. This was insufficient to meet the continued increases in demand and 100,000 acre-feet per year were contracted from the State Water Project, arriving in 1965, with further contracts to the Central Valley Project in the 1980s. The main method of controlling groundwater abstraction has been a pump tax in defined groundwater zones, with industry paying four times the agricultural rate of US\$11/ML in 1983. Injection wells were installed to mitigate saline intrusion but later found not to be needed as groundwater levels are now stable at 10

m shallower than their historical maximum and there appears to be no further land subsidence.

Similar histories exist in the Los Angeles County Coastal Plain and in Orange County Water District, with slight differences – in the former case, a groundwater replenishment district was created in the combined central and west basin in 1959 which levied a pump tax to cover the costs of groundwater recharge and subsequently water transfers. In Orange County, yet another alternative to the adjudication of groundwater rights has been found: the water resource is treated in its entirety as a public utility, and supply is guaranteed to all users at a constant price, regardless of source. By contrast Kern County remains a predominantly agricultural area, irrigating roughly 450,000 ha in 1980, and continuing to have an annual overdraft of more than 616,000 ML in 1989, even though artificial recharge began in the early 1980s. Water tables have declined 60 m this century with a consequent decline in water quality, and land has subsided up to 3.3 m.

Irrigation deliveries from the Central Valley Project began in 1955, and were supplemented by SWP flows following the formation of the Kern County Water Agency in 1961, although delivery did not start until 1968. Levels of artificial recharge have steadily risen, and on aggregate, additions have exceeded extractions by 1.36 mML since 1977. Inter-annual and inter-drought period storage has been 'banked' since 1982, and is the property of KCWA, which sells it to its members. A two-band tariff on pumping was instituted in 1975 to finance transport, treatment and recharge, with agricultural rates half those for all other uses. A surcharge is levied on those who benefit from water table stabilisation, but who do not receive or pay for state water. The accumulated overdraft at the end of the 1980s was still large, and subsidence is still occurring, and it was feared that unless inter-basin transfers could be further increased, overdraft was likely to increase as the remaining 30,000 ha of unwatered but irrigable land is farmed. The various groups in Kern County have all resisted adjudication of rights, and have pinned their faith in obtaining further imports of water from the SWP and CVP, both under intense pressure to increase allocations to other districts, and for in-stream and delta allocation. A serious salt accumulation problem is emerging as the basin is enclosed and has no outfall. To an extent the narrow self-interest of agricultural users in Kern county has been overtaken by the prolonged drought of 1987–91 and the California Water Plan Update in 1993.

Institutional Development

Public sector reform

In the last 15 years federal agencies such as the USBR have moved away from construction and service provision, to planning, data collection and water resources management, particularly following the act of 1982. The USBR has remained the custodian and operator of hydroelectric dams and has continued to manage large and complex water transfer projects such as the CVP, which have continued to be cross-subsidised by concessionary electricity tariffs. Whilst the Bureau has itself attempted to at least cover the costs of electricity generation, it has met with powerful and organised resistance from the irrigation districts, who have delayed and challenged price reforms in the courts.

In California, the Central Valley Improvement Act of 1992 makes four key reforms to present arrangements:

A minimum of 490,000 ML is to be allocated for environmental purposes, (10% of historical delivery capacity). It envisages environmental use of up to 1.23 mML, a quarter of CVP capacity (DWR, 1993). It requires the staged removal of operational subsidies on irrigation water costs and immediate parity with the SWP pricing system. It enables water trading within and outside of the project area.

The legislation first became operational in 1993–94, when 490,000 ML of water were reallocated to benefit winter-run salmon and the Delta smelt. A similar amount was dedicated to other environmental uses, including pulse flow and controlled release in the Sacramento and American river basins to modify in-stream temperatures and flow rates at key times, such as spawning. Such releases have been given precise specifications on the quantity and timing of flows. It is expected that some demand pressure will be eased by the conservation induced by increased pricing and changes to higher value cropping systems in the service area, but there is also the possibility of increased groundwater overdraft in the San Joaquin Valley, due to remaining inconsistencies in water policy which effectively regulate surface water but have limited impact on groundwater abstraction.

Organisational arrangements

The organisational framework in California is a complex mix of private, public and not-for-profit entities; 'privatisation' is not as big an issue as in UK and developing countries. Irrigation districts have been privatised gradually in California since the 1970s, the largest being the Kings River ID, which benefited from previous experience in the Columbia Basin (see Box 2). These 'private' entities continue to receive operational and capital subsidies. The CVPIA has reduced but not removed these distortions.

The performance of 438 public and private water utilities serving 25,000 Californians was investigated in 1992, with some surprising results

Box 2 The transfer of irrigation management in the Columbia Basin (after Svendsen and Vermillion, 1994)

The Columbia Basin Project is a large multi-purpose reservoir-based project located near the Canadian border on the Columbia River. Construction of the Grand Coulee dam began in 1933, water deliveries in 1951, and an area of 230,000 ha is now under irrigation – roughly half the planned area. Water is lifted 85 m out of the dam, and thereafter flows by gravity through the system. Three irrigation districts were established in 1939, each comprising between 2000 and 2500 landowners who signed repayment contracts with the construction and management agency (the USBR) from the outset. The system was transferred to the irrigation districts in 1969 following complex and protracted negotiations resulting in a contract between each of the three districts and the USBR, which adopted a new roles as a wholesaler of water, an environmental regulator and a planner and manager of water resources at a more general level.

The study conducted by IIMI analysed the hydrologic and financial performance before and after transfer and concluded that service quality was high under USBR management and continued following transfer, although conveyance efficiency in the main and branch canals dipped over an initial five to six- year adjustment period. As the system has aged, however, there has been a consistent decline in conveyance efficiency in the main system, attributed to neglect of the rising maintenance loads and a desire to minimise water charges. In contrast tertiary-level performance has improved as higher value and less water-intensive crop patterns have been adopted, facilitated by farmer investment in sprinkler and centre-pivot technology. Hydropower generating equipment was installed in the main canals in 1985 and there has been a sharp increase in the volumes of water ordered since, possibly reflecting the profitable nature of electricity generation.

When adjusted for inflation, water charges to the financially autonomous districts are only 78% of that charged under USBR management. Simultaneously net returns to farmers have risen steadily over the past 30 years; reduced water charges are thought to have accounted for a 15% increase in net farm income. The irrigation districts negotiated very favourable capital repayment terms, mainly through a 10-year grace period and a total repayment period of 50 years, resulting in net repayment of about 12% of total construction costs, including additional works and drainage negotiated prior to hand over. The cost of pumping is cross-subsidised from hydroelectricity generation by nominal electricity rates for pumping water out of the dam, rates fixed in 1945 and which are now 1/34th of the summertime market value. The USBR is seeking to double the tariff just to cover the costs of power generation, and the issue was still in court in 1994.

It is impressive that such large and complex systems can be handled by three irrigation associations, and this is one example of a recurring pattern throughout the American west, with the King's River Irrigators Association in Fresno California managing nearly half a million hectares.

The IIMI study cites the following enabling factors, leading to successful transfer:

- Established federal policy on transfer and cost recovery generated an air of inevitability, but also co-opted farmer participation from the outset. Agreement to recover the 'full' cost of operation and maintenance was reinforced by legally binding contracts specifying the rights and obligations of both parties (the USBR and the irrigators' associations).
- The CBP was effectively and professionally operated before transfer, and a culture of partnership has been fostered between the USBR and the districts since then. The internal ramifications of transfer to USBR personnel were smoothed by the transition in the role of the agency and the possibilities of employment as professional managers in the irrigation districts.
- Pragmatism in not attempting to recover full capital costs, and indeed in maintaining some operational subsidy, whilst maintaining a consistent federal irrigation policy that encourages farmers to invest in new technology and longer term investment. Negotiated improvements to the system prior to transfer.
- A social context where there is a relatively homogenous and small group of farmers, who are well educated and commercially oriented and who hold considerable legal and political power plus secure land and water rights.
- Strong legal basis for irrigation associations, supported by a relatively impartial and accessible legal system.
- An insistence on mandatory external audits.

In conclusion, what has been a successful transfer to private management in administrative and functional terms, is 'compromised' by the power of the privatised associations to maintain considerable operational subsidies and defer capital repayment while increasing actual water use. So, although there has been progress in improving irrigation management and reducing the direct burden on the state, broader objectives in rational water resources management, particularly rational and economic allocation of water, have not been well served.

(Bhattacharya et al., 1994). The study was undertaken with the American Waterworks Association and analysed complete data sets for 257 publicly owned and 32 private water utilities. Both had significant relative price inefficiency and excessive capitalization. The private utilities were *less* efficient than public ones, both technically and in their use of variable inputs such as labour, energy and materials. The range of efficiency in public utilities was greater, however, and private utilities were more consistent in their degree of inefficiency. Both utilities have a negative marginal product of capital, but private utilities, tending to be larger were on average more scale efficient. The investigators argue that the attenuation and non-transferability of shares in public firms has not resulted in inferior production processes and service delivery, a finding that has important implications for the tradeable water rights debate and to privatisation strategies in developing countries, both cases where similar evaluations are not yet possible.

Accommodating environmental needs

Environmental groups have become more proactive, less obstructive. Federal programmes, such as the Conservation Reserve Programme (CRP) of 1985, have tried to improve federal–state coordination and cooperation. The CRP attempts to meet agricultural supply control, wildlife habitat, water quality and soil conservation goals through targeted subsidies and dovetailing with state incentive programmes (Reichelderfer, 1990). However, this and similar arrangements have not satisfied economic and environmental objectives, partly because contradictory state and federal policies, or unrecognised counter-incentives. Reichelderfer concluded that absolute cost and cost-effectiveness of such programmes is determined as much by the manner in which agro-environmental incentives are implemented as in the nature of the incentive itself; and that incentive programmes need to be designed for the longer term, in anticipation of shifting social, political and economic conditions, and stress the importance of alternative incentive strategies that are triggered as changes take place.

The economic appraisal of environmental regulations and provisions in water management is imminent: the Federal Wetland Reserves Programme has identified 22.3 million ha throughout the USA that are eligible for reclassification as agricultural wetland reserve. Easement costs were estimated for 18.6 million ha based on capitalised net returns to crop production, to which restoration costs were added. The average costs for the least expensive 2 million ha range from US\$1,245 to 4,850 per ha (Heimlich, 1994), but much further work is needed to assess the aggregate environmental benefits. A pilot project has sought cost-effective voluntary enrolment in nine states, and actual per ha costs in California proved to be considerably higher than estimated due to urban influences on land values. Heimlich has noted that GIS and large database systems

are important tools for managing effectively and analysing environmental policy and support programmes such as the Wetlands Reserve.

There has been considerable scepticism in California about environmental regulation through governmental agencies that may easily be 'captured' by those they seek to regulate, or may simply not have the capability and capacity to enforce standards and codes of practice. In 1986 the Safe Drinking Water and Toxic Enforcement Act became law in California, and was mainly authored by private environmental organisations (Helfand and Archibald, 1990). It has become known as Proposition 65 and it seeks to control human exposure to toxic substances through explicit warning requirements and endows consumers with rights to uncontaminated drinking water, shifting the burden of proof to manufacturers and vendors that these rights are not infringed. It assumes that the consumer is a more discerning judge of acceptable risk than a government agency and provides incentives to the public to seek adjudication in court under the 'bounty hunter' provision of the act, which grants a successful plaintiff 25% of the penalties awarded against a violator. The act explicitly recognises that zero risk is not attainable in many instances and specifies minimum acceptable risk as a way of incorporating some cost effectiveness into the preventative measures that must be undertaken. The list of specified substances (carcinogens and toxins) that come under the warning provisions is already long and is expanding. Opponents of Proposition 65 claim that compliance costs are very high and that it is over-responsive to (unjustified) public fears about toxins in food and water, without estimating possible social benefits from some of the very same chemicals. The success of this approach, promises new opportunities for regulation and for addressing enforcement problems, providing the guiding rules of the legislation are balance between costs of compliance and satisfaction of their true intention.

The 'three-way process'

Possibly the most significant institutional innovation is the three-way dialogue that is emerging between representatives of the major interest groups in urban, water and environmental use. For 15 years agriculture and urban interests have been fighting a rearguard action to protect and increase their water supplies and have been thwarted by environmental interests who have developed considerable power to delay or halt projects and programmes. Despite this apparent power, environmentalists were unable to get support for their own agendas and a climate of mutual antagonism and stalemate resulted (Keller et al., 1992).

The drought that began in 1987 sharpened the appreciation of this impasse and prompted representatives of the California Urban Water Agencies and the California Farm Coalition to discuss transfer of water from agricultural to urban use. The 'Pardee group', as it was known, concluded that such transfers would be severely constrained without

resolution of the problems associated with exporting water from the Delta, and therefore sought dialogue with environmental interests, in so doing forming the 'Hetch-Hetchy group', named after the venue where they met in 1991. This resulted in a clear statement of the minimum requirements of each group (as outlined below), and set a framework for constructive dialogue to develop long-term solutions:

Urban position:

- Urban agencies must be assured that they will be able to obtain appropriate quality water supplies with a high degree of reliability to meet current and future demands.

Agricultural position

- Farmers and agricultural interests sought assurance that they would not lose control over 'their' water and that production would not fall and neither would rural communities suffer social or economic disruption.

Environmental requirements

- Immediate amelioration of environment through increased in-stream allocations and habitat improvement.
- A longer term process for continued improvement in environmental benefits.
- Creation of a legal entity to safeguard these gains.

About 60 people were initially involved in informal and relaxed discussions, with sub-committees delegated to look at specific issues. The group has enlisted technical support and data provision from the DWR. To date there has been little of substance in the literature on the outcomes of this development, although it is considered to be remarkable, constructive and a model for other pro-active and cooperative agreements. The Consensus project is one such example: the USBR and the Fish and Wildlife Service will develop analytical decision-support tools for water management, based on technical and institutional considerations. This initiative resulted from the CVPIA and has now taken on board a private company, Water Resources Management Inc. and the Natural Heritage Institute as partners (World Wide Web, 1995).

Drought contingency plans

In 1988, a survey (Moreau, 1991) of 408 large water utilities showed that approximately half had ordinances or other written drought policies; only 28% had a mechanism for triggering conservation efforts; and most thought that they were already doing a good job. Ramamurthy and Singh (1989) proposed a framework to investigate relationships between

agricultural, hydrological and meteorological droughts as an aid to public policy development in drought mitigation. In response to critical state-wide shortage, the Governor signed an ordinance in October 1991 that required all municipal suppliers providing water to more than 3000 people or more than 3.7 ML/yr to develop a water shortage contingency plan. This requires forward estimates over 12 to 36 months of worst-case water availability and a staged action plan for water supply shortages of as much as 50%, with appropriate trigger mechanisms. Consumption limits must be specified and the utilities should provide a method to overcome revenue impacts of reduced services – a topical contrast to the UK private water companies' thinking on this matter! Plans had to be lodged with DWR by early 1992. This initiative appears to be making a broader impact with recent calls to define roles of local, state and federal agencies and to establish appropriate risk levels for intervention in drought water resources management (Grigg and Vlachos, 1993).

Water markets as part of institutional reform to mediate reallocation of water

Arguments have long-raged about the pros and cons of water marketing, particularly in California, and have remained largely theoretical due to the small numbers of transactions, even though the volume of the transactions dwarfs those in neighbouring western states (see Box 1). In 1988, Satoh (1988) suggested that efficient water markets in California were constrained by legal uncertainties surrounding non-quantified water rights and water-pricing problems originating in the subsidies of the SWP and CVP (one-quarter of the SWP cost per ML). He suggested that there should be tolls charged on actual water use by contractors and that profits should be allowed from unused transfers, and he justified this on the basis of modelling water selling (as opposed to transfer of rights).

Contrary to neo-classical theory, the development of private property rights to water in the Kings River Water District demonstrated that such allocations institutionalise rather than neutralise existing structures and distributions of power (Coontz, 1991). Intrigued by the low level of water transfers in California, Young (1986) observed that

- the willingness to pay for water, when real money is at stake, is not that high at the margin;
- transaction costs to negotiate and process contracts and protect third-party interests are large relative to the potential gains;
- conveyance and storage costs are also likely to be large in comparison to the advantages of trades; and
- there is great potential for indirect third-party effects of trades that is difficult to quantify and compensate for.

He concluded that the prevailing margin between values in alternative uses was not in fact sufficient to justify the cost of transfers, because in many theoretical studies the true values were not calculated on

comparable bases – such as the inclusion of capitalization of water into land values, the long-term value of agricultural livelihood and lifestyle, knock-on effect to rural industry and economies, and the conflicting effects of subsidies in water and commodity prices, to name but a few.

It is likely that the development of water markets in California will remain fairly low key and Rosegrant (1994) identifies the following reasons:

- A strong burden of proof is placed on the potential transferors to verify consumptive use and investigate and assure no harmful third-party impacts to other users or the environment under state law.
- The necessity to balance competing interest groups of agricultural, urban and environmental users, which is complicated by the environmental restrictions on the transfer of water throughout the Delta, which is the hub of the water system.
- The need for careful timing of water transfers to account for environmental and capacity constraints in a system that is fully committed to supplying existing contractors.

Although it has been claimed that big institutional players (water districts, federal projects, agricultural corporations) have opposed development of water markets as inimical to their interests, the drought bank experience points to an increased role for DWR and CVP in broking and supporting intersectoral transfers. Rosegrant calls for further decentralisation and deregulation to stimulate water markets (1994), but controversy and cautious development will occur precisely because many Californians and diverse interest groups will see the 'impediments' noted above as being necessary and 'fair', and not lightly deregulated. A number of commentators have indicated that public money should be used to purchase rights to enhance in-stream flows and for environmental allocation, partly and perversely to give the agricultural community some compensation for such reallocation.

The drought water bank provided the first real experience with intersectoral reallocation of water by a market-like mechanism, and takes the discussion of water markets at least one step beyond theory (Keller et al., 1992). The infrastructural, procedural and institutional impediments to water marketing have been illuminated in rather more substance, although other commentators claim the institutional environment for market-based transfer in California is unusually hostile (Rosegrant, 1994). Market proponents also claim that the restrictions on the physical transfer of water imposed by the environmentally set limits on exports from the Delta make California a unique case (Rosegrant, 1994), whereas others (Keller et al., 1992) maintain that the state's

capacity for water movement is almost second to none. It is certainly true that California's water infrastructure is more sophisticated, more comprehensive and employs better technical management than almost any developing country water system. It hardly seems rational to claim that the impediments found to water marketing in California are unique – on the contrary, one would expect to find many more in South and South-east Asia.

The subject of inter-state water marketing is frequently discussed, and the federal Supreme Court's decision that water should be tradeable across state lines is seen as an enabling factor (Young, 1986). It is notionally a very neat idea with respect to Californian water demands and the uneconomic irrigation development in the upper Colorado Basin. Although the water accounting and storage problems are probably simpler in large up- to down-stream water transfer, the actual mechanics and transaction costs of broking the trades may be more complicated than within state, especially if groundwater is involved. For the time being, inter-state water markets remain an idea and are unlikely to become a reality for some time.

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Australia

Background

The state has been more involved in water and municipal services in Australia than in the western USA. Although irrigation was started by private trusts it was soon overtaken by public investment, implementation and management. Irrigation is now part of a major export industry and contributes to about 28% of GNP (grains, fruits, vegetables and milk products), along with large marginal enterprises such as irrigated pasture for wool, mutton and beef. Irrigation development began at about the same time as it did in the US (late 18th century) and received major boosts in the inter- and post-war years, peaking slightly later in the 1970s. The total irrigated area in Australia (predominantly the Murray-Darling Basin (see Map 3) is less than that of California alone, and since 1980, less than that of Spain.

User-financing and contracting to repay the capital as well as the operational costs of water development infrastructure has only recently emerged in Australia. In the USA it is embedded (at least in theory) in the framework of the Reclamation Act of 1902. A fundamental difference between the Australian and North American situation is that price support and other agricultural subsidies are very rare in Australia, although large subsidies have been applied in the provision of and, until recently, the operation of irrigation systems in the states of Victoria, New South Wales, South Australia and Queensland.

The environmental movement has not been far behind the USA, and environmentally sound water management has been a major driving force in water policy and has been high on the political agenda for nearly 15 years.

History of Australian Water Development, Predominantly in the Murray–Darling Basin

1853	Steamer Navigation – construction of locks begins
1870	Development of irrigation by private trusts in NSW and Victoria (the Chaffey brothers move over from California)
1880	Navigation flows affected by irrigation diversions; railways becoming important carriers
1886	Government of Victoria establishes state sovereignty over

- stream flows
- 1901 Federal Government formed with Commonwealth of States
- 1904 In Victoria, all but the First Mildura Irrigation Trust have failed
- 1905 First Water Act (of Victoria) followed by 15 separate pieces of legislation to 1980: all combined and revised in the Consolidated Water Act of 1989. Murray–Darling Basin Commission (MDBC) affected the process significantly, particularly water quality
- 1906 Victorian Government establishes the State River and Water Supply Commission which energetically pursues water development in line with the state government’s objectives
- 1914–1915 Drought – flow in Murray almost ceases in South Australia
- 1915 Murray Waters Agreement
- 1915–1979 Rapid rise in water demand (see graph). Construction of joint works and storages under Murray River Commission

Major storage works	1000 ML
Hume (starts to fill 1929)	3000
Dartmouth finished 1979	4000
Lake Victoria (off	680
Lake Mulawalla	1170

R. Murray: 13 weirs and locks; R. Murumbidgee: 2 weirs completed between 1922 and 1979

- 1940 5 barrages constructed between Lake Alexandrina and mouth of R. Murray in South Australia to prevent saline intrusion
- 1948 Murray River Commission granted powers of investigation throughout catchment
- 1949 Snowy Mountains Hydro-electric Authority created
- 1960s–80s Expansion of Snowy Mountains Hydroelectric Scheme – plus guarantees of minimum drought flows to augment Murray system
- 1970 Clean Water Act (New South Wales)
Murray River Commission introduces of water quality assessment to determine operation of major storages to provide dilution flows
- 1973 Australian Water Resources Council formed to develop national water planning and strategy. Funded by federal government, evolved slowly through various stages until 1979. Accompanied by development of individual states’

	Water Resources Acts in mid-70s.
1979	National Water Policy; National Water Resources Programme (NWRP) initiated
1982	NWRP proposals to protect and improve water quality
1984	Rural Water Commission formed from the State Rivers and Water Supply Commission, Victoria (SRWSC).
1985	Murray–Darling Basin Commission (MDBC) formed
1988	Salt credit scheme (MDBC)
1989	Water Act (Victoria) consolidates and rationalises all previous legislation in plain English
1992	Queensland ratify agreement and become full members of MDBC
1993	Corporatisation of the Rural Water Corporation of Victoria
1995	Privatisation of the Rural Water Corporation of Victoria

There are three levels of government in Australia: federal, state and local. The states have been responsible for land and water management since federation, but the federal government has become involved through capital grants for major works, financial support for water resources planning (since 1964), and initiatives which transcend political boundaries, such as coordination of development in large river basins and water research (since 1968). States cannot levy taxes on personal income, which is collected by the Commonwealth government and then redistributed (roughly pro rata) to each state. Local government can raise revenues to provide and recover costs for municipal services.

As the Murray–Darling Basin (Map 4) dominates the history and extent of water development in Australia, most of the ensuing discussion will concentrate on its major member states, Victoria, New South Wales and South Australia. Constable (1995) identifies three stages of water resources activity in Victoria, which reflect a similar pattern of events in the other eastern states:

Experimental water development. The opening up of the interior of the continent, largely on the basis of private enterprise.

The development period. The 1905 Water Act established a Water Commission which was responsible for the allocation of water rights as well as for constructing and operating irrigation and drainage projects. Legislation gradually introduced up to the 1940s was introduced to remove all inherited (British) Common Law obstacles to State Development in surface and groundwater development and to allow the creation of authorities to provide rural and urban water supply and dispose of the associated wastes.

New approaches to water management. From 1980 the rising importance of

environmental impacts of water development initiated a decline in construction and development and an increase in allocative and regulatory activity, which was fully consolidated in the Water Act of 1989. This act does not interfere with any existing private rights and presumes that government powers should be used sparingly, strategically and only when required. Recognition of the unity of the three phases of the hydrologic cycle is a fundamental of the act which requires that all aspects of water be administered in an integrated and comprehensive fashion.

Randall, a US academic on sabbatical in Australia, was prompted to summarise the expansionary (or development) and mature phases of water development and management (Table 5) which is reproduced here without alteration as it sets the tone for the ensuing discussion.

Table 5: Characteristics of expansionary and mature phases

Item	Expansionary phase	Mature phase
1. Long-run supply of impounded water	Elastic	Inelastic
2. Demand for delivered water	Low, but growing; elastic at low prices; inelastic at high prices	High and growing; elastic at low prices; inelastic at high prices
3. Physical condition of impoundment and delivery systems	Most is fairly new and in good condition	A substantial proportion is ageing and in need of expensive repair and renovation
4. Competition for water among agricultural, industrial and urban uses, and instream flow maintenance	Minimal	Intense
5. Externality, etc., problems	Minimal	Pressing: rising water tables, land salinisation, saline return flows, groundwater salinisation, water pollution, etc.
6. Social cost of subsidising increased water use	Fairly low	High, and rising

Source: Randall, 1981

Institutional Arrangements for Water Management

Two major bodies reflecting the mix of state and local jurisdictions, both accountable to Parliament, emerged during the development period. The State Rivers and Water Supply Commission, Victoria (SRWSC) was constituted to provide irrigation and water services to rural towns and settlements outside the metropolitan area of Melbourne, which was serviced by an autonomous metropolitan authority known as the Melbourne Board of Works. Both organisations were expected to be financially self-sufficient, although it proved impossible to recover all costs from irrigators and subsidies were provided to support services to small rural communities on the grounds of social equity (Constable, 1995). A similar pattern of development occurred in New South Wales, with a state Department of Water Resources and a number of metropolitan authorities, notably for Newcastle and Sydney.

By 1970, Melbourne needed inter-basin transfers to augment its own basin, which resulted in friction between MBW and SRWSC. Rising environmental concerns and public pressure for greater devolution and participation in rural water management led to the creation in 1976 of a body to oversee water resources, the Department of Water Resources (DWR), and to be responsible for state-wide strategic planning. This department has had ministerial and sub-ministerial status and has been affiliated to different ministries at different times, but is now part of the Ministry of Conservation and Environment. The SRWSC was reconstituted as the Rural Water Commission (RWC) in 1984 and lost some of its administrative and regulatory roles to the Department of Water Resources.

MBW became an autonomous quasi-private corporation known as Melbourne Water in 1989, heralding further changes in the water sector. Economic rationalism and the philosophy of 'user-pays' emerged strongly towards the end of the 1980s and with the accession of a conservative government in Victoria, the RWC was put under increasing pressure to become financially self-sufficient. The outstanding capital debts incurred by the RWC and its predecessor from building storage diversion and distribution works was written off by the state government and the RWC was corporatised to become the Rural Water Corporation in 1992. It was committed to achieve a zero internal rate of return on trading on its operations by 1994 and it met that target. In June 1995 the irrigation system was privatised into a number of autonomous regional water boards, or Corporations. Operation of the headworks remained with a RWC and has been absorbed into DWR, which is now responsible for all planning, regulation, data collection and monitoring.

Although economic-rationalist policies have been pursued for rather longer in neighbouring New South Wales, privatisation of irrigation systems has proceeded with more caution. Pigram and Mulligan (1991)

reviewed the experience with privatisation and corporatisation in New Zealand (1988) and both the initiatives underway to develop autonomous irrigation districts in the Lower Murray and Riverland regions of South Australia. They concluded that:

'change for change's sake is not justified, and more than commitment to political ideologies or free-enterprise philosophies is needed to justify the accompanying disruption to established structures and modes of operation'.

They (rightly) pointed out that a more fundamental question is the extent to which improvements in technical and economic efficiency can be delivered under either public or private management, and doubted the efficacy of converting public monopolies into private ones. The brief success of reforms under corporatised management of the RWC illustrates what is possible under state jurisdiction, and the stage is now set for an interesting comparison between the developments under fully privatised management in Victoria and the evolving state-backed arrangements in NSW.

The experiences of New Zealand and South Australia showed the importance of consultation and public participation for the devolution of irrigation system management in NSW. A survey of irrigators in the Lachlan Valley (NSW) indicated that 75% of those balloted opposed private management of the Jermalong–Wylde irrigation district and 95% were against private ownership (Pigram and Mulligan, 1991). The development of Business Plans to specify key management objectives was identified as fundamental to reforms, whatever the institutional arrangements selected for water management, and as it happened this was fundamental to the corporatisation of the RWC in Victoria.

NSW has a policy of transferring irrigation management from the state government to community-based management boards (Prathapar et al, 1994). Broadly speaking there are three options: (1) 'commercialisation' under joint management between the NSW DWR and the management board (Musgrave, 1994); (2) corporatisation requiring operational self-sufficiency by the management board; and (3) privatisation, following the write-off of major capital debts. These latter two options were formally authorised in 1993 following a 3- to 5-year process of increasing the management responsibilities of the management boards (NSW DWR, 1993). In the Murrumbidgee region there are two irrigation districts: the older (settled intermittently from 1912 to 1960) Murrumbidgee Irrigation Area (MIA) (484,000 ha gross) has opted for corporatisation because of its age and infrastructural deficiencies, a broader spectrum of attitudes to private management and mix of cropping systems. The relatively new and modern Colleambally Irrigation Area (CIA) was first settled in 1960 and is smaller in extent (79,161 ha) but accounts for a larger proportion of the net irrigated area of 136,000 ha in the region. Farmers in the CIA have opted for privatisation because of the relatively small size and

homogenous nature of the farming systems and infrastructure; 85% preferred privatisation over the corporatisation option and 77% preferred the creation of a private irrigation district. The process of electing board members and facilitating the handover is complete, but it is far too early to assess performance.

The historical institutional arrangements in Australian water management were relatively straightforward compared to the situation outlined in the western United States in the previous chapter. The emerging institutional landscape may develop more complexity, but it is founded on a broadly homogenous base and has a more unified and consistent legal foundation between states, particularly with regard to water rights, which have been state-owned for most of this century (see Box 4). This simplicity makes it convenient to summarise early on, but much of the innovation in Australian water resources management requires a more detailed understanding of the setting and hydrology of the Murray–Darling Basin (MDB) and the role and impacts of irrigated agriculture. Most recent reform in water resources management in Australia is concerned with cost recovery and economic efficiency (two major concerns of developing countries), and is less explicitly concerned with reallocation of water to higher value economic uses, particularly for cities and industries which are located predominantly along the coastal belt (see Box 5 on the Hunter Valley). Suitable mechanisms to enable the transfer of water from low- to high-value uses are under consideration and being tested in the MDB member states as a means of enhancing efficiency. It is argued that displacement of low-value agriculture by export-oriented and horticultural enterprises will improve the cost recovery and self-financing of irrigation systems and contribute to lower water use with positive benefits on the water logging and salinity problems that are crucial to long-term economic and environmental sustainability. Re-allocation of water for environmental use is also important, but as the states currently own water and allocate usufructuary rights, it is not necessarily true that payments will be made for transfers of water from irrigation to other uses, particularly the environment.

Box 4 Water rights in Australia

Towards the end of the 19th century, the riparian rights system inherited from Great Britain was replaced by state ownership and the allocation of usufructuary rights, specified for a limited period only. The state of Victoria assumed sovereignty over water in 1886 and riparian rights were abated if they came into conflict with the state's interest. The state retained the right to alter or suspend water rights in times of shortage, such as drought.

The system of rights that has evolved in Victoria and the other eastern states is well adapted to the cyclic variation in water availability in a country that regularly experiences both floods and drought. Water rights are divided into three categories: the **basic water right** is attached to land and is allocated so that even in bad (but not the worst) drought year, the full amount (or 100%) of water right will be delivered. The actual volume involved depends on the storage security and the system where a farmer is located. The second, **optional portion** of right can be purchased up to a maximum volume that is determined by the water managers on the basis of the amount of water held in storage at the beginning of an irrigation season, and on the basis of likely depletion of that storage depending on drought forecasting and so on. In good years, farmers may be able to purchase additional water to more than double the value of their basic allocation – in the local jargon 'sales' could be up to 200% of water right (100% of basic right plus 100% sales). Farmers may also purchase additional unallocated water held in storages and, since the early 1980s, may purchase **unused sales water** or complete allocations from neighbouring irrigators.

The water right allocated to a farm is rarely enough to irrigate the entire area, and may have seasonal limits attached, so that the allocation for summer irrigation is specified as a different right from allocations made for, say, winter pasture and supplementally irrigated winter crops such as faba beans.

In Victoria, water supplied to each farm is measured using a flow metre known as a Dethridge Wheel, which is mounted in a casement where water is discharged from the main channel into the farmers' field channel system. The metre measures accumulated flow and is accurate to about 3% if installed and maintained correctly, but may err by up to 8% – although measurement errors usually favour the farmer. A farm may have more than one metre, depending upon its allocation of water right, the topography of the farm with respect to command from the channels, and whether the farm has absorbed other holdings in the past. Farmers pay for the cost of the metre itself and for its installation.

Water that is diverted directly from a river, lake or from a borehole is also licensed and metered, but it is only charged at the bulk rate which is approximately one-third of the full delivery charge. Volumetric measurement and charging has been the norm in Victoria since the 1960s, but was only introduced in the late 1970s in NSW.

Farmers are billed on metered water supply in arrears at a number of times through the season. Orders must be made at least four days in advance and requests can be placed by telephone and are recorded by an answering service, in place of the older system of giving orders in writing to the local water bailiff. If farmers require less or more water than ordered, they inform the scheduling office to avoid inconveniencing farmers who are next on the roster.

The Murray–Darling Basin

Setting and Background

The Murray–Darling Basin contains four principal rivers (Darling, Lachlan, Murumbidgee and Murray), which drain an area of about 1.1 million square kilometres, which is most of south-eastern Australia and one-seventh of the country's total land surface. The basin is hydrologically complex, owing to the considerable geological age of the area, and is politically complex, as it covers four states plus the Australian Capital Territory (ACT). It covers 75% of the state of New South Wales and 56%

of Victoria, with peripheral areas of South Australia (8%) and Queensland (15%) (Musgrave, 1994).

It is the fourth longest river system in the world (3700 km) but, as much of the catchment is arid and semi-arid, average flows are small and account for only 5% of average Australian runoff. However, the mean annual flow of 12 mML supports 75% of all Australian water use and 95% of its irrigated land. Water is sourced from the system to support a total population of 1.6 million including those in 16 major cities such as Canberra (population 25,000). The Murray supplies 43% of normal demand in Adelaide (1 million), rising to 80% in a drought year (Alexander, 1990).

Water resources of the Murray–Darling

For most of its length the Murray is very flat, although the headwaters are at 2000 m on the boundary-forming Great Dividing Ranges to the south and east of the basin. Summer monsoon rainfall generates flow in the Darling in the northern region, but there is often little flow through the arid areas in between. The MDB has a very variable hydrology, with a 13-fold variation in flow into Lake Hume. Both severe flooding and drought occur because of the extreme variability of the area's hydrology (see inter alia, McMahan, 1984), and flood protection works for rural towns and farms has resulted in many stretches of the river being trained and embanked. Clear felling of the upland forest has in the past caused severe local flooding and soil erosion, but controls over logging and land clearance and more recently the advent of Integrated Catchment Management (ICM) have made a positive impact.

As a consequence of this variability more than 400 reservoirs have been constructed along its length, with a total capacity of 30 million ML or roughly 2.5 times mean annual flow. In comparison to the Colorado, the river is not highly regulated in the sense that there is a minimum outflow to the sea – total annual use is approximately 10 mML and flows in the lower Murray are typically 5 mML/yr. Irrigation absorbs 90% of use, while stock and domestic supplies account for 6% and the remaining 4% is supplied to urban centres. Modal flows in the system are much higher, for example reaching 19.7 mML inflow in 1989 with the result that South Australia received flows of 12.4 mML. In 1992–3 and 1993–4, the net flows were similar and are 6 to 7 times greater than the minimum allocation specified in the Murray Waters Agreement (1.85 mML). Total diversions in NSW were 3.3 mML and 2.9 mML in Victoria in 1993–4 (MDBC annual report, 1993–4).

Some assurance of drought period flows has been afforded by interbasin transfers from the Snowy Mountains Scheme (a complex system of storages designed to meet minimum monthly electricity (total installed capacity, 3700 MW) and irrigation demands). Guaranteed supplies can be called on under the Snowy Mountains Agreement

between the Murray–Darling Basin Commission and the Snowy Mountains Council (Constable, 1995).

Development and the natural environment

Land clearance, forestry, pastoral development and irrigated agriculture have all been developed at some historical and continuing cost to the natural environment, but have also provided the backbone to Australia's economic development. One-third of all Australian natural resources production occurs within the basin, including 67% of fruit production and 75% of irrigated cereals including rice (more detail is provided later in this chapter).

Just over half the original basin vegetation remains (Alexander, 1990) and the Murray supports over 7,000 wetlands covering about 118,000 ha. Wetlands are natural basins and depressions that store water after floods have receded; well-defined channels across the flood plain; and small inlets adjacent to river banks. Billabongs (oxbow lakes) are plentiful along the meandering path of the Murray in its flat flood plain, as are lakes, marshes, swamps, lagoons and creeks. The complexity and ecological diversity of wetlands, reflecting the great climatic variation along the Murray, has made them an issue of great importance to the environmental movement and subsequently to the state authorities. Saline return flows from irrigation have caused significant degradation to some wetlands and the importance of billabongs and aquatic ecology in the floodplain ecosystem is being seriously researched (MDBC, 1990). The ecology of much of the basin is adapted to cyclical droughts and

Figure 1: Murray River salinity profile

periodic flooding, the dynamics of which are being studied by organisations such as the Freshwater Research Centre in Albury–Wodonga, with a view to monitoring and quantifying environmental degradation and specifying flow regimes and requirements to water managers to sustain the Murray's natural environment.

Flood plain vegetation, particularly the Red Gum Forests along the banks of the Murray and Edward rivers between Tocumwal and Robinvale, have been highly valued for many years. These forests are watered by over-bank river flooding and from localised groundwater recharge from the river system, so concern was noted as far back as 1991 when construction of the Hume dam began. Increased summer water levels in the reaches below the dam extended the submergence period, killing many trees in lower lying areas. In 1939, regulators and protection embankments were built to control flooding in the Barmah–Millewa forests, and research and management have increased progressively since the end of World War 2. This forest is the largest single stand of river red gum in the world and its preservation has become an issue of national significance; management strategies have been outlined that, given occasional precedence in allocation to forests, can achieve similar stands and tree quality as existed in pre-river regulation times (MDBC, 1990).

Throughout southern Australia, there is a widespread and fundamental readjustment in environmental equilibrium, as regional aquifers fill up in response to land use change brought about by European settlement (Macumber in MDBC, 1990). Salinity is a major manifestation of this process, although it is not new and highly saline conditions have prevailed in the past. If the current rates of groundwater pressure rise continue, it is predicted that the Riverine Plain will become a zone of regional groundwater discharge (*ibid*). Much of the groundwater is naturally saline¹ and rising groundwater tables have resulted in outflows to streams making them brackish. The salinity gradient along the river Murray is illustrated in Figure 1 and shows that water quality progressively deteriorates from source to outfall in South Australia. The contributory effects of irrigation and land clearance for rainfed farming are described in more detail in following sections.

Algal blooms in the Murray–Darling system have created fresh controversy and debate about intensive agricultural practices. Phytoplankton naturally occur and are not normally visible to the human eye, but under certain conditions they become apparent as a green slime that eventually turns the water bluish-green or even red. Algal blooms

¹ Many authors have attributed salinity to previous marine history of the parent geology, but it has been shown that much of the concentration of salts has occurred due to capture of salt from sea spray and deposition through rainfall (Macumber, in MDBC, 1990)

were recorded as far back as 1878 along the shores of Lake Alexandrina in South Australia, and were noted when livestock died from drinking water contaminated by its naturally produced toxins. Although low stream flows, turbidity and favourably hot climatic conditions provide good conditions for rapid multiplication of phytoplankton, nutrient loading from fertiliser use in upland and riparian catchments is a significant trigger to an outbreak. Nitrate contamination of drainage and runoff from agricultural land, plus sediment-borne phosphates are key compounds in exacerbating algal blooms (Harrison, 1994), and MDBC and the state water authorities have been promoting point source control of urban and feedlot wastewater; agricultural drainage and fertiliser management initiatives; and land disposal of nutrient rich wastewater. Further work to understand better these complex interactions is being undertaken to minimise the frequency of algal blooms.

One of the strengths of institutional reform in water resources management in Australia is that it has taken a system-wide approach that has been consciously integrated with land-use management. It recognises explicitly that natural conditions together with intensive irrigated and dryland farming practices all contribute to the increasingly evident environmental changes, and that solutions will only emerge from a clear understanding of the processes coupled with relevant management strategies applied through community-based initiatives.

Drought protection

Statistically, only one year in five is drought-free in Australia, and in gross terms this is quickly explained by the deficit between average annual rainfall (420 mm) and average annual evapotranspiration demand (more than 1200 mm). These figures mask a very broad range of inter-annual and inter-seasonal variability in rainfall. Major droughts have occurred 7 times in the last 80 years, with periodicities of 2–4 years and 6–7 years. There has been much recent interest in drought prediction based on state-of-the-art CSIRO work using two indices of the El Nino Southern Oscillation (ENSO): the Southern Oscillation Index to predict seasonal inflow in the main storages; and Sea Surface Temperature for the Wright Index region of the eastern equatorial Pacific for inter-annual conditions (MDBC, 1994). Prolonged and severe drought such as that of 1982–3 triggered considerable interest in demand management techniques to contain agricultural and urban water use, as elaborated in the Californian example.

During drought periods, severe desertification has occurred through wind-assisted loss of topsoil in the dryland farming areas such as the Mallee (1 million ha), which is reminiscent of the dust-bowl period of the American mid-west, but on a less dramatic scale.

Coping and management strategies that emerged from the droughts of the early 1980s were summarised by Framji (1986), and include:

- establishing an adequate hydrological and water demand data-base;
- routine monitoring of water use, especially at critical times;
- seasonal demand forecasting;
- seasonal groundwater licensing for drought use only;
- adjusting livestock numbers to available forage supplies, in turn minimising stock water-demand;
- re-using drainage water;
- urban conservation measures such as rationing (alternate day supplies, split tariffs, sprinkler ban for amenity watering; etc.) and
- initiatives to reduce delivery losses in agricultural and urban water supply.

He also noted that Australian drought management capability was underwritten by:

- an efficient operation of strategic storages (Snowy Mountains scheme);
- a flexible water rights allocation system that reflects seasonally variable supply and demand; and
- widespread metering of urban and rural water supply.

Interstate Cooperation in Water Resources Development and Management

Early in this century, conflicts between navigation and increasing irrigation development were serious enough to instigate the River Murray Agreement (1915) which guaranteed equal shares (specified in monthly allotments) of all flow sourced upstream of Albury (NSW) between NSW, Victoria and South Australia, whilst giving individual states retain rights to tributary flows. The agreement established the River Murray Commission (RMC) with defined responsibility for (1) planning, and apportioning costs and benefits of development leading to implementation of works in each state and (2) overseeing the distribution of water (Constable, 1985). Subsequently, this model was applied to establish the Dumaresque–Barwon Commission to administer shared rivers along the NSW–Queensland Border and also to set up the Snowy Mountains Hydroelectric Authority (Constable, 1995).

The major storages of the basin were constructed by the RMC using state contributions and later federal monies, and were built by the 'state constructing authorities' such as SRWSC in Victoria and DWR in NSW. Responsibility for cost recovery was initially left to the contributing states, and federal help has usually been given as a grant. The major storages of the Hume and Dartmouth have been operated by the state agencies, under guidelines from the basin authority.

Over time the agreement was modified to broaden the role of the RMC. In 1948 it was granted powers of investigation with a mandate for catchment protection and rights to inspect catchment protection works.

The Commission's jurisdiction was further expanded to include water quality and salinity investigation in 1970, resulting in comprehensive monitoring of biological, bacteriological, chemical and physical characteristics of River Murray waters. Operating schedules were modified to accommodate dilution flows for salinity management, and consultants were engaged to investigate water quality problems. Constable (1986) considers the agreement to have been fundamental to establishing rational and equitable water use despite its political shortcomings, and that without it urban allocation and environmental consequences would be far worse.

Increasingly vocal lobbying from Adelaide concerning the cost of maintenance and refurbishment of its municipal water supply infrastructure because of in-stream salinity led to further changes. In 1982, the RMC began to control water quality, salinity and waterlogging arising from the expansion of irrigated agriculture in northern Victoria and southern NSW. These 'powers' were limited to the right to make recommendations to the states on water quality standards and objectives, and stopped short of executive responsibility.

Constable (1995) outlined three major flaws of the previous arrangements, including the:

- assumption of discretionary powers and unilateral development by individual states;
- lack of executive power leading to 'self-regulation' by RMC to avoid interstate conflict; and
- poor impact on tributary management, because the states resisted the 'interference' of a non-political institution in sovereign matters.

The 1985 agreement diminished state sovereignty over water and gave the MDBC the key role of coordinating strategies and policies for *land and environmental* management. The Murray–Darling Basin Agreement of 1986, modified in 1988, specifically sought to achieve:

- an 'improvement in and maintenance of water quality for all beneficial uses – agricultural, environmental, urban, industrial and recreational;
- the control of existing land degradation, and where possible rehabilitation of land resources to ensure sustainable utilisation of these resources; and
- the conservation of the natural environment and the preservation of sensitive ecosystems.'

Queensland sought membership with observer status in 1991 and obtained the status of 'Contracting Government' in 1993, following further amendments to the agreement in 1992 resulting in the River Murray Act of 1993 (MDBC, 1994). This act includes additional commitments such as the salinity and drainage strategy and specifies a system of continuous water accounting of water use by NSW and Victoria.

Representation in the commission has evolved over time. Initially, each

state had one representative (**commissioner**) but now has three, supplemented by three federal commissioners. They are appointed for 5-year terms and may be re-elected, and are now supported by a full-time staff of about 80 specialists and administrators. An independent arbitration procedure on appointments has existed for many years but has never been used. Unanimous agreement was required of all representatives before executive decisions or recommendations could be made public, and this has been a root cause of the self-regulation noted above. MDBC reports to a **Ministerial Council**, which coopts all federal and state ministers with responsibilities that involve water, land and environmental management. The council is routinely represented by a standing committee and is supported by five working groups. A **Community Advisory Committee** was established to advise the Ministerial Council after the formation of MDBC in 1985, and its members are drawn from technical specialists, the academic community and the general public. Capital and administration costs are shared by the four states and the federal government on a pro rata basis, and Queensland makes a small contribution towards the Commission's administrative costs (MDBC, 1994).

MDBC has traditionally coordinated data collection and monitoring activities and compiled the results, but has contracted the physical collection effort to the state water managers, whose costs have been included in their respective state contributions. The 1993 act introduced greater flexibility in budget management and now allows funds to be carried over from one year to the next, with the approval of the Ministerial Council (MDBC, 1994). At present the Commission's programme budget is allocated to five programmes with a total value of Aus\$63.2 million in 1993–4. Each programme has specific objectives against which performance and outcomes are assessed, including land resources, water quality, natural ecosystems, the River Murray and community involvement.

Irrigation and the Value of Agriculture

The 1.1 million ha irrigated in the Murray–Darling Basin, consumes nearly 8,000 GL of water per annum (Blackmore and Lyle, 1993), about 87% of mean natural stream flow.

Rural production accounted for only 28% of Australia's 1992 export earnings, a steady decline from 40% in the 1980s. Traditional earners have been cereals and grains (13.5% in 1984–5, down to 4.7% in 1993) and wool, which has declined from a mid-1980s figure of 14% of export income to only 5% (Smith, 1993). Gross value of farm output in 1991–2 was Aus\$20.5 billion, of which 77.1% was exported, although the economic importance of the agricultural sector is now shifting to food

and fibre processing, with a total value of Aus\$30 billion in 1992 (Bonano, 1993).

Irrigation produced about 25% of the farm gate value of the country's entire agricultural production in 1991 (Wood and Banks), mostly in the Murray–Darling Basin. Price (1993) presented the following table on the relative area, water use and value of three broad groups of enterprise:

Table 6 Enterprise area, water use and returns

Enterprise	% of total irrigated land	% of irrigation water used	% of total value of irrigated produce
Pasture and livestock	54	50	20
Field crops	36	35	24
Horticulture	10	15	56

Source: After Price, 1992

The farming system is always in a state of flux, but there are strong pressures to increase holding size in all forms of enterprise. This has been true for twenty years, during which time there has been a steady decline in mixed farming. Because of recently declining profit margins in dairying and the meat industry, there is renewed interest in horticulture, particularly in annual crops, and in winter cropping of pulses and oil seeds which receive supplemental irrigation (Drew, pers. comm., 1992).

The predominant land use in Victorian irrigation districts is pasture for dairy and beef production. The irrigation water applied to pasture accounts for about 60% of on-farm deliveries. Until recently, the area of perennial pasture was limited by the water right historically allocated to each farm, but since 1993 farmers may transfer water rights separately from the land title and may sell or exchange water rights on a seasonal or long-term basis. The irrigation methods used reflect this emphasis on pasture as shown in Table 7.

Environmental Impacts of Irrigation in the Murray–Darling Basin – Salinity

Irrigation has been practised here since European settlement began, and salinisation and rising water tables have been a problem since around 1890. The mechanisms that contributing to these twin problems have been the subject of much research and discussion since the 1970s. The north of Victoria overlies naturally saline groundwater and comprises of

Table 8 Irrigation methods in Victoria with water tables below 2 m and economic losses due to salinity in the riverine plains zone

Irrigation method Region	Percentage of		Economic losses		Value of production without salinity \$Aus m/yr
	Area with shallow water tables (ha) 1985	Area with shallow water tables (ha) 2040	in \$Aus m/yr 1990	2040	
Border	2				
Furrow	3				
Sprinkler					
Victoria					
Micro	1				
Kerang	240,000	317,000	19	33	66
Shepparton 1993	120,000	315,000	11	36	88
New South Wales					
Wakool	34,000	230,000	4	12	21
Deniliquin	22,000	270,000	4	22	55
Murrumbidgee	143,000	185,000	6	20	82
Totals	559,000	1,317,000	44	123	132

Source: After Blackmore and Lyle, 1993

naturally saline soils. The equilibrium of pre-European settlement has been upset by land clearance for pasture in the hilly areas and by localised irrigation development. Accessions to the deep and shallow aquifers have increased because of greater summer infiltration than that

Figure 2: Water logged area in the Goulburn Murray Irrigation District, 1981–1990 (after Malano, 1992)

which occurred when natural bush conditions prevailed in the dryland areas, and from deep percolation from poorly managed irrigation.

Salinity levels in the Murray river rise from 0.06 dS/m (deci-Siemens/metre) in the headworks storages to 0.8–1.0 dS/m 2,500 km downstream where the river approaches the sea. The total estimated cost of salinity to river water users is estimated to be Aus\$40 million per annum and is incurred mainly by urban and industrial users in South Australia (Blackmore and Lyle, 1993). Other estimates have ranged from Aus\$65 million (1990 prices) annual costs to the city of Adelaide to maintain its water supply system, and Aus\$37 million (1990 prices) lost from agricultural production (ABARE, 1991). Although most of the direct economic impacts of salinity occur in South Australia (Musgrave, 1990), if environmental costs are accounted for the total cost estimates are over Aus\$300 million (Alexander, 1990).

Most of the salt load is discharged from the irrigation districts, particularly the Barr Creek catchment, near Kerang in northern Victoria, which contributes about 127,000 tonnes of salt per year. The inferred average discharge conductivity of this load is 2.2 dS/m (Trehwella, 1984), which amounts to 33% of the total salt load, measured at Morgan in South Australia.

Water-table rise and severe salinisation has been a feature of the Kerang Lakes area (Victoria) since irrigation began in the late 1870s, when water tables were initially 7–10 m below ground surface. By 1900, the perched water table had risen to 3 m from the surface and 80 ha of land was salinised. Following completion of the Torumbarry Weir in 1923, water was cheap and plentiful and salinisation was unchecked until the installation of surface drains from 1934–6. Rising water tables and accompanying salinisation has only recently (post-1970s) been accepted as a reality by farmers in the Murrumbidgee and Goulburn irrigation districts.

The area with water tables closer than 2 m to the surface has been estimated by Blackmore and Lyall (1993) for the entire Murray–Darling Basin and is presented, unchanged, in Table 8. The increase in water-logged area from 1981–90, defined as water tables less than 1 m from the surface, has been calculated by Malano and is shown in Figure 2 for the Goulburn Murray Irrigation District in Victoria (GMID).

The situation in New South Wales is not as bad as that of its southern neighbour yet, and there is time to implement salinity management strategies based on experience in the Kerang Lakes Area – the are most severely affected in the 1930s.

The connection of the deep and shallow aquifers is spatially varied and the precise delineation of recharge and outfall areas is continuing (Macumber, 1978 and following). Prior streams have been identified as one of the main mechanisms by which water moves from areas of high accession to deeper groundwater recharge areas.

Figure 3: Dryland salinity explained (After Sadler and Cox, 1986)

Recent work (Nathan and Earl, 1992) indicates that much of the salt loading of the river system occurs in winter runoff from saturated saline soils. The picture is very far from clear, however, and work is needed to develop a complete model of the component processes of water table rise and solute transport before meaningful management strategies can be investigated. The source of accessions has become something of a political agenda with different interest groups claiming 'someone else's' source to be the major contributor to the problem.

Accessions need to be meaningfully partitioned as follows:

- deep percolation from inefficient irrigation;
- deep percolation from the winter rainfall and from summer runoff from the irrigated area;
- accessions from rainfall on the dryland area within the catchment;
- losses due to channel seepage and leakage; and
- accessions by lateral groundwater flow from outside the irrigation area.

The interconnection of aquifers has to be much more precisely defined than at present and more physical data is needed so that some generalisations can be made. Channel seepage has recently been measured rigorously by McLeod (1993) but extrapolation is difficult.

*Processes of Salinisation in Irrigated and Dryland Areas***Irrigation-induced salinity**

Soil salinity problems arise largely from rising perched water tables or shallow aquifer water tables which pass through sub-soil strata of high natural salt content. When a water table approaches to within 1.5–2 m of the soil surface, capillary rise results in the deposition of salt in the upper horizons. The electrical conductivity of the deeper groundwater is even more spectacular than the 5–50 dS/m of some of the shallower water, and some discharge areas occur where the piezometric pressure is above ground level at over 70 m, leading to very saline areas.

The irrigation districts all have the same problems of reducing accessions to groundwater and of controlling salt build up in agricultural soils, whilst at the same time trying to contain the net discharge of salt into the Murray River. The advance of the problem varies according to location. In the Kerang and Tragowel Plain areas, the shallow water table is already within 1 m of the surface, although it has established a dynamic equilibrium of decline through the summer period and rise to within 20 cm of the soil surface during the winter (Poulton, pers. comm., 1991).

Dryland salinity

In recent history (the last 50,000 years) dryland salinity has been an extensive natural phenomenon of the Australian landscape. Natural and human-induced salinity currently affects 32 million ha of the continent. The affected area in non-arid Australia is much smaller, at 1.6 million ha, and it is estimated that 'only' 40,000 ha are affected in the MDB compared to 120,000 from irrigation induced sources. There is a degree of imprecision and assumption in the partition of the sources of salinity however, and it is an on-going political debate that has become institutionalised within the research fraternity, which is itself divided into a number of factional viewpoints.

The mechanism is best considered in conjunction with a schematic diagram (Figure 3) and has been understood in western Australia since the early part of this century, although it was obviously forgotten or ignored by policymakers intent on placing returned soldiers in settlement farming areas after the Great War, and again after World War II. The national policy to develop high agricultural export capacity in the 1960s also forced a convenient loss of memory and understanding about the origins and nature of salinisation (Sadler and Cox, 1986).

Under native forest cover, upland catchments achieved an equilibrium with the prevailing rainfall regime, so that nearly all rainfall was transpired and very little percolated through to augment the water table. Land clearance for agriculture allows a small accession of about 30–40 mm/yr, which over the course of 10 to 30 years results in substantial

rises in water tables. Salts present either in the original groundwater, or in the overlying soil strata are then brought close to the surface. Natural revegetation or agriculture then results in salts being concentrated near the soil surface, and in turn leads to seepage and saline contamination of streams and other surface water bodies.

In the 1970s there was a sharp reversal of public opinion about the merits of agricultural development, particularly in the drylands of Western Australia, which was heightened by an extended drought period. The research base improved and considerable academic and professional activity raised public awareness of the issue at a time when general environmental awareness was developing. As in the USA the professional interests of previously marginal services such as forestry, fisheries and wildlife contributed much to development of solutions. Salinity control strategies that emerged for the drylands of Western Australia have been incorporated into the Integrated Catchment Management philosophy, which then found a much wider application in the eastern states. Typical components of salinity control strategies in dryland areas are (after Sadler and Cox, 1986):

- regional embargoes on alienation (sale or franchise) of state forest;
- legislation to control land clearance, accompanied by compensation to the landowner;
- prohibition of clear felling and zoning of land clearance in catchments;
- reforestation via land purchase; and
- engineering measures to treat in-stream salinity, such as dilution or treatment.

Institutional Responses to Environmental Degradation and Economic Losses from Salinity: The Salt Credit Scheme

The MRC and its successor the MDBC have been both hailed as successful coordinating and enabling institutions and vilified for not standing up to the states and imposing a more forceful agenda for good environmental husbandry and professional water management. As detailed earlier, the Commission was essentially constituted as an advisory body, initially drawing strength from its ability to coordinate and construct major infrastructural development and access federal funds. Following the demise of the construction age, it has had to draw strength from the provision of access to all relevant technical, environmental and political information at its disposal, and represent a broad constituency of interests (Constable, 1995). The problem of salinity management has resulted in a much stronger executive role for the commission, which since 1988 has specified contractual rights and obligations between the member states and diminished their sovereign power over water resources management.

An Integrated Approach to Resource Management and Environmental Degradation

Salinity levels in the river are a consequence of reduced downstream dilution due to the diversion of flows upstream for irrigation, the direct discharge of saline effluent from irrigation areas, and contamination by saline groundwater sourced from both irrigated and dryland farming areas.

Once saline water tables have risen to the surface, even if they are subsequently controlled or stabilised, a significant problem remains – *disposing* of the salt. The economic and ecological implications of disposing salt into the main river system, directly or indirectly, are severe. The Salt Credit Agreement limits disposals to the River Murray to reduce salinity levels downstream, but leaves the means by which this is done entirely up to each state and to the farming and rural communities living within their borders.

The scheme has the following objectives (inter alia, Musgrave, 1990):

- 1988 salinity levels at Morgan, in South Australia, should be adopted as the baseline for evaluating and developing all future management strategies. The long-term strategy is to reduce levels by 113 EC units (0.113 dS/m) from the current average of 640.
- Each state should stabilise its salt loading of the river at values that should not be exceeded at an average of peak loadings.
- No state should be allowed to increase the net cost of salinity beyond its 1988 value in real terms.

The agreement thus links land degradation and salinity control in an explicit but flexible way and has established an important link between basin level resource management and individual state policy, and between state policy and the public. The states have effectively forgone the right to unilateral land and irrigation development.

There are two components to the strategy, enshrined in the 1992 Salinity and Drainage strategy of the formal 1992 Murray–Darling Basin Agreement, and given added weight when formalised as the Murray–Darling Basin Act of 1993: (1) the interception of saline flows entering the system and (2) the limiting of the actual salt loads generated.

Each state will be permitted to dispose of saline drainage water in exchange for joint funding of downstream mitigation works which will reduce in-stream salinity by 80 EC units at Morgan, equivalent to a credit of 15 EC per state. The downstream mitigation methods largely involve interception drainage to prevent saline groundwater from entering the river (MDBC, 1990) and the credits will come into force on completion

of the works.

Over the long term, each state only has the right to contribute a maximum of 4 EC units of salinity at Morgan, and has to manage its in-stream discharges accordingly. For example, the average contribution from Barr Creek in Victoria is nearly 10% of the salt loading at Morgan and has been allocated a credit of 2 EC units, or half the state's total credit. Victoria must implement management strategies to comply with this limit, and make further improvements in the long term in order to allow an internal transfer of credit to the Goulburn Murray Irrigation District, where water tables are rising to the surface over an increasing area.

In theory, the salt credits of each state are transferable, but there has been little discussion of reallocation between states, nor how this might be mediated. The focus of activity has been on the southern part of the basin, especially in Victoria where environmental impacts have been the greatest.

The key factor in the agreement is the provision of incentives at the macro and micro levels, as discussed, but this is in turn supported by substantial federal funding of Aus\$335.5 million over thirty years (at 1986 prices, discounted at 5% to give total present value of costs) (Musgrave, 1990). There is additional state funding both for joint works within the salinity and drainage strategy and for within state initiatives and community action, which make the total cost of the programme rather harder to estimate, since it is bound up with other initiatives, such as the decade of LandCare (1989–99), which is costing an estimated Aus\$340 million. Similarly, private funding by farmers to achieve targets set in their local management strategies and to improve irrigation practice on-farm is hard to quantify reliably, but total salinity related expenditure has been estimated to run as high as Aus\$110 per annum. The MDBC's drainage programme is bilaterally funded by individual state governments and the federal purse on a 50:50 share-matching contribution arrangement. Of 20 projects funded in 1993–4 (MDBC, 1994) and costing Aus\$11.47 million, activities were limited to:

- the preparation of the drainage component of land and water management plans;
- the design, investigation and implementation of drainage works; and
- investigations for future works.

Following in the same vein, MDBC produced a draft Algal Management Strategy in 1993–4 and endorsed its Irrigation Management Strategy, begun in 1992, by funding two integrated projects in Sunraysia and in Shepparton. These programmes have been conceived within a broader framework of the 1993–4 Murray–Darling Basin Regional Economic Development Policy to ensure that the goals and objectives of regional economic development are incorporated into all MDBC programmes and strategies (MDBC, 1994).

The development of the salinity management strategy for the basin is in harmony with the LandCare programme, particularly in its philosophy of public participation and public action to develop and implement appropriate responses to the salinity problem.

LandCare was the outcome of an historic partnership between two unlikely bedfellows, the National Farmers Federation (NFF) and the Australian Conservation Foundation (ACF), an increasingly influential environmental lobby group. The key element of a 10-year strategy was to provide funding for LandCare groups and property planning (Campbell, 1994), and owed much to the efforts of similar initiatives in Western Australia (following the Soil Conservation Act of 1983) and Victoria (farm tree groups and Salinity Action Groups established under the Salt Action programme of the mid-1980s). By 1994, there had been an explosive growth in LandCare groups from only 250 in 1989 to 2000 (Campbell, 1994) and the institutionalisation of *integrated catchment planning* (ICM) through community-based *catchment management groups* (CMGs) which are given technical support from specialists working in the state agencies or the federal and universities' science research community (e.g. CSIRO and the individual states technical departments).

Typical details of the ICM approach are clearly set out in a 1991 Queensland Government Bulletin that recognises the following principles:

- Land and water resources are basic and interactive parts of natural ecosystems and their management should be based on river catchments as geographic units which account for the interactions between these resources.
- The management of river catchments must take account of the continuous process of change in response to natural processes and human activity.
- Sound land and water management is best achieved through informed action of individual users and managers of these resources.
- A balance between economic development and conservation of land and water resources must be maintained.

The strategy was devised to ensure community understanding, good coordination between government and community and effective cooperation between all interested parties in and outside of government. Through this process it was intended to develop commonly agreed goals in water and land management with full backing from all stakeholders, and to ensure that resulting actions fully recognised all environmental and resource security implications in a systematic, prioritised fashion. The final goal is that all initiatives should be targeted at achieving

economic and ecological sustainability.

Starting with a commitment to increase awareness of land and water management issues to a very broad public, the strategy seeks to emphasise the value of individual as well as community action and intends to avoid duplication or marginalisation of existing LandCare and other community groups. Where no appropriate groups exist, there is an undertaking to form and support them until they are functional entities. Catchment Coordinating Committees (CCC) are set up to link local planning and action at community level with catchment-wide planning and strategy development. Elected representatives of each community group may sit on a CCC and in turn lobby and liaise with government agencies and regional and state coordinating committees for ICM.

Within the irrigated areas of the Murray flood plain, Salinity Action Groups substitute for the CMGs and operate over a jurisdiction defined by administrative and irrigation system boundaries. These community groups have a high percentage of farmers on their boards, but representation of wider interests is normally apparent – local business, government agencies, teachers and even environmentalists. Formal educational modules in secondary schools, pioneered in Victoria for drought awareness and preparation (Framji, 1986), is an important part of the LandCare programme, as are other approaches to improving *land literacy*, such as:

- farmer fly-overs to enable farmers to see catchments and irrigated areas from the air and observe trends in degradation (or amelioration);
- education packs to explain and allow individuals to recognise emerging problems; and
- community action research exemplified by *Saltwatch*, *Drainwatch* and *Water Table Watch*.

Water Table Watch in Victoria has encouraged participating farmers to install and monitor piezometers on their land so that they understand how water tables fluctuate and if they are rising. The data collected also contributes to local and regional databases which give the community groups and the technical agencies detailed information to support their planning activities. On the basis of education, experiential learning, dialogue and data collection, communities are empowered to develop, evaluate and adapt environmental management plans for their areas, and are more likely to be 'in-tune' with broader regional goals. Federal and state money supports the initiation of such groups and underwrites some of their activities. The groups develop strategies to manage the problems as they perceive them, in accordance with funding requirements that they must meet from their own pockets and supported by targeted subsidies available for certain activities, such as the capital grants for pumped drainage.

It is probably too early to undertake an economic evaluation of these initiatives, and the results will only be seen in the long term, but it is

clear that an enormous momentum has been generated, which has resulted in a considerable change in thinking, especially with respect to independence from government and development of local initiative. Clearly, success is not found everywhere and there will always be groups whose best-perceived option is continued government support for exactly what they are doing now and have done for years. One SAG in northern Victoria has achieved some notoriety by refusing to accept the reality of its situation and rejecting the strategies of its previous board, which was replaced by a more 'representative', but indecisive, faction. The previous committee had obtained considerable capital subsidies for its proposal, but it required all the beneficiaries to contribute to operational and management costs – something they were not prepared to do (Horking, pers. comm, 1991).

There is also a continuing 'turf war' between the different state departments, such as conservation and environment versus agriculture, and water providers versus water regulators, which indicates that the institutional arrangements are far from perfect despite the bold initiatives in inter-state arrangements. A sense of inter-state rivalry is also very deeply seated, particularly between Victoria and NSW, illustrating that establishing institutional arrangements for rational resources management is an essential but not sufficient step: in common with many developing countries with far less-developed institutional frameworks, the culture of cooperation, inter-personal skills and political agendas play important roles in shaping and articulating the progress made in policy reform and implementing supporting strategies. The historical success of MDBC in coordinating conflicting agendas of the member states has as much to do with the passage of time and the avoidance of outright conflict as it does with radical innovation and enthusiastic common vision.

Salinity Management Strategies at the Local Level

Each irrigation district has a *salinity management* plan or is in the process of drawing one up. The plans are community-based in conjunction with the various state and parastatal agencies involved in irrigation. The overall strategy is to limit the salt load discharged into the Murray in accordance with Murray–Darling Agreement, and local strategies must evolve for salt disposal, water table control and improved irrigation management. The salt credit allowed for the Tragowel Plains Salinity Management Plan, south of Kerang, is a 0.002 dS/m increase² in river salinity at Morgan. In Victoria, the main task is to reduce the salt discharge from the Kerang area and thus provide some leeway for rising

² EC units in Victorian common usage.

salinity loads from the Shepparton area.

Disposal options for saline outflows are limited due to cost, but the fundamental problem of controlling soil salinity in the root zone will not go away and requires at least some disposal to account for the additions from even relatively good quality irrigation water. Drainage options are limited by the dramatic increase in salt load that would result, especially where upward groundwater fluxes would be intercepted.

Although drainage is under consideration in Kerang and pumped drainage is already widely used to control water table levels in fruit-growing areas in the GMID, sustainable cropping cannot be realised without minimising deep percolation from irrigation.

On-farm strategies to control salinity revolve around minimising the amount of percolation contributing to water table rise (Turrall, 1993) and include:

- Improved farm layout: remodelling farms has received considerable attention from organisations such as the RWC in Victoria, which initially undertook 'Whole Farm Plans' for individual farms which were then implemented and financed by their owners. Latterly grants were offered towards the cost of hiring consultants to undertake these plans, which has expanded to include grants for recirculation of on-farm drainage. Saline drainage returns are mixed with good quality water from boreholes or channels to further minimise salt loading to the river system.
- Better water management through: improved on-farm distribution channel layout and capacity; laser grading of fields; use of automation; water alarms to warn farmers when fields have been given enough water; and various measures to allow efficient watering at night-time, when the worst water application practices are followed.
- Gradual introduction of water conserving irrigation technology – surge flow, drip and micro-sprinklers, centre pivot and other overhead technologies to replace or substitute for surface irrigation.
- Pumped drainage to stabilise water tables – with disposal of saline water to local evaporation basins.
- Tree planting – the results of this practice have not yet been adequately quantified, but there is good evidence that localised reductions in groundwater levels are observed underneath copses, and that trees planted parallel to the distribution channels may intercept a useful proportion of seepage (Heuperman, pers. comm., 1993). On-farm tree planting programmes have become very popular in recent years, and although establishment is often difficult, the appearance of

Box 5 Drought, demand management and community – The Hunter Valley in NSW

The Hunter Valley covers some 22,000 km² (almost 17% of the area of England) to the east of Newcastle, a major industrial city on the west coast of mid-New South Wales, where most of the population of 500,000 is located. The region is one of the oldest coal-producing centres in Australia, with an annual output in the mid-1980s of around 40 million tonnes. Irrigated agriculture, covering a relatively modest 30,000 ha, has been practised since the mid 19th century, but ranching and other agricultural activities generated a total of US\$ 223 million in 1982–3.

Both drought and flooding have been severe in the valley, and the worst recent droughts on record occurred in 1964–6 and 1979–84. This latter drought coincided with the peak of coal and power development in the central valley, exacerbating conflict between industry and agriculture. The river is highly regulated, although some legally unprotected provisions for minimum flows existed in the mid-1980s, and the Water Act (NSW) of 1912 shows that industry and domestic water took precedence over agricultural requirements, particularly those for annual crops and pasture.

The prevailing institutional framework for water management would be familiar to many developing country water managers: it was fragmented and involved multiple competing interests, nearly all of them state-owned agencies. The Water Resources Commission (NSWWRC) was responsible for water resources planning, monitoring and irrigation, and it worked (at a distance) with the State Electricity Commission, in the development and construction of hydroelectric facilities. The Public Works Department was responsible for all tidal rivers and flood mitigation works associated with them. In practice, irrigation and small town water supply was decentralised from the NSWWRC whilst the Hunter District Water Board (HDWB) managed metropolitan and coastal industrial needs and sanitation. The dominant philosophy up to 1982 was that of engineering-led supply augmentation rather than demand management, and it is perhaps surprising that prior to this date, industrial water demand did not feature in NSWWRC planning documents.

Although agricultural water demand has continued to rise, forecasts for energy demand were so great in the mid-1980s that it was expected that industrial water demand would exceed agricultural needs by 2005. The drought period of 1979–84 signalled a number of changes and introduced the era of demand management:

- Annual diversion along the river itself (10,000 ha irrigated) fell to less than 20% of normal season flows by 1979 and spurred the introduction of metered supply and volumetric charging to replace flat area taxes in 1980. However, under continued pressure of the drought no water was allocated for non-perennial crops (all except tree fruits and vines) in 1983. Farmers increased groundwater use considerably, both from licensed and illegal bores.
- The precedence of power generation interfered both with irrigation storage levels and with cooling storages for coal-fired power stations and industry. Forecasts for continued dynamic growth in power and the construction of new facilities to provide it is the major factor in water management strategies. The coal industry has however revised its needs on the basis of improved water-use efficiency.
- Local scarcity in rural towns was exacerbated by inward migration as workers 'flocked' to the coal and power industries; augmentation projects could not keep pace with demand, especially in terms of drought-proof supplies.
- environmental demand was just beginning to be articulated with the realisation that 30% of mean average flow in the river was lost through infiltration and evaporation alone.
- Urban water supply was very seriously affected as HDWB had no drought contingency plans and appeared to be little concerned with the problem until storage volumes fell sharply in 1979, reaching an all time low of 32% in 1981.

Full cost recovery for urban water supply was mandated in 1982, after HDWB had imposed water rationing, and sprinkler and hosepipe bans for urban consumers. Even with these restrictions, the volume in storage in 1981 would only have provided supply for about 30 weeks, so something more was required. At the same time inconsistencies in the application and policing of bans had aroused much ill-feeling among the general public. The local press also became a very vocal participant in the water debate, which for a time took precedence over other regular popular themes. The press took sides with the 'persecuted' irrigators and made little analysis of the projected water shortages in the upper Hunter, nor of the state government's preparation for (and management of) drought and imminent water allocation problems due to rising competition for water.

Box 5 continued

HDWB introduced a two-part water tariff in 1983, and adjusted prices to ensure full cost recovery and the ability to self-finance new capital works, following a critical review by external consultants in 1981. Over 33% of water was consumed by just 16% of urban consumers prior to price reform, and unaccounted for water losses ran at about 30%. Industry obtained more water than it paid for and commercial consumers paid 15.5% of the charges for only 8.4% of the water. A new president of HDWB was appointed in early 1982 with a mandate for sweeping reform, and the 'water hogs' were the targets of a new two-part tariff – the lower part to cover the cost of service, which was set according to land value. A variable charge for volume supplied and sewerage services made up the second part, and resulted in a reduction of 30% in per unit residential demand. This carried over into the second year, when high level consumers reduced their use, although there was a significant increase in total use among the previously low band (0–99 kL/yr) customers. Construction of a major new engineering works was deferred for 10 years until the 1993 expansion of the Grahamstown reservoir and a further on-stream storage scheduled for 1989 has also been deferred.

The need for bureaucratic and price reform was not generally appreciated by the Board of HDWB, whose members were fearful of adverse public reaction and the implications for job security in pushing through the two-part tariff. With almost no prior public consultation, the board was inundated with over 160,000 telephone calls and suffered a very hostile media campaign that resulted in the formation of the Hunter District Water Consumers Committee, which made life very uncomfortable for the board and its members. Successful introduction of the price reforms is remarkable considering the lack of consultation and the resulting outcry and is attributed to:

- a new and motivated president of the board who would stand by his policies;
- dominance of labour party seats in the metropolitan area – implying strong local government backing;
- previous and continuing severe drought;
- solid backing by the State Minister and Premier.

A decade after this saga, HDWB was corporatised and now recovers all costs, is self-sufficient in capital financing, and also returns dividend to the state government. In return customers have a deemed contract which defines their right and obligations. Day (1995) comments that public consultation may have been the death knell of rapid introduction of a 'user pays' policy, and therefore stymied strategic reform and foregone considerable community benefit – an interesting point of view and one that defies present thinking on the fundamental nature of public consultation in water resources reform.

Sources: Day, 1987 and Day and Read, 1995

the landscape will be radically altered in some areas, such as the Kerang District, over the next 10 to 15 years. It remains to be seen whether this will have a significant effect on controlling water table levels.

A major factor that will contribute to improved irrigation management will be land retirement and land conversion. A process of structural adjustment in Australian irrigated farming began in the early 1990s (Musgrave, 1994), with the result that irrigated livestock production (mutton, wool and beef) has become increasingly vulnerable, especially on marginal lands. Pasture accounts for 90% of irrigated land use in northern Victoria and slightly less in the Riverina. The two main enterprises are extensive livestock (wool, mutton and beef) and intensive dairying which, along with the compact horticultural industry, is export-oriented. There has been considerable discussion on moving the focus of

Table 9 Irrigation water charges in key regions within the Murray–Darling Basin

Region	Current Aus\$/ML	Full recovery Aus\$/ML
Murray irrigators	4.82	8.98
Shepparton-Murray	17.27	23.64
Shepparton-Goulburn	17.62	29.76
Kerang-Murray	17.22	27.93
Kerang-Goulburn	16.34	23.89
Sunraysia	60.29	62.71
MIA broadacre	12.57	19.26
Riverland-government	50.40	90.14

Source: ABARE, quoted in Musgrave, 1994

agriculture to a more dynamic horticultural and cropping-based system with emphasis on quality and niche export markets, but this is not an immediate reality for most farmers ('The Future of Irrigation in the Murray-Darling Basin, Symposium, 1993).

To date, real-life responses have varied from bankruptcy to expansion of holding size, concentration of irrigation on smaller areas of higher value field crops, and abandonment. In the long term, fewer younger people are farming unless there are very sound enterprises to be taken on, which will have a significant effect on water use and water table loading in marginal areas.

Demand Management and Reallocation of Water

In contrast to California, the main impetus to manage demand and reallocate water is not rapidly rising and insistent urban and industrial demand, except perhaps in the Hunter Valley (see Box 5).

Like many developing countries, the federal and state governments can no longer afford to subsidise the operation and maintenance of irrigation and other water supply infrastructure, although most state governments have been more than ready to write off capital debt and have not engaged in the pretence of capital cost recovery that is characteristic of USBR projects after handover to private management. The adoption of demand management (especially in urban centres) is also a consequence of recurrent drought and environmental externalities associated with

'excessive' water use.

The Commonwealth has been undertaking a programme of micro-economic reform since 1989–90 based on the premise that welfare could be improved by maximising the difference between the cost and value of production. Much of the reform has concentrated on removing constraints to market forces to allow resources to be allocated to those who value them most highly (ABARE, 1991). State governments have imitated such policies with varying degrees of enthusiasm, and with regard to water have determined that price reform is the first priority in reducing public expenditure deficit. They have also realised that environmental degradation, mainly from salinity, is a direct consequence of subsidising the irrigation of low-value enterprises on marginal lands, and that price reform may therefore be a good way to control profligate and uneconomic use of water to mitigate environmental problems. In this case, reallocation of water from low- to high-value uses is largely restricted to transfers within agriculture or from agriculture to the environment to enhance streamflows, seasonal flooding of flood plain habitat and so on. Victoria has followed the most aggressive state policy and prior to its current privatisation had embarked on a staged programme of price reform, to the point where it was almost fully covering operating costs (IRR (internal rate of return) in 1991 was -0.34). As illustrated in Table 9, all states have found it hard to do this, although IRRs on assets in government-managed irrigation schemes had improved, by 1991, to -1.9 in NSW, -1.73 in Queensland and -5.1 in South Australia (Musgrave, 1994). NSW is now undertaking partial privatisation prior to seriously reforming water pricing and in the knowledge that it has a large pending investment requirement (up to Aus\$600 million) to rehabilitate an infrastructure that is in considerably worse condition than that in Victoria.

In Victoria, operation and maintenance costs were dramatically increased by running the main delivery canals well over their design capacity, to ensure delivery of peak demands. They have cut costs (and services) by sticking more closely to the design rules.

Further change towards price reform, subsidy removal, decentralisation to regional irrigation boards, and ultimately privatisation is envisaged for Australia (Musgrave, 1994). The Water Policy Agreement by the Council of Australian Governments (COAG) has provided new weight to these proposals and provides a strategic framework for the water industry, committing all the states to:

- further price reform to achieve full cost-recovery and removal of cross-subsidies;
- minimal federal or state financing in asset refurbishment, and full recovery of costs in enhancing or refurbishing infrastructure for bulk supply by state-owned enterprises;
- clarification of water rights;

- allocation of water to the environment;
- adoption of arrangements to allow trading of water – inter-sectorally, inter-state, and within agriculture;
- institutional and organisational reform; and
- community consultation and participation.

A second more strategic development has been the legislation that requires uniform action on behalf of governments belonging to the recently formed Agriculture and Resource Management Council of Australia and New Zealand.

Transferable water entitlements

In some ways, the discussion of transferable water entitlements is a solution looking for a problem. Musgrave (1990 and 1994) has damned the water rights system for its high degree of attenuation, although in a hydrologic sense it is a highly flexible system that allows water to be redirected under contract terms to where it is most needed. Since major inter-sectoral transfers are simply not in demand, some of the most interesting possibilities relate to interstate transfer of 'bulk entitlements'.

First discussions of water markets in Australia emerged in the early 1980s following the visit of an American academic to the University of New England, Armidale in New South Wales, which has since become a vocal promoter of economic reform in water management. Water markets were seen in a slightly different context of easing the pain of otherwise politically intractable price reform in the irrigated sector: reallocation would become voluntary and marginal producers would be compensated for being forced to the margin by being able to sell their water right, even if using it themselves was no longer a viable option without some level of subsidy (Randall, 1981 and Musgrave, 1994).

For efficient markets to exist property rights must be non-attenuated – which means that they must be clearly specified and enforceable, and be exclusive, comprehensive and transferable (Pigram and Musgrave, 1989). Since water rights are usufructuary and attached to land, and because water availability is highly variable due to the extreme vagaries of Australian hydrology, there have been calls to reform the attenuated rights system of the economically inefficient command and control system of water allocation and ensure security of supply (Musgrave, 1994). Fixed-term ownership of entitlements is seen as a block that could be removed (although it has its advantages in environmental regulation and resource-use control, namely groundwater licences), but achieving security of supply could only be entertained by having a much smaller volume of water allocated that was immune from supply variations imposed by nature and the adroitness of the management of the main storages.

The proponents of more active water markets have no real case to make concerning improved security of supply, nor of protection of third

party impacts. Add to this that the infrastructure is much less comprehensive than say in California, and that trades can only be successfully mediated by allocation from major upstream storages, and at the moment have absolutely no prospect of being diverted more than 400 km to the coast for industrial or urban use.

Anderson (1990) identified some key differences between US and Australian water markets:

- Most irrigated land in Australia is a government development, compared to a high level of private development in most western states (excluding California).
- Australian water rights are administered by usufructuary allocations of limited duration (5–15 year licences) compared to private prior appropriative rights in the US.
- The non-use of water does not result in loss of right (and allows the possibility of sleeper licences being used for speculative trading, (Musgrave, 1994)).
- Water transfer experience is new and restricted to agricultural transfer, compared to a long history of transfer of active rights within agriculture in Colorado and other western states.

Water transfers have been possible since 1982–3 in NSW and South Australia (SA) and were introduced on a pilot basis in the late 1980s in Victoria, Queensland and Western Australia. Initially, only temporary transfers (per season/year) were allowed, but permanent transfers are now possible in all states except Tasmania (Musgrave, 1994). The water supply agency charges a one-time fee for transfers, typically more for a permanent sale. A volumetric charge is levied in SA, which discourages large transfers. The buyer and seller negotiate the price of the transfer in all cases, and formal restrictions normally prevent the size of the transfer from significantly altering the flow regime and water quality in the channels, nor having any foreseen adverse environmental impact.

Transfers may be restricted only to other irrigators, but to date nearly all transfers have been between irrigators. In Victoria, the bulk of transfers have been of surplus storage in Dartmouth reservoir (Simon and Anderson, 1990), at a time of plentiful supply. Six water auctions were held at the start of the 1988–9 irrigation season and began promisingly with 20 farmers bidding for 2000 ML (enough water for a 200 ha farm, growing pasture), paying prices of Aus\$175–775/ML, with a median of Aus\$320 in the first and Aus\$158 in the second. The maximum sale allowed to one buyer was 10% of the volume offered but in the first two auctions all the water was sold, despite a protest walkout

by objectors who had assembled to make their point. The remaining four auctions saw very few sales and only 20% of those achieved the reserve price of Aus\$100/ML, as it appeared that farmers quickly re-appraised the 'value' of such purchases. A more recent auction of further water released following completion of salinity mitigation works in South Australia (AQUA, 1994) generated spirited bidding and realised prices ranging from Aus\$132–311/ML for Dartmouth water and Aus\$416–500/ML for lower Murray water.

The volume of transfers in NSW has been rather greater, with a peak one year transfer of 300,000 ML in 1988 (DWR, 1991), compared to total deliveries of roughly six times that amount, although better rainfall caused a decline to around 120,000 ML in the following three years. The value claimed for this transfer is vary spurious as it is based on an estimate of the gross margin per ML of the dominant crop grown in the area, claimed to be Aus\$17 million in 1988 (Aus\$566/ML at 1991 prices).

The recent deliberations between COAG and MDBC have brought the issue of interstate water trading for irrigation and rural water supply to the fore, although background work on transferable bulk entitlements has been undertaken by the Department of Water Resources in Victoria (Williamson, pers. comm., 1993). A severe drought in NSW and increased water demand in South Australia has reinforced interest and the first interstate trade of 20,000 ML, (ironically) reserved for environmental purposes was made for irrigation in NSW in late 1994, through open tender and discounting for the greater level of subsidy applied to irrigation water in NSW compared to Victoria.

ABARE (1991) suggested that tradeable pollution licences might be applied to salinity management, but that a discharge tax might be equally effective and rather more efficient. Non-point source degradation from direct groundwater accession is almost impossible to measure and apportion, but surface drain discharges could be measured, and there have been proposals for a drainage levy for some time in Victoria. The problem with a drainage levy is that it penalises dischargers of differing qualities of water equally, as sufficiently robust and affordable technology does not exist to distinguish and record water quality at the farm outlet. It is equally likely that farmers could evade such measurement by re-routing surface drainage and other malpractice that would be very difficult to police.³ Since the COAG/MDBC deliberations

³ An interesting aside that has some bearing on this is that the RWC had been reducing its dependence on water bailiffs to mediate orders and undertake deliveries of water on farm, following the introduction of a telephone-based, computer assisted ordering and scheduling system. In the past, bailiffs have had responsibility for checking that water meters are working and have not been jammed or reset, a practice which is less and less easy to detect without a staff presence on the ground. Design and construction defects in the system have also been 'covered' by bailiffs who know when an incorrectly installed water meter provides

tradeable salt permits are again on the agenda, as an institutional alternative or modification to the administered salt credits.

Privatisation and its Implications for Interstate Cooperation in the Murray–Darling Basin

MDBC does not currently support COAG and the Victorian government's policy on full cost recovery of rural water supplies, but has yet to work out an explicit policy on transferable bulk entitlements.

The privatisation of the RWC into regional management boards may have been precipitate as the transfer of its regulatory and data collection activities was not fully developed at the time. Although the Victorian Department of Water Resources will assume responsibility for monitoring, data collection and some regulatory activity, it is understood that there is a hiatus and a break in continuity of these tasks. Similarly, it is not clear how the data collection delegated by the MDBC under terms of the Murray River Agreement will be carried out. The RWC was delegated responsibility for management of Dartmouth Reservoir by MDBC, and it is understood that a regional management board continues to do this on a stop-gap basis. In 1993–4 the RWC, acting as a corporation with a large government shareholding, was obliged to pay a dividend to the state government and provided Aus\$1 million financed out of margins on its bulk water charges. Presumably, the *privatised districts* now have to do this, but there then remains a grey area between those who operate headworks and primary distribution infrastructure and those who more clearly just distribute and manage water within a district.

Current Victorian proposals suggest the MDBC becomes a bulk seller to the privatised irrigation districts and in effect becomes a business, Murray Water, so that it relies on revenue instead of state contributions to fund its running costs and river management programmes, including salinity mitigation. Differences in the member states' attitude to the extent and pace of privatisation cause significant problems in the short term, but even if they were agreed, an agreed framework for bulk water charges would be needed which implies the removal of all subsidies to farm-gate delivery to achieve an undistorted market for water across state borders.

Another stumbling block that is emerging is whether bulk water charges would cover the costs of resource management and monitoring

lower flow rates to a farm than that recorded in the design; under such circumstances they raise water levels to adjust flow rates accordingly, but under computerised ordering and eventually automation, such finesse will no longer be possible and farmer dissatisfaction will increase requiring expensive remedial work.

services currently undertaken by MDBC or whether these should be considered as a **community service obligation** (CSO) and continue to be paid by state contributions. At present, bulk water rates to rural towns in Victoria are 3 to 3.5 times greater than for irrigation, and under a bulk-charging system this differential would be slated for removal or reduction. It reflects the difference between state government requirements for a rate of return of 4% on drinking water supply and sanitation compared to 0% for irrigation, and its removal might come under the provisions of a CSO to maintain rural economies. Environmental allocations might also be considered as CSOs but would have to be accounted for and paid for by the relevant department.

Returning for a moment to more mundane water management, it is extremely unclear what implications there are for salinity management and river basin sized integrated planning and management under a hybrid system. Neither the state nor privatised irrigation boards have clear functional commitments to the Murray–Darling Basin Agreement, even if it is now enshrined in law. It is already clear that the privatised boards see little role for strategic activities such as research, regional planning and hydrologic monitoring and have every intention of minimising water charges by paring down ancillary services (Malano, pers. comm., 1995).

It will be very interesting to see how these issues resolve themselves, both within the contrasting states (Victoria, sweeping reform; NSW cautious open-ended reform with continuing state backing, and SA and Queensland, which maintain strong government involvement, albeit working to 'sound economic principles') and (more importantly) on the recently achieved purpose and substance of interstate cooperation.

Groundwater Management in Australia

The fact that much shallow and perched aquifer groundwater in Australia is naturally saline has restricted the opportunities for widespread development. Furthermore, much of the higher quality water in the MDB is held in deep aquifers (such as the Deep Leads in Victoria), and even though some have high artesian pressures, pumping is too expensive for most agricultural uses. Nevertheless, a number of the nation's groundwater systems were considered to be under stress (Jacobson and Lau, 1988) with annual extraction exceeding 1.5 mML per year from 400,000 operating bores in 1986. (To put this figure in context, it is only marginally greater than the continuing state-wide groundwater overdraft in California!) In the arid zone, groundwater recharge may be of the order of only 1 mm/yr (ibid) and recharge rates elsewhere are generally low. The stressed groundwater systems were characterised by annual extractions greater than 10,000 ML per year, and in all but one

extractions are controlled through water allocations and bore licences.

Coastal aquifers have been most at risk to overdraft, as industry and urban centres are generally located in the coastal margin, but the best known case is that of the Bundaberg area on the central Queensland coast where there is heavy use of supplemental irrigation for sugar cane production. Engineering solutions played a large part in stabilising the saline intrusion that occurred: a dam was constructed to substitute surface water for groundwater over half the area and also to contribute to artificial recharge. The oldest recharge scheme to stabilise saline intrusion and rapid local water table fluctuations was financed and developed by cane farmers in the Burdekin area of Queensland, and has been operating since 1965. This system pumps water through recharge channels and pits. Both these schemes now have sophisticated conjunctive use of surface and groundwater to maintain aquifer quality and resource availability.

Within the MDB itself, a deliberate policy of groundwater mining for agricultural use has been adopted in the Namoi Valley, in New South Wales. Large reserves of low salinity groundwater are being exploited to irrigate cotton and meet stock, urban and rural domestic requirements. Annual extraction of 37,000 ML exceeds natural recharge by about 2,000 ML per year. Saline degradation may halt irrigation earlier than exhaustion or uneconomic pumping levels, and incentives to conserve use have been implemented through licensing and water allocations to prolong the life of the aquifer. A similar story unfolded in the Murray Basin in South Australia, although injector wells have subsequently been installed to stabilise drawdown and prevent further degradation from surrounding saline deposits and groundwater.

Groundwater has played an important role in drought mitigation: in Victoria, licences may restrict abstractions in high rainfall years to enhance inter-annual storage, saving large flows for drought periods. Conjunctive use strategies mix poor quality groundwater with good quality surface water (Prendergast, 1993) and many farmers adopt this strategy in drought years when the percentage of optional water right is low (see Box 4), or if they are using pumped drainage to control water tables. Since hydrogeologists are still uncertain of the exact nature of the many connections between deep and shallow aquifers and of the processes determining recharge and discharge points, there is much basic work to be done before more elaborate groundwater use is contemplated. Extensive mapping has already been undertaken, and recent activities within state salinity action plans are providing much more detail on water quality and water table height and fluctuation.

The 1969 Groundwater Act of Victoria introduced groundwater zoning on the basis of metering and extensive water table measurement in critical (coastal) zones. A groundwater conservation area was declared in the Western Port region and licensing was used to secure existing

irrigation use and freeze further development for irrigation in critical areas. Jacobson and Lau (1988) report that on average irrigation usage accounted for only 35% of licensed entitlements in normal years, but that it rose to 50% in dry years. In 1985, when many licenses came up for renewal, the revised terms stipulated shorter terms and lower entitlements.

Pollution of groundwater has been a more pervasive problem; water from the shallow basalt aquifer between Koroit Creek and Maryrbinong River in Melbourne has been rendered virtually unusable by industrial and urban pollution, forcing industries to source more expensive deep aquifer water. There are many localised problems of industrial, land-fill and urban waste-water pollution of shallow aquifers, but many have been amenable to engineering and regulatory solutions.

The lesson from this summary is that there is considerable merit in the state securing control over groundwater licensing and implementing its regulations vigorously, along with investigating thoroughly and monitoring to understand better the dynamics of specific aquifers. Groundwater policy has been strongly and openly argued and coordinated with surface water development, perhaps as a consequence of the small number of institutional players involved. It also helped that individual have no property rights to groundwater, unlike in California, where the population and industrial growth measures have admittedly been much greater.

4

Spain

An Ancient Tradition

Spain has a long, colourful and detailed history of water development, principally for agriculture, and during the 20th century irrigated area trebled from 1 to 3 million ha, enabled by a revolution in construction methods and motivated by agricultural development in a semi-arid climate. The technical history of irrigation development in Spain is illustrated by waves of imported technology – syphons, wooden pipes and clay tiles from Greece; aqueducts from the Romans; barrages from the Romans and Moors; and *shaduf*, pumps and windmills from the Arab world and later northern Europe (Perez and Gallardo, 1987¹).

Pre-history

Pre-Roman canals (Tartic?) can be found in the Guadalquivir, where collective farming (known as *vacceos*) was practised by free men of the region. The incoming Roman settlers favoured large landlords and reduced the smallholders of the *vacceos* to day-labourers as tenants or share-croppers, a precursor of the *latifundias* later found in feudal Spain and its colonies. The largest dam built in Roman times remains today at Proserpina; it is 400 m long and 20 m high, and Roman technology was not bettered for dam and barrage construction until the late 19th century. A dark age of Visigoth domination from the 5th to 7th centuries saw a breakdown of Roman colonial land ownership and little construction, but new laws concerning water rights and punishing water theft emerged.

A Mix of Traditions – The Moors in Southern Spain

The present system of water rights and water distribution date from the Moorish domination of southern Spain from the 8th century to the reconquest by Castille in the 1200s. In the principality of Grenada the sovereign controlled water allocation and introduced public finance for water development, whilst in Valencia water-user associations emerged

¹ Much of this brief history of Spanish water development is taken from Perez and Gallardo's french text for an ICID congress in the 1986.

to develop irrigation with their own and sometimes public monies. The famous Water Tribunal of Valencia and an irrigation inspectorate were established as the introduction of rice, oranges, cotton, sugar cane and mulberries for silk all spurred irrigation development. This era saw little large-scale development, but widespread small-scale development and improvements in practice, creating the now traditional Spanish run-off river irrigation using groynes and training bunds as a substitute for expensive barrages. Groundwater extraction using animal-powered water wheels was an important technological innovation of the time.

Although agriculture and irrigation in particular suffered in the struggle to oust the Moors, Arab water practice and law was confirmed by the new royal rulers of the 13th century, and water rights were specified as irrevocably tied to land. Some Roman practices such as strict rotational distribution and rights to re-use runoff were incorporated. Some of the earliest details of privately financed canals and headworks are recorded at this time: the first private canal in Europe was funded by its users in 1149 in de Tauste and similar arrangements saw the construction of the Reservoir d'Almansa near Albacete, a structure that was raised in 1384, 1586 and in 1911, although it now has only a third of its original capacity due to siltation.

Over the 16th to 18th centuries, water was a 'principality' subject (as in the federal USA and Australia of modern times), and permission to develop water resources was accorded by local government and sometimes by parliamentary decree. In 1529, the Emperor agreed to fund irrigation works in Saragosa providing the rights and responsibilities of all parties were clearly defined. 19 Years later the king was asked by the Cortes's of Vadallodid to undertake a national study of river flows and resource use. The real expertise in irrigation was still the south of Spain, but this declined severly when the remaining Moorish settlers were repatriated during the 16th century. New Royal (Castillian) law was superimposed on Moorish custom and resulted in a confused legislative framework (which persisted until the beginning of this century). New engineering expertise developed and the Tibi dam, at a height of 43 m, held the world record for 300 years from 1590. Like the Hoover Dam, it was completed very quickly – in only 10 years when normal lead times were typically 100 years. Clearly, economics was not the dominant science that it is today!

Agriculture stagnated in the 1600s, possibly due to preoccupations with Spain's colonial expansion in the Americas, but a number of earlier projects continued through this period. In 1550 design studies began on Spain's first inter-basin transfer – to join the River Carrion to the Pisuerga for transport and irrigation use – but construction did not begin until 1753.

Water and the Nation State

During the first half of the 18th century, the majority of the population was rural and Madrid contained only 250,000 people, who consumed an average of only 10 lpcd (litres/capita/day) (compared with more than 200 lpcd today!) Although the Canal de Isabella II was built to bring water from Lozoya to improve the situation, a population explosion did not occur until improved public health care in this century lowered mortality rates and lengthened life expectancy. As in Australia, turn of the century advances and enthusiasm for sanitation engineering played a big role in defeating endemic and epidemic disease (NHP, 1993).

The Bourbon dynasty of the 18th century jerked the Spanish people out of their 'lethargy' as national mapping was undertaken and an engineer was assigned to each province (Perez and Gallardo, 1986). Canals were financed and the old Valencian system of public provision was adopted by the throne, which split the returns from irrigation 50:50 between the crown and producers. At the turn of the century Tovellanos diagnosed that a lack of irrigation in arid Spain was holding back national development and lobbied for rapid construction of barrages and high dams, dramatically reducing lead times to six to eight years. National water laws of 1816 and 1819 promoted irrigation development by local government and community, effectively uniting two disparate legal traditions from Aragon (free use to riparians allowing private development) and Valencia (development by royal sanction only). In 1849, service rules and codes for collective agricultural interest were introduced and tax exemptions were offered to potential investors in irrigation works.

Eleven years on, rivers, streams and river beds were declared public property and national water law was imposed on Aragon and Valencia, restated in the Water Law of 1866 and the Civil code of 1879 which finally established the almost pan-European formula of public ownership of surface water with riparian usufructuary rights and private groundwater ownership accruing to the overlying landholder (NHP, 1993). Syndicates, concessionaires and water-user associations that had financed diversion works themselves obtained a primary right to use water, but where public funds had been used (as was becoming increasingly necessary for major works), users held only secondary rights of use. The 1866 Water Law was also the last in a series of rulings enshrining the importance of irrigation associations (syndicates and concessions) and establishing the primacy of water tribunals in solving disputes – arrangements which remained in force until the national water law of 1975.

The powerful figure of Joaquin Costa arrived in Spanish politics with a vision of irrigation development and agricultural reform as key

components of national development. He sponsored the Law of 1896 that released public finance to build the Aragon and Tamarite canals and heralded a new era of public intervention. By 1900, work had begun on 16 barrages of more than 10 m height and 70 smaller ones, bringing total irrigated area to 1 million ha (NHP, 1993).

Despite the Gasset Law of 1911 on irrigation diversion and flood protection, private enterprise remained the major force in financing and developing water resources, albeit with government assistance, and the politics of water was increasingly bound up with the politics of interior settlement (or recolonisation) (Perez and Gallardo, 1986). Subsidies to users and for irrigation infrastructure were approved in the name of National Development.

By the 1920s, 70% of the workforce still worked in agriculture and industrial development was very limited (NHP, 1993), and most public policy had an agrarian focus. In 1926, River Basin Authorities (RBA) were established over the entire country (modelled on the Basin Confederation of the Ebro) and the river basin became a superior unit of management to the political-administrative boundaries. The RBAs were to manage the hydrologic cycle in a scientific, rational and integrated manner, with full autonomy for water allocation, coordination, management and development and a mandate to act as an umbrella organisation for existing user organisations in a participatory manner.

Modern Times

Parallel to the US Reclamation Act, the National Plan for Hydraulic Works of 1933 promoted substantial water transfer from the Atlantic to the Mediterranean coasts and the rapid development of the interior. National storage capacity increased from 10 mML to 44.4 mML with the completion of 917 dams and weirs by 1987, with a further 77 still under construction at that time. There are 431 reservoirs for irrigation, of which 157 double as providers of hydroelectricity. The highest dam is La Serena at Badajoz on the Zucar river which towers to 92.45 m and supplies irrigation water for 60,000 ha from a storage of 3.23 mML (about the same size as Dartmouth in Australia). Hydraulic development has been fundamental to Spain's economic development, again in parallel to North American and developing country experience, but occurring sometime between the two (NHP, 1993).

Just over half the workforce was engaged in agricultural activities in the mid-1950s, but rising industrial demand for electricity instigated a jump in installed hydroelectric capacity from 1,900 MW in 1950 to 11,000 MW in 1970. Thermal energy output (from coal and oil) actually overtook hydropower for the first time in Spanish history in 1973 (NHP, 1993).

Substantial migration from rural to urban areas occurred from the

1950s to 1970s, creating a demand for water supply and sanitation services. There is increasing evidence that this trend has stabilised, and in some cases reversed, as small businesses and industry relocate to small towns. Thus the demand for municipal water is still rising rapidly, and availability has a great bearing on small town urban development (NHP, 1993).

Internal colonisation laws have promoted groundwater development which has contributed 25% of the 3 million ha under irrigation at the beginning of the 1990s. But private groundwater development, in common with that in South Asia, has not been rational and sustainable in all cases, as technology has improved. This necessitated redesignation of groundwater as public property in the 1985 and the issuance of permits and licenses to pump from aquifers. In this new and consolidated law, both surface and groundwater are licensed for fixed terms, over-riding the previous provisions of the 1879 law to allow permanent use of state property. Other provisions of this act include the (NHP, 1993):

- further decentralisation and management by users;
- non-separability of water and land;
- rationalisation of irrigation water use and the transfer of water to drier areas and zones of groundwater depletion;
- promotion of water conservation, limiting supply discharges and encouraging wastewater re-use for irrigation and industrial purposes. It proposes the use of desalination technology for saline water and brackish aquifers, and for coastal (tourist area) potable water supply;
- protection of the environment and assessment of impact in water development and management;
- goal of balanced economic and social development; and
- reaffirmation that irrigation remains a national priority.

Irrigation produces more than 50% of total agricultural output in Spain from only 15% of its cultivated area, and provides many of the business opportunities in the economy through agro-industrial development, even though only 10% of the population is actively engaged in agriculture now. As with Australia, tourism has displaced agriculture as the principal contributor to GNP (*World Water and Environmental Engineering* 4, 1994).

Many aquifers remain overexploited and part of the momentum leading up to the National Hydrologic Plan has been generated by calls to stabilise aquifers by groundwater recharge as happened on a grand scale with the SWP and CVP in California. Custodio (1978: 319) noted that aquifers in Spain were not extensive and were likely to be depleted rapidly as a consequence of burgeoning groundwater use and entry to the Common Market in 1986. Recharge management was already proposed (Martin, 1978: 317) to limit groundwater use to 10% of total

consumptive use, and although such limitations are no longer desirable, recharge of overdrafted areas is a fundamental objective of the National Hydrologic Plan.

Inter-basin transfer has been justified because of ancient historical precedent and more recently the successful completion of the Segura transfer to Lorca. Thirteen years after initial studies began, the transfer was approved in 1979 and now delivers 33 m³/s to completely irrigate 71,000 ha and provide supplemental water to a further 60,000 ha, and aims to mitigate drought in the high-value orchard industry. Water is pumped over a head of 243 m to the main storage reservoir, requiring the largest pumping station in the country – rated at 40,000 kW. The system can be run in reverse to generate hydroelectricity for peak demand. Interestingly this transfer, first proposed by Pardo in 1933, is cited as an example of uneconomic development typical of the 1960s and early 1970s by the authors of the 1993 National Hydrologic Plan (NHP). The NHP asserts that most irrigation development at the end of the 1970s was economically sensible, but that little concomitant attention was being paid to water quality and environmental issues – a statement that would have many environmental economists reaching for their word processors!

The Rain in Spain – A Precis of the Nation’s Hydrology and Water Resources

Resources

Mean annual rainfall for the whole of Spain is 670mm, which 3400 mML of water. Evaporation rates are high and reduce the average water availability to 230 mm/yr or 1140 mML, of which only 200 mML actually recharges the nation’s aquifers. Although average available water is some 22% less than the European average, water availability of 3 ML/person/year is 20% higher than the rest of Europe, because of the low population density.

Rainfall in the south-east is as low as 200mm/yr (Almeria), but rises to more than 1,800mm in Galicia on the north-western Atlantic coast. Such variation and considerable seasonal and inter-annual differences mean that reliably available supplies are only 8% of the average figure, at 92 mML per year or only 240 m³ per person per year, which is less than a quarter of the internationally recognised minimum for countries not experiencing water stress (Herrerias, 1994). Rainfall declines along the north–south and west–east axes, whilst evaporation increases, so that the north has a disproportionate share of water resources, much greater than that available in the most poorly resourced Jucar–Segura area of the south-east.

Demands

Consumption of water for irrigation is much greater than in other European countries and accounts for 80% of total consumption. Consumptive use by agriculture is 242 mML per year, with a further 43 mML used by drinking water supply and sewerage and a modest 19 mML going to industry. When basin level water use efficiency is considered, the NHP (1993) estimates that 90% of existing irrigation water use cannot be reclaimed. This is an interesting figure, and one that has no parallel in the water accounting exercises undertaken in the USA and Australia.

Non-consumptive use by hydroelectric facilities accounts for 160 mML/yr and a further 4 mML are run through industrial cooling systems. Of that 95% returns to rivers, and must be returned at near to the mean natural stream temperature to comply with environmental legislation. Gross demand therefore runs at 370 mML/yr. The NHP does not make explicit allocations for environmental use, although minimum streamflows are specified in all basins.

Municipal water demands for drinking water and sewage treatment take priority over all other uses and 80% of this allocation is returned unconsumed. Spain has already quite sophisticated re-use for agriculture, but under relatively lax standards compared with northern Europe and current EC water quality directives relating to non-point source pollution.

Most recent statistics show that Spain has more than 1000 dams that are higher than 15 m or impound more than 100 ML. Total national storage capacity is more than 500 mML (NHP, 1993), which is a margin of less than 50% above average annual use, compared to 400–500% in the Murray–Darling Basin in Australia. Half a million wells extract 55 mML/yr, including about 10 mML of mined water – similar to the net overdraft in California. Total re-usable groundwater resources at 40% of annual recharge is estimated to be much higher at 463 mML/yr, although much of it cannot be economically pumped. Despite this overall excess of groundwater, saline intrusion is a common feature along the eastern coast, where tourist development has placed high local demands on vulnerable aquifers. In summer, coastal populations can increase by a factor of five (*World Water and Environmental Engineering* 4, 1994).

The National Hydrologic Plan

Concept and Objectives of the NHP

The NHP was conceived in the wake of the 1985 consolidated water law to improve the organisational arrangements under the 10 water Confederations (River Basin Administrations) and to provide for improved coordination between them at a national level (Abadin, 1986). The NHP is intended to address the following subjects (Herrerias, 1993), within the context of satisfying demand while:

- ' balancing and coordinating sectoral and regional development, increasing water availability, protecting its quality, economising and rationalising its use in harmony with the environment and other natural resources....'
- coordination between river basin and watershed plans;
- evaluation of the alternative proposals for each river basin and watershed, leading to selection of the most appropriate one;
- establishment of conditions and enabling provisions for transfer of water resources between basins and watersheds.

Hydrological planning is therefore supposed to be achieved at the river basin level and more centrally at the national level, and the NHP provides a framework over 20 years for development and approval of water resources management initiatives. Herrerias (1993) summarises the long-range goals of the river basin (and constituent watershed) plans as the:

- provision of detailed inventories of water resources (already largely done);
- definition of current and future water use and prediction of demand;
- selection of criteria for determining priorities in water use;
- assignment and preservation of water resources;
- setting of standards for sewage and wastewater treatment;
- zoning of irrigation use within guidelines for soil conservation;
- establishment of guidelines for water resources protection and rehabilitation;
- development of strategies for aquifer protection and recharge;
- listing and costing of basic infrastructure improvements to meet the plan's targets;
- evaluation of hydroelectric power development; and
- definition of criteria for flood management and flood damage prevention

It is clear that this list is somewhat out of tune with the tone of reforms

and planning processes in North America and Australia, and although it mentions environment and economics and assumes an already well-established base of participation and decentralised management, it is very much an engineers' and scientists' agenda.

Although the NHP is a broad-reaching document (three main volumes of more than 1000 pages, and a mountain of annexes), its central concern is that of inter-basin transfer (*trasvases*) to make good deficits of 300 mML in water-scarce south-eastern Spain, predominantly in the Jucar and Segura Basins. It explicitly acknowledges that the substantial water development and regulation to date is inadequate to meet demand and that even with recycling of wastewater, conservation measures and strategic use of desalination, further supply augmentation is necessary. Net transfers of 270 mML per year have been calculated as necessary over and above the current 50 mML already made. Whole rivers are to be manipulated to transfer water from three major northern basins along an east coast corridor stretching south from the Ebro.

The Guadalquivir Basin is the most stressed and has the greatest negative environmental impact including salinity, nitrate contamination and degradation of historic wetlands, but is not slated for substantial transfers and will have to find other, at present not publicly announced solutions. A considerable number of the options evaluated in the NHP are not alternatives to long-distance water transfers, but economic and technical variations in approach.

Other activities envisaged under the NHP include:

- Water quality improvement – Although 97% of the population have access to piped water supplies, only 40% are served by sewage treatment works, and planning and distribution of sanitation facilities has been haphazard.
- Flood protection – Average annual flood damage is estimated to cost around US\$500 million and five economically damaging floods are expected every year, based on 500 years of records (one of the oldest data sets in the world). The plan envisages expenditure of around US\$500 million in structural works.
- Improvements in irrigation policy and development – In the wake of Spain's entrance to the Common Market and the requirements of the Common Agricultural Policy (CAP), the projected target of an extra 2 million ha of irrigated land has been reduced to 600,000 ha and will be concentrated in the southern mediterranean regions where comparative advantage is greatest (but water supplies are most vulnerable and limited). A reforestation policy is advocated for central Spain where rain-fed farming lands will be retired in

compliance with EC quotas on grain crops and milk products.

- Expansion of installed hydroelectric capacity by a further 8000 MW – Older facilities will be upgraded and a limited number of new dams will be sited where appropriate mainly to stabilise peak loads, which cannot easily or economically be met from thermal power stations.
- Maintenance of the hydraulic infrastructure – Estimated at US\$50 billion over the 20-year life of the NHP (Herrerias, 1993).
- Environmental protection and restoration – Assurance of minimum flows, forest and soils conservation plans, recreational planning.
- Research and development to support implementation of the various programmes of the NHP.

Financing, EC Regulations and Competing Demands on the Public and Private Investor

Although Spain has benefited considerably from EC funds for infrastructural development and from the provisions of the CAP, water quality standards have caused upheaval and need considerable expenditure. The provisions for improved wastewater treatment in the NHP do not take full account of the European Urban Wastewater Directive (ECUWWD 91/271), although it proposes to spend US\$15 billion (Herrerias, 1993) in improving the coverage and standard of water treatment services to 48 million inhabitants of towns larger than 15,000 by the year 2000, and to provide secondary treatment in smaller towns by 2005. Many water managers in Spain feel that the EU standards are almost impossible to observe, particularly with respect to verifying levels of pesticide and fertiliser contamination from non-point sources (*World Water and Environmental Engineering* 4, 1994). Spain has been arguing for concessions from the EC in the scope of its water quality programme, although much surface water is seriously polluted and many rivers in the industrial north do not even meet Spain's own much less stringent standards. Wastewater treatment has since been excised from the NHP to become the National Sanitation and Wastewater Plan, which was approved by Parliament in the spring of 1995, and receive 25% of the US\$15 billion price tag from the Ministry of Public Works, Transport and the Environment, which in turn hopes to secure substantial contributions through the EU's Cohesion Funds. The balance is still expected to be provided by regional and municipal governments, which may be optimistic (*Water and Environment*, July 1995).

Cost estimates for the NHP vary. Jose Borrell, the Minister of Public

Works, has quoted figures of US\$27 billion, of which US\$15 billion is required to fund the water transfer schemes, and he has revised the total downwards on a number of occasions (*World Water and Environmental Engineering* 4, 1994). Herreras (1993), who has been very active in development of the plan, quotes larger sums: US\$40 billion funded through Public Works plus an additional US\$25 billion sourced from other national and regional government bodies as well as private sources, which would average US\$3 billion per year over the life of the plan. A study undertaken in the late 1980s by a UK engineering firm put the price tag even higher at US\$4 billion per year to 2015 (*World Water and Environmental Engineering* 4, 1994). Borrell has proposed to increase household water charges by US\$25 per household to finance the implementation of the NHP, but at the outside, this would raise a gross figure of around US\$500 million.

Drought and the Re-emergence of Regional Politics

A severe drought began in 1990 and continued with increasingly severe impacts until 1995. In 1994 reserves were down to 10 to 20% of capacity and in some large southern cities such as Cadiz and Seville, the situation was even worse with reserves standing at only 5%. Emergency measures including hosepipe bans and cessation of night-time deliveries barely coped with demand, particularly in the tourist areas.

By 1995 the government had spent almost US\$165 million in emergency measures to cope with drought which included interest-free loans and tax-free credits to badly affected southern farmers (*Economist*, 20 May 1995). In Andalusia, only 10% of storage capacity remained and total losses to farmers across the nation were expected to reach US\$2.49 billion for the year, despite a moratorium on irrigation fees. Knock-on impacts on casual harvest work has provided further hardship in the south, where food prices have risen dramatically.

Spain has a long history of public participation in water development, and the authors of the NHP claim that it was carefully researched and sought considerable participation and consensus in its development. Parliamentary groups unanimously approved a resolution to designate the NHP as a State Subject and present it to Parliament for approval (Herreras, 1993). The drought may have contributed to such consensus, but it is clear that this has unravelled badly in the following two years as the impacts of the drought and its implications hit harder. The *Economist* (20 May, 1995) reported that regions have been threatening violence against each other and municipalities have been at odds with regional governments, which are as a consequence attacking central

government in Madrid. Regional political leaders have polarised the debate on water transfers accusing the 'profligate south' of stealing northerners' water. There is strong resistance to the exiting proposals to raise water charges across the board to subsidise developments that largely benefit the arid south, an argument that recalls the successful public opposition of North-South transfers in California in 1982.

It appears that consultation for the NHP was actually restricted to a narrow, technocratic caucus of people who would understand the logic of national planning and water transfers, without consideration of the environmental lobby and Spain's emerging regional politics, particularly in Catalunya, where the Ebro river is a key feature of all transfer proposals.

The drought has focused the debate, in this case in an unexpected way, and has also brought agricultural and environmental interests in direct conflict as the degradation of wetlands and rivers has become extreme: the famous Tablas de Damiel bird sanctuary has almost dried up. Environmentalists and opponents of excessive government expenditure in an increasingly straitened economy have united to suggest that conservation could be further improved through better technology and pricing, opposing the technocrats view that these mechanisms are insufficient and are anyway already well-implemented. The proponents of price control note that per capita water consumption in Spain, at 1000 ML/yr, is only surpassed in the USA, Canada and Russia, and that new programmes such as the proposed sanitation tax to half-fund the National Sanitation and Wastewater Plan, will lead to further economic reform to control water use (*Water and Environment*, July, 1995).

It is ironic that the NHP, built on the basis of longstanding and 'ideal' institutional arrangements for water management, should have opted for such a whole-hearted engineering approach to national water management, some 15 to 20 years after such solutions have been rejected by governments and the general public in the USA and Australia. It would be foolish to say that Spain has not regarded history elsewhere, for further large-scale water transfer projects may yet be promoted (in California for instance), once the effects of demand management and adjustment in the agricultural sector have ceased to restrain demand within the limits of available supplies. Further developments in this story will prove to be illuminating, but above all indicate that even the most 'rational' and comprehensive institutional frameworks for water management are insufficient, in the final analysis, to achieve equitable and sustainable water management – the political dimension, famously ignored by engineers the world over, remains the key that unlocks the door. Achieving political consensus in a democracy often requires more than simple logic, or improvements in national welfare that are not reflected in the majority of the nation's regions.

The Environment – A Latecomer in Spain's Water Politics Equation

The key to the emergence of an environmental lobby in Spain appears to be the nation's wetlands, which have been severely affected by agricultural and, to a lesser extent, industrial development. Wetland conservation and rehabilitation pits environmentalists squarely against agriculture over competition for limited water resources in the arid south of the country, competition which is heightened in drought periods. Degradation has occurred because of a wide range of (mainly agricultural) activities, including:

- drainage;
- dredging;
- sediment deposition from agriculture and urban development (coastal);
- direct water extraction;
- water-level control;
- water pollution from intensive agriculture and industry;
- introduction of 'exotic' species such as the Louisiana Red Crayfish;
- intensive aquaculture; and
- road construction.

Agriculture covers 40% of Spain's land area (20.4 million ha), 27% of the total arable area of the EC. Intensification has increased since the end of Franco's era, and the irrigated area trebled this century. The irrigated area grew by 13% from 1977–86 and rice cultivation increased by 16% over the same period. The distorting economic effects favouring short-term agricultural growth to obtain the benefits of CAP subsidies has been targeted for particular criticism.

Groundwater mining has severely degraded the Tablas de Damiel wetlands where local laws favour agriculture development over conservation. In La Mancha, a long -distance water transfer to restore water table levels for wetland habitat has not worked as it has proved to hard to replicate the natural dynamics involved.

Almost half of Spanish rice is grown in the lower Guadalquivir, where salinity is becoming a problem, as is the level of water control applied to rice culture. A US\$ 727 million ha irrigation project in the Ebro basin (also a major rice producer) has resulted in salinity affecting land and water resources on and adjacent to the 66,000 ha Monegros II scheme. Drainage proposed to mitigate salinity will have further negative impacts on wetlands. Historically, wetlands have been drained to control malaria as well as for conversion to arable land, especially after 1860, when a series of amendments to the 1879 Water Act encouraged drainage works. Private agriculture and tourism development in the wake of land tenure reforms in 1952 and promotion of the tourist industry in the 1960s, often had more impact than state developments. In Huelva, the number of

housing units rose from 33,000 to 341,000 over 20 years of tourism development from 1964 onwards.

Wetlands no longer play a major role in flood mitigation and detention due to the high degree of river regulation across the country, but are still important sites for groundwater recharge and discharge, wildlife (especially birds), and scenic value in an otherwise dry landscape. Aquaculture and hunting have been important business and recreational activities whose constituents have tended to throw in their lot with environmentalists.

It is estimated that 60% of Spain's natural wetlands have already been lost, although full inventories were not undertaken until the 1940s, when it was concluded that the conversion of many wetlands was not economic. A comprehensive inventory using the RAMSAR convention classifications was completed in 1988; it identified 20,000 units but only 2000 covered more than 0.5 ha. The Conservation and Natural Species Act was passed the following year and sets out administrative arrangements for wetland protection and conservation. As environmental protection agencies existed in only four autonomous states at the time, implementation of the act has been less than whole-hearted, and the abolition of the Inter-Ministries Commission on the Environment was a further setback to the 'green cause'. Designation of nationally important wetlands as parks failed to check their degradation as no restrictions were placed on groundwater abstraction in the surrounding land overlying connected aquifers.

Although there is a clear national policy on water resources development and use, there was no comparable policy on the environment at the beginning of the decade. The roots of this oversight can be traced further back into the confusing and overlapping jurisdictions of different laws governing ports, shores, coastal protection and land reform that were not consolidated and rationalised until the Water Law of 1985. Revisiting the NHP from an environmental perspective also gives the impression that ecology, habitat, in-stream flows and even surface water pollution have been given fairly superficial treatment in comparison with the requirements for ecologically sound water management that are being articulated in other developed countries.

The fragmented past structure of government laws and organisational arrangements for environmental protection has been addressed by more recent water and environmental legislation, but active pursuit of their goals lags considerably behind events in the United States, where environmental pressure groups have established powerful positions through the courts on the basis of stringent federal and subsequently state legislation. Similarly, the environmental agenda is well represented by state agencies in Australia, which now have the dominant behind-the-scenes power in natural resources administration, as well as an effective

public mandate. The recent gains made by the green lobby in Spain as a political force, indicate that significant changes are in store for the carefully wrought NHP and for water management in general in Spain.

5

Common Themes and Divergent Experiences – A Synthesis of Approaches to Reforms in Water Resources Management

General Points

Institutional Reform

There is little retrospective and comparative analysis on water resources policy reforms and their implementation. Reisner's witty but polemic history of western American water development is an exception, but what is usually written describes current initiatives or, more often, reacts to known proposals and problems, offering opinions on what might happen next, based either on modelling or simply a point of view.

It has proved difficult in practice to use the analytical framework set out in Chapter 1 as more than a set of guiding principles, and impossible to establish much of the anticipated detail with the information available. More importantly, breaking down all interactions within the institutional framework is tedious and ultimately uninteresting and incomprehensible to the reader, so a more thematic treatment was used.

It is clear that institutional reform, although something of an icon in today's development thinking, has been a common feature in the history of water resources development, and that in many ways, the institutional arrangements set up to respond to past policy, notably that of water development, were effective....too effective and too limited in their scope. Many calls for institutional development and reform presuppose an 'institutional desert', although in developing as well as developed countries this may not be the case. Policy objectives have changed to meet changed political and economic contexts, new and more complete understanding of natural systems, and public concern over the management of natural resources and the environment. The problem is really one of how to develop a clearly articulated transition in policy and how best to re-order existing institutional arrangements to be not only responsive, but also proactive in meeting new objectives.

Technical and technically biased institutions have developed along parallel, but not necessarily linked paths, and the study indicates that technology and institutional development will continue to be closely linked. There is evidence of a cycle of technological innovation to meet demand, followed by institutional adjustment to manage both demand

and, sometimes, the consequences of the technology used. As needs increase beyond the limits of existing technology and institutional capacity to satisfy demand, new technology is deployed, often supported by considerable public subsidy.

In two of the three countries examined in this study there are no longer any large-scale, publicly financed capital works on technical, economic and, above all, environmental grounds. Now, local micro-technologies are managing demand, conserving water, and augmenting supply (e.g. by desalination). Where shortfalls in resources are severe, technology is still invoked: Israel is investing considerable funds in new approaches to low-cost desalination, including improbably massive wind-shear towers (Water and Environment, March 1995). Israel also intends to use only treated wastewater for irrigation by the middle of the next century, a goal that requires considerable infrastructural development, with a parallel plumbing system for dirty water running in parallel to the national water carrier. These are extreme and expensive solutions, but it is foolish to imagine that institutional reform alone will solve water supply problems indefinitely.

The imperatives to substitute demand management and water management for supply development are different in all three case studies, even though there is much common ground between the solutions proposed and applied. In the western USA, there is direct competition between urban and industrial needs on the one hand and agriculture on the other. In Australia, water conservation is an integral part of the strategy to mitigate salinity and other negative environmental impacts, and is not explicitly driven by competing urban and industrial needs. The problem for planners in Spain is simply one of a general shortage of water for all (justifiable?) economic activity in the south of the country, and assumes that competition between sectors will not arise if supplies are increased; the possibility that agriculture might surrender some of its water for other uses has not been seriously entertained, whereas it is clearly the key factor in balancing demand and supply over a range of important economic activities in California. Water demands for the environment are now at least as large as for agriculture in both the western USA and Australia, but not yet in Spain.

Whilst there has been much justified criticism of past excess and the economic 'madness' of pursuing water development at all costs, particularly for irrigation, it is clear that the environment has usurped the godhead of water policy and is in danger of sponsoring the same distortions and misuse of public funds. Water treatment and delivery is the giant of the US environmental industry with total revenues in 1994 of US\$64 billion (Water and Environment, July 1995), of which US\$13 billion was treatment and chemical supply.

The global environment market is estimated at US\$305 billion, much of which will be spent on basic infrastructure investment in southern

Europe, South-east Asia and Latin America. The World Bank puts the bill for water-related expenditure as high as US\$600 billion over the next 10 years (Seregeldin, 1994 and 1995): a considerable and possibly intractable financing problem. The cycle of technological development and institutional reform has tended to oscillate from one 'extreme' to another, as the overriding power of politics¹ over neatly conceived arrangements for management is a major factor in both the time lag and degree of swing in reform.

Better institutional arrangements would concentrate on achieving consensus between potentially opposing interests and on establishing procedures and a culture of awareness that looks outside the received nostrums of the day, ensuring rapid, smooth adaptation. The Australian approach addresses this problem by internalising much of the politics of water management and encouraging development through community-led initiatives. This route is expensive, and although the environment now commands almost unquestioned public expenditure, it is a situation that sits uneasily with many governments' professed economic rationale for removing the subsidies given to water consumers.

The alternative approach in the United States relies on a more chaotic mix of federal and state law, implemented through an adversarial court system. The resulting culture of litigation, particularly in the State of Colorado, is expensive and encourages polarisation. Dissatisfaction with the effectiveness of a state-administered regulatory approach led to the innovative Proposition 65 in California, which tries to improve the implementation of environmental protection. Early indications are that this is also a costly process and that economic efficiency is not one of its priorities. The dilemma for Spain in meeting the EU directives on water quality is similar: massive investments are required, largely in technology, to meet standards that many would claim are too stringent – although much has to be done to meet even the country's own relatively lax requirements. Environmental economics is not exactly a new science, but there remains a shortage of information and capacity to value both key aspects of the environment and strategies that might be adopted to conserve or enhance it. Clearly much further research is needed in specifying environmental needs in detail so that appropriate and economically justified action can be taken.

Science, Knowledge, Truth and Information

In theory, water resources management is founded on sound science and sound economics, but this study (and others concerning international

¹ conflict between opposing 'narrowly defined' interests

water allocation) show that science can easily be misrepresented to suit conflicting agendas. A long-term goal of reforms must be to ensure the even-handed provision of well-collected and -collated data, that has been analysed with as dispassionate and open a mind as possible. Equal access to good quality data has been a fundamental precept of cooperation within the Murray–Darling Basin, whereas the major remaining problems in water allocation in the Colorado derive from an inability to revise allocation arrangements made, in 1922, on the basis of partial and ultimately incorrect analysis.

Scientific truth is even harder to come by in demand forecasting. It can be manipulated for different purposes easily, and leaves out important variables – often not taking account of demand management and conservation methods (although it is not clear if these impacts should be considered as one-time improvements or will continue incrementally).

Reform or Revitalisation?

Debate in the developed countries has not been about provision of services so much as about improving standards of 'satisfactory' services to meet increasingly stringent public health, water quality, sustainability and economic efficiency criteria. Most developing countries are still talking about how to achieve sufficient coverage of effective and economically sustainable service provision; develop basic professional capacity; and meet minimum standards of service provision and environmental protection.

Full cost recovery is widely recommended to developing country water suppliers as a means of improving efficiency and reducing the public expenditure burden, but the study shows that developed countries have made strong *historical* use of substantial capital and operational subsidies in water development and service provision; have *continued* capital subsidy, and selected operational subsidies, some which are reducing, some not; and offer considerable *price support* for agricultural commodities (in Spain and the USA, but not Australia).

Water Policy

The institutional framework in the United States is, compared with Australia and Spain, confused by multiple federal and multiple state bodies empowered to deal with different aspects of water resources management and development. The historical confusion of construction- and development-related agencies now includes environmental and regulatory agencies, which have little sympathy with broader problems of water provision and management.

Prolonged drought in California and the Hunter Valley has been the trigger for institutional reform and the key to the acceptability of demand management. Pricing reform in the Metropolitan Water District of California and in the city of Newcastle (Hunter Valley) has been introduced with minimal public consultation under the smoke-screen of a drought crisis. It is still rare to find true long-run marginal cost pricing (LRMC) being practised in the water industry, but alternative supply arrangements for Californian industry are now based on this principle as a result of disciplines imposed by drought. Other economic tools have been introduced, such as bulk discounts for adopting water conserving technologies, and are used in conjunction with penalties for excessive consumption.

Public participation in the western USA has been achieved through strong private sector and private association involvement (which may not be widely representative) and via public referenda, namely the proposed North–South California and Mississippi–Texas water transfers. Public representation has been widened by reforming membership of water districts to include all those on the electoral register, not simply the (declining proportion of) landholders, but there has been less inclination to involve the public directly in policy formulation and implementation of water management strategies. In contrast, active and concrete public participation lies at the heart of all current Australian strategies of land and water resources management, which are integrated at the watershed level where possible. This has been an expensive undertaking and it will be hard to evaluate the economic efficiency of this investment, although there is little doubt that it is already making a considerable impact. In Spain, a strong tradition of participation in water affairs was submerged under the long dictatorship of General Franco, when technocrats were able to develop the nation's resources and management systems. Although the tradition has re-emerged with democracy, government departments inviting participation appear to have done so on their own terms and neglected two powerful emerging constituencies – regional political identity and belated environmental awareness.

Two significant historical water policy failures in California have been the non-integration of surface and groundwater management and the allocation of private property rights to groundwater. Although this has been redressed by recent amendments to state water law and by technical interventions such as recharge and long-distance transfer, clearly integrated policies for efficient and equitable conjunctive use are a very recent 'innovation'. The cycle that water development followed in California may repeat itself in many developing countries where ground- and surface water policies are not well articulated and actively pursued:

- settle – develop surface water resources
- *develop groundwater resources in face of rising urbanisation,

- industrialisation and development of irrigated farming
- feel negative impacts of development, but continue
- understand negative impacts of development and seek augmentation of supply to mitigate negative impacts of groundwater mining and increase total supply (inter-basin transfer)
- manage demand and reallocate water – augment supply for higher value uses
- return to*

Most arrangements to mitigate groundwater mining in the USA have been initiated by competing users taking a longer term view and enforcing common restraint on dissenters through the court system. The momentum of growth has been so great, however, that these self-formed institutional arrangements have been overwhelmed and supply augmentation has settled the problem in 90% of the historical cases.

Groundwater was brought under state ownership and allocated through renewable licenses in both Spain and Australia, where it has been a manageable exercise because of the limited development of groundwater, effective enforcement of regulatory codes (with some drought exceptions in Spain) and the relatively small number of extractors involved.

Environment versus Resource Management

In many ways, the environment rather than the problem of matching demand and supply drives the reform agenda. The volume of environmental demand is on a par with irrigation allocation and is much larger than municipal and industrial needs.

Environmental legislation has attained a theoretical dominance over provision of water services in the United States, but it is not always as economically or practically efficient as its proponents would like. The assumption that the state is the obvious and rightful originator and enforcer of regulations has been challenged in California, not on economic but on performance grounds, resulting in the innovative but as yet incompletely evaluated Proposition 65: environmental regulation policed by the public through the courts. The resulting 'environment industry' looks set to become huge, with expenditures which may dwarf those invested in the infrastructure that generated some of the problems in the first place. In the past 15 years strong alliances have developed between environmentalists and public sector reformers to promote full cost recovery and the valuation of water as an economic resource in order to curb excessive (predominantly agricultural) use and mitigate its negative externalities. In the long term, the blocking tactics that have historically been the main weapon of the environmentalists will have to

give way to more constructive modes of action, and ones which survive similar economic scrutiny.

Salinity management remains a considerable and costly challenge: the Australian approach of establishing a state-level management framework with mutually agreed targets appears to work, allowing flexibility in the adoption of appropriate technology, land management strategy, cost management, and institutional development at a state level. The importance of public participation in this strategy has already been summarised, but formal education has also played a significant role for both the general public and more specialised interests. However, the federal government subsidising and promoting the best course of action is curiously parallel to the construction and water development age – the level and targeting of public expenditure on the environment should be carefully scrutinised, so that we do not repeat the overspending of the past for little substantial and long-term return.

The interaction between water management, the environment and agriculture must be clearly understood, and although it can be modelled, analysis done to date has little overall policy coherence. Taking land out of irrigation may enhance streamflow and natural habitat and may allow for reallocation to higher valued uses, but it may also require substitute production elsewhere on rainfed lands – where erosion and other environmental externalities may occur. Local food security and export production are still important national priorities in all three study countries. Although Spain and Australia are industrial midgets compared to the USA and some European nations, their trade base is no longer founded on agricultural exports, as tourism has become the premier contributor to GNP. The extent of structural adjustment in agriculture in the USA and Australia has so far been modest, despite recent declining trends in net irrigated area. The twin impacts of trade reforms and environmental regulation will have a determining role in the extent and rate of land use change and ultimately on the amount of water freed up through land retirement.

There is still a *basket of needs* when it comes to incorporating environmental values into water policy and management practice:

- better specification of habitat and indicators of habitat degradation;
- specification of volume, duration and timing of environmental flows; and
- estimation of the costs and benefits of environmental allocation and modification to water resources systems.

Significant problems remain in ensuring effective compliance with environmental standards, and require innovative solutions: institutional inertia and possible capture of state regulators requires alternative arrangements such as the Proposition 65 approach, but there is considerable risk of massive litigation resulting in an expensive and unworkable system. The historical common property resource institution

of Californian recharge district is an attractive alternative, where considerable effort in consultation prior to establishing binding legal agreements among the majority of groundwater abstractors reduced legal costs considerably in the case of the Central Basin (Chapter 2). Other community-based approaches such as Integrated Catchment Management have great potential to establish arrangements acceptable to a broad range of interests without incurring massive legal costs, although they may be able to enforce the resulting agreements effectively through appropriate development or modification of local laws.

In all three countries, water quality degradation has added a new and more serious dimension to groundwater mining, because exorbitant treatment costs make much chemical degradation effectively irreversible. By contrast containing and mitigating saline intrusion has improved through better hydrological understanding, recharge barriers, and stabilisation by inter-seasonal storage and recharge strategies.

Wetlands

There have been many calls to integrate wetland conservation and management into river basin strategies (Hollis and Acreman, 1994), and there is considerable evidence that this has happened to a significant degree in California and the Murray–Darling Basin, but not so in Spain. The following wetland habitat conservation activities should be a part of basin management strategies:

- Make an inventory of all wetlands within a basin, whether untouched, degraded or lost.
- Assess their existing and potential functions and values.
- Recognize their location, role and importance via formal classification within land-use assessment and planning.
- Enhance public and political awareness of their value and function.

Integrated catchment management policies are increasingly pursued in all three study countries, but foremost in Australia. From an ecological perspective, integrated catchment *management* requires:

- quantification of hydrological needs in different parts of the basin's hydrological cycle;
- consultation and cooperation with the entire population of wetland users and consideration of all species of flora and fauna; and
- maintenance and enhancement of wetlands as part of sustainable water resources management.

Water Allocation

Reallocation of water from agriculture to environmental, urban and industrial use has been achieved by:

- land purchase for water right (water farming);
- voluntary sale of water right or excess (water trading and marketing on temporary and permanent bases);
- administrative fiat (environmental legislation and in-stream water use in SWP);
- short-term water sale to a water bank (Californian droughts);
- cooperative conservation agreement – MWD in southern California pays for lining in Imperial Valley in return for transfer of saved water;
- negotiated adjudication of water right in groundwater as with southern California groundwater in the Raymond, Central and Western basins;
- traditionally, on an *interstate basis*, by compact – although Colorado Basin legal apportionments exceed annual average streamflows, allocation in the Murray–Darling Basin is determined on basis low flows, and in most years downstream flows are considerably greater than the minimum allocation;
- or by sale of bulk entitlements across state boundaries by central agency (MDBC proposals in Australia), or by private sale (possible under US federal law but opposed by state legislation in the few cases that have arisen to date);
- (rarely) by loss of water right through failure to maintain beneficial use (possibly through redefinition of 'beneficial' use); and
- cessation of license which is re-awarded to other uses/users; land retirement in agriculture in the western USA and Australia will result in water rights returning to the state/ bulk supplier as beneficial use is no longer proven, or licenses are revoked.

Inter-seasonal storage and allocation is increasingly being managed by banking groundwater (including artificial recharge) in non-drought years to build up an assured supply for drought use (California). Little data has been presented on the relative economics of inter-seasonal storage in aquifers compared to reservoir storage, but it has many potential advantages in access and minimal capital costs which are traded for complications in regulation of uses and increased operational costs. Groundwater banking may be coupled with licensing and other restrictions on non-drought abstraction (Australia). The use of this strategy is limited where raising water tables will result in water contamination from pollutants such as salt or nitrates from agriculture, and unless there is a discrete closed basin (as in the Arvin Edison example), water accounting may be too complicated for satisfactory management and agreement between the various stakeholders.

Water Markets

Water markets are just one of a range of transfer instruments and mechanisms and their importance has been overblown and based too frequently on theoretical considerations, with little evidence from actual practice. Market transfers are much more extensive than recent literature indicates and have been practised for almost 30 years in western USA. Excepting California, water right transfers do not suffer from major structural/water right/legal impediments.

Although there are many transfers, the actual volume is low, except interestingly in California, where major transfers are brokered and made by bulk sellers and irrigation utilities. Drought water banking is a market-like transaction, but is not strictly speaking water marketing, since transfers are temporary, and are mediated and promoted by a public agency which specifies purchase and sale prices across the board. In Utah, the subdivision of water rights for sale has exaggerated the number of transactions, when in fact the total volume is very modest. Significantly, a large proportion of transactions in the western states are conducted between farmers and not between sectors, and in Australia most transfers to date are of previously unallocated water, bought almost exclusively for irrigation use.

The transaction costs of water right sales vary and can be quite high, but they are much easier to assess than the actual sale price, which is private information unless the use changes. Even where water trading is active, the time to process transfers can be a significant impediment – the adversarial water court system in Colorado (N) averages 20 months for settlement, compared to 2 to 3 months in New Mexico, which has an administered market operated by the state engineer.

The restrictions that remain in place in the western states and Australia reflect concerns about third party impacts of transfer – to neighbouring irrigators, downstream users of returned water, and as a result of the new use. Water quality needs to be specified in water right transfers, but this may pose problems beyond the capacity of the system managers to guarantee, as would be the case in transfers of water downstream in the increasingly saline conditions of the Murray and Colorado rivers. In hydrological and environmental terms, careful scrutiny of proposed water right transfers is both advisable and necessary, and unlikely to be sacrificed to market efficiency.

Critics of current water rights arrangements hold that market transfers need to be based on securely specified quantities and timings of flows. A contrary 'real world' view is that the nature of the hydrology of semi-arid and arid areas does not allow absolute security and requires either specification of smaller reliable basic rights, augmented by optional entitlements (as in the Australian irrigation systems); or a tiered rights

system with high reliability (high price supplies) which must necessarily be small volumes, and lower security high-volume rights. Transfer of seniority accompanying water rights sales under the prior appropriation doctrine presents considerable practical difficulties unless water is reallocated downstream of a common source or storage: even then, water accounting and establishing seniority in a new locale can cause great confusion in the successful administration of 'imported' rights. One reason that a large proportion of transfers are between irrigators is that they are manageable because of their proximity and the consequent ease of administration.

While California has one of the most comprehensive infrastructures to allow longer distance water trading, and managers have the capacity to account for consumptive and non-consumptive use in different parts of the water system, most developing countries could not tackle the basic administration when the infrastructure is a fixed, imperfect and often sub-optimally managed irrigation network. There have been suggestions that *public* agencies should promote water trading more actively and that they might establish transfers for environmental use in this way, with longer term stimulation of a more vibrant market.

There is a need to develop better methodologies for valuing water in competing uses, and to take account of factors such as capitalization of land value, job security, lifestyle, and longer term livelihood strategies when valuing water rights. Such insight might help to explain why short-term trading and direct sales of water are more common and more attractive than permanent sale of water rights. Good research is hampered by the difficulty of obtaining hard data on prices paid for permanent transfers of water rights away from the agricultural sector.

Water Conservation

Reallocation of water without loss of agricultural production cannot be contemplated without conservation, and conservation is an integral part of strategies to reduce per capita domestic water consumption to allow existing supplies to be spread further. Conservation strategies need a system-wide approach, however, especially to avoid third-party effects, such as the loss to Mexico of fresh groundwater supplies as a result of lining the Grand Canal in the Imperial Valley.

Land retirement – increasingly common in Australia, Texas and California, is probably the most cost-efficient form of water conservation and also has the greatest impact on reductions in salt loading. Agricultural production may suffer locally, but overall impacts on the state- or basin-scale economy have not been great, as it is generally extensive enterprises on marginal lands that 'go under'. There can be unexpected consequences of land retirement; soil surface stabilisation or

permanent revegetation may be required to prevent land degradation and resulting dust-storms, imposing new costs and requiring some continued apportionment of water for that purpose. It is the hard option, where adverse terms of farm trade are left to come into play, restructuring farms without compensation. Alternatively, incentives must be offered to retire land, and these can and have included land purchase. What is adequate compensation? Accounting for knock-on effects to rural life, rural economies and agro-industry is a difficult, expensive, and political question.

Water conservation has been more successful in urban water supply and industrial settings than in agriculture: wastewater treatment and re-use in industry has been very successful. Amenity watering has been reduced by a combination of technology, price, re-use, publicity campaigns and alternatives such as xeri-scaping. There is increasing acceptance of wastewater generally although this may be less acceptable in some cultures.

Water conservation in urban, industrial and rural water supply and sanitation has been achieved by:

- better average cost pricing and the introduction of inverted multiple block tariffs – especially in drought periods;
- LRMC pricing in a few instances, such as MWD's industrial water supply incentives for recycling and on-site treatment;
- rationing and restriction;
- land zoning (such as the Tucson land subdivision requirements of 100 years of guaranteed supply); and
- improved technology and processes.

Agricultural use *has* been reduced on farm but could be reduced more. Much of the failure to *translate* improved water-use efficiency into 'spare' water for inter-sectoral transfer is because:

- savings are used on farm, either because it makes economic sense to the farmer (and price is still subsidised) or because, in rarer cases, it is not possible to sell unused parts of water right;
- losses on-farm and return flows made up significant portions of supply downstream (an extreme example is Imperial Valley–Mexico situation described earlier);
- establishing accurately the flows made available at any given time may be hard to do given the limits of flow measurement and detailed capability in water accounting;
- on-farm savings do not necessarily translate into the same volume stored for alternative use due to evaporation and seepage losses from storages, and flow patterns resulting from their operating regime; and
- water quality considerations.

Australian water conservation has been limited due to the predominance

of surface application techniques on heavy soils, although significant improvements can be made using a minimum of control and automation. Scheduling, and improved farm layout (for which subsidies and subsidised services were provided) and water control have been the main approaches, along with recent interest in on-farm water re-use to minimise saline disposal to the water courses.

A major obstacle to more widespread adoption of conservation technology and practices in irrigation is the disincentive of highly subsidised water, particularly in US federal projects (e.g. CVP costs of delivery are 10 times greater than charges in 1985). Water conservation technology (overhead and micro-irrigation, surgeflow, channel lining) has made less impact on total water use than land retirement, particularly where there has been groundwater mining, (such as the Ogallala aquifer in New Mexico and Texas). Some water conservation technologies may reduce water demand but involve yield losses which make adoption unattractive under prevailing agricultural market conditions.

In-stream and habitat allocations are very sizeable compared to projected savings from improved agricultural use, and provide the largest element of uncertainty in forward planning (such as the San Joaquin Valley/Sacramento river allocation and moratorium on water development and use in the delta region).

Demand Management versus Augmentation

Demand in California has been so great that it has not been solved by demand management for more than short periods, and inter-basin transfers have so far guaranteed reliability in supply. Sea and saline water treatment is tantalisingly close to being an economic option for enhanced urban and industrial supply, and is already used in many situations where the local economics do make sense (e.g. 650 industrial and municipal locations in California by the mid-1980s, followed by a smaller number of very much larger and more efficient facilities in the early 1990s). Continued research into new technologies for 'low-cost' production is crucial to economic acceptance of this energy-expensive technique. One such programme is the wind shear electrical generation system under development in Israel (cost US\$0.4/m³, compared to wastewater treatment in California at US\$0.25/m³). It involves construction of a 1000 m (!) wind tower housing turbines and leaves many questions unanswered, not least disposal of sea salt at a cost US\$400 million.

Inter-basin or long-distance water transfer has been fundamental to the development of the western USA and to the mitigation of groundwater over-abstraction, although it has become too expensive to contemplate, even where it is the least expensive augmentation option. It has also

proved politically unpopular with voters and state politicians, who have defeated most proposals that emerged in the last 15 years. By contrast, Spain would like to embark on a highly ambitious national (rather than state level) programme of water transfers, and is starting to run into the same level of public opposition, in addition to more mundane problems of actually raising the required finances. Although there is probably more experience of demand management in California and Arizona than elsewhere in the world, it is not clear that such measures do more than allow a breathing space when population and hence demand is continually rising. Conservation in agricultural water use has not yet had the expected impact, and although small real reductions in irrigation consumption (10%) are adequate to satisfy a doubling of all other demands, even this target has so far been hard to reach, either by administrative or water-market-based reallocation. Substantial public subsidies are still afforded irrigators in the United States, not only because they are a sizeable and vocal portion of the western electorate, but because irrigated farming supports a much broader range of rural industry and enterprise.

The next stage in the US is likely to be whether, on completion of good programmes of demand management, further long-distance supply augmentation will be economically feasible, and financially affordable; politically acceptable in the donor region; and cheaper and more politically acceptable than retiring irrigated land on a substantial scale, including valuation of the consequences for US food policy.

It would appear that Spain is approaching the same dilemmas that the western United States faced in the mid-1970s, when long-term agricultural commodity prices were expected to continue rising beyond 2010. Instead, prices have decreased consistently for the past 15 years, although price support has shielded the individual farmer from much of the economic impact. Substantial reduction in EC agriculture price support, (not likely but ultimately inevitable), will have a severe negative impact on the economic justification for Spain's National Hydrologic Plan.

The environmental lobby in Spain has only recently emerged as a significant political force and is implacably opposed to much of the NHP, and shows little sympathy for the irrigation development which has already taken a considerable toll on Spain's wetlands. It is ironic given that Spanish water policy, basin administration and the NHP itself have evolved over centuries, that the 'most logical' hydrologic outcome for development and management is set to founder on late-developing regional hydropolitics and almost unrecognised environmental issues.

The resolution of conflict and dispute over large-scale long-distance transfer would seem best addressed by public referendum, following a clearly presented set of options and views of the protagonists and antagonists. If there is reasonable consensus, self-financing or partial self-

financing becomes considerably more likely.

Alternative Administrative Arrangements

In the USA, there is a characteristic mix of public and private enterprise developing and providing water-related services, and there has been throughout this century. It is odd to have pure private water distributors supplied by subsidised federal or state bulk sellers (CVP and SWP), and considerable distortions in the economic rationale for private ownership, management and financing are still evident. Both Spanish and Australian development has been state-led and state-coordinated, although Australia is now embarking on a programme of privatisation which may end up having some of the characteristics of western US water, including relying on court mediation of disputes. The Victorian and NSW experiences with corporatisation (Melbourne Water, the RWC and Hunter Water Corporation) have shown that significant strides can be made in cost recovery and attainment of self-financing *within* public ownership. The Australian approach of writing off outstanding capital debt contrasts with the insistence on capital cost recovery in US privatisation, where the actual total contribution to depreciation by irrigation districts has been very small and substantial operational subsidies have continued to be applied.

Many public sector water utilities operate as corporations in western USA, but the only broad evaluation of private and public metropolitan utilities shows both to be price-inefficient and over-capitalised. Public utilities are superior technically and in the use of inputs such as labour, energy and materials (Bhattacharya et al., 1994), but overall are less consistent in their performance than the private sector.

In California organisational innovation is dealing with groundwater mining through the voluntary formation of water management districts, groundwater recharge districts (only one) and user-developed agreements, restrictions and levies (pumping taxes). Both the state and private organisations have made considerable use of the private sector for background information and analysis (engineering and hydrology consultants as well as lawyers), although historically the Water Districts (both in irrigation and bulk municipal supply) had better links with federal agencies in terms of influence and access to information. A key feature of self-imposed organisational change and self regulation by competing water users has been the importance of prime movers with long-term interests who are prepared to shoulder a large portion of the legislative costs of developing, coercing and finalising a binding agreement for more sustainable management.

Non-government organisations have had relatively unimportant roles in water management until the emergence of the environmental debate, in

which they have clearly been instrumental in gradually and then substantially changing the agenda in water resources development and management, at least in Australia and the USA. Major environmental NGOs now appear to be moving beyond opposition, lobbying and activism to a more pro-active involvement with state and private agencies to manage all aspects of the water cycle and to attempt to harmonise productive and conservation interests – examples of this are the 3-Way agreement in California and the genesis of the LandCare programme in Australia.

Water Rights

There has historically been a sharp distinction between hydrological and legal understandings of water resources and the US legal approach separates ownership of atmospheric (!), surface and sub-surface waters, and does not recognize the linkages between them through the hydrologic cycle. Hence there is still a need to reform and develop an integrated water law in the USA as seen in the emergence of the proposed model codes – a continuing process and one that pits engineers versus the legal profession and its vested interests (note the number of water lawyers in Colorado). The broader compass of public water management in Spain and Australia allowed this integration to be achieved at a much earlier stage of water development and has avoided some of the ensuing excesses in groundwater abstraction and the institutional complications that have arisen.

There have been few real problems of registration of water right in recent history in any of the study countries, except where minority rights are concerned (for North American Indian, and possibly Aborigine claims). Customary use is by its nature incorporated into the appropriative rights doctrine, and has also been formalised by even-handed and open processes of licensing and registration in Spain and Australia.

From a distance, it is hard not to feel that there is almost unnecessary complication in the appropriative rights doctrine (even in model code form) compared to an administered, license-based system as exemplified by irrigation water rights in Australia, which satisfactorily incorporates variable specification of flows due to stochastic (drought) uncertainty and spreads water shortages evenly amongst users. Such specification is viewed by some economists as a restraint on water transfers, but intuitively it is hard to see why this understanding and sensible accommodation of reality cannot be specified as part of a transferable property right.

There is direct conflict in requirements for completely unattenuated rights for good marketability and quality/re-use/in-stream flow

requirements at other points in the system. The indispensability of such safeguards has not yet been well thought through by marketeers and it is likely that these attenuations will not only remain but be more closely specified (such as the model code requirements for proof of no impacts on other right-holders when making an application to transfer water).

Water quality degradation by return flows from all users is a problem that many would solve by adding appropriate standards to the specification of water right. This is very difficult to police in agricultural situations, however, as identification and attribution of the degree of pollution is difficult to determine and it is even harder to enforce sanctions against those judged to be the culprits. In Australia, where the water quality of off-farm return flows may be very poor and water rights may well be amended to specify discharge quality, it is more likely that a flat rate levy on metered discharge off farms will be imposed.

Hydrologically Sound Scales of Management and Political Administrative Boundaries

It has been said that the Tennessee Valley Authority has provided the 'default model' of water management for engineers in the USA and for their colleagues in developing countries. This model, though not discussed in detail here, has integrated all development planning at the river-basin scale and established a new political-administrative arrangements where only weak ones existed before. Over time, the TVA has probably been less successful in its objectives in integrated water resource management (see Helen Ingrams' writings) as power production has become its main concern. Even in the USA, the TVA fell foul of competing federal agencies, such as the USBR, who resented their turf and expertise being usurped.

In many situations where river basin management arrangements are introduced, there is immediately some form of conflict between the jurisdiction and power of the umbrella organisations and the civil administrative structure of regional and local government that has been in place for many years. Ingram's various analyses of this conflict indicated long ago that it is naive to conceive of integrated, 'one-stop-shop' administrative structures and that the real task of institutional development is to establish effective links and arrangements between the different jurisdictions. Developments in interstate cooperation in the Murray-Darling Basin are perhaps the most relevant examples of how time, mutual understanding and common goals result in the binding arrangements to manage a resource to mutual advantage and subjugate state autonomy in water management to a coordinating body that has no overriding federal or legal authority.

Constable (1995) makes four observations (founded on long practical

experience) concerning institutional arrangements for sustainable management of water resources where multiple political jurisdictions are involved:

- Any agreement will generally be limited to the extent of the individual rights and privileges each jurisdiction is prepared to cede in achieving the common good.
- The institutional arrangements established to administer such an agreement must provide clear-cut and uninhibited processes for ensuring that each party is able to access information relevant to its own political, economic and environmental interests. These arrangements should include measures to reach agreement on technical, operational, management and policy levels.
- The charter under which the institution operates should have sufficient depth and flexibility to address all relevant matters. Each party should be represented and provided with expertise of each relevant discipline.
- There must be clear identification of the rights and obligations of each party, but the institution should possess sufficient executive powers to act independently of individual parties for the common good.

Privatisation

Privatisation will continue to be a major thrust in reforming institutional arrangements for water management, but it is clear that there is insufficient experience of how best to manage the divestment of state enterprises in a way that takes account of the complex nature and multiple interests involved in water management. The cost of regulation has conventionally been assumed by the state, and there is clearly a need to separate both price and environmental regulators from service providers, although US experience is beginning to question the efficiency and effectiveness of such arrangements. Further privatisation of state roles, such as provision of flood and drought insurance and policing of environmental legislation has been one solution.

Privatisation of irrigation in Victoria has been rapid and conducted with great thoroughness, without making any pretence at recovering capital (sunk) costs. The Rural Water Corporation was dissolved and government staffing and expenditure rationalised. The target of zero rate of internal return on the RWC's operations was achieved for the two years prior to privatisation, when it was run as a semi-autonomous corporation – the importance of realising cost recovery pricing *before* privatisation. US experience indicates that privatisation itself is unlikely

to instill full cost recovery, especially if the privatised entities are large, financially powerful and capable of lobbying effectively for the continuation of substantial subsidies.

A major question mark hangs over the viability of the interstate agreement on managing the Murray–Darling Basin, particularly the Salt Credit Scheme, following the formation of private, cost-conscious irrigation associations in the two states. Safeguarding data collection and paying for research are immediate casualties of a tendency to price to a minimum and ignore maintenance costs, and there is an implicit assumption by privatised irrigation districts that the state will be obliged to bail them out later on. The evolution of the linkages and arrangements that ensure good interstate cooperation and action following privatisation and the establishment of a more complex and confused institutional landscape, will be very valuable experience for other countries in the future.

6

Implications for Developing Countries

Preliminary Points

There are five important characteristics that distinguish developed from developing country water management:

- Systems of data collection, management and dissemination; hydrological understanding; and an inventory of actual use all provide a solid *foundation* for planning and management. Widespread monitoring and measurement is carried out by professional agencies and the resulting data is available for public consumption.
- Well-established, if imperfect, water rights codes exist, with uniform registration of rights, permits and licences covering most uses. In contrast with developing countries there is insignificant, unacknowledged *de facto* or customary water use.
- It is common for professionally managed, service-oriented organisations to be responsible for water delivery in both public and private sectors. There is a longer history of public accountability of public and private organisations, with relatively open access to impartial if often expensive arbitration via the courts.
- There are long traditions of water legislation which have been actively upheld, underpinning a resource-based approach to water development, that has enabled a *transition* to integrated water management and incorporation of environmental values. There have been obstacles and excesses along the way, but the basic foundations to allow development of institutions of rational management have been in place for many years.
- There has been a historical commitment to full recovery of operational costs of water services – and partial commitment to recovery of capital depreciation – within the framework of strategic public investment, although practice has often not reflected the letter of this commitment.

Lessons

Policy Reform

A very basic priority for most developing countries is the establishment of a clear national water policy, with equivalent policies at state or regional level. National water policy needs to be supported by an appropriate set of institutional arrangements. The development of such a policy explicitly requires a review of the existing arrangements and a commitment to establish a coherent water law, and an oversight administration to research, oversee and support policy and its implementation. At a minimum, water policy needs to be coherent with agricultural and urban policies, and has to recognise economic constraints in public funding and increasing commitment to user-financing of operational and even some capital costs associated with carrying out works arising from water management strategies.

Water resources management is an increasingly complex and dynamic process. Water resources policy and management strategy is therefore in a constant process of reformulation and evolution. There may be priority issues that vary considerably between regions *and* specific localities within a country *or* drainage basin, as well as those which are generic.

The duplication and overlapping responsibility of government water agencies must be removed and the agencies bound into an integrated set of institutions. This does not mean creation of one super-organisation, although it may mean creation of an oversight and coordinating body.

It is not helpful to imagine that a discrete package of reforms in developing country water resources management is likely to achieve more than very short-term goals. Rather, the reforms need to establish a sound and adaptable institutional base with in-depth capacity to evolve and respond to a continually changing situation, and capable of identifying short- and long-term goals accordingly. The Department of Water Resources in California is now mandated to undertake a formal review every five years, and periodic review should be a fundamental part of establishing and evolving an effective water policy in developing countries.

Institutional Development

Apart from the pressing need to establish a coherent and integrated water management policy in many developing countries, there is a complementary need to 'get the basics right' and address the issues raised in the five bullet points above.

Developing countries are faced with awesome funding problems in the

provision of basic urban and rural water supply and sanitation alone. Hydrometric networks have often been neglected and detailed knowledge of actual water use is at best patchy. Sound provision of services and adequate management of the resource base cannot be undertaken without considerable improvements in data collection and management. Cost and a culture of secretiveness are the main obstacles to this, compounded by duplication of roles from overlapping technical jurisdictions. Establishing an integrated and effective national water intelligence system is a lot less ambitious than achieving comprehensive institutional arrangements for integrated and rational water management, and is a realisable goal in the relative short term. Outside agencies can help to establish local professional expertise and available information technology is increasingly cheap and effective.

This process should upgrade professional and administrative capacity and introduce incentive systems for good service provision, both in public and private sectors. It is important to develop a broad base of local capacity and minimise the use of external (international) consultants in the long term.

Planning capability can be improved by developing capacity for sensible modelling on the basis of reliable real-world data-sets to undertake:

- better demand forecasting;
- economic analysis, especially pricing and feedback for demand management;
- allocation and environmental impact studies; and
- investigation of groundwater–surface water interaction and water quality impacts of development;

Beyond the basics – A sound legal framework for water management

Effective capacity to manage water resources depends on sound institutions which in turn must be built on a sound legal basis. Water law (incorporating environmental law) provides the skeleton of the institutional framework. Historically, all three study countries have evolved complex and at times conflicting water and associated laws, which were unified and simplified in recent years. The continuing development of the 'model code' in the United States shows that it is particularly important to integrate surface, sub-surface and atmospheric legal provisions to accord with the physical realities of the hydrologic cycle. However, the development of two forms of model code (one for the riparian eastern states and one for the western states' doctrine of prior appropriation) indicates that although the form of this unification may be similar in substance, it may be considerably different in detail due to the difficulty of parting with legal precedent and long-established custom. Water quality and environmental-related water legislation has

often been developed separately, and effort is needed to make environmental provisions coherent and compatible with water legislation.

Although it is easily said and less easily done, care should be taken to avoid over-legislation and the promotion of a climate of adversarial litigation which will rapidly become unmanageable and ineffective. Thus there appears to be a continuing need for good extra-legal fora for arbitration, so that the courts are used in the last resort. The volume, expense and protracted nature of many civil actions in the USA is inefficient and damaging to rational and integrated management.

A distinct difference between the study countries and most developed countries is that many of the latter do not have an effective rights system, nor a representative register of right holders, nor the administrative apparatus to run it. So, whereas much of the discussion relates to refining and developed countries' water rights system, definitions, provisions and enablement of transferability, developing countries have almost to start from scratch. Starting from scratch is a worrying process given the typical levels of corruption in public administration where there is short-term financial gain to be made. Further, comprehensive registration may require considerable, tedious effort and discomfort for those given the responsibility of its administration. Practices such as posting notices *requiring* registration are often substitutes for pro-active effort and are less than desirable – especially if they are only posted on the agencies' own notice board, something that is not unknown.

There is a substantial caveat that points to broader levels of reform in public and civil administration: water legislation and registration of rights is pointless without adequate assurance of 'inexpensive' access to courts or substitute arbitration, and impartiality to all parties.

Administrative reform

In many developing countries, there is still the need to break the dominance of irrigation agencies, the construction agenda and its associated bandwagon. This has been the key to internal organisational reform in the USA and Australia, but reformers should beware the potential for a new construction bonanza in urban and rural water supply and sanitation which could easily lead to the new agenda of sustainable management being bypassed. It is clearly important to actively oversee the transition in public agency role both from implementation to management and service delivery and from service delivery to regulatory, data collection and planning/coordination roles. In many developing countries it would be wise to concentrate on service delivery foremost, while setting in motion the longer term transition to a regulatory role; a potential pitfall is that a step-wise approach may cause difficulties further down the road with overlapping jurisdiction with other regulatory agencies, most likely those responsible for

environmental protection.

Privatisation has a clear role to play, although for developing countries it is probably more important to attract private capital to finance urban water supply and wastewater treatment. Privatisation is most appropriate in sectors where service provision is clearly defined and 'easily' controlled and where willingness to pay is clearly demonstrated (potable water, industrial supply and possibly wastewater treatment). It is worth reiterating that even in the USA private sector performance is no better than state, although management and service standards are ahead of most developing countries.

Incentive systems must be rethought for good agency performance. Joint management arrangements with corporatised, but state-owned utilities may provide more effective service than fully privatised but inadequately prepared entities. The long history of the mixed public-private arrangements in the USA and the corporatisation of metropolitan utilities in Australia points to the importance of mutually established contracts between providers and clients at all levels of water distribution. Adequate sanctioning systems must then be in place to ensure contract compliance to the advantage of customers and service providers alike, which returns us to the murky and uncertain world of legal and civil reform in many developing countries.

Public participation is expensive and needs to be targeted at appropriate levels. Policymakers should adopt a careful strategy in developing countries and should begin with a reorientation of attitudes within the state agencies. The US practice of public participation by referendum is probably not replicable in many developing countries although it appears to be cheap compared to the Australian model.

Sustainable Resource Use

Environmental issues of water quality and resource availability are closely related, and sustainable management of water resources relies strongly on understanding hydrological and environmental interactions, and on being able to identify emerging environmental problems in time to apply solutions. The California experience shows that it is possible to reverse groundwater mining by combining regulation and alternative supply arrangements, and making use of groundwater as a strategic drought-period water resource. The Salt Credit scheme in Australia is an innovative, inter-state and basin-level initiative to halt degradation of in-stream water quality and minimise adverse economic effects on downstream urban users.

Pre-empting groundwater mining

The critical sustainability problem in developing countries is a localised, but in some cases frequent, occurrence of groundwater mining and degradation. which all too frequently only occasions a paper response of new legislation. Retrospective legislative systems are of dubious worth if they *cannot* be effectively monitored and policed, which is likely considering the sheer number of wells in many developing countries.

Permit systems and licensing need to be developed as early as possible in groundwater exploitation, but should not be administered in a way that obstructs economic development. This is a delicate balancing act which requires a clearer understanding of national and regional hydrogeology than normally exists today. Areas where water table decline or industrial and non-point source pollution are degrading groundwater quality must be *prioritised*, as this is often irreversible, or at least very expensive and difficult to reverse. Saline intrusion can be mitigated by injection technology to create barriers, and possibly to mitigate groundwater mining, but is useless without *corresponding institutional development* to control or limit withdrawals. Substantial first steps can be made in many developing countries by introducing rational energy pricing and removing operational subsidy in groundwater use, especially for irrigation. Capital subsidy may make sense in many situations, but in return development should be controlled and licensed.

Huge populations make voluntary organisation and cooperation (as in California's recharge districts) unlikely, at least not until many under-capitalised (or well-connected) pumpers have gone out of business from the expense of lifting water from excessive depths or from water quality degradation. In many cases, it will already be too late for economic remediation.

The study has highlighted many possibilities for groundwater recharge, and seasonal, inter-annual storage in groundwater basins rather than in surface reservoirs. Internal and sectoral reform is needed in many developing countries to bring groundwater and surface water agencies together before coordinated conjunctive-use strategies can be explored. Drought-coping strategies in the USA and Australia make groundwater use a key response, and balance recharge and long-term storage within controlled extraction in normal recharge years with temporary overdraft during drought years. Although this is a sophisticated and subtle course of action, and a complex one to understand and control, it has much to recommend it for developing country use; in reality, it would be difficult to institute without considerable improvements in the general institutional framework.

Drought

Drought has played a major role in promoting change in water policy in all three study countries. Drought emergency measures in the western USA have been innovative and have carried over into longer term planning and management.

Water resources managers in drought-prone developing countries need to have clearly defined drought management strategies, including 'trigger' conditions for the implementation of appropriate responses. This has taken a long time to evolve in California, and is still some way from reality in the privatised world of UK water. The whole basis for water management and development in Africa requires a solid foundation in drought planning and coping strategy that is responsive to drought, but also takes drought water availability clearly into account when developing projects and extracting supplies.

Drought or unusual natural water shortages provide the opportunity to insist on administrative and pricing reforms, and policymakers should be aware of the possibility. In many situations, however, the effect of drought may be so unbalancing and chaotic that it offers little chance for lasting and constructive innovation in the rush to attend to the crisis itself.

River Basin Administration and Decentralisation – Avoiding the Pitfalls of Administrative Competition

Rational water policy and hydrologically sound management (at the basin scale) do not have to work against the political-administrative apparatus of civil government and, on a day-to-day basis, there is little evidence of serious conflict between hydrologic and civil administration in the western USA and Australia. The situation in Spain shows that even with a long-term commitment to river-basin management, politics has far greater momentum than the logic of rational management alone. Water is a highly political resource, and the importance of political voice has not been lost on environmental activists who have restrained resource development and set a new agenda for water allocation in all three study countries.

Conflict between hydrologic scale management and civil-political administration is most likely to occur when:

- Large resource transfers are involved (viz the Arizona project, Colorado Basin and the National Hydrologic Plan in Spain)
- The legal system is not clear, transparent and impartial.

There are no unifying management problems, such as drought, water quality and gross environmental impacts.

In the Colorado Basin unconstrained development has been followed by periods of adjustment during which competition between irrigation and urban–industrial demand has emerged in California and other focal points such as Phoenix and Tucson. Local institutional adjustment checked urban and industrial demand for a short time in California, but as demand rose further, supplies were augmented by interbasin transfer which in turn led to inter-basin and inter-state (Colorado basin) and intra-state (N–S California) competition. Environmental and economic considerations changed the institutional framework and innovative solutions appeared, but it remains to be seen if demand measures will stabilise or whether, inter-state and interbasin transfers will reappear to augment supplies and satisfy relentlessly rising demand. Other factors may limit demand, but it is not clear yet what they might be – developing countries share this uncertainty, despite having far less capacity for planned and controlled urban and industrial development. The implication is that it is desirable to avoid concentrating growth and demand in one particular state that lies within a large basin, to avoid the consequent technical and political/administrative complications arising from inexorable but skewed economic development.

Developing countries should:

- make administrative arrangements that do not conflict with federal or state agencies, unless they clearly co-opt or replace them;
- avoid establishing parallel administrations without any authority or with potential for conflicts of authority, but rather try to bind them in and across state and local administrative boundaries, as with the MDBC;
- realise that it is not practical or pragmatic to attempt to replace politico-administrative boundaries with TVA type authorities – rather there is a need to find sensible ways of linking the two, and ensuring that water policy and practice are coherent at the larger scale; and
- use the RBA as a forum for resolving the administrative–political problems of different jurisdictions.

The international agencies (World Bank and UN family) have stressed the importance of public (stakeholder) participation in reform of water resources policy. It is unclear how this is to be meaningfully achieved in practice. The Australian Land Care programme is the only substantial example of wide community involvement in water resources management in the three study countries. It integrates bottom-up, catchment-level planning and management within the interstate framework for river basin management in the Murray–Darling system, but is underwritten by a 30-year programme of substantial federal and

state funding. Similar financial commitment would be required in developing countries, although it is harder to see this being a practical outcome in the prevailing economic environment.

The interdependence of water resources with land use and land use policy has led to the widespread adoption of *integrated catchment management* in both the USA and Australia, and points to the importance of having a coherent forest policy for management, conservation and preservation of upland watersheds to minimise adverse downstream impacts such as sedimentation and reduced base-flows. It is this author's experience in developing country situations that there is almost no contact between forest management agencies and specialists and their water resources/irrigation sector colleagues. This apparently straightforward oversight should be addressed within the framework of River Basin Management and integrated catchment management at the sub-catchment scales.

Demand and Reallocation of Existing Supplies

Outside drought periods, there is little evidence of widespread or long-term transfer of water from agriculture to other uses. There has been a consistent decline in agricultural area in Southern California from 1970 to 1990, accounting for less than 5% of the total area. It is unclear whether this has liberated an equal quantity of water for urban, industrial and environmental use, due to re-use of agricultural return flows and higher proportions of consumptive use elsewhere in the system. Water conservation technology in agriculture has certainly been successful in improving water-use efficiency, but the net releases for transfer have been relatively small.

The main implication must be that it is exceedingly unwise to allow full development of water resources for irrigation, and that it would be far better to reserve flows for metropolitan use in the longer term.

Demand management programmes have been most successfully developed in urban and industrial water supply, although price has not been considered to have had a major role. The Metropolitan Water District of Southern California (MWD) is a bulk supplier to 28 retail utilities and has experimented with long-run marginal cost pricing through concessionary rates to encourage wastewater re-use by industry and rising block tariffs. However, the most successful measure appears to have been providing bulk discounts for buyers implementing water conservation strategies. In times of drought, use restrictions, particularly on amenity (garden and public space) watering have been the major

contributors to reduced demand; with the exception of 'xeriscaping' in Arizona, these have not proved to be structural measures.

MWD/DWR have a long-term demand management strategy in Southern California to 2020, to cope with an estimated extra 7 million incomers: conservation measures in urban and industrial water supply will yield a net amount of 1.11 mML from 1.60 mML compared to a net agricultural contribution of 0.37 mML from a gross saving of 2.1 mML. Further storage and supply augmentation projects will contribute 0.61 ML. In fact, in more extreme demand situations, demand management cannot substitute entirely for supply augmentation, partly for reasons of timing and storage in ensuring the reliability of supply; and the contribution made by water conservation is not as significant as was originally envisaged. Developing country water planners will find many similar situations requiring careful forward planning and need to ensure that such work is undertaken on the basis of good information and local research.

It is possible that price-related demand management measures fail to make big long-term impacts because either long-term demand is fundamentally too inelastic; the price remains too low to have any real effect to urban and industrial consumers; or farming lobbies have sufficient political weight to protect their water allocations and maintain low prices.

Developing country demand management strategies would be unwise to pin too much faith in pricing, especially as capacity to pay and service reliability are considerably below developed country standards. An overall package of education, water conserving technology and restriction will ultimately be necessary, but improvements are first required in tracing unaccounted-for water (in drinking water supply and sanitation) and improving the coverage and reliability of service.

Environmental water demand is rare in developing countries, but these concerns will no doubt develop in response to overseas environmental activism, rapidly growing local environmental awareness, and raised consciousness among professionals through education and other forms of intellectual and professional exchange with developed country water resources issues.

Water Markets and Reallocation of Water

The *total volume* of inter-sectoral transfers of water has so far been modest in both the US and Australia. Proponents of water markets point out that the water rights systems in use are inimical to the development of tradeable property rights, and therefore should be reformed. A major

reason for reluctance to transfer water entitlements is that water availability is capitalised into the value of irrigated land, but serious problems remain with the adequate specification of rights in terms of reliability and third party effects of transfers.

Drought period transfers from agriculture have been more successful, but this is temporary sale of water, rather than the sale of the water right. The Drought Water Bank of California has been very successful in obtaining agricultural water in the short term, and requires land to be fallowed as proof of transfer – savings must be absolute as technology is not sufficiently good to show savings though more efficient use. Half of the 0.99 mML obtained by the bank in 1991 was sourced from fallowing, much of it in the Delta region, and the total number of contracts for agricultural, ground and stored water was 350. There has been a major public sector effort to establish and run the water bank, which raises the idea of an administered rather than open market in water.

There are considerable infrastructural problems restraining inter-sectoral water trades in both the USA and Australia, where transfers have largely been restricted to within the same irrigation system and for agriculture. Although Rosegrant (1994) has shown that such transactions have not been restricted by infrastructural shortcomings in Chile, it seems clear to this author that arise in most developing countries where there are more severe and obvious technical and operational deficiencies in the water infrastructure, which is supported by the wealth of introspective literature on irrigation system performance and management.

Water markets seem to this author to be an order of sophistication above current practice so should not be an immediate priority for developing countries as there are many more basic problems to attend to first – not least registration of rights; establishment of sufficient system and hydrological knowledge to assess third-party impacts; development of accessible fora of conflict resolution; and above all, rational pricing which at least covers operation and maintenance costs.

Water trading within irrigation systems should be encouraged and water *sales*, as opposed to transfer of right, should be allowed, but monitored to establish some market intelligence. Markets are certain to be culturally unacceptable in some cases and would need to be accompanied by a long-term awareness programme to alter attitudes to water use. The best options for participation lie in strategies that make the problems of water management self-evident and encourage people to collectively take action (even if led by particular interest groups).

The greatest immediate opportunities for reallocation are by encouraging conservation through pricing and technology on *bulk users* – from major storages and *reallocating surpluses* – especially since rights

are not allocated in precise terms in many administered systems.

Long-term reallocation from agriculture is mainly by land retirement in the USA and Australia but would be a severe problem in developing countries due to agricultural population density and equity. There may be considerable environmental (salinity and water-logging related) imperatives for land retirement as well as to improve application efficiency, which may make a positive contribution. As it is likely that food security will continue to be a priority (and in many cases a necessity), even while commodity prices decline, the prospects for land retirement are very slim. How these conflicting influences are managed in the longer term will have a major effect on developing country agricultural water use.

Conservation strategies in developing country irrigation

It is hard to envisage widespread adoption of micro- and sprinkler irrigation because of high capital costs, and more importantly recurrent costs in energy for pumping. Radical changes in irrigation scheduling are limited by the physical and operational characteristics of the delivery systems and by the large number of relatively small deliveries to individual farms or even blocks. Some improvements are possible through better system operation and maintenance, and in land levelling and farm layout. Diversification through changing crop patterns or seasonal composition to minimise water use also hold out some promise, but require improved system management to allow sufficient flexibility in supply and operation.

Cost Recovery and Water Prices

Historically, there has been a strong commitment to recovery of capital and operational costs of public water investment in the USA and Spain. In practice, this has been applied more to urban and domestic water supply than to irrigation. Transfer of irrigation systems to private, professionally run, irrigation associations in the USA has involved considerable concessions in capital repayment and, in some instances, continued operational subsidies. The Central Valley Project (federal) and State Valley Projects (state funded) do not recover much capital cost, as bulk suppliers, and may still have substantial operational subsidies. If it is difficult to realise capital repayment in the commercial world of US irrigation, there can be little point in insisting on capital repayment in most developing country irrigation projects, many of which will not have been built or operated to equivalent standards of service.

There has been no attempt to recover costs of infrastructure in Australia, although corporatisation and privatisation in irrigation are based on full repayment of operational costs. There is mounting evidence

that 'private' agricultural water users neglect long-term system maintenance in order to keep irrigation fees as low as possible in both the USA and in Australia, with uncertain implications for sustainability and funding of rehabilitation in the future. This may imply that cost recovery is better managed by the state to ensure coverage of operation and true maintenance costs, although there are many intermediate mechanisms for doing so which also allow increased autonomy to water users (see Turrall, 1995).

Capital finance is the major problem facing the Spanish National Hydrologic Plan, which requires US\$26 billion, two-thirds of which is to fund the infrastructure for inter-basin transfers. It was envisaged that this would be met out of future revenue, but political opposition and legal action to restrict tariff increases makes this unlikely. In all three study countries, legal action has been taken by users to restrict price increases for water, a trend which is emerging in developing countries (e.g. Tamil Nadu, in India). The study intimates increasing dissonance between legislation (and the legal apparatus) and economically rational approaches to water management and cost recovery.

Clear price signals from central and local administrations are needed for rapid attainment of full operational cost recovery and the use of enforceable contracts, both in public, private and public-private arrangements, is required. It makes sense to promote price incentives to encourage wastewater re-use and adoption of conservation technology in urban, industrial and agricultural activities and to promote rational (and stop excessive) use.

In the implementation of administrative reform, it is advisable to sequence full operational cost recovery prior to substantial privatisation, and develop it incrementally unless there is a 'fortuitous drought' that allows publicly acceptable 'leaps' or changes in rate structures.

There is a clear need to establish *transparent* cost recovery systems, preferably through tariffs, and to institute independent *audits* of accounts at all levels of water management (within government and within the private sector and water user associations). Better pricing should go hand-in-hand with the development of wholesaling and retail agencies in irrigation and metropolitan water – in both public and private sectors as appropriate and effective in a given context. The structure of bulk selling to retail contractors seems to help transmit the right price signals down to the consumer, providing the major wholesaler is committed to full recovery of operational and capital costs. As the ultimate bulk supplier is still a national or state agency in many cases, there is in practice continuing capital subsidy (e.g. CVP in California), and this subsidy should be the prime target of reform if pricing is to have any meaningful effect on demand.

In domestic water supply, there have been many studies of willingness

to pay in the study countries, but as water charges represent a very small part of average income (roughly 1%), there has been little innovation in structuring water charges to ensure service provision to the poorest. Developing countries must capitalise on their own experience with such measures. There is an underlying problem that metering is required to establish of good management and cost-recovery practices. In urban situations, metering is bedevilled by problems of payment for the maintenance and monitoring of meters, and it does not have a good track record in many developing countries so far. It is unlikely that many developing country irrigation systems would be able to introduce individual metering of supplies (as in Australia), even at the 40 ha 'turnout' scale: considerable improvements would be made by the installation of water metres in all tertiary canals, however, and would be required for any meaningful bulk water supply arrangements.

Self-financed projects are more common in the domestic and industrial water supply sector. Quasi-public corporations have historically raised capital by bond issues or being empowered to levy local taxes: these organisations have since become public utilities operated commercially mode, covering operational costs as well as raising sizeable amounts for continued investment (for example, the Metropolitan Water District in California). Tariff income has largely replaced tax revenue as these arrangements have developed, leading up to a range of experiments with long-run marginal cost pricing to cover the burden of long-term infrastructural development. Berkoff (1995) notes that in Vietnam (as in many other developing countries) private financiers almost invariably prefer discrete investments (such as treatment plants) to rather more risky diffuse investments such as water distribution and sewerage collection. He cautions against unbalanced investment and sees little practical alternative to continued state financing in urban and agricultural water infrastructure.

Environment

Federal environmental legislation in the USA now has a dominant restraining influence on further water resources *development*. State water quality regulations are also becoming more demanding. Dams are being decommissioned and removed from rivers to enhance streamflow and restore habitat, although new dams are proposed for flood control and supply augmentation. Flood control dams appear to have better justification in environmental terms, but recent decisions in southern California call for the re-design and evaluation of a proposed flood mitigation project for multi-purpose use (on economic grounds). Rivers in Spain, western USA and the Murray–Darling system are highly regulated, and are now having to redress the environmental

compromises of water resources development, often at great expense. Although environmental sensibilities are less powerfully articulated in developing countries, they are clearly rising in importance. There remains a dilemma in finding a compromise between water resources development and sustainable management of the environment and the resource: where developing countries still have the option, it is clear that they should evaluate the environmental consequences and costs of all development options very carefully. The economic tools for this analysis are as yet imperfect, however, and this perspective requires a higher level of sophistication, capacity and information in water resources planning and management. A recent study for the NRA in the UK concluded that information and techniques are inadequate for estimating environmentally related water costs, so clearly this will be an increasingly important issue in both developed and developing countries.

The added environmental aspect of water resources management further strengthens the need for substantial policy development and capacity building in developing countries. It is one that can be addressed by donor agencies working with public and private sectors and in higher education.

Developing countries can use developed country experience to understand and diagnose environmental problems in water management. They should prioritise the regulation and treatment of irreversible problems such as groundwater pollution, and develop long-term programmes to restore mined aquifers. It should be possible for many developing countries to build in sufficient environmental planning in water resources development to avoid some of the major economic problems associated with retroactive legislation and conservation.

Salinity is a major and all too common problem. Prevention is better than cure, and early implementation of drainage still remains the most cost-effective way to minimise long-term water table rise and salt disposal problems in established irrigation systems. Land zoning may help if it can be effectively implemented and fresh groundwater in coastal and inland aquifers should be protected.

Severe water pollution problems are on the horizon from non-point source agro-chemicals to complement those already emanating from industry (see for instance the Indian studies undertaken by WRN's collaborators in 1994 – Vani et al.; Appasamy). It is much harder to see a way forward in the detection and enforcement of controls on diffuse pollutants. Although standards are clearly required, legal regulations will not mean much at this stage and such degradation remains perhaps the greatest cause for real concern in developing country water management. A large amount of diagnostic and treatment technology is under development in the west, but whether it will be affordable and institutionally appropriate is another matter; within Europe, Germany is

already in danger of pricing itself out of the environmental services market as its standards and therefore costs are even more stringent than in its competitors

Industrial pollution problems are the easiest to control in theory, but the dynamics of local power and short-term self-interest are at present more likely to prevail.

Post script

In the introductory chapter, it was postulated that developed country reforms, at least in countries with substantial irrigation water use, had meaningful and relevant experience to forthcoming policy reform and subsequent adoption of new water management strategies in developing countries. In Chapters 5 and 6 some of the more obvious limitations and implications have been explored and there is much that is of relevance to developing country water policy analysts and managers. Deciding what is relevant is a task that is best left up to those with the relevant local and technical expertise, and the one statement that can be made with any certainty is that there are no models or prescriptions that can be transplanted directly. The writings on water policy emerging from the international agencies are based, in an accretionary way, on the experience of developed countries, particularly the USA, and a broad knowledge of developing country water management issues. They do however suggest that there are prescribed components and models that can be picked up and applied. This study urges more caution in evaluating what is most relevant and appropriate and encourages developing country reformers to consider the key limiting factors to management and service provision in their own water sectors, and to develop appropriate strategies accordingly.

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