3 Hydrology and Water Resources Management for Sustainable Development in the 21st Century

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"The human right to water is indispensable for leading a life in human dignity. It is a prerequisite for the realisation of other human rights."

United Nations (2002a)

3.1 INTRODUCTION

The previous chapter provided an overall quantification of the global nature and severity of the imbalance between water resource availability and demand. This chapter examines the contribution of hydrology and hydrologists to resolving water resource issues and provides more discussion on the policy-related aspects of hydrological science. The chapter focuses on the first part of the Hydrology 2020 Working Group mission statement that states "*We will explore how hydrological sciences can evolve into a discipline capable of meeting the world water challenges that are expected to prevail by 2020*". It centres on the role of the hydrological community in meeting current and future water resources challenges, and thus has more of a societal focus than a scientific one. It will examine the critical role of hydrological science and how we feel that the scientific community can take responsibility for addressing these challenges in the next decades. It is clear that science has a role to play as an independent authority and knowledge generator. The scientific community must therefore actively support and get involved in policy processes and the development of sound water resources management strategies.

Approaching water-related policy issues in a broader sense is a huge task and it would be pretentious to claim that we, in one short chapter, can cover more than a fraction of the entire complexity of water policy issues and societal needs. We have therefore decided to highlight a few specific areas in this chapter that are highly relevant to the scope and purpose of this book:

– presentation of what we perceive to be the most challenging water-related issues to be dealt with in the next decades, within the wider context of water's role in sustainable development (most of these are already key challenges to society today);
– discussion of how hydrological sciences can better support policy and decision-making processes in terms of reliable data, information and the development of new thinking and concepts;

– elaboration of how science can play a more direct and active role in policy-making processes and how the (hydrological) scientific community could be more influential in such processes through better understanding of how they function.

Based on this, we will also present a selection of recommendations for future and more policy-oriented actions that the hydrological community could take or advocate in various fora. More scientifically oriented recommendations are further explored in Chapter 7.

The literature in the field of water resources management and water policy is enormous and the topic is very multidisciplinary, encompassing natural sciences, economic sciences, social sciences, law and management. Much of the text has been developed by the chapter authors, but is based on material from more policy-oriented books, articles and United Nations and government publications where the original "reference" is often difficult to identify. We have therefore identified only a few selected references in the text itself where appropriate.

3.2 WATER RESOURCES ISSUES IN THE 21st CENTURY

3.2.1 Water as a natural resource and service provider

As discussed in Chapter 2, water is the bloodstream of the biosphere and is always on the move, making it unique compared to all other natural resources. Water is the very foundation for all biological life and it serves as the link between the biosphere, geosphere and the anthroposphere. In the light of past management failures, there is obviously still a need to better explain the critical role of water for all life support systems (see for instance Falkenmark & Rockström, 2004). Many also consider water related issues to be the greatest future human global crisis (see for instance Clarke, 2004 and Gleick, 2004). As such, the scientific community has a professional and moral responsibility to be actively involved in problem identification and solution.

Numerous sources within the United Nations have estimated that over 40% of the world's population will be living in regions where water resources may pose a limiting factor to development (water-scarce region) by 2025 (see United Nations, 2003, for information). Factors that will exacerbate this predicted water challenge include population growth and, in particular, unsustainable rates of usage of water resources and unfavourable climate conditions. While there are certainly great efforts toward achieving the Millennium Development Goals (MDGs) and the Johannesburg Programme of Implementation (JPoI) goals of halving the population without proper access to water and sanitation by the year 2015, an aggravating problem that hampers any efforts towards achieving these goals is water scarcity, be it due to physical or societal reasons, in many of the most poorly served countries. Water resources issues are not only important to address for water service provision alone. Water will, and does already, significantly affect many different sectors within society, as well as the environment, and in particular in developing countries with low management capabilities. In the worst cases, it threatens to disrupt economic development and creates possible reasons for domestic and even international conflicts. Hence the critical role of water as a natural resource cannot be disputed.

Water is also a fundamental component of ecosystems goods and services. Daly (1997) has defined ecosystem services as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life". Such goods can be clearly visible to people (timber, food), but sometimes more invisible (e.g. pollination by insects, photosynthesis). It is critical to explain how the benefits of such goods and services can be and should be incorporated in planning and development strategies. All natural resources can be measured as a stock of natural assets (see for instance Costanza & Daly, 1992; Hinterberger *et al.*, 1997). Non-renewable resources, or resources renewable only over geological timescales (thousands of years), have a fixed stock and extraction results directly in a lower total stock. On the other hand, renewable resources such as water have an inflow, growth to the stock, and, if the outflow and inflow are equal, then the resource use is sustainable. Nevertheless, although water is a renewable resource, its renewability can be adversely affected by other environmental problems, such as pollution. Resource management considerations may require temporarily lower inflows than outflows. However, such tampering with natural systems must be controlled; control is based upon the availability of data, information, knowledge and appropriate management structures.

We argue that there is still a fundamental lack of knowledge concerning water—both in relation to its critical function in the natural and human landscape, and also as the connector between different systems on earth. Science still has to improve its understanding of these issues and improve the capacity to explain such inter-relationships to policy makers. Hydrological science, in close cooperation with other scientific communities, has a critical role to play as water is a cross-cutting issue. Creating awareness and building capacity to design and enforce water governance is a crucial step for the scientific community to inject its knowledge and experience into the water resources management arena.

3.2.2 Increased pressure on water resources in an increasingly complex world

The complexity of water management will continue to increase and new comprehensive policies must be developed to cope with future challenges. Old management structures, and even political structures, will not have the capacity to respond to such changes. We will need to cope with the accelerated pace of change created by globalization, further population growth, urbanization and technological development, but also new regional and international cooperation mechanisms as well as changes in information and communication. The world is, and has always been changing, but we need new mindsets to deal with the dramatic increase in the pace and the magnitude of change, as many old management strategies have so obviously failed to solve the problems or meet new challenges. Science will be critical to this, and the ability of the scientific community to think in new ways and present new knowledge will be a fundamental issue to discuss further. The scientific community has a collective responsibility to support innovative, and sometimes even bold, thinking.

The human, economic and environmental costs as a result of decades of not-doing-enough, or being blind to the critical issues that we must address, is staggering. Over a billion people continue to lack access to safe drinking water and close to three billion lack adequate sanitation (see for instance figures in the United Nations Millennium Project, Task Force on Water and Sanitation, 2005). World Health Organisation figures show that every year 12 million people die from water-related diseases. More than 1.5 billion people live in river basins where so much water is already allocated that nothing more can be used without substantial ecosystem degradation (see for instance Smakhtin *et al.*, 2004). Land degradation continues, affecting the quality and quantity of water resources, in particular in semi-arid regions. Water use is expected to increase by as much as 40% by 2020 compared to 2000 (see for instance World Water Council, 2000). Water for food production is probably the most critical issue for future managers, with currently 852 million people undernourished worldwide, a number that has increased since 2000 (FAO, 2004) with 70 million added to the global population annually. To achieve global food security will require global water withdrawals to increase to 3800 m^3 $year^{-1}$ in 2025, and to 5600 m^3 $year^{-1}$ in 2050. This should be compared with the current worldwide water withdrawal of 3500–4000 m^3 $year^{-1}$ for all uses (see for instance Stockholm International Water Institute *et al.*, 2005a, and Sections 2.4 and 2.5). The estimated 40% increase in water use may therefore be a conservative figure.

Some may argue that the majority of such problems are confined to certain areas in developing countries. So why then should water issues be seen as global challenges or a global problem that we collectively have to deal with? The central argument is that lack of clean water, infrastructure and efficient water management strategies represent lost opportunities for economic and social development; this is apart from the fact that it causes extensive human suffering. Measures to reduce or prevent further stress on water resources and reverse the ongoing negative trend should be considered as a critical investment opportunity rather than just costs to society as it is often perceived and discussed (see for instance Stockholm International Water Institute *et al.*, 2005b). There are also ethical and moral aspects that need to be considered. The consequences of poverty—refugees, conflicts, and human suffering for example—have widespread direct consequences that we all have a responsibility to deal with, both in society as a whole, but also for each individual that faces them. This too adds to the complexity of water issues and water resources management.

3.2.3 Science, policy development and water resources management

Improving the management of water resources and efficiency in water use must be seen as a continuous process and it will be important to establish clear goals, targets and responsibilities, and both national and international frameworks in which these can continuously be reviewed and revised. Public sector policy makers will primarily have to take a proactive role in developing new policies, formulating implementation strategies, conducting follow-up studies, setting standards, enforcing legislation and establishing an enabling framework. This should be seen as part of “good governance” within the water sector.

Has the scientific community a specific role in all this? Some critical questions need to be discussed regarding the specific role of the scientific community. How can the scientific community take a more active role in solving current and future (foreseen or currently not foreseen) problems and transfer knowledge into decision making? Is part of the inability to solve water-related problems to be found within science itself—how it is conducted, what it focuses on and how knowledge is disseminated? Are we still lacking critical knowledge, or is it more an issue of communication—to ensure that what we already know is incorporated into policy—and decision making?

The fact that we have a more policy-oriented approach in this report possibly represents a change in mindset compared to our earlier colleagues in the Hydrology 2000 Working Group. In their report, policy issues did not have high visibility, although societal needs were, of course, discussed (see e.g. Kundzewicz *et al.*, 1987) and the role of hydrologists as active partners in policy making and in solving societal problems was not extensively highlighted. Such an attitude from the scientific community, to stand aside from more politically oriented processes, is not unique to hydrology. It is commonplace and perhaps suggests that a paradigm change is required in the way that science sees itself and its role in relation to society and its needs. The Hydrology 2020 Working Group argues that science must have, as one of its fundamental corner-stones, the role of serving global societal needs and that this should be seen as one of the *raisons d'être* for the scientific community.

There are of course a multitude of reasons to be pessimistic about the future. Many problems will get worse: for example, pollution will continue as will the degradation of ecosystems, and conflicts over water will increase. However, as a community, we must believe that things can also be done; that we can influence how the future will be shaped and that there are ways to mitigate problems and reverse negative trends. Human ingenuity will be at the centre stage and, if we have learnt anything from the past, it is that critical decisions, at the right time, can make a difference. Such critical decisions should be based on the best available knowledge, and it is one of the key roles of science to provide such knowledge.

3.3 WATER AND SOCIETAL CHALLENGES

There are many different and complex relationships between water issues and sustainable development that must be fully understood and better explained by the scientific community. The argument here is that all scientific disciplines, as principal knowledge generators and problem solvers, have a key role to play in solving fundamental societal and environmental challenges. In this section, we will highlight some of the most fundamental water and societal challenges as currently perceived in the international arena. There are indeed many others!

The role of hydrological science must increasingly be to address such fundamental challenges, to make sure that data and information are made available for water resources management and that "new thinking" is transferred to active policy and decision making. Special consideration, and support, must be provided to developing countries and to build national capacity in such countries. It is quite clear that no single group can deal with complex societal problems in isolation from other critical actors. Science is one actor, and a key one, that therefore needs to closely cooperate with other stakeholders.

The societal issues that we have identified are briefly discussed below. We have not attempted to be comprehensive, but to stimulate additional thought and discussion by highlighting key issues and identifying examples of how we think the hydrological community could strengthen its efforts to resolve such issues in the future.

3.3.1 Water and poverty

Poverty remains the most critical societal challenge in the 21st century. Poverty alleviation therefore needs to be integrated into all global policies for sustainable development in the coming decades. Of the world's 6 billion people, 2.8 billion live on less than US$2 a day, and 1.2 billion on less than US$1 a day (see for instance World Bank figures in numerous reports). Chronic hunger affects more than 800 million people (UNDP, 1994; FAO, 2004) and is among the starkest and most absolute manifestations of poverty. It is an absolute scandal that in this era of progress and plenty, 17% of the world's people are on the brink of starvation, and 11 children under five years of age die from malnutrition every minute (for further data, see the United Nations Millennium Project, Task Force on Water and Sanitation, 2005).

The Millennium Development Goals (MDGs) involve ambitions to increase welfare in developing countries, but alleviating hunger and sustaining income generation is intimately linked to increased water needs and increased waste production. This means that water issues must increasingly be incorporated in socio-economic planning and management processes and that the water management perspective has to be considerably broadened. Water problems are in many different ways closely associated with poverty and it is therefore too simplistic to say that the link is straightforward. However, it is quite clear that the availability of good quality water resources is a fundamental prerequisite for sustained human development.

When examining the relationship between people living in poverty and water, three dimensions of poverty stand out (from the United Nations Millennium Project, Task Force on Water and Sanitation, 2005). The first is the issue of human health. The health of poor people is disproportionately affected by contaminated water and poor sanitation services. This causes a negative spiral of ill-health and further impoverishment. The financial and personal "costs" are staggering. The second is the broader livelihood perspective. In many rural areas, the poor's livelihood systems are rooted in the natural world and therefore depend upon ecosystem health. Contamination of water resources (lakes, rivers and coastal areas) directly translates into less food, income and livelihood opportunities for the poor. Poor water management therefore inhibits development options, and thus represents lost development opportunities. However, ecosystem services are of course fundamental for all societies so ecosystem health is not only an issue for poor people! The third aspect that the Task Force highlights is that of vulnerability as a critical dimension of poverty. Poor people are particularly at risk from a range of environmental shocks, crises and changes. Frequent and severe natural disasters (cyclones, hurricanes, floods, landslides, droughts and tsunamis) as well as changes in rainfall patterns, shifting agricultural zones, and rising sea levels, often impact more directly on developing countries and the poor who live there are affected disproportionately. Damage caused by floods and droughts and other extreme climate events can undo many years of steady development and growth in a short period as demonstrated by the effect of hurricanes in Central America.

The following list describes some of the roles that hydrologists can take on to address the relationship between poverty and water.

Examples of the role of hydrologists:

– Access to water supply and sanitation as well as water resources development are critical to counteract poverty and enhance development. Water resources assessments, as well as the collection and dissemination of hydrological data, are critical areas in which the hydrological community needs to be more proactive.
– Water related indicators need to be further developed that are relevant to poverty reduction strategies and decision making. Such indicators should be a central part of existing and new monitoring systems.
– As the problems occur in developing countries, the development of low-cost technologies, as well as transfer of knowledge and capacity, are critical. International organizations, like the UN, already play an important role, and other

professional organizations, not just scientific organizations, must follow and support developing countries in general, and in particular, the scientists working within these countries. Hydrologists need to ensure the effective transfer of appropriate knowledge to scientists in developing countries.

– A better understanding of vulnerability, and the development of strategies to deal with vulnerability, and how vulnerability is linked to poverty and development, is probably the most important area where hydrology as a science can contribute. This includes better data and information, as well as new knowledge and policy advice, and increasing cooperation across disciplines. The hydrological community has a key role in providing the fundamental knowledge base and, in cooperation with other experts, the basic understanding that can form the platform for management strategies and appropriate infrastructure development.

3.3.2 Water and health issues

Over and above the impact of domestic water supplies and sanitation on human health, the management of water resources more generally has significant health impacts in terms of vector-borne diseases and water contamination. The health impact of poor quality water and sanitation services and water-related diseases on developing countries is devastating: at any given time, close to half the people in the developing world are suffering from one or more of the main diseases associated with inadequate provision of water and sanitation. The result is that more than half the hospital beds in the world are filled with people suffering from water-related diseases. Approximately 4 billion cases of diarrhoea occur each year causing 2.2 million deaths, mostly among children under five. Improved water provision, sanitation facilities and hygiene can reduce diarrhoeal diseases by between one-quarter and one-third (see for instance information and data in United Nations 2003, and the United Nations Millennium Project, Task Force on Water and Sanitation, 2005). Adequate water supply and sanitation, coupled with hygienic behaviour are thus fundamental to improved health. Addressing water and sanitation problems, and in particular the linkages to health issues, in developing countries is critical to reducing morbidity and mortality and therefore, a “must do” if development is to succeed.

Examples of the role of hydrologists:

– Improved information and appropriate monitoring networks that specifically focus on the availability, quality and sustainability of surface water and groundwater for water supply and sanitation purposes should be developed and made available. The hydrological community needs to push for such development.

– Understanding of water flow pathways and residence times in soil water and groundwater should be utilized to minimize pollution of water resources from sanitation facilities.

– Greater efforts should be made to improve understanding of the role of water in pathogen transmission and to communicate the outcomes to water users.

– Hydrologists should campaign for more support from governments, professional hydrological societies and international organizations for the scientific capacity building needed in developing countries in order to address the critical water–health interlinkages.

3.3.3 Water and wider socio-economic development issues

Improved access to domestic water supply and sanitation as well as improved water resources management brings considerable economic benefits, both at the household level but also to society at large. Socially and environmentally responsible investments in water infrastructure, such as dams and irrigation schemes, can act as a catalyst for local and regional development. Figures show that, depending on the region and technologies used, economic benefits ranging from US$3–34 per US$ invested would be gained in health, agricultural and industrial sectors if the MDG water and sanitation targets are reached (for further information on macro-economic indicators, see for instance Stockholm International Water Institute *et al.*, 2005b and references therein).

Not understanding water resource management challenges, or not having the capacity to cope with such challenges, can cause serious short- and long-term consequences. An example is coping with extreme events. Although the impacts of extreme events often start with direct damage, for instance to infrastructure and crops, they will often be amplified throughout many areas of economic activity leading to widespread macroeconomic, financial and political consequences. Flooding alone cost the world economy US$27.3 billion in 2002 (Munich Re, 2002). In Kenya, for example, the World Bank estimated that the combined cost of flooding during the El Niño event of 1997/98 was some US$2.39 billion through the loss of infrastructure such as roads, pipelines and water treatment plants. The 1998–2000 drought similarly is estimated to have cost about US$2.41 billion through crop and livestock loss and reduced hydropower and industrial production. The total cost of losses related to these water resource challenges was about US$4.8 billion, approximately 22% of Kenya’s GDP during that period, demonstrating the potential economic benefits of improved water management.

Water supply and sanitation is not only a social issue but fundamental for all development. The lack of such systems causes widespread poor health, and thus inhibits both social and economic development in general. Water resources management, as well as water supply and sanitation issues, must therefore be integrated into all national planning strategies. The main conclusion of the UN’s Millennium Project Task Force on Water and Sanitation (2005) was that the MDGs as a whole will not be met unless “there is deliberate planning and investment in water resources management and infrastructure”.

Examples of the role of hydrologists:

– Water resources assessments need to increasingly include economic indicators and highlight the role of water management for economic development, and the macro-economic consequences of poor investments. The hydrological community needs to provide data and information that is useful for such purposes.

– Training of hydrologists from developing countries to better understand the linkages between water resources issues, the provision of water supply and sanitation, and macro-economic issues, is needed. Professional hydrological societies should support such efforts.

3.3.4 Water, land management and food production

The water required to produce more food is probably, from a water perspective, the most challenging issue to deal with in the coming decades. If we are to be serious in our efforts to reduce the hunger among the approximately 850 million people that FAO (2004) currently estimates are undernourished, and if we are to feed the additional three billion that the world's population will increase by in the next two generations, enormous efforts must be made by scientists, engineers, managers, politicians, farmers and other actors to increase food production, while ensuring that water is still available for other sectors and securing environmental sustainability.

The current best estimate is that agriculture accounts for about 70% of the annual withdrawal of renewable freshwater resources at a global scale (Cosgrove & Rijsberman, 2000). Regional variations are very large, the figure mostly being higher in semi-arid areas where agriculture still remains the primary activity. Another problem is that this figure only includes irrigated agriculture; 80% of all agricultural land is used for rainfed agriculture, producing 60–70% of food. Rainfed agriculture dominates where there is sufficient rainfall for crop production, but also where there is a lack of infrastructure, such as in sub-Saharan Africa. In such places, limited infrastructure development would allow for some irrigation during dry periods which could dramatically increase crop production (Falkenmark & Rockström, 2004). Such infrastructure would however require accurate meteorological and hydrological data and good forecasting systems, something that is absent in many developing countries.

However, agriculture is not only about food production; it is also fundamental for local livelihoods and economic development at all scales. Agriculture is, and will continue to be for a long time, a key sector for economic development in low-income countries. Limited and unreliable access to water is a determining factor in agricultural productivity in many regions, a problem that is rooted in rainfall variability. A critical issue for the future is that this is also likely to increase with climate change. Retaining as much water as possible for food production is therefore a question of basic survival for many people. In arid areas, a substantial amount of rainwater is lost through surface runoff and evaporation. It is critical that managers and planners better understand the processes associated with low rainfalls, high variability in precipitation and high intensity rainfall and associated soil crusting and water erosion.

Examples of the role of hydrologists:

– Systems should be developed to calculate and clearly present sustainable water yields from surface and groundwater resources and which also consider the high variability of many water sources.
– More research should focus on soil–water relationships, and support the development of methods to maximize soil water resources.
– Prediction of the responses of rainfall and soil moisture to climate variability and change should be improved.
– Virtual water flows should be quantified at global and national scales, and their effect on water resources identified under different trade regimes.
– The engagement of hydrologists in decision making related to agricultural polices and land management should increase, at global, national and local scales.

3.3.5 Water and environmental sustainability

The efficient use of natural resources is a key element for sustainable development. The exponential increase in the use of renewable and non-renewable natural resources since the 19th and 20th centuries has resulted in the development of many theories concerning resource scarcity, resource management and resource efficiency. Long before the term “Sustainable Development” became commonplace in policy making, policy makers were making trade-offs between resource use and resource conservation. The linkages between resource efficiency, environmental protection and, increasingly, social issues are dynamic and continuously monitored and updated by actors in both the public and private sector. It is encouraging that such links have gained in importance since the United Nations Conference on Environment and Development (UNCED) 1992 meeting, through Agenda 21, the Rio Principles (United Nations, 1992) and various ensuing international policy documents, not least the World Summit on Sustainable Development in Johannesburg, 2002. Apart from such general policy documents, numerous resource efficiency concepts have emerged over the past decade, such as carrying capacity, population dynamics, maximum yield, factor 10, ecological footprints and eco-space, to support policy development on resources management. Resource efficiency is therefore increasingly considered a fundamental part of environmental, economic and social development.

Water can in many ways be considered as the most fundamental of all environmental resources. It is the ultimate resource for securing the viability and long-term sustainability of the world’s ecosystems. Several threats to overall ecosystem health, and consequently to the ability of ecosystems to provide the services upon which human life depends, are particularly relevant to water resources. The United Nations Millennium Project Task Force on Water and Sanitation (2005) identifies a wide range of relevant issues that, from a water perspective, need further attention in the coming decades. These include climate change and the resulting alterations in weather patterns, water distribution, and fisheries; loss of species diversity and genetic diversity within species; the degradation of global fisheries, marine ecosystems and coastal habitats; degrading freshwater ecosystems due to less or altered runoff, silting, fertilizers, pollution, and invasive species; and degrading drylands due to desertification, falling water tables and over-irrigation. The Millennium Ecosystem Assessment (2005) is an equally important document that can serve as a basis for further research and policy development. As all human activities impact on water resources, there is a fundamental need to understand the complexities and interlinkages between water, the environment and human activities.

Examples of the role of hydrologists:

- Improved ability to predict the effect of climate variability and change on water resources (spatial and temporal), extreme events and aquatic ecosystems is required.
- Appropriate indicators for quantifying human impacts on water resources and the ecosystems services they provide need to be developed and used to actively influence policy and decision makers.
- An improved understanding of the causes and interactions of both natural and human-induced water quality issues is needed.
- More research is required to understand the role of water flow variability in ecosystems, improving the capability for providing worldwide calculations of necessary environmental flows.

3.3.6 Water and the urban–rural nexus

The second half of the 20th century witnessed an exponential increase in the urbanization of the world's population and the movement of people from rural to urban areas is predicted to increase in the coming decades. From 1950 to 2000 the percentage of the world's population living in urban areas increased from 30% to 47% and this figure is predicted to rise to 61% by 2030. Although the current level of urbanization is currently considerably lower in developing countries (42% compared to 74% of the population in developed countries), urban populations are increasing rapidly (2.7% per year compared to 0.5% per year in developed countries) (United Nations, 2001).

This trend has the potential to create and exacerbate tensions between urban and rural areas relating to water resource issues. Increasing urban populations place demands on rural areas to provide a number of water-related services that are essential for the functioning of the urban economy. Such services include: the availability of a clean water supply; water for waste disposal; cheap, plentiful food (which often requires water for its production through irrigation of crops or watering of livestock); freedom from upstream flooding and sediment deposition and in some cases provision of electricity from upstream hydropower development. The reliance of urban populations on water services arising from rural areas was demonstrated by the recent finding that around one third (33 out of 105) of the world's largest cities obtain a significant proportion of their drinking water from protected basins (Dudley & Stolton, 2003). Equitable water allocation is required to resolve the water demands of urban and rural populations but decision making is often affected by political considerations to satisfy the increasingly urban-based electorates.

Examples of the role of hydrologists:

– The values of water in urban and rural settings and the interlinkages between them need to be assessed by hydrologists and communicated to populations and decision makers.

– Hydrologists can provide decision makers with information concerning the availability of water of particular qualities in rural and urban settings as a basis for scientific-based water allocation. Through modelling, hydrologists can also simulate the effects of different water allocation decisions and the impact of climate change on water resource availability. However at the same time the uncertainties surrounding hydrological information and predictions should also be communicated.

– In collaboration with other disciplines, hydrologists can develop and promote more efficient use of water resources in rural and urban settings. For example, water sensitive urban design, rainwater storage tanks and water recycling can reduce the water demands of urban areas. Action can also be taken to reconcile the water demands of urban and rural areas, particularly through closing the sanitation loop. Hydrologists can contribute to developing guidelines for the safe re-use of urban wastewater as a source of water and nutrients to agriculture.

3.3.7 Water pollution and water quality

Although water pollution issues are commonly regarded as an environmental problem, they should equally be seen as "hydrocide" (Lundqvist, 1998)—a human health issue and a threat to long-term sustainable development. Water pollution is a vast and

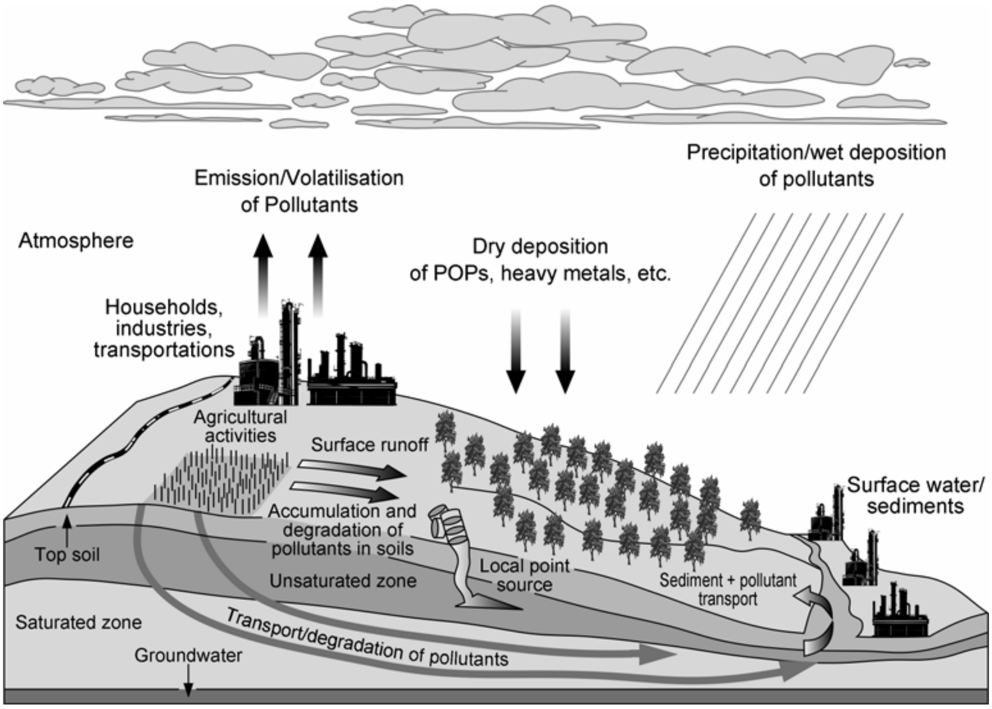

Fig. 3.1 *Sources and pathways of anthropogenic water pollution (modified from Georg Teutsch, personal communication).*

well-researched topic so only a few examples of its causes and effects are discussed briefly here. Water pollution can arise from natural as well as anthropogenic sources (illustrated in Fig. 3.1), although frequently natural and human processes interact to exacerbate the problems. A tragic example of this is the waterborne arsenic poisoning that has been occurring in Bangladesh and West Bengal, India, since the mid-1990s. An estimated 30 million people in Bangladesh and 2 million people in West Bengal are at risk of cancers caused by arsenic poisoning. The outbreak is attributed to the consumption of groundwater containing naturally high concentrations of arsenic, accessed from shallow tubewells that international aid agencies encouraged the population to dig in order to avoid surface water supplies contaminated with faecal pathogens.

Although the enforcement of stricter environmental legislation since the 1960s has reduced water pollution in developed countries from point sources (industrial and wastewater effluents), point source water pollution remains problematic in developing countries. This has been exacerbated partly in recent years by the export of water pollution from developed countries through the increasing tendency of global corporations to locate production facilities in developing countries where laws to curb water pollution are less rigorously enforced. In the past decade attention has shifted to nonpoint source or diffuse water pollution which now accounts for the majority of water pollution in more developed regions. Diffuse water pollution normally occurs due to poor land use and management or deposited atmospheric pollutants, resulting in the release of contaminants such as potentially toxic metals, sediment, nitrates, phosphates, oils and other organic compounds. Not only does diffuse water pollution impact directly on water resources and aquatic ecosystems but it also has negative impacts on other economic activities. For example, the costs of freshwater eutrophication in England and Wales, which largely results from diffuse water pollution, were estimated to be US$105–160 million per year in damages (including US$4–16 million in lost tourism revenue) and US$77 million per year in policy responses (Pretty *et al.*, 2003). Managing diffuse pollution is extremely challenging because it arises from complex interactions of soil, atmospheric, hydrological, biotic and human processes. Unlike point source water pollution there are no quick fixes for diffuse water pollution: effective solutions often require reductions in the inputs of manmade chemicals or developing less polluting alternatives and also changing human behaviour and land management practices. Best Management Practices (BMPs)—long-term, low-cost and more sustainable "soft engineering" methods—such as buffer strips, wetlands and ponds, that harness biological processes to treat polluted water, are increasingly promoted in developed and developing countries to alleviate diffuse water pollution.

A water pollution threat that has emerged in the latter half of the 20th century is the introduction into the environment of manufactured chemicals whose long-term effects on human health and ecosystems were, or remain unknown, for example endocrine-disrupting substances (particularly oestrogenic steroids deriving from human contraceptive pills). Persistent organic pollutants (POPs) that include substances such as PCBs, DDT and dioxin and are derived from pesticides, other agrochemicals, industrial chemicals and their byproducts can accumulate in living organisms to levels harmful to both human and environmental health. Because the production and use of POPs confers economic advantages, for example in pest control, international agreements, such as the Stockholm Convention on POPs, are required to control production and use.

Examples of the role of hydrologists:

- Professional societies and individual hydrologists should campaign for cleaner alternatives and reduced usage of polluting substances.
- Quantifying the extent and severity of diffuse pollution is more difficult than for point source pollution because pollution events are often associated with unpredictable storm events. Hence there is a need for hydrologists to devise new water quality monitoring programmes and develop indicators for assessing changes in diffuse pollution.
- An understanding of hydrological flowpaths and surface-groundwater interactions is essential for assessing the pollution threats of human activities and devising measures to reduce diffuse water pollution (e.g. land-use zoning, re-location of polluting activities).

3.3.8 Water and human rights

The Right to Water is described by the United Nations (2002a) as "indispensable for leading a life in human dignity" and "a prerequisite for the realization of other human rights". Within its General Comment 15, the Committee on Economic, Social and

Cultural Rights of the United Nations Economic and Social Council stated that "the human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses". While the right to water has been implicit in the rights to health, housing, food, life, and dignity already enshrined in other international conventions, General Comment 15 is the first to focus explicitly on the right to water and the responsibilities that governments have in delivering clean water and adequate sanitation services to all. Given that water has been identified as a human right, some are now questioning whether paying for water, a human right, is ethically acceptable.

Examples of the role of hydrologists:

- Hydrologists need to recognize the ethical dimensions of their work and respect social, cultural and religious differences.
- Scientific societies need to make a clear stand on their views of "water as a human right".

3.3.9 Water and security: the politics of water

Throughout the world there are about 260 shared basins spanning national boundaries (Fig. 3.2). Historically, the first manifestation of problems arising from shared rivers was the delimitation of borders between countries. Then, from the 1600s to the early 20th century, questions relating to the freedom of navigation arose on many large rivers. Today, transboundary water issues are more complex for a number of reasons: water resources are diminishing in both quantity and quality, there are greater pressures for political control over water resources, larger infrastructure development (in particular dams) impact on downstream water users, and there are increasing concerns about the environmental aspects of water resource use. Thus, competition between countries and within countries among different users is probably increasing.

Fig. 3.2 *World map of shared basins that span international boundaries (after Wolf, 1999).*

The linkages between water and conflicts are not always easy to describe. International laws, which could control them, are poorly developed, contradictory, and mostly unenforceable. The majority of treaties and settlements of these conflicts are made within the framework of agreements between neighbouring countries to cooperate in managing transboundary water resources.

On a national level, new water legislation and the development of integrated water resources management plans will be necessary to tackle increasing competition between different sectors and between urban and rural areas. Although “efficiency” of water use is an important consideration, such policies must also be equitable.

The impending water crisis should not be viewed as a direct threat everywhere on Earth but rather as a vulnerable situation that necessitates other approaches to security than those commonly used. It is therefore important to increase understanding of the political linkages between states within an international river basin context. UNESCO’s International Hydrological Programme has recently initiated two projects to help address the challenges of shared water resources management in river basins (PC-CP, “From Potential Conflicts to Cooperation Potential”) and aquifers (ISARM, Internationally-Shared Aquifer Resources Management).

Examples of the role of hydrologists:

– Trust is built from common knowledge and sharing information. The hydrological community should strive to enhance transboundary cooperation and push for the implementation of policies that make hydrological data and information openly accessible to all potential users.
– The hydrological community should push for the development of joint monitoring and information sharing networks in international river basins and the establishment of joint scientific mechanisms that meet regularly to share information and experiences.
– The hydrological community should not let itself be politicised but be prepared to take a clear independent stance in regions where there are transboundary conflicts over water resources.

3.4 LINKING SCIENCE, WATER RESOURCES MANAGEMENT AND POLICY PROCESSES

Although an entire section on policy may initially appear out of place in a book focussing on hydrology, interaction with policy and policy makers is increasingly important for hydrologists and the science of hydrology and will only become more critical in the future. Influencing policy is one of the main means by which the outputs of hydrological research can help address the water challenges faced by society and discussed in Section 3.3. Furthermore, policy makers are a large source of funding for hydrological research and thus hydrologists need to enter into a dialogue with policy makers to ensure that the most relevant and scientifically sound research is funded. In order to interact effectively with policy and policy makers, hydrologists need to have a better appreciation of how policy operates at different scales. These aspects are briefly dealt with in the different sections below and some suggestions are also provided of how hydrologists can increase their interaction with policy and policy makers.

The past 25 years have brought about large changes in environmental policies throughout the world as environmental concerns have moved to the forefront of public concern. More and increasingly detailed environmental laws have been developed supported by strong enforcement mechanisms to ensure compliance. Support for such command and control policies has not been universal, and some groups even argue that they are not the best way to provide increased environmental protection. Policy makers have increasingly looked for alternatives to regulation, often based on market solutions and consumer focused programmes. Social and economic policies have also increased in importance, where governments use stakeholder-based policy-making processes and incentives rather than punishments.

There is a tendency to focus on "universally agreed principles" in water resources management and policy development. The concept of "Integrated Water Resources Management" is one such example. Though not necessarily wrong, it is important to recognize the large local, national and regional differences that must be considered in the formulation of water management strategies. These range from physical (climate, soil, topography) to socio-economic (urban or rural, developed or developing, industrialized or agricultural economy), to political (decentralized or centralized, political system), to cultural and religious. This highlights the necessity for interdisciplinarity when water management strategies are developed.

3.4.1 The global policy perspective

Water experts and professionals, including the scientific community, have so far not been successful enough in their efforts to place water issues sufficiently high on all relevant political agendas. The emphasis has been too much on environmental and social aspects, while the more financial aspects of water management have not been given enough consideration.

Water has had a prominent role within many United Nations processes, such as the meetings of the Commission on Sustainable Development (CSD) (including UNCED and WSSD) or the World Water Forums. However, what is central is to get water issues high on the agendas that in reality have the most profound impact on economic and social development at both international and national levels; many of these are currently found outside of the UN or water-related processes. It is worthwhile to make comparisons with how the climate change issue has been addressed at the international policy level. It has been incorporated into national development policies and, although not perfect, a set of financial tools has been developed to deal with the issue in a way that markets can handle (such as tradable permits and clean development mechanisms). The main reason for this is probably because, to a much higher degree than water issues, climate change has been addressed from a "financial risk" perspective, as well as from more traditional socio-economic and environmental perspectives.

However, it may be that this negative picture of water in the international policy arena has started to change. At the G8 meeting in Evian, France, in May 2003, water issues were given a (comparatively) high role. Furthermore, the World Economic Forum has adopted a water action programme, the World Business Council for Sustainable Development (WBCSD) has specific water initiatives and the financial sector has increased its interest in water issues, through the UNEP-Finance Initiative for example. This represents a major change, as it involves key actors controlling both the political as well as the financial power in the world.

But will this interest turn into concrete action? May be we do not need additional high-level political commitment, but rather on-the-ground actions. Despite common knowledge of the role of water as the central resource for human development and prosperity, often reiterated at many international conferences held during the last decade, water management issues continue to be marginalized in key development discussions and strategies that are essential for on-the-ground activities. Public awareness is not high enough to provoke political pressure to act.

At the Second World Water Forum in The Hague, 2000, it was stated as a key recommendation that water is "everybody's business". What needs to be added is that cooperation is everybody's responsibility in order to solve the problems. So, what is the business of the scientific community in solving current and emerging water issues? May be the barrier here is more about cooperation and communication rather than "finding new knowledge". Although it has recently been recognized that the complex problems associated with water resource systems demand interdisciplinary research, collaboration and funding, too often science continues to focus on small-scale investigations within narrow areas of expertise, without clear linkages to a wider picture.

The more recent "goal setting" by the international community is the formulation of the eight Millennium Development Goals (MDGs). Although most of these goals had already been developed in different international processes, the "new thinking" was to combine these goals within one framework, thus showing the interlinkages among them and that it is difficult to reach one goal without caring about the others. The MDGs stem from the United Nations Millennium Development Summit in New York, 2000, when world leaders agreed to set timetables and goals for combating poverty, hunger, disease, illiteracy, environmental degradation and gender inequality. The MDGs are now the centrepiece of the global development agenda and they represent the political commitment to handle the daunting challenges within the next 20 years. At the same time, the MDGs are the international policy agenda that the scientific community must influence and participate in if it is to contribute to the resolution of global water issues.

Examples of the role of hydrologists:

- Hydrologists should translate their research into the "big picture" that policy makers are facing by turning theory into practice and demonstrating the gains realized from policy based on good science.
- The hydrological community can improve communication between science and policy makers and ensure that the appropriate research is funded.
- Hydrologists should strive to understand the interconnections between the different systems of the Earth in order to develop viable and scientifically based solutions to current and potential future water problems.
- Promoting exchange of knowledge and ideas through improved communication among experts belonging to the various disciplines concerned will be a continuing future challenge. Hydrologists must dare to leave their compartmentalized thinking and encourage policy makers to promote such dialogues.

3.4.2 Linking water management with poverty reduction and socio-economic development

The recently developed Poverty Reduction Strategy Papers (PRSPs) discussed in more detail in Section 3.4.3 may provide a means of improving the linkage between water management, poverty reduction and socio-economic development. Currently PRSPs only consider limited aspects of water, mostly linked to water supply and sanitation. Because water is crucial for all forms of development, water management (and Integrated Water Resources Management, IWRM) must be made an integral part of policies for economic and social development as well as policies dealing with environmental aspects and development. Efficient water management should be seen as an opportunity from an economic, social and environmental perspective. Thus, rather than developing PRSPs and IWRM/water efficiency plans separately, these efforts should be coordinated to ensure that water issues are effectively and properly incorporated in PRSPs. This is currently not the case.

Examples of the role of hydrologists:

– It is important that IWRM plans map onto PRSPs. By interaction with policy makers, hydrologists can ensure that the execution of water related projects contribute efficiently to poverty reduction and the promotion of socio-economic development.

– The hydrological community should clearly show and demonstrate the link between water resource management, poverty reduction and socio-economic development in order to encourage increased investment in water sectors.

– The economic character of water has to be highlighted by the hydrological community.

3.4.3 National-level water policy

Water resources are increasingly seen as the key resource for achieving all forms of development which, in turn, makes their management very complex. Population growth and distribution, changing consumption and production patterns, increased food production (rainfed and irrigated), changing trade policies, and socio-economic development in general all influence and are influenced by water resources, at all levels, and thus need to be considered in management and development strategies.

Over the last couple of years, there has been an increased recognition of the need to change the way water is managed on local, national and regional levels. On a national level, such concerns have increasingly translated into the formulation of new water laws (see for instance South Africa, Kenya and the new EU Water Framework Directive) and more general calls for IWRM plans. There was also a political call from the World Summit on Sustainable Development that each country should have such a plan in place no later than 2005. The format and content of such plans are unclear, but the planning process is often as important as the final plan.

From a more specific development-policy perspective, an example of new national policy instruments that could be relevant for water management are the Poverty Reduction Strategy Papers (PRSPs) developed by the World Bank. They have emerged as a strategic tool to increase the coordination and efficiency of development-oriented work in many developing countries. A PRSP describes a country’s macroeconomic, structural and social policies and programmes to promote growth and reduce poverty, as well as associated external financing needs. Governments PRSPs are prepared through a participatory process involving civil society and development partners, including the World Bank and the International Monetary Fund (IMF). Thus, they follow a similar process as the more narrow IWRM plans but have a stronger emphasis on economic and financial elements.

Examples of the role of hydrologists:

– Be more involved in national policy processes at all levels by bringing scientifically-based and comprehensive propositions.
– Propose research plans that aim to assist the sustainable development of local populations and that fit national policy frameworks (for example, PRSPs).
– Participate in the formulation of water laws that are scientifically-based.

3.4.4 The scientific mandate – should it include policy making?

At the global level, water related issues and the role of science in striving towards sustainable development are recognized by being accorded their own chapters in Agenda 21: Chapter 18 (the most extensive) and Chapter 35, respectively (United Nations, 1992). In Chapter 35, the role of science in a wider sense is described, not only that linked to water:

"*The sciences are playing an important role in linking the fundamental significance of the Earth system as life support to appropriate strategies for development which build on its continued functioning. The sciences should continue to play an increasing role in providing for an improvement in the efficiency of resource utilization and in finding new development practices, resources, and alternatives. There is a need for the sciences constantly to reassess and promote less intensive trends in resource utilization, including less intensive utilization of energy in industry, agriculture, and transportation. Thus, the sciences are increasingly being understood as an essential component in the search for feasible pathways towards sustainable development*". (United Nations, 1992).

Although now more than 10 years old, the thinking in Chapter 35 of Agenda 21 is still as valid today as it was then. What is expressed here is one of the key challenges for the scientific community: to move from its classical role as primarily a knowledge generator to a more active contributor to socio-economic development.

The contribution of science to resolving the water crisis can take three main forms. The first is the more traditional role of knowledge generation. From this perspective, dealing with the "water crisis" would largely involve overcoming the communication and cooperation gaps that still exist between those (scientific disciplines) that together have the capacity to address the problems and identify solutions. The second is the communication of knowledge so that other stakeholders, notably policy and decision makers, will understand the issues and problems, what is the most appropriate solution (from a scientific perspective) and what the priorities are. In this context, dealing with the "water crisis" is more about how scientists interact with and provide support to policy and decision-making processes. Thirdly, there is the role of science as a direct policy advisor or even policy maker. The last two roles are not always regarded as key areas within traditional scientific thinking and practice.

Interdisciplinary efforts will also be fundamental for the science of the future and a whole chapter (Chapter 6) of this book is devoted to this topic. Cooperation is necessary among actors, from those that understand the problems, to those that can identify solutions and ways to overcome barriers to implementation, be it a lack of financial and/or human resources or a pure lack of will to act due to self-centred political or stakeholder interests. A key challenge to managing conflicting demands will thus be to overcome stakeholder fragmentation and to establish a language that different stakeholders can understand.

Examples of the role of hydrologists:

– Hydrologists should strive to bridge the communication gap between scientists themselves and with policy makers.
– The hydrological community should participate in and promote interdisciplinary research involving other scientists, decision makers and stakeholders.
– Hydrologists can contribute to the development and demonstration of new technologies (e.g. remote sensing, GIS, models) that increase the capacity for monitoring at a moderate cost.
– The hydrological community should campaign to ensure that information from new hydrological tools is made available to users.
– The widespread utilization of new hydrological tools often requires initial training, especially in developing countries. The hydrological community can assist in this technology transfer, for example through participating in strong partnerships between academic institutions in developed and developing countries that are promoted and supported by governments and international organizations.

3.4.5 Understanding policy-making processes and evaluation is crucial

Many policies and decision-making instruments are complex, and will relate to the interests of many different stakeholders. In current policy- and decision-making structures, the responsibilities of developing policies and instruments in a particular field often fall on one government agency. Water issues are in a way different as they often involve many different agencies, with different responsibilities (such as: water and energy, water and agriculture, water and environment). As water policies become even more complex, the various decision-making bodies will have to strengthen their collaboration.

The necessity, therefore, of having a clear framework for organizing policy-making efforts from a public sector point of view needs further consideration. Such a framework not only needs to include the steps for taking a policy from development to implementation, but also policy review and follow-up. The critical role of different actors in policy making, including the scientific community, must be clearly stated.

The aim of new policies can be either to provide a framework for more efficient and comprehensive decision-making processes in the public or private sector, or to provide guidance for direct actions through the application of instruments. Due to a constantly changing world and changes in our knowledge base, policies need to be flexible (changeable) as inflexible policies are likely to create new unwanted issues and problems in the future. What is "best scientific knowledge" today is not necessarily correct tomorrow. To establish reliable feedback between scientific knowledge and policy is essential. Such feedback will provide information necessary for further policy development and implementation and be important for the scientific community in identifying new problems and issues.

Policy intervention at the right level is crucial to success. Some policies may primarily target international or regional issues while others focus on national and local level interventions. More detailed policies may be developed at a sector level. Policies therefore serve different functions, involve different stakeholders, and have various levels of complexity. Alternatives for achieving the same or better results also need to be discussed during the policy-making process and could include the identification of issues related to technological innovation, available financial and human resources, commitment and built-in incentives.

Being involved in politically controlled policy processes can be a frustrating experience for a scientist. There are many different aspects that eventually will influence the policy or the decision made and the concept of "sanctioned discourse" is relevant to this arena (see for instance Jägerskog, 2003). It essentially refers to a normative paradigm within which certain hypotheses might be raised while others may not. Thus, the sanctioned discourse sets the "boundaries" for what is politically feasible, although this may not be logical from a scientific point of view.

Examples of the role of hydrologists:

– Training in policy and communication should be included in the education of hydrologists so that the hydrological community can participate more effectively in the policy-making process.
– Feedback loops should be established between the hydrological community and policy making, e.g. national overview reports, reporting on progress towards targets and goals, conferences and seminars, stakeholder dialogues, round-tables, expert groups.

3.4.6 Science in a bigger context – areas of effective intervention

It is important for scientists to identify the level of policy intervention on which to focus. It is also essential to consider time frames when making policy recommendations, not least for long-term issues such as water issues. Complex policies often imply long time frames for their implementation, which, from a political and economic point of view, can be complicated to handle. Meadows (1999) identified a hierarchy of 12 different levels of intervention in a system (society) (Fig. 3.3). Level one represents the most ambitious and effective level, but also the most complex and difficult to implement. It includes actions such as influencing culture and attitudes (to establish a long-term transition in norms and values in society) and addressing the mindset or paradigm of a society. Level 12 is considered to be the least effective but, at the same time, the simplest to implement. It includes, for instance, establishing constants, parameters and numbers (e.g. subsidies, taxes, setting of standards).

Complex policies that can actually change the way we manage water may require stepwise interventions. Some policy tools, like economic and legal instruments, are applicable to different levels, depending on their scope, number of affected stakeholders and ambition. There is a big difference, for example, in the level of

1	The power to transcend paradigms
2	The mindset or paradigm out of which the system - its goals, structure, rules, delays, parameters - arises
3	The goals of the system (e.g. growth, resilience)
4	The power to add, change, evolve or self-organize system structure
5	The rules of the system (such as incentives, punishments, constraints)
6	Information flows (who does and does not have access to what kinds of information)
7	Reducing the gain around positive feedback loops (slowing the growth)
8	Strengthen negative feedback loops, relative to the impacts they are trying to correct against
9	The lengths of delays in feedback, relative to the rate of system change
10	The structure of material stocks and flows (such as transport networks, population age structures)
11	The sizes of buffers and other stabilizing stocks, relative to their flows
12	Constants, parameters, numbers (such as subsidies, taxes, standards)

Fig. 3.3 *Leverage points: places to intervene in a system (in decreasing order of effectiveness) (adapted from Meadows, 1999).*

intervention if water prices are raised a few percent, compared to restructuring the whole water sector. It is important to make clear that the different levels are not directly referring to the quality or importance of the intervention; it is merely referring to the complexity in implementing higher-level policies. Intervention will be necessary at all levels, and high-level intervention policies will be dependent on the implementation of actions at lower levels.

Examples of the role of hydrologists:

– In order to increase its influence on policy, the hydrological community should identify the most effective levels at which to intervene in the policy-making process.

– The hydrological community needs to maintain interaction with the policy-making process over long timescales to ensure that water policy is implemented and that it is based on sound science.
– Policy and decision making need to consider how high-level goals are affected by low-level policies.
– The hydrological community should explain to policy makers how different policies may interact to affect water resources. Sometimes policies, taken at different levels, may have different and even counteracting water-related goals.

3.4.7 Setting objectives and targets as indicators of progress

As well as determining the appropriate level of intervention, a crucial step in effective policy making is to establish clear objectives and targets. Targets need to be clearly measurable (quantity, time) in order to evaluate policies and to make policy makers more "accountable" for their decisions. As discussed above, a "stepwise approach" to policy making (or intervention at different levels at different times) is often most appropriate. To achieve increased resource efficiency is a continuous process, not a short-term quick fix. Long-term policy (goals to be achieved by 2010, 2025 and so on) needs to be formulated and represents a high-level intervention, but clear intermediate goals are equally important (lower-level interventions).

Example of the role of hydrologists:
– The hydrological community should help develop targets and indicators of progress in achieving water resources/hydrological goals. These can serve the purpose of a communication tool between hydrologists and policy makers and indicate if further actions may be required in order to reach stated (long-term) objectives.

3.4.8 Understanding stakeholder interests and improving dialogue

Different stakeholders have different goals and incentives for participating in discussions on the formulation and implementation of water resources management policies and plans, and may also be active at different levels of intervention as discussed above. These differences are critical to understand if scientists are to take a more active advocacy role.

The government as a stakeholder will continue to play an important role in many aspects relating to water resources management. The protection of a resource base is an important area where there is a clear role for public sector policy makers. In addition, water supply and sanitation systems often remain the responsibility of public sector authorities (although these are privatized in many countries government control remains high). National water policies will continue to be a critical instrument for water resources management and scientific input to these policies is essential.

The private sector is likely to approach resource efficiency more as an economic issue, aiming at saving costs. This may include economic benefits as a result of reduced raw material needs, saving on energy consumption and transport, paying less environmental taxes and fees, and promoting products as being environmentally friendly (green market mechanisms, consumer pressure). It has an interest in research and development and how such development can contribute to efficiency and cost savings.

Other stakeholders can also take an active role in policy formulation and implementation or act as intermediaries between policy makers and stakeholders. These include consumer groups, environmental and social NGOs and international organizations. Their level of intervention will often depend on how public policy makers decide to work, but they will probably increasingly take direct action and apply further pressure on businesses directly and through active lobbying of national and intergovernmental bodies. Consumer pressure has also become an important stakeholder involvement process and, from a business perspective, has led to substantial changes in the production of many consumer goods, and thus the use of natural resources.

Most of the issues raised by different stakeholders are interrelated, as resource efficiency is an integral part of almost all development strategies. The process of policy formulation and implementation therefore often benefits from multi-stakeholder dialogues. However, multi-stakeholder dialogues are time consuming and must be managed properly. To be most effective, such dialogues need to be introduced in the early stages of policy formulation, as otherwise frustration and even negative involvement can occur. It is also crucial to determine clearly the interests of each individual stakeholder, to identify potential conflicts between them, and to have a clear framework for participation. The latter needs to include: who should participate and when, the number of meetings, lines of responsibility, and sharing of costs. The success of the policy depends to a large extent on the early design of the planning and decision-making process (see for instance The Consensus Building Institute, 1999).

Examples of the role of hydrologists:

- The hydrological community should ensure that it is represented in multi-stakeholder dialogues in water resource management decision-making processes.
- In order to participate effectively in multi-stakeholder water resource management discussions, hydrologists need to understand the goals and incentives of the different stakeholders.

3.5 SCIENCE NEEDS TO SUPPORT THE FURTHER DEVELOPMENT OF WATER MANAGEMENT PARADIGM SHIFTS – SOME EXAMPLES

3.5.1 Integrated water resources management

Integrated Water Resources Management (IWRM) may be defined as: “A process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems” (Global Water Partnership, 2000).

The need for better integration within water management through IWRM and water efficiency plans has increased as pressure on water resources (locally, nationally and regionally) escalates. Water management is increasingly about managing competing demands to ensure that water is used in an efficient but also equitable manner. Water cannot be managed only by the water sector or water professionals in isolation from other development and management processes. Other actors, traditionally not directly associated with water management, will have to become more involved in the planning and implementation of efficient water management strategies, either directly or through more efficient dialogue. Although integrated management has consistently been described as the “only way forward”, it is challenging to achieve in reality.

In the Johannesburg Plan of Implementation (United Nations, 2002b) a target that all countries should have IWRM and water efficiency plans by 2005 was adopted. The main challenge will not be to develop such plans, but rather to implement them and ensure that a truly integrated approach is taken. It will also be critical to evaluate if water resources issues are incorporated into other national development strategies, such as Poverty Reduction Strategy Papers and national budget plans.

Examples of the role of hydrologists:
– Hydrologists can provide the knowledge base necessary for IWRM and water efficiency plans.
– The hydrological community can serve as a facilitator of integration between different scientific disciplines that need to cooperate to provide the holistic approach necessary for integrated water management.

3.5.2 The river basin as a management unit in a political setting: striving for hydrosolidarity

Too frequently international rivers have been a source of conflict, but increasingly such rivers can actually promote cooperation rather than conflict. A change in thinking is occurring as we move from a situation of “no change” to acceptance of “living with change”. Hydrosolidarity is defined as sharing the benefits of water use and providing development opportunities while safeguarding key ecological services (Falkenmark & Folke, 2002). Solidarity restrains individual freedom of choice for the common good.

Hydrosolidarity can be applied at many different spatial and administrative levels, but the focus is primarily to achieve it at a river basin scale. Achieving a balance between development and safeguarding ecological services, as an integral component of development, is a central theme in hydrosolidarity. Ecosystems should not only be seen as users of water but also as the fundamental providers of services that humankind depends upon for survival.

There are also a number of security dimensions that need to be considered: water security, food security, and economic or livelihood security. Water security is complex and includes, for instance, water supply, water for plant growth, freedom from floods and droughts. Ecological security can be in conflict with water and economic security. Environmental flow requirements in rivers and the amount of water that needs to be preserved in order to maintain vital ecosystem services limit the degrees of freedom for development (Dyson *et al.*, 2003). A crucial dimension of ecological security is water quality, notably the characteristics of water after-use. Economic or livelihood security means that water must be linked to income generation, for instance, increasing the value/benefits per m^3 of water.

The dynamic interaction and the opportunities for enhanced exchange between urban and rural development need to be considered in basin-based hydrosolidarity.

Worldwide, the former urban minority is becoming the majority compared to the rural population. This affects socio-economic development and power structures as urban expansion often implies strengthened economic development. The focus may shift from water for food production to water for industrial development; positive from an economic perspective but sometimes negative from a more social perspective. Decoupling affluence and increased water pollution (effluence) is also proving to be very difficult (see for example Lundqvist, 1998).

From a more international perspective, hydrosolidarity needs to emphasize the management of transboundary and shared water resources. Solidarity is necessary for a more equal distribution of benefits from globalization. It should be the interest of each country that the whole surrounding region develops as this also has a positive impact on each individual country. Water can play an important role in this, as has been the case in southern Africa. Hydrosolidarity can ensure both equitable allocation and equitable management of water. Water resources management, and in particular IWRM, can be a driver for institutional change and regional cooperation. In the long run, this leads to positive mutual development and peace. At a global scale, trade and virtual water balances become important aspects of hydrosolidarity. Many countries are dependent on outside water, both directly and indirectly through the purchase of food on the global market.

Trade-offs between different users are a central part of hydrosolidarity. In many basins today, benefits flow upstream while wastewater flows downstream, often towards the poor. This must be changed. How to achieve change is in many ways about governance, providing the framework in which hydrosolidarity can be realized. The fair allocation of power, not just the allocation of water, is imperative for water management. Hydrosolidarity can be developed into some kind of common, basic ethic and used as a tool to improve the mindset within water management. The concept needs to be used in a wide sense as a means to achieve the higher goal of human sustainable development.

Examples of the role of hydrologists:

– Hydrologists can promote the concept of hydrosolidarity within hydrology (e.g. within the training of young hydrologists) and to policy makers.
– Hydrologists should conduct their work within the concept of hydrosolidarity, for instance, by cooperating and working with other hydrologists in transboundary basins.
– Hydrologists should provide the knowledge base upon which hydrosolidarity operates, for example, by identifying environmental flow requirements or assessing the impact of water use on the water quality received by downstream users.

3.6 BRIDGING THE COMMUNICATION GAP: TWINNING SCIENCE AND POLICY-MAKING PROCESSES

The water management sector is one arena where socio-economic factors interact closely with physical and environmental factors, and this needs to be clearly reflected within scientific modelling and political planning. As discussed earlier, dialogue among various experts is a key factor in successful management strategies. However, apart from the exchange of scientific ideas, water-related issues must be brought forward to the level of political action. The knowledge gathered by various scientific and technical disciplines needs to be presented in a way that it is taken seriously and can be properly used by decision makers, at all levels of society.

To achieve this, scientific projects need increasingly to respond to, or at least be linked to, issues relevant to socio-economic development. This is important, as there are signs over recent years of declining respect for science and scientists from policy and decision makers. Over 2000 years ago Socrates stated that "There is only one evil for humanity—ignorance". The ignorance of politicians is indeed dangerous, but it can partly be attributed to the inability of scientists to present relevant information and guidance in response to emerging issues for policy and decision making in broader terms. To provide "yes or no" answers is difficult, but the precautionary principle, one of the Rio Principles (United Nations, 1992), provides support for the "best guess" approach if required.

A common problem is that although policy makers within water management could greatly benefit from the input of scientists who have been associated with the particular water problem over the life of the issue, many scientific programmes are restrained by short-term funding. Funding for scientific research is generally encapsulated into projects that can be conducted by a few investigators over just a few years. Funding for the transfer of research results into policy guidance is not plentiful. Thus it is prudent that water policy makers be involved in developing proposal descriptions, so that scientific research can be more closely aligned with societal need, and also that funds for the transfer of research or technology into policy guidance are directly built into the project.

Examples of the role of hydrologists:

– The hydrological community needs to identify more effective routes of communication to "market" its results to policy makers and society to ensure that they are incorporated into national and international policies. Many scientists think that good research results almost automatically permeate into policy but this is seldom (if ever!) the case.
– Hydrologists should frame their research to better address issues and provide guidance in response to specific societal needs, where appropriate.
– In international scientific debate (on water as well as on other issues) there is a tendency among scientists to give too much weight to their own area of expertise. Hydrologists should ensure that their research is presented in an unbiased fashion.
– Where appropriate, hydrologists should incorporate issues such as political feasibility, ideology and cultural aspects into analysis of water problems and proposed solutions. The hydrological community should campaign for increased funding to encourage such approaches.
– Hydrologists should interact with all organizations that relate to hydrology and water resources, e.g. government agencies, international organizations and NGOs. The politics of water is not only about politicians.

3.7 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE ACTIONS

The future will present us with many water challenges that we, the next generation of scientists and policy makers, must handle. Some of them are already known but others will emerge. To resolve both known and unforeseen water challenges strong scientific and political leadership is essential, based on both a positive vision of what can be achieved, but equally important on long-term commitment, not least within science. This leadership must be well informed. Only if the scientific communities work together with policy and decision makers can water issues be successfully addressed. An integrated approach to freshwater management is the way forward as it offers the means of reconciling competing demands with dwindling supplies and a framework in which hard choices can be made, and effective action taken. We hope that the ideas and recommendations presented above will spur further discussion but also concrete action among individual scientists and, in particular, scientific organizations.

To conclude this chapter we present some general recommendations, or more food for further thought, that we feel will facilitate further progress in resolving water issues throughout the world and to complement the ideas presented above:

1. Establish an international coordination mechanism for hydrology and water resources issues, similar to the ideas that were initially behind the establishment of the secretariat of the International Decade on Natural Disasters Reduction (now transformed into the International Strategy for Disaster Reduction). This would imply building on existing resources and the political basis of the UN system, but with a clear mandate to reach out and strive towards increased cooperation between both UN and non-UN international actors. It is not realistic to consider the establishment of a single water agency as water is on the agenda of most UN agencies and there are many other more water-focused global bodies, such as IAHS and the Global Water Partnership. However, a wider, non-political coordination mechanism could be warranted, to complement the existing UN-wide mechanism “UN Water”. One role of such a secretariat could be to initiate a process aiming to summarize current scientific understanding as an input to the World Water Development report, that in turn provides support for policy decisions in water resources management.

2. Increased knowledge and understanding of water issues is essential and must be further promoted at all levels throughout society. Leading hydrologists should play a more active advocacy role and get involved in politics. We should increase awareness of, dissemination to, and influence on, political circles. Public awareness often leads to political pressure, which is needed for water issues. National and international information networks, using modern technologies, must be strengthened. Capacity building and professional training are crucial in many developing countries, where international assistance in financial and human resources needs to be enhanced.

3. Further efforts should be directed at funding and facilitating the international exchange of hydrological and related data and products, so that global studies of freshwater resources and its links to socio-economic and environmental issues can be conducted and useful results produced are a benefit to humankind.

4. Scientific results must be translated into clear action-oriented recommendations so that they can be used in national and international policy evaluation, formulation,

and planning. Scientists need to consider what it is that we want decision makers to do with our “knowledge”. This is crucial if the scientific community is to strengthen its credibility and further enhance the possibility of receiving financial support for what are sometimes costly long-term projects.

5. The scientific community has to find innovative ways of improving collaboration among scientific disciplines and also with new important actors such as the private sector (that often has extensive practical knowledge and research capacity). This could be in the form of closer cooperation between scientific professional organizations and organizations representing the business sector, such as the World Business Council for Sustainable Development and the World Economic Forum.

6. International, regional and national organizations should be encouraged to find innovative ways to strengthen cooperation among countries which share river basins or aquifers, in particular, through bilateral or other intergovernmental mechanisms. From a scientific perspective, this includes the development of agreements to share data and other information, and joint scientific studies of shared resources. It is quite clear that water (on this level) can be a source for peace.