Governance for a Sustainable Future. IV: Working with Water

Report of the Commission on Water

IV

Working with Water

The Commission on Water

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Rapporteur	*Dr Anne Powell, UK*
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MR I KHAN COMES HOME

Mr. Khan fastened his seat belt and sighed. It had been a long week, tiring, but rewarding.

Mr. Khan, Senior Officer in the Ministry of Water Affairs of Riperia, was flying home from the final session of the Working Group on the Potamos Basin Agreement. Riperia, Humidia and Middleland shared the Potamos catchment, and tensions had gradually increased over the last ten years because of the dwindling discharge of the river.

In his mind, he recapitulated the general nature of the problems: Upstream Humidia was constantly increasing its irrigated area for growing rice and vegetables, Middleland was complaining about the irregular supply of process and cooling water for its pulp mills and power stations, (However, Middleland was rapidly cutting down its own forests as raw material for the mills, and discharging waste water after only perfunctory cleaning!). His own country, Riperia, was experiencing a migration from the rural hills to the cities, in particular to Mr. Khan's own home city, the capital Aquapolis on the Potamos estuary. The water supply and sanitation system of the city was on the brink of complete breakdown, and the census people said the capital would probably pass the 10 million mark and become a megacity within five years. It was all a headache and a mess. That is, until the Working Group was set up two years ago.

He was genuinely surprised over the amount of consensus achieved in spite of the conflicting interests. The draft agreement signed this morning included provisions for a joint and quite powerful Potamos Basin Commission, a Water Resources Development Fund, and a water quantity and quality monitoring system linked to the so-called HYCOS. All three countries were now parties to the UN Convention on Non-navigational Uses of International Watercourses, which had come into force two years ago. The working group had therefore taken the Convention as a starting point, but had soon come to a halt over a debate on what should be meant by 'equitable utilisation'. Mr. Khan prided himself of having contributed to the agreement by proposing that the Water Resources Development Fund should be based on national contributions proportional to the respective economic benefits from using the Potamos water.

The new framework would certainly create a lot more work. He glanced in his pocket calendar for next week: a presentation of the draft Potamos Basin Agreement on Tuesday for the Parliamentary group responsible for natural resources…receiving two representatives from the World Bank on Thursday to discuss the new water and sanitation plan for Aquapolis…and the week after that…

Mr. Khan sighed again, and asked the stewardess for a glass of water.

EXECUTIVE SUMMARY

There is a deep and nagging suspicion that some day soon the scarcity of freshwater that is presently afflicting some parts of the world will become much more intense and widespread and that a global water crisis will ensue. This crisis would not just mean water shortages. Floods in Mozambique, pollution of the Danube, contamination of groundwater in the USA, drought in Ethiopia, displacement of settlements in India for dam construction, desertification in the Sahel, the shrinking of the Aral Sea with its associated health problems, together with similar contemporary issues are serious problems now and a foretaste of things to come. They demonstrate the range of threats posed to humankind and the importance of water to the environment. Global climate change adds a dimension of uncertainty and makes earnest consideration of what should be done all the more urgent.

'Why has this situation arisen?' and 'what can be done about it?' are two obvious and repeated questions. The uneven distribution of water resources, the rapidly expanding human population, the accelerated demand for water and the deterioration of the world ecosystems are part of the answer to the first question. Human attitudes to water as a God-given, free, and an under-appreciated resource in many cultures may also have a role to play. Answers to the second question involve the mechanisms and measures that have been evolved to cope with water in terms of science, engineering, economics, politics, management, government, society, culture and other areas. It is often argued that enough is known about water from a technical viewpoint to solve our water problems, but that solutions are not put in place because of the difficulties of applying that knowledge. What are these difficulties?

The WHAT Commission on Water has examined these difficulties and Working with Water identifies some of the leading issues and instruments for dealing with them, particularly in the field of governance. The report is made up of three main sections followed by a series of recommendations.

Setting the Scene examines some of the contemporary ideas influencing our decision making in relation to water. These include globalisation, advances in information technology and developments in science, including those in economics. This section also considers human numbers, our attempts to dominate and control water, and the ecosystem approach, which proposes strategies for the integrated management of water and the life it supports, and advocates the sustainable use of the resource in an equitable manner.

Leading Issues is concerned with using water more efficiently, how to value it appropriately, with law and institutions and with the impediments to decision making, such as those resulting from the poor appreciation of the distribution of water resources in space and time. It also considers the potential benefits of demand management, the application of new technologies and the risks to human health. Virtual water and perverse subsidies are among the subjects discussed in this section.

Governance deals with organisational systems, including the different institutions that plan, manage and operate the administration of water at the global, regional, national and local levels. It reviews the range of activities of bodies of the UN, national governments and the public and private sectors and it refers to those of certain nongovernmental organisations and other groupings. It touches on a new architecture for governance.

Conclusions and Recommendations offers a number of principles on which policy development in should be based, together with recommendations for action:

- Water management at national, regional and international levels must be based on the catchment.
- Integrated catchment management should allow separate authorities for the operational development of the resource and for the regulatory supervision to protect public values.
- Legislation should require that those managing water catchments have the accountability, professional competence and the legal authority to carry out their duties, and should make possible the meaningful participation of all interested parties.
- The precept 'working with water' should be the basis of laws, regulations and practices in order to achieve sustainable management and to minimise the risks and costs of working against water.
- In managing water resources, institutions and individuals must take into account the impacts of their activities on ecosystems and the precautionary principle.
- Governments must actively encourage a greater awareness of sustainable water use and water issues at all levels of society.

- International and regional bodies should seek to design and create a global water knowledge system open to all.
- The achievement of catchment-based, integrated management may require the revision and/or reinforcement of existing institutional structures, bodies and treaties or the creation of new supranational organisations
- Economic and other incentives should be introduced or revised to encourage sustainable water management.
- Governments should ratify promptly the 1997 UN Convention on the Law of the Non-navigational Uses of International Watercourses. Negotiation and dispute settlement processes conducted by the UN and its agencies should support international laws relating to water.
- No body, individual or corporate, should have the right to extract from, or discharge into, a body of water without a time-, volume- and quality-limited permit from a public authority.
- Governments should prepare legislation immediately to ensure that full cost recovery is achieved with a tariff structure designed to increase efficiency of water use.
- Governments should develop and implement water demand policies and should encourage the adoption of appropriate new technologies, water saving measures and other actions consistent with fairness and sustainable development.
- Subsidies, existing or proposed, should be carefully evaluated to ensure that they accomplish the socio-equity goals advanced as their justification and do not impose unacceptable environmental impacts.
- Governments and international financial institutions should forgive public debt owed by developing countries conditional upon the development of catchment-based management systems within and across national boundaries, and a programme for the removal of direct subsidies.
- Investment in water projects in international catchments should encourage co-operation between catchment countries.
- All financial investment should require proof that sustainable and efficient water use will be guaranteed. Assumptions that water will be provided for all new developments must cease.

1. Introduction

With the prospect of a world water crisis emerging later this century, this report by the WHAT Commission on Water addresses global water problems at the start of the third millennium. We aim to raise awareness and stimulate fresh thinking, and highlight the need for a change in approach to this precious but finite resource. The Commission believes that the traditional approach to planning and management is based on a philosophy which does not always identify the environmental costs. This approach needs to be altered to recognise the true economic costs of long-term activities which work against the natural behaviour of water. This is on the understanding that present management strategies adopted to protect human health, safeguard lives and counter erosion and pollution need to be maintained.

The main thrust of this report is in the area of governance (the system of governing), that often-neglected domain in water affairs with the most severe constraints, but where the rewards of overcoming them would be greatest. The existing machinery is discussed, problem areas are identified and proposals are made to overcome some of the shortcomings, while acknowledging that there are many more questions which require attention. As part of the background, this report ranges over a number of legal, scientific and social issues, but does not attempt to cover the entire field. Other factors are the billion or so people without wholesome and reliable supplies of water and the many more lacking sanitation. There are also the countless numbers who are victims of floods and droughts; those who have to pay too high a price for a meagre domestic supply and those who squander water to produce low-value crops or keep their lawns green.

A number of initiatives have attempted to tackle global water problems, some promoted by the UN, some by national governments and some by nongovernmental organisations (NGOs)—from the UN Water Conference in 1977 to the Second World Water Forum in March 2000. There is the prospect (January 2002) of a follow-up to the International Conference on Water and the Environment which was held in Dublin, preceding the Rio Plus 10 Conference. *Working with Water* is offered to provide a different perspective on an old and pervasive problem.

2. Setting the Scene

2.1. Working With, and Against Water

Water is vital to human life but in excess can be a threat to life. The importance of water may be seen in its influence on human history. It is not surprising that for thousands of years human ingenuity has been directed at solving problems of water. The earliest settlements were near to water and the first cities occupied river valleys. Water has been channelled, drained, dammed, redirected, modified, transferred, transported, constrained and generally manipulated in almost every part of the globe. Many of these schemes stand as great engineering monuments, but frequently they were undertaken with little recognition of the long-term effects on parts of the environment which, at the time, appeared to be of no immediate 'use' to people. Since the 1992 UN Conference on Environment and Development and the general acceptance of the concept of sustainability, the wisdom of past actions is increasingly being questioned. Now plans have started to be made within a context that evaluates the environmental risks of proposals and takes account of environmental costs and benefits. The development of a rational method of translating environmental factors into economic and fiscal terms would encourage some progress towards sustainable water management. Sustainable management includes not imposing the cost of clean-up, or of putting right historic damage, onto future generations. Although the cost of prevention of water pollution is high, it is less than the cost of clean-up. 'Prevention is always better than cure', and the precautionary principle needs to be promoted. It is also necessary to re-examine the economic criteria applied to schemes designed to correct unsustainable activities in the past.

Fortunately, there are signs that spending on water and other natural systems is being modified so that future generations will be less committed to endless and costly maintenance. Flood management is an area where habits are changing. Recent floods on the Mississippi and many European rivers have shown that river dyking must be treated with extreme care. Disconnecting rivers from their floodplains violates ecosystem continuity and cuts rivers off from the 'flood pulse' which is crucial for their health. Even more important is the fact that there will always be a bigger flood than the ones on which the dykes were designed. Flood protection misleads people into believing they are safe and inspires ideas of flood 'prevention'. For those living in areas at risk, the consequences of this misconception are catastrophic.

2.2. More People and Less Water

Whether one looks at the developed or the developing world, rural or urban situations, there is a growing number of problems associated with water. This applies at all scales: locally, nationally, regionally and internationally, and increasingly affects human survival and sustainability. The issues involved are many and range from lack of safe drinking water and sanitation, through flooding, to disputes about water for irrigation and concern over the aquatic habitat. The result of lack of solutions is that each year millions die from water-borne diseases, large numbers lose incomes, the environment is degraded and stress is generated between those sharing a river basin.

The rapid growth in the human population, coupled with increasing per capita water use and rising aspirations for improvements in living standards, indicate that solutions need to be found quickly. The potential for conflict between nations over shared water is an additional spur to action, while the likely impact of climate change on the hydrological cycle, although uncertain in extent at present, adds to the urgency.

2.3. Water and Ecosystems

Almost every human activity necessarily produces changes in the water environment, and these changes have economic and political consequences. Changes to the landscape, as a result of deforestation, urban development and the construction of dams and other structures, although initially thought to be economically and socially justified, modify the nature of runoff, impact the hydrological cycle and change ecosystems. Such changes were usually not anticipated but they have often produced radical effects over a range of time scales: for example where deforestation has led to increasing floods in the short term, causing erosion, soil loss and reduction in land productivity. Such changes have led to hunger, starvation and death.

In the analysis of the parameters defining sustainable global water management, the concept of the ecosystem is a useful tool. Ecologists have used this concept for many years to express the interdependence of the planet's living components (animals, plants, micro-organisms) with the nonliving components (minerals, rock, soil, water, air and energy). Civilisation and urban growth have led to humans (and their decision making) becoming increasingly disconnected from other components of the world's ecosystems. No component, not even *Homo sapiens*, is able to isolate itself completely from the other parts of the ecosystem. Recognition of this is an essential starting point.

An ecosystem is an entity within which most raw materials naturally recycle and through which energy (from the sun) flows, although it is recognised that there is influence and exchange of materials between adjacent ecosystems. Human interference can change the type of interaction between ecosystems. If a dam is built it traps the silt carried by the river, thus depriving the area downstream of the nutrients in the silt, vital for regular reinvigoration of the soils of the floodplain (see Appendix B).

Many have observed that general biological, genetic and habitat diversity appears to confer stability, resilience, robustness and 'health' on ecosystems. Natural ecosystems are self-sustaining, fairly stable (in human time scales) and diverse, with a variety of species adapted to particular niches. As biodiversity is reduced, the health of ecosystems declines, and eventually collapse may occur.

A river with its tributaries can be considered as an ecosystem, as can a lake or a pond. In the context of water management where there is growing support for the basin or catchment to be considered as the basis for management, it may be helpful to consider the whole, clearly bounded basin or catchment as an ecosystem.

There is a vital need to maintain a robust environment by working with aquatic ecosystems and not against them. Indeed, more diverse, natural and stable ecosystems make for the improved wellbeing of the biosphere. Sustainable management of water resources must take account of the needs of species other than *Homo sapiens*. Ignoring the relationship between human populations and the needs of the living world has resulted in degradation of the environment that has hurt the human population deeply.

2.4. Factors Influencing Attitudes to Water

Technical, scientific and social changes have influenced human attitudes to water in the past; present developments are likely to have unforeseen effects on how water is managed in the future.

Globalisation—the tendency of the world economy to act as one single market and one production area—may have a bearing on solutions to water problems. Globalisation will mean larger markets and may increase opportunities for finding supranational solutions, in some cases to water problems.

Advances in information and communications technology have improved our ability for real-time monitoring and management of water resources, in water distribution systems and in other areas of water services. Such improvements have facilitated decision making and upgraded the capacity for rapid crisis response. Information about rivers and other aspects of water posted on the internet is leading to a better-informed society.

Renewable energy sources, when they have been developed further, will impact on future solutions in many ways: desalination will become more competitive, dependence on fossil fuels that pollute air and water will be reduced and there may be less pressure on the remaining sites that have potential for hydropower development.

Other relevant new developments include manipulation of genetic material in the widest sense—although this area may present risks. Transgenic salmon have been developed for farming purposes but there are fears that escapees from farms could seriously damage the genetic integrity of wild stock by interbreeding. The UK House of Lords Subcommittee on Genetic Modification in Agriculture emphasised this danger in a report in 1999.

Ecological accounting, environmental economics and valuations of natural capital are all approaches that could affect the way we manage water resources. Added to the economic and technical changes is climate change, which will alter hydrological regimes, ecosystems and patterns of water use as well as increasing uncertainty and raising risk.

2.5. Ways of Managing Water

The global water resource is finite, so management may often mean sharing, rationing and moving quantities from place to place. Using water efficiently, improving its quality and reusing it can effectively increase its availability. The need to have some kind of regulatory system for the management of water is understood in every part of the world and a variety of statutory, legal, economic, administrative and other instruments and mechanisms have been developed. This has led to a multiplicity of state-run, public and private bodies and NGOs of local, regional, national and supranational dimensions being set in place. In many instances these bodies have become part of the problem.

Water management is in a satisfactory state in many countries but there are parts of the world where severe difficulties are experienced in providing the desired level of service. Others have no water services at all. In many places services are getting worse, often because of lack of money and/or diminished water resources: there is an increased risk of error, inappropriate methods are being used, control is poor and there are obvious flaws in governance. Corruption, bribery and other sorts of crime can flourish under these conditions. A number of the prestigious water projects financed by international institutions have not been successful: some have encouraged corruption and some have caused social unrest.

Everyone should have the right to safe drinking water, and this leads many to think that water should be free. However, these two concepts may result in wasteful use of water on the one hand, and to under-investment on the other, resulting in poor maintenance and high levels of leakage. In many (probably most) parts of the world, present patterns of water use are not sustainable. The resource that limits the growth of any population is the resource that runs out first. With increasing frequency, water will be this limiting resource.

2.6. Urban and Rural Contrasts

The State of the World's Population Report (UNFPA, 1999) indicates that the figure of 6 billion was reached in 1999 and is rising by about 78 million a year. By 2030, 60% of the population will live in urban areas compared with fewer than 50% today. The number of megacities (those with more than 10 million inhabitants) is expected to reach 26 by 2015, with 22 in less-developed regions and 18 of these in Asia. The growth of cities increases the demand for water while building of roads, parking lots, shopping centres, houses and buildings of various types reduce the permeable surfaces, which allow rain to percolate into the ground and ultimately into aquifers. Runoff is increased, leading to flood problems during heavy rain and the overcharging of sewers, with attendant pollution. In some urban areas leakage from water mains and sewers provides the major part of groundwater recharge.

The lakes, rivers and aquifers that provide the water resources to satisfy urban demand often receive discharges of inadequately treated or untreated industrial effluents and domestic wastewater, making them increasingly unsafe to use (WRI *et al*., 1996). While it is recognised that lakes are closed systems (compared with rivers) and more vulnerable to the impact of pollutants, aquifers have not been protected from pollution to the same extent. Many polluted aquifers may not recover for centuries. The anticipated urban growth will, increasingly, lead to cities being connected by longer and longer aqueducts to ever more distant water resources, with associated high leakage rates and unpredicted consequences for the environment in the basins where water is abstracted. Excessive withdrawal of groundwater at rates exceeding natural recharge leads to higher pumping costs and then to shortages and to land subsidence.

Rural areas suffer from different, but no less important, problems. Even where suitable water resources are available for food growing, the investment necessary to construct systems to provide safe drinking water and sanitation may, on present economic criteria, be deemed to be too expensive to be funded through conventional institutions. It is useful to distinguish between the large volume demand in rural situations and value demand in urban developments. Effects of forest loss, erosion and sedimentation, nitrates and pesticides can impact rural water supplies. Naturally occurring contaminants, for example fluorine in parts of east Africa and arsenic in Bangladesh, can cause health problems and render the sources unfit to use (DPHE, BGS, MML 1999). It is estimated that 2 million out of 4 million wells in Bangladesh contain dangerous amounts of arsenic.

2.7. Science and Decision Making

While there is much common ground among scientists on the science of water, disputes may arise about priorities and there are many nonscientific factors at work in the decision-making processes. This report recognises that there are many institutions that consider scientific and technical questions in great detail, so the attempt here is to look beyond these questions.

Often, there is a large measure of technical agreement on what ought to be done, but the final decision may be very different, suggesting that other factors are more important, or that there are deficiencies in the decision-making process. These may be structural, or the result of wrong or incomplete criteria. This report attempts to identify such deficiencies in

BOX 3-1. THE MUDA IRRIGATION SCHEME

The Muda Irrigation Scheme in northwest Penisular Malaysia is designed for double cropping of paddy rice and depends on the efficient use of limited water; direct rainfall, stream flow and reservoir release. The Muda Agricultural Development Authority, a quasigovernment agency, has introduced water conservation measures including

- a management information system that ensures real-time matching between demand and supply using a radio telemetry system for gathering hydrological data;
- a water recycling programme amounting to 17% of reservoir release without adverse environmental impact;
- dry seeding, reducing water use by 28% over the transplanting method (especially important in dry years).

the decision-making process and seeks to describe the kinds of changes in governance, locally, nationally, regionally and internationally, that would lead to sustainable policies for water management.

For more than 20 years there has been a slight but continuing rise in the global mean air temperature. This rise is ascribed to modifications in the Earth's radiation budget brought about by increasing emissions of carbon dioxide and other greenhouse gases. Global atmospheric circulation models with increased greenhouse gas scenarios have been used to portray how this rise is likely to continue for years into the future. Such methods have resulted in forecasts of a 1–2 ^{o}C increase in the global mean temperature, and a 30–50 cm rise in sea level. These figures are likely to be made more precise with the publication of the Third Scientific Assessment Report on Climate Change of the WMO/UNEP Intergovernmental Panel on Climate Change. There are also forecasts of the likely changes in the hydrological cycle, such as an increase in precipitation towards the poles, but these are considered less reliable.

Knowledge of the probable changes in the hydrological cycle, and particularly the alterations to the patterns of precipitation and evaporation, are especially important for water resources. This is because the impact of climate change on virtually every sector of the economy and society is most likely to be experienced through changes to the hydrological cycle and the consequences of these changes for water resources. Agriculture and forestry, hydropower production and other areas of industry, the aquatic environment, as well as water supply and sanitation will be more vulnerable to these changes and less to changes in the temperature regime and those of other climatic variables. In these different sectors there are 'knock on' effects which are important in areas like human health, farming methods, and so on.

For planning future water resources and their management, it is imperative that decisions taken now should include climate change as one of the variables. This may lead to wider margins being incorporated in designs, changes in management, rising costs and increasing prices. However, these are small considerations in comparison with the problems likely to be engendered by ignoring climate change.

3. Leading Issues

3.1. The More Efficient Use of Water

Whereas some types of water use require large amounts of water of moderate quality (e.g., for irrigation), others require only small quantities of a very high quality (e.g., for drinking), while other uses do not influence the state of the water resource, such as fisheries and river navigation. Water which has been abstracted for industrial cooling, however, is returned 10 ^{o}C warmer. Current estimates indicate that the world as a whole uses 66% of abstracted water for irrigation, 20% for industries and 9% for the domestic sector, and that 5% is lost by evaporation from reservoirs (Cosgrove and Rijsberman, 2000).

The water resources sector as a whole is characterised by inefficiencies in allocation among alternative uses while significant wastage occurs in individual subsector use. In irrigation, only a small part of water diverted by conventional gravity systems is available for plant use, typically around 25–30% compared with 60–70% in advanced systems (such as sprinkler, drip or trickle systems). In urban water supplies, there is also substantial waste (25–30%) of water in distribution systems and in homes, industries, commercial establishments and public facilities. From these statistics, it is commonly inferred that large amounts of water could be saved to meet growing demands. However, water use in an entire river basin is often more efficient than appears at first sight, since a large proportion of the 'wasted' water re-enters the system for use downstream through return flows and groundwater recharge.

An example of inefficient water provision is in Riyadh (Saudi Arabia), which relies on water from desalination plants 600 km away, with 60% of this expensive water leaking along the way (Monod, 1999). The amount of water (and energy) wasted by inefficiency is difficult to quantify because data on water use are notorious for their uncertainties; few nations have systems for recording and collecting water use data and most of the figures quoted are estimates.

The situation might improve in many countries if there is a political will. The Department of Agriculture of Andalusia (Spain) has put a database inventory on the Internet of the characteristics of irrigated areas in Andalusia (see http://www.cap.junta-andalucia.es). This inventory is interactive and farmers can contribute their observations and suggestions. Recent studies in Andalusia (Hernández-Mora *et al.*, 1999) suggest that irrigation using groundwater is more economically efficient and generates more employment than agriculture using surface water.

3.2. Demand Management

Strategies for water resources management are generally a combination of supply-and-demand oriented measures as dictated by physical, social and economic factors in each country. World water consumption is set to rise with increase in population and with increasing living standards. More water tends to be used in warm and dry regions than in temperate or humid areas. However, the sustainable use of water requires a global shift in strategy towards greater demand management. Demand management is defined as the management of the total quantity of the water abstracted from a source of supply using measures to control waste and consumption (NRA, 1997).

Technical measures for water saving have financial and administrative implications. Hence, the character of demand management is multidisciplinary and includes an array of instruments:

- *technical:* water conservation, recycling, water saving technology (including retrofitting), leakage control, cropping patterns;
- *economic:* subsidies, incentives, tax and price policy, tariffs;
- *legal and administrative:* water law, water rights, licenses, regulations, penalties, enforcement, capacity building;
- *operational:* operating rules, water allocations;
- *educational:* awareness, communication, education; and
- *political:* priorities, objectives.

The combination of these instruments differs from country to country depending on physical, socio-economic and cultural environments.

The introduction of metering, often seen as a vital component of demand management, improves the quality of information about consumption. Where consumers reduce water use and private water companies have assumptions based on expanding sales, there may be transitional problems requiring regulation to balance profit margins, cost recovery and recognition of the needs of the poorest members of society.

Demand management requires decisions on where (that is, in which sector) and how, water demand can be reduced. There will be conflicts between competing users, and trade-offs have to be made between the benefits obtained by different users within the context of the local and national economy. Conflicts commonly arise between agricultural use on the one hand and industrial and urban use on the other. Successful demand management also requires programmes of awareness raising and promotion, and of education and training.

3.3. Potential Technological Solutions

When there is a mismatch between supply and demand, either the demand has to be reduced or the supply increased, or both. In addition to managing demand there are opportunities for improving the availability of water, for instance through use of so-called *nonconventional water resources*. Desalination and water recycling/reuse are of particular interest. It must be borne in mind that these nonconventional sources do not create more water, but are in fact short-circuits and accelerations in the hydrological cycle, providing water at a place or a time which better suits human needs than if the natural cycle were allowed to proceed.

Further improvement may help currently expensive technologies to become competitive. A study of the Middle East and North Africa indicates that reducing demand through efficiency and conservation costs US5–50 cents per cubic metre, while treatment and reuse of wastewater for irrigation

BOX 3-2. CASE STUDY: REUSE OF GREY WATER IN THE UK.

Research in British universities led to the conclusion that between 42% and 63% of water used indoors is for toilet flushing. The potential savings are large. Between 1994 and 1997, Loughborough University (Leicestershire) designed, built and tested a biotreatment plant to refine grey water (i.e., from baths, showers, hand basins and washing machines) and roof water (from precipitation runoff).

The experiment, conducted at a student hall of residence (40 students), proved that grey water was more than sufficient to provide water for toilet flushing. It does not require large storage equipment. Biotreatment does not induce sludge or odour problems. One-third of drinkable water can be provided by recycling grey water. Payback is over five years on new buildings, and ten years on retrofit.

runs at 30–60 cents. By contrast, desalination of brackish water costs 45–70 cents, and desalination of seawater 100–150 cents, although costs are reducing (World Bank, 1995).

It is valuable to distinguish between reuse (using again but for a different purpose) and recycling (using again for the same purpose). Wastewater irrigation, based on up-to-date engineering technology and public health safeguards, is becoming a viable strategy and is often the least-cost solution for wastewater treatment and disposal. The consensus of the world public health community today is that the new microbial guidelines provide a safe and rational basis on which countries can build a sound programme of wastewater reuse.

Although water recycling appears attractive, particularly for industrial use, the general view today is that it is not likely to make a major contribution to irrigating field crops. However, more positive views are held by some, who maintain that, over a few decades, use of reclaimed wastewater could expand dramatically. Israel is often quoted as an example, where 65% of wastewater is reused.

In water-scarce countries, where irrigation can account for up to 80% of total water use, relatively small transfers from agriculture would substantially increase the water available to other sectors. An alternative would be to use nonconventional water resources but these can present difficult choices: for instance, the growing use of desalination will increase energy consumption and raise CO_2 levels; enhancing precipitation in one area may reduce precipitation in other areas; large-scale water imports, should they take place, will have environmental and sociopolitical impacts, both at the giving and receiving end. In every case, there is a need for decisions from a policy-making authority on a level above the local catchment, such as a river basin authority, or on a supranational level in the case of shared basins (see Appendices C and D).

3.4. Broader Application of Technologies

Pollution control can improve efficiency of use of water, because pollution of rivers and groundwater prevents reuse of water. Most of the wastewater discharged in the developing world is untreated, as is some in the developed world. In order to increase the quantity of water available for use and to ensure its quality, adequate treatment is necessary. This is needed both to reduce water-borne disease and to protect the ecological quality of the receiving water. Low-cost wastewater treatment methods of varying scales exist and the treated water can be reused for different uses depending upon its quality. At greater cost, wastewater can be treated to a very high standard.

Since the development of synthetic asymmetric membranes in 1960, interest in membrane processes in water and wastewater treatment has grown steadily, and these technologies are now the object of substantial research, development, commercial activity and full-scale application. This relatively recent global increase in the use of membranes in environmental engineering application can be attributed to at least three factors: (1) increased regulatory pressure to provide better treatment for both potable and waste waters, (2) increased demand for water requiring exploitation of water resources of lower quality than those relied upon previously and (3) market forces surrounding membrane technologies which have driven down real costs.

In areas of water scarcity, the upgrading (using filtration techniques) of treated municipal wastewater for indirect potable and direct industrial reuses, as well as internal industrial recycling, has become an attractive means of extending existing water supplies, and reclamation for direct potable reuse is practised in some places, for example in Namibia. The membrane bioreactor is a newly developed process which has been used in many countries for reclamation of municipal wastewater.

There are various engineering solutions which could have wider applicability: for example, inter-basin transfers, which may increase regional efficiency of water use. However, such transfers must be carefully evaluated and introduced with extreme caution, as transfer of non-endemic species, pests and diseases can occur. The redistribution of water from surface to ground, through aquifer recharge, can help replenish depleted groundwater resources.

Design techniques for constructing artificial wetlands which can provide increased storage, flood control, pollution control, and at the same time maximise benefits to wildlife and biodiversity, need to be further developed and applied. Sustainable Urban Drainage Systems (SUDS) are gaining popularity with planners and developers in parts of Europe and the USA (Martin *et al*., 2000) (see Appendix F).

3.5. Health Risks Related to Water

Water-related diseases include those which are water-borne (e.g., cholera), water-based (malaria, dengue fever) and water-washed (dermatitis). The World Health Organisation (WHO, 1996) estimates that more than one billion people worldwide lack access to safe drinking water and that annually up to four million die prematurely from water-borne diseases. An additional one to two million people die each year from malaria, the incidence of which has quadrupled in the 1990s compared with the 1980s. Diseases related to contamination in coastal marine environments, for example cholera, and harmful algal blooms present a growing threat. These red tides are growing in intensity, duration and extent worldwide and are affecting the health of humans and marine life across a wide range of taxonomic groups (mammals, shore birds fish and coral reefs). The shortage of quality drinking water is often related to the failure to treat wastewater. A World Bank report estimates that the amount of water made unusable by pollution is almost as great as the amount used to meet human needs (Reilly, 1996).

Climate change and the expected increase in extreme weather events (flooding and droughts) present new stresses on already multiply stressed ecosystems. Diseases transmitted by water (e.g., cholera, *Cryptosporidium* and viruses) are directly affected. Heavy precipitation and flooding flush micro-organisms, nutrients and chemical contaminants into waterways which contribute to the growing epidemic of harmful algal blooms in waterways and along coasts (Epstein, 1998). Mosquito-borne diseases (malaria, dengue fever) flourish in floodplains; in mountainous areas droughts can leave stagnant breeding pools.

There is a need to promote community-based water quality surveillance methods for remote rural areas. This requires development of simple qualitative tests that can enable rural communities to perform routine monitoring of their water without the help of technicians. This will provide an early warning of possible water quality problems such as bacterial contamination that could lead to epidemics.

Agricultural pests and pathogens also respond to water stresses. Floods foster fungi while droughts encourage aphids, locusts and virus-carrying white flies. Pests, pathogens and weeds eliminate almost half of growing and stored crops, amounting to a global loss of US$244,000 million annually (Pimental, 1997). Climate change, including extreme events and greater water stress, may enhance all three agricultural threats, and impact human nutrition.

3.6. What is the Value of Water?

Water has spiritual, symbolic, religious and aesthetic value as well as economic value to people and is essential to nonhuman species in the biosphere. The notion of water as an economic resource, subject to scarcity and dependent upon rational management is by no means universally accepted. Water has often been presumed to follow economic laws different from those that apply to other resources. Water management activities have been frequently influenced by the belief that water is a ‘free good’ which should be provided in the cheapest possible way in any quantity desired. Even in countries where water is extremely scarce, it is often diverted to relatively low-value uses to the detriment of other uses and of future supplies (for example, away from wetlands and floodplains).

There are two possible interpretations of the ‘value’ of water. Firstly, there is the value of water ‘in use’: for example, water in irrigation, potable water or water used for industrial cooling. Secondly, there is the value of water in exchange for another commodity. If the other commodity is money, the value of water is its price. As water gets scarcer it gets more valuable. Water scarcity does not only mean that the available resources are limited, either quantitatively or qualitatively. A necessary condition is that people must want the water.

How can growing scarcity be coped with? The answer is to use water in such a way that it produces the socially highest value of possible outputs, regardless of whether the value of those outputs can be valued and traded off in monetary terms. Reallocation of water from low- to high-value use is one of the key challenges. To meet this challenge, it is crucial to estimate properly the value of water, taking into account all aspects of its use, irrespective of whether or not they are reflected in the market. The relatively new concept of total economic value, which includes direct and indirect use values, is helpful here.

The value of water in various uses provides only part of the information needed for decisions about water development and allocation. Because of the combinations of uses (and reuses) of water that are possible within a water system, it is important to know how uses combine and interact in the total system (including ‘upstream–downstream’ relationships). The possibility of using water more than once, either simultaneously or sequentially, means that the total value gained from use of a given unit of water may be several times greater than the value in any single use. The return of water to the system after use raises possibilities for getting additional value from the water in another use, at another time and place in the system. Wise use of recycling is one of the principles in obtaining most value from the available water resources.

BOX 3-3. CASE STUDY: A FRENCH LAKE IN THE ALPS

Annecy Lake, in the French region of Savoie, was once renowned as ‘the mirror of the Alps’. Its water was crystal clear and fishermen could catch the ‘prince of freshwater fish’ called *Omble chevalier*. But by the early 1950s, the water was no longer clear and Annecy dwellers were complaining that they could no longer catch their favourite fish.

In 1957, the 22 municipalities of the river basin signed a sanitation agreement and resolved to build a sewer around the lake, which would bring all used water to a sanitation plant in Annecy. It took 11 years (1961–72) to construct 350 kilometres of pipes and 33 pumping stations.

In 1993, the measured transparency of water was 12 metres deep, as it was at the beginning of the century, and the *Omble chevalier* was back.

Comparison of water value in alternative uses will become increasingly important in the future, as growing demand competes for limited natural supplies. The opportunities for net gains by better allocation of scarce water resources will be much greater. Economic values provide the best general indication of the basic worth of water if they are properly calculated, as long as protection of environmental values is taken into account.

3.7. Invisible Transfers of Water

Some water-stressed areas sell products which absorb large amounts of water. When arid or semi-arid areas grow fruit or vegetables and export them, they are in fact exporting water: water is consumed to grow the items and buyers receive it for no water expense. Countries such as Israel, Spain, Morocco, Senegal, Chile and parts of the USA (e.g., California and Florida) consume and export a scarce resource to areas well endowed with water. Even areas with abundant water supplies can exhaust their supplies: to grow 200 g of rice, a cubic metre of water is required. This trade in 'virtual' water exacerbates the natural variations in water availability.

Contrast this with the booming trade in bottled water: it might seem paradoxical that some well endowed areas sell a little of their plentiful water at a very high price (one litre of bottled water costs about as much as 1000 litres of tap water) while other, water-stressed, regions export a large amount of their precious water at minimal value in order to make a living.

3.8. Perverse Subsidies

Perverse subsidies, that is those which are damaging to economies and the environment, are widespread. Myers and Kent (1998) have analysed, worldwide, the subsidies in several sectors (transportation, energy, fisheries, forestry, agriculture, water, etc.). They estimate that about 90% of the subsidies granted for agriculture and water might be perverse. Several factors may be responsible for this situation. For instance, subsidies which were appropriate 50 years ago when in most countries there was food scarcity are now perverse because the green revolution has produced a surplus of food. However, institutional inertia, some professional bias and vested interests tend to perpetuate the subsidies that have now become perverse.

The pervasive use of perverse subsidies in the agriculture (and irrigation) sector has contributed significantly to the current water resource crisis. The Andalusian study mentioned above (Hernández-Mora *et al.*, 1999) suggests that a global analysis of surface- and groundwater irrigation from the economic, ecological and social (employment) point of view would show that in many stressed regions there might be enough water for irrigation if the policy of giving practically free water to the farmers were to be progressively changed.

3.9. Improving Institutions and the Law

Existing legal regimes simply are not working adequately for allocating water to particular uses, for accommodating new uses in fully utilised water sources or for protecting the ecological integrity of water and water-related resources. Stress on institutional and legal arrangements will be especially severe in areas where precipitation declines as a result of global climate change. Integrated systems of basin-wide management of water resources are required. Existing legal regimes are centred on one of three possible paradigms regarding the nature of legal rights to use water: 'common property,' 'private property' and 'public property'. Although legal regimes combine particular aspects of the three paradigms in seemingly endless permutations, the basic elements can be summarised (see Table 3-1).

Table 3-1: *Aspects of property regimes.*

Type	Owned by	Managed by	Consequence for water resources
common	all in defined group	each owner individually	tragedy of the commons
private	one person, natural or artificial	each owner individually	market paralysis
public	the Public	public entity	flexible management

Experience shows that treating water as common property—where each potential user decides for itself how much water to use with little or no regard for the consequences for other users—leads, as soon as demand begins to approach supply, to the 'tragedy of the commons'. Experience also teaches that markets have proven unworkable in practice because of legal protection for third-party rights. Unless strongly regulated, private property regimes nearly always result in the freezing of water use patterns at the point where the resource is first fully committed. Decreeing that parties to transactions can disregard the effect of their transaction on third parties does open up markets, but at the social cost of further impoverishing small users without necessarily leading to the most efficient use of the resource. It is not for nothing that economists use water metaphors such as 'common pool resource' and 'spill-over effects' to discuss public property generally.

As a corollary to devising regimes for integrated management, institutions and laws will have to be built around recognition of the inherently public nature of water resources—the paradigm of 'public property'. In public property regimes a public institution is responsible at least for the most basic decisions about how water is to be used. Even as public property regimes are instituted, however, greater attention to economic incentives and tools will be essential. Economic tools provide for efficient information gathering and flexible management, and also serve to prevent too great a concentration of social control in a centralised water bureaucracy. There is, however, difficulty in developing and implementing appropriate economic incentives, especially when water use data are poor.

Effective institutional and legal reforms will require coordinated change at the international, national and local level. The challenge at all levels will be to respond to the increasing and changing patterns of human demand for water without unduly destabilising investments made in reliance on a reasonable expectation of the continuance of existing legal rights. While change is imperative, change that is not sensitive to reasonable expectations will only generate resistance. To some extent, the principle of subsidiarity—that decisions should be made at the lowest level of government at which the decision can be made effectively—may serve to alleviate these problems. Yet the ambient nature of water as a resource assures that often effective decisions can only be made at the national or even the international level. Water simply does not respect human boundaries.

Given the relatively primitive state of international legal institutions, devising and implementing appropriate international institutions could possibly be the most difficult and time-consuming aspect of crafting effective institutional and legal reform. In 1997, the UN completed a Convention on the Law of Non-navigational Uses of International Watercourses, (UN, 1997). This Convention codifies the existing customary international law, removes lingering debate over the content of the rules, and provides a framework within which particular nations can negotiate specific arrangements for water basins. The UN Convention, for the first time, undertakes to integrate the emerging body of international environmental law into the rules regarding international allocation of water resources. The Convention will come into effect when ratified by 35 nations; in the first three years after approval by the General Assembly, 12 nations have ratified it.

The coming into effect of the UN Convention will not resolve all necessary questions regarding the reform of international legal institutions. The Convention speaks only in highly general terms that require states sharing a water basin to develop detailed rules and institutions. Nor does it require that states implement the systems of integrated basin-wide management that are increasingly essential to the sound management of water resources. Efforts to improve legal and institutional arrangements at all levels will require continuing careful attention (see Appendix F).

3.10. The Need for Reliable Data

Globally, the current understanding of water systems (and the knowledge base underpinning that understanding) is far from ideal—even in countries which have the machinery for collection and management of data. For the foreseeable future, policy, at all levels of governance, will need to be made in a climate of uncertainty. This uncertainty is of two kinds. The first is due to the lack of reliable data on resources, supply and demand, in terms of spatial distribution and by sector. The second is due to the complexity of the freshwater ecosystem and its links to other parts of the natural and man-made world. Public policy and value judgements have to be made with incomplete information of uncertain validity and predictive capacity.

Where data are incomplete this should not prevent action. The precautionary principle is explicitly designed to avoid inertia. The principle states that 'Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation' (The Bergen Ministerial Declaration on Sustainable Development in the ECE Region (NME, 1990)). However, there are some instances when to be precautionary is an excuse to do nothing and when both sides in a dispute invoke the precautionary approach to support their arguments. All the information required to manage water resources will rarely be reliable, but carefully targeted R&D, free sharing of information and good translation from the technical into management language, together with risk analysis (and the capacity to work with water, not against it) should allow for improved management.

3.11. People's Understanding of Water

In countries where it is scarce or remote, people value water, especially women and children who carry it from distant sources. In developed countries, where water is often a public service, its value is generally unappreciated. As water distribution systems usually run underground, few people care about them. Water is frequently considered as a free natural resource. So its use is abused, even when it is paid for (usually at a low price). This must change. Nobody, even in countries endowed with copious water, has the right to waste it. Bringing water to the tap involves dams, reservoirs, pumping stations, pipes and wastewater treatment plants—much costly equipment and infrastructure. When someone drinks a glass of water, he or she drinks not only H_2O, but kilowatts, chemicals and the sweat of people involved in water management (and civil engineering construction). This has a cost for society in general and also for the environment.

People need knowledge to enable them to be involved in making decisions and choices—some of which rely on complex arguments. There is a need to focus attention on education and training, so that every person on this planet becomes aware of the real value of water. It must be highlighted that water saving is a necessity, everywhere, in all seasons. Small simple measures (cleaning teeth with a glass of water instead of an open tap, use of showers, low-flush toilets, efficient domestic appliances and less lawn watering) can aggregate and make a big difference. Water saving is always beneficial. The benefits are obvious: financial and

BOX 3-4. CASE STUDY

South Africa has initiated a Vision 2020 school project as part of the National Water Conservation Campaign. Schools in urban areas are doing an audit of water use in their schools. Based on the success of this project, schools have initiated retrofitting of their water supply and sanitation facilities with water-saving devices.

As a result of this initiative, water demand has been reduced substantially in the participating schools. The pupils are also making their parents more conscious of water conservation. Approaches like this are more sustainable than one-off media campaigns.

environmental. Not only is water and the environment conserved for the future, but so too are the energy and other natural resources consumed in water supply systems. It is the responsibility of governments, key stakeholders, associations and local communities to promote this awareness. Water companies, who make a profit from consumption, cannot be relied on for these campaigns.

People need knowledge to enable them to be involved in making decisions and choices—some of which rely on complex arguments. One critical question is, how can consensus on controversial water management measures be obtained and maintained—at a local, national, regional and international level?

4. Governance

4.1. The Present Challenges

Among the range of activities and responsibilities for ordering human affairs, those concerned with fresh water rank among the most complex. This complexity is not only because water enters into so many facets of life in today's world, both directly and indirectly, but also because these facets range in scale from those impacting the individual, to those functioning at the river basin level and upwards to those at the global level. The variety of instruments and mechanisms which are employed to administer the different activities concerned with water have to reflect the wide and diverse interests associated with it and the scales on which they operate. Ideally, the effects of these instruments should all be compatible, but this state is not often attained. There is also the problem that the overriding need to provide safe and reliable drinking water to several billion people can lead to short-term solutions which bring other problems in their wake.

Such is the variety of viewpoints with which water is regarded across the globe, from one nation to another and even from region to region within the larger nations, that any attempt to encapsulate the affairs of water and its instruments and mechanisms is confounded. An example is the differing views of the arid and semi-arid countries to those in the humid parts of the world. In the former, the importance of water is paramount and this importance is reflected in the various instruments and mechanisms of government which pertain there. In the latter, the situation is often characterised by weaker institutional arrangements, because of the lesser importance attached to water in the life of the nation.

4.2. The Global Level

Within the UN system there are more than 20 bodies and specialised agencies with programmes concerned with water. There are organisations that have roles in funding, education, labour relations, training and the legal and other aspects of water as well as those involved in research, promoting water supply and sanitation projects. The history of system-wide coordination of water affairs is rather short. It became formalised with the UN Water Conference in Mar del Plata in 1977, where the hopes for a UN Water Organisation foundered. However, the conference gave rise to the International Drinking Water and Sanitation Decade, which was carried forward largely by WHO and UNDP in the 1980s. This was followed by the preparations for the UN Conference on Environment and Development (UNCED) where the Subcommittee on Water Resources of the UN Administrative Coordinating Committee (ACC) was responsible for piloting the work for the water chapter (Chapter 18) of Agenda 21 (UN, 1992), in particular through the Dublin International Conference on Water and the Environment (WMO, 1992).

More recently, for the 1997 session of the Commission on Sustainable Development, members of the subcommittee, aided by several national bodies, conducted an assessment of world water resources. The subcommittee continues to work within the ACC machinery, and to the plan set out in Chapter 18 of Agenda 21, in order to provide global action on the development and management of water and water resources through their separate programmes for the benefit of, and with the participation of, their member nations.

Some measure of support to these aims is given by the Global Environment Facility and the Global Water Partnership.

BOX 4-1. WHAT'S DEFINITION OF GOVERNANCE

Governance is the framework of social and economic systems and legal and political structures through which humanity manages itself.

However, as in many of the other fields where the UN and its agencies are active, the aspirations are not often matched by the achievements, as the rate of progress depends on the attitudes of the member states. Although the policy may be clear, some of the levers of global governance, which should be available to implement that policy, may be missing.

Although the UN is an important player on the global stage, there are a number of other actors involved. Many developed nations conduct bilateral aid programmes amongst the poorer countries. These programmes have parallels in the assistance provided by regional bodies, such as the EU, and by humanitarian and developmental NGOs such as OXFAM. While these mechanisms are aimed at the third world, there are similar initiatives operating globally in the scientific and educational fields promoted by organisations within the International Council for Science, the Union of Technical Associations and similar NGOs in the fields of science and engineering. A recent addition to the spectrum of nongovernmental water bodies is the World Water Council and 'the Vision' it prepared for the Second World Water Forum held in The Hague in March 2000.

4.3. Regional and International River Basin Levels

There are a number of bodies actively concerned with water at these subglobal levels. Groupings of nations such as the EU and the Southern African Development Community, stimulate co-operation amongst their members through various activities concerned with water, and sometimes through the implementation of agreed policies on water and water development. For example, the forthcoming European Framework Directive on Water prescribes the river basin as the unit for water management and provides for harmonisation of regulations across a range of water-related activities, but the responsibility for monitoring compliance currently rests with member states. In addition, NGOs such as the International Network of Basin Organisations and the International Rivers Network have active programmes.

There are 260 or so international river basins worldwide. A small number of them are covered by treaties and conventions between some or all of the riverine states. Such agreements aim to facilitate water saving and are often based on the Helsinki Rules (ILA, 1966) and may, in future, follow the pattern set out in the 1997 UN Convention on the Law of the Non-navigational Uses of International Watercourses. However, few of these river conventions are satisfactory instruments, often just promoting exchange of data, and seldom binding the parties with rules that are overseen by a river basin authority, backed by a mechanism for settling disputes or penalties for errant parties.

Integrated river basin management, which is usually upheld as a guiding principle, is handicapped just where it is most needed, namely in these international river basins. There are often impediments to optimum political, legal, educational, financial and administrative arrangements, impediments set against a background that the parties involved find it difficult to accept that the national interest may have to be sacrificed for the international good. This is despite the availability of some funding from UN and regional sources, together with the possibility of supporting programmes in research and education.

BOX 4-2. ACCESS TO INTERNATIONAL RIVER BASINS

Nearly 40% of the world's people live in more than 200 river basins that are each shared by at least three countries.

(Serageldin, 1995).

4.4. The National Level

Water is treated in a variety of ways in the structure of national government. Ministries of water or water resources may exist in some countries; there are others where responsibility for water is shared with other interests of government, such as forestry (South Africa), or between a number of bodies of government at the federal and state levels (Australia, USA), often with a minimal amount of coordination between them. In some countries, water interests are submerged within departments and ministries representing wider governmental responsibilities (Japan). Quasi-governmental bodies or agencies play an important role in a number of nations (Ghana), while in others the responsibility for water is vested largely in regional governments (Canada, Germany) and the national bodies that exist coordinate regional efforts and meet international obligations.

Some countries have systems where one ministry, often the ministry of the environment, has the responsibility for a national water council heading a system of river basin authorities, each with its own council and further subdivisions of each basin (Spain). Water supply and sanitation is often separately organised from such a system and can be in the charge of municipal and local government (Switzerland) and separate from other water activities.

Although there has been a great deal of publicity about the benefits of the combination of land and water management, there seem to be few countries where this has been achieved. However, in some circumstances voluntary groupings of governmental and nongovernmental bodies coming together for particular tasks has proved a valuable means of tackling some problems of water and the environment: for example, in the case of the difficulties associated with the San Francisco Bay delta in California.

BOX 4-3. CASE STUDY: THE AMERICAN GREAT LAKES

In 1969, a floating oil slick on the Cuyaboga river burnt for hours in Cleveland, Ohio, where the waterway empties into Lake Erie—one of the five American Great Lakes that make up the world's largest system of inland lakes. Newspapers declared 'Lake Erie is Dead'. In 1970, mercury pollution in Lake Erie and other waterways in the Great Lakes system bordering Canada and the United States led to a ban on fishing in parts of the region. A chemical plant in Canada was thought to be the source of potentially dangerous discharges. That same year, the state of Michigan issued a warning to the public about consumption of fish from Lake Michigan. High levels of residues from toxic PCB were found in lake trout and salmon.

In 1972, the US Congress passed the Clean Water Act. The same year, the United States and Canada signed the Great Lakes Water Quality Agreement '…to restore and maintain the chemical, physical and biological integrity of the waters of the Great Lakes basin ecosystem'. Ten years later, the result was stupendous: fishing was permitted again in Lake Michigan and Chicagoans could enjoy swimming on their beach. Concentrations of all pollutants had decreased.

Today, the situation is much better than 30 years ago, in spite of population increase and urbanisation of the area. There are still concerns about the quality of water and some changes in the ecosystem (fewer big fish and proliferation of unwanted zebra mussels and sea lamprey). But the fight against pollution has been won.

The departments, ministries, quasi-autonomous public-sector agencies, municipal bodies, private companies, etc. which manage water have been established through different processes. Statutes in particular countries have put in place specific mechanisms for regulating water affairs—sometimes as entities, sometimes as part of another area of interest.

Where municipal or government agencies have responsibility for provision of water services, those same or related agencies often have a parallel responsibility for setting environmental and service standards and for monitoring for compliance. This combination of roles tends to blur management objectives, often leading to inefficiency and poor compliance. Separation of the roles of regulation and operation (as in the UK) leads to greater clarity and accountability.

Involvement in the private sector may be brought about through operating contracts, where the assets remain in public ownership, or through full privatisation of assets and their operation. The trend since the 1980s has been towards the privatisation of part, or all of, government responsibility for water. This privatisation has taken place in many parts of the world, in some cases fostered by assistance from donor governments. These privatised water services are able to offer their facilities to an increased number of customers who are willing to pay for a regular supply of fresh water and for their wastewater to be conveyed away. The premise often is that this payment will be less than the charges currently made to customers by water vendors. These moves sometimes come up against the problem that the supply of water to the home is free in a number of countries, while in others there are many illegal connections to the water mains. But these problems have to be set against the difficulties encountered in those places where domestic water supplies are turned on for only a few hours each day and the many other locations without public water supplies.

Regulation of such private companies must start with proper acknowledgement and allocation of risks and must include mechanisms to ensure compliance with clearly defined standards of performance and systems of economic regulation. Economic regulation should provide incentives to improve efficiency and include regular reviews to ensure consumers share the benefits. Many economic regulatory requirements arise from the monopoly nature of the water service and would in theory disappear with the introduction of competition. Competition is difficult to achieve because of the need for a single system of infrastructure for water. Environmental regulation must take into account competing demands for resources (water supply, irrigation, cooling, etc.). Judgements have to be based on analysis of the total costs and benefits (including externalities) of those demands and of the balance required by river basin management considerations, including wastewater standards. In many parts of the world rural water supply and sanitation require special consideration.

4.5. The Grassroot Level

In the richer countries the concern at the local level is often with matters of water quality and the hazards faced from accidental pollution and sources in industry, agriculture and road drainage. There are many bodies, often branches of national organisations, concerned with the rivers, lakes, streams and wetlands and with the life that depends on them, as well as a long list of other interested bodies and individuals (from anglers to water skiers, and freshwater ecologists to water diviners). Some of these interests are represented on local councils and bodies concerned with water, often by appointed members, but sometimes elected: for example, in the Netherlands local communities have been electing representatives since the thirteenth century to flood-defence and water control bodies.

The nature of these concerns for water contrasts with those in poorer countries where the focus is usually on access to water for drinking and the disposal of waste. Community supplies of drinking water are lacking and there is no public body responsible for their provision. The consumer has to depend on vendors who charge a price which is invariably many times the price of water from a public water supply. Local groups, particularly groups of women, have been set up in many of the poorer countries to organise water supply. Often they are supported by aid from the richer countries, sometimes through women's NGOs. The Kenya Water for Health Organisation ensures that women are involved in the siting of wells and gives them training in the construction and maintenance of wells and repair of hand pumps. With the help of a specialist water NGO, 15 villages in southern India have installed hand pumps and women have been trained as pump caretakers. Women have been involved in the design and installation of latrines in Zimbabwe and other countries in Africa. There has also been involvement of women in other problem areas where water is involved, such as erosion control and in flood preparedness. Many measures leading to sustainable development start at the grassroot level and involve water.

There is a need to go beyond the general rhetoric for more capacity building and participation of women at all levels within the water sector. There should be wider recognition of the pivotal role of women as providers and users of water and concrete steps are required to create an enabling environment for their meaningful involvement in the institutional arrangements for managing water. If society is going to address the challenge of sustainable management of water resources, there is a need to allocate all available resources, including human resources, in an efficient manner in order to provide clean and safe water for all.

4.6. A New Architecture for Governance

Greater participation, greater involvement, more cohesion and more transparency would be some of the facets of a new architecture for governance. The large number of bodies and interests involved at all levels suggests that each level would benefit by improving the framework that brings them together. Sharing in programmes and decisions would certainly assist in cohesiveness. For example, at the UN level, although the Administrative Coordinating Committee Subcommittee on Water Resources has existed for more than 20 years, it has rarely worked as an entity. The establishment of a UN world water programme, built on the hitherto separate programmes of the members of the subcommittee, would be a step forward. National and local water programmes, for those nations without them, would also be a move towards improved governance.

5. Conclusions and Recommendations

5.1. Integrated Water Management and Catchments

The river basin offers great advantages as a unit for planning, regulation, monitoring and awareness raising, but difficulties arise because catchment boundaries do not fit administrative and/or political boundaries. The catchment is the natural unit for water resource management, and its size should guide the governance structures used, which may be international.

The river basin approach recalls the theme of the 1999 World Water Day—'Everybody lives downstream'. Upstream changes in land use, construction work and other developments will affect downstream dwellers, whether they rely on surface- or groundwater. Even mountain dwellers are affected by pollution transported by air.

Effective integrated river basin management relies on all stakeholders being involved, even if the basin crosses national borders. All the people concerned must be brought around the same table to give their opinion at the beginning of a project, then smaller groups can make decisions. The most efficient way to manage a basin is to run a specific budget, paid for by people living in the basin.

5.1.1. Recommendations

- *Water management at national, regional and international levels must be based on the catchment.*
- *Integrated catchment management should allow separate authorities for the operational development of the resource and for the regulatory supervision to protect public values.*
- *Legislation should require that those managing water catchments have the accountability, professional competence and the legal authority to carry out their duties, and should make possible the meaningful participation of all interested parties.*

5.2. The Ecosystem Approach

The sustainable maintenance of the global ecosystem must be considered when making water management decisions. Deficiencies in understanding the ways in which ecosystems function and the way water behaves need to be made good. Nation states need to extend the exchange of monitoring data and information used in water resources assessment and in the processes of abstraction, distribution, treatment of waste etc. The precautionary principle should be adhered to: i.e., where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.

5.2.1. Recommendations

- *The precept 'working with water' should be the basis of laws, regulations and practices in order to achieve sustainable management and to minimise the risks and costs of working against water.*
- *In managing water resources, institutions and individuals must take into account the impacts of their activities on ecosystems and the precautionary principle.*

5.3. Education and Public Participation

Education is important, for the decision makers of today and tomorrow, and for the public as consumers, citizens and inhabitants on this planet. Continuing education for the public should aim for high standards and an appreciation of risk analysis and management. The challenge is to raise awareness of water and keep it high.

5.3.1. Recommendations

- *Governments must actively encourage a greater awareness of sustainable water use and water issues at all levels of society.*
- *International and regional bodies should seek to design and create a global water knowledge system open to all.*

5.4. New Institutional Responsibilities

There is already a plethora of institutions. Are new institutions required or can we build on, or coordinate and integrate, existing institutions? It should be possible for existing institutions to work together more effectively to bring about improved governance, recognising that the solutions are always nation- and basin-specific. There is a balance to be struck between rules and voluntary agreements, as there is between the 'bottom-up' and the 'top-down' approach.

Governments, statutory bodies, and NGOs are increasingly able to deal with issues on the scale required. Many good analyses and ideas come from the NGO sector. Institutions need to make better use of technical and scientific information, recognising that, although the role of the technical advisor is critical, it must be 'on tap not on top'.

5.4.1. Recommendations

- *The achievement of catchment-based, integrated management may require revision and/or reinforcement of existing institutional structures, bodies and treaties or the creation of new supranational organisations.*
- *Economic and other incentives should be introduced or revised to encourage sustainable water management.*
- *Governments should ratify promptly the 1997 UN Convention on Non-navigational Uses of International Watercourses. Negotiation and dispute settlement processes conducted by the UN and its agencies should support international laws relating to water.*

5.5. Ownership and Valuation of Water

In most countries water *per se* is not a private good: it remains in public custodianship, but the provision of water services and the right to use water may be privatised. The allocation of the resource remains a function of government. Water should not be owned or appropriated by an individual or group—it should be a public resource. Access, property rights, responsibilities and incentives need to be defined and require careful management.

Water has a multidimensional value in a social, economic, aesthetic and cultural context. What is the value of a clean river? Should we strive to achieve a pristine environment or try to establish a balance between use and a healthy aquatic ecosystem and invoke a cost/benefit analysis approach?

Except in circumstances where equity strongly demands otherwise, human users of water should, at a minimum, pay the full cost of providing water and services. Economic incentives, including subsidies, should be used to promote the sustainable use of water while being careful to give due regard to fairness.

5.5.1. Recommendations

- *No body, individual or corporate, should have the right to extract from, or discharge into, a body of water without a time-, volume- and quality- limited permit from a public authority.*
- *Governments should prepare legislation immediately to ensure that full cost recovery is achieved with a tariff structure designed to increase efficiency of water use.*
- *Governments should develop and implement water demand policies and should encourage the adoption of appropriate new technologies, water saving measures and other actions consistent with fairness and sustainable development.*
- *Subsidies, existing or proposed, should be carefully evaluated to ensure that they accomplish the socio-*

equity goals advanced as their justification and do not impose unacceptable environmental impacts. They should not, in principle, be applied through tariff structures.

5.6. Funding Agencies, Investment and Debt

Development banks, such as the World Bank and the Asian Development Bank (ADB) have been responsive to some extent to modern principles of water management. For example, the World Bank, working with the IUCN (the International Union for the Conservation of Nature), is supporting studies of the World Commission on Dams to evaluate the 'development efficiency' of dam building. The World Bank issued a policy paper on water resources management soon after UNCED and the ADB is working on a similar paper. These developments are to be welcomed but we should like to see the UNCED 92 principles taken into the policies of World Bank and ADB more quickly.

5.6.1. Recommendations

- *Governments and international financial institutions should forgive public debt owed by developing countries conditional upon the development of catchment-based management systems within and across national boundaries and a programme for removal of direct subsidies.*
- *Investment in water projects in international catchments should encourage co-operation between catchment countries.*
- *All financial investment should require proof that sustainable and efficient water use will be guaranteed. Assumptions that water will be provided for all new developments must cease.*

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Appendix A: A Table of Problems and Remedies *by Usha Raghupathi*

Problem	Actions Required	Policy Recommendations
depleting water resources	increasing availability of water through: (i) nonconventional means such as desalination, water recycling/ reuse, aquifer recharging and rain water harvesting (ii) prevention of water pollution (iii) inter-basin transfers (iv) constructing artificial wetlands	governments should encourage the adoption of new technologies and water saving measures to improve water availability no individual or corporate should have the right to extract from, or discharge into, a body of water without a time-, volume- and quality-limited permit from a public authority
inefficient use of water	improving irrigation techniques for efficient use of water reuse of wastewater for agricultural and nonagricultural uses demand management through technical, economic, legal, administrative, operational, educational and political means	a ‘water impact assessment’ should be made mandatory for all new investments supported by financial institutions in order to ensure efficient and sustainable use of water governments should develop and implement demand management policies that achieve equitable sharing of this limited resource
health risks due to poor water quality	introduction of clean technologies improvement of water treatment and the reach of treated water promotion of community-based water quality surveillance methods	governments should enforce standards for water quality and wastewater/effluent disposal by encouraging involvement of local communities
water not valued as an economic good	proper pricing of water and improving cost recovery charging for sanitation services removing/minimising subsidies establishment of water markets enforcement of the polluter-pays principle	governments should prepare legislation to ensure that full cost recovery is achieved in as short a period as possible and also ensure that price increases with the volume of water used. Equity and social affordability concerns should be given proper attention in this process subsidies, existing or proposed, should be carefully evaluated to ensure that they accomplish the socio-equity goals advanced as their justification and that they avoid damage to ecosystem and contribute to a sustainable water future

Problem	Actions Required	Policy Recommendations
the need for institutional and legal reforms	establishment of organisations for integrated basin-wide management of water resources creation of a single national organisation to deal with all matters related to water, embracing regional, rural and urban sectors involvement of the private sector in various aspects of water supply the drafting of international and regional water agreements and conventions	water management legislations at national, regional or international level must be based on the river basin; legislation should ensure that river basin managers have cognitive and execution capacities to discharge their responsibilities laws, regulations and practices should be based on the precept that sustainable management involves working with water and recognise the risks and costs of working against it institutional structures, including economic incentives, should be revised in a flexible and holistic way and altered, if necessary, at all levels of government to accommodate the change to management by river basin creation of supranational bodies and treaties and the re-enforcement of existing ones should be brought about wherever such entities would help in catchment-based integrated management policy development governments should ratify the 1997 UN Convention on Non-navigational Uses of Water promptly, and should consider improving and strengthening its provisions
lack of reliable data and information lack of appropriate training for managing water resources	the setting up of mandatory systems for data collection and monitoring at various levels collection of data through surveys where data do not exist capacity building of water professionals and water users in integrated water management and management of water systems	water bodies should seek to foster the design and creation of a global water knowledge system governments must actively encourage the exchange of information and a greater awareness of sustainable water use and water issues at all levels of society
people's involvement	encourage the formation of local organisations for effective water management. These organisations could be provided training input in education and health aspects of water women's groups should be given special encouragement	decision making must take place democratically at the appropriate level
lack of finance to improve water systems	encourage public–private partnerships as well as privatisation for financing water supply projects devise mechanisms for ensuring funds allocated for and generated from water sector be put into improving water resources management support and encourage financial investments from local communities	dependence on government should be reduced by encouraging private-sector funds. Unbundling of water supply service provides opportunities for private-sector involvement in various activities disinvestment by the state could also be encouraged for managing water supply services

Appendix B: The Benefits of Restoration of Habitats *by Anne Powell*

B.1. Introduction

This paper is about restoring habitats, especially those associated with freshwater. The case is made that restoration based on the catchment ecosystem has many benefits and can make a contribution to sustainable water management.

Since the 1992 Rio Earth Summit, people have struggled with the concept of sustainable development, usually taken to mean ‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’ (UN, 1992). Deciding what actions are sustainable is difficult. For example, Sir Crispin Tickell, the convenor of the UK Government Panel on Sustainable Development recently referred to the ‘somewhat slippery concept of sustainable development’.

Recently, the UK Government has tried to turn the concept into action and has produced *A Strategy for Sustainable Development for the UK—a Better Quality of Life* and a number of subsidiary strategies: for example, *A Strategy for more Sustainable Construction—Building a Better Quality of Life*. These papers suggest that there are three ‘legs’ supporting sustainable development, namely economic, social and environmental, and that trade-offs can be made between the three. The environmental leg is ranked third, and is sometimes implied to be optional. In reality, the opposite is the case.

A major way in which it is sometimes suggested that sustainable development can be delivered is through integrated management. This is a common theme in policy statements from regulators, including the Environment Agency for England and Wales (EA). The EA, in its corporate plan, states that its primary aim is to protect or enhance the environment and make a contribution towards the delivery of sustainable development through the integrated management of air, land and water. As a relatively young organisation it is still in the early stages of achieving this.

Similarly, managers widely accept that water is best managed in an integrated way on the basis of the catchment or the water basin. Integrated river basin management (IRBM) or, as in Agenda 21, integrated water basin management (IWBM), attempts to treat the river and its tributaries together with the land and underground water as a unit. It recognises the need to manage the river basin as an entity, and implies the importance of land use, as well as the value of ponds, lakes and wetlands within the basin. The National River Authority’s Catchment Management Plans (CMPs), the subsequent EA Local Environment Agency Plans (LEAPs) and the plans generated under Local Agenda 21 (LA21) are examples of a way of thinking sometimes referred to as ‘catchment consciousness’ (see, for example, Newson *et al.* (2000)). This idea links society and economics to the more familiar technical aspects of water management. However, CMPs were river focused, LEAPs are of variable quality and LA21 plans are also of variable quality and incomplete.

The catchment is being adopted as the basis for legislation and management in many parts of the world. Newson *et al.* give examples of authors who have advocated the catchment as a management tool and countries with catchment planning experience. The catchment is central to the proposed Water Framework Directive, which will require EU member states to develop administration and prepare management plans for river basins; the Fisheries Legislative Review (MAFF, 2000) advocates catchment management from the viewpoint of sustainable fisheries.

Surprisingly, while some are striving to integrate, others appear to be doing the opposite. The World Water Vision, launched by the World Water Council in August 1998 has developed ‘sector visions’ for Water for People, Water for Food and Rural Development, Water and Nature and Water in Rivers, which were discussed at the World Water Forum in The Hague in March 2000. What a curious split! The multi-utilities that have grown to provide energy, water and treat sewage might also resist integration in their response to market forces, shareholders’ interests and increasing regulation.

The paradigm suggested in this paper is that sustainable development must first consider the environment upon which economic and social factors ultimately depend. It invokes an integrated approach: in the EA’s terms (air, land and water), in terms of the integration of the relevant disciplines (including social and economic) and by recognising the interdependence of all the water and land in the catchment. The paradigm recommends that this is done using the ecosystem approach, and that restoring aquatic ecosystems is key to sustainable management of freshwaters.

B.2. Ecosystem Stability and Health

The ecosystem is a concept that assists our understanding of the way in which living organisms, nonliving chemical and physical components and energy interact. All ecosystems have characteristics in common. Firstly, they are largely self-contained: their interaction with adjacent ecosystems occurs mainly at the edge or ecotone (for example, the sea and the land in the littoral zone). Although most of the materials within these systems recycle, links exist between them—they are not completely isolated and materials and biota move between them. Secondly, following the original idea of Lindeman (Deevey, 1984) the sun's energy can be considered to flow through each ecosystem. It is captured by plants in photosynthesis, and transformed from light energy into chemical energy and stored in the tissues of plants to be released when the plant is consumed by herbivores or by detritivores or micro-organisms when the plant is dead. All levels in the food web use some of this energy for respiration (thus liberating energy from the ecosystem in the form of heat) and pass some on, usually about 10% of intake, to the next trophic (feeding) level. Thirdly, materials such as nitrogen, phosphorus and carbon recycle within the ecosystem. There are losses and gains and some cycles are complex, but the continued 'running' of the ecosystem relies on the availability of simple chemical substances being available to plants for growth. Materials (and energy) are passed on to herbivores and various levels of carnivores in the food chain during which the chemicals are transformed into amino acids, proteins and larger molecules of which bodies are built. Decomposition pathways in the food web break large molecules down into simple chemicals to be recycled once again. The implication is that ecosystems (rather like engines) have finite limits and can be measured in terms of inputs, efficiency and production.

Ecosystems are biodiverse—they contain many species of plants, animals and micro-organisms. Equally important is genetic diversity within species, age groups within populations, habitat diversity and the number of different niches or 'life styles' available in the system. Some systems are inherently less biodiverse than others. For example, desert ecosystems are less diverse than tropical rainforests and, in both cases, as the living components are studied their interdependence becomes obvious. The most direct way in which many species are connected is through the food web. Although there are many examples of feeding specialisation, most animals rely on a number of food species depending on availability. This adaptability helps to explain stability.

On the human time scale, ecosystems seem to be stable, normally self-sustaining and to function well. They may have marked seasonal or cyclical changes but only change slowly over the years. Some (simplistic) views regard ecosystems as evolving, growing old towards a stable climax. Lakes have history, as shown by their sediments, and are referred to as primitive (oligotrophic) or evolved (eutrophic) and there is some evidence of change from the former to the latter state. However, modification to a more oligotrophic state can also occur: as, for example, when peats are formed due to climate change or water level change. Size affects stability and small lakes and ponds change more rapidly than larger ones, filling in to become dry land in a series of stages. Although they seem stable, even very large ecosystems can dramatically change when upset by large-scale natural events (such as volcanic eruptions, meteor impacts, floods, fires) or by human impacts (pollution, dams, irrigation on a large scale, etc.).

In the 1960s and 1970s, a number of authors (see Deevey, 1984) working on small model systems defined ecosystem stability as resistance to perturbation or homeostasis—implying feedback and self-regulating mechanisms. The suggestion was made that diversity influenced stability and that less diverse ecosystems were less robust and more likely to crash. Some of this discussion related to lake systems where nutrient inputs, when increased by man, appear to accelerate the evolution of a lake to a more eutrophic state (anthropogenic eutrophication). Eutrophic lakes have high biomass of fewer species and it was suggested that they were unstable. The search was on for a quantitative theory of ecosystem stability. It is now generally agreed that although eutrophic lakes do have less species diversity they cannot be said to be unstable. Rather, they show a departure towards a new equilibrium which is reversible on reduction of the driving stress (see Bailey-Watts *et al.*, (2000)).

Enriched and polluted lakes are not as healthy, or as exploitable, as un-impacted water bodies, but although suboptimal, they are not necessarily unstable. Ponds, when enriched, fill with sediments and can be considered unstable, but rivers are inherently dynamic and continuously adjusting to changes in conditions. When dramatically interfered with they show 'instability', just as constrained rivers struggle to be free and require constraint and maintenance to control their instability.

Some scientists and policy makers refer to 'ecosystem health', drawing comparisons with the health of a person or animal and recognising poor function, eventual death and, under certain conditions, the capacity for self-repair and recovery. In just the same way as people can withstand loss of cells and parts of organs, ecosystems can 'cope' with loss of species. The degree of damage that can be withstood without significant loss of function is difficult to predict in people and even more difficult in ecosystems. The idea of river health is creeping in, and is often used (as by Meyer (1997)) to encompass a human dimension as well as an ecosystem one.

The connection between diversity and sustainability is also gaining ground. For example, good water quality is defined in the proposed Water Framework Directive as a water body (lake or river) that has a rich, balanced and sustainable ecosystem. Biodiversity is a general measure of ecosystem health and, increasingly, ecological methods are being developed to monitor aquatic systems (such as the River Invertebrate Prediction and Classification System

(RIVPACS) and the Predictive System for Multimetrics (PSYM)). Biodiversity is not merely a sentimental concern or add-on, but should be recognised as a measure of ecosystem health and a way to judge whether actions taken are sustainably successful or not.

Although understanding grows, we still cannot predict how much damage a catchment can take before collapsing, nor do we know how much water a river needs to avoid lasting damage. Similarly, recovery after treatment is unpredictable in both organisms and ecosystems. 'Dead' rivers, so described because no life could be seen, have revived (for example, the Thames). Recognising that the basins on which we depend are damaged, it may be that rehabilitation can restore them to health, thus allowing further (sustainable) exploitation.

Ecosystems are convenient, if complex, units for study. A river, with its tributaries, can be considered as an ecosystem, as can a lake or a pond. In the context of water management, and taking account of the extent to which the land influences flowing and standing water within a catchment, it may be helpful to consider the whole clearly bounded basin or catchment as an ecosystem. This is not a new idea: Deevey (1984) in considering stress, strain and stability of lake ecosystems insists on considering the lake and its catchment (which he refers to as the paralimnion) together, and a similar approach is suggested by Newson *et al.* (2000).

B.3. *Homo sapiens* and Ecosystems

A fundamental issue, which has been addressed by religions and traditions throughout history, is the relationship between man and nature. A strong theme running through the classical and Christian tradition is that humans are dominant over nature. Ponting (1991) concludes that the human view of the world is supported by philosophical, religious, scientific and economic traditions which foster exploitation of the natural world. The language of environment and sustainability documents published by the UK Government emphasises how man sees himself apart from the ecosystem, and this separation is reflected in the apparent distinction between 'water for people' as opposed to 'water for nature'. For example, John Prescott, in one of the government's earlier sustainability documents, refers in his introduction to people *and* ecosystems.

When the global human population was small its impact on ecosystems was minimal. 'Ecological man' lived as an integral part of the ecosystem: the world around him was stable, sustainable and, barring meteors and volcanoes, ecosystems continued to function well. The growth of human population and the accompanying changes, species loss and ecosystem damage is well documented. Ecosystems have been changed by many things, including agriculture, deforestation, draining, hunting, plant collection, and introductions. The pace of change, the loss of biodiversity and ecosystem damage by man's activities has increased particularly since the fifteenth century, with the European domination of the globe.

As the population accelerates towards 10 billion later this century, ecosystem damage may threaten human survival far more overtly than at present. Loss of species may become translated into a measure of the threat to human survival. Some major types of physical impact are considered below, and the possibilities for restoration examined.

B.4. Changes in Vegetation Cover

Deforestation and growth in agriculture over the past 5000 years in the UK has been dramatic and has changed water quantity and quality. Currently, 70% of the UK is agricultural crops and grassland, 10% is wooded (about half being coniferous), 10% is urban and 10% is derelict land and mineral workings (Robinson *et al.*, 2000). On valley slopes changes in vegetation can result in instability of soils and erosion, adding silt to watercourses which coats the stones and fills up the interstices between the components of the substrate, changing its nature and the types of organisms it can support: for example, fish eggs and fry. In particular, valuable salmonid fisheries have been reduced or eliminated by the loss of spawning beds. In the UK, large amounts of money are spent annually raking gravel to clean out soil particles and displace them downstream where, when they reach a lower current speed, they re-sediment. There is growing concern about the decrease in soil quality: organic matter content has declined making soils more vulnerable to erosion (this has increased since the 1950s, due to the increase in arable and stock grazing).

Over the past 70 years, significant restoration has taken place in the UK in the form of reforestation of parts of catchments and revegetation of the margins of rivers (buffer zones), so that there is almost twice as much woodland now as there was in the 1930s. Further tree planting implies a further reduction in land used for growing food, and may be encouraged by future reform of the EU Common Agricultural Policy (the CAP) and further use of set-aside provisions, etc.

However, extensive tree planting can have negative effects, and there is considerable debate about how woodlands influence river flows. Trees generally have higher evaporation rates than grassland or arable land and this gives rise to fears that the extensive reforestation planned for the UK lowlands may reduce the recharge of aquifers which form a major part of the water supply. Farm-based measures for ecosystem protection, such as contour ploughing and maintenance and replacement of hedges, should be encouraged, and some crop growth, for example of maize, winter wheat and potatoes, should be discouraged in areas where it may promote excessive runoff.

B.5. Drainage of Ponds, Wetlands and Floodplains

In England, river valleys have been consistently drained to make way for agriculture or development, first by ridge and furrow techniques, and in the last 200 years increasingly by subsurface pipes, so that England is now one of the most extensively drained countries in the world. English Nature (Acreman and Jose, 2000) concludes that since the 1930s huge losses of wet grassland have taken place, especially in the southern and eastern parts of the country: for example, 64% of the wet grassland in the Thames valley has disappeared. Getting the water off the land as quickly as possible was an aim of 'improving' the land which has cost UK tax payers huge sums of money in the last 100 years. The loss of wet meadows, water meadows and wetlands (referred to as the 'kidneys of landscape') has reduced biodiversity and cost society in lost products, functions and services (as shown by Acreman and Jose) and the intensification of farming on drained floodplains has resulted in further undesirable changes in rivers. Although theoretically protected by a number of conventions and regulations, many wetlands in the UK are still at risk from abstraction.

Restoration of wetlands is popular and many good examples exist. This is done by reconnecting the floodplain with the river (allowing over-topping so that flood meadows are revived), nonrenewal of under-field drainage in selected catchments (or parts of catchments) or digging of still waters (temporary or permanent). The EA has set up a Wetland Liaison Group which is working towards a strategy for catchment-based restoration of wetlands but, to date, no such plan exists. Water Level Management Plans were initiated by MAFF for a number of vulnerable wetlands, but without any funds to bring about the necessary changes.

Ponds (water bodies between 1 m^2 and 2 ha) have been lost by drainage and pollution at a huge rate: 75% of those existing at the end of the nineteenth century have gone and many that remain are impacted by pollution (Williams *et al.*, 1998). Comparisons of species richness in rivers and ponds show that ponds support more species and more unusual species of conservation importance.

The work of the Ponds Conservation Trust and others has shown how much ponds are appreciated and used. Because many ponds have small catchments (especially those fed mainly by surface runoff) they can be easily protected and restored. Many are being created by community and NGO projects for amenity and education, and by local authorities and water undertakings to balance flood flows for urban areas and to assist source control of pollutants. A strategic approach is needed whereby clusters and mosaics of ponds of a range of sizes and types (permanent and seasonal) can be created. Pinkhill Meadows in Oxfordshire is one such artificial complex, which has demonstrated its success by being colonised in its first six years by 20% of all wetland plants and macroinvertebrates in Britain.

B.6. Changing the Course and Shape of Rivers

The River Habitats Survey (Raven *et al.*, 1997) showed that less than 10% of the river reaches sampled were unmodified. Straightening, widening, and deepening rivers was, like wetland drainage, seen as an 'improvement' as it helped to transmit water more quickly downstream. The industrial revolution resulted in many thousands of dams, mill lakes, weirs and sluices being constructed, interfering with the behaviour of the river and its wildlife, particularly with fish. Channel modification done today is mostly for land drainage and flood protection, but fishing interests undertake extensive enhancements in salmon rivers involving redistribution of gravel shoals, channel narrowing to scour silts and construction of upstream features designed to create scour pools for fish to lie in. Intensive livestock rearing right up to the river's edge leads to bank erosion, so that the river becomes shallower, wider, and slower, and silts deposit in what were clean gravels. Straightened and deepened rivers are remarkably unattractive, contain low diversity and, in most cases the fisheries become less valuable. They also increase the risk of flooding for the downstream sections of the same system. The initial works cause disturbance to the river; maintenance may be frequent and is expensive.

There is a large literature on river restoration techniques (RSPB, 1994). Most authors agree that river restoration has many benefits and it is widely undertaken. In some case it can be inexpensive: for example, excluding stock from riverbanks allows plants to grow and the channel to narrow and meander, cleaning gravel and encouraging fish. Meandering can be encouraged by 'letting the river go' to find its natural bed, although in low-energy channels active restoration is required.

The more natural the river the lower the cost of maintenance, so the aim should be to approach the pre-disturbance state and economic sustainability by encouraging the river to be as natural as possible. Usually, the maximum advantage is not achieved because schemes are small, often exclude the floodplain and are rarely catchment-wide.

B.7. Floodplain Development and Urbanisation

Housing and industrial development in the floodplain is economically attractive because the land is flat. The cost of flood protection (dykes and bunds) is high and, when upstream development or other factors increase flood risk the cost becomes even higher. Development usually involves covering the ground with impervious surfaces, speeding up runoff and adding to downstream problems. Water quality of the runoff from concrete and asphalt surfaces, especially when storms follow a dry spell, is poor. Storm waters are, in many parts of the country, directed away from sewage works, which would be quickly overwhelmed, and go straight into the river. Maintenance and upkeep costs will be a liability on future generations.

The Sustainable Urban Drainage Systems (SUDS) approach aims to bring water back into the community and considers all aspects of amenity, flooding, pollution, biodiversity, landscape, safety and water resources. It is another example of an integrated approach. In urban parts of catchments SUDS schemes intercept rain as near the source as possible and store it for use, and include porous car parks and paved areas thereby reconnecting the surface water with the ground water and the aquifers whilst at the same time reducing risk of flooding. The Dunfermline Eastern Extension Area is an example where a variety of SUDS schemes have been used: including swales, wetlands and retention ponds. Many schemes do not reach their ecological potential and SUDS needs to lose its urban connotation and reconnect the urban and rural parts of the catchment for best effect.

B.8. Conclusions

Unmodified rivers which are hydrologically connected to their floodplains have a patchwork of habitats forming a complex and diverse ecosystem with many self-regulating functions that have benefits for flood peak attenuation, sediment storage and nutrient recycling. Man's interventions generally result in reduction in biodiversity and ecological, social, economic and aesthetic impoverishment, and are examples of nonsustainable activities, compromising the future and costly. For example, decline in salmon means loss of fishing with economic and social consequences, and polluted water means more clean-up costs in the future.

The interventions of the past have been designed to solve immediate water problems but have created problems of their own. Traditionally, we have called on engineers to find solutions by continuing to intervene, but things are changing. Large-scale projects of the past are increasingly out of favour and water conservation programmes are becoming more common. (Yet we have a government willing to fund massive projects in India and Turkey with overseas aid!) Increasingly, innovative, smaller-scale solutions are more common and 'soft' engineering solutions are proving as effective, and sometimes cheaper, than 'hard' engineering. New ideas include water conserving, land management techniques and rainwater harvesting. These approaches are working with the water system, not against it, but we need to go further.

Sustainable management of freshwater requires a new paradigm—to regenerate the system to as near its natural state as possible. The action required is to strengthen and restore ecosystems. We had the 'green revolution' and people are now talking about the 'blue revolution'. The technologically driven green revolution brought about a huge increase in food production by plant breeding, pesticide and fertiliser use. Somehow there is an idea that technology can massively increase the amount of potable water available for human use. An alternative is to take a more natural, ecological, ecosystem approach to repair and restore catchments.

There is no absolute baseline against which to measure anthropogenic effects in catchments and research into land use impacts on water resources is needed to achieve an integrated understanding of water ecosystems. Most importantly, a robust scientific understanding of the interactions between ecological, hydrological and geomorphological processes across the catchment is required, with cost benefit knowledge of the long-term responsibilities of future generations.

We have to accept that there are three interrelated factors for sustainable development; social, economic and environmental. People's attitudes and economic systems can change and are under human control, whereas the environment can only be managed within certain limits. If these are exceeded we suffer. There is more importance in understanding the ecosystem 'facts of life' than the 'economic and human behaviour facts of life'. It has to be clear that the environment is the least negotiable factor, not one to be dispensed with in the face of high costs.

All the restoration techniques discussed aim to retain water in the catchment, stabilise soils, reduce sedimentation, maximise infiltration and recharge of aquifers, reduce surges and amplitude of river hydrographs. The benefits of this approach will be increased stability and sustainability. The measures outlined can reduce siltation and loss of soil and increase biodiversity. There are economic benefits, including more clean water, flood protection, the saving of maintenance money for flood defence and improved fisheries. Climate change brings all of these matters into higher relief. Translating the effects of climate change into impacts depends on how the water is managed and catchment restoration is only one (at present underutilised) form of management, but it deserves consideration.

Restoration of ecosytems is already happening, but in a small-scale and piecemeal way because the implications of a healthy ecosystem have not been widely recognised and the way in which grants for habitat work are obtained mitigates against 'joined-up' activity. Farmers change land use in a catchment in a largely piecemeal way as individual firms respond to changes in legislation and market forces, there being no inducement for them to co-operate. To achieve catchment-wide demonstrations of the benefits that can accrue, estates or owners with control over entire catchments should be targeted and the need to invest to strengthen river ecosystems must be articulated more actively to politicians and the public, pointing out that this is not a peripheral exercise but enlightened self-interest.

Perhaps the UK should launch a decade of ecosystem restoration—a programme, backed by government, to strengthen catchments (rural and urban) in a holistic way? The Fisheries Legislative Review (MAFF, 2000) with improvements of fish habitats in mind, recommended a coordinated programme of river and river corridor restoration. This could form part of a fully integrated catchment restoration initiative tackled through a process of public participation based on LEAPs and driven, or at least planned, by the EA.

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Appendix C: Nonconventional Water Resources *by Arne Tollan and Janusz Kindler*

Abstract. There is no panacea for eliminating water scarcity. Yet, as a supplement to limiting water demand, there still exist unexploited possibilities to extend freshwater availability. Nonconventional water resources, in particular desalting, recirculation and reuse, offer such possibilities, and are discussed. Other technologies are also described: the growing of salt-tolerant plants, evaporation control, groundwater storage, artificial precipitation, rainwater harvesting, and water import.

These technologies, although able to provide significant additions locally and within a reasonable time span, do not create new water, but may improve water availability in space and time compared with the natural cycle. Nonconventional water resources, in particular desalting, water recirculation in industry, and reuse of purified sewage water may help in bridging the transition to a future world exercising tighter control on water demand. The potential for increased use of these technologies is significant.

C.1. Introduction

There is no single way to deal with water scarcity. When there is a mismatch between supply and demand, either the demand has to be reduced or the supply increased, or both. Today, it is increasingly clear that demand management of water resources is necessary. However, there are still unexploited opportunities for improving the availability of water, for instance through use of so-called nonconventional water resources. Several important approaches are discussed here.

It must be borne in mind that these nonconventional sources do not create more water. The methods described are in fact short-circuits and accelerations in the water cycle, providing water at a place or a time which better suits human needs than if the natural cycle was allowed to proceed. This may substantially help to allocate water rationally among competing uses.

Among the many options available, special weight has been given in this paper to desalination, water recycling and wastewater reuse. These technologies have reached advanced stages of development, and could supply significant amounts of water on local and regional scales in the foreseeable future.

An economic, environmental, and social analysis to determine whether the use of nonconventional water resources is justified is required in all water projects. It must be demonstrated that the expected benefits are sufficiently greater than the project cost (for example, of desalination, recirculation or water reuse) to warrant the required investment.

C.2. Desalination

C.2.1. Status

Desalination requires sources of clean brackish water or seawater (with content of dissolved salts of 1,000–35,000 mg per litre) and methods for disposing of brine solution. Desalination provides independence from external supply, and the operational certainty is high. Apart from its use as drinking water, desalinated water is also used in industry: for example, in thermal power plants. A wide range of proven systems are available.

Multi-stage flash distillation produces high-quality fresh water, with a salt concentration of 10 ppm. Present techniques use 200 kJ/litre, and reduction to less than 100 kJ/litre might be possible. *Multiple-effect* distillation is an old and efficient method, using evaporators and condensers in series. Steam from a boiler is used to first vaporise and then condense seawater. The evaporation and condensation phase changes require more energy than the liquid separation at ambient temperature occurring in the reverse osmosis process. *Reverse osmosis* (RO) uses semipermeable membranes, separating the smaller water molecules from salts and solids when a pressure difference, higher than atmospheric, is maintained across the membranes. The energy requirement depends directly on salt concentration, making RO most economical for brackish water (15 kJ/litre, as against 90 kJ/litre for seawater).

Electrodialysis relies on the ionisation of salts in solution, and uses membranes that are selectively permeable to anions or cations. Energy requirements range from 36 kJ/litre (brackish) to 150 kJ/litre (seawater). *Ion-exchange* methods use resins. Replacement costs make the process unattractive. *Freeze separation* techniques utilise the insolubility of salts in ice. The temperature of the saline water is gradually lowered until ice crystals are formed. Present energy needs are 100 kJ/litre, and are expected to be reduced by about 40% (Gleick, 1993; Buros, 2000).

One of the first successful solar stills was built in Las Salinas, Chile, in 1872. The first commercial large-scale desalination plant was constructed in the mid-1950s in Kuwait, (Rosenbom, 1998). During the 1980s Saudi Arabia spent US$10,000 million on desalination plants, providing 15% of potable water for its citizens, the rest coming from groundwater (Myers and Kent, 1998).

At the beginning of 1990 there were 70,000 desalination plants worldwide, mostly small, purifying 13.3 million m^3 a day (over 4,000 million m^3 a year). This is still only 0.1–0.2% of total world freshwater use. Typical plant capacity is 100,000 m^3 a day for seawater, and 20,000 m^3 a day for brackish water A major portion, about 70%, of global desalination capacity is installed in the Middle East (Saudi Arabia 26.8%, Kuwait 10.5%, United Arab Emirates 10%), and 12% is in the USA. Of the 150,000 million m^3 of water consumed annually by the Arab states, only 1% is desalinated. Israel desalinates 4 million m^3 a year in 33 units, meeting 0.2% of its total water consumption. More than one-half of the installations used RO technology, whereas the largest volumes of desalted water were produced by multi-stage flash distillation. 65% of the raw water sources were seawater, 27% brackish. The remainder is made up of river water and wastewater. Ships using on-board distillation technology are not included in these figures (Gleick, 1993; Nachmani, 1997).

At present (1998), more than 22 million m^3 a day are produced in more than 12,000 water desalination units (of a unit size >100 m^3 a day) around the world, and major installations are being constructed and planned. The largest capacity is within the Arab Gulf and the Red Sea areas. (IDA, 1998; Rosenbom, 1998).

A major desalination plant (250 million m^3 a year, costs about US$1,000 million: US$600–700 million for basic overheads and US$250 million over 15 years for operating costs. The resulting desalinated water would theoretically still cost US$0.25 per cubic metre, considerably more expensive than farmers currently pay anywhere.

The present disadvantages of desalination technology include high energy costs (the main cost item), the need for highly skilled technicians and the foreign exchange requirement for buying equipment. The unit price trend for desalination is encouraging. Prices quoted in 1985 were US$0.25–1.00 per cubic metre for brackish water, and US$1.30-8.00 for seawater. Commercial companies now offer to desalinate brackish water for 45 cents per cubic metre and seawater for 65 cents per cubic metre, but estimates are uncertain (Nachmani, 1997).

Desalination plants using wind and solar energy produced 1,600 m^3 a day in 1989, while installations producing 3,500 m^3 a day have been planned in Libya.

C.2.2. Trends

Desalination is already playing a part in the water supply of both arid and nonarid countries. Saudi Arabia alone accounts for 30% of world capacity, with the rest of the Middle East accounting for a comparable share. In Malta, desalination accounts for almost 50% of total water supply. Desalination is still expensive, although recent cost reductions combined with the rising cost of conventional resources makes it surprisingly competitive in some countries. Large-scale desalination must always be associated with low-cost energy, and use of solar energy may one day become competitive. Provided that energy is assured, desalinated water is a much more predictable and reliable resource than conventional supplies, avoiding many of the management problems associated with the latter (World Bank, 1994). However, an obvious limitation on the use of desalted seawater is the cost of distribution inland and uphill.

Since the start of large-scale desalting in the 1950s, capacity has grown with accelerating speed, in step with technological improvement and cost reduction. Over the last 20 years, the capacity has increased annually by close to one million m^3 a day. Of the 22.7 million m^3 a day being produced in 1998, 13.3 million came from seawater desalination plants. There are no signs that brackish water desalination will increase in the future, because of sinking groundwater levels and the depletion of historical aquifers (Wangnick, 1995).

Despite the potential savings from use of large plants, and a drop in the m^3 price of desalinated water to one-third of its level 25 years ago, desalinated water is not expected to solve agricultural needs in the near future. Desalting of local/regional inland saline waters will, however, make a contribution. Desalination will therefore probably continue to serve mainly domestic (and some industrial) requirements (Nachmani, 1997).

Existing desalination technologies should be further improved, particularly as regards the reduction of associated investment and operating costs. The theoretical minimum amount of energy required to remove salt from one litre of seawater is 2.8 kJ. The best plants now operating use nearly 30 times this amount, though improvements in technology could reduce this to about ten times the theoretical minimum. Other current technological improvement include membrane pretreatment.

Due to the increase of energy costs in recent years, the RO process is now emerging as the most energy- and cost-efficient desalting system. The trend is a steady shift toward RO facilities.

Greater energy efficiency is realised when RO systems use energy recovery devices on high-pressure brine reject streams. There is still a potential for further considerable increases of specific water production in dual-purpose systems: i.e., power and water (Altmann, 1998; Gleick, 1993).

The EC (EC, 1992) sees two approaches available for improving potential application: to develop competing technologies (novel membrane processes, electrochemical ion exchange, crystallisation) requiring less energy and to reduce energy costs by tapping renewables (fuel cells, solar power via photovoltaics).

Linkage with renewable energy sources such as solar energy is a possibility in regions like the Middle East. Israel's official view, for example, sees desalination as the only long-term remedy for water-poor areas (Nachmani, 1997). Market analysts still see the Middle East as the most interesting market, but it is expected that European countries bordering the Mediterranean will also increase their capacities considerably (Wangnick, 1995).

In the long run, desalination will be limited by the amount of energy needed and energy costs. Unless technical advances and energy costs improve substantially, desalination will be limited to water-poor and/or energy-rich regions, or cases where a high water price is acceptable, such as tourist resorts. It must be underlined, however, that even so, desalination may significantly relieve other conventional water sources from overexploitation in such regions (Torres Corral, 1998).

There are also studies which anticipate a fall of up to 50% in the electricity production cost over the next 20–30 years, due to improved technology and system reconfiguration, triggered by more open energy markets. Such energy price reductions would obviously make desalinated water more competitive for urban water supply (al-Alawi *et al.*, 1999).

C.3. Reuse and Recycling of Water

This section deals with reuse of water (utilisation for other than the original purpose) and recycling of water (utilisation for the original purpose).

C.3.1. Status

The greatest gains from reusing wastewater may come from reuse of municipal wastewater in agriculture. Today, 40 % of the world's food production comes from irrigated lands, although irrigated agriculture occupies only 17% of the world's total arable land.

The idea of applying wastewater to cropland is not new. 'Sewage farms' were operating in Edinburgh, Scotland, as early as 1650, and soon after were also established outside London, Manchester, and other English cities (Postel, 1992). In coastal areas of Turkey treated wastewater from the coastal settlements has long been reused to irrigate the green areas and parks (Sarikaya and Eroglu, 1993). Recycling of sewage for use in agriculture is widespread in Asia, with, however, some problems in protecting the public from pathogens (Rydzewski and bin Abdullah, 1992).

Unfortunately, the wastewater reuse practices in many developing countries are far from safe and sanitary. Large volumes of municipal wastewater get no treatment, and in water-scarce areas they are applied raw to edible crops. For example, raw flow from Santiago, Chile makes up almost the entire flow of the Rio Mapocho during the dry season (Postel, 1992). This water irrigates about 16,000 ha of vegetables grown for city markets; a practice linked to typhoid fever outbreaks in Santiago in the mid-1980s.

To avoid health problems, agricultural reuse of municipal wastewater requires that the wastewater is carefully treated and that treatment plants are properly operated and maintained. Cultural and aesthetic acceptance may be a problem. Artificial recharge of aquifers with adequately treated sewage effluent can be an effective way of conserving this water resource in a manner that is reassuring to the public. For example, the city of El Paso in the USA (Texas) injects highly treated wastewater into an aquifer, where it travels a few kilometres downstream for two to four years before it is recovered by the city's water supply wells. Thus-produced drinking water is expensive, of the order of US$0.70 a cubic metre.

Advanced treatment of wastewater involves a cost that can exceed US$0.10 a cubic metre. Pathogenic agents, notably parasitic worms, are completely removed by settling and stabilisation ponds at about 20% of the above cost (Rydzewski and bin Abdullah, 1992).

Large-scale reuse of wastewater requires major equipment and construction. Advantages include proven techniques, a wide range of suppliers, nonpotable applications and reduced problems with wastewater disposal. The year-round availability of considerable amounts of wastewater is another advantage. However, for use in irrigation during the summer, seasonal storage may be needed during winter. Evaporation losses from ponds then become a problem.

Usable treated wastewater ranges in quality from secondary (restricted agricultural use) to tertiary—including disinfection (unrestricted agricultural use). There is a tremendous asymmetry in volumes between agriculture and domestic uses: one large irrigated farm in the western United States consumes as much water as a town of 15,000 people produces wastewater (Rogers, 1992).

According to Postel (1992), about 500,000 ha of cropland in some 15 countries are now being irrigated with appropriately treated municipal wastewater. Although this amounts to only about 0.2% of the world's irrigated area, in water-scarce regions wastewater can make up an important share of agriculture's water supply. Including *untreated* sewage effluent, China has been irrigating 1.33 million ha (FAO, quoted in Abdel-Dayem (2000)).

Agricultural reuse of drainage water is also important in several arid and semi-arid countries. For example, by the end of the 1980s drainage water as a fraction of the irrigation water supplies in the Nile Delta in Egypt was of the order of 0.30 (Abu-Zeid and Abdel-Dayem, 1993). In the future, improvement of irrigation efficiency and better on-farm water management are expected to yield less drainage water. These improvements will, however, take place over a relatively long time during which drainage water will continue to be an important water resource. For example, Egypt reuses 5.2 km^3 a year of agricultural drainage water (1998–9). The volume is expected to increase to 8 km^3 after completion of large land reclamation projects (Abdel-Dayem, 2000).

Municipal wastewater reuse is also of great and growing interest for other purposes in arid and semi-arid regions and on smaller islands. Because conventional water sources are sometimes located far away, direct recycling of municipal wastewater has also been practised without the use of irrigation as an intermediary. The city of Windhoek, Namibia has successfully recycled large quantities of municipal water for more than 20 years without apparent problems. In the Netherlands polluted Rhine water is filtered through the riverbanks before being abstracted for urban water supply. Even coppermine tailing effluent has been diverted to grow crops in a barren valley in Chile (Rogers, 1992; Rydzewski and bin Abdullah, 1992). Investment amounts to some tens of millions of US$ for local municipal plants in communities over 100,000 residents. The total cost (treatment, storage and conveyance) per m^3 of secondary recycled water, projected for the year 2010, ranges from US$0.16 to US$0.42 (Nachmani, 1997).

Reuse/recycling of urban rainwater is another concept in development. Experimental systems using rainwater for toilet flushing, washing machines, garden watering and car washing show promising results, decreasing the freshwater demand locally by up to 30%. This is especially relevant for larger buildings such as offices and apartment blocks (EC, 1990).

Recycling of water is, for obvious reasons, simplest to achieve in industrial processes. In contrast to the water used in agriculture, only a small fraction of industrial water is actually consumed. Most of it is used for cooling and processing activities that may increase water temperature or pollute water but do not use it up. It should be recognised that the main incentive for industrial water recycling has come from pollution control regulations. Japan, the USA and the EU have achieved striking gains in the area of industrial water recycling. Given proper incentives, industries of many types have shown that they can reduce their water requirements by 40–80%, while at the same time protecting rivers, lakes and groundwater aquifers from pollution.

C.3.2. Trends

The World Bank (1994) has reviewed the potential for use of treated wastewater in irrigation. This report concluded that wastewater reuse can both augment water supply and have important environmental effects, provided its use is carefully controlled. Although in most countries total wastewater flows will remain small relative to total conventional water resources, they are rising rapidly and in water-short countries they may represent important long-term water supply for intensive irrigated agriculture. Large areas are already developed in several countries (e.g., Israel, Jordan and Saudi Arabia) and pilot projects are being established elsewhere. The costs of wastewater treatment are quoted by the World Bank as being US$0.12–0.40 per cubic metre depending on the technology employed, which compares favourably not only with desalination but also with more expensive interbasin water transfer schemes. The additional costs, which must be borne if water is to be used directly in irrigation, are in many cases not much more than would be required to meet regular environmental standards.

Israel is an example of a country that utilises treated effluents to a high degree in its water supply. There has been an increasing demand for the use of effluents in agriculture in Israel, because of growing demand for high-quality water in the urban and industrial sectors (Nachmani, 1997). Israel already recycles 65% of its municipal wastewater for use on farms, where wastewater accounts for 30% of all supply, a figure planned to rise to 80% by the year 2025. As a measure of the significance of Israel's efforts, it has been pointed out that if all countries were to recycle 65% of their domestic and municipal wastewater (as Israel does today), they could theoretically boost their agricultural output by 350 million tonnes of wheat. This is almost 20 % of all grain grown today (Avnimelech, 1993; Nachmani, 1997; Postel, 1996).

But recycling can never offer more than a partial solution to water problems. The urban sector consumes 20–25% of the global consumption, and only 60–70% of domestic sewage and 40% of industrial wastewater is recyclable. California, which uses about 400 million m^3 of recycled water annually, is the leading user of recycled water in the United States. Yet, recycling accounts for less than 1% of the state's conventional water supplies. This quantity might have been even lower if it were not for federal regulations requiring effluent discharged into rivers to undergo at least secondary treatment and the past availability of federal subsidies for the construction of treatment plants (Frederick, 1993). A research requirement with respect to wastewater reuse in agriculture is the setting of water quality standards.

Although water reuse and recycling for industrial and domestic uses appears attractive and a worthwhile investment for vegetable gardening, the general view today is that it is not likely to make a major contribution to irrigation of field crops. It takes the wastewater of 50 people to irrigate the land required to grow the food for one person (Rogers, 1992). However, more positive views are held by some. Myers, quoting Gleick, maintains that in California, within 25 years, use of reclaimed water could expand fivefold. There is potential for similar grandscale savings throughout the USA. A recent assessment of the potential for recycling water for industrial use in Azerbaijan estimates the overall potential in that country at 3 km^3, but points to the lack of new technologies as a bottleneck (Mamedzadeh, 1998).

C.4. Other Nonconventional Sources

C.4.1. Use of Low-quality Waters

If there is no restriction on cost, water of the worst quality can be made pure. In reality, lower quality has to be accepted, and one application of low-quality water is seawater agriculture. In the late 1970s researchers expected to see commercial seawater farming within 10 years. Twenty years later seawater agriculture is still at the prototype stage of commercial development. Several companies have established test farms of the salt-tolerant plants *Salicornia* (high content of oil and protein) or *Atriplex* in California, Mexico, Saudi Arabia, Egypt, Pakistan and India. However, none seem to have entered large-scale production. Farm sizes up to 250 hectares are mentioned (Glenn *et al.*, 1998).

Current opinion is that there will be a tendency to use more saline and sodic groundwater for irrigation, especially as more salt-tolerant varieties are developed. Soil condition has to be carefully monitored. Research experience has convinced scientists working in the field of the feasibility of seawater agriculture. In addition to forage production, oilseeds and vegetables, other applications are salt uptake for land reclamation, chemicals (gums, resins), pulp and fibre.

Whether the world ultimately turns to this alternative will depend on future food needs, economics and the extent to which freshwater ecosystems are withheld from further agricultural development (Rydzewski and bin Abdullah, 1992; Glenn et al., 1998).

C.4.2. Evaporation Control

To reduce evaporation losses from reservoirs, it is possible to cover the water surface with a thin layer of quick-spreading chemical compound. Long-chain organic molecules, such as hexadecanol, are often used. The film reduces evaporation, but is susceptible to wind break-up and dust.

C.4.3. Artificial groundwater recharge for storage

Surplus surface water may be stored underground, where evaporation losses are negligible. The selection of reservoirs requires careful geotechnical investigation. Successful use of such storage is reported from Morocco. Groundwater recharge is practised for other purposes also, such as infiltration of river water into alluvial banks and for use as raw water supply (forced feeding). Artificial recharge is also practised to correct overpumping from aquifers.

C.4.4. Weather modification

Weather modification techniques attempt to introduce a small disturbance to a weather system, providing more water for precipitation. Production of latent heat, for instance by providing artificial condensation nuclei, usually silver iodide at temperatures below –5°C, will cause convection, cooling of the air and subsequent precipitation. The air mass can also be cooled with dry ice (frozen CO_2). Ice crystals will grow faster than water droplets, and eventually fall out of the cloud.

But even if the technology is perfected and the economics are favourable, cloud seeding might face legal obstacles. Towns receiving more snow might object to higher snow-removal costs, downstream residents might suffer increasing spring flooding, and downwind communities might feel that they are being deprived of precipitation that otherwise would have fallen on them (Frederick, 1993).

Cloud seeding experiments have been carried out in several countries, notably Israel, reporting limited success, and the USA, where results are considered inconclusive. Anyway, the success of precipitation enhancement depends on more air moisture being brought into the area. There is also the risk that inducing rainfall in one area could reduce rainfall in other areas. Current evaluation methods do not permit very reliable assessments (Herschy and Fairbridge, 1998).

C.4.5. Water harvesting

Water harvesting (or rainwater harvesting) comprises a range of methods of collecting and concentrating runoff from various precipitation sources (rain, dew and fog), mainly for crop production, and mostly in arid and semi-arid areas (Reij *et al.*, 1988; Stenlund, 1991). Such methods often use small-scale walls, terraces and furrows in order to concentrate water from a collecting area into a receiving and storing area. The ratio between collecting and receiving areas may typically be 20:1. The diversion of runoff to cisterns is also an ancient technology to make better use of rainfall to supplement water supplies. Modern examples include Kenya and north-eastern Thailand, where use of 6000-litre jars for catching rainwater is widespread. Local communities in many countries use roof-water for cleaning, gardening and flushing toilets, and at the same time reducing urban floods (CSE, 1998).

Although water harvesting has been practised for a very long time, little research has been carried out, and the extent and importance for food production in quantitative terms is largely unknown. Dew and fog collecting devices such as earthenware pipes and stone cones were used in ancient times. Modern versions utilise netting-surfaced traps and polyethylene sheets, but the yields are modest: several litres a day for small installations (Prinz and Wolfer, 1998). Fog traps in Chile, Peru and South Africa produce approximately ten litres a day per m^2. The fog drip in Californian forests is estimated as up to 0.8 mm a night.

Water harvesting normally demands high labour input, but little technologically advanced equipment. It should be based as much as possible on indigenous techniques and local environmental knowledge. Some experts hold that parts of sub-Saharan Africa, characterised by high-intensity rainfall, crusted soils and low slopes, have a considerable potential for water harvesting (Reij *et al.*, 1988). Other experts warn against overoptimism in viewing it as a salvation for a hungry world.

C.4.6. Water imports

Various nonconventional alternatives have been suggested for importing water into water-scarce regions. They include pipeline or canal projects for delivering water from surplus river basins, importation of water by tug or tanker, or more exotic projects like icebergs towed from polar regions. Each of these alternatives carries high costs. Moreover, inter-basin canals and pipelines bear the risks attached to monopoly suppliers and political interference.

A feasibility study of the importing of water from Turkey to Israel by tugs dragging water in bags estimated the related costs at US$0.22 per cubic metre, although the entire concept has still to be proven feasible (World Bank, 1994). The alternative involving water transportation by conventional tankers is much more expensive, of the order of US$1.00 per cubic metre.

C.5. Assessment of Options

An assessment of the potential for nonconventional water resources should take into account the following factors: availability of basic physical conditions, resource cost (for instance, expressed as price per m^3 of water) both at the processing unit and for the end consumer, the stage of technological development (which influences the reliability of operation), short- and long-term perspectives, and the spatial scale of applications.

The necessary physical conditions for the various options are fairly obvious: for example, proximity to the ocean for seawater desalting, and access to wastewater for recycling or reuse. The abundance of seawater has made some optimists speak of desalting of seawater as ‘the ultimate solution’ to water scarcity. However, energy costs are still high, and transportation inland from the coasts will always be a problem. Desalination is today limited to water-poor and/or energy-rich regions. It must be underlined, however, that even so, desalination may significantly relieve other conventional water resources from overexploitation in such regions.

Economic assessment is important, but difficult. Large-scale economics, along with further technological improvement, may help technologies that today are very expensive to become competitive. A comparison made for the Middle East and North Africa indicates that reducing demand through efficiency and conservation costs US$0.05–0.50 per cubic mere, while treatment and reuse of wastewater for irrigation runs at 30–60 cents. By contrast, desalination of one m^3 of brackish water costs 45–70 cents, and desalination of seawater 100–150 cents. Development of marginal water sources comes in at 55–85 cents, a high cost partly because there are few good dam sites left (World Bank, 1995). It should be pointed out that more recent price quotations of large-scale seawater desalination are lower than given here.

Wastewater irrigation, based on up-to-date engineering technology and public health safeguards, is becoming a viable strategy for conserving water, developing agriculture and protecting the environment. Furthermore, wastewater reuse is often the least-cost solution for wastewater treatment and disposal. The consensus of the world public health community today is that the new microbial guidelines provide a safe and rational basis on which countries can build a sound programme of wastewater reuse, and reap the agricultural and environmental benefits (Shuval, 1990).

Although water reuse and recycling appears attractive and a worthwhile investment for many purposes, particularly for industrial use, the general view today is that it is not likely to make a major contribution to irrigating field crops. However, more positive views are held by some, who maintain that use of reclaimed wastewater could expand dramatically within a few decades. Israel is often quoted as an example, reusing some 65 % of its wastewater.

A range of other nonconventional options for supplying water has been briefly described above. Most experts believe that these shortcuts in water cycling could become important in the longer term. However, they do not seem to promise any quick relief to more widespread water scarcity.

C.6. Conclusions

As long as conventional water resources are available, these can be used to meet most sector requirements. As water supplies are more fully utilised, greater emphasis is typically placed on demand management to postpone the need for increasingly costly new investments. In such situations, desalination, water reuse and other nonconventional sources should also be fully explored, especially for water reallocation from low-value to high-value uses.

It should be recognised in this context that in many water-scarce countries irrigation accounts up to 80% of the total water use, so relatively small transfers from agriculture would substantially increase water availability to other sectors. Nonconventional water supplies play an increasingly important role in supporting such processes. Most societies will probably have to adopt a more ‘water-stingy’ future. Nonconventional water resources may help to bridge the transition period.

The most promising way forward in adding substantial nonconventional water resources to more traditional exploitation of natural surface water and groundwater seems to be with the techniques of desalination of seawater and reuse of wastewater. These options should be vigorously pursued. Other options should also be supported in circumstances where they are economically acceptable and environmentally sustainable.

This appendix has raised a number of issues concerning to the governance of water which have to be addressed, particularly in relation to the user of nonconventional water resources. The choices which will have to be made will quite often confront local benefits with larger-scale disadvantages, or vice versa.

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Appendix D: Enhancing Efficiency of Irrigation *by Nozibele Mjoli*

D.1. Introduction

Globally, agriculture consumes about 69% of all freshwater, while industry uses 24% and domestic use accounts for the remaining 7% (Christofidis, 1998). This indicates the importance of promoting more efficient water use in irrigation. Most countries are achieving some success in water conservation within the domestic sector. However, as this sector uses less water, savings here will not significantly alter the current picture.

High costs associated with the development of new water resources to meet the demand projected by 2025 makes it necessary to direct more attention to the improvement of the efficiency with which water is utilised in irrigation. Seckler *et al.* (1998) summarised the ways in which the productivity of irrigation water can be increased:

- increasing the productivity per unit of evapotranspiration,
- reducing flows of usable water to sinks and converting this into productive use,
- controlling salinity and pollution,
- re-allocating water from lower-valued to higher-valued crops.

Water productivity in irrigated areas can also be increased by genetic and agronomic improvements that could lead to increased yield per unit of water such as development of crop varieties with better tolerance for drought or saline conditions.

D.2. The Southern African Experience

The Southern African region has vast water resources, but the supply and demand for water is unevenly distributed. South Africa, Botswana and Namibia are threatened by chronic shortages of water within the near future and it is projected that demand for water in 2020 will exceed the total water resources available to South Africa. Swaziland, Malawi and Zimbabwe could face similar shortages by the year 2030. On the other hand, water availability in Angola, Mozambique, Tanzania and Zambia could exceed projected demands by a wide margin in the year 2020.

Regional co-operation in the efficient and equitable management of water resources within Southern Africa is crucial to ensuring economic and social development. More than 70% of water consumed in the region is used for irrigation. The demand for irrigation will continue to increase as efforts are made to increase food production for the growing population. Most countries within the region share watercourses, therefore all the member countries must co-operate in the promotion of efficient irrigation methods.

Economic co-operation among the counties of Southern Africa could provide an opportunity for the promotion of the concept of ‘virtual water’. This involves the trade of food rather than the transfer of water and allows countries with abundant supplies of water to export food to water-scarce countries. Currently, South Africa is using very extensively developed water to irrigate low-value crops such as maize; it could import maize from neighbouring countries with abundant water resources, and rather use its water to irrigate high-value crops.

Research supported by the Water Research Commission (Oosthuizen *et al.,* 1996) showed that farmers were willing to pay for information on more efficient irrigation methods, especially if the irrigation water was limited and the soil quality was poor. The study recommended that special attention be paid to making the information on efficient irrigation methods easily accessible to farmers. Irrigation water in South Africa is highly subsidised, therefore there are presently no incentives for farmers with easy access to water to use water-efficient irrigation methods. However, the proposed increase in the price of water which will be implemented as part of the New Water Act (1998) could change this.

D.3. Global Trends

The Israel-developed drip irrigation method (which is 95% efficient) has still found limited application worldwide (Beekman, 1998). Studies in South Africa showed that this method was only used by independent tomato farmers who have adopted this technology for management reasons (de Lange, 1994).

According to Keller *et al.* (1996), when farmers improve their irrigation efficiency they tend to extend the area irrigated, using the apparent water savings. This leads to a depletion of return flows: upstream users expand their irrigated area while users downstream suffer and thus the result is no real water saving. Seckler (1996) argued that demand management was valid in terms of local efficiency in the water basin as a whole. He proposed that the focus should be on 'real' not 'paper' water savings (he refers to this as 'wet' not 'dry' water savings).

Perry and Narayanamuthy (1998) reported that farmers generally aim to maximise returns based on resource availability. For example, when the water was scarce, farmers managed their irrigation systems to achieve maximum productivity under these conditions of scarcity.

Worldwide perverse subsidies encourage the use of water to grow crops that are worth less than the water itself. These subsidies encourage farmers to use inefficient irrigation methods.

D.4. Policy Issues

There is a need for policy reform in most countries to address the problem of inefficient use of water irrigation. A search through the literature shows that a high usage of water for irrigation is not caused by lack of more efficient methods but by a lack of incentives and policies that will promote better water management within the sector. There is also a lack of political will to change the status quo. Governments must be encouraged to reduce subsidies with a view to eventually phasing them out. It is also necessary to provide more accurate information on both the economic and social costs of subsidies.

D.5. Conclusion

The Commission can contribute to the promotion of efficient irrigation methods by making the general public aware of the economic and social costs associated with the government subsidies of wasteful irrigation methods. Claims of potential water savings at field level must be analysed in terms of their consequence to downstream users within the basin level. The challenges facing irrigated agriculture in water scarce countries cannot be solved by technology alone, but there is a need for a holistic approach that includes institutional, managerial and technological innovations. There is also a need for political commitment to review irrigation policies in order to promote more efficient irrigation practices.

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Appendix E: Sustainable Water Use in Practice *by Qian Ji*

The damage that water pollution causes is great, including damage to human health, reduction of agricultural and fisheries production (and even industrial production), the resulting unpleasant status of water bodies and the negative effects on recreation activities. Damage to the quality of water resources reduces the quantity of water available for use. Water pollution creates water scarcity in water-rich areas, and makes water scarcity more serious in areas where water is already short. Experiences and lessons from developed and developing countries all illustrate that prevention of pollution at source is much more cost effective than later remedial action.

Efficient use of water is one important way to prevent water pollution: less water demand means less water consumption and, consequently, less wastewater. Therefore, water saving should be an important strategy not only in water-scarce areas but also in areas that have plenty of water.

Cleaner production is an essential strategy for preventing pollution. Cleaner production involves utilising raw materials at the maximum rate while minimising pollution and harmful effects on the environment. It involves switching from toxic raw materials to nontoxic ones, modifying production processes, recycling water (and products manufactured using water) and improving management systems. The costs of implementing cleaner production options are generally recovered within three years. The careful use of chemical fertilisers and pesticides can reduce non-point source pollution (especially of nitrogen, phosphorous and organic toxins) and can be seen as cleaner agricultural production.

Wastewater treatment technology has been developing fast, driven by the recognition of pollution effects and the need to reduce costs over the past 50 years. Organic matters, heavy metals, inorganic nutrients (N, P) and traces synthetic organic compounds need to be removed at a rate that depends on the receiving water and its function. For discharge into lakes, estuaries, reservoirs and bays, where water flow is usually very weak, nutrient removal is required to avoid eutrophication. However, when the effluent is to be used for agricultural irrigation, nutrients in the water are welcome.

Natural purification systems, including land application and stabilisation ponds, are among the systems that can be used to purify wastewater by physical, chemical and biological means when the water, and nutrients, are to be used for agricultural purposes. Such systems should be used where the land area required is available and climate conditions are favourable.

The anaerobic biological process is a process that produces energy rather than consuming it. Compared with the aerobic biological process, it is more ecological and sustainable, and should be given higher regard. Systems combining anaerobic and aerobic biological processes can achieve high treatment rate at low cost, especially when applied to industrial wastewater containing refractory organic pollutants.

There are a number of techniques for raising oxygen transfer efficiency so as to increase the treatment efficiency of aerobic biological treatment processes. Combinations of high-efficiency biological processes with high-efficiency physical or chemical treatment processes also show promise. For example, the membrane bioreactor system can produce perfect effluent (free of bacteria and suspended particles) for reuse. However, the capital and operational costs are higher than for traditional treatment processes at the present time.

Beijing is located in an area of severe water scarcity. The water resources available are around 400 m^3 per capita, which is one-sixth of the average in China and 1/24 of the global average. There is a long-term plan to convey water from the south, but this will not be operational until 2010. In the interim, water saving, wastewater treatment and reuse, and rainwater harvesting measures are planned. Projecting current water usage, the city authorities estimate water supply and demand (in billion m^3 per year) as follows:

	2005	2010
Municipality	0.8–1.6	1.2–2.0
Urban Beijing	0.2–0.7	0.4–0.9

It is planned to save 0.3 billion m^3 of water per year by water-saving projects in the industrial, agricultural and domestic sectors by 2005 and 0.4 billion m^3 water per year by 2010. A series of wastewater treatment plants are to be built and reclaimed municipal wastewater reused for agricultural and urban green belt irrigation and industrial cooling. The quantity of reused effluent is expected to reach 0.4 billion m^3 per year in 2005 and 0.6 billion m^3 per year in 2010. It is estimated that rainwater harvesting will provide 0.05 billion m^3 per year in 2005 and 0.11 billion m^3 per year in 2010. The result is that the available water resources and predicted water demand can be almost balanced.

The differences for 2005 and 2010 are estimated (in billion m^3 per year) as

	2005	2010
Municipality	0.02–0.8	0.13–0.77
Urban Beijing	0.18–0.27	0.08–0.33

This plan is now being implemented and it is expected to expand the potential for water resource utilisation in Beijing in a sustainable way.

Appendix F: Adapting The Law of Water Management to Global Climate Change *by Joseph W. Dellapenna*

Abstract. Changing technologies and growing populations are already stressing legal regimes for the management of water resources. Today the planet is undergoing significant and alarming climate change. Climate change can be managed without disastrous consequences only through major reforms to water law regimes at the local, national, and international levels. At the local and national levels, water resources must be treated as public property rather than as common or private property. At the international level, water must be managed at the drainage basin level rather than according to national boundaries largely drawn without reference to rational water management criteria. The public nature of water precludes true markets as a significant management tool.

F.1. Introduction

There is little reason for doubt today that the planet is undergoing significant and even alarming climate change. After nearly a millennium of a slow but steady cooling trend, the twentieth century saw a dramatic upsurge in average global temperatures that steadily accelerated as the century wore on. These changes—whether the result of human agency or otherwise—inevitably impact on the patterns of precipitation around the world. Our responses, whatever they are, will have to be carefully planned in order to be sustainable rather than ultimately self-destructive as were many of the adaptations after the end of the Ice Ages.

Adaptations to global climate change will necessarily centre on the management of water resources. Fresh water is, after all, one of the most essential resources for human survival, let alone for human thriving. Because of the variability of water in quantity and quality, water, while found nearly everywhere, is often in the wrong place, or inadequate in amount, or too impure. Usable forms of water are a scarce and valuable commodity. Despite the limitations on the amount of usable water on the planet, there has been a nine-fold increase in per capita consumption of water worldwide since 1900, arising from changing technologies and changing personal habits (CSD, 1997; Postel, 1992; WWPRC, 1998). The burgeoning global population further increases demand, at least in societies that do not adjust their water consumption patterns to current realities (Dellapenna, 1997a).

How global climate change will impact on human societies, of course, will not be known for a century or more. Furthermore, the impact of climate change on water resources—as on temperature and other variables—will not be uniform. Thus, projecting the actual impact of climate change on the water available for human use even in large river basins remains a highly uncertain affair. For example, Stakhiv (1998) found that all but one of six projections of the impact of climate change on the flow of the Nile at Aswan predicted significant increases over the next century. Forecasted increases ranged from 6% to 137%, while one projection predicted a decline of 15%. He found similarly divergent projections for many rivers in the USA. With such uncertainty, one cannot recommend precise responses to projected climate change even on the level of a river basin, let alone for the entire planet. Nonetheless, certain generalisations are possible.

Global climate change is likely to add considerable stress onto existing legal regimes as water management systems struggle to adapt to the altered precipitation and flow patterns. Many existing legal regimes already feel stress as they struggle to respond to the increasing and changing demands for water without unduly destabilising existing expectations expressed in investments in water use facilities (Brans *et al.*, 1997; Postel, 1992). To the extent that global climate change reduces the supply of water in particular basins, competition between new or enlarged uses with existing uses can only intensify. If global climate change leads to an increase of water supplies in particular basins, it would at least temporarily ease stress on the water regime in that basin, although possibly creating a need for new legal responses to flooding or the like.

The question then is whether existing legal regimes can be modified at the local, national, and international level to better accommodate change without so unsettling water users as to provoke extensive, and perhaps violent, resistance. Too much legal response can produce as much social turmoil as inadequate legal response certainly will. In the light of such concerns and believing that existing engineering tools are fully adequate to manage the transition, Stakhiv argues for 'adaptive management' over what he terms an 'anticipatory strategy' (Lins and Stakhiv, 1998; Stakhiv, 1998). By this he means applying existing legal regimes with little or no change, counting on the flexibility already in such regimes to adapt gradually to the pressures induced by a combination of population growth, climate change, and technological innovation.

In my view, major changes are in order for existing legal regimes regardless of how significant climate change will be on hydraulic patterns. Population change and increasing demand per capita for consumptive uses of water have already rendered existing legal regimes obsolete if they are too inflexible. Factoring in the enormous increases for nonconsumptive uses—for the protection of environmental, ecological, and aesthetic values—the ability of existing legal regimes to adapt is open to serious question. Global climate change can only exacerbate these problems.

F.2. The National Dimension

Traditionally, different legal regimes have been used for dealing with water in defined surface water bodies, diffused surface water, groundwater, and weather modification. In addition, most societies have special rules relating to pollution, navigability, and to deal with ecological or environmental needs. For more than 50 years, experts in many water-related fields have consistently argued that such an approach is obsolete, that only the integrated management of the waters of an entire basin can deal adequately with the mix of uses and needs that compete for the resources (Linsley and Franzini, 1979; McDonald and Kay, 1988; Rice and White, 1990; Teclaff, 1967; UNESCO, 1991; UN, 1972, 1992a, 1992b; UN DESA, 1970). This conclusion represents the long-term trend of legal reform for all levels of water management regime (Dellapenna, 1994a, 1994c).

Economists and others advance private property and markets for global, national, or local environmental management processes in general and for problems of local, national, and international water management in particular, as automatic and nearly painless means for resolving problems of water allocation, distribution and preservation (Anderson and Leal, 1991; Anderson and Snyder, 1997; Dinar and Letey, 1991; Gibbons, 1986; Pearce and Turner, 1990; Saliba and Bush, 1987; Smith, 1988; Wolfrum, 1996). Markets, we are told, will introduce the necessary flexibility into water management while allowing the appropriate integration of water quality and water quantity issues into a single managerial model. They anticipate that the results will be accorded the strong presumption of validity that market-based allocations have always been accorded in capitalist societies, a presumption strengthened by the utter failure of classic socialism.

Actual markets for free-flowing water have always been extremely rare (Clyde. 1984; McCormick. 1994; Smith. 1988; Wahl, 1989). Such markets as there have been were for the transfer of water among small-scale similar users (Gray *et al.*, 1991; Roos-Collins, 1987; Thompson, 1993). Water markets have seldom accomplished significant changes in water usage (O'Brien, 1988; Pigram and Hooper, 1990). So-called markets that were used to bring about major changes in water usage have functioned only through rather heavy-handed state intervention (NRC, 1992). This pattern gives rise to an all too obvious question: If markets for water are so good, why are they so seldom used? Supporters of markets seldom address this question except to denigrate their critics as holding cultural, religious or even mystical prejudices about water. Water, however, is not like other resources.

F.2.1. The Public Nature of Water.

Water is not only one of our most essential resources, it has also long been considered to be the quintessential public good. A public good shares two qualities: indivisibility and publicness (Kaul *et al.*, 1999; Williams, 1995). Because a good is indivisible, one cannot simply divide it up and buy as much as one wants, and because it is public, it is impossible to keep others from accessing and enjoying the good so long as it is accessible and enjoyable by anyone. Public goods generally are free goods as far as markets are concerned because consumers cannot be excluded from enjoying the good. How much can one charge others for viewing the blue sky over one's property? The only costs, if any, associated with a public good are the costs of capture, transportation, and delivery, not a cost for the good itself.

This creates an important problem. If you invest in developing or improving a public good, others who invest or pay nothing will enjoy the benefits of your investment. You cannot exclude them from enjoying the good (Coase, 1974). Such 'free riders' seriously inhibit investment unless the government (or some other institution) is able to assure that all (or nearly all) pay for the benefits they receive. Consider air pollution. If many people voluntarily invest in cleaner running cars in order to protect the air we breathe, I will have cleaner air just as much as they will—even if I do not buy a cleaner running car. As more people realise this reality, fewer will voluntarily buy a cleaner running car. The market simply will not work; regulation will.

Economists are so accustomed to considering water a paradigm of a public good that they use water metaphors to discuss public goods generally: 'common pool resource', 'spill-over effects' and so on. Water is, of course, not indivisible and public in the strictest sense, and a few economists therefore have denied that it is a public good. But few things are strictly indivisible and public. What a culture treats as a public good, however, is not determined just by its physical characteristics, but also by its social and economic characteristics. When the costs to exclude others would be so high that it is impractical to exclude others from access to the good, or when there are other (perhaps cultural) reasons why a society will not exclude some of its members from access to the good, the good is treated as if it were a public good.

The social or economic characteristic that usually leads to treating something as a 'public good' is because transaction costs are so high that no market can function with even minimal effectiveness (Howe *et al.*, 1990; Schlag, 1989; Shelanski and Klein, 1995). When transaction costs make markets impossible yet a good is considered essential for the minimum wellbeing of members of society, the government undertakes to provide the good to all without direct charge. Such goods could be termed socially created public goods. Examples of socially created public goods include fire protection or public education. Water is just such a commodity. This is most obvious for the protection of instream flows. Less obvious, but no less true, is the public nature of water when withdrawn for private use. While it is easy enough for someone to own and manage water unilaterally in small amounts (for example, bottled water), a river is an ambient resource that can never be fully controlled or owned. Doing something to water on a large scale necessarily affects many others, making it difficult to procure the contractual assent of all significantly affected persons. Transaction costs on all but the smallest waterbodies quickly become prohibitive. This reality underlies the treating of water as a free good—a good available to all at no cost for the water itself, but only for the cost of capturing, transporting, and using the water.

Advocates of markets for allocating and managing water are demanding an end to the treatment of water as a free good. Water should not be a free good. Economic incentives including fees, taxes, and 'water banks' should be introduced for those who use water so they will more realistically evaluate the social consequences of their conduct (Wolfrum, 1996). But resort to economic incentives should not obscure the fact that water remains the prime example of a public good for which prices cannot be set in a marketplace. The reality of transaction costs should give even the most free-market oriented economist pause to consider whether true markets could function effectively for water resources (Howe *et al.*, 1990). Ultimately, true markets must remain marginal to the management of large quantities of water for numerous diverse users.

F.2.2. Patterns of Property in Water.

In thinking about 'property' in water, one is likely to have in mind a system of rules that define rights and duties pertaining to water in clear and certain terms, with law serving to protect these entitlements except insofar as changes occur through market transactions. A close model of such an arrangement is the American law of appropriative rights; similar systems are found in other countries as well (Dellapenna 1991, ch. 8). A rule that permits anyone to use a 'common pool resource' so long as the use is 'reasonable' hardly seems like a rule of property at all. Such a rule leaves courts to sort out conflicting claims of right to the common resource solely through a rule prohibiting tortious interference with other users (Dellapenna 1991, ch. 7). This amounts to a rule of common property, rather than a rule of private property. The American law of riparian rights is the prime example of such a legal regime; the Roman law of flowing water was similar. The third possibility is active public management of the common resource. The newest system of American law for the allocation of surface water, 'regulated riparianism,' corresponds to such a public ownership model; examples are found in a growing number of other countries as well (Dellapenna 1991, ch. 9).

While actual legal regimes often mix aspects of two or all three of these systems, analysing the 'pure types' makes clear the strengths and weaknesses of each approach (Harris, 1995). The correspondence of forms of water law to theoretical models enables us to predict with some certainty whether a form is adaptable to changing circumstances, or whether an entirely new form must be substituted when water demand or supply changes dramatically (Abrams, 1989a). Conclusions drawn from the American experience are largely translatable to other societies (Teclaff, 1985). Treating water as common property leads to tragic overexploitation as soon as water begins to be scarce. It seems increasingly clear that a common property system cannot survive (Hardin, 1968; Rose, 1991). Which system should be substituted, however, is less clear. As markets fail when one attempts to treat the right to use water as private property, private property systems like appropriative rights are experiencing increasing stress as demands surge and unappropriated water becomes rare. What works best (albeit imperfectly) is treating water as inherently public property for which basic allocation decisions must be made by public agencies.

Private-property market systems—the best mechanism for allocating resources when it works—fail if there are significant barriers to the functioning of a market (Coase, 1960). Markets do not work well for ambient resources like water because when one user attempts to convey a water right to another, particularly to one seeking to make a completely different use of the water, the problem of 'externalities' arises. Theoretically it might be possible for a properly structured market to cope with these concerns. In any hydrologically large and complex system, the difficulty and expense of structuring the necessary transactions (transaction costs) in fact prevent markets from developing unless the law chooses to disregard the externalities. The law, however, protects against such externalities. The law of appropriative rights consistently prohibits even an appropriator from changing the time, place, or manner of use if the change would produce a significant injury to another—even junior—appropriator (Gould 1988). Because of the protection of third-party rights, small-scale transfers of water rights among farmers or ranchers making roughly similar uses at similar locations are the only ones that regularly occur without heavy state intervention (NRC, 1992). As a result, treating water as private property tends to freeze patterns of use rather than to create a market.

The California Water Bank is often presented as an example of a successful market for water rights (Gray, 1994; Israel and Lund, 1995; O'Brien and Gunning, 1994; Wahl, 1994). The California Water Bank, however, was a most unusual market. For the 350 persons selling water rights, the state was the only buyer and for the 20 institutions buying water rights, the state was the only seller. California simply decreed that when the state buys or sells it need not concern itself with the effects of its transactions on third parties, even third parties holding valid water rights. The state underscored its offers to buy with implicit or explicit threats of condemnation, and the state sold at a standard price to buyers selected on the basis of criteria other than willingness to pay the price a market would set.

The California water bank system was simply a set of economic incentives to encourage other actors to comply with the state's policy choices that disregarded the effects of the state's actions on yet other actors whose claims, if recognised, would preclude accomplishment of the state's goals (Gray, 1994; Wahl, 1994). Flexibility was introduced to enable fundamental transformation of water uses within the state, and (incidentally) wealth was transferred from those who formerly used water to those who thereafter would use water—from small (and relatively poor) users to large (and relative rich) users (Easter and Hearne, 1995; Gray, 1994; Harbison, 1991; O'Brien and Gunning, 1994). In short, the California Water Bank is state management hiding behind the facade of a market—management that exacerbated social inequities.

F.2.3. The Public Property Option

Today, both eastern and western states in the United States are increasingly turning to active public management for water management (Abrams, 1989b, 1990; Dellapenna, 1991, ch. 9, 1997b). State governments have concluded that, despite the considerable difficulties in defining what are the proper public goals or in making the right decisions to achieve those goals, a transition to public property offers significant advantages over common and private property in terms of efficiency and distributive justice (Smith, 1988).

The core concept of public property in water as found in regulated riparian statutes is that all uses qualifying for a permit must be 'reasonable' (Dellapenna, 1991, Section 9.03(b)). The decision whether a proposed use is reasonable is made before investment in the use through issuance or denial of a permit. The administering agency includes an analysis of generalised interests widely diffused among the public that were only theoretically recognised in traditional riparian rights. Such a programme of public management might very well fall short of its goals. It undoubtedly could be improved by introducing economic incentives into the public management scheme (Cummings and Nercissiantz, 1992). One should not, however, confuse economic incentives with markets.

Administration of a public property system will be less than perfect. Whether such a permit process is superior to traditional riparian rights, appropriative rights, a pure market system (if such were possible) or some other regulatory system is hotly debated (Abrams, 1989b, 1990; Butler, 1986; Dellapenna, 1991, ch. 9; Dempsey, 1989; Freyfogle, 1986; Komesar, 1994; Rose, 1990; Trelease, 1974). Still, one cannot have much confidence in a private property/market system given the scarcity of actual empirical evidence that such a system can work and the transaction costs and externalities as barriers to the successful operation of a market for water rights.

F.3. The International Dimension

Water has another quality that, combined with its unusual importance, gives rise to a considerable risk of conflict between neighbouring communities: it is an ambient resource that largely ignores human boundaries. Some 264 river basins in the world—including all the larger rivers and home to about 40% of the world's population—are shared by more than one nation.

Cordial and co-operative neighbouring states have found it difficult to achieve acceptable arrangements for governing transboundary surface waters even in relatively humid regions (Garretson *et al.*, 1967; Teclaff, 1967; Zacklin and Caflisch, 1981). No wonder English derives the word 'rival' from the Latin word *rivalis,* meaning persons living on opposite banks of a river. Considerable evidence, however, suggests that co-operative solutions to water scarcity problems are more likely than prolonged conflict (Dellapenna, 1997a; Wolf, 1998). Historian Robert Collins summarised this same reality in a comment on the rivalries in the Nile basin: '[m]an will always need water; and in the end this may drive him to drink with his enemies' (Collins, 1990).

A well-developed body of international law addresses transboundary water problems. A growing body of international law also regulates the activities driving global climate change—mostly relating to activities that impact on the air and not directly on water (Churchill and Freestone, 1991; Goldenman, 1990; Jurgielwicz, 1996; Tarlock, 1991; UN, 1985, 1987). Water's status as a public good is central here as well (Kaul *et al.*, 1999; Merrett, 1997). As such, it usually cannot simply be parcelled out among competing users. The international community must co-operate to increase trust and eliminate water as a possible reason for going to war. International law (particularly customary international law) by itself cannot solve this problem, yet international law is an essential element of any solution.

F.3.1. Customary International Law

The international legal system lacks the specialised institutions—executive, legislative, and judicial—of modern national legal systems. Customary international law consists of practices of states undertaken out of a sense of legal obligation—a sense that the practice is required by law (D'Amato, 1971; Wolfke, 1993). Despite the obvious difficulties in determining the precise content of customary international law, the system has been remarkably successful.

This should hardly surprise. No form of international life could exist without shared norms that are largely self-effectuating in the conduct of that life (Henkin, 1979; Koh, 1997). Focusing exclusively on a relatively few highly dramatic instances of international legal failure creates an impression of entire ineffectiveness. Focusing on similar failures in national legal systems would lead to a similar reaction to those systems as well.

Successful areas of customary law have tended to be codified under UN auspices. A rich body of customary law regarding internationally shared fresh water has emerged, largely in the last century or so (Dellapenna, 1994b; ILA, 1966; McCaffrey, 1986; Schwebel, 1982). That law was codified in the UN Convention on the Law of Non-navigational Uses of International Watercourses, approved by the General Assembly on May 21, 1997, by a vote of 104–3 (UN, 1997). The Convention will come into effect if 35 states ratify it. The Convention already serves as the best statement of the customary international law (Danube River Case, 1997).

Under customary law, only riparian states—states across which, or along which, a river flows—have any legal right, absent agreement, to use the water of a surface water source (UN, 1997, Arts. 2(c), 4). Riparian states in turn are bound by the rule of 'equitable utilisation' (PC, 1929; UN, 1997, Art. 5). Equitable utilisation requires each state to use water in such a way as not to injure unreasonably other riparian states. Reliance on customary international law, however, to allocate surface or subsurface waters among states is too cumbersome and uncertain to satisfactorily resolve disputes over interstate sources of water and too primitive to solve the continuing management problems in a timely fashion (Benvenisti, 1996; Dellapenna, 1997a). Furthermore, relying upon an informal legal system alone to legitimate and limit claims to use shared water resources is inherently unstable.

Despite the evident failings of customary international law for managing internationally shared waters, no solution is possible without the creation of the necessary law. If a co-operative management system is to be put in place for internationally shared fresh waters, that system must entail some sort of a legal mechanism for the orderly investigation and resolution of disputes (Dellapenna, 1994b; Kliot *et al.*, 1998). Recurring bitter disputes (even overt military conflict) would inevitably continue if there is no effective alternative mechanism for resolving them. While stress on water resources itself creates real pressures for co-operative solutions to the problems confronting communities sharing the resource, the creation of a formal legal system is a necessary prerequisite to preventing conflict over water in any set of communities where water resources are under stress.

Co-operative management has taken many forms around the world, ranging from continuing consultations, to active co-operative management that remains in the hands of the participating states, to the creation of regional institutions capable of making and enforcing their decisions directly (Dellapenna, 1994b).

F.3.2. Groundwater Internationally

In contrast to the considerable state practice regarding the sharing of surface water sources, remarkably little state practice exists regarding the sharing of underground sources of water. Before the spread of vertical turbine pumps after World War Two, groundwater was a strictly local resource that could not be pumped in large enough volumes to affect users at any considerable distance away. With the newer technologies, and the exponential growth in the demand for water of the last several decades, groundwater has emerged as a critical transnational resource that has increasingly become the focus of disputes between nations, yet for which no consistent body of state practice has emerged. All too typical examples are the several treaties dealing with waters shared between the USA and Mexico: despite the growing importance of groundwater in the border regions, the treaties are silent on groundwater, with potentially disastrous results (Rodgers and Utton, 1985).

Most legal scholars have concluded that groundwater must be subject to the same rule of equitable utilisation as applies to surface sources (Barberis, 1991; Donauversinkung, 1931; Hayton and Utton, 1989; ILA, 1986; Rodgers and Utton, 1985; Teclaff and Utton, 1981). As the hydrologic, economic and engineering variables involved are the same for surface and subsurface water sources, the law must also be the same for both sources. Groundwater and surface water are not merely similar, they are in fact the same thing: simply water moving in differing stages of the hydrologic cycle. The UN Convention did not, however, include groundwaters except to the extent that they are tributary to an international watercourse (UN, 1997, Art. 1).

Foremost among the problems in applying equitable utilisation to an aquifer is the lack of firm knowledge of the characteristics of the resource (Tsur, 1995). We know quite a lot about surface water sources, having made accurate and ongoing measurements of these sources for a century or more, observing where surface water flows and what variables affect its behaviour. Groundwater, like surface waters, responds to gravity, seeking its lowest level, yet it does not flow as freely as surface waters do. The movement for groundwater is determined by the structure, porosity, and slope of the rocks or soil through which it seeps or percolates. With highly variable subsurface conditions, there is a great deal we do not know about the characteristics of particular aquifers. To acquire more knowledge is expensive. We are only able to make tentative allocations that informal processes such as customary regimes are ill adapted to revise or supplement.

F.3.3. Does Customary Law Provide a Suitable Mechanism for Responding to Global Climate Change?

The most significant developments not directly reflected in the customary rules relating to international waters are the emergence of environmental concerns, integrated management and sustainable development as central principles of international resource and environmental law (Carley, 1998; CSD, 1997; Kirkby *et al.*, 1995; Kiss and Shelton, 1991; Lammers, 1984; Magraw, 1991; Nollkaemper, 1993; Pearce *et al.*, 1990; Sand, 1992; Sands, 1994; Weiss, 1988). This new body of international environmental law is compatible with the rule of equitable utilisation. Yet equitable utilisation is sufficiently uncertain for some critics to argue that the principle focuses too strongly on the procedures for resolving disputes over water and presupposes that water is to be consumed even if consumption is not sustainable (Rahman 1995). The political processes within the International Law Commission and the Sixth Committee virtually assured that their results would be a compromise that elides serious problems where the various competing legal principles conflict most directly. If the law governing the allocation of internationally shared waters is to be a positive contribution to the solution of the looming global water crisis rather than an expression of obsolete formulas reflecting a vanished time of plentiful water, that law must be revised to incorporate these new concerns.

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A DAY IN THE LIFE OF MRS. EVE RYBODY.

Eve backed the car into the garage after returning from an evening meeting in the Fountaintown Water Council. The big issue tonight had been the hearing in the case of Worldwide Chemicals Ltd. The company's factory in nearby Upton was planning an increase in its product spectrum, and applied for an extension of its current permit to discharge effluents to the Winding River. Fountaintown Water Council, like all other councils along the river, was being heard in the case before the Winding River Catchment Board.

Eve found it difficult to be clearly for or against recommending a new permit. Worldwide Chemicals meant both stable employment and considerable tax incomes for the municipalities along the Winding River. On the other side was the river quality, which was a permanent worry for people. Young Rybody Jr, who took part in school-organised monitoring of the river had told his mother today that the BOD was slightly up on the previous week. (She had had to consult the web to learn more about biological oxygen demand.) Finally the council's advice had been to grant a licence, but it demanded that BAT was used to reduce emissions. (She would have to consult the web again!)

She rested for a while at the steering wheel, remembering that water issues had been the topic of conversation even at the dinner table. The Water and Sanitation bill for the last half-year had been paid, and her husband who was a master of detail—too much so, at times—had noted that the rate was lower than before. Whether this was caused by greater efficiency in the now-privatised water and sanitation service, or by the slight decrease in their water consumption because of their recently installed meter was not easy to tell. The average daily use per person in the family was down from 121 to 118 litres—or so the statistics in the bill said. Her husband believed that the water savings were entirely due to his using the new dirt-repellent car coating which required less frequent car washes. Wasn't it produced by Worldwide Chemicals, by the way?
Eve stepped out, locked the glistening car, and sighed to herself. Why didn't somebody invent a dirt-repellent coating for use on schoolboys?