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1 Water Resources Planning and Management: An Overview

Water resource systems have benefited both people and their economies for many centuries. The services provided by such systems are multiple. Yet in many regions, water resource systems are not able to meet the demands, or even the basic needs, for clean fresh water, nor can they support and maintain resilient biodiverse ecosystems. Typical causes of such failures include degraded infrastructures, excessive withdrawals of river flows, pollution from industrial and agricultural activities, eutrophication from excessive nutrient loads, salinization from irrigation return flows, infestations of exotic plants and animals, excessive fish harvesting, floodplain and habitat alteration from development activities, and changes in water and sediment flow regimes. Inadequate water resource systems reflect failures in planning, management and decision-making – and at levels broader than water. Planning, developing and managing water resource systems to ensure adequate, inexpensive and sustainable supplies and qualities of water for both humans and natural ecosystems can only be successful if such activities address the causal socio-economic factors, such as inadequate education, population pressures and poverty.

1. Introduction

Over the centuries, surface and ground waters have been a source of water supplies for agricultural, municipal and industrial consumers. Rivers have provided hydroelectric energy and inexpensive ways of transporting bulk cargo between different ports along their banks, as well as water-based recreational opportunities, and have been a source of water for wildlife and its habitat. They have also served as a means of transporting and transforming waste products that are discharged into them. The quantity and quality regimes of streams and rivers have been a major factor in governing the type, health and biodiversity of riparian and aquatic ecosystems. Floodplains have provided fertile lands for agricultural production and relatively flat lands for roads, railways and commercial and industrial complexes. In addition to the economic benefits that can be derived from rivers and their floodplains, the aesthetic beauty of most natural rivers has made lands adjacent to them attractive sites for residential and recreational development. Rivers and their floodplains have generated and, if managed properly, can continue to generate substantial economic, environmental and social benefits for their inhabitants.

Human activities undertaken to increase the benefits obtained from rivers and their floodplains may also increase the potential for costs and damage when the river is experiencing rare or extreme flow conditions, such as during periods of drought, floods and heavy pollution. These costs and impacts are economic, environmental and social in nature and result from a mismatch between what humans expect or demand, and what nature (and occasionally our own activities) offers or supplies. Human activities tend to be based on the 'usual or normal' range of river flow conditions. Rare or 'extreme' flow or water quality conditions outside these normal ranges will continue to occur, and possibly with increasing frequency as climate change experts suggest. River-dependent, human activities that cannot adjust to these occasional extreme conditions will incur losses.

The planning of human activities involving rivers and their floodplains must consider certain hydrological facts. One of these facts is that flows and storage volumes vary over space and time. They are also finite. There are limits to the amounts of water that can be withdrawn from surface and groundwater bodies. There are also limits to the amounts of potential pollutants that can be discharged into them without causing damage. Once these limits are exceeded, the concentrations of pollutants in these waters may reduce or even eliminate the benefits that could be obtained from other uses of the resource.

Water resources professionals have learned how to plan, design, build and operate structures that, together with non-structural measures, increase the benefits people can obtain from the water resources contained in rivers and their drainage basins. However, there is a limit to the services one can expect from these resources. Rivers, estuaries and coastal zones under stress from overdevelopment and overuse cannot reliably meet the expectations of those depending on them. How can these renewable yet finite resources best be managed and used? How can this be accomplished in an environment of uncertain supplies and uncertain and increasing demands, and consequently of increasing conflicts among individuals having different interests in the management of a river and its basin? The central purpose of water resources planning and management activities is to address and, if possible, answer these questions. These issues have scientific, technical, political (institutional) and social dimensions and thus, so must water resources planning processes and their products.

River basin, estuarine and coastal zone managers – those responsible for managing the resources in those areas – are expected to manage them effectively and efficiently, meeting the demands or expectations of all users and reconciling divergent needs. This is no small task, especially as demands increase, as the variability of hydrological and hydraulic processes becomes more pronounced, and as stakeholder measures of system performance increase in number and complexity. The focus or goal is no longer simply to maximize net economic benefits while ensuring the equitable distribution of those benefits. There are also environmental and ecological goals to consider. Rarely are management questions one-dimensional, such as: 'How can we provide more high-quality water to irrigation areas in the basin at acceptable costs?' Now added to that question is how those withdrawals would affect the downstream water quantity and quality regimes, and in turn the riparian and aquatic ecosystems. To address such 'what if' questions requires the integration of a variety of sciences and technologies with people and their institutions.

Problems and opportunities change over time. Just as the goals of managing and using water change over time, so do the processes of planning to meet these changing goals. Planning processes evolve not only to meet new demands, expectations and objectives, but also in response to new perceptions of how to plan more effectively.

This book is about how quantitative analysis, and in particular computer models, can support and improve water resources planning and management. This first chapter attempts to review some of the issues involved. It provides the context and motivation for the chapters that follow, which describe in more detail our understanding of 'how to plan' and 'how to manage' and how computer-based programs and models can assist those involved in these activities. Additional information is available in many of the references listed at the end of each chapter.

2. Planning and Management Issues: Some Case Studies

Managing water resources certainly requires knowledge of the relevant physical sciences and technology. But at least as important, if not more so, are the multiple institutional, social or political issues confronting water resources planners and managers. The following brief descriptions of some water resources planning and management studies at various geographic scales illustrate some of these issues.

2.1. Kurds Seek Land, Turks Want Water

The Tigris and Euphrates Rivers (Figure 1.1) in the Middle East created the 'Fertile Crescent' where some of the first civilizations emerged. Today their waters are

Figure 1.1. The Tigris and Euphrates Rivers in Turkey, northern Syria and Iraq.

Figure 1.2. Ataturk Dam on the Euphrates River in Turkey (DSI).

critical resources, politically as well as geographically. In one of the world's largest public works undertakings, Turkey is spending over $30 billion in what is called the Great Anatolia Project (GAP), a complex of 22 reservoirs and 19 hydroelectric plants. Its centrepiece, the Ataturk Dam (Figure 1.2) on the Euphrates River, is already completed. In the lake formed behind the dam, sailing and swimming competitions are being held on a spot where, for centuries, there was little more than desert (Figure 1.3).

Figure 1.3. Water sports on the Ataturk Reservoir on the Euphrates River in Turkey (DSI).

When the project is completed it is expected to increase the amount of irrigated land in Turkey by 40% and provide up to a quarter of the country's electric power needs. Planners hope this can improve the standard of living of six million of Turkey's poorest people, most of them Kurds, and thus undercut the appeal of revolutionary separatism. It will also reduce the amount of water Syria and Iraq believe they need – water that Turkey fears might ultimately be used for anti-Turkish causes.

The region of Turkey where Kurd's predominate is more or less the same region covered by the Great Anatolia Project, encompassing an area about the size of Austria. Giving that region autonomy by placing it under Kurdish self-rule could weaken the Central Government's control over the water resources that it recognizes as a keystone of its future power.

In other ways also, Turkish leaders are using their water as a tool of foreign as well as domestic policy. Among their most ambitious projects considered is a fifty-mile undersea pipeline to carry water from Turkey to the parched Turkish enclave on northern Cyprus. The pipeline, if actually built, will carry more water than northern Cyprus can use. Foreign mediators, frustrated by their inability to break the political deadlock on Cyprus, are hoping that the excess water can be sold to the ethnic Greek republic on the southern part of the island as a way of promoting peace.

2.2. Sharing the Water of the Jordan River Basin: Is There a Way?

A growing population – approximately 12 million people – and intense economic development in the Jordan River Basin (Figure 1.4) are placing heavy demands on its scarce freshwater resources. Though the largely arid region receives less than 250 millimetres of rainfall each year, total water use for agricultural and economic activities has been steadily increasing. This and encroaching urban development have degraded many sources of high-quality water in the region.

The combined diversions by the riparian water users have changed the river in its lower course into little better than a sewage ditch. Of the 1.3 billion cubic metres (mcm or 10^6 m^3) of water that flowed into the Dead Sea in the 1950s, only a small fraction remains at present. In normal years the flow downstream from Lake Tiberias (also called the Sea of Galilee or Lake Kinneret) is some 60 mcm – about 10% of the natural discharge in this section. It mostly consists of saline springs and sewage water. These flows are then joined by what remains of the Yarmouk, by some irrigation return flows and by winter runoff, adding up to an annual total of 200 to 300 mcm. This water is unsuitable for irrigation in both quantity and quality, nor does it sufficiently supply natural systems. The salinity of the Jordan River reaches up to 2,000 parts per million (ppm) in the lowest section, which renders it unfit for crop irrigation. Only in flood years is fresh water released into the lower Jordan Valley.

Figure 1.4. The Jordan River between Israel and Jordan.

One result of this increased pressure on freshwater resources is the deterioration of the region's wetlands, which are important for water purification and flood and erosion control. As agricultural activity expands, wetlands are being drained, and rivers, aquifers, lakes and streams are being polluted with runoff containing fertilizers and pesticides. Reversing these trends by preserving natural ecosystems is essential to the future availability of fresh water in the region.

To ensure that an adequate supply of fresh, high-quality water is available for future generations, Israel, Jordan and the Palestinian Authority will have to work together to preserve aquatic ecosystems (National Research Council, 1999). Without these natural ecosystems, it will be difficult and expensive to sustain high-quality water supplies. The role of ecosystems in sustaining water resources has largely been overlooked in the context of the region's water provision. Vegetation controls storm runoff, filters polluted water and reduces erosion and the amount of sediment that makes its way into water supplies. Streams assimilate wastewater, lakes store clean water, and surface waters provide habitats for many plants and animals.

The Jordan River Basin, like most river basins, should be evaluated and managed as a whole to permit the comprehensive assessment of the effects of water management options on wetlands, lakes, the lower river and the Dead Sea coasts. Damage to ecosystems and loss of animal and plant species should be weighed against the potential benefits of developing land and creating new water resources. For example, large river-management projects that divert water to dry areas have promoted intensive year-round farming and urban development, but available river water is declining and becoming increasingly polluted. Attempting to meet current demands solely by withdrawing more ground and surface water could result in widespread environmental degradation and depletion of freshwater resources.

There are policies that, if implemented, could help preserve the capacity of the Jordan River to meet future demands. Most of the options relate to improving the efficiency of water use: that is, they involve conservation and better use of proven technologies. Also being considered are policies that emphasize economic efficiency and reduce overall water use. Charging higher rates for water use in peak periods and surcharges for excessive use, would encourage conservation. In addition, new sources of fresh water can be obtained by capturing rainfall through rooftop cisterns, catchment systems and storage ponds.

Thus there are alternatives to a steady deterioration of the water resources of the Jordan Basin. They will require coordination and cooperation among all those living in the basin. Will this be possible?

2.3. Mending the 'Mighty and Muddy' Missouri

Nearly two centuries after an epic expedition through the western United States in search of a northwest river passage to the Pacific Ocean, there is little enchantment left to the Missouri River. Shown in Figure 1.5, it has been dammed, dyked and dredged since the 1930s to control floods and float cargo barges. The river nicknamed the 'Mighty Missouri' and the 'Big Muddy' by its explorers is today neither mighty nor very muddy. The conservation group American Rivers perennially lists the Missouri among the United States' ten most endangered rivers.

Its wilder upper reaches are losing their cottonwood trees to dam operations and cattle that trample seedlings along the river's banks. In its vast middle are multiple dams that hold back floods, generate power and provide pools for boats and anglers.

Figure 1.5. Major rivers in the continental United States.

Its lower third is a narrow canal sometimes called 'the Ditch' that is deep enough for commercial tow-boats. Some of the river's banks are armoured with rock and concrete retaining walls that protect half a million acres of farm fields from flooding. Once those floods produced and maintained marshlands and side streams – habitats for a wide range of wildlife. Without these habitats, many wild species are unable to thrive, or in some cases even survive.

Changes to restore at least some of the Missouri to a more natural state are being implemented. Protection of fish and wildlife habitat has been added to the list of objectives to be achieved by the government agencies managing the Missouri. The needs of wildlife are now seen to be as important as other competing interests on the river, including navigation and flood control. This is in reaction, in part, to the booming \$115 million-a-year outdoor recreation industry. Just how much more emphasis will be given to these back-to-nature goals depends on whether the Missouri River Basin Association, an organization representing eight states and twenty-eight Native American tribes, can reach a compromise with the traditional downstream uses of the river.

2.4. The Endangered Salmon

Greater Seattle in the northwestern US state of Washington may be best known around the world for its software and aviation industry, but residents know it for something less flashy: its dwindling stock of wild salmon (see Figure 1.6). The Federal Government has placed seven types of salmon and two types of trout on its list of threatened or endangered species. Saving the fish from extinction will require sacrifices and could slow development in one of the fastest-growing regions of the United States.

Before the Columbia River and its tributaries in the northwestern United States were blocked with dozens of dams, about 10 to 16 million salmon made the annual run back up to their spawning grounds. In 1996, a little less than a million did. But the economy of the Northwest depends on the dams and locks that have been built in the Columbia to provide cheap hydropower production and navigation.

Figure 1.6. A salmon swimming upstream (US Fish and Wildlife Service, Pacific Region).

For a long time, engineers tried to jury-rig the system so that fish passage would be possible. It has not worked all that well. Still too many young fish enter the hydropower turbines on their way down the river. Now, as the debate over whether or not to remove some dams takes place, fish are caught and carried by truck around the turbines. The costs of keeping these salmon alive, if not completely happy, are enormous.

Over a dozen national and regional environmental organizations have joined together to bring back salmon and steelhead by modifying or partially dismantling five federal dams on the Columbia and Snake Rivers. Partial removal of the four dams on the lower Snake River in Washington State and lowering the reservoir behind John Day Dam on the Columbia bordering Oregon and Washington (see Figure 1.7) should help restore over 300 km of vital river habitat. Running the rivers in a more

Figure 1.7. The Snake and Columbia River reservoirs identified by the Columbia and Snake Rivers Campaign for modification or dismantling to permit salmon passage.

natural way may return salmon and steelhead to the harvestable levels of the 1960s before the dams were built.

Dismantling part of the four Lower Snake dams will leave most of each dam whole. Only the dirt bank connecting the dam to the riverbank will be removed. The concrete portion of the dam will remain in place, allowing the river to flow around it. The process is reversible and, the Columbia and Snake Rivers Campaign argues, it will actually save taxpayers money in planned dam maintenance by eliminating subsidies to shipping industries and agribusinesses, and by ending current salmon recovery measures that are costly. Only partially removing the four Lower Snake River dams and modifying John Day Dam will restore rivers, save salmon and return balance to the Northwest's major rivers.

2.5. The Yellow River: How to Keep the Water Flowing

The Yellow River is one of the most challenging in the world from the point of view of water and sediment management. Under conditions of normal and low flow, the water is used for irrigation, drinking and industry to such an extent that the lower reach runs dry during many days each year. Under high-flow conditions, the river is heavily laden with very fine sediment originating from the Löss Plateau, to the extent that a hyperconcentrated flow occurs. Through the ages the high sediment load has resulted in the building-out of a large delta in the Bohai Sea and a systematic increase of the large-scale river slope. Both have led to what is now called the 'suspended river': the riverbed of the lower reach is at points some 10 metres above the adjacent land, with dramatic effects if dyke breaching were to occur.

The Yellow River basin is already a very water-scarce region. The rapid socio-economic development in China is putting the basin under even more pressure. Agricultural, industrial and population growth will further increase the demand for water. Pollution has reached threatening levels. The Chinese government, in particular the Yellow River Conservancy Commission (YRCC), has embarked on an ambitious program to control the river and regulate the flows. Their most recent accomplishment is the construction of the Xiaolangdi Dam, which will

Figure 1.8. The Yellow River Basin.

control water and sediment just before the river enters the flat lower reach. This controlling includes a concentrated release of high volumes of water to flush the sediment out to sea.

In the delta of the Yellow River, fresh water wetlands have developed with a dynamic and unique ecosystem of valuable plant species and (transmigratory) birds. The decreased and sometimes zero flow in the river is threatening this ecosystem. To protect it, the YRCC has started to release additional water from the Xiaolangdi dam to 'supply' these wetlands with water during dry periods. The water demand of the wetlands is in direct competition with the agricultural and industrial demands upstream, and there have been massive complaints about this 'waste' of valuable water. Solving this issue and agreeing upon an acceptable distribution over users and regions is a nearly impossible task, considering also that the river crosses nine rather autonomous provinces.

How can water be kept flowing in the Yellow River basin? Under high-flow conditions the sediment has to be flushed out of the basin to prevent further build-up of the suspended river. Under low-flow conditions water has to be supplied to the wetlands. In both cases the water is seen as lost for what many consider to be its main function: to support the socio-economic development of the region.

2.6. Lake Source Cooling: Aid to Environment or Threat to Lake?

It seems an environmentalist's dream: a cost-effective system that can cool some 10 million square feet of high school and university buildings simply by pumping cold water from the depths of a nearby lake (Figure 1.9), without the emission of chlorofluorocarbons (the refrigerants that can destroy protective ozone in the atmosphere) and at a cost substantially smaller than for conventional air conditioners. The water is returned to the lake, with a few added calories.

However, a group of local opponents insists that Cornell University's $55-million lake-source-cooling plan, which has replaced its aging air conditioners, is actually an environmental threat. They believe it could foster algal blooms. Pointing to five years of studies, thousands of pages of data, and more than a dozen permits from local and state agencies, Cornell's consultants say the system could actually improve conditions in the lake. Yet another benefit, they say, is that the system would reduce

Figure 1.9. The cold deep waters of Lake Cayuga are being used to cool the buildings of a local school and university (Ithaca City Environmental Laboratory).

Cornell's contribution to global warming by reducing the need to burn coal to generate electricity.

For the most part, government officials agree. But a small determined coalition of critics from the local community argue over the expected environmental impacts, and over the process of getting the required local, state and federal permits approved. This is in spite of the fact that the planning process, which took over five years, requested and involved the participation of all interested stakeholders from the very beginning. Even the local chapter of the Sierra Club and biology professors at other universities have endorsed the project. However, in almost every project where the environmental impacts are uncertain, there will be debates among scientists as well as among stakeholders. In addition, a significant segment of society distrusts scientists anyway. 'This is a major societal problem,' wrote a professor and expert in the dynamics of lakes. 'A scientist says X and someone else says Y and you've got chaos. In reality, we are the problem. Every time we flush our toilets, fertilize our lawns, gardens and fields, or wash our cars, we contribute to the nutrient loading of the lake.'

The project has now been operating for over five years, and so far no adverse environmental effects have been noticed at any of the many monitoring sites.

2.7. Managing Water in the Florida Everglades

The Florida Everglades (Figure 1.10) is the largest single wetland in the continental United States. In the mid-1800s it covered a little over 3.6 million ha, but since that time the historical Everglades has been drained and half of the area is now devoted to agriculture and urban development. The remaining wetland areas have been altered by human disturbances both around and within them. Water has been diverted for human uses, flows have been lowered to protect against floods, nutrient supplies to the wetlands from runoff from agricultural fields and urban areas have increased, and invasions of non-native or otherwise uncommon plants and animals have out-competed native species. Populations of wading birds (including some endangered species) have declined by 85 to 90% in the last half-century, and many species of South Florida's mammals, birds, reptiles, amphibians and plants are either threatened or endangered.

The present management system of canals, pumps, and levees (Figure 1.11) will not be able to provide adequate water supplies or sufficient flood protection to agricultural and urban areas, let alone support the natural (but damaged) ecosystems in the remaining wetlands. The system is not sustainable. Problems in the greater Everglades ecosystem relate to both water quality and quantity, including the spatial and temporal distribution of water depths, flows and flooding durations (called hydroperiods). Issues arise due to variations in

Figure 1.10. Scenes of the Everglades in southern Florida (South Florida Water Management District).

Figure 1.11. Pump station on a drainage canal in southern Florida (South Florida Water Management District).

Figure 1.12. Europe's major rivers and seas.

the natural/historical hydrological regime, degraded water quality and the sprawl from fast-growing urban areas.

To meet the needs of the burgeoning population and increasing agricultural demands for water, and to begin the restoration of the Everglades' aquatic ecosystem to a more natural state, an ambitious plan has been developed by the US Army Corps of Engineers (USACE) and its local sponsor, the South Florida Water Management District. The proposed Corps plan is estimated to cost over $8 billion. The plan and its Environmental Impact Statement (EIS) have received input from many government agencies and non-governmental organizations, as well as from the public at large.

The plan to restore the Everglades is ambitious and comprehensive, involving the change of the current hydrological regime in the remnant of the Everglades to one that resembles a more natural one, the re-establishment of marshes and wetlands, the implementation of agricultural best-management practices, the enhancement of wildlife and recreation areas, and the distribution of provisions for water supply and flood control to the urban population, agriculture and industry.

Planning for and implementing the restoration effort requires application of state-of-the-art large systems analysis concepts, hydrological and hydroecological data and models incorporated within decision support systems, integration of social sciences, and monitoring for planning and evaluation of performance in an adaptive management context. These large, complex challenges of the greater Everglades restoration effort demand the most advanced, interdisciplinary and scientifically-sound analysis capabilities available. They also require the political will to make compromises and to put up with lawsuits by anyone who may be disadvantaged by some restoration measure.

Who pays for all this? Both the taxpayers of Florida, and the taxpayers of the United States.

2.8. Restoration of Europe's Rivers and Seas

2.8.1. The Rhine

The map of Figure 1.13 shows the areas of the nine countries that are part of river Rhine basin. In the Dutch area of the Rhine basin, water is partly routed northward through the Ijssel and westward through the highly interconnected river systems of the Rhine, Meuse and Waal. About 55 million people live in the Rhine River basin and about 20 million of those people drink the river water.

In the mid-1970s, some called the Rhine the most romantic sewer in Europe. In November 1986, a chemical spill degraded much of the upper Rhine's aquatic ecosystem. This damaging event was reported worldwide. The Rhine was again world news in the first two months of 1995 when its water level reached a height that occurs on average once in a century. In the Netherlands, some 200,000 people, 1,400,000 pigs and cows and 1,000,000 chickens had to be evacuated. During the last two months of the same year there was hardly enough water in the

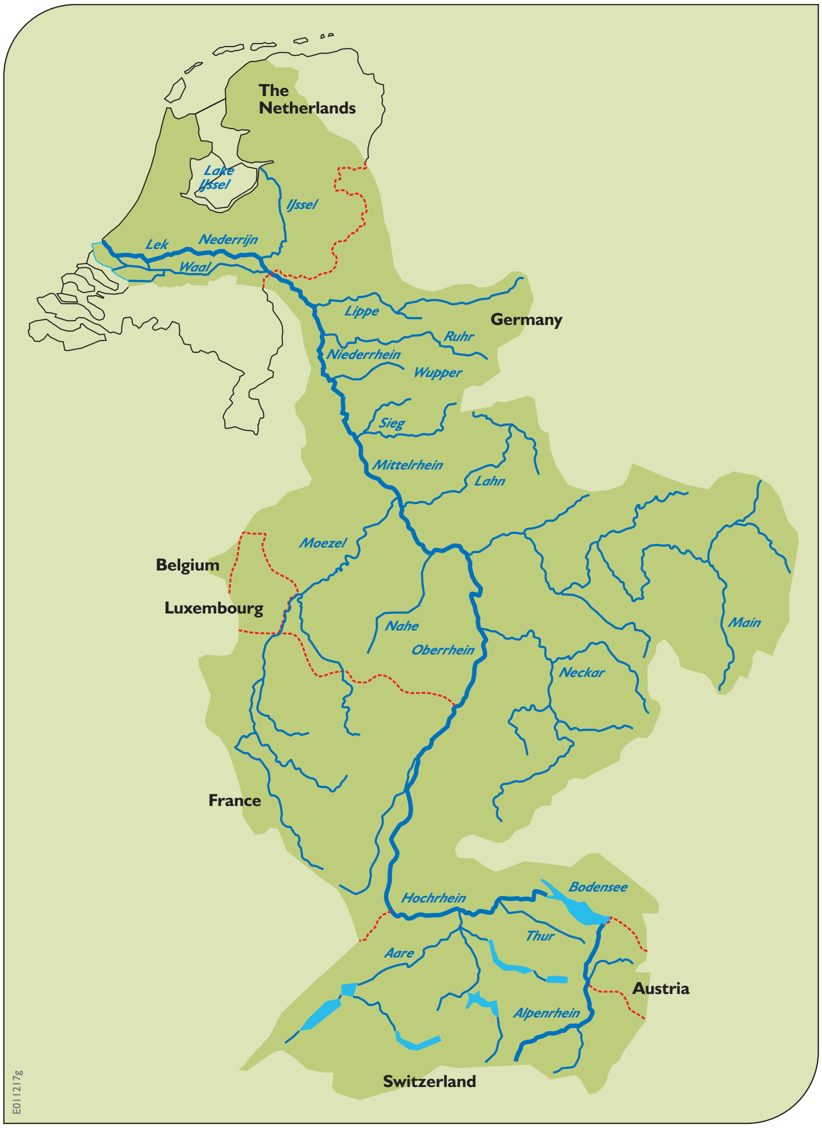

Figure 1.13. The Rhine River basin of western Europe and its extent in the Netherlands.

Rhine for navigation. It is fair to say these events have focused increased attention on what needs to be done to 'restore' and protect the Rhine.

To address just how to restore the Rhine, it is useful to look at what has been happening to the river during the past 150 years. The Rhine, the only river connecting the Alps with the North Sea, was originally a natural watercourse. To obtain greater economic benefits from the river, it was engineered for navigation, hydropower, water supply and flood protection. Floodplains, now 'protected' from floods, provided increased land areas suitable for development. The main stream of the Rhine is now considerably shorter, narrower and deeper than it was originally.

From an economic development point of view, the engineering works implemented in the river and its basin worked. The Rhine basin is now one of the most industrialized regions in the world and is characterized by intensive industrial and agricultural activities: it contains some 20% of the world's chemical industry. The river is reportedly the busiest shipping waterway in the world, containing long canals with regulated water levels, connecting the Rhine and its tributaries with the rivers of almost all the surrounding river basins, including the Danube. This provides water transport to and from the North and Black Seas.

From an environmental and ecological viewpoint, and from the viewpoint of flood control as well, the economic development that has taken place over the past two centuries has not worked perfectly. The concerns aroused by the recent toxic spill and floods, and from a generally increasing interest by the inhabitants of the basin in environmental and ecosystem restoration and the preservation of natural beauty, have resulted in basinwide efforts to rehabilitate the basin to a more 'living' sustainable entity.

A Rhine Action Programme has been created to revive the ecosystem. The goal of that program is the revival of the main stream as the backbone of the ecosystem, particularly for migratory fish, and the protection, maintenance and revival of ecologically important areas along the Rhine. Implemented in the 1990s, the plan was given the name 'Salmon 2000,' since the return of salmon to the Rhine is seen as a symbol of ecological revival. A healthy salmon population will need to swim throughout the river length. This will be a challenge, as no one pretends that the engineering works that provide navigation and hydropower benefits, but which also inhibit fish passage, are no longer needed or desired.

2.8.2. The Danube

The Danube River (shown in Figure 1.14) is in the heartland of central Europe. Its basin includes large parts of the territories of thirteen countries. It additionally receives

Figure 1.14. The Danube River in central Europe.

runoff from small catchments located in five other countries. About 85 million people live in the basin. This river encompasses greater political, economic and social variations than arguably any other river basin in Europe.

The river discharges into the Black Sea. The Danube delta and the banks of the Black Sea have been designated a biosphere reserve by UNESCO. Over half of the delta has been declared a 'wet zone of international significance.' Throughout its length the Danube provides a vital resource for drainage, communications, transport, power generation, fishing, recreation and tourism. It is considered to be an ecosystem of irreplaceable environmental value.

More than forty dams and large barrages, plus over 500 smaller reservoirs have been constructed on the main Danube River and its tributaries. Flood-control dykes confine most of the length of the main stem of the Danube River and the major tributaries. Over the last fifty years natural alluvial floodplain areas have declined from about 26,000 km^2 to about 6,000 km^2.

There are also significant reaches with river training works and river diversion structures. These structures trap nutrients and sediment in the reservoirs, which causes changes in downstream flow and sediment transport regimes that reduce the ecosystems' habitats both longitudinally and transversely and decrease the efficiency of natural purification processes. Thus, while these engineered facilities provide important opportunities for the control and use of the river's resources, they also illustrate the difficulties of balancing these important economic activities with environmentally sound and sustainable management.

The environmental quality of the Danube River is also under intense pressure from a diverse range of human activities, including point source and non-point source agricultural, industrial and municipal wastes. Because of the poor water quality (sometimes affecting human health), the riparian countries of the basin have been participating in environmental management activities on regional, national and local levels for several decades. All Danube countries signed a formal Convention on Cooperation for the Protection and Sustainable Use of the Danube River in June 1994. The countries have agreed to take 'all appropriate legal, administrative and technical measures to improve the current environmental and water quality conditions of the Danube River and of the waters in its catchment area, and to prevent and reduce as much as possible the adverse impacts and changes occurring or likely to be caused'.

2.8.3. The North and Baltic Seas

The North and Baltic Seas (shown in Figure 1.12) are the most densely navigated seas in the world. Besides shipping, military and recreational uses, there is an offshore oil and gas industry, and telephone cables cover the seabed. The seas are rich and productive, with resources that include not only fish but also crucial minerals (in addition to oil) such as gas, sand and gravel. These resources and activities play major roles in the economies of the surrounding countries.

Since the seas are so intensively exploited and are surrounded by advanced industrialized countries, pollution problems are serious. The main pollution sources include rivers and other outfalls, dumping by ships (of dredged materials, sewage sludge and chemical wastes) and operational discharges from offshore installations and ships. Deposition of atmospheric pollutants is an additional major source of pollution.

Those parts of the seas at greatest risk from pollution are where the sediments come to rest, where the water replacement is slowest, and where nutrient concentrations and biological productivity are highest. A number of warning signals have occurred.

Algal populations have changed in number and species. There have been algal blooms, caused by excessive nutrient discharge from land and atmospheric sources. Species changes show a tendency toward more short-lived species of the opportunistic type and a reduction, sometimes to the point of disappearance, of some mammal, fish and sea grass species. Decreases of ray, mackerel, sand eel and echinoderms due to eutrophication have resulted in reduced plaice, cod, haddock and dab, mollusk and scoter. The impact of fishing activities is also considerable. Sea mammals, sea birds and Baltic fish species have been particularly affected by the widespread release of toxins and pollutants that accumulate in the sediments and in the food web. Some species, such as the grey seal and the sea eagle, are threatened with extinction.

Particular concern has been expressed about the Wadden Sea, which serves as a nursery for many North Sea species. Toxic PCB contamination, for example, almost caused the disappearance of seals in the 1970s.

The 1988 massive seal mortality in the North and Wadden Seas, although caused by a viral disease, is still thought by many to have a link with marine pollution.

Although the North Sea needs radical and lengthy treatment, it is probably not a terminal case. Actions are being taken by bordering countries to reduce the discharge of wastes into the sea. A major factor leading to agreements to reduce discharges of wastewaters has been the verification of predictive pollutant circulation models of the sea that identify the impacts of discharges from various sites along the sea boundary.

2.9. Egypt and the Nile: Limits to Agricultural Growth

Egypt, located in a belt of extreme aridity, is nearly completely dependent on the River Nile (Figure 1.15) for its water resources. Therefore, it is no wonder that most of Egypt's population lives close to the Nile. In relation to arable land and water, Egypt's population density is among the highest in the world: of its population of 63 million in 2000, 97% lives on 5% of land in the small strip along the Nile and in the Delta where water is abundant. The population density continues to increase as a result of a population growth of about 2% per year.

To relieve the population pressure in the Nile Delta and Nile Valley, the government has embarked on an ambitious programme to increase the inhabited area in Egypt from the present 5% to about 25% in the future. The agricultural area is to be enlarged by 'horizontal expansion', which should increase the agricultural area from 3.4 million ha in 1997 to 4.1 million in 2017. New industrial areas are planned in the desert, to be supplied by Nile water. Most of these new agricultural and industrial developments are based on public–private partnerships, requiring the government to give guarantees for the availability of water. The Toskha project in the south and the El-Salaam scheme in the Sinai are examples of this kind of development.

However, the availability of Nile water remains the same. Under the present agreement with Sudan, Egypt is allowed to use 55.5 billion m^3 of Nile water each year. That water is nearly completely used already and a further increase in demand will result in a lower availability of water per hectare. Additional measures can and will be taken to increase the efficiency of water use in Egypt, but that will not be sufficient. It is no wonder that Egypt is looking into possibilities to increase the supply by taking measures upstream in Sudan and Ethiopia. Examples are the construction of reservoirs on the Blue Nile in Ethiopia and the Jonglei Canal in Sudan that will partly drain the swamps in the Sudd and decrease the evaporation from them. Cooperation with the other (nine) countries in the Nile basin is essential to enable those developments (see Figure 1.15). Hence, Egypt is a strong supporter of the work of the Nile Basin Initiative that provides a framework for this cooperation. Other countries in the basin are challenging the claim of Egypt for additional water. If Egypt is unable to increase its supply, it will be forced to lower its ambitions on horizontal expansion of agriculture in the desert and to provide other means of livelihood for its growing population.

2.10. Damming the Mekong

The Mekong River (Figures 1.16 and 1.17) flows some 4,200 km through Southeast Asia to the South China Sea through Tibet, Myanmar (Burma), Vietnam, Laos, Thailand and Cambodia. Its 'development' has been restricted over the past several decades because of regional conflicts, indeed those that have altered the history of the world. Now that these conflicts are reduced, investment capital is becoming available to develop the Mekong's resources for improved fishing, irrigation, flood control, hydroelectric power, tourism, recreation and navigation. The potential benefits are substantial, but so are the environmental and ecological risks.

During some months of the year the lack of rainfall causes the Mekong to fall dramatically. Salt water may penetrate as much as 500 km inland. In other months the flow can be up to thirty times the low flows, causing the water in the river to back up into wetlands and flood some 12,000 km^2 of forests and paddy fields in the Vietnamese delta region alone. The ecology of a major lake, Tonle Sap in Cambodia, depends on these backed-up waters.

While flooding imposes risks on some 50 million inhabitants of the Mekong floodplain, there are also distinct advantages. High waters deposit nutrient-rich silts on the low-lying farmlands, thus sparing the farmers from having to transport and spread fertilizers on their fields. Also, shallow lakes and submerged lands provide spawning habitats for about 90% of the fish in the Mekong Basin. Fish yield totals over half a million tons annually.

Figure 1.15. The Nile Basin.

Figure 1.16. The Mekong River is one of the few rivers that is still in equilibrium with surrounding life.

What will happen to the social fabric and to the natural environment if the schemes to build big dams across the mainstream of the Mekong are implemented? Depending on their operation, they could disrupt the current fertility cycles, habitats and habits of the fish in the river. Increased erosion downstream from major reservoirs is also a threat. Add to these the possible adverse impacts the need to evacuate and resettle thousands of people displaced by the lake behind the dams. How will they be resettled? And how long will it take them to adjust to new farming conditions?

There have been suggestions that a proposed dam in Laos could cause deforestation in a wilderness area of some 3,000 km^2. Much of the wildlife, including elephants, big cats and other rare animals, would have to be protected if they are not to become endangered. Malaria-carrying mosquitoes, liver fluke and other disease bearers might find ideal breeding grounds in the mud flats of the shallow reservoir. These are the types of issues that need to be considered now that increased development seems possible, and even likely.

Consider, for example, the impacts of a dam constructed on the Nam Pong River in northeast Thailand. The Nam Pong project was to provide hydroelectric power and irrigation water, the avowed purposes of many reservoir projects throughout the world. Considerable attention was paid to the social aspects of this project, but not to the environmental impacts. The project had a number of unexpected consequences, both beneficial and adverse.

Because the reservoir was acting as a bioreactor for most of the year, the fish population became so large that a major fishery industry has developed around the reservoir. The economic benefits of fish production exceeded those derived from hydropower. However, lack of adequate planning for this development resulted in less than ideal living and economic conditions for the migrating fishermen who came to this region.

Despite the availability of irrigation water, most farmers were still practising single-crop agriculture after the dam was built, and still growing traditional crops in their traditional ways. No training was provided for them to adapt their skills to the new conditions and opportunities. In addition, while farming income did not decrease, the general welfare and health of the population seems to have deteriorated. Again, little attention was given to diet and hygiene under these new conditions.

The reservoir itself had some adverse impacts along with the beneficial ones. These included increased erosion of the stream banks, silting up of the channel and a large increase in aquatic vegetation that clogged hydraulic machinery and reduced transport capacity.

3. So, Why Plan, Why Manage?

Water resources planning and management activities are usually motivated, as they were in each of the previous section's case examples, by the realization that there are both problems to solve and opportunities to obtain increased benefits from the use of water and related land

Figure 1.17. The Lower Mekong River Basin.

resources. These benefits can be measured in many different ways. Inevitably, it is not easy to agree on the best way to do so, and whatever is proposed may provoke conflict. Hence there is the need for careful study and research, as well as full stakeholder involvement, in the search for a shared vision of the best compromised plan or management policy.

Reducing the frequency and/or severity of the adverse consequences of droughts, floods and excessive pollution are common goals of many planning and management exercises. Other goals include the identification and evaluation of alternative measures that may increase the available water supplies or hydropower, improve recreation and/or navigation, and enhance the quality of water and aquatic ecosystems. Quantitative system performance criteria can help one judge the relative net benefits, however measured, of alternative plans and management policies.

System performance criteria of interest have evolved over time. They have developed from being primarily focused on safe drinking water just a century ago, to multipurpose economic development a half-century ago, to goals that now include environmental and ecosystem restoration and protection, aesthetic and recreational experiences, and more recently, sustainability (ASCE, 1998).

Some of the multiple purposes served by a river can be conflicting. A reservoir used solely for hydropower or water supply is better able to meet its objectives when it is full of water, rather than when it is empty. On the other hand, a reservoir used solely for downstream flood control is best left empty, until the flood comes of course. A single reservoir serving all three purposes introduces conflicts over how much water to store in it and how it should be operated. In basins where diversion demands exceed the available supplies, conflicts will exist over water allocations. Finding the best way to manage, if not resolve, these conflicts that occur over time and space are other reasons for planning.

3.1. Too Little Water

Issues involving inadequate supplies to meet demands can result from conflicts or concerns over land and water use. They can result from growing urbanization, the development of additional water supplies, the need to meet instream flow requirements, and conflicts over private property and public rights regarding water allocations. Other issues can involve trans-basin water transfers and markets, objectives of economic efficiency versus the desire to keep non-efficient activities viable, and demand management measures, including incentives for water reuse and water reuse financing.

Measures to reduce the demand for water in times of supply scarcity should be identified and agreed upon before everyone has to cope with an actual water scarcity. The institutional authority to implement drought measures when their designated 'triggers' – such as decreasing storage volumes in reservoirs – have been met should be established before the measures are needed. Such management responses may include increased groundwater abstractions to supplement low surface-water flows and storage volumes. Conjunctive use of ground and surface waters can be sustainable as long as the groundwater aquifers are recharged during conditions of high flow and storage volumes.

3.2. Too Much Water

Damage due to flooding is a direct result of floodplain development that is vulnerable to floods. This is a risk many take, and indeed on average it may result in positive private net benefits, especially when public agencies subsidize these private risk takers in times of flooding. In many river basins of developed regions, the level of annual expected flood damage is increasing over time, in spite of increased expenditures on flood damage reduction measures. This is mainly due to increased economic development on river floodplains, not to increased frequencies or magnitudes of floods.

The increased economic value of the development on floodplains often justifies increased expenditure on flood damage reduction measures. Flood protection works decrease the risks of flooding and consequent damage, creating an incentive for increased economic development. Then when a flood exceeding the capacity of existing flood protection works occurs, and it will, even more damage results. This cycle of increasing flood damage and cost of protection is a natural result of the increasing values of floodplain development.

Just what is the appropriate level of risk? It may depend, as Figure 1.18 illustrates, on the level of flood insurance or subsidy provided when flooding occurs.

Flood damage will decrease only if restrictions are placed on floodplain development. Analyses carried out during planning can help identify the appropriate level of

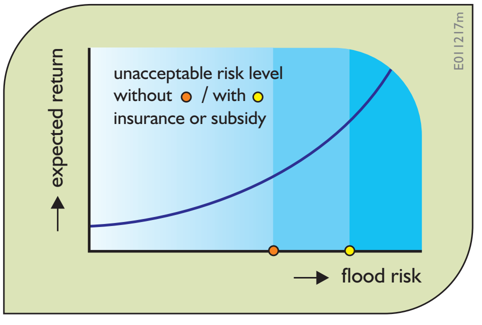

Figure 1.18. The lowest risk of flooding on a floodplain does not always mean the best risk, and what risk is acceptable may depend on the amount of insurance or subsidy provided when flood damage occurs.

development and flood damage protection works, on the basis of both the beneficial and the adverse economic, environmental and ecological consequences of floodplain development. People are increasingly recognizing the economic as well as environmental and ecological benefits of allowing floodplains to do what they were formed to do: store flood waters when floods occur.

3.3. Polluted Water

The discharges of wastewater by industry and households can have considerable detrimental effects on water quality and, hence, often on public and ecosystem health. Planning and management activities should pay attention to these possible negative consequences of industrial development, population growth and the intensive use of pesticides and fertilizers in urban as well as in agricultural areas. Issues regarding the environment and water quality include:

- upstream versus downstream conflicts on meeting water quality standards
- threats from aquatic nuisance species
- threats from the chemical, physical and biological water quality of the watershed's aquatic resources
- quality standards for recycled water
- non-point source pollution discharges, including sediment from erosion
- inadequate groundwater protection compacts and concerned institutions.

We still know too little about the environmental and health impacts of many of the wastewater constituents found in river waters. As more is learned about, for example, the harmful effects of heavy metals and dioxins, our plans and management policies should be adjusted accordingly. Major fish losses and algae blooms point to the need to manage water quality as well as quantity.

3.4. Degradation of Aquatic and Riparian Ecosystems

Aquatic and riparian ecosystems may be subject to a number of threats. The most important include habitat loss due to river training and reclamation of floodplains and wetlands for urban and industrial development, poor water quality due to discharges of pesticides, fertilizers and wastewater effluents, and the infestation of aquatic nuisance species.

Exotic aquatic nuisance species can be major threats to the chemical, physical and biological water quality of a river's aquatic resources, and a major interference with other uses. The destruction and/or loss of the biological integrity of aquatic habitats caused by introduced exotic species is considered by many ecologists to be among the most important problems facing natural aquatic and terrestrial ecosystems. The biological integrity of natural ecosystems is controlled by habitat quality, water flows or discharges, water quality and biological interactions including those involving exotic species.

Once exotic species are established, they are usually difficult to manage and nearly impossible to eliminate. This creates a costly burden for current and future generations. The invasion in North America of non-indigenous aquatic nuisance species such as the sea lamprey, zebra mussel, purple loosestrife, European green crab and various aquatic plant species, for example, has had pronounced economic and ecological consequences for all who use or otherwise benefit from aquatic ecosystems.

Environmental and ecological effectiveness as well as economic efficiency should be a guiding principle in evaluating alternative solutions to problems caused by aquatic nuisance organisms. Funds spent on proper prevention and early detection and eradication of aquatic nuisance species may reduce the need to spend considerably greater funds on management and control once such species are well established.

3.5. Other Planning and Management Issues

Navigation

Industrial and related port development may result in the demand for deeper rivers to allow the operation of larger-draught cargo vessels in the river. River channel improvement cannot be detached from functions such as water supply and flood control. Narrowing the river for shipping purposes may increase floodwater levels.

River Bank Erosion

Bank erosion can be a serious problem where people are living close to morphologically active (eroding) rivers.

Bangladesh, where bank erosion is considered to be a much more urgent problem than the well-known floods of that country, is an example of this. Predictions of changes in river courses due to bank erosion and bank accretion are important inputs to land use planning in river valleys and the choice of locations for bridges and hydraulic structures.

Reservoir Related Issues

Degradation of the riverbed upstream of reservoirs may increase the risks of flooding in those areas. Reservoir construction inevitably results in loss of land and forces the evacuation of residents due to impoundment. Dams can be ecological barriers for migrating fish species such as salmon. The water and sediment quality in the reservoir may deteriorate and the in-flowing sediment may accumulate, reducing the active (useful) capacity of the reservoir. Other potential problems may include those stemming from stratification, water related diseases, algae growth and abrasion of hydropower turbines.

Environmental and morphological impacts downstream of the dam are often due to a changed river hydrograph and decreased sediment load in the water released from the reservoir. Lower sediment loads result in higher scouring of downstream riverbeds and consequently a lowering of their elevations. Economic as well as social impacts include the risk of dams breaking. Environmental impacts may result from sedimentation control measures (e.g., sediment flushing) and reduced oxygen content of the out-flowing water.

The ecological, environmental and economic impacts of dams and reservoirs are heavily debated among planners and environmentalists. In creating a new framework for decision-making, the World Commission on Dams compiled and considered the arguments of all sides of this debate (WCD, 2000).

4. System Components, Planning Scales and Sustainability

Water resources management involves influencing and improving the interaction of three interdependent subsystems:

- the natural river subsystem in which the physical, chemical and biological processes take place
- the socio-economic subsystem, which includes the human activities related to the use of the natural river system
- the administrative and institutional subsystem of administration, legislation and regulation, where the decision and planning and management processes take place.

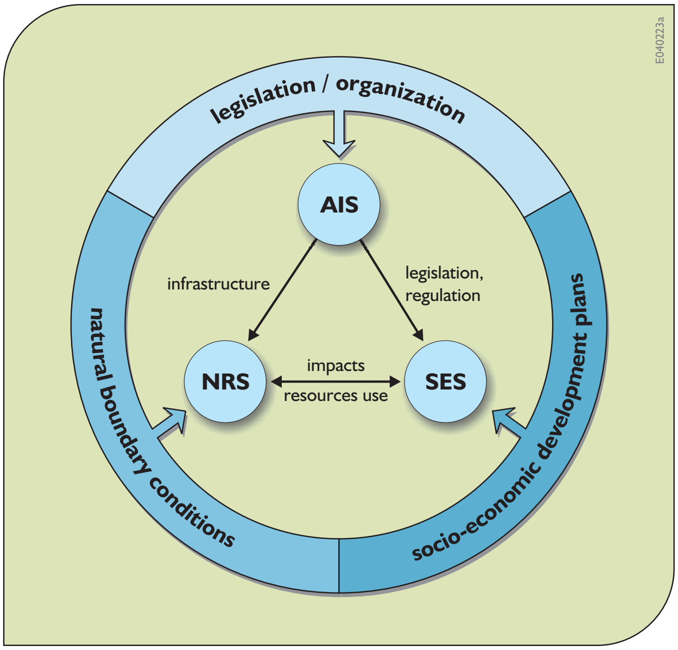

Figure 1.19. Interactions among subsystems and between them and their environment.

Figure 1.19 illustrates the interaction between these subsystems, all three of which should be included in any analysis performed for water resource systems planning and management. Inadequate attention to one can destroy the value of any work done to improve the performance of the others.

Appendix A describes the major components of the natural system and their processes and interactions.

4.1. Spatial Scales for Planning and Management

Watersheds or river basins are usually considered logical regions for water resources planning and management. This makes sense if the impacts of decisions regarding water resources management are contained within the watershed or basin. How land and water are managed in one part of a river basin can affect the land and water in other parts of the basin. For example, the discharge of pollutants or the clearing of forests in the upstream portion of the basin may degrade the quality and increase the variability of the flows and sedimentation downstream. The construction of a dam or weir in the downstream part of a river may prevent vessels and fish from travelling upstream. To maximize the economic and social benefits obtained from the entire basin, and to ensure that these benefits and accompanying costs are equitably distributed, planning and management is often undertaken on a basin scale.

While basin boundaries make sense from a hydrological point of view, they may be inadequate for addressing particular water resources problems that are caused by events taking place outside the basin. What is desired is the highest level of performance, however defined, of the entire physical, socio-economic and administrative water resource system. To the extent that the applicable problems, stakeholders and administrative boundaries extend outside the river basin, the physically based 'river basin' focus of planning and management should be expanded to include the entire applicable 'problem-shed'. Hence, consider the term 'river basin' used in this book to mean problem-shed when appropriate.

4.2. Temporal Scales for Planning and Management

Water resources planning requires looking into the future. Decisions recommended for the immediate future should take account of their long-term future impacts. These impacts may also depend on economic, demographic and physical conditions now and on into some distant future. The question of just how far into the future one need look, and try to forecast, is directly dependent on the influence that future forecast has on the present decisions. What is most important now is what decision to make now. Decisions that are to be made later can be based on updated forecasts, then-current information and planning and management objectives. Planning is a continuing sequential process. Water resources plans need to be periodically updated and adapted to new information, new objectives, and updated forecasts of future supplies, demands, costs and benefits.

The number and duration of within-year time periods explicitly considered in the planning process will be dependent in part on the need to consider the variability of the supplies and demands for water resources and on the purposes to be served by the water resources within the basin. Irrigation planning and summer-season water recreation planning may require a greater number of within-year periods during the summer growing and recreation season than might be the case if one were considering only municipal water supply planning, for example. Assessing the impacts of alternatives for conjunctive surface and groundwater management, or for water quantity and quality management, require attention to processes that take place on different spatial and temporal scales.

4.3. Sustainability

Sustainable water resources systems are those designed and managed to best serve people living today and in the future. The actions that we as a society take now to satisfy our own needs and desires should depend not only on what those actions will do for us but also on how they will affect our descendants. This consideration of the long-term impacts on future generations of actions taken now is the essence of sustainable development. While the word 'sustainability' can mean different things to different people, it always includes a consideration of the welfare of those living in the future. While the debate over a more precise definition of sustainability will continue, and questions over just what it is that should be sustained may remain unanswered, this should not delay progress toward achieving more sustainable water resources systems.

The concept of environmental and ecological sustainability has largely resulted from a growing concern about the long-run health of our planet. There is increasing evidence that our present resource use and management activities and actions, even at local levels, can significantly affect the welfare of those living within much larger regions in the future. Water resource management problems at a river basin level are rarely purely technical and of interest only to those living within the individual river basins where those problems exist. They are increasingly related to broader societal structures, demands and goals.

What would future generations like us to do for them? We don't know, but we can guess. As uncertain as these guesses will be, we should take them into account as we act to satisfy our own immediate needs, demands and desires. There may be tradeoffs between what we wish to do for ourselves in our current generation versus what we think future generations might wish us to do for them. These tradeoffs, if any, between what present and future generations would like should be considered and debated in the political arena. There is no scientific theory to help us identify which tradeoffs, if any, are optimal.

The inclusion of sustainability criteria along with the more common economic, environmental, ecological and social criteria used to evaluate alternative water resources development and management strategies may identify a need to change how we commonly develop and use our water resources. We need to consider the impacts of change itself. Change over time is certain – just what it will be is uncertain. These changes will affect the physical, biological and social dimensions of water resource systems. An essential aspect in the planning, design and management of sustainable systems is the anticipation of change. This includes change due to geomorphologic processes, the aging of infrastructure, shifts in demands or desires of a changing society, and even increased variability of water supplies, possibly because of a changing climate. Change is an essential feature of sustainable water resources development and management.

Sustainable water resources systems are those designed and operated in ways that make them more adaptive, robust and resilient to an uncertain and changing future. They must be capable of functioning effectively under conditions of changing supplies, management objectives and demands. Sustainable systems, like any others, may fail, but when they fail they must be capable of recovering and operating properly without undue costs.

In the face of certain changes, but with uncertain impacts, an evolving and adaptive strategy for water resources development, management and use is a necessary condition of sustainable development. Conversely, inflexibility in the face of new information, objectives and social and political environments is an indication of reduced system sustainability. Adaptive management is a process of adjusting management actions and directions, as appropriate, in the light of new information on the current and likely future condition of our total environment and on our progress toward meeting our goals and objectives. Water resources development and management decisions can be viewed as experiments, subject to modification, but with goals clearly in mind. Adaptive management recognizes the limitations of current knowledge and experience as well as those that we learn by experimenting. It helps us move toward meeting our changing goals over time in the face of this incomplete knowledge and uncertainty. It accepts the fact that there is a continual need to review and revise management approaches because of the changing, as well as uncertain, nature of our socio-economic and natural environments.

Changing the social and institutional components of water resources systems is often the most challenging task, because it involves changing the way individuals think and act. Any process involving change will require that we change our institutions – the rules under which we as a society function. Individuals are primarily responsible for, and adaptive to, changing political and social situations. Sustainability requires that public and private institutions also change over time in ways that are responsive to the needs of individuals and society.

Given the uncertainty of what future generations will want, and the economic, environmental and ecological problems they will face, a guiding principle for the achievement of sustainable water resource systems is to provide options to future generations. One of the best ways to do this is to interfere as little as possible with the proper functioning of natural life cycles within river basins, estuaries and coastal zones. Throughout the water resources system planning and management process, it is important to identify all the beneficial and adverse ecological, economic, environmental and social effects – especially the long-term effects – associated with any proposed project.

5. Planning and Management

5.1. Approaches

There are two general approaches to planning and management. One is from the top down, often called command and control. The other is from the bottom up, often called a grass-roots approach. Both approaches can lead to an integrated plan and management policy.

5.1.1. Top-Down Planning and Management

Over much of the past half century, water resources professionals have been engaged in preparing integrated, multipurpose 'master' development plans for many of the world's river basins. These plans typically consist of a series of reports, complete with numerous appendices, describing all aspects of water resources management and use. In these documents alternative structural and non-structural management options are identified and evaluated. On the basis of these evaluations, the preferred plan is presented.

This master planning exercise has typically been a top-down approach that professionals have dominated. Using this approach there is usually little if any active participation by interested stakeholders. The approach assumes that one or more institutions have the ability and authority to develop and implement the plan, in other words, that will oversee and manage the coordinated development and operation of the basin's activities that affect the surface and ground waters of the basin. In today's environment, where publics are calling for less governmental oversight, regulation and control, and increasing participation in planning and management activities, top-down approaches are becoming less desirable or acceptable.

5.1.2. Bottom-Up Planning and Management

Within the past decade water resources planning and management processes have increasingly involved the active participation of interested stakeholders – those affected in any way by the management of the water and land resources. Plans are being created from the bottom up rather than top down. Concerned citizens and non-governmental organizations, as well as professionals in governmental agencies, are increasingly working together towards the creation of adaptive comprehensive water management programs, policies and plans.

Experiences of trying to implement plans developed primarily by professionals without significant citizen involvement have shown that, even if such plans are technically flawless, they have little chance of success if they do not take into consideration the concerns of affected local stakeholders and do not have their support. To gain this, concerned stakeholders must be included in the decision-making process as early as possible. They must become part of that process, not merely as spectators or advisors to it. This will help gain their cooperation and commitment to the plans adopted. Participating stakeholders will have a sense of ownership, and as such will strive to make the plans work. Such plans, if they are to be successfully implemented, must also fit within existing legislative, permitting, enforcement and monitoring programmes. Stakeholder participation improves the chance that the system being managed will be sustainable.

Successful planning and management involves motivating all potential stakeholders and sponsors to join in the water resources planning and management process, determining their respective roles and establishing how to achieve consensus on goals and objectives. Ideally this should occur before addressing conflicting issues so that all involved know each other and are able to work together more effectively. Agreements on goals and objectives and on the organization (or group formed from multiple organizations) that will lead and coordinate the water resources planning and management process should be reached before stakeholders bring their individual priorities or problems to the table. Once the inevitable conflicts become identified, the settling of administrative matters doesn't get any easier.

Bottom-up planning must strive to achieve a common or 'shared' vision of goals and priorities among all stakeholders. It must be aware of and comply with all applicable laws and regulations. It should strive to identify and evaluate multiple alternatives and performance criteria – including sustainability criteria – and yet keep the process from producing a wish-list of everything each stakeholder wants. In other words, it must identify tradeoffs among conflicting goals or measures of performance, and prioritize appropriate strategies. It must value and compare, somehow, the intangible and non-monetary impacts of environmental and ecosystem protection and restoration with other activities whose benefits and costs can be expressed in monetary units. In doing so, planners should use modern information technology to improve both the process and product. This technology, however, will not eliminate the need to reach conclusions and make decisions on the basis of incomplete and uncertain data and scientific knowledge.

These process issues focus on the need to make water resources planning and management as efficient and effective as possible. Many issues will arise in terms of evaluating alternatives and establishing performance criteria (prioritizing issues and possible actions), performing incremental cost analysis, and valuing monetary and non-monetary benefits. Questions must be answered as to how much data must be collected and with what precision, and what types of modern information technology (e.g., geographic information systems (GIS), remote sensing, Internet, decision support systems, etc.) can be beneficially used for both analyses and communication.

5.1.3. Integrated Water Resources Management

The concept of integrated water resources management (IWRM) has been developing since the beginning of the eighties. IWRM is the response to the growing pressure on our water resources systems caused by growing population and socio-economic developments. Water shortages and deteriorating water quality have forced many countries in the world to reconsider their options with respect to the management of their water resources. As a result water resources management (WRM) has been undergoing a change worldwide, moving from a mainly supply-oriented, engineering-biased approach towards a demand-oriented, multi-sectoral approach, often labelled integrated water resources management.

In international meetings, opinions are converging to a consensus about the implications of IWRM. This is best reflected in the Dublin Principles of 1992 (see Box 1.1), which have been universally accepted as the base for IWRM. The concept of IWRM makes us move away from top-down 'water master planning' (see Section 5.1.1), which focuses on water availability and development, towards 'comprehensive water policy planning' which addresses the interaction between different sub-sectors, seeks to establish priorities, considers institutional requirements and deals with the building of management capacity.

IWRM considers the use of the resources in relation to social and economic activities and functions. These also determine the need for laws and regulations for the sustainable use of the water resources. Infrastructure made available, in relation to regulatory measures and mechanisms, will allow for effective use of the resource, taking due account of the environmental carrying capacity (Box 1.2).

Box 1.1. The Dublin Principles

1. Water is a finite, vulnerable and essential resource, essential to sustain life, development and the environment.
2. Water resources development and management should be based on a participatory approach, involving users, planners and policy makers at all levels.
3. Women play a central role in the provision, management and safeguarding of water.
4. Water has an economic value in all its competing uses and should be recognized as an economic good.

Box 1.2. Definition of IWRM

IWRM is 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*.

(GWP, 2000)

5.2. Planning and Management Aspects

5.2.1. Technical Aspects

Technical aspects of planning include hydrological assessments. These identify and characterize the properties of, and interactions among, the resources in the basin or region, including the land, the rainfall, the runoff, the stream and river flows and the groundwater.

Existing watershed land use and land cover, and future changes in this use and cover, result in part from existing and future changes in regional population and economy. Planning involves predicting changes in land use/covers and economic activities at watershed and river basin levels. These will influence the amount of runoff, and the concentrations of sediment and other quality constituents (organic wastes, nutrients, pesticides, etc.) it contains as a result of any given pattern of rainfall over the land area. These predictions will help planners estimate the quantities and qualities of flows and their constituents throughout a watershed or basin, associated with any land use and water management policy. This in turn provides the basis for predicting the type and health of terrestrial and aquatic ecosystems in the basin. All of this may affect the economic development of the region, which in part determines the future demands for changes in land use and land cover.

Technical aspects also include the estimation of the costs and benefits of any measures taken to manage the basin's water resources. These measures might include:

- engineering structures for making better use of scarce water
- canals and water-lifting devices
- dams and storage reservoirs that can retain excess water from periods of high-flow for use during the periods of low-flow (and may reduce flood damage below the reservoir by storing floodwater)
- open channels that may take the form of a canal, flume, tunnel or partly filled pipe
- pressure conduits
- diversion structures, ditches, pipes, checks, flow dividers and other engineering facilities necessary for the effective operation of irrigation and drainage systems
- municipal and industrial water intakes, including water purification plants and transmission facilities
- sewerage and industrial wastewater treatment plants, including waste collection and ultimate disposal facilities
- hydroelectric power storage, run-of-river or pumped storage plants,
- river channel regulation works, bank stabilization, navigation dams and barrages, navigation locks and other engineering facilities for improving a river for navigation
- levees and floodwalls for confinement of the flow within a predetermined channel.

Not only must the planning process identify and evaluate alternative management strategies involving structural and non-structural measures that will incur costs and bring benefits, but it must also identify and evaluate alternative time schedules for implementing those measures. The planning of development over time involving interdependent projects, uncertain future supplies and demands as well as costs, benefits and interest (discount) rates is part of all water resources planning and management processes.

With increasing emphasis placed on ecosystem preservation and enhancement, planning must include ecologic impact assessments. The mix of soil types and depths and land covers together with the hydrological quantity and quality flow and storage regimes in rivers, lakes, wetlands and aquifers affect the riparian and aquatic ecology of the basin. Water managers are being asked to consider ways of improving or restoring ecosystems by, for example, reducing:

- the destruction and/or loss of the biological integrity of aquatic habitats caused by introduced exotic species
- the decline in number and extent of wetlands and the adverse impacts on wetlands of proposed land and water development projects
- the conflicts between the needs of people for water supply, recreation, energy, flood control, and navigation infrastructure and the needs of ecological communities, including endangered species.

And indeed there are and will continue to be conflicts among alternative objectives and purposes of water management. Planners and managers must identify the trade-offs among environmental, ecologic, economic and social impacts, however measured, and the management alternatives that can balance these often-conflicting interests.

5.2.2. Economic and Financial Aspects

The fourth Dublin principle states that water has an economic value in all its competing uses and should be recognized as an economic good. This principle addresses the need to extract the maximum benefits from a limited resource as well as the need to generate funds to recover the costs of the investments and of the operation and maintenance of the system.

The maximization of benefits is based on a common economic market approach. Many past failures in water resources management are attributable to the fact that water has been – and still is – viewed as a free good. Prices of water for irrigation and drinking water are in many countries well below the full cost of the infrastructure and personnel needed to provide that water, which comprises the capital charges involved, the operation and maintenance (O&M) costs, the opportunity cost, economic externalities and environmental externalities (see GWP, 2000). Charging for water at less than full cost means that the government, society and/or environment 'subsidizes' water use and leads to sub-optimal use of the resource.

Recognizing water as an economic good does not always mean that full costs should be charged. Poor people have the right to safe water and this should be taken into account. For that reason the fourth Dublin principle is often referred to as water being an economic and social good.

Cost recovery is the second reason for the fourth Dublin principle. The overriding financial component of any planning process is to make sure that the recommended plans and projects are able to pay for themselves. Revenues are needed to recover construction costs, if any, and to maintain, repair and operate any infrastructure designed to manage the basin's water resources. This may require cost-recovery policies that involve pricing the outputs of projects. Beneficiaries should be expected to pay at least something, and in some way, for the added benefits they get. Planning must identify equitable cost and risk-sharing policies and improved approaches to risk/cost management. In many developing countries a distinction is made between cost recovery of investments and cost recovery of O&M costs. Cost recovery of O&M costs is a minimum condition for a sustainable project. Without that, it is likely that the performance of the project will deteriorate seriously over time.

In most WRM studies, financial viability is viewed as a constraint that must be satisfied. It is not viewed as an objective whose maximization could result in a reduction in economic efficiency, equity or other non-monetary objectives.

5.2.3. Institutional Aspects

The first condition for successful project implementation is to have an enabling environment. There must exist national, provincial and local policies, legislation and institutions that make it possible for the right decisions to be taken and implemented correctly. The role of the government is crucial. The reasons for governmental involvement are manifold:

- Water is a resource beyond property rights: it cannot be 'owned' by private persons. Water rights can be given to persons or companies, but only the rights to use the water and not to own it. Conflicts between users automatically turn up at the table of the final owner of the resource – the government.
- Water is a resource that often requires large investment to develop. Many water resources development projects are very expensive and have many beneficiaries. Examples are multipurpose reservoirs and the construction of dykes along coasts and rivers. The required investments need large financial commitments which only can be made by the government or state-owned companies.
- Water is a medium that can easily transfer external effects. The use of water by one person often has negative effects on others (externalities). The obvious example is the discharge of waste into a river that may have negative effects on downstream users.

Only the government can address these issues and 'good governance' is necessary for good water management.

An insufficient institutional setting and the lack of a sound economic base are the main causes of water resources development project failure, not technical inadequacy of design and construction. This is also the reason why at present much attention is given to institutional developments in the sector, in both developed and developing countries. In Europe, various types of water agencies are operational (e.g., the Agence de l'Eau in France and the water companies in England), each having advantages and disadvantages. The Water Framework Directive of the European Union requires that water management be carried out at the scale of a river basin, particularly when this involves transboundary management. It is very likely that this will result in a shift in responsibilities of the institutions involved and the establishment of new institutions. In other parts of the world experiments are being carried out with various types of river basin organizations, combining local, regional and sometimes national governments.

5.3. Analyses for Planning and Management

Analyses for water resources planning and management generally comprise several stages. The explicit description of these stages is referred to as the *analytical* (or conceptual) framework. Within this framework, a set of coherent models for the quantitative analysis of measures and strategies is used. This set of models and related databases will be referred to as the *computational* framework. This book is mainly about the computational framework.

The purpose of the analyses is to prepare and support planning and management decisions. The main phases of the analytical framework therefore correspond to the phases of the decision process. Such a decision process is not a simple, one-line sequence of steps. Inherent in a decision-making process are factors causing the decision-makers to return to earlier steps of the process. Part of the process is thus cyclic. A distinction is made between comprehension cycles and feedback cycles. A *comprehension* cycle improves the decision-makers' understanding of a complex problem by cycling within or between steps. *Feedback* cycles imply returning to earlier phases of the process. They are needed when:

- solutions fail to meet criteria.
- new insights change the perception of the problem and its solutions (e.g., due to more/better information).
- essential system links have been overlooked.
- situations change (political, international, societal developments).

As an example, the analytical framework that is used by Delft Hydraulics for WRM studies is depicted in Figure 1.20. The three elementary phases of that framework are:

- inception
- development
- selection.

During each phase the processes have a cyclic component (comprehensive cycle). Interaction with the decision-makers, or their representatives, is essential throughout the process. Regular reporting through inception and interim reports will improve the effectiveness of the communication.

The first phase of the process is the inception phase. Here the subject of the analysis (what is analysed under

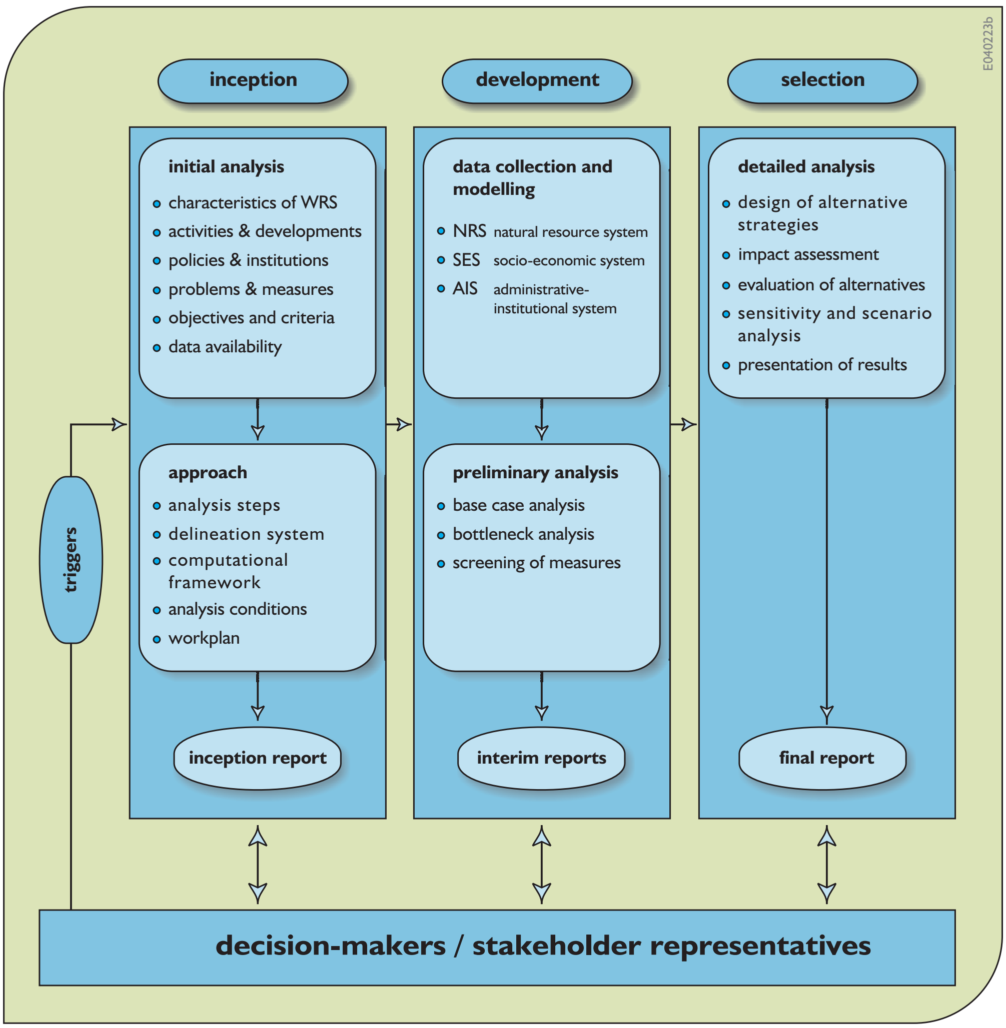

Figure 1.20. Typical analytical framework for water resources studies.

what conditions) and its object (the desired results of the analysis) are specified. Based on this initial analysis, during which intensive communication with (representatives of the) decision-makers is essential, the approach for the policy analysis is specified. The results of the inception phase are presented in the inception report, which includes the work plan for the other phases of the analysis process (project).

In the development phase tools are developed for analysing and identifying possible solutions to the WRM problems. The main block of activities is usually related to data collection and modelling. Various preliminary analyses will be made to ensure that the tools developed for the purpose are appropriate for solving the WRM problems. Individual measures will be developed and screened in this phase, and preliminary attempts will be made to combine promising measures into management strategies. The development phase is characterized by an increased understanding of the functioning of the water resources system, starting with limited data sets and simplified tools and ending at the levels of detail deemed necessary in the inception phase. Scanning of possible measures should also start as soon as possible during this phase. The desired level of detail in the data collection and modelling strongly depends on what is required to distinguish among the various measures being considered. Interactions with decision-makers are facilitated through the presentation of interim results in interim reports.

The purpose of the selection phase is to prepare a limited number of promising strategies based on a detailed analysis of their effects on the evaluation criteria, and to present them to the decision-makers, who will make the final selection. Important activities in this phase are strategy design, evaluation of strategies and presentation. The results of this phase are included in the final report

Although it is clear that analyses are made to support the decision-making process, it is not always clear who will make the final decision, or who is the decision-maker. If analyses are contracted to a consultant, careful selection of the appropriate coordinating agency is instrumental to the successful implementation of the project. It is always advantageous to use existing line agencies as much as possible. Interactions with the decision-makers usually take place through steering commissions (with an interdepartmental forum) and technical advisory committees. Appendix E of this book describes this analytical framework in more detail.

5.4. Models for Impact Prediction and Evaluation

The process of planning has undergone a significant transformation over the past several decades, mainly due to the continuing development of improved computational technology, and various water resource simulation and optimization models together with their associated databases and user-friendly interactive interfaces. Planning today is heavily dependent on the use of computer-based impact prediction models. Such models are used to assist in the identification and evaluation of alternative ways of meeting various planning and management objectives. They provide an efficient way of analysing spatial and temporal data in an effort to predict the interaction and impacts, over space and time, of various river basin components under alternative designs and operating policies.

Many of the systems analysis approaches and models discussed in the accompanying chapters of this book have been, and continue to be, central to the planning and management process. Their usefulness is directly dependent on the quality of the data and models being used. Models can assist planning and management at different levels of detail. Some are used for preliminary screening of alternative plans and policies, and as such do not require major data collection efforts. Screening models can also be used to estimate how significant certain data and assumptions are for the decisions being considered, and hence can help guide additional data collection activities. At the other end of the planning and management spectrum, much more detailed models can be used for engineering design. These more complex models are more data demanding, and typically require higher levels of expertise for their proper use.

The integration of modelling technology into the social and political components of the planning and management processes in a way that enhances those processes continues to be the main challenge of those who develop planning and management models. Efforts to build and apply interactive generic modelling programs or 'shells,' on which interested stakeholders can 'draw in' their system, enter their data and operating rules at the level of detail desired, run simulations, and discover the effect of alternative assumptions and operating rules, has in many cases helped to create a common or shared understanding among these stakeholders. Getting stakeholders involved in developing and experimenting with their own interactive data-driven models has been an effective way of building a consensus–a shared vision.

5.5. Shared-Vision Modelling

Participatory planning inevitably involves conflict management. Each stakeholder or interest group has its objectives, interests and agendas. Some of these may be in conflict with others. The planning and management process is one of negotiation and compromise. This takes time but, from it can come decisions that have the best chance of being considered right and fair or equitable by most participants. Models can assist in this process of reaching a common understanding and agreement among different stakeholders. This has a greater chance of happening if the stakeholders themselves are involved in the modelling and analysis process.

Involving stakeholders in model-building accomplishes a number of things. It gives them a feeling of ownership. They will have a much better understanding of just what their model can do and what it cannot. If they are involved in model-building, they will know the assumptions built into their model.

Being involved in a joint modelling exercise is a way to understand better the impacts of various assumptions. While there may be no agreement on the best of various assumptions to make, stakeholders can learn which of those assumptions matter and which do not. In addition, the process of model development by numerous stakeholders will itself create discussions that will lead toward a better understanding of everyone's interests and concerns. Though such a model-building exercise, it is possible those involved will reach not only a better understanding of everyone's concerns, but also a common or 'shared' vision of at least how their system (as represented by their model, of course) works.

5.6. Adaptive Integrated Policies

One of the first issues to address when considering water resources planning and management activities is the product desired. If it is to be a report, what should the report contain? If it is to be a model or a decision support system, what should be its capabilities?

Clearly a portion of any report should contain a discussion of the water resources management issues and options. Another part of the report might include a prioritized list of strategies for addressing existing problems and available development or management opportunities in the basin.

Recent emphasis has shifted from structural engineering solutions to more non-structural alternatives, especially for environmental and ecosystem restoration. Part of this shift reflects the desire to keep more options open for future generations. It reflects the desire to be adaptive to new information and to respond to surprises – impacts not forecasted. As we learn more about how river basins, estuaries and coastal zones work, and how humans can better manage those resources, we do not want to regret what we have done in the past that may preclude this adaptation.

In some situations it may be desirable to create a 'rolling' plan – one that can be updated at any time. This permits responses to resource management and regulatory questions when they are asked, not just at times when new planning and management exercises take place. While this appears to be desirable, will planning and management organizations have the financing and support to maintain and update the modelling software used to estimate various impacts, collect and analyse new data, and maintain the expertise, all of which are necessary for continuous planning (rolling plans)?

Consideration also needs to be given to improving the quality of the water resources planning and management review process, and focusing on outcomes themselves rather than output measures. One of the outcomes should be an increased understanding of some of the relationships between various human activities and the hydrology and ecology of the basin, estuary or coastal zone. Models developed for predicting the economic as well as ecologic interactions and impacts due to changes in land and water management and use could be used to address questions such as:

- What are the hydrological, ecological and economic consequences of clustering or dispersing human land uses such as urban and commercial developments and large residential areas? Similarly, what are the consequences of concentrated versus dispersed patterns of reserve lands, stream buffers and forestland?

- What are the costs and ecological benefits of a conservation strategy based on near-stream measures (e.g., riparian buffers) versus near-source (e.g., upland/site-edge) measures? What is the relative cost of forgone upland development versus forgone valley or riparian development? Do costs strongly limit the use of stream buffer zones for mitigating agriculture, residential and urban developments?
- Should large intensive developments be best located in upland or valley areas? Does the answer differ depending on economic, environmental or aquatic ecosystem perspectives? From the same perspectives, is the most efficient and desirable landscape highly fragmented or highly zoned with centres of economic activity?
- To what extent can riparian conservation and enhancement mitigate upland human land use effects? How do the costs of upland controls compare with the costs of riparian mitigation measures?
- What are the economic and environmental quality tradeoffs associated with different areas of various classes of land use such as commercial/urban, residential, agriculture and forest?
- Can adverse effects on hydrology, aquatic ecology and water quality of urban areas be better mitigated through upstream or downstream management approaches? Can land controls like stream buffers be used at reasonable cost within urban areas, and if so, how effective are they?
- Is there a threshold size for residential/commercial areas that yield marked ecological effects?
- What are the ecological states at the landscape scale that, once attained, become irreversible with reasonable mitigation measures? For example, once stream segments in an urban setting become highly altered by direct and indirect effects (e.g., channel bank protection and straightening and urban runoff), can they be restored with feasible changes in urban land use or mitigation measures?
- Mitigating flood risk by minimizing floodplain developments coincides with conservation of aquatic life in streams. What are the economic costs of this type of risk avoidance?
- What are the economic limitations and ecological benefits of having light residential zones between waterways and commercial, urban or agricultural lands?
- What are the economic development decisions that are irreversible on the landscape? For example, once land is used for commercial development, it is normally too costly to return it to agriculture. This would identify limits on planning and management for conservation and development.
- What are the associated ecological and economic impacts of the trend in residential, commercial and forest lands replacing agricultural lands?

The answers to these and similar questions may well differ in different regions. However, if we can address them on a regional scale – in multiple river basins – we might begin to understand and predict better the interactions among economy, environment and ecology as a function of how we manage and use its land and water. This in turn may help us better manage and use our land and water resources for the betterment of all – now and in the future.

5.7. Post-Planning and Management Issues

Once a plan or strategy is produced, common implementation issues include seeing that the plan is followed, and modified, as appropriate, over time. What incentives need to be created to ensure compliance? How are the impacts resulting from the implementation of any decision going to be monitored, assessed and modified as required and desired? Who is going to be responsible? Who is going to pay, and how much? Who will keep the stakeholders informed? Who will keep the plan current? How often should plans and their databases be updated? How can new projects be operated in ways that increase the efficiencies and effectiveness of joint operation of multiple projects in watersheds or river basins – rather than each project being operated independently of the others? These questions should be asked and answered, at least in general terms, before the water resources planning and management process begins. The questions should be revisited as decisions are made and when answers to them can be much more specific.

6. Meeting the Planning and Management Challenges: A Summary

Planning (the formulation of development and management plans and policies) is an important and often indispensable means to support and improve operational management. It provides an opportunity to:

- assess the current state of the water resources and the conflicts and priorities over their use, formulate visions, set goals and targets, and thus orient operational management
- provide a framework for organizing policy relevant research and public participation
- increase the legitimacy, public acceptance of (or even support for) the way the resources are to be allocated or controlled, especially in times of stress
- facilitate the interaction, discussion and coordination among managers and stakeholders, and generate a common point of reference – a management plan or policy.

Many of the concerns and issues being addressed by water resources planners and managers today are similar to those faced by planners and managers in the past. But some are different. Most of the new ones are the result of two trends: first, a growing concern for the sustainability of natural ecosystems and second, an increased recognition of the need of a bottom-up 'grass-roots' participatory approach to planning, managing and decision-making.

Today planners work for economic development and prosperity as they did in the past, keeping in mind environmental impacts and goals as they did then, but now recognizing ecological impacts and values as well. Water resources management may still be focused on controlling and mitigating the adverse impacts of floods and droughts and water pollution, on producing hydropower, on developing irrigation, on controlling erosion and sediment, and on promoting navigation, but only as these and similar activities are compatible with healthy ecosystems. Natural ecosystems generally benefit from the variability of natural hydrological regimes. Other uses prefer less variability. Much of our engineering infrastructure is operated so as to reduce hydrological variability. Today water resource systems are increasingly required to provide rather than reduce hydrological (and accompanying sediment load) variability. Reservoir operators, for example, can modify their water release policies to increase this variability. Farmers and land-use developers must minimize rather than encourage land-disturbing activities. Floodplains may need to get wet occasionally. Rivers and streams may need to meander and fish species that require habitats along the full length of rivers to complete their life cycles must have access to those river reaches. Clearly these ecological objectives, added to all the other economic and environmental ones, can only compound the conflicts and issues with respect to land and water management and use.

So, how can we manage all this conflict and uncertainty? We know that water resources planning and management should be founded on sound science, efficient public programme administration and the broad participation of stakeholders. Yet obtaining each of these three conditions is a challenge. While the natural and social sciences can help us predict the economic, environmental and ecological impacts of alternative decisions, those predictions are never certain. In addition, these sciences offer no help in determining the best decision to make in the face of multiple conflicting goals held by multiple stakeholders – goals that have changed, and no doubt will continue to change. Water resources planning and management and decision-making is not as easy as 'we professionals can tell you what to do, all you need is the will to do it'. Very often it is not clear what should be done. Professionals administering the science, often from public agencies, non-governmental organizations, or even from universities, are merely among all the stakeholders having an interest in and contributing to the management of water.

Each governmental agency, consulting firm, environmental interest group and citizen typically has particular limitations, authorities, expertise and conflicts with other people, agencies and organizations, all tending to detract from achieving a fully integrated approach to water resources planning and management. But precisely because of this, the participation and contributions of all these stakeholders are needed. They must come together in a partnership if indeed an integrated approach to water resources planning and management is to be achieved and sustained. All views must be heard, considered and acted upon by all involved in the water resources planning and management process.

Water resources planning and management is not simply the application and implementation of science. It is creating a social environment that brings in all of us who should be involved, from the beginning, in a continuing planning process. This process is one of:

- educating ourselves about how our systems work and function
- identifying existing or potential options and opportunities for enhancement and resource development and use

- resolving the inevitable problems and conflicts that will result over who gets what and when, and who pays who for what and when and how much
- making and implementing decisions, and finally of
- monitoring the impacts of those decisions.

This process is repeated as surprises or new opportunities or new knowledge dictates.

Successful water resources planning and management requires the active participation of all community institutions involved in economic development and resource management. How can this begin at the local stakeholder level? How does anyone get others interested in preventing problems before those problems are apparent, and especially before 'unacceptable' solutions are offered to deal with them? And how do you deal with the inevitable group or groups of stakeholders who see it in their best interest not to participate in the planning process, but simply to criticize it from the outside? Who is in a position at the local level to provide the leadership and financial support needed? In some regions, non-governmental institutions have been instrumental in initiating and coordinating this process at local grass-root levels.

Water resources planning and management processes should identify a vision that guides development and operational activities in the affected region. Planning and management processes should:

- recognize and address the goals and expectations of the region's stakeholders
- identify and respond to the region's water-related problems
- function effectively within the region's legal/institutional frameworks
- accommodate both short and long-term issues
- generate a diverse menu of alternatives
- integrate the biotic and abiotic parts of the basin
- take into account the allocation of water for all needs, including those of natural systems
- be stakeholder driven
- take a global perspective
- be flexible and adaptable
- drive regulatory processes, not be driven by them
- be the basis for policy making
- foster coordination among planning partners and consistency among related plans
- be accommodating of multiple objectives
- be a synthesizer, recognize and deal with conflicts
- produce recommendations that can be implemented.

All too often integrated planning processes are hampered by the separation of planning, management and implementing authorities, turf-protection attitudes, shortsighted focusing of efforts, lack of objectivity on the part of planners, and inadequate funding. These deficiencies need addressing if integrated holistic planning and management is to be more than just something to write about.

Effective water resources planning and management is a challenge today, and will be an increasing challenge into the foreseeable future. This book introduces some of the tools that are being used to meet these challenges. We consider it only a step towards becoming an accomplished planner or manager.

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